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HELLENISTIC ASTRONOMY

The Science in Its Contexts

Edited by

Alan C. Bowen & Francesca Rochberg

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Hellenistic Astronomy

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Contents

Thematic Questions

PART C
Contexts

Hellenistic Astronomy in Public Service

Hellenistic Astronomy in Literature

Hellenistic Astronomy in the Training and Work of Priests

Astral Divination and Natal Astrology

Theological Contexts

Hellenistic Astronomy in the Philosophical Schools

Preface

The Hellenistic science of astronomy was one aspect of a distinctive intellectual culture arising in the Near East and Western Mediterranean—indeed, in all three of the Antigonid, Seleucid, and Ptolemaic Empires in the geographical area briefly unified by the conquests of Alexander the Great—during a period roughly extending from the late fourth century BCE to the rise of Arabic astronomy. As a result of cultural contacts, some of longstanding and even more ancient roots, the development of astronomy in this period came to bear the impress particularly of Babylonian knowledge and practices. The significance of Babylonian influence is a key feature of the development of astronomy in the Hellenistic Period; whereas, at the same time, the development of Babylonian astronomy itself reached its apex in Babylonia under Seleucid rule. The characteristic features of Hellenistic astronomy as manifested in the various parts of the Near Eastern and Mediterranean worlds during this period and the contexts within which it functioned and was further developed are the remit of this volume.

Of all the sciences created in Antiquity, astronomy is second in importance only to medicine in its impact on human lives. And, for this reason, like medicine, it achieved remarkable sophistication. The development of astronomy in Greco-Roman culture from a qualitative science in the late fourth century BCE to a fully quantitative and predictive science in the second century CE that was the paradigm of human knowledge and a rival to philosophy is truly astounding. So there is no denying the historical importance of astronomy as a basis for insight into the Greek and Roman worlds of that time. But ancient astronomy also developed in other geo-cultural domains and their understandings of the heavens are also important and merit close attention because they influenced, and were influenced by, the Greco-Roman science. In effect, each of these cultures played a role in defining ancient astronomy as a set of historically interacting bodies of knowledge that lasted in various forms to the beginnings of Arabic astronomy in the latter half of the eighth century CE.

One of the fascinations of astronomy in the period from roughly 300 BCE to 750 CE, which we call Hellenistic, is surely that its geographical range was vast, spanning regions that were, prior to Alexander's unification, culturally distinct. Even before Alexander the Great briefly formed a single inhabited world (*oikoumene*), the layers of culture and language, especially in the eastern part of that conquered area, were many and already integrated with one another in various ways. Thus, for example, in Mesopotamia, the region of the Seleucid Empire, the ancient Sumerian and Akkadian traditions of the third millennium fused into a Babylonian tradition that was followed by an Assyro-Babylonian form in the first millennium that was replaced yet again by a Late Babylonian form (after *ca* 500 BCE), within which mathematical astronomy first made its appearance.

The Persian Empire had its own impact on the cultures of its political domain, accounting for the rise of Aramaic as a learned language in many parts of the Near East in the sixth to fourth centuries BCE. The Hellenistic Near East, however, ushered in an unprecedented culture of intellectual transmission and circulation of knowledge. The component of Hellenistic astronomy that we see in Judea [chs 13.1–2] is an important instance of the influence of the Babylonian astronomical tradition within the new Hellenistic world and its adaptation for local interests in the Eastern Mediterranean.

Pre-Hellenistic Egyptian knowledge of the heavens was also absorbed within new forms of Hellenistic Egyptian astronomy [chs 4.8 and 11.1]. The capital city of the Ptolemies, Alexandria, became a center for scientific activity and served under the Ptolemaic dynasts to foster intellectual culture and, with it, the combined astral sciences of astronomy and astrology. Some of the most significant Greek treatises, such as the *Almagest* and *Tetrabiblos* by Claudius Ptolemy, came from Alexandria during the second century of our era.

Needless to say, therefore, any historical analysis that does not account for the impact of the cultures of the eastern regions of the *oikoumene* will be inadequate for understanding the Hellenistic sciences, particularly astronomy and astrology, since the East is where these sciences originated. In much the same way, the Hellenistic traditions of medicine and magic and, indeed, the combinations of these with astronomy to produce new ideas and practices (such as astral medicine [ch. 9.3] or astral magic) were equally products of the circulation of knowledge and the remarkable intellectual transmission of ideas from the East that characterizes the Hellenistic world.

Just as the geographical domain for the study of astronomy in the Hellenistic Period is extensive, so too is the range of the sources to be considered. The textual evidence for Hellenistic astronomy stems from tablets and papyri (or artifacts and inscriptions) from Seleucid Babylonia, Ptolemaic Egypt, and Macedonian Greece, as well as from the Roman Near East, where it may be found, for example, in the astronomical texts of the Qumran community in the first century BCE [chs 13.1–2]. In tracing the continuation of Hellenistic astronomy in even later periods, it is clear that the Late Antique heirs in both East and West carried on certain elements of Hellenistic astronomical culture. These late manifestations of the tradition, such as in Christianity [ch. 13.3], Stoic and Neoplatonic philosophy [chs 14.1–2], and Hermeticism [ch. 13.5], have a place in the history of Hellenistic astronomy, and consequently a place in the present volume.

In order to accommodate the different languages, cultures, religions, and intellectual traditions that supported astronomy and astrology, we have adopted what is perhaps an ultra-long Hellenistic Period for our chronological framework (*ca* 300 BCE to 750 CE). Our chronological limits are determined not by singular political turning points but rather by developments within the science considered as a transcultural phenomenon of shared knowledge. We have not found the standard date-limits given for the 'Hellenistic Period' (323–31 BCE), the 'Greco-Roman Period' (332–395 CE), the 'Byzantine Period' (330–1453 CE), or 'Late Antiquity' (third to eighth centuries CE in the West and third to mid-eighth CE in the East) to be appropriate or useful in delimiting chronologically the long period within which astronomy appeared and then persisted until the major shift that occurred in the development of the science as it entered the Islamicate world of the eighth century. Such transculturally shared and interactively created systems of knowledge demonstrate yet again greater staying power than kingdoms and empires. Astrology, after all, was one of the longest lasting sciences of all from Antiquity.

Apart from delimiting the geographical and chronological framework for studying Hellenistic astronomy, what is called for is a history that is ever mindful of the fact that its great success was due to the development of an impressive mathematical apparatus, yet aware as well that this very success entailed addressing needs and requirements deriving from the diverse contexts in which this science was pursued. Our goal, then, is to provide critical analyses that lay out the great success that astronomy enjoyed by addressing the complex interplay between these needs or requirements and the mathematical apparatus developed to meet them.

But there is a caveat. The present volume is only a first step toward the larger project of understanding astronomy as a scientific and social phenomenon of the Hellenistic world. Given that the ambit of Hellenistic astronomy as we conceive it is extremely wide, it should not come as a surprise that this volume is incomplete in both its temporal and geo-cultural coverage. Practical constraints have necessitated that our focus be on the Mediterranean and Near East and mainly in the interval from 300 BCE to 300 CE . And so much remains to be said and much more to be done. But completeness can only be a goal in a project that proposes to set Hellenistic astronomy in its diverse cultural contexts in order to understand both why and how its ideas and practices developed.

We are mindful, of course, that the very features that made Hellenistic astronomy such a success in its time, its technical apparatus, can prove an impediment to readers today, even to the few who have some knowledge of the heavens. And so, astronomy, that magnificent science which afforded its results, insights, and authority to so many aspects of Hellenistic culture [e.g., ch. 10.2] is often not given its due in studies of the cultures to which it was once such an integral part. Thus, this volume strives to overcome our modern preference for compartmentalizing knowledge, particularly scientific knowledge, in order to understand the more complex processes by which Hellenistic astronomy came to be the paradigmatic science that it was, and came to represent, as against a number of alternative cosmological pictures, a basic geocentric, spherical construction of the universe that lasted until the Early Modern Period.

Accordingly, we have divided the volume into three parts:

A Technical Requirements;

B Observations, Instruments, and Issues; and

C Contexts

A Technical Requirements

The opening Part of our volume presents Hellenistic astronomy as a mathematical science with an ever evolving vocabulary and budget of techniques and results. Our aim here is to provide readers with enough of the theory to facilitate their understanding of Hellenistic documents bearing on astronomy and to supplement this with a scholarly apparatus that directs them to further reading. This means that Part A is not the complete and comprehensive handbook to Hellenistic astronomy that is ultimately needed: the list of topics covered is not complete and there is often more to say in covering them. There is, for example, no full-blown study of the great changes in theorizing that the work of Claudius Ptolemy embodies. The reasons for this are practical. Ptolemy's writings are technically demanding. Furthermore, the great challenge, once one has mastered the technical aspect of his work, is to locate it in the context of his own times, a daunting task that still lies ahead.

For those interested in Hellenistic Greco-Roman astronomy and who wish to learn more about what was known at the time, we recommend Geminus' *Introductio astronomiae* [Evans and Berggren 2006] or Cleomedes, *Caelestia* [Bowen and Todd 2004] and then Ptolemy's *Syntaxis* or, as it was later known, *Almagest* [Toomer 1998]. Macrobius' *In somnium Scipionis* and Martianus Capella's *De nuptiis* c. 8 [Stahl, Johnson, and Burge 1977] will also reward attention. For Babylonian astronomy, one may consult the texts collected in Neugebauer 1955, Hunger 2001–2012, and Rochberg 1998, and turn to Hunger and Pingree 1999 for an overview. For Egyptian astronomy, there are Neugebauer and Parker 1960–1969, Ross 2006a, and Clagett 1989–1999, vol. 2.

B Observations, Instruments, and Issues

In Part B, we turn to astronomy understood as a system or complex of knowledge and practice. The first task here is to characterize Hellenistic astronomy by considering the ways in which theory was grounded in observation and the various instruments developed as tools of astronomical practice. The second is to provide a critic's overview of the problems defining astronomy during the Hellenistic Period. Accordingly, we offer chapters on the role of observation [chs 5.1–2] and on instruments and their use [chs 6.1–4] that are followed by chapters dealing with the basic problems and subjects of astronomy in Egyptian, Babylonian, and Greco-Latin sources [chs 7.1–3].

C Contexts

To counteract any tendency to reduce the history of Hellenistic astronomy to its technical results, be they parameters, techniques for observation and calculation, or hypotheses, Part C is devoted to an exploration of the uses of astronomy in a variety of contexts, from practical to theological. By this means, we aim to contextualize the science itself, that is, to understand astronomy in its various intellectual and social contexts, and to do this from the diverse standpoints of those who drew on astronomy in their own enterprises. In this Part, the focus is on the numerous ways in which Hellenistic astronomy affected, and was affected by, the culturally diverse communities in which it was practiced. Accordingly, we offer chapters on the professional astronomer/astrologer [ch. 8], astronomy in public service [chs 9.1–10.2], astronomy as priestly knowledge [chs 11.1–2], and the use of astronomy in medicine, in divination and natal astrology [chs 12.1–4], as well as in theological and philosophical contexts [chs 13.1–5, 14.1–2].

Astronomy and Astrology

Our culturally oriented approach to ancient astronomy necessarily gives due weight to the centrally important aspect of astrology, whether in the form of celestial divination or astral omens, nativities, or horoscopes. This too was an integral part of the science of astronomy, which, accordingly, had predictive as well as prognosticatory dimensions. We have not found it necessary to discuss the modern philosophical issue of the demarcation between science and non-science since it in no way applies to ancient astronomy and astrology. This is not to say, however, that practitioners did not make their own demarcations and separated those varying dimensions of the science of the stars, only that their demarcations are not the same as the ones made today. On examining the evidence, we have found the inclusion of the astrological aspect of many of the sources produced throughout the regions of the period to be a necessary component of any study of the science of Hellenistic astronomy in its contexts.

Conclusion

In accordance with the foregoing description of this volume, we reiterate in conclusion that the primary aim has been the contextualization of the ancient science of Hellenistic astronomy in as wide a framework as we could defend. Therefore, together with the description and analysis of Hellenistic astronomy as an exact, or mathematical, science, we wish to emphasize as well its cultural reach and, in particular, the central role played by astrology in the astronomy of the Hellenistic cultures of the Near East (Egypt and Mesopotamia) and of the Eastern and Western Mediterranean regions.

Acknowledgments

This volume, which has been long in coming, was initiated in 2012 at the welcome request of Irene van Rossum, then Senior Acquisitions Editor, Classical Studies and Ancient Philosophy at Brill Publishing. It is a great pleasure and no small relief to see it in print and we thank her, Caroline van Erp, Tessel Jonquière, and Giulia Moriconi, all of Brill, for their assistance and guidance in its production.The preparation of the volume benefitted as well from the technical assistance of Eduardo Escobar, Anabela Carneiro, and especially H. Hraban Ramm (hraban@fiee.net), whose advice in matters concerning ConTEXt was invaluable. To each of them, we likewise extend our thanks and gratitude.

We also thank our colleague Zoë Misiewicz and our copyeditor, Kelly Burch (kellycopyedits@gmail.com), for their aid as the chapters contributed by our numerous authors came in. Kelly also provided invaluable assistance by serving as our proofreader when the volume was finally complete and in hand.

The volume itself was sent to various readers either in part (William R. Bowen, Bernard R. Goldstein, Robert Hannah, and John M. Steele) or in whole (Sonja Brentjes) for review and comment. Their response was exemplary: indeed, their criticisms and suggestions were most helpful to us in revising the volume and trying to enhance its coherence. We thank each of them for the expert advice so freely offered.

Last, but hardly least, we thank our contributors. Working with them on this volume proved to be not a merely mechanical effort to assemble disparate work but a truly collaborative attempt to set the study of Hellenistic astronomy on a new footing for future research. We are inspired by each of them and are now most eager to take the next steps.

Figures, Plates, and Tables

Figures

Ch. 1

Ch. 3.2

Ch. 4.1

Ch. 4.3

Ch. 4.4

Plates

Tables

Ch. 9.1

Ch. 9.3

Ch. 12.1

Ch. 12.4

Ch. 13.2

Ch. 13.4

Glossary

Abbreviations

A	Tablet siglum in the collection of the Oriental Institute, University of Chicago.
ACT	*Astronomical Cuneiform Texts*. See Neugebauer 1955.
ADO	Demotic ostraca in the Ashmolean Museum, Oxford University.
AL	*Augustinus-Lexikon*. Basel. 1986–.
AnL	Riese, A. 1906. *Anthologia Latina sive poesis latinae supplementum*. Leipzig.
AnP	Beckby, H. 1957–1958. *Anthologia Graeca*. Munich.
AO	Antiquités orientales. A documentary service in the Department of Antiquities of the Louvre Museum, Paris.
BAM	Köcher, F.; R. D. Biggs; and M. Stol. 1963–. *Die babylonisch-assyrische Medizin in Texten und Untersuchungen*. 10 vols. Berlin.
BM	The British Museum. London.
BOR	*Babylonian and Oriental Record*. London. 1886–1901.
BRM	Clay, A. T. 1920–1923. *Babylonian Records in the Library of J. Pierpont Morgan*. 4 vols. New Haven.
CCAG	*Catalogus Codicum Astrologorum Graecorum*. 1898–1953. 12 vols. Brussels.
CH	Corpus Hermeticum. See Ramelli 2014.
	CH 1. *Poimandres*. See Reitzenstein 1904.
CIL	*Corpus Inscriptionum Latinarum*. Berlin. 1862–.
CodBGn	*Codex Berolinensis Gnosticus*. Berlin Museum.
CodIust.	*Codex Iustinianus*. Berlin.
CodLBPG	*Codex Leidensis Bibliothecae Publicae Graecus*. See *CCAG* 9.2.176–178.
CodTh.	*Codex Theodosianus*. Berlin.
CodVat.	*Codex Vaticanus*. Bibliotheca Apostolica Vaticana. Rome.
CT	Cuneiform Texts from Babylonian Tablets in the British Museum. London.
DC	The Drower Collection. Lady E. S. Drower's collection of Mandaic manuscripts, which is now housed in the Bodleian Library, Oxford.
DPS	Diagnostic-Prognostic Series. See Heeßel 2000.
GS	Goh, M. and C. Schroeder. 2015. *The Brill Dictionary of Ancient Greek by Franco Montanari*. Leiden/Boston.
HAMA	*A History of Ancient Mathematical Astronomy*. See Neugebauer 1975.
Hist. Aug.	*Historia Augusta*. See Hohl 1965.
HSM	Harvard Semitic Museum. Cambridge, MA.
ILS	Dessau, H. 1892–1916. *Inscriptiones Latinae Selectae*. 3 vols. Berlin.
JdE	*Journal d'Entrée*. The series for acquisitions by the Egyptian Museum in Cairo.
KB	*Keilschrifturkunden aus Boghazköi*. 1921–. Berlin.

LSJ	Liddell, H. G.; R. Scott; and H. S. Jones. 1996. 9th edn. *A Greek-English Lexicon*. Oxford.
MLC	Morgan Library Collection. A siglum of the Yale Babylonian Collection, New Haven.
NHC	Nag Hammadi Codices
	NHC 2.1 Apocryphon of John. See *CodBGn* 5802.2; Waldstein and Wisse 1995.
	NHC 2.5 *On the Origin of the World*. See Layton 1989.
	NHC 3.2 Gospel of the Egyptians. See Böhlig and Wisse 1975.
	NHC 6.6 *Discourse on the Eighth and Ninth*. See Meyer 2007.
	NHC 6.7 *The Prayer of Thanksgiving*. See Meyer 2007.
	NHC 6.8 *Asclepius 21–29*. See Meyer 2007.
	NHC 7.1 *Paraphrase of Shem*. See Böhlig and Wisse 1975.
	NHC 9.3 *Testimony of Truth*. See Giversen and Pearson 1977.
	NHC 13.1 *Trimorphic Protennoia*. See Turner 1990.[1]
NP	Cancik, H. and H. Schneider. *Der Neue Pauly*. Stuttgart.
NT	Field numbers of tablets excavated at Nippur by the Oriental Institute and other institutions. For 11NT4, see Civil 1974.
OCD	Hornblower, S. and A. Spawforth. 1996. *The Oxford Classical Dictionary*. 3rd rev. edn. Oxford.
ODem.	Record of Demotic ostraca acquired by the Ashmolean Museum.
ODN	Demotic ostraca from Narmouthis (Medinet Madi). See Bresciani, Pernigotti, and Betrò 1983 for ODN 1.1–33; Gallo 1997 for ODN 2.34–99; Menchetti 2005b for ODN 3.100–188.
OGlasD	Ostraca held in the Hunterian Museum D, Glascow.
OḤor	*Ostracon Ḥor*. See Ray 1976.
OMM	Ostraca Medinet Madi. An inventory series for ostraca from Medinet Madi (Narmouthis).
PatL.	*Patrologiae cursus completus*. Series Graeca. J. P. Migne ed. 1857–1866.
PatG.	*Patrologiae cursus completus*. Series Latina. J. P. Migne ed. 1844–1864.
PBer.	*Berlin Papyri*. Berlin.
PCair.	Papyri in the Cairo Museum. For *PCair*. inv. 31222, see Hughes 1951.
PCarls.	See Neugebauer and Parker 1960–1969, 3.240–241 and pl. 79B.
PDM	*Papyrus Demoticae Magicae*.
PGM	Preisendanz, K. *et alii*. 1973–1974. *Papyri Graecae Magicae*. 2 vols. Stuttgart.
PHerc.	*Papyri Herculanensi*. For *PHerc*. 1018, see Dorandi 1994.
PHib.	*The Hibeh Papyri*. 2 vols. London. 1906–1955.

1 For a synopsis of NHC 2.1, 3.1, and 4.1 with *CodBGn* 5802.2, see Waldstein and Wisse 1995.

PIR	Groag, E.; A. Stein; and L. Petersen. 1933. *Prosopographia Imperii Romani saeculi I. II. III. Pars I* (*A–B*). 2nd edn. Berlin/Leipzig.
PKell.	*Papyri from Kellis*. Oxford.
PLond.	*Greek Papyri in the British Museum*. 7 vols. London.
PLou.	*Papyrus du Louvre*. For *PLou.* 3129, see Schott 1929.
PLRE	Jones, A. H. M.; J. R. Martindale; and J. Morris. 1971–1992. *The Prosopography of the Later Roman Empire*. 3 vols. Cambridge, UK.
PMich.	*Papyri in the University of Michigan Collection*. Ann Arbor.
POAstr.	The paypyri from Oxyrhynchus published in Jones 1999a.
POxy.	*The Oxyrhynchus Papyri*. London. 1898–.
PPar.	*Notices et textes des papyrus du Musée du Louvre….* Paris.
PPrinc.	*Papyri in the Princeton University Collections*. 3 vols. Baltimore/Princeton.
PSI	Vitelli, G.; M. Norsa; *et alii*. 1912–. *Pubblicazioni della Societa Italiana per La ricerca dei papiri greci e latini in Egitto: Papiri Greci e Latini*. Florence.
PWarr.	Warren, P.; M. David; B. A. van Groningen; and J. C. van Oven. *The Warren Papyri* (*P. Warren*). Leyden. 1941.
Q	Wise, M. O.; M. G. Abegg Jr; and E. M. Cook. 2005. *The Dead Sea Scrolls*. rev. edn. New York.
RE	Pauly, A.; G. Wissowa; and W. Kroll. 1894–. *Real-Encyclopädie der classischen Altertumswissenschaft*. Stuttgart.
STT	Gurney, O. R.; J. J. Finkelstein; and P. Hulin. 1957–1964. *The Sultantepe Tablets*. 2 vols. London/Ankara.
Suda	Bekker, I. 1854. *Suidae Lexicon*. Berlin. Repr. Athens. 2002.
TCL	*Textes Cuneiforms du Louvre*. 1910–1967.
TLG	*Thesaurus Linguae Graecae: A Digital Library of Greek Literature*. Online: http://stephanus.tlg.uci.edu.
TLL	*Thesaurus Linguae Latinae*. Online: https://www.degruyter.com/view/db/tll.
Tm	Trismegistos. An interdisciplinary portal of papyrological and epigraphical resources formerly from Egypt and the Nile valley (800 BCE – 800 CE), now expanding to the ancient world in general. Online: http://www.trismegistos.org.
UlpMos.	*Ulpiani mosaicarum et romanorum legum collatio*. See Lenel 1889.
UM	Tablet siglum in the collection of the University Museum. Philadelphia.
VAS	Vorderasiatische Schriftdenkmäler der Königlichen Museen zu Berlin.
VAT	Vorderasiatische Abteilung. Tontafeln. Vorderasiatisches Museum. Berlin.

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CHAPTER 0

Prolegomena to the Study of Hellenistic Astronomy

Alan C. Bowen and Francesca Rochberg

1 Introduction

If it is prudent at any time to reflect on the assumptions underlying a question, it is surely prudent at the outset of this volume to set forth our presuppositions in asking the question What is Hellenistic astronomy? The aim of such preliminary reflection is not, of course, to answer the question but to clarify the terms on which we expect it to be answered. So, let us start with a definition and an observation.

The definition is a lexical stipulation: in what follows, the term "astronomy" will cover knowledge of the heavens no matter whether it is used for describing the heavens, for predicting celestial and meteorological phenomena or, astrologically, for understanding and prognosticating human lives and events in them. In making this stipulation, we step aside from modern concerns about science and pseudo-science. Our justification is that, while the ancients did indeed ponder how astronomy differed from astrology, they regarded both as real sciences and even as aspects of the same science in spite of their different epistemic reach.

The observation is that no idea is born or lives in the abstract, that ideas are conceived in specific contexts by people living in given places at given times in determinate communities in diverse cultures, and that they are preserved in media that are ultimately material using the languages and scripts of those communities and cultures. For us, this observation gains particular interest when the ideas concern the world about us and the question becomes Under what circumstances do groups unified by some project or shared understanding change their ideas when confronted with new ones arising either from within the group as consequences of what was held before or from without?

To bring this last question to the history of astronomy, we elaborate the observation as follows:

(1) Science as a body of knowledge and practices is entirely embedded within the historical and cultural framework of those who know and practice it. It is in no way separable from such frameworks. Thus, while we continue to learn from the work of Otto Neugebauer and his students—without it, we would not have our current understanding of Ptolemy's debt to the

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Babylonians or of the ways in which he either transformed and made it Greek or was prominent in this process—we will not limit our study of ancient astronomy in any culture to considering its mathematical methods and parameters, an approach exemplified in Neugebauer's monumental *A History of Ancient Mathematical Astronomy* [1975].

(2) Understanding a culture's science and appropriating or interpreting it in one's own framework is made possible to the extent that science is about, or concerns, a shared world and that the cultures involved and individuals within them share some commonalities.

(3) Change in science does not arise only in response to the solution of technical problems within the science; it may also be brought about proximately by ideas that come from outside the boundaries of the science as conceived and practiced at the time.

(4) Since any such change in ideas is, however, mediated by the individuals and groups that have them, the acceptance of new ideas may ultimately depend on interests and concerns that are far from scientific themselves.

(5) Accordingly, such acceptance can bring about radical change not only in the scientific ideas that a community or culture has, it may also bring about new scientific practices and even professions as well as broad challenges to previous norms of belief and behavior.

(6) Finally, when communities and cultures interact and share knowledge in part, it makes sense not only to speak of the science of one group in distinction from that of another but also to view the science embedded in both together as a single transcultural phenomenon, that is, as a locus where questions of what is and is not admitted in each gain real meaning.

It is true, we admit, that adopting premises of this sort is self-fulfilling: to look at the history of a particular science under these terms is pretty much to guarantee that they will be found to be the case. Yet, this is not a fault but a feature of most inquiries: in intellectual history especially, the findings tend to confirm the terms under which they were found. Indeed, the real test for such an inquiry once completed is whether it encompasses all and only what should be encompassed. With this in mind, then, let us spell out what we take to be the guiding principles of the kind of answer that we expect in asking the question What is Hellenistic astronomy?

Since Hellenistic astronomy has been an object of modern scholarship for close to 300 years, we begin with the adjective "Hellenistic" because its use in classical scholarship bears the weight of established tradition.

2 Why "Hellenistic"?

There are many ways in which historians divide their subject into periods. It is important to keep in mind that, when such periodization is done properly, it is with an eye to the subject itself and its internal structure. Like Plato's butcher [cf. *Phaedrus* 265e1–3], one must carve the animal at its joints. To introduce periods that belong to another subject or class of questions is a misstep that will separate what ought to be grasped at once and keep together what should be separated. Thus, for example, periodizing the history of ancient Greek mathematics by reference to the Archons of Athens would not be a particularly good idea. So let us turn to the history of ancient astronomy by itself.

When one considers ancient astronomy in the Near East and Mediterranean as a transcultural phenomenon, that is, as a set of diverse but interacting astronomies,[1] it becomes readily evident, nowadays at least, that Babylonian mathematical astronomy and astrology were the original instigators of a great change in other cultures that demarcates one period of astronomical theorizing in the history of Western thought from the next. (This is not to deny that older forms of theorizing persisted.) Scholars will, of course, set the timing of this change differently in different cultures. For the Greeks and Romans, it started in the late fourth century BCE. This is important because the Greco-Roman transformation[2] of the earlier native science, a process involving the appropriation of Babylonian astronomy that was effectively completed in the works of Claudius Ptolemy, became itself an instigator of change in other cultures, primarily as recorded in Greek. Moreover, it persisted even with the emergence of Christianity as a political power and it is not until the mid-eighth century CE, when the Arabs took Greco-Roman science in new directions, that we see the end of the era that began roughly a millennium earlier. For this reason, then, we maintain that the period from the late fourth century BCE to the mid-eighth century CE is a discrete era in the history of Western astronomy and that it is rightly called Hellenistic.

1 In speaking of astronomies, it is important not to burden the term "astronomy" with Greco-Roman and later connotations. For the various ways in which knowledge of the heavens was spoken of during the Hellenistic Period, see Glossary, p. 633.

2 We will use "Greek" and "Latin" to indicate the *languages* in which texts were written and not the *ethnicity* of their authors, which can be different. The question of the cultural context in which these texts were written is complicated. We will use "Greco-Roman" to indicate one of the cultural contexts in which these texts were written and understood.

3 Hellenistic Astronomy as a Subject

For students of astronomy in Greco-Roman intellectual culture, what makes this view of Hellenistic astronomy especially interesting is that astronomy in this period was actually contested, that Greek and Latin writers urged divergent views of what astronomy is and should be without there being clear winners, Ptolemy's great synthesis notwithstanding [Bowen 2007, 2018; Jones 1990c]. Indeed, one defining question for authors writing in Greek and Latin was whether to include Babylonian astronomy in the traditional astronomy that went back to Plato and Aristotle, and, if so, how much of it, all or some [Bowen 2013b].

Such concern about what to appropriate from Babylonian astronomy is not limited to Greco-Roman culture; it is reflected in other cultures too and points to the more basic fact that the process of appropriation is a complicated one of interpretation, rejection, and transformative acceptance.[3] Moreover, this process was often bi-directional: while Babylonian astronomy left its mark on other cultures (and not always by the mediation of work in Greek and Latin) without signs of changing much itself, there are indications that these other cultures, Egyptian for example, likewise impacted astronomy in Greco-Roman culture even as they were in turn influenced by it. The upshot for inquiry into Hellenistic astronomy as we propose is two-fold:

– First is that to understand how and why the various Hellenistic astronomies took the form that they did will require exploring the intellectual and social contexts of each in its culture. This entails that we must reject any personification or essentializing of culture or civilization—Greco-Roman or whatever—as though it were an agent and had impermeable boundaries. To the contrary, the history of Hellenistic astronomy shows exactly how permeable these supposed boundaries of language and culture can really be.
– But second is that this will make sense only if we distinguish Hellenistic astronomy from Hellenistic astronomies without reifying the former as a body of knowledge and making it anything more than a meta-historical category. In other words, on our terms, while it is useful and necessary to speak of Hellenistic astronomy, it was not a body of knowledge held by any one community or culture in Antiquity. Further, there was no single, authoritative way of understanding the heavens that merited the title "astronomy" before all others or was universally valued as such.

3 On the role of expertise in the process, see Misiewicz 2018.

Consequently, in asking What is Hellenistic astronomy?, we rule out any assertion that Hellenistic Greco-Roman astronomy was the authoritative paradigm for knowledge of the heavens, since this would impede our understanding the very processes by which this particular astronomy or any of the others was formed and transformed. As we see it, then, Greco-Roman astronomy has nothing to do with any modern hierarchy of value attached to ancient sources for science and will have no more centrality or epistemic authority than Babylonian or Egyptian astronomy, for example, in our discussions.

4 The Geo-cultural Reach of Hellenistic Astronomy

Once Hellenistic astronomy is viewed as a corpus of interacting astronomies, the question becomes Whose astronomies does it include? In our view, it should include the astronomical science of each of the geo-cultural regions that was engulfed by the Alexandrian conquest in the late fourth century BCE. Well, almost all. In this volume, however, we do not address Indian astronomy because it makes better sense to us to present it as a subject while considering astronomy in the Arab world as it impacted the Latin West and Byzantine East.

5 The Challenge of Contextualization

Such contextualization of Hellenistic astronomy as we propose raises a problem that may be cast as a dilemma: while ignoring the contexts of a science by abstracting its ideas is to miss the *history* of that science, to focus on these contexts and to ignore the ideas and their role in bodies of knowledge is to miss the history of the *science*. The challenge to be faced in our asking What is Hellenistic astronomy? is to pass between the horns of this dilemma which is at once historiographic and philosophical.

So far as the two opposed schools in the historiography of science in evidence today are concerned, this is easy enough. To internalists who restrict their study of astronomy to its technical content, that is, to its observations, the use of these observations to quantify models, and the parameters of these models, we propose by virtue of our concern with context an answer to the Why?-questions that they broach only on the most restricted terms, if at all. That is, we propose a course that will allow much fuller explanations of changes in the technical theorizing of Hellenistic astronomy. To those historians who focus on scientists and scientific institutions, we are proposing here a case study of astronomy that connects the socio-cultural environment of a body of scientific learning to its technical apparatus and structures.

As for those in either school who advocate histories of *longue durée*,[4] we here set out a theme by which to study more than a millennium of thought. Granted, this theme comes with no hope for a narrative—and this not just because the evidentiary materials for such are lacking but because in focusing on Hellenistic astronomy understood as a number of interacting astronomies each with its own cultural context, we embrace the adventitious character of human history and, thus, its resistance to overarching storylines and narratives of continuous progress.

6 Conclusion

Thus, our understanding of what is involved in asking What is Hellenistic astronomy? is that, while it is a body of knowledge to be acquired by historians, it has no historical standing, no meaning in Antiquity. To ask about and study Hellenistic astronomy is, in our view, to ask about and study a set of numerous, interacting astronomies held in the interval from 300 BCE to 750 CE, say, by the cultures of the various regions brought into contact by Alexander the Great in the late fourth century BCE.

4 For the most recent call to this kind of historiography as part of a largely misguided effort to influence policy-makers, see Guldi and Armitage 2015.

PART A

Technical Requirements

CHAPTER 1

The Celestial Sphere

Clemency Montelle

1 Introduction

One of the most fundamental assumptions in Hellenistic astronomy and its derivatives was that the celestial realm was spherical. Plato (429–347 BCE) alludes to this often in the cosmological designs of the *Timaeus* [e.g., 44d, 62c]; and in *De caelo* 2.4, Aristotle (384–322 BCE) reasons that the heavens are spherical by necessity. Eudoxus of Cnidus (*ca* 370 BCE) was one of the first Greek inquirers to produce a coherent description of the celestial sphere thus conceived and, from then on, astronomical endeavors focused on reproducing the apparent motions of the heavenly bodies against this spherical backdrop of fixed stars [see ch. 2 §2, p. 24]. Accounting for these details included describing the constellations, the fundamental spheres and circles, the risings and settings of the stars and planets, the rising-times of the zodiacal signs, and precession [see Glossary, p. 648]. Earlier cultures, including the Babylonians and the Egyptians, had already advanced sophisticated mathematical patterns to model these astral phenomena, though the cosmological assumption of a celestial sphere appears to have been absent in their reckoning.

Astronomical thought in Hellenistic Antiquity was guided by many assumptions. However, several were singled out as being fundamental. Although some ancient authors considered them open to debate, these assumptions were to form the basis from which further astronomical inquiry could proceed. Ptolemy [*Alm.* 1.2] lists them as follows:

- the heavens are spherical in shape,
- the heavens move as a rotating sphere,
- the Earth is spherical in shape,
- it is located at the center of the heavens,
- the Earth in size and distance has the ratio of a point to the sphere of the fixed stars, and
- the Earth has no motion from place to place.

These assumptions were known by many Greek and Latin writers as *hypotheses*, a noun which is best captured by the term "starting-point".[1] Ptolemy devotes

1 For analysis of this term, see Bowen 2007, 345. For alternative translations as "basis" or "foun-

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a chapter to each of these particular *hypotheses* in book 1 of his *Almagest*, establishing their coherence by dismissing the alternatives and validating their consequences both logically and empirically. After outlining the contradictions inherent in alternative propositions, Ptolemy also noted that subsequent considerations which followed from these assumptions were consistent and that they were also compatible with the readings of various astronomical instruments (such as sundials). In addition, Ptolemy also invoked in support of his assumptions the various physical properties of the aetherial and terrestrial substances that were held at the time to constitute reality [see ch. 4.2 §2.4, p. 84 and ch. 4.4, p. 112].

Ptolemy used observations and conventions derived from Egyptian and ancient Near Eastern scholars. But his exposition also built upon centuries of prior investigation made by his predecessors, including Autolycus of Pitane (fourth century BCE (?)),[2] Eudoxus of Cnidus (early fourth century BCE), Heraclides of Pontus (fourth century BCE), Euclid (*ca* 300 BCE (?)),[3] Aristarchus of Samos (third century BCE), Eratosthenes (third century BCE), Hypsicles of Alexandra (*flor.* early second century BCE), Hipparchus (second century BCE), and Geminus (first century BCE),[4] to name a few. What was crucial to investigations in this area was the conviction that heavenly phenomena could be understood using geometry and that great circles and points carried about by giant spheres could account for celestial motion qualitatively. Furthermore, these considerations were explored for a long period before quantitative significance was demanded from astronomical research. As the success of Ptolemy's *Almagest* revealed, huge potential was unlocked by these practitioners in bringing geometry to bear on the domain of astronomy.

2 The Constellations

Many ancient societies organized the heavens by means of arranging the myriad visible stars into various recognizable configurations and assigning them names. Not only did this imbue the celestial realm with human significance, it

dation", see Toomer 1998, 23–24 and Taub 1993, 40–45. See also chs 4.2, p. 71 and 4.3, p. 95.

2 For discussion regarding the uncertainty of his dates, see Bowen and Goldstein 1991, 246n29.

3 Euclid's dates are problematic. Typically this date, which rests on Proclus' account, is given; however, Bowen and Goldstein 1991, 246n30 convincingly argue that the most one should conclude is that Euclid was either a predecessor or a contemporary of Archimedes.

4 See Jones 1999b: cf. Bowen 2006, 199n4.

also provided a useful system of reference against which to situate the heavenly bodies and gauge their motions. Several of the constellations that the Greeks recognized originate from the ancient Near East.[5] For instance, the constellation Leo derived from the Babylonian MUL.UR.GU.LA (the Lion); Taurus came from GU_4.AN.NA (the Bull of Anu). In the case of the constellation the Hired Man (written «MUL.LÚ.ḪUN.GÁ» or «Agru» in Akkadian), the derivation was circuitous. In Seleucid astronomical texts, this name was abbreviated to «MUL.LU» because of the homophony between «LÚ» and «LU». The Sumerogram «LU» (read «UDU») was read as "immeru" in Akkadian, which means "ram". Thus, the Hired Man became the Ram in Late Babylonian times, and then Κριός in Greek and Aries in Latin.[6] Even Capricorn (Αἰγοκέρως, Capricornus), which is sometimes represented as a goat with a fish's tail thus marking its association with the rainy season, derives from the ancient Near East, specifically, from MUL.SUḪUR.MÁŠ, the Babylonian Goat-Fish.

Eudoxus is generally credited with standardizing the accepted names of various constellations. His account is preserved with some changes in Aratus' *Phaenomena* (*ca* 270 BCE), the earliest surviving description of constellations [see ch. 2 §3, p. 29]. A later work, the *Catasterismi* (*Constellations*) by Eratosthenes was written as a supplement to Aratus' work. Eratosthenes lists the constellations and gives the accompanying mythological connections for each one. Much later, Ptolemy included a star-catalog in books 7–8 of the *Almagest*, where he gives the name, positions, and magnitude of over 1000 stars grouped into the traditional 48 constellations. Of all constellations, those that served in defining the zodiac or zodiacal band were especially important. These 12 groupings of stars gave their names to 12 equal segments of the zodiacal band. These segments had the same name as the arcs of 30° that they cut off on that great circle of the celestial sphere known as the zodiacal circle (or ecliptic nowadays). These arcs too had been adopted from Babylonian sources and were used by Greek practitioners as early as the third century BCE [Table 1, p. 12].[7]

Various physical models, some copies of originals, some only described in texts, visually capture arrangements of the constellations on the celestial

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5 The Perseus and Argo groups, e.g., are Greek inventions.

6 Hellenistic seals from Uruk represent Aries as a ram looking over its shoulder: see Wallenfels 1993, 282 figure 1.

7 One must be careful to distinguish between the zodiacal signs—the 30°-arcs of the zodiacal circle or the 12 segments of the zodiacal band that define them—and the constellations bearing the same name. While these constellations were originally chosen because they crossed the zodiacal circle and were thus roughly coincident with the zodiacal signs, precession [see §7, p. 22] has meant that the constellations are now found outside of the zodiacal arc bearing the same name.

TABLE 1 The 12 zodiacal signs/constellations

English name	Latin name	Greek name
The Ram	Aries	Κριός
The Bull	Taurus	Ταῦρος
The Twins	Gemini	Δίδυμοι
The Crab	Cancer	Καρκίνος
The Lion	Leo	Λέων
The Maiden	Virgo	Παρθένος
The Balance	Libra	Ζυγός
The Scorpion	Scorpius	Σκορπίος
The Archer	Sagittarius	Τοξότης
The Goat	Capricornus	Αἰγοκέρως
The Water-Bearer	Aquarius	Ὑδροχόος
The Fish	Pisces	Ἰχθύες

sphere. For instance, the Farnese statue of Atlas, now situated in Naples, features a celestial globe depicting the various constellations laid out on the sphere [see ch. 2 §2, p. 24]. This is the earliest surviving globe, dated from the first or second century CE—apparently a copy of an original supposed to be several centuries older. Manuscripts of astronomical works often have pictures drawn by scribes of the constellations, such as the one in Plate 1, p. 13 found in *CodVat. gr.* 1291, which includes a copy of Ptolemy's *Can. man.* that was written in the early ninth century.[8]

3 The Diurnal Rotation, the Fundamental Circles

Ptolemy notes at the outset of the *Almagest* that it was the observation of the circular orbits of circumpolar stars that led the "ancients" to posit a celestial sphere. Indeed, he claims, the circular paths of the stars, some of which are always visible and some of which rise and set, prompted this notion in addition to several other key assumptions. These circular orbits were centered on a point defining the axis of rotation. This was to be known for those in the

8 For further discussion of ancient globes and related physical renderings of the heavens, see, for instance, Dekker 2013.

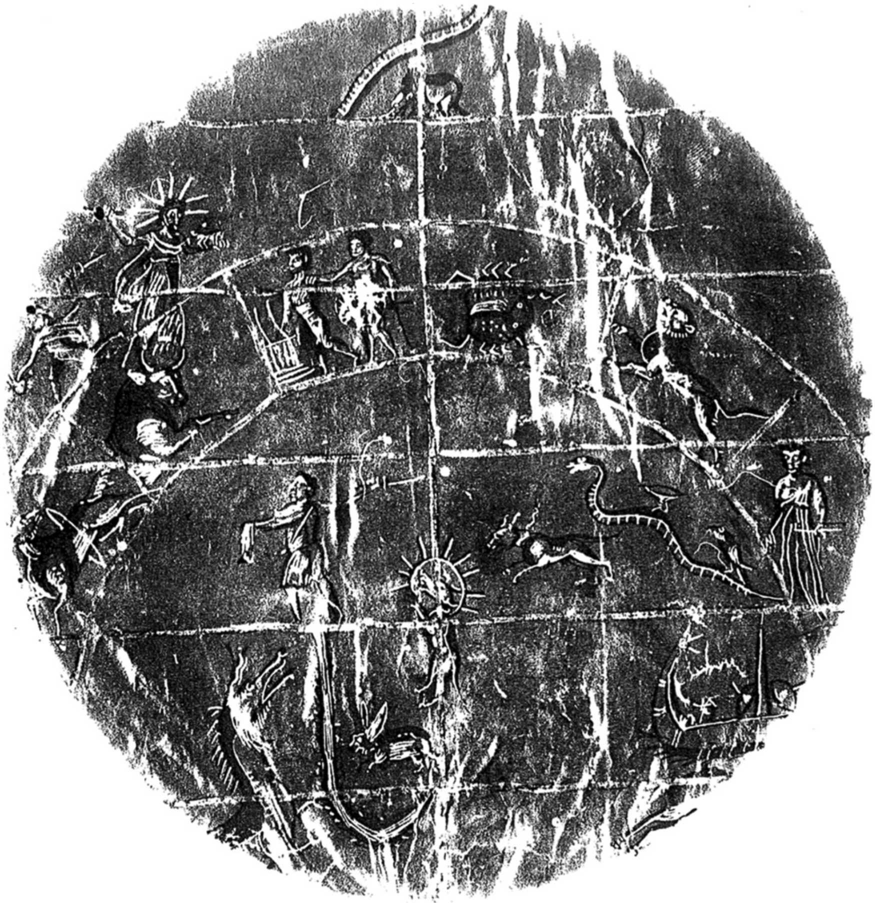

PLATE 1 An image from *CodVat. gr.* 1291 showing the constellations
The zodiacal constellations Taurus, Gemini, Cancer, Leo, and Virgo (reading left to right) are visible between the two arcs in the image.

northern hemisphere as the North Celestial Pole. A star very close to it at that time, Polaris (sometimes called the North Star), visually demarcated the North Celestial Pole. For observers looking northward at locations in the northern hemisphere, the circumpolar stars appear to move counterclockwise around the North Celestial Pole; those that rise and set rise from the east and set in the west. This easily observable phenomenon suggested to the ancients that the celestial sphere rotated westward (that is, from east to west) and completed an entire rotation once a day. That the celestial sphere rotates westward around a stationary Earth was the dominant view in Antiquity. However, there were diverging opinions which circulated that entertained the possibility that it was the Earth which was in rotation while the celestial sphere stayed fixed. Later thinkers in Antiquity ascribed such views to Heraclides of Pontus, among others, though this has been cast into doubt by recent rereading of the texts.[9]

Some of the earliest extant approaches to these phenomena were notably formal and abstract. For instance, Autolycus' *De sphaera* opens with the proposition:

> If a sphere rotates uniformly about its axis, all the points situated on the surface of the sphere which are not on the axis describe parallel circles that have the same poles as the sphere, and that are perpendicular to the axis.
>
> AUJAC, BRUNET, and NADAL 1979, 41

What is notable here is that no reference is made to the empirical interpretation of this sphere, these points, and the resulting parallel circles to the observable celestial sphere and the stars and planets therein. In fact, all 12 propositions in Autolycus' treatise remain firmly in the realm of abstract geometry. Yet, this work is clearly motivated by astronomical speculations and for the purpose of advancing astronomical theorizing. Furthermore, Autolycus' system is devoid of any numerically quantitative considerations. There is no measuring of these circles or arcs nor any making of predictions.

Contemporaries of Autolycus too approached the celestial phenomena mathematically and many did make explicit links with astronomy. For instance, the 18 "theorems" that Euclid set out in his *Phaenomena* use geometry to demonstrate various propositions about the celestial sphere. For instance, proposition 3 reads:

> Of the fixed stars that rise and set, each [always] rises and sets at the same points of the horizon.
>
> BERGGREN and THOMAS 1996, 60

Euclid's demonstration of this proposition invokes the properties of the celestial sphere as a sphere and, by geometry, demonstrates a fact that is empirically verifiable. Similarly, proposition 11 reads:

> Of [two] equal and opposite arcs of the ecliptic, while the one rises the other sets; and, while the one sets, the other rises.
>
> BERGGREN and THOMAS 1996, 80

9 See Todd and Bowen 2009 for a thorough analysis of the passages.

This proposition invokes the symmetry of great circles on the celestial sphere. However, it is only indirectly empirically verifiable. One does not "see" the zodiacal circle when one observes the heavens, much less arcs of it. It is rather a simple mathematical consequence of the geometry of a sphere and a fact that was to prove useful for establishing astronomical aspects such as rising-times. Demarcating these invisible great circles by means of constellations was one way in which ancient observers gauged their motion. It also reveals the delicate interaction between observation and subsequent theorizing during this time [see ch. 5.2, p. 190].

Propositions such as these and the ways in which they are demonstrated reveal interplay between observation and theory in this tradition. While observations might prompt rudimentary explanations to account for the phenomena, very rapidly a sophisticated abstract sky-geometry was developed to explain the appearances. At first this could only reproduce general motions and features of the celestial dynamics; but in time, various parameters and measures were added to these kinematic geometric models so that they could closely account for the actual motions and positions of the heavens.

Ancient thinkers conceived of various features of the celestial sphere in order to demarcate the positions and motions of its celestial bodies. Of all the circles traced by various points on the sphere, four of them were especially important: two great circles (the celestial equator and the zodiacal circle or ecliptic) and the two circles parallel to the equator and tangent to the zodiacal circle (the northern tropic and the southern tropic circles). The celestial equator, as the name implies, is that great circle which makes daytime and nighttime equal in length. It is the celestial equivalent of the terrestrial equator. The zodiacal circle, the apparent path of the Sun over the course of a year, is inclined with respect to the celestial equator at an angle of around 24°. Many ancient authors called the zodiacal circle or ecliptic the circle through the middle of the signs, the signs here being the 12 equal segments of the zodiacal band.

Geminus, writing an introductory guide to astronomy, the *Introductio astronomiae* or Εἰϲαγωγὴ εἰϲ τὰ φαινόμενα in Greek, gives detailed descriptions of these circles as well as many others. He calls the celestial equator "the equinoctial circle" and, when the Sun is on this circle, it makes daytime and nighttime equal:

> The equinoctial circle is...bisected by the horizon so that a semicircle is situated above the Earth and a semicircle below the horizon. When the Sun falls on this circle it produces the equinoxes, that is, the vernal equinox and the autumnal equinox.
>
> *Intro. ast.* 5.6

Previously, Geminus had noted that when the Sun is at the summer or winter tropic circle, the summer and winter solstices are produced, respectively. He also carefully describes the zodiacal circle:

> The band of the 12 signs is an oblique band. It is itself composed of 3 parallel circles, two of which are said to define the width of the zodiacal band, while the other is called the circle through the middle of the signs.... The zodiacal circle is called oblique because it cuts the parallel circles....
>
> *Intro. ast.* 5.51

4 Demarcating the Celestial Sphere

Other points and circles were also conceived in order to demarcate the celestial sphere further. An important group of these were those associated with one's local horizon. Overhead an observer at any locality is the zenith point, that is, the point on the celestial sphere directly above the observer. Furthermore, a great circle that bisects the sky is the meridian. This great circle goes through the terrestrial North Point, the observer's zenith, and the South Point. Perpendicular to it is the prime vertical which goes through the West Point, the zenith, and the East Point. Indeed, the sky appears different to observers situated in different places on the Earth. In this context, the point around which all stars appear to rotate, the celestial pole, will appear at different altitudes for different observers. In fact, the altitude of the celestial pole is equal to the terrestrial latitude for any observer.

Various coordinate systems were developed and used to gauge the motion and positions of celestial phenomena. Any point on the sphere can be uniquely determined by three elements: a great circle, its pole, and a point on that great circle serving to fix a "zero" point. In early astronomy, three coordinate systems were often used when describing the celestial phenomena. These were the zodiacal (or ecliptic) coordinates, the equinoctial coordinates, and the horizon-coordinates.

4.1 *Zodiacal Coordinates*

Zodiacal or ecliptic coordinates [Figure 1, p. 17] are used to measure the longitude and latitude of the stars and the planets. This system, as its name implies, is oriented with respect to the zodiacal circle, the pole of this circle, and the vernal equinoctial point (the intersection of the zodiacal circle and the celestial equator) as its zero point. This point, Aries 0°, is typically written as ♈. Celestial longitude (λ) is measured eastward from the vernal equinox along the zodia-

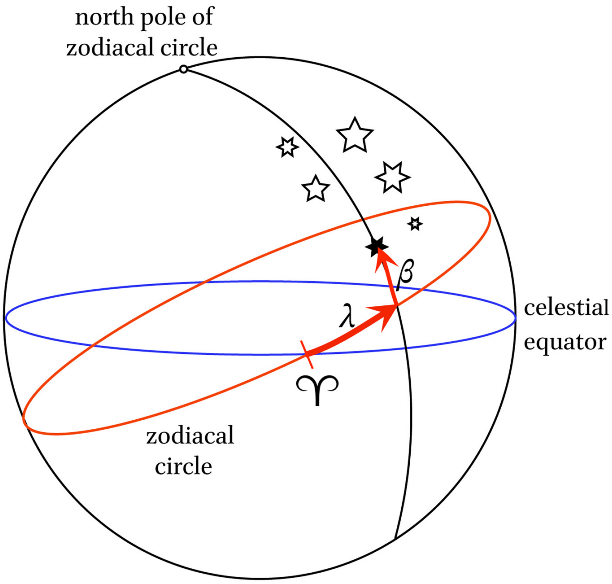

FIGURE 1 Zodiacal or ecliptic coordinates giving longitude (λ) and latitude (β)

cal circle, and celestial latitude (β) is the angular distance of the arc dropped perpendicularly from the body to the zodiacal circle.

4.2 *Equinoctial Coordinates*

Equinoctial coordinates [Figure 2, p. 18] use the celestial equator, the North Celestial Pole, and the vernal equinoctial point as their references. This system is also used to express the positions of the stars and planets, using right ascension (α) and declination (δ). Right ascension is measured eastward along the celestial equator from the vernal equinox and declination is the corresponding angular distance between the body and the celestial equator. While declination is measured in degrees, right ascension, because it is a measure of the equator, is most typically expressed in hours and minutes but may also be given in degrees. The ancients viewed these degrees as simple measures of circular arc and as divisions of a complete rotation of the celestial sphere, that is, as divisions of the day. In the latter case, they were sometimes identified as time-degrees, a unit of measure in which one complete daily rotation is equated to 360° (so that 1 time-degree is equal to 4 minutes).

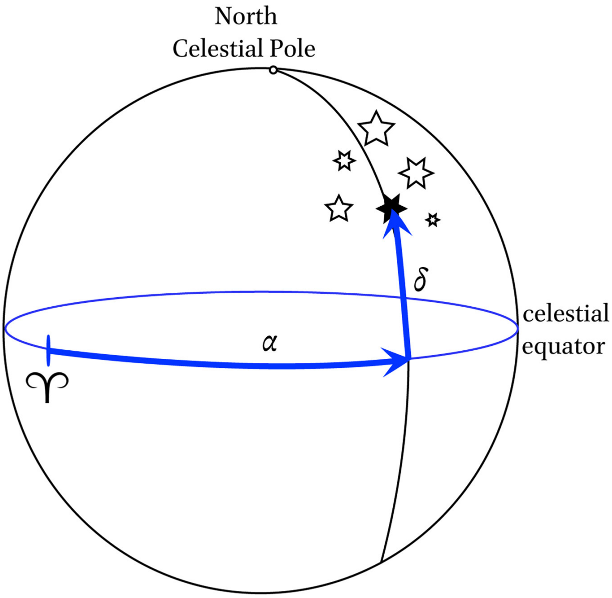

FIGURE 2 Equinoctial coordinates giving right ascension (α) and declination (δ)

4.3 *Horizon-Coordinates*

Horizon-coordinates [Figure 3, p. 19] are particular to an observer's locality. They are based on the plane of the horizon, the zenith, and, most commonly, the North Point. Stars and planets can be located with respect to their angular distance above the horizon, known as the altitude, and the arc clockwise around the horizon from the North Point, known as the azimuth. These are expressed in degrees.

5 Risings and Settings

As noted previously, the night sky is different for observers at different latitudes. The closer one gets to the terrestrial North Pole, for instance, the higher in the sky the north star, Polaris, becomes. If one were to observe the heavens while standing at the North Pole, the Pole Star would be directly overhead at the zenith and the celestial sphere would carry the stars around in circles parallel to the horizon. From this vantage point, the visible stars would neither rise nor set during the night but be always visible. Furthermore, at this position, for half of the year the Sun would be above the horizon and for the remaining six months it would be below the horizon. This creates a daytime of six months fol-

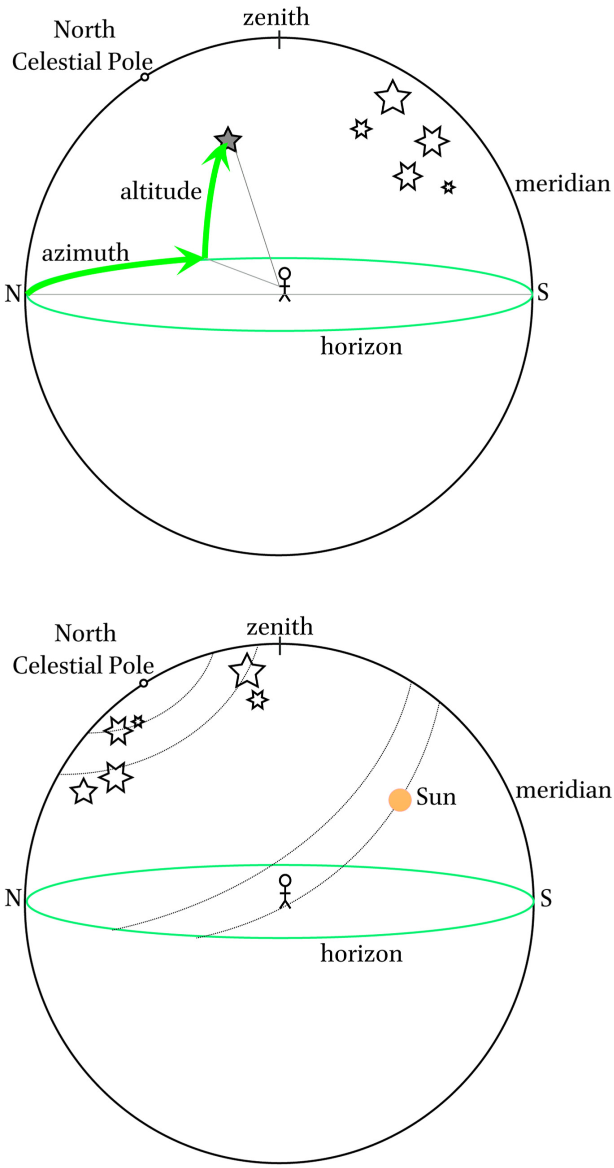

FIGURE 3 Horizon-coordinates giving altitude and azimuth

lowed by a nighttime of six months! This orientation is sometimes referred to as the *sphaera parallela* or the parallel sphere because the direction of celestial rotation is parallel to the horizon.

In contrast, when an observer is located on the equator, the celestial poles are situated on the horizon. Here, because the axis of rotation is, as the ancients thought, in the horizon-plane (in modern terms, one would say "parallel to the horizon"), the stars are carried on circles perpendicular to the horizon. Thus, all stars visible from this vantage point rise and set—none remain always visible or always invisible. In addition, the stars spend 12 hours above the horizon and 12 hours below, all year round. Because the circles traced by the stars on the celestial sphere are perpendicular to the horizon, this orientation is known as the *sphaera recta* or the right sphere.

Most inhabitants on Earth though are situated somewhere between these two extremes. At these localities, the axis of rotation of the celestial sphere is neither on the horizon nor at the zenith but somewhere in between depending on the latitude. For this reason, these orientations are known as the *sphaera obliqua* or the oblique sphere. By some simple geometry, it can be shown that the altitude of the Pole Star at any given location is in fact equal to the terrestrial latitude of that locality. At *sphaera obliqua* some stars are circumpolar: they are always visible, as the circles they trace out around the North Celestial Pole never dip below the horizon. Other stars rise and set. Others still are always invisible. Those stars that are circumpolar and those that rise and set are different for different terrestrial latitudes.

6 Oblique Ascensions

One of the many challenges for astronomers in Antiquity was reckoning time. Most timekeeping techniques and devices relied on the Sun in some way, with the consequence that when it was nighttime and the Sun was below the horizon, other methods were necessary. One approach was to use the rising-times of the zodiacal signs. Because the zodiacal circle is a great circle on the celestial sphere and will, thus, bisect any other great circle on the sphere such as the horizon circle, over the course of a night six zodiacal signs will rise and six will set. This fact can be used to keep track of time during the night. However, because the zodiacal circle is inclined to the celestial equator, the time that each zodiacal sign takes to rise will be different. One's own terrestrial latitude will also affect the lengths of the rising-times as well. Accordingly, astronomers used mathematical techniques to compute the amount of time that each sign takes to rise and compiled tables specific to various terrestrial latitudes. They are often referred to as tables of ascensions.

Ptolemy includes a table of ascensions in *Alm.* 2.8 for several terrestrial latitudes. He computes his rising-times for a 10°-band of each zodiacal sign and expresses them in time-degrees rather than hours. For instance, at Rhodes where the terrestrial latitude is 36°, the first 10° of Aries rises in 6°14′. To convert this into a standard measure of time, one multiplies by $^{24\mathrm{hr}}/_{360^\circ}$, so that $6^\circ 14' \times ^{24hr}/_{360^\circ} = 24'56''$. The values in Ptolemy's table of ascensions depend on trigonometry [see ch. 3.2, p. 54] but other approaches existed.

One procedure which relies on arithmetic techniques alone is found in a work by a predecessor of Ptolemy, Hypsicles of Alexandria, who determined the rising-times using arithmetic sequences. This work, the *Anaphoricus*, opens with several mathematical propositions which demonstrate three key relations between the terms and the sums of arithmetic sequences. He then uses these abstract mathematical relations with various properties concerning the symmetry of the zodiacal signs along with one piece of empirical data (the ratio of the longest to shortest day in Alexandria) to compute his rising-times of the signs and each degree thereat. In his text, he works through the steps to determine several values only and presents the resulting rising-times in a circular table. Given his careful explanation, Hypsicles presumably intended working astronomers to compile their own tables for their local geographical circumstances.[10]

One notable feature of Hypsicles' exposition is his division of the circle into 360 parts. This reveals the influence of earlier Babylonian sources in which the UŠ, a 360th part of 24 hours, is used extensively. He states:

> With the circle of zodiacal (signs) being divided into 360 equal arcs, let each of the arcs be called spatial degrees (μοῖραι τοπικαί). Indeed, in the same way, when the time in which the zodiacal circle returns from a point to the same point is divided into 360 equal time-intervals, let each of these (time-intervals) be called time-degrees (μοῖραι χρονικαί).
>
> DE FALCO and KRAUSE 1966, 36.55–59

Furthermore, Hypsicles also emblematizes the blending of mathematical calculation and data from observation to quantify celestial phenomena. Such mathematical astronomy used mathematical inferences and propositions to solve problems in astronomy and minimized reliance on observational data, which could be difficult to obtain, inaccurate or imprecise, or even impossi-

10 For the Babylonian origins of these arithmetical schemes, see Rochberg 2004a; Montelle 2016.

ble to observe directly. Despite the rise of technically more sophisticated, more accurate trigonometric approaches, arithmetic techniques, such as Hypsicles', continued to be used, particularly by Greek and Roman astrologers [Jones 1999a].

Geminus too appears to have been familiar with arithmetical approximative approaches to the problem of rising-times. He gives a "4-hour" rule-of-thumb for rising-times:

> And for each of the signs, the total time of the rising and setting is equal to 4 equinoctial hours.[11]
>
> GEMINUS, *Intro. ast.* 7.36–37

In other words, the sum of a zodiacal sign's rising-time and its setting time is 4 equinoctial hours. This rule is approximate and involves various simplifying assumptions. It is clearly not based on computing the rising-times trigonometrically, but rather it is what is produced when one computes rising-times arithmetically, [12] again testifying to the continuation of Babylonian methods.

7 Precession

Another factor which affects the appearance of the celestial sphere over time is precession. Precession accounts for the rotation of the backdrop of fixed stars eastward with respect to the poles of the zodiacal circle. This revolution is extremely slow—about 1° every 72 years. As this motion is with respect to the zodiacal circle, only the longitudes of the stars change; their latitudes remain unaffected.[13] Thus, when considering the zodiacal or ecliptic coordinates of various stars over long periods of time, a correction for precession must be applied. This was the basis, in Ptolemy's view, for the distinction between the tropical year (that is, the time the Sun takes to travel from the vernal equinox back to the vernal equinox) and the sidereal year (that is, the time the Sun takes to travel from a fixed star back to the same fixed star).

11 Equinoctial hours are 1⁄24 the length of daytime plus nighttime on the day of equinox and are thus a constant standard throughout the year, whereas seasonal hours are divisions of the length of daytime (or nighttime) into 12 equal parts and are thus constantly changing throughout the year as the length of daytime and nighttime change [see ch. 9.1 §2, p. 340f].

12 See Evans and Berggren 2006, 173ff. for further discussion.

13 However, in the equinoctial coordinate system, both right ascension and declination change markedly.

Ptolemy discusses precession in *Alm.* 7.2–3 at some length. He concludes that precession is 1° in 100 years, a value which is slightly too low. He opens his investigation of precession with a discussion of Hipparchus' contribution to the topic. He refers to Hipparchus' now lost work titled *On the Displacement of the Solstitial and Equinoctial Points* and cites several observations recorded by Hipparchus concerning the star Spica with respect to the autumnal equinox. Ptolemy notes that Hipparchus concluded in another work, titled *On the Length of the Year*, that "…in 300 years they should have moved not less than 3°" [*Alm.* 7.2]. In this section, Ptolemy indicates that Hipparchus discovered the phenomenon of precession but did not attempt to quantify it with any degree of certainty because of the state of his observational evidence.[14] The effects of precession seemed to be poorly understood or deemed irrelevant by later authors; for apart from Ptolemy, it is hardly ever mentioned in the ancient astronomical literature.

Precession is an effect so slight that it is barely noticeable over the working career of an astronomer. However, over longer periods of time, its cumulative effect should not be ignored. In this way, accounting for precession epitomizes the ingenuity of the astronomers from Antiquity. Subtle but significant perturbations in the phenomena were not gauged directly but rather demonstrated using comparisons of observations over long periods of time and by recourse to mathematics when direct observation was impossible. All explanations had to be consistent with their basic geometrical understanding of the celestial sphere.

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14 For details, see Goldstein and Bowen 1991, 111–114.

Chapter 2

Methods of Reckoning Time

Robert Hannah

1 Introduction

Even the most complex of mechanisms for telling time in the ancient world were influenced at some point by reference to the celestial sphere, where the movements of the Sun, Moon, and stars gave a ready means for marking out the year, seasons, months, days, and hours. People's observations of the movements and appearances of these celestial bodies underpinned the methods of reckoning time in Antiquity and formed the basis of the principal demarcations of time from the year and its months to the day and its hours, which will form the focus of this chapter. So to understand the methods of reckoning time and its major divisions in Antiquity—the hours, days, months, years, and cycles of years—it is useful to reflect on the ancient perception of the cosmos, within which time was bound for people.

2 The Celestial Sphere

In some respects, it is relatively easy to express ancient cosmological concepts in terms that a modern reader can understand. We still have the same essentially geocentric perspective in our language: we talk of the rising and setting of the Sun, Moon, stars, and planets, because that is what our senses tell us is happening. We know that this is not in fact the case but that it is the Earth rotating on its axis, thus creating the illusion that the celestial bodies circle about us—much as we can be caught sometimes sitting in a stationary vehicle and, upon seeing another vehicle move in the opposite direction past us, feel that we are ourselves moving and that the other vehicle is stationary.

Further, we still use for much of the night sky, especially in the northern hemisphere, names for the constellations that derive from the ancients. Many of these may be grouped around classical myths—such as the Perseus group or the Argo group—and represent "mapping" projects of the Classical and Hellenistic Periods, while others, such as the zodiacal constellations, are older still, being Latin translations of Greek translations of Babylonian constellation-names.

 | DOI:10.1163/9789004400566_009

Between the second century BCE and the second century CE, Greek astronomers from Hipparchus to Ptolemy developed a coordinate system of longitude and latitude for situating stars on the celestial globe. Before then, the constellations, perceived in anthropomorphic or zoomorphic forms, provided the usual means of placing fixed stars and planets in the night sky by means of reference to parts of imaginary bodies. Let us take an example from Aratus' poem, the *Phaenomena* (third century BCE), in which he describes the stars and their relative positions without relying on a system of coordinates. It is clear from this that the imaginary figures that formed the constellations provided rough-and-ready means of navigating one's way across the sky:

> Let the left shoulder of Andromeda be a sign for the northern Fish, for it is very near to it. Both of her feet indicate her bridegroom, Perseus, as they move always on his shoulders. He is taller than others in the north. His right hand is stretched out toward the seat of his mother-in-law's throne and, as if pursuing on foot, he lengthens his stride, running in the world of his father Zeus. Near his left knee altogether are the Pleiades. Not much space at all holds them all and they are faint to observe.
>
> ARATUS, *Phaen.* 246–256

The poet asks us to imagine our eyes moving from Andromeda's shoulder (near which is the Northern Fish) to her feet, from which he signals Perseus' shoulders and then his right hand and left knee, from which are mapped, respectively, Cassiopeia's throne and the Pleiades. It may be easier for us to imagine this mapping process if we see it in graphic form; and in this case we are fortunate in being able to refer appropriately to an image that stems from the Hellenistic Period. Plate 1, p. 26 shows an ancient sculptural representation of the constellations on a celestial sphere that is carried by the Titan Atlas. The sculpture is nowadays called the Farnese Atlas from a previous collection in which it was housed. It is dated to the second century CE and, therefore, to the time of Ptolemy; it is in fact a Roman version of an earlier but now lost Greek original, which was made in the Hellenistic Period.[1] In Plate 1, I have added a frame around the group of stars described by Aratus. All but the Pleiades in Aratus' description are presented—Andromeda, the Northern Fish, Perseus, and Cassiopeia on her throne. The star lore that underpins the constellations on

1 Naples, Museo Archeologico Nazionale inv. 6374; Evans and Berggren 2006, 28–29, fig. I.2. There is a much smaller globe (11 cm in diameter, in contrast to the Farnese Atlas' 65-cm-diameter globe), a second-century CE bronze specimen in Mainz, Römisch-Germanisches Zentralmuseum inv. O.41339 [Evans and Berggren 2006, 28, 30–31, figs. I.3–4].

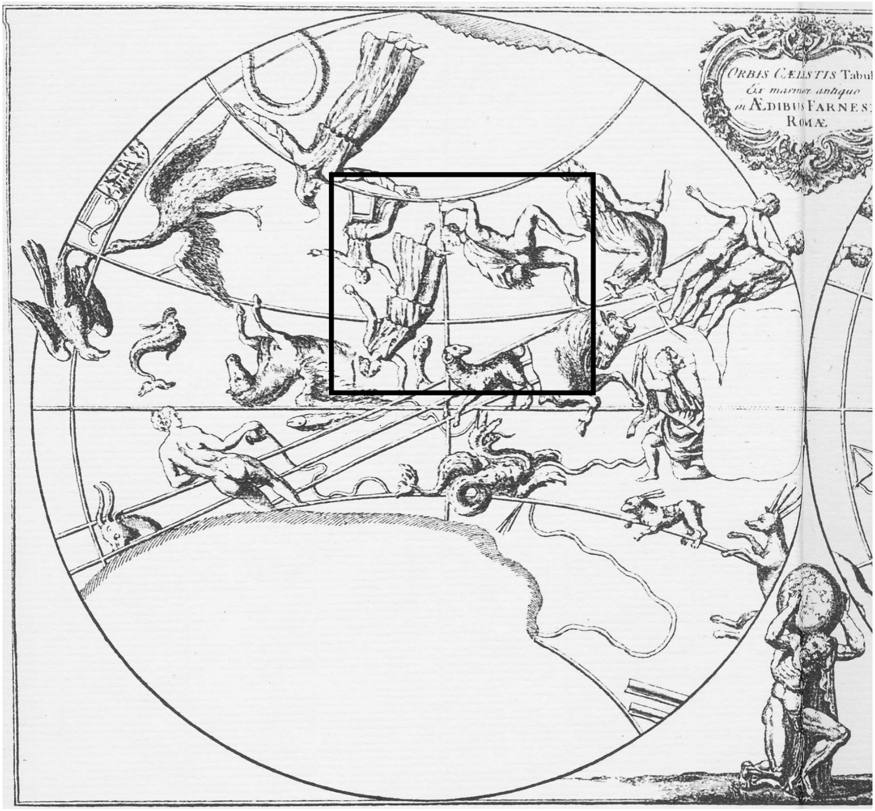

PLATE 1 The Farnese Atlas
Northern constellations, Andromeda, Fish, Perseus within frame.
NAPLES, MUSEO ARCHEOLOGICO NAZIONALE INV. 6374

the globe has been thought to reflect the influence of Hipparchus himself or other Hellenistic astronomers such as Crates of Mallos.[2]

It is likely that Aratus had something akin to this globe in front of him when he described the constellations. His poem's astronomy derives from that of Eudoxus' prose *Phaenomena* and *Enoptron* [see ch. 10.1, p. 383]. Eudoxus, a contemporary of Plato in the fourth century BCE, probably worked with some such globe; and it is certain that Hipparchus did so in the second century BCE. No working mechanical model survives, so the closest we can get to imagining what one looked like in reality is through the artistic representations of celestial globes such as this large-scale specimen borne by the Farnese Atlas. This one

2 See Schaefer 2005; contrast Rawlins 2005.

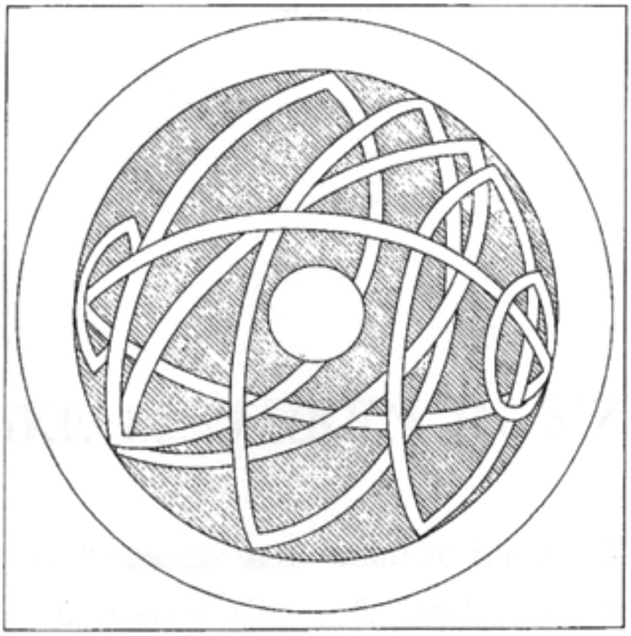

PLATE 2 Mosaic of an armillary sphere (Solunto, Casa di Leda)
VON BOESELAGER 1983, TAF. 15 ABB. 29

presents 41 constellations in figural form set against a backdrop of the parallel circles of the equator between the two tropics and the two polar circles (arctic and antarctic); the slanting zodiacal circle or ecliptic, with the broader zodiacal band or belt, runs from one tropic to the other across the celestial equator; and from pole to pole run the equinoctial and solstitial colures across the equinoctial and solstitial points, respectively, on the zodiacal circle [Dekker 2013].

As a slight digression, we may follow something of the history of such artifices in the Hellenistic Period. If we strip a celestial globe down to its bare essentials and form just a framework of rings and hoops to mark the various circles of the celestial equator, zodiacal circle (ecliptic), tropics, and so on, leaving empty the spaces in between, we end up with the armillary sphere [see ch. 6.4 §5, p. 250]. This is simply a three-dimensional skeleton of the celestial globe.

The earliest surviving image of an armillary sphere is in a mosaic floor panel from the so-called Casa di Leda (named after another piece of decoration) in Solunto in northwest Sicily [see Plate 2].[3] It dates probably to the late second century or early first century BCE [von Boeselager 1983, 57, 60; Westgate

3 See von Boeselager 1983, 56–60, pl. 15, figs. 29–30; Evans and Berggren 2006, 32–33, fig. I.5.

2000, 261, 264n39], a little later than the period of Hipparchus. Represented as ribbon-like bands surrounding a spherical Earth (a significant cosmological concept in itself) are the celestial equator or equinoctial circle, the two tropics, the zodiacal circle, both polar circles, and the equinoctial colure [Hannah 2009, 174n7]. Clearly a portrayal of an astronomer's working instrument, the mosaic sphere is an intriguing embellishment to a private house's floor decoration on an island where one of the outstanding astronomers of Antiquity, Archimedes, had chosen to live (and die) a century earlier [von Boeselager 1983, 60].[4]

Why the house's owner chose this mosaic decoration in particular is unknowable.The three-dimensional physical model on which the mosaic image is based is obviously of earlier date. There are hints of a construction of this type more than 200 years earlier, when Plato in the fourth century BCE describes the creation of the world by the Demiurge, who fashioned a long band marked off according to arithmetic and harmonic intervals. This band was then split lengthways, creating two strips, which were in turn bent round to form two circles. These were then placed one inside the other to form the dynamic structure of the universe. In astronomical terms, they correspond to the celestial equator (or, extrapolated, the sphere of fixed stars) and the zodiacal circle, in which the planets describe their orbits. The first circle he caused to move to the right and named it the circle of the Same; the second circle he caused to move diagonally to the left and named it the circle of the Different [Plato, *Tim.* 36b6–c7].

In Plato's *Timaeus*, Socrates and company are entertained with a semi-mythic account of the nature of things. The creative force, personified as a Craftsman or Demiurge (δημιουργός), seeks to make the cosmos as much like its model, the best of intelligible things, as possible and instills order in the preexisting chaos. We are told that the cosmos is a living creature, a copy of the Living Creature who embraces the intelligible realm [*Tim.* 30c–d]. This creature is described structurally as a sphere that is perfect and uniform. The sphere is considered the shape most complete and most like itself [*Tim.* 33b6]. The Demiurge, "turning [the cosmos] round in the same way, in the same place and within itself, caused it to move, turning in a circle" [*Tim.* 34a3–4]. The body of the cosmos is thus set revolving uniformly around itself and has no part in the six irrational movements (up, down, east, west, north, south). These are embraced and indeed constrained by its spherical order [Pedersen and Hannah 2002].

4 A later painting from Stabiae near Pompeii, dating before the eruption of Vesuvius in 79 CE, illustrates another armillary sphere but is less well preserved [Picard 1970, 84, pl. LVIII (color); Arnaud 1984, 73].

3 The Seasonal Year

It is against this scientific and philosophical conception of the cosmos that we can set Aratus' poem. The various divisions of the celestial sphere—the equinoctial circle with its parallel tropics and polar circles, the zodiacal circle and zodiacal belt, and the equinoctial and solstitial colures—form the structural basis of the sky that he describes.

For Aratus, the constellations are multifunctional. They can be used, as we have seen, to map the sky. But that raises the question Why? He is aware of the use of stars for navigation, as he mentions the difference between Greeks and Phoenicians regarding which of the Bears, Great or Little, that they use for sailing. But his lack of detail betrays a lack of interest or of knowledge in how the stars may serve this purpose in practice: one star, or even constellation, does not a system of navigation make [Hannah 1997]. More significant for the poet, however, is the use of the constellations to mark out time in the agricultural year. In that sense, the poem stands in the long tradition stemming from Hesiod's wisdom poem, the *Works and Days* (seventh century BCE), in which a handful of stars was used to mark out the times of the year for plowing, sowing, and harvesting [Reiche 1989]. In Aratus' *Phaenomena*, however, agriculture takes a back seat, as astronomy is foregrounded, with a large increase in the number of stars to 48 constellations. It may be, therefore, that the Hellenistic poet is setting himself also in another tradition, again stemming from Hesiod, to whom a poem, the *Astronomy*, was attributed. In this arena, the stars are enumerated in poetic fashion and often provided with etiological myths to explain their existence in the night sky [see ch. 10.1 §§2–4, p. 384]. At the very start of the *Phaenomena*, Aratus invokes Zeus (and only later the Muses, the traditional inspirers of poets) as the father who helps humanity in gaining its livelihood from agriculture and who to that end

> set signs in the sky, marking out the constellations, and considered for the year which stars would chiefly give to mankind constant signs of the seasons, so that everything may grow without fail.
>
> ARATUS, *Phaen.* 10–13

Throughout the poem, reference is made *via* the constellations to the seasons:

> Beneath [the Bear's] head are the Twins, and beneath her middle is the Crab, and under her hind legs the Lion appears brightly. There the tracks of the Sun are hottest and the fields appear empty of their ears of wheat when the Sun first comes together with the Lion.
>
> ARATUS, *Phaen.*, 147–151

And if we continue the passage with which we introduced Aratus:

> Near his left knee altogether are the Pleiades. Not much space at all holds them all, and they are faint to observe.... They are equally small and faint, but famous they circle early and in the evening, and Zeus is the cause, who ordered them to be a signal of the beginning of summer and of winter and the arrival of ploughing.
>
> ARATUS, *Phaen.*, 254–256, 264–267

This use of the stars or constellations to signal the seasons and even the weather appears in another form in Greek astronomical documents, namely, the *parapegmata* [see ch. 5.2 §3, p. 198]. Both epigraphic and literary versions of these survive in a variety of forms [Lehoux 2007]. The best-known collection of them, or collation of elements from them, survives in an addendum to Geminus' *Introductio astronomiae* (mid-first century BCE).[5] *Parapegmata* were almanacs of the risings and settings of certain stars, sometimes associated with meteorological data. Geminus excerpts star data from the fifth century, with material from Meton and Euctemon, to the third century BCE, with data from Dositheus. At some time after *ca* 300 BCE, the list of phenomena was reorganized under the zodiacal months, which is how Geminus then presented them [Hannah 2002]. He mentions the astronomer Eudoxus the most, with 60 references, then Euctemon, with 47. An example illustrates the form in which Geminus presents the data:

> The Sun passes through Leo in 31 days.
> On the 1st day, according to Euctemon, the Dog [Sirius] is visible and the stifling heat begins; signs of weather.
> On the 5th, according to Eudoxus, the Eagle [Aquila] sets at dawn.
> On the 10th, according to Eudoxus, the Crown [Corona] sets.
> On the 12th, according to Callippus, the Lion [Leo], half rising, makes a very strong heat.
> On the 14th, according to Euctemon, the heat is at its greatest.
> On the 16th, according to Eudoxus, signs of weather.
> On the 17th, according to Euctemon, the Lyre [Lyra] sets; and it also rains; and the Etesian winds stop; and the Horse [Pegasus] rises.
> On the 18th, according to Eudoxus, the Dolphin [Delphinus] sets at dawn. According to Dositheus, Protrygeter [Vindemiatrix] rises at nightfall.

5 See Bowen 2006, 199–200n4; Evans and Berggren 2006, 231–240.

On the 22nd, according to Eudoxus, the Lyre [Lyra] sets at dawn; signs of weather.
On the 29th, according to Eudoxus, signs of weather. According to Callippus, the Maiden [Virgo] rises; signs of weather.
GEMINUS, *Cal.* Leo

This gives a more detailed astronomical picture of the height of summer than did Aratus above [*Phaen.* 147–151], although the fullness of the picture may be illusory since we have here a compilation of different astronomers' *parapegmata* rather than a single one. Eudoxus, for example, figures six times in the whole zodiacal month of 10 "observations". Indeed, whether we should classify these as actual observations rather than as calculations derived from other means, such as the use of an armillary sphere or celestial globe, is moot. My own view is that in the fifth century BCE and even later, a mixture of actual naked-eye observation and the use of a simple timing device, such as a waterclock (*clepsydra*), provided the basis for the data in the *parapegmata*. These data then tell us, in effect, that a star was visible for the first or last time when the Sun was a certain distance below the horizon, with that solar depression being measured in terms of time not of degrees. In other words, the basis of "visibility" was not the magnitude (brightness) of the star as it is nowadays but a fixed length of time before the Sun rose or after it set.[6]

4 Calendrical Cycles

Extraordinarily sophisticated machines which marked time in various ways were, however, developed in the Hellenistic Period. We may note in passing the elaborate waterclocks of Ctesibius and Archimedes in the third century BCE that are described in the written sources [Vitruvius, *De arch.* 9.8.4–15; Lewis 2000, 364–365]. It is archaeology, in fact, that provides us with a surviving and intriguing example in the so-called Antikythera Mechanism [see Plate 3, p. 32: cf. ch. 9.2, p. 340]. Usually dated to somewhere in the second century BCE, this multi-geared instrument managed to correlate the motions of the Sun, the Moon, and at least two of the planets (and possibly all five known to the ancients). It also presents different forms of calendrical cycle:

6 See, e.g., Fox 2004; Robinson 2007, 2009; Hannah 2018.

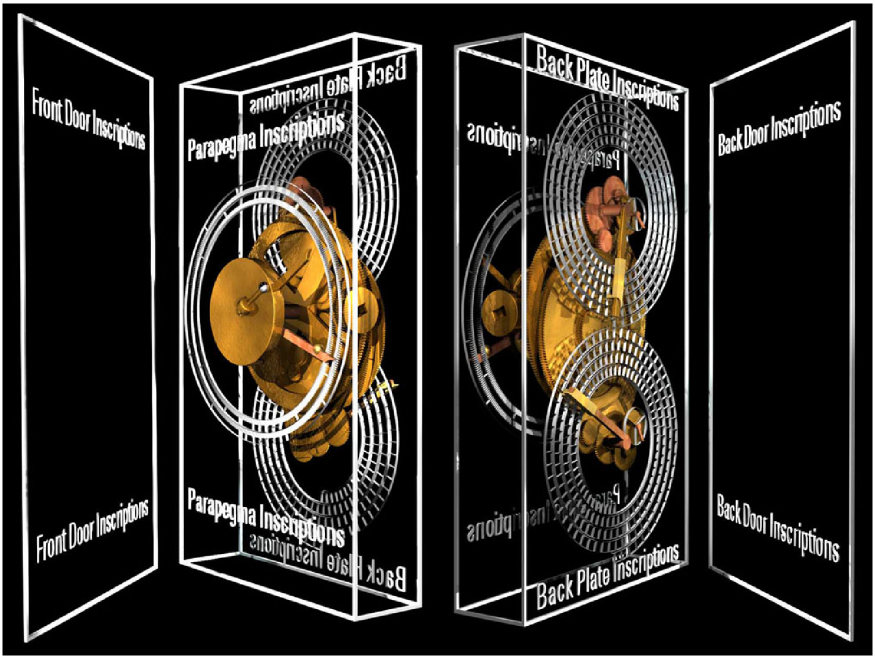

PLATE 3 A reconstruction of the Antikythera Mechanism
FREETH, BITSAKIS, MOUSSAS, SEIRADAKIS, TSELIKAS, MAGKOU, ZAFEIROPOLOU, HADLAND, BATE, RAMSEY, ALLEN, CRAWLEY, HOCKLEY, MALZBENDER, GELB, AMBRISCO, AND EDMUNDS 2006

- two solar
  - a calendar listing zodiacal months and
  - an Egyptian calendar;
- one stellar, as a *parapegma*; and
- one lunar, by way of a localized civil calendar.

All this was packed into a very confined space, not much bigger than a pair of sandals.

With this array of calendrical cycles, the Mechanism enabled a variety of computations, including the prediction of eclipses and the start of solar and lunar months. The *parapegma*, which may have been on a plate on the exterior of the instrument, was keyed into the solar zodiacal dial *via* a sequence of letters set against the observations in the *parapegma* and inserted over particular days into each zodiacal month. The lunar civil calendar is a very recent discovery and is little understood. Its dialect is Doric Greek and this may help us to learn the origin of the Mechanism itself. One study has sought to associate the instrument with the period, place, and indeed the person of Archimedes himself in Doric Syracuse, Sicily [Freeth 2014]. But this will undoubtedly not be the last word on the subject. Another more recent paper has argued persuasively that the Mechanism's civil calendar is of the Corinthian family of calendars, yet not Syracusan as previously thought but Epirote instead; this study hypothesizes that the Mechanism was made on Rhodes for an Epirote patron [Iversen 2017].

5 The Calendar Year

Greek cities tended to have their own calendars. Athens' was different from Sparta's, for instance, and it was different in some respects from that of Delos, even though the two cities were ethnically and politically related. The start of the new year could differ but was usually associated with one of the cardinal points in the seasonal year—the solstices in summer or winter or the equinoxes in spring and autumn. In Athens, for example, the year started with the sighting of the first New Moon after the summer solstice. There followed (ideally but irregularly in practice) 12 lunar months, alternately of 29 and 30 days in length, the whole sequence adding up to 354 days. Table 1, p. 34 shows for comparison the civil calendars of Athens and Delos alongside the Mechanism's calendar; the first month of the year is italicized.

A lunar year of 354 days is 11 days short of a solar seasonal year, to which agricultural and, hence, religious festivals were necessarily tied. Over three such years, the lunar year would shoot ahead of the solar year by 33 days. This is very close to another lunar month, so adding such a month in the third year—intercalating the month—applies a brake to the lunar year and brings it closer to alignment with the solar. Various schemes were tried by the Greeks and other cultures, notably the Babylonian, to find the best fit over a series of lunar years to minimize the discrepancy between the two types of year.

The ultimate solution in Antiquity to the problem of which years carried 13 lunar months instead of 12 was the 19-year, "Metonic Cycle" of 6940 days, in which an extra month was added to 7 of the years [see chs 4.6 §4, p. 140; 5.2 §4, p. 201; 9.2 §3, p. 345]. The cycle was developed in Athens in the late fifth century BCE by Meton, a contemporary of Euctemon, whom we saw in the *parapegma* above. As a cycle of years and months, it had been developed in Babylonia at least from the second half of the sixth century BCE and systematically governed intercalations there from 475 BCE on [Ossendrijver 2018]. If it came to Greece from the East, the Greek contribution was to introduce the day-count. The Antikythera Mechanism also uses this Metonic Cycle. To what extent city-states used the cycle, as opposed to its being purely within the domain of astronomy, is a moot point; but through the Hellenistic Period there

TABLE 1 Greek month-names

Athens	**Delos**	**Antikythera mechanism**
Hekatombaion	Hekatombaion	Apellaios
Metageitnion	Metageitnion	*Phoinikaios*
Boedromion	Bouphonion	Kraneios
Pyanepsion	Apatourion	Lanotropios
Maimakterion	Aresion	Machaneus
Poseideon	Posideon	Dodekateus
Gamelion	*Lenaion*	Eukleios
Anthesterion	Hieros	Artemisios
Elaphebolion	Galaxion	Psydreus
Mounichion	Artemision	Gameilios
Thargelion	Thargelion	Agrianios
Skirophorion	Panemos	Panamos

is evidence that Athens did. There seems to have been no general, systematized agreement over which seven years gained the extra month, as even in Hellenistic Athens a variety of schemes for intercalation appears to have been used. For the Mechanism, it looks likely that the system of intercalation allowed for an extra month in years 1, 4, 7, 10, 12, 15, and 18 of the cycle [Antikythera Mechanism Research Project 2016, 169–170].

Month-names were rarely ordinal (first, second,...) but were generally derived from a festival held in the month. So, for example, Anthesterion in Athens contained the spring festival of the Anthesteria, which celebrated the opening of jars of the previous autumn's wine vintage. The month name Artemisius on the Antikythera Mechanism is, in that form or as Artemision elsewhere, the most common one in surviving Greek calendars; and it is regularly placed in springtime, doubtless because of its association with the cult of the goddess Artemis [Trümpy 1997, 142, 154, 178, 217, 244].

A document from the start of the Hellenistic Period organizes various calendrical elements in the zodiacal-month scheme, which the Mechanism also recognized, and then in the Egyptian calendar. This is a papyrus, known nowadays as *PHib.* 27 from its findspot, el-Hibeh, in Egypt, which presents a festival calendar for the Temple of Neith at Sais, southwest of Alexandria in the Nile Delta [Lehoux 2007, 153–154, 217–223]. It goes month by month according to the Egyptian calendar, telling when the Sun enters each zodiacal sign, indications of when certain stars rise or set, measurements of the length of day

TABLE 2 *PHib.* 27.66–87

Mecheir	6	[The Sun is] in Taurus. The Hyades set in the evening; the night is $11\frac{1}{2} + \frac{1}{10} + \frac{1}{30} + \frac{1}{90}$ hours; the day, $12\frac{1}{3} + \frac{1}{45}$; and Hera burns. And there is a change in the weather and the south wind blows; but if it gets strong, it burns up the produce of the land.
	19	Lyra rises in the evening; the night is $11\frac{1}{3} + \frac{1}{15} + \frac{1}{45}$ hours; the day, $12\frac{1}{2} + \frac{1}{15} + \frac{1}{90}$; and there is an assembly at Sais for Athena and the south wind blows: but if it gets strong, it burns up the produce of the land.
	2..	…rises in the evening; [the night is 11 …hours]; the day, 12[…;] they observe…
	27	Lyra sets in the evening; the night is $11\frac{1}{6} + \frac{1}{90}$ hours; the day, $12\frac{2}{3} + \frac{1}{10} + \frac{1}{30} + \frac{1}{45}$; Feast of Prometheus, whom they call Iphthimis and the south wind blows; but if it gets strong, it burns up the produce of the land.

CF. LEHOUX 2007, 217, 220

and night, days when festivals are due to take place, and weather forecasts. The excerpt in Table 2 gives the readings for the Egyptian month of Mecheir (equivalent to our early April to early May).

The Egyptian calendar was an administrative one, in which each year had exactly 365 days divided into 12 months, each of 30 days, plus 5 extra days (ἐπαγόμεναι in Greek, hence epagomenal days in English). The names of the months are given in Table 3, p. 36. The month drawn from the Hibeh Papyrus in Table 2, p. 35, is, therefore, the sixth in the year. The five epagomenal days were added at the end of the year after the month of Mesore.

TABLE 3 Egyptian month-names

I	Thoth	VII	Phamenoth
II	Phaophi	VIII	Pharmouthi
III	Hathyr	IX	Pachons
IV	Choiach	X	Payni
V	Tybi	XI	Epeiph
VI	Mecheir	XII	Mesore

6 Days and Hours

The Hibeh Papyrus' recorded measurements of the length of daytime and nighttime present an appearance of extreme precision (for Antiquity). They might be derived from use of a waterclock or simply from an artificial scheme of the seasonal lengthening and shortening of the hours of daytime through the year or a combination of both. There is no evidence outside astronomy that such precise measurements of time were in practical, everyday use.

On the contrary, time-telling devices such as sundials, even very large ones, generally show no more than the hour [see Plate 4, p. 37: cf. chs 3.1 §3, p. 44; 9.1, p. 323]. Before the first centuries BCE/CE, sundials had no hour numerals and sometimes not even hour lines but bore inscriptions identifying only the placement of the solstices, equinoxes, and zodiacal signs. In the literary record, it is from the first century CE that we find, in both Roman and Greek contexts, that the hours are numbered. Among writers from the Imperial Roman Period such as Martial, Pliny the Younger, and Artemidorus, it is characteristic to recognize sharper definition in the subdivision of daytime by means of numbered hours. Half hours were recognized from the fourth century BCE, to judge from a fragment of the dramatist Menander; but we do not know what instrument the poet had in mind for such a measurement nor why he noted it. So the sundial served primarily as a calendrical device telling the time of year rather than as a device to tell the time of day. Only from the first century CE did sundials become an instrument to tell both the time of day and the time of year [Price 1975, 369].

Nonetheless, other evidence suggests that at a popular, albeit bureaucratic, level, explicitly numbered hours were recognized and used. In the mid-third century BCE, the Ptolemaic postal system operated with "hour-passes". These numbered the hours at which the courier reached the stations, specifically the hour before dawn and then the 1st, 6th, 11th, and 12th hours [Remijsen 2007]. The surviving logbook does not indicate how the hours were measured, whether by means of a sundial or a waterclock.

PLATE 4 Conical sundial (Theater of Dionysus, Athens)
PHOTOGRAPH: R. HANNAH

A more rough-and-ready system of telling the time existed in the simple quartering of daytime into three-hour blocks, demarcated by the 3rd, 6th, 9th, and 12th hours. In Republican Rome, an official known as the *accensus* had the job of announcing when it was the end of the third, sixth, and ninth hours of the day [Varro, *De ling*. 6.89: cf. Pliny, *Nat. hist*. 7.212]. The sixth hour, signaling noon, was noted not by the height of the Sun but by a distinctly artificial observation within the built environment in Rome—the passage of the Sun between the Rostra and the Graecostasis in the Forum, when viewed from the Senate House—thus creating a makeshift sundial out of the local architecture. We are not told in the literature how the third and ninth hours were recognized; but, since a few sundials do survive with these hours specifically marked out, some such mechanism would seem most likely.[7]

The origins of the notion of the 12- or 24-hour day are still hard to trace. From around 2400 BCE, the Egyptians began to tell the time by hours at night by watching the risings of the decanal stars.[8] (The hours became associated with certain stars or star-groups which rose heliacally at 10-day intervals through the

7 See Gibbs 1976, 300, no. 3080 for a list of the sundials so marked.
8 See chs 4.8 §1, p. 160; 7.1 §4, p. 264 and §7, p. 267; 12.1 §5, p. 448.

year. Sirius was one of these and it was joined by 35 other stars, whose identification is still a matter for conjecture. Collectively they are now known as the “decans”, after the Greek name for the 10-day interval.) By about 2150 BCE, these hours numbered 12 [Parker 1974, 53]. But why they did so remains unclear and has been the subject of speculation. Other influences appear to come from the Near East or Greece. The history of the division of the day into smaller units of time—notably this 12-hour division of daytime or the 24-hour division of day and night—has never been the subject of systematic investigation. It is now, however, attracting attention from a collaborative team of experts in Egyptology, Assyriology, and Hellenistic science.[9]

7 Conclusion

In this brief overview, we have seen how the fundamental basis for reckoning time in Greco-Roman Antiquity lay in the perception of the cosmos as a sphere that provided a relatively regular framework for the periodic revolutions of the Sun, the Moon, and the stars. Armillary and celestial spheres were developed in the Hellenistic Period to represent this view of the cosmos and to assist in the use of those heavenly motions to tell time, since these motions could serve to demarcate the year, the month, the day, and divisions of the day. We have seen how this time-marking served a number of purposes: initially and primarily religio-agricultural and later scientific. The Sun governs the seasons, which in turn cause the cyclical growth of plants for food. It is in this context that we have read Aratus’ *Phaenomena*. Concern over the stability of that growth and thanksgiving for its success and regularity set agricultural production within the broader framework of religious belief and practice, so that festivals were held to ensure the continuity of growth and hence of societies’ survival.

The Hibeh Papyrus illustrates the incorporation of astronomical timekeeping into the religious life of a community of Hellenistic Egypt. But other communities were also interested in the capacity for astronomy to help tell time. The Antikythera Mechanism is the most sophisticated surviving engineering device that incorporated solar, lunar, and stellar methods of reckoning time. It is assumed that it was made and used for scientific purposes and that may be the case. But even so, the extreme localization of that time-reckoning within a particular subculture of Hellenistic Greece may suggest other purposes beyond the paradigm of “science purely for science’s sake” under which we live now.

9 A team led by Professor Sacha Stern (London) and Dr Jonathan Ben-Dov (Haifa) is investigating the origins of the use of the day as a unit in Antiquity and the Middle Ages.

Quantitative Tools

CHAPTER 3.1

Techniques of Measurement and Computation

Mathieu Ossendrijver

1 Calendars Used by Astronomers

In Babylonian astronomy, dates were expressed in the lunisolar civil calendar. A Babylonian date consisted of a year number, a month-name, and a day-number between 1 and 30. Before the introduction of the Seleucid Era (SE), which was shortly after 311 BCE, years were counted as regnal years of the ruling king. After that, the year was a running number counted from SE year 1 = 311/310 BCE. The year began on day 1 of the month Nisannu. In the period of concern, the new year always fell within about 30 days of the vernal equinox, that is, around 23 Mar on our calendar.[1] The other 11 months of the Babylonian calendar are given in Table 1, p. 42. The day began at sunset.

A new month was declared when, at most a few days after the New Moon, the first lunar crescent was sighted shortly after sunset. In the Babylonian calendar, this occurred at the end of either day 29 or day 30. If, due to bad weather, the crescent could not be observed at the end of day 30, then day 1 of the new month was nevertheless proclaimed. Hence, a Babylonian month always had either 29 or 30 days. A normal year contained 12 months, which added up to a total of about 354 days, roughly 11 days shorter than the solar year. In order to prevent the months from drifting through the seasons, an intercalary month was occasionally added to the year. Probably from 475 BCE, a 19-year cycle was used for this [Ossendrijver 2018], whereby one second Ulūlu (VI_2) and six instances of a second Addaru (XII_2) were inserted according to a fixed rule,[2] resulting in a cycle of 235 months.

Most Greco-Roman astronomers, for example, Claudius Ptolemy in his *Almagest*, used the Egyptian calendar for dating astronomical phenomena. In this calendar, 1 year contained 365 days, which were divided into 12 months of 30 days each and 5 so-called epagomenal days. The month names were Hellenized versions of Egyptian months [Table 3, p. 36]. Since the year was about

1 Between 350 BCE and 1 CE, the Julian date of the vernal equinox shifted from 25 to 22 Mar.

2 However, until 384 BCE, a few intercalations were still implemented in a different month or year than prescribed by the final 19-year pattern.

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TABLE 1 Babylonian month-names

I	Nisannu	VII	Tašrītu
II	Ajjaru	VIII	Araḫsamna
III	Simānu	IX	Kislīmu
IV	Du'ūzu	X	Ṭebētu
V	Abu	XI	Šabāṭu
VI	Ulūlu	XII	Addaru

¼ of a day shorter than the solar year, the months slowly drifted through the seasons, completing one cycle in 1,460 Julian years (= 1,461 Egyptian years). Hence, there was no fixed correspondence between Egyptian months and Babylonian months. Ptolemy used this calendar for constructing a uniform chronological framework, setting out from year 1 of the Babylonian king Nabonassar, which corresponds to 747/746 BCE.

In some Greco-Roman astronomical works, other calendars were used [see ch. 2 §5, p. 33]. The main alternative to be mentioned here is the Alexandrian calendar, which became the civil calendar of Roman Egypt during the reign of Augustus. In this calendar, a sixth epagomenal day was inserted once every four years, thereby removing the drift of the months through the seasons. The month-names were the same as in the Alexandrian calendar. The Julian and other Roman calendars were also used by astronomers. Like the Alexandrian calendar, a normal Julian year contained 365 days, with an intercalary day added in February once every four years.

2 Units of Time

In the astronomical Diaries and in the lunar texts of Babylonian mathematical astronomy, time-intervals were expressed in the unit UŠ, which corresponded to 1⁄360 of 1 day or 4 modern minutes.[3] «UŠ» is often translated as "time-degree" but the Akkadian reading and literal meaning are unknown. This unit must often be inferred from the context because the sign «UŠ» was rarely written after the number. The next larger unit associated with it was the *bēru*, which

3 «UŠ» is written in capital letters because it is a transliterated logogram and not an Akkadian phonetic rendering, which remains unknown.

contains 30 UŠ, amounting to two modern hours. Hence, 1 day = 12 *bēru* = 360 UŠ.[4] The only other named unit associated with the UŠ is the *nindanu* (literally, rod), which corresponded to 1⁄60 UŠ. The *bēru*, the UŠ, and the *nindanu* were originally units of length and geographical distance.[5] In the Diaries and some other astronomical texts, time-intervals were expressed as a whole number of *bēru* plus a sexagesimal number of UŠ between 0 and 30 [see §7, p. 51]. In mathematical astronomy, however, time was more often expressed as a single multi-digit sexagesimal number of UŠ, even when this number exceeded one *bēru*. In these texts, the *nindanu* is rarely mentioned.

In horoscopes and other Babylonian astrological texts, time was sometimes expressed as an integer number of seasonal hours (*simānu*) between 1 and 12 [Rochberg 1989a, 1998]. Depending on whether the event took place during the daytime or nighttime, a seasonal hour corresponded to 1⁄12th of daytime or nighttime. Since the length of daytime varied in the course of a year, so did the seasonal hours. However, seasonal hours do not appear to have been used for reporting or computing the time of astronomical events. For instance, in the astronomical Diaries, the time between sunset and moonset and other intervals was always expressed in UŠ.

A comparable situation existed in the Greco-Roman world, where seasonal hours (ὥραι καιρικαί) were commonly used in astrology and in daily life, while astronomers preferred to use equinoctial hours (ὥραι ἰσημέριναι), defined as 1⁄24 of 1 day, which have a constant duration [see ch. 2 §6, p. 36]. The equinoctial hours were usually counted from midnight or noon. This unit had no counterpart in Babylonian astronomy. Greco-Roman astronomers also adopted the time-degree, which they used in exactly the same manner as the Babylonian UŠ, that is, 1 day consisted of 360° of time. The intervals measured in time-degrees were referred to as equinoctial times (χρόνοι ἰσημέρινοι).

In Babylonian mathematical astronomy, time-intervals were expressed differently for planetary phenomena. In the synodic tables for the five planets [see chs 4.1 §3, p. 66; 4.6 §3, p. 137], the computed date of a synodic phenomenon was usually expressed as a year-number, a month-name, and a number between 0 and 30 representing what are now called mean *tithis*. "Tithi", a term borrowed

4 In the older literature, this was often translated as "double hour" because it represented 1⁄12 part of a full day.

5 As a unit of time, the UŠ is not attested before about 1200 BCE. As a unit of geographical distance, corresponding to about 360 m, it can be traced back at least to the Ur III period (2100–2000 BCE), as is also true for the *beru*. For the units of time and distance used in Babylonian astronomy, see also Brown 2000a.

by historians today from Indian astronomy, denotes an artificial unit of time corresponding to 1⁄30 of the mean synodic month (≈ 29.53 days). However, the Babylonian astronomers did not use a distinct word for it other than “day”. Times expressed in mean *tithis* were sometimes tabulated with up to three sexagesimal digits. The advantage of using mean *tithis* instead of real days was that this circumvented the problem of computing the lengths of future months (29 or 30 days). The price to be paid was that the equivalent real date might differ from the number of mean *tithis* by plus or minus one.

Apart from the synodic tables, mean *tithis* were used in some daily-motion tables of the planets. In these, the computed positions pertained to mean *tithis* rather than actual days.

The synodic tables for the Moon contain several columns with time-intervals giving, for example, the time of the Full Moon. They were always expressed in the unit UŠ (time-degree) and usually defined with respect to the immediately preceding or following sunset, sunrise, or midnight. In order to specify the time of the event fully, the day-number of the reference time, for example, midnight, was mentioned alongside the duration of the interval. The mean *tithi* of the planetary tables was not used in the lunar theories. However, in a few lunar tables, quantities were tabulated for every 1⁄30 of the variable synodic month. This implicit unit of time might be called a real *tithi* because its duration varied from month to month in accordance with the duration of the synodic month itself.

3 Measurement of Time

How the time-intervals expressed in UŠ were measured is not revealed in any Babylonian text. One method that might have been used during the night involves the observation of so-called *ziqpu*-stars.[6] These stars form a band distributed along a circle parallel to the celestial equator that passes through the zenith for an observer in Babylonia [see Figure 3B, p. 17]. By observing which *ziqpu*-stars culminate at the beginning and at the end of an astronomical event, for example, an eclipse, the duration of the event could be quantified. No later than the Seleucid Era, the astronomers used tables listing the number of UŠ between successively culminating *ziqpu*-stars. Since 1 day amounts to 360 UŠ, these intervals ideally added up to 360 UŠ for the full circle. However, many time-intervals that are reported in the Diaries occur near sunrise

6 For the *ziqpu*-star texts, see Hunger and Pingree 1999, 84–90.

or sunset, when few or no *ziqpu*-stars may have been visible. It is, therefore, highly doubtful that these time-intervals were measured by observing *ziqpu*-stars.

Another method for measuring time in UŠ, which does not rely on stars, involves the waterclock. No archaeological remains and no descriptions of such an instrument have been found in Babylonia.[7] But its existence is implied by Old-Babylonian tablets with mathematical problems involving waterclocks [Neugebauer 1935–1937, 142–193, 219–233][8] and by numerous astronomical texts in which the duration of daylight and other time-intervals are tabulated in *minas* of weight, where 1 *mina* ≈ 500 grams, apparently representing the amount of water passing through a waterclock. Various suggestions have been made as to the construction of this instrument but none of them has thus far been confirmed [Brown, Fermor, and Walker 1999–2000; Fermor and Steele 2000].

Not much is known about the use of waterclocks in Greco-Roman astronomy. Vitruvius describes a sophisticated type of waterclock called an anaphoric clock, which included a rotating drum indicating seasonal hours. Archaeological remains of anaphoric clocks from the Roman Era were found in Austria and France [Evans 1998, 155–156].

A third method for measuring time, usable only during daytime, involves the sundial. No archaeological evidence of sundials has been uncovered in Mesopotamia. But two groups of tablets prove that they were used in Babylonia: first, there are tables recording times after sunrise, expressed in *bēru* and UŠ, for given lengths of the shadow of a gnomon; second, there are two procedure-texts, probably dating between 450 and 150 BCE, giving detailed instructions for constructing a sundial.[9] The instructions imply that this sundial contained markings for seasonal hours, as is true for most known Greek and Roman sundials [see ch. 9.1, p. 323].[10]

Herodotus famously suggests that the Greek sundial was modeled after the Babylonian one: “The sundial (πόλος) and the *gnomon* and the division of the

7 However, the British Museum holds a Neo-Assyrian copper bowl with a hole at the bottom that has been tentatively interpreted as a waterclock of the sinking-bowl type [Brown 2000a, 119].

8 These mathematical problem texts are only partly understood. They appear to be concerned with the relation between the water-level and the amount of outflowing water.

9 For the shadow-texts, see Hunger and Pingree 1999, 79–83; Steele 2013. These procedure-texts remain untranslated but some passages of these difficult texts are discussed in Rochberg 1998.

10 The dial from Oropos is taken to record equatorial hours [Schaldach 2006, 116–121, no. 23].

day into 12 parts (μέρεα) the Greeks took from the Babylonians" [Herodotus, *Hist.* 2.109.3]. In the Greco-Roman world, the use of sundials was widespread. Vitruvius wrote extensively about this instrument in *On Architecture* [Evans 1998, 132–135]. Archaeological remains of ancient sundials have been found in all parts of the Roman Empire. Sundials from different regions often have a similar appearance but their construction usually reflects the local geographical latitude [see ch. 9.1 §4, p. 328]. Hence, the Greco-Roman sundials reflect a body of geographical knowledge, including an awareness that the Earth is spherical. By contrast, the Babylonian texts about shadow-lengths and sundials do not suggest that the length of a shadow varies with the geographical location.

4 Units of Celestial Distance

Babylonian astronomers used two different systems of units for expressing distances in the sky.[11] In the astronomical Diaries and related texts, lunar and planetary positions are usually reported in terms of distances "in front of " or "behind" and "above" or "below" a nearby reference star. A more or less fixed group of about 32 stars that straddle the zodiacal circle, referred to as Normal Stars [see Glossary, p. 650] in the modern literature, are used for this. Most of them have been securely identified.[12] In addition to distances to Normal Stars, the Diaries report distances between the planets or between the Moon and a planet, expressed in cubits (*ammatu*) and fingers (*ubānu*), where 1 cubit = 24 fingers. Like the UŠ, they are ancient units of length that were transferred to astronomy from daily life.

Modern analyses of the reported distances have revealed that 1 cubit ≈ 2.27° and that the directions "in front of" or "behind" and "above" or "below" are to be understood as roughly parallel and perpendicular, respectively, to the path of the Sun [Graßhoff 1999; Jones 2004b]. In Babylonian mathematical astronomy, the cubit is rarely used. In the few known instances, it is equated to either 2 UŠ or 2;30 UŠ,[13] the latter being referred to as the large cubit.[14] Since these

11 For a detailed discussion of celestial measurement in Babylonian astronomy, see Brown 2000a; Steele 2007b.

12 For a list of the most common Normal Stars, see Sachs and Hunger 1988–1996, 1.17–19; see also Jones 2004b, 481–491.

13 For this notation, see §7, p. 51.

14 For the large cubit equivalent to 2.5° and consisting of 30 fingers, see Neugebauer and Sachs 1967, 204–205. It has been claimed that the large cubit is also attested in the astro-

TABLE 2 Babylonian names of the 12 zodiacal signs/constellations

Babylonian	Hired Man	Stars/Brush	Twins	Crab	Lion	Furrow
modern	Aries	Taurus	Gemini	Cancer	Leo	Virgo
Babylonian	Scales	Scorpion	Pabilsag	Goat-Fish	Gula	Tails
modern	Libra	Scorpius	Sagittarius	Capricorn	Aquarius	Pisces

Stars/Brush: "stars" is the literal translation of the logogram "brush" of its Akkadian reading. Pabilsag is an ancient warrior deity. Gula is not the Babylonian goddess of healing but a deity associated with Enki/Ea, the god of wisdom and subterranean water. Alternative Babylonian names of the sign Tails (Pisces) are "Ribbon of the Fish" or "Swallow".

values are incompatible with the length of the cubit as reconstructed from the Diaries, they are valid only within mathematical astronomy.

Cubits and fingers also appear in Ptolemy's *Almagest*, in passages that are translations of Babylonian observational reports [*Alm.* 9.7, 11.7]. As in Babylonian astronomy, 1 cubit = 24 fingers. Before Ptolemy, Hipparchus was the first Greek astronomer to use these units. There is some evidence that the Greek astronomers assumed 1 cubit = 2° [Neugebauer 1975, 591–592].

Near the end of the fifth century BCE, Babylonian astronomers invented the zodiacal circle or ecliptic by dividing the path of the Sun into 12 segments or signs of 30 UŠ, each named after a nearby constellation. The full circle comprised 360 UŠ, so that this usage of the UŠ was more or less equivalent to the modern degree.[15] The Akkadian word for constellation, «lumāšu», was from then on also a technical term for zodiacal sign. The zodiacal circle was probably conceived in analogy to the existing division of the day into 12 *bēru* of 30 UŠ (time-degrees) mentioned earlier. Unlike the UŠ, the *bēru* was not adopted for expressing celestial positions or distances. Note that the UŠ continued to be used as a unit of time; hence, two fundamentally different usages of the UŠ must be distinguished after the introduction of the zodiacal circle. For the Babylonian names of the zodiacal signs, see Table 2.

In mathematical astronomy, which developed shortly after 400 BCE, the positions of the Moon, the Sun, and the planets were computed in a two-

nomical Diaries [Neugebauer 1975] and related texts but this has been refuted in Jones 2004b (see esp. 511–515).

15 However, in the Babylonian texts, the celestial distances in UŠ are always defined parallel or perpendicular to the zodiacal circle, whereas the modern degree is measured along any great circle.

dimensional coordinate system based on the zodiacal circle or path of the Sun and the direction perpendicular to it. The coordinate of the Moon, the Sun, or a planet along the zodiacal circle, more or less corresponding to longitude, was called position (*qaqqaru*). It was indicated by a zodiacal sign and a number of UŠ between 0 and 30 counted from the beginning of the sign. The position was typically computed with up to four, sometimes seven sexagesimal digits. The UŠ was subdivided into 60 *nindanu* (rods), though this unit, corresponding to the second sexagesimal digit of the number of UŠ, is rarely mentioned. The boundary between two signs was referred to as 30 UŠ of the preceding sign, thus avoiding the zero. Furthermore, in some tables, positions within the first UŠ of a sign, say x, were referred to as $30 + x$ of the preceding sign. Outside mathematical astronomy, for example, in the astronomical Diaries, celestial distances continued to be expressed in cubits and fingers after the introduction of the zodiacal circle. In these texts, zodiacal signs only appear in a brief section listing for each planet the sign in which it was located during that month. These sections are found only in Diaries written after about 400 BCE.

Babylonian zodiacal positions are sidereal, that is, fixed with respect to the stars, as opposed to the longitudes in Greco-Roman astronomy, which are tropical, that is, defined with respect to the moving vernal equinox [see ch. 1 §7, p. 22]. As a result, there is a systematic drift between the Babylonian zodiacal positions and modern tropical longitudes. For some Normal Stars, positions are preserved in Babylonian star-catalogs; others can be reconstructed from the astronomical Diaries and related texts. By comparing these positions with modern data it has been determined that the mean longitudinal difference, Babylonian minus modern, can be described by the expression:

$$\Delta\lambda(Y) = 3.0800° - 1.3828°Y \pm 0.3300°,$$

where Y measures Julian centuries from year 0 [Britton 2010]. Hence, the origin of the Babylonian zodiacal circle, 0 UŠ of Aries, does not coincide with the vernal equinox. The alignment of this circle probably resulted from the selection of certain Normal Stars as convenient markers of boundaries between zodiacal signs or of the exact midpoint of a zodiacal sign. According to one plausible scenario, the Normal Stars α Tau and α Sco were located at 15 UŠ of their respective signs [Britton 2010].

Other conventions for the vernal equinox, all different from the one underlying the observational texts, were embedded in lunar Systems A, B, and K of mathematical astronomy. Each incorporated an algorithm whereby the duration of daylight was computed from the zodiacal position of the Sun. According to these algorithms, the equinox occurred when the Sun was at 8° of Aries in System B, at 10° of Aries in System A, and, probably, at 12° of Aries in System K.[16] There is reason to believe that these lunar systems were created in the chronological sequence K, A, B. If this is correct, then the Sun's position at the vernal equinox was redefined to a smaller value each time a new lunar theory was developed.

The tablets with mathematical astronomy also contain computations of the distance of the Moon or a planet to the zodiacal circle. This quantity was called height or depth, depending on whether the Moon or the planet was above or below this circle. Unlike modern latitude, height and depth were both counted positively, since there was no concept of negative numbers in Babylonian mathematics. Several different units were used for this quantity. In lunar System A, the Moon's distance to the zodiacal circle, which is tabulated in so-called column E [see ch. 5.1 §6, p. 183], was expressed in a special unit called a barleycorn, where 1 barleycorn = 1⁄72 UŠ. The reason for this is not really clear since the barleycorns are converted to UŠ in further computations contained on the same tablets.

In lunar System B, a related measure of the Moon's distance to the zodiacal circle is tabulated in column Ψ or in its variants. This distance is expressed in fingers, UŠ, or a special unit corresponding to 18 fingers. In these texts, 1 finger = 1⁄12 UŠ, which can be traced back to the equivalence 1 cubit = 2 UŠ. Compared to the lunar texts, distance to the zodiacal circle is rarely addressed in the planetary texts. None of the extant planetary tables contains a column for this quantity. But some procedure-texts for Jupiter and Saturn do provide an algorithm for computing it. In these texts, it is expressed in cubits or fingers, using the same equivalence 1 cubit = 24 fingers = 2 UŠ.

The precise date when the Babylonian zodiacal circle was first adopted by Greek astronomers is unknown; but by the close of the fourth century BCE, Autolycus and Euclid were familiar with it [Neugebauer 1975, 593]. The Greek names of the zodiacal signs and their modern Latin equivalents were essentially translations or reinterpretations of the Babylonian ones. The Greco-Roman iconography of the zodiacal signs can also be traced back to Babylonian depictions [see ch. 1 §2, p. 10].

After the discovery of the precession of the equinoxes by Hipparchus, the sidereal year was distinguished from the tropical year [see Glossary, p. 648]. From then on, Greek astronomers counted zodiacal longitude from the moving

16 For Greco-Roman attestations of these locations of the vernal equinox, see Neugebauer 1975, 594–600. For the vernal equinox in lunar System K, see Ossendrijver 2012.

vernal equinox, which was defined as 0° of Aries. However, some Greco-Roman astronomical and astrological works continued to mention various older traditions in which the vernal equinox was fixed at 8°, 10°, or 12° of Aries, as in Babylonian mathematical astronomy [Neugebauer 1975, 594–600]. Along with the zodiacal circle, Greek astronomers adopted sexagesimal place-value notation for computing celestial positions [see §7, p. 51].

5 Measurement of Celestial Distance

It is unclear how the distances in cubits and fingers as reported in the Babylonian Diaries were measured. No archaeological remains of a likely instrument have been found. By itself this is not surprising because the instrument was presumably constructed from a perishable material such as wood or reed. What is peculiar is that no mention of such an instrument has been found in any cuneiform text, while other instruments, in particular the waterclock and the sundial, are frequently attested. It must, nevertheless, be assumed that some instrument comparable to the medieval Jacob's staff with appropriate markings for cubits and fingers was used for measuring the celestial distances. One can only speculate as to its form. Perhaps it was shaped like an elongated T with markings for cubits and fingers at the top bar.

The Babylonian astronomical texts do not reveal any awareness that the Earth was spherical. Neither do they address the spatial arrangement of the celestial bodies. By contrast, these issues were fundamental to most Greek astronomers and natural philosophers whose writings have come down to us. Whereas in Babylonia astronomical theory was primarily expressed in arithmetic form, astronomers in the Greco-Roman world often approached these issues with geometric methods. Eratosthenes, Aristarchus of Samos, Claudius Ptolemy, and others developed geometric methods for measuring the size of the Earth, the Moon, the Sun, and the distances between them.

6 Periods and Their Use for Astronomical Computation

In Babylonia, the use of periods for astronomical prediction had a long tradition that can be traced back to the Old-Babylonian Era. In Babylonian mathematical astronomy, periods were not used directly. Instead, all of its algorithms were based on period-relations, some of which are explicitly mentioned in procedure-texts [Ossendrijver 2012]. However, the astronomical Diaries and related texts testify to the undiminished usage of period-based methods for astronomical prediction after 400 BCE. The main example of this are Goal-Year texts, in which lunar and planetary phenomena are predicted by means of periods expressed as a number of calendar years plus or minus a correction in days. Similar methods, sometimes based on identical periods, were used in Greco-Roman astronomy, especially outside the main traditions of scholarly astronomy that have come to us through manuscripts. Important examples of such alternative methods of astronomical computation are the Keskintos inscription[17] and the Antikythera Mechanism [see ch. 9.2, p. 340].

7 Sexagesimal Place-Value Notation and Astronomical Computation

Babylonian astronomers performed their computations in a sexagesimal (base 60) place-value notation (SPVN) inherited from Old-Babylonian mathematics (1800–1600 BCE). Numbers were given in sequences of digits, each having a value between 0 and 59. Every digit was associated with a power of 60 that decreased by 1 in the rightward direction. By the fifth century BCE, a special sign, usually transliterated as "0", was introduced for indicating vanishing intermediate digits, that is, powers of 60 that are not represented by a digit in the sequence. As opposed to our decimal system, which is an absolute notation, Babylonian SPVN is called floating or relative because vanishing initial or final digits were usually not written and there is no cuneiform equivalent of the decimal point. Hence, the power of 60 corresponding to each digit can only be inferred from the context, which is, however, rarely a problem in the astronomical texts. In the commonly used modern representation of SPVN, a semicolon (";") is placed between the units with power 0 ($60^0 = 1$) and those for the digits of power −1 ($60^{-1} = 1/60$), the analog of our decimal point; and commas are placed between all other digits. However, in transliterations, the floating character of the cuneiform notation is usually preserved by using the period (".") as a separator between all digits.

For a proper understanding of the role of SPVN, note that it was primarily a tool for computation in both accounting and science. Any cuneiform scribe learned to do elementary arithmetic in SPVN during the scribal education. However, the written form of SPVN is found only in astronomical and mathematical texts. Outside these scholarly corpora, for example, in administrative texts, there is virtually no written trace of it because lengths, surfaces, weights, and other quantities were always written in non-positional, tradi-

17 For the Keskintos inscription, see Jones 2006b.

tional metrologies. It is generally assumed that the scribes of the administrative texts also used SPVN but only for performing intermediate computations. Before writing the result, a conversion to the appropriate non-positional metrology was performed by consulting conversion tables. In the scholarly realms of astronomy and mathematics, such conversions were rarely done. SPVN is also attested in the astronomical Diaries but only for reporting time-intervals expressed in UŠ, which usually contain two digits. Recall that the distances to the Normal Stars were expressed in a non-positional metrology based on cubits and fingers.

At the practical level, the only arithmetic operations found in Babylonian astronomy were addition, subtraction, and multiplication. Division did not occur in the algorithms for computing lunar and planetary tables because it was reformulated as multiplication by a reciprocal number. Little is known about the execution of these arithmetic operations for the period after 400 BCE. Unlike for the Old-Babylonian Era, only a few tables for multiplication have been found. A commonly suggested explanation is that the scribes no longer needed such tables because they were using an abacus-type device.

As was the case for the zodiacal circle, the exact date when sexagesimal calculation was adopted by Greek astronomers is unknown. It is generally agreed that this happened between 300 and 200 BCE. Eratosthenes is the earliest Greek scholar who is believed to have used it [Neugebauer 1975, 591]. With Hipparchus, SPVN became a central tool of astronomical computation, the prime example being Ptolemy's *Almagest*. The Greek version of SPVN differed from the Babylonian one in several respects. First, usually only the digits smaller than 1 were written in a truly sexagesimal positional system, while the whole degrees were often written as a decimal number. Furthermore, the sexagesimal digits were not written with a distinct set of number signs but with ordinary letters. As in Babylonia, a special sign was used for indicating vanishing digits (0). Essentially the same Greek version of SPVN was also used in the tables in the Greco-Roman astronomical papyri from Oxyrhynchus, some of which were computed using methods that were essentially Babylonian.

Many of the more sophisticated mathematical concepts, methods, and notations that are encountered in Babylonian mathematical astronomy were unknown before the fifth century BCE. By that time, the Old-Babylonian terminology for the arithmetic operations was largely replaced by a new one. While the old terms were typically used only in certain well-defined contexts, a single set of arithmetic terms could now be applied to all kinds of quantities. Second, many columns of the lunar and planetary tables contain additive or subtractive corrections, which are expressed as numbers followed by an instruction to add or subtract. This new concept of additive and subtractive numbers reflects the important role of numerical differences in Babylonian mathematical astronomy.

Other innovations of mathematical representation that were probably triggered by the needs of astronomical computation can be identified in the procedure-texts [Ossendrijver 2012]. In particular, the Mesopotamian convention of presenting solution-procedures in terms of numerical examples gave way to a more abstract formulation involving named quantities of undetermined magnitude, not unlike variables. In this formulation, the parameters of an algorithm were specified but the quantity that was to be computed did not assume a numerical value within the instructions. The computational steps underlying the production of the tables are quite accurately known. This is because the astronomers tabulated not only final results but also various quantities pertaining to intermediate steps of their computation. Hence, these tables can be viewed as tabular representations of algorithms, like a modern spreadsheet.[18]

18 For the different categories of these tables, see ch. 4.6, p. 135. For the computational methods underlying Ptolemy's astronomical tables, see chs 3.2, p. 54; 4.4, p. 112.

CHAPTER 3.2

Planar and Spherical Trigonometry

Glen Van Brummelen

1 Introduction

The motions of the stars influenced the ancients in various ways: they helped them to track times of year; they provided them a means to predict the future on Earth; and, when suitably interpreted, they enabled the ancients to predict the future in the celestial realm. To be able to foretell major events like eclipses as well as the risings, settings, and conjunctions of planets, ancient astronomers were obliged to quantify what they saw. Some cultures (especially that of the Babylonians) employed arithmetic schemes to represent the recurring patterns which they observed and then projected into the future. Hellenistic astronomy chose a different path: it began geometrically by representing the celestial motions in terms of circles and straight lines linked in various ways. But using these representations to make predictions required the introduction of quantitative measurements into the representations themselves; and so trigonometry was born. Since the object of study was the celestial sphere rather than a flat surface, spherical trigonometry was fundamental to locating objects in the sky. In cases in which all the relevant motions are within a plane (such as the motions of the Sun, the Moon, and the planets along the zodiacal circle), planar trigonometry sufficed.

2 Ancient Trigonometry

The word "trigonometry" means the measurement of triangles; and today it conjures up sines, cosines, and tangents. But none of these functions existed in Hellenistic trigonometry. Indeed, the subject itself was not really an independent discipline but simply the mathematical underpinning needed to convert geometrical representations into astronomical predictions—in a sense, a transformation of Euclidean geometry into a scientific tool. However, as is not the case in modern science, the scope of the applications of trigonometry remained strictly astronomical.

Since the typical astronomical diagram consisted of circles representing the Sun or the Moon or various components of orbital paths, the heart of the quan-

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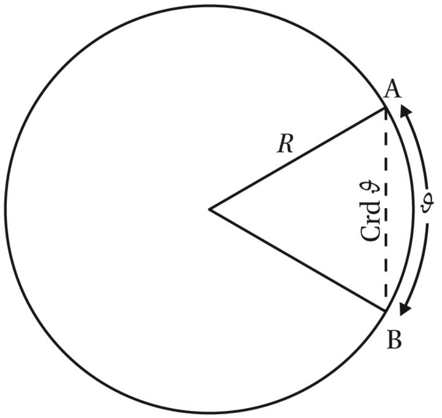

FIGURE 1 The definition of the chord

titative problem was to convert the lengths of arcs into lengths of related line segments and *vice versa*. Probably as early as Hipparchus of Rhodes (*ca* 130 BCE), this problem was reduced to its essence. In Figure 1, p. 55, suppose that we have a circle of a given radius *R* and that we know some arc ϑ on it. (Note: the arc ϑ is equal in value to the angle at the center of the circle.) The goal is to determine from this information the length of segment *AB* subtending ϑ (literally, to determine the straight line (εὐθεῖα γραμμή) *AB*). If this one task can be accomplished, then it can be adapted to extend the knowledge of quantities in astronomical diagrams. Obviously this length (which we call Crd ϑ since it is the chord subtending arc ϑ) depends on the size of the circle. Since Claudius Ptolemy (*ca* 140 CE) calculated in a sexagesimal number system, he chose the radius *R* of 60 in the *Almagest*. Hipparchus' earlier value is not known since his work is lost but he might have chosen $R = 3{,}438$. This apparently peculiar choice has an explanation: if one divides the circle into minutes of arc and considers each of the 21,600 minutes to be a very short straight line of unit length, then the radius of the circle will be approximately 3,438 of these units ($21{,}600/2\pi \approx 3{,}438$).

3 Determining Chord-Lengths

Some chord-lengths are easy to determine geometrically, for instance, in Figure 1, $\vartheta = 60°$, so the triangle is equilateral and Crd $\vartheta = R = 60$ (using Ptolemy's value of *R*). One can also find the chords of arcs with lengths 90° and 120° and, with a little more effort, 36°, 72°, 108°, and 144°. To compose a table of chords of many arcs one at a time would be tedious; instead, theorems were derived that

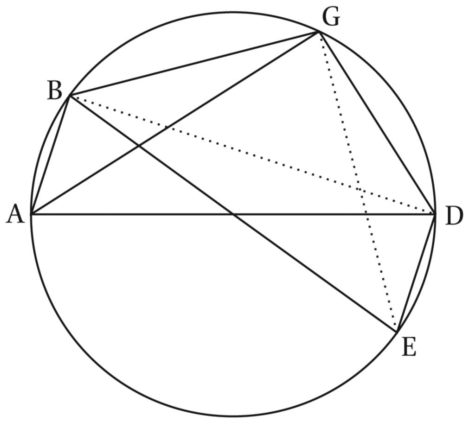

FIGURE 2 Finding the chord of the sum of two arcs whose chords are given

generated many chord-lengths at once. For instance, in Figure 2, which is from *Almagest* 1.10, suppose that chords *AB* and *BG* are given. Let *AD* be a diameter of the circle, and let $AB = DE$. Then, since *ABD* and *AGD* are right-angled triangles, we may use the Pythagorean theorem to calculate *BD* and *GD*. Next, Ptolemy's theorem of cyclic quadrilaterals, when applied to figure *BGDE*, gives us $BD \cdot GE = BG \cdot DE + BE \cdot GD$, which allows us to find *GD*. But since *AGD* is also a right-angled triangle, we can calculate *AG*. Therefore, given the chords of any two arcs, we have a method to find the chord of the sum of those arcs.

Other theorems allow us to find the chord of the difference between two arcs whose chords are given as well as the chord of half an arc whose chord is given. This makes it possible (eventually) to calculate the chords of all arcs that are multiples of 3° as well as the chords of 1½° and ¾°. However, if one wants to generate a table of chords of arcs of all multiples of 1°, one is forced to use an approximation. Ptolemy used

$$\frac{2}{3}\mathrm{Crd}\,\frac{3}{2}^{\circ} < \mathrm{Crd}\,1^{\circ} < \frac{4}{3}\mathrm{Crd}\,\frac{3}{4}^{\circ}$$

in the *Almagest* and computed both bounds as 1;2,50.[1] From this value, he went on to tabulate the chords of arcs from 0° to 180° in ½° increments.

1 $1;2,50 = 1 + \frac{2}{60} + \frac{50}{60^2}$.

4 Solving Problems in Planar Trigonometry

The ancient Greek chord table may be used to solve problems from conventional planar trigonometry. For example, suppose we wish to solve a right triangle in which the angles and one side length are known. In Figure 3, p. 58, we have a gnomon *AB* of length 60 units; the Sun has an altitude $\angle C = 25^\circ$ (so $\angle A = 65^\circ$) and casts a shadow on the ground *BC*. Then, in units of "demidegrees", $\angle C = 50^{\circ\circ}$ and $\angle A = 130^{\circ\circ}$. Inscribe $\triangle ABC$ in a circle; since it is a right triangle, *AC* is the diameter, which we assume temporarily to have 120 parts. Now, chord *BC* subtends an arc twice the value of $\angle A$.[2] So from the chord table, $BC = \text{Crd } 130^\circ = 108;45,25$ and in the same units, $AB = \text{Crd } 50^\circ = 50;42;51$. To find the length of the shadow according to the units that we used to measure the gnomon, we simply rescale:

$$BC = 108;45,25 \cdot \frac{60}{50;42,51} = 128;40,14.$$

Suppose instead that we are given a side *AB* and the opposite $\angle C$. In this case, we temporarily assume that $AC = 120$ units and use the chord table to find *AB* and then rescale to get *AB* in the units of the original problem. If two sides including the hypotenuse are known, say *AB* and *AC*, then we rescale to new units so that *AC* is 120 and then we enter the value of *AB* into the chord table to get the corresponding arc, thereby determining $\angle C$. If the two known sides are *AB* and *AC*, today one might use an arctangent to determine the angles; but a chord table cannot be used directly to solve this problem. Instead, the ancients first used the Pythagorean theorem to find *AC* and then fell back on the previous method.

5 Solving Problems in Spherical Trigonometry

Calculations like those in the examples above were made by astronomers when working on a single planar surface (often the plane of the zodiacal circle). However, a great deal of mathematical astronomy takes place on the surface of the celestial sphere. So it was often important to convert coordinates on the sphere from one to another of three reference circles: the equinoctial, the zodiacal, and

2 Euclid *Elem.* 3.20 states that if *BC* is joined to the center *O* of the circle, then $\angle BOC = 2 \cdot \angle A$, and $\angle BOC$ is equal to arc *BC*, that is, $\widehat{BC}$.

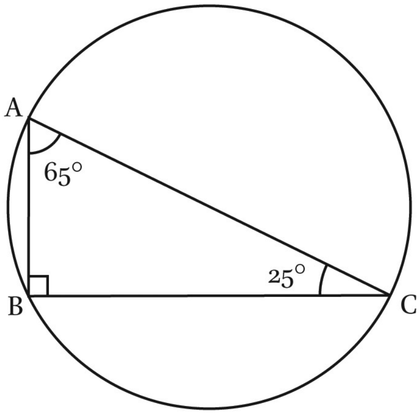

FIGURE 3 Solving a right triangle with given angles

the horizon [see ch. 1 §4, p. 16]. The zodiacal circle, for instance, is most useful when dealing with the motions of the planets since they stay within a few degrees of it at all times. But if one wants to locate an object in the sky, it is better to know where it is situated with respect to one's horizon.

5.1 *Menelaus' Theorem*

Almost all ancient spherical trigonometry relies on a single figure and a pair of related propositions, today jointly called Menelaus' theorem. In Figure 4, p. 59, each arc is a part of a great circle and distances along them are measured in degrees. The two theorems, which first appear at the beginning of the third and last book of Menelaus' *Sphaerics*, state the following:[3]

$$\frac{\text{Crd } 2a}{\text{Crd } 2b} = \frac{\text{Crd } 2(c+d)}{\text{Crd } 2d} \cdot \frac{\text{Crd } 2g}{\text{Crd } 2h}, \tag{1}$$

$$\frac{\text{Crd } 2(a+b)}{\text{Crd } 2a} = \frac{\text{Crd } 2(g+h)}{\text{Crd } 2g} \cdot \frac{\text{Crd } 2f}{\text{Crd } 2(e+f)}. \tag{2}$$

Like other results in the *Sphaerics*, these propositions refer only to arcs on the surface of the sphere—not to any geometric constructions within the sphere itself. This made the theorems especially easy to apply to problems on the celes-

3 The *Sphaerics* survives in Arabic translation and in these manuscripts the chords have been converted to sines. The same two theorems appear using chords in the *Almagest*.

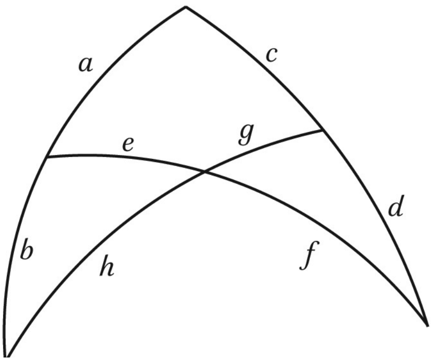

FIGURE 4 The configuration for Menelaus' theorem

tial sphere. Also, the theorems refer only to arcs, not angles. Since problems in spherical astronomy tend to refer more to arcs than to angles, this is not very cumbersome, although occasionally angles do become important.

5.2 *Determining Solar Declination*

One typical problem was the determination of the Sun's declination δ from its longitude λ, where λ is determined from the date. This is half of the conversion of the Sun's position to equinoctial coordinates (the other half is the determination of the right ascension). In Figure 5, p. 60, the zodiacal circle and the celestial equator intersect at ♈, the vernal equinoctial point, that is, the beginning of the zodiacal sign Aries; the Sun is at ⊙. According to Ptolemy, the angle of inclination of these two circles is $\varepsilon = 23;51,20^\circ$. To use this value in the problem, one must construct the great circle that is the equator to ♈'s pole, along the edge of the figure. The arcs from ♈ to this equator are, therefore, all 90° in length. This in turn implies that $\widehat{AB}$ is equal to ε.

From here the problem becomes one of finding the appropriate Menelaus configuration in the diagram. If one extends arcs *BA* and *C*⊙ to the North Celestial Pole *N*, we find such a configuration, namely, *BAN*⊙♈*C*. Applying the Menelaus relation (2) to the figure with $\angle\odot\Upsilon C = BA = \varepsilon$, we have:

$$\frac{2R}{\mathrm{Crd}\ 2\varepsilon} = \frac{2R}{\mathrm{Crd}\ 2\delta} \cdot \frac{\mathrm{Crd}\ 2\lambda}{2R}, \tag{3}$$

where *R* is the radius of the trigonometric base-circle, or

$$\mathrm{Crd}\ 2\delta = \frac{\mathrm{Crd}\ 2\lambda \cdot \mathrm{Crd}\ 2\varepsilon}{2R}. \tag{4}$$

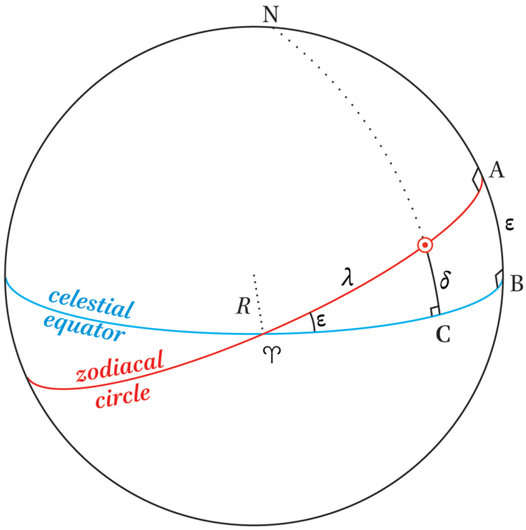

FIGURE 5 Calculating declination with Menelaus' theorem

While Menelaus' theorems may be applied to arbitrary figures such as the one in Figure 4, p. 59, this type of application—in which a number of the arcs are 90° in length and many of the great circles intersect at right angles—was far more common.

Menelaus' theorem and the other methods that we have described were not as efficient as later trigonometric approaches but they sufficed for their purpose. Armed with these quantitative tools, ancient astronomers could, in principle, solve any of the mathematical problems that they faced.

Theory of the Sun, Moon, and Planets

CHAPTER 4.1

Fundamentals of Planetary Theory

Nathan Sidoli

1 Introduction

The five planets visible to the naked eye can be divided into two groups which exhibit quite distinct observational features:
(1) the inner or inferior planets—Venus and Mercury; and
(2) the outer or superior planets—Mars, Jupiter, and Saturn.
(From a heliocentric perspective, the inner planets revolve between the Earth's orbit and the Sun and never reach opposition, while the outer planets revolve outside the Earth's orbit and reach opposition [see §3, p. 66].) To the untrained eye, the planets look much like stars and, in the ancient period, they were often considered to be a type of star.[1] It is said that stars twinkle more than planets; but the extent to which this can be perceived by the unaided eye depends on a number of factors, including the acuity of the eye in question and local atmospheric conditions. Nevertheless, the eye readily learns to differentiate the planets from the stars and to identify them by their motions, brilliance, and distinctive colors.

In this chapter, I discuss what one may observe of the planets first from the perspective of the local horizon over the course of some years and then as considered against a presumed background of the fixed stars, irrespective of the observer's location on Earth. The question of if, or when, ancient practitioners actually became aware of the phenomena discussed here are significant historical issues not covered in this chapter.

2 Observing the Planets

The more conspicuous phenomena associated with the planets are not necessarily the ones most useful to theoretical considerations. In the course of a single night, one cannot discern much about the planets to distinguish them from other stars. When the Sun sets, the planets can sometimes be found in

1 In Greco-Roman astronomy, the distinction was made between fixed and wandering stars.

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the night sky either, in the case of the inner planets, in the direction of the sunset or, in the case of the outer planets, anywhere in the general vicinity of the Sun's day-circle (that is, the circle on which the Sun appears to travel from east to west each daytime). The planets all move throughout the course of the night on day-circles parallel to those of the nearby stars and set at the western horizon, to all appearances as though they were themselves fixed stars. An outer planet can also sometimes be seen to rise into the night sky from the eastern horizon either just after sunset or at any time throughout the course of the night. When it does this, it crosses the sky with the nearby stars until the Sun rises and they all disappear into the dawning light. An inner planet, if it was not seen in the evening in the west, can also sometimes be seen to rise in the east the following morning. It rises in the general neighborhood of the coming sunrise as a bright point of light against the growing dawn and it quickly disappears into the light of the morning sky.

As one observes the planets over a number of nights, one may identify a range of phenomena. The most obvious of these is that the planets, like the fixed stars in the vicinity of the Sun's day-circles, repeatedly exhibit certain phenomena which we call appearances or phases. For example, like the stars, planets are sometimes visible and sometimes invisible, depending on their angular separation or elongation from the Sun; hence, like the stars they exhibit first and last appearances in a synodic cycle. (The synodic phenomena of the planets are, however, different from those of the stars.) The term "synodic", which derives from the Greek word «ϲύνοδοϲ», originally referred to a meeting or conjunction with the Sun but came by abstraction to indicate a more general relation to the Sun and its position. A full understanding of planetary synodic cycles takes a large number of observations made against a background of fixed stars. Hence, I will return to a discussion of the full synodic cycle after a brief discussion of the planetary phenomena as seen from the local horizon.

The wandering of the planets becomes clear after a relatively short time when they are observed in reference to the local horizon. If we look at the same planet over a sequence of nights, we find that, whether in relation to the horizon or the fixed stars, it moves around in the night sky. Consider Venus. If one had observed it just after sunset at the beginning and middle of every month in relation to a fixed object on one's western horizon at a location near Babylon in the year 199 BCE, one would have seen Venus appear at the sequence of positions given in Figure 1, p. 65. Then, on any given night, after sunset, Venus would descend from one of the dots in the diagram and set at the western horizon as it follows a path parallel to that taken by the Sun in its descent. Figure 1 was made by plotting the positions of Venus in local coordi-

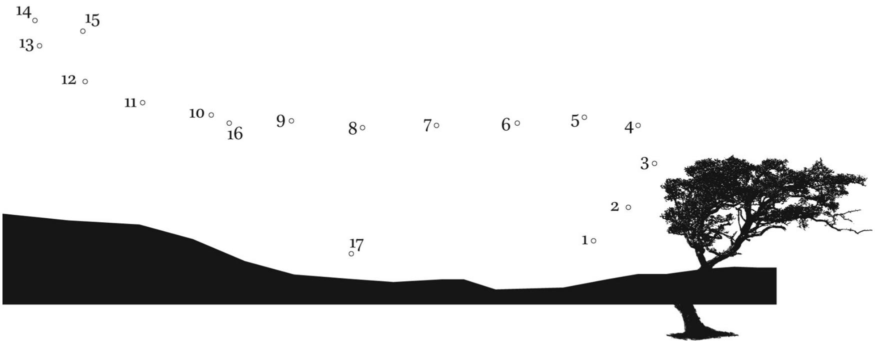

FIGURE 1 Positions of Venus as an evening star, viewed in relation to a fixed object on the western horizon at a location near Babylon just after sunset at 15-day intervals in 199/198 BCE

nates [see ch. 1 §4.3, p. 18] at 15-day intervals when the Sun was just below the observer's horizon. This means that everything other than the horizon is in a different location on each sighting—the local time and the location of sunset both vary and the positions of the fixed stars are displaced by roughly 15° west at each interval. Moreover, it is difficult to know whether Venus actually would have been seen at positions 1 or 17 because the timing of first and last evening appearances depends on many factors that we cannot now control, such as the physiology of the observer and the accidents of local weather. So let us assume a first evening appearance between 1 and 2, and a last evening appearance between 16 and 17.

Of course, there are no images of this sort from Antiquity; nor is there evidence that ancient scholars plotted successive positions of a planet in this way. Nevertheless, by considering this diagram, we can describe a number of planetary phenomena that ancient observers could have noticed even without precise, or carefully recorded, observations. Namely, as Venus moves away from the Sun to the east, it appears as an evening star in the western horizon, setting sometimes to the north and sometimes to the south of where the Sun sets. It moves farther away from the Sun for a while but then returns toward the Sun and disappears again. After some time, Venus will reappear as a morning star just before sunrise in the eastern sky and then exhibit a similar range of phenomena. Mercury, if it is seen at all, appears faintly for a short while, low in the sky, as either an evening or a morning star. This observational situation means that it was difficult for ancient observers to form a detailed understanding of the phenomena associated with Mercury.

The related phenomena for the outer planets, when considered with the horizon as a reference, is simpler than that of the inner planets—which fact, even without any developed theory, is sufficient to differentiate clearly between the two types of planets. Because the outer planets move through their eastward courses more slowly than the Sun, their synodic phenomena are similar to those of the fixed stars, with only one period of invisibility throughout the entire synodic cycle. Like the fixed stars, an outer planet has its first visibility in the eastern sky as it rises above the horizon for a few minutes before disappearing into the light of the coming dawn. In the following days, the outer planet will rise earlier and earlier each night and, during any given night, it will move with the nearby stars and eventually vanish with the sunrise. As time passes, it will become so far removed from the Sun that it will set at the western horizon just around sunrise and then rise at the eastern horizon when the Sun sets. In the following evenings, the planet will already be in the night sky after sunset, progressively approaching the western horizon, at which it sets. As this process continues, the planet is found farther and farther to the west at sunset until it is so close to the Sun that it is again invisible for some time.

3 The Synodic Planetary Phenomena

The forgoing account has been a qualitative description of the phenomena that are most obvious with respect to the local conditions of observation. Even without carefully recorded observations, it is clear that the most significant planetary phenomena are those based on the planets' angular separation from the Sun. Hence, in that phenomena such as these depend on some relation to the Sun, they are called synodic phenomena.

In order to form a clearer understanding of these phenomena, however, it is better to consider the position of the planets against a reference of the fixed stars. Such an understanding can only be developed on the basis of accurately made, and carefully recorded, observations of the relative positions of the planets and the stars in the vicinity of the zodiacal circle (that is, the ecliptic). In Figure 2, p. 67, we see the hypothetical path of an outer planet plotted against a background of fixed stars. The frame of this diagram is different from that of Figure 1, p. 65, which depicts positions of Venus relative to local coordinates. Figure 2 disregards the observer's horizon so that we have a theoretically constructed view of the motion of a planet as projected from the center of the Earth onto a point of the celestial sphere, in zodiacal coordinates. No observer on Earth will actually see such a series of planetary positions as is plotted here, even given perfect weather conditions and continuous observations. At best one could construct a sort of dotted line against the fixed stars. Moreover, Babylonian and Greek observers did not make continuous observations of planetary

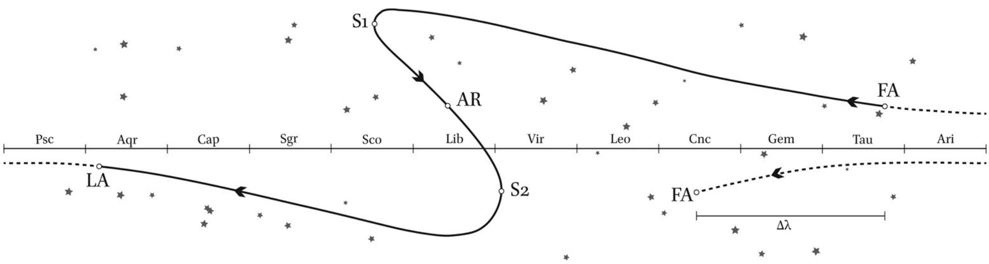

FIGURE 2 A hypothetical synodic cycle of an outer planet, considered against a background of fixed stars
The dotted paths indicate when the planet is too close to the Sun to be visible in the night sky. Note that the dotted line below the zodiacal circle on the right-hand side is a continuation of that from the left-hand side.

TABLE 1 The synodic phenomena or phases of the outer planets

FA	Γ	First appearance or phase	
S_1	Φ	First station	Retrogradation
AR	Θ	Acronychal rising (*Opposition*)	Retrogradation
S_2	Ψ	Second station	Retrogradation
LA	Ω	Last appearance or phase (*Conjunction*)	

positions at fixed temporal intervals as would be necessary to generate this sort of curve. Rather, they noted observationally significant events when they happened, such as first and last appearances, a planet's rising or setting opposite the Sun, the passage of a planet by a significant star, and so forth. Finally, there is no evidence in ancient sources for the sort of visual presentation of planetary phenomena presented in Figure 2.

Nevertheless, in order for us to speak clearly about the sorts of phenomena that formed the basis of ancient planetary theory, it is useful to consider diagrams of this sort. Since the synodic cycle of the inner planets is different from that of the outer planets, we will consider them separately. The synodic cycle of the outer planets is simpler; so let us start with it.

3.1 *The Outer Planets*

A synodic cycle for an outer planet may be said to begin on the morning when we first see the planet in the eastern sky just before sunrise. In Figure 2 [also

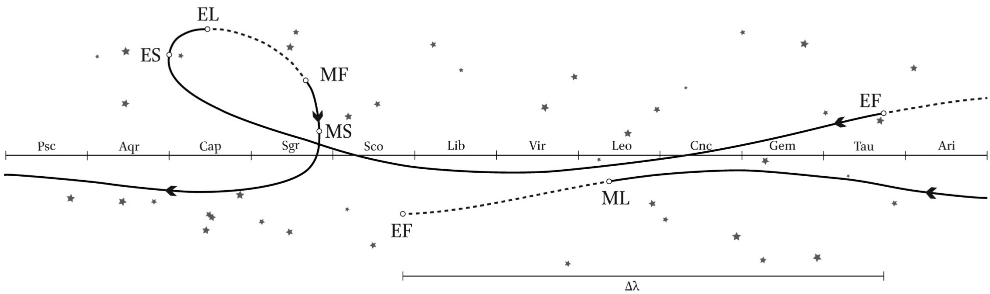

FIGURE 3 A hypothetical synodic cycle of an inner planet, considered against a background of fixed stars
The dotted paths indicate when the planet is too close to the Sun to be visible in the night sky.

Table 1, p. 67], we see a hypothetical outer planet plotted against the fixed stars. The diagram is orientated such that the daily motion of the stars westward is from left to right, so that the Sun and the planets all make their proper motion to the east from right to left in the order of the zodiacal signs. Our hypothetical outer planet begins a synodic cycle with its first appearance (FA or Γ)[2] and then has a direct (or prograde) motion to the east as its elongation from the Sun increases. When the planet begins to approach an elongation of 180°, its eastward motion appears to slow and stop against the background of the fixed stars. The short interval when the planet has no longitudinal motion along the zodiacal circle is called first station (S_1 or Φ). After first station, the planet moves backward through the zodiacal signs in a retrograde motion. During its course along this retrograde arc, when the planet reaches true opposition with an elongation of 180° from the Sun, the planet can be seen to rise at the same time as the Sun sets, which is called its acronychal rising (AR or Θ). The planet then continues in retrograde motion until second station (S_2 or Ψ), after which it returns to direct motion, moving forward in the order of the signs until it rises just before the Sun and finally disappears again in its last appearance (LA or Ω). While the planet is near the Sun in conjunction, it remains invisible until its next first appearance, which is displaced along the zodiacal circle and marks the start of a new cycle in which the same phenomena are repeated in the same order.

2 We use the abbreviations introduced in Ossendrijver 2012 for the planetary synodic phenomena but have also included the Greek letter abbreviations used in a number of classic studies, such as in Neugebauer 1975. Due to the use of the latter abbreviations, synodic phenomena are sometimes called Greek letter phenomena.

TABLE 2 The synodic phenomena or phases of the inner planets

<table>
<tr><td>EF</td><td>Ξ</td><td>First evening appearance or phase</td><td></td></tr>
<tr><td>ES</td><td>Ψ</td><td>Evening station</td><td></td></tr>
<tr><td>LE</td><td>Ω</td><td>Last evening appearance or phase
(Inferior conjunction)</td><td rowspan="3">Retrogradation</td></tr>
<tr><td>MF</td><td>Γ</td><td>First morning appearance or phase</td></tr>
<tr><td>MS</td><td>Φ</td><td>Morning station</td></tr>
<tr><td>ML</td><td>Σ</td><td>Last morning appearance or phase
(Superior conjunction)</td><td></td></tr>
</table>

3.2 *The Inner Planets*

A synodic cycle for an inner planet may be said to begin on the night when we first see the planet in the western sky just after sunset. In Figure 3, p. 68 [also Table 2], we see a hypothetical inner planet plotted against the fixed stars. The synodic cycle of the inner planets is slightly more involved than that of the outer planets because the inner planets have two periods of invisibility. An inner planet begins its cycle with its first evening appearance (FE or Ξ) as it moves in direct motion to the east in the order of the signs. It continues in direct motion until its first station, which we call evening station (ES or Ψ), after which it goes into retrograde motion and its elongation from the Sun begins to decrease. When the planet gets sufficiently close to the Sun it appears one last time in the western sky in its last evening appearance (LE or Ω). It then continues in retrograde motion, although it is not visible to the observer, during which period it has its inferior conjunction with the Sun. After some time, the planet reappears, now before sunrise in the western sky in its first morning appearance (MF or Γ). Fairly shortly after its reappearance, the planet will undergo its second station, known as morning station (MS or Φ), and return to direct motion. It will then continue in direct motion for most of its time as a morning star until it catches up with the Sun again and has its last morning appearance (ML or Σ). After its second period of invisibility, its superior conjunction, the star will again have a first evening appearance, EF, and the cycle will begin again, exhibiting the same phenomena in the same order.

4 Conclusion

It becomes clear, when we consider the phenomena of the planets with respect to a background of the fixed stars, that the planets not only wander but display a striking pattern of periodicity. After a sufficient length of time, we see that the same phenomena always occur in the same pattern. This gives rise to the idea that any given phenomenon occurs again and again after some period of time known as the synodic period Δt, and that succeeding phenomena are displaced from the preceding ones along the zodiacal circle by some whole number of circuits plus a difference in longitude known as the synodic arc $\Delta\lambda$. The core of ancient planetary theories—such as those found in the tablets of Babylonian mathematical astronomy or in Ptolemy's *Almagest*—build upon these period-relations by developing mathematical accounts that incorporate the time-intervals of these periods (Δt) and the longitudinal displacement of the synodic phenomena ($\Delta\lambda$), that is, their synodic arc. This may be done by considering the whole synodic cycle or by considering the interval between occurrences of an individual synodic phenomenon, such as one of the appearances, and its displacement along the zodiacal circle. Babylonian astronomers calculated the locations of the synodic phenomenon directly without regard for the motion of the planet between the synodic phenomena and, in rarer cases, where they computed an intermediate position of a planet, they used techniques of interpolation. Greek astronomers, however, tended to work through the intermediary of geometric hypotheses meant to depict continuous motion [see chs 4.2, p. 71; 4.3, p. 95; 4.4, p. 112], on the basis of which they hoped to exhibit some set of synodic phenomena.

CHAPTER 4.2

Hypothesis in Greco-Roman Astronomy

Alan C. Bowen

1 Introduction

The critical exegesis of Aristotle's works in the first century BCE is a decisive moment in the history of Hellenistic astronomy, coming as it did at a time when diverse authors were introducing Babylonian astronomy to their readers and debating its adoption. In appropriating this new knowledge of the heavens, writers at the time drew on Aristotle, who ultimately provided the intellectual framework in which they began to transform the classical accounts of the planetary motions found in his writings and in those of Plato. This is, I admit, a matter of inference, albeit a reasonable one given that:

(a) while there is no direct evidence dating from when this new knowledge, specifically, Babylonian planetary theory, first came to the Greco-Roman world, we do have indirect evidence in Ptolemy's remarks about Hipparchus and in the Antikythera Mechanism itself;[1]

(b) there are non-technical texts written in the interval from the late second to the first century CE advocating or rejecting Babylonian astronomy, typically identified with astrology, and indicating that the planets make stations and retrogradations;[2]

(c) there is no evidence dating from before the second century BCE that the Greeks or Romans were aware of such planetary phenomena;[3]

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1 Toomer 1996 puts Hipparchus' *floruit* in the second half of the second century BCE. The date of the construction of the Antikythera Mechanism is difficult to determine and controversial [see ch. 9.2 §4, p. 345]. Several of the Mechanism's features suggest 205 BCE as a *terminus post quem*. The *terminus ante quem* is, of course, the date of the shipwreck, sometime *ca* 60 BCE. See Evans and Carman 2014 for the suggestion that the eccentric and epicyclic hypotheses of planetary motion may derive from the craft of making celestial spheres and devices such as the Antikythera Mechanism to represent the celestial motions.

2 See Diodorus, *Bib*. 2.29–39; Vitruvius, *De arch*. 9.1.5–16, 9.6; Geminus, *Intro. ast*. 1.1; and Pliny, *Nat. hist*. 2.1–83. For discussion, see Bowen 2013b and 2018.

3 There are, of course, numerous earlier passages that scholars have interpreted in ways that assume such awareness. But these interpretations are anachronistic: there is in each instance a plausible reading of the same passages that draws on what is explicitly given in their context and does not assume any awareness that the five planets make stations and retrogradations. See Bowen 2013a, 230–248.

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(d) the idea that the planets *actually* make stations and retrogradations flatly contradicts classical theories of planetary motion as found in the cosmologies of Plato and Aristotle;
(e) to any who recognized that the planets do at least *appear* to move in this way, the challenge would be to account for such appearances on the terms set by Plato and Aristotle; and
(f) not only does one writer, Posidonius, in the late second and early first centuries BCE enunciate this challenge, it figures in the very presentation of technical and philosophical works by others subsequently.[4]

Still, what seems reasonable does not by itself amount to a fact. So, given the state of our evidence, the best course is, then, to take my opening statement as a working hypothesis. Accordingly, the following account of the theories of planetary motion put forward in early Hellenistic Greek and Latin texts focuses on an important feature common to all those that reflect on such theory, that is, on the fact that they are called hypotheses (ὑποθέϲειϲ). After explaining why this is so and what it came to signify, this account will then turn in ch. 4.3, p. 95 to a review of some of the early theories actually proposed.

2 The Astronomical Hypothesis

It is common nowadays to view the Hellenistic astronomical hypotheses of the planetary motions as models since they involve arithmetical or geometrical representations of these motions and serve to account for the facts of these motions.[5] The problem is that calling these hypotheses models is anachronistic and misleading in general: so far as Greco-Roman astronomy in Hellenistic times is concerned, it wrongly suggests that, for those who wrote of the planetary motions and hypotheses for them, the framing issue was the relation of the planetary models to the observable, quantifiable reality that they were to capture. As the term «ὑπόθεϲιϲ» indicates, however, the fundamental issue was, in fact, the standing of astronomy itself as a body of knowledge, that is, whether its

4 On Posidonius, Geminus, and Ptolemy, see §§2.3–4, p. 80 and ch. 4.3 §2.4, p. 102 on Pliny. On Seneca's reaction in *Epist.* 88, see Bowen 2009. Cleomedes' debt to Posidonius is evident throughout his *Caelestia* [Bowen and Todd 2004, esp. 5–17; Bowen 2003] and is explicitly acknowledged at its end [Todd 1990, 2.7.11–14].

5 By "model", I mean the mathematical analog established on the principle that its essential numerical and/or geometrical properties must correspond to observed (or observable) properties of the planetary motions. Such usage figures prominently in that particular understanding of what the history of astronomy is a history of that was established by Otto Neugebauer [see ch. 0 §1, p. 1].

premisses (ἀρχαί: starting-points, first principles) were true and how this could be known. This holds, I think, even for Ptolemy, whose proposal for establishing the truth of his planetary hypotheses entailed treating them as models.[6]

Granted, casting in this way the question of what "hypothesis" signifies makes it an issue that is meta-theoretical to the science itself. That is to say, questions about what counts as a hypothesis, like those about how they may be known to be true, belong to discourse about astronomical argument and not to argument in astronomy itself. Indeed, the standpoint from which these questions were addressed is not only one which *we* might call philosophical, it was established by Stoic and Peripatetic philosophers[7] in the light of their interpretations of Aristotle. Moreover, there is no evidence that the question was taken up in any other context. This means that, with the exception of Ptolemy, any account of the term "hypothesis" and its significance in astronomy may not have been relevant to the actual practice of the science (e.g., to research) or to how its practitioners viewed their science.[8]

2.1 *Aristotle on Astronomy*

The basic ideas that Hellenistic Greco-Roman writers drew on in addressing the challenges of adapting Babylonian astronomy to their intellectual requirements are found in numerous Aristotelian texts, chief among which is *Phys*. 2.2 [cf. *Meta*. 6.1]. Here, Aristotle distinguishes three branches of theoretical science (μάθημα: cf. 194a7):

6 Ptolemy's use of the word «ὑπόθεϲιϲ» is significant and points to the context in which he was writing: see §2.4, p. 84.

7 In general, philosophers count as Stoic if they belong to that series of thinkers of which Zeno of Citium (335–263 BCE) was the first. Zeno gave lectures in the Athenian Agora, specifically, at the ϲτοὰ Ποικιλή (Painted Colonnade), which gave these thinkers their name. Philosophers are called Peripatetic if they belong to that series of thinkers of which Aristotle (384–322 BCE) was the first. Their school, which met, or was located at, the Lyceum, derives this name from the habit of walking about (περιπατεῖν) while discussing issues. The school itself is sometimes called the Peripatos (Περίπατοϲ).

8 Some underlying issues, which I will not address on this occasion, are: When did astronomy become a profession, what did the professional astronomers actually do, what were the institutional loci of their work, and how did they train their successors? The clearest evidence for the profession of astronomy in Greco-Roman society comes with the emergence of a class of those who made their living by making prognostications about human events and affairs on the basis of the configuration of the heavens at a given time, i.e., astrologers. Their texts, however, do not seem to cross the divide codified by Ptolemy between predictive and prognosticatory astronomy by considering or developing any theory of how the planets move.

(1) mathematics (μαθηματική) as represented by arithmetic and geometry;
(2) the more natural sciences (τὰ φυσικώτερα τῶν μαθημάτων), *scil.* optics, harmonic science, and astronomy;[9] and
(3) the science of nature (φυσική) [*Phys.* 193b22–35].

The distinction of these sciences is based, first, on the unstated thesis that they are to be understood as sciences about natural bodies (φυσικὰ σώματα). Next, it proceeds by examining how each treats the two natures of all natural bodies, their matter (ὕλη) and their form (εἶδος),[10] in defining its proper objects. Thus, the science of nature focuses on natural bodies themselves, that is, on bodies that have within themselves a source of change and rest [*Phys.* 2.1]. It addresses both their form and their matter but matter only insofar as it comes to be and is for the sake of form.[11] Mathematics, however, proceeds differently in that it focuses solely on the quantity and physical limits of natural bodies. To do this, it separates in thought their number and various spatial limits from the bodies themselves and their changes (e.g., straight line from edge, plane from surface). In effect, mathematics studies such attributes of natural bodies but not as attributes *of* these bodies.

In between mathematics and φυσική lie the more natural sciences, that is, the sciences whose objects of study are more like those of natural science than those of geometry and arithmetic. In general, these sciences make the separation characteristic of thought in mathematics but differ in treating the objects separated as physical or natural, by which Aristotle means, I think, that they reintroduce change (κίνησις) in some form. In his example, while optics follows geometry in treating the visual flux, say, as a cone-shaped bundle of straight lines, it differs in treating these straight lines as visual rays, that is, as lines with physical properties: thus, unlike straight lines in geometry, these rays are not only limited in their length, they have a direction of flow, as it were, and so can also be reflected and refracted [*Phys.* 2.2.194a9–12].[12]

Aristotle assumes that astronomy counts as a more natural science, that is, as a science more natural than arithmetic and geometry because of how it defines its objects, but does not elaborate why. Still, we may surmise, for instance, that,

9 *scil.* sciences more natural than mathematics.

10 In *Phys.* 2.1, Aristotle shows that when we speak of the nature (φύσις) of a natural thing, we mean either its matter or its form; and that we regard the form as more the nature of the thing than its matter. In opening 2.2 [194a12–15], he puts aside the claim about the priority of form to matter.

11 For an excellent discussion of this chapter and its function in the development of Aristotle's contention that there is a single science of nature, see Lennox 2008.

12 Cf. e.g., *Meteor.* 3.2–6, esp. 372a16–34: in these chapters, «ὄψις» means "visual ray".

in focusing on the heavens, the astronomer begins *more geometrico* by separating in thought circles from the planetary circuits and then reintroduces change by construing each circle as the constant, unchanging trace of a moving point.[13]

Moreover, we may also surmise from Aristotle's remarks that, unlike mathematics, which studies and is about numbers, lines, planes, and so forth but not as the limits of a natural body, astronomy studies, and is *about*, the heavens that we see [*Meta*. 1077a1–8]. This is, I presume, why Aristotle holds that the φυσικός and the astronomer sometimes talk of the same things, e.g., the shape of the Sun and Moon, and whether the Earth or the cosmos itself is spherical [2.2.193b25–30]. Indeed, he does on occasion argue for a conclusion as a φυσικός and then introduces considerations and even the same conclusions which, he says, come from astronomy [see, e.g., *De caelo* 2.10–11 (with 2.8), 2.14].[14]

This is plainly not possible in mathematics. After all, when the φυσικός talks of edges and surfaces, for instance, he is not speaking of the same things as the mathematician: not only does φυσική differ from mathematics in treating the shape of a natural body as an attribute of that body, it does not ignore how such attributes belong to natural bodies [193b31–33] and so does not keep them apart from the source of change that is the nature of any natural body.[15]

As for the more natural sciences, Aristotle says nothing. Still, it is clear that practitioners of these sciences and the φυσικός will say the same thing insofar as the φυσικός establishes what each takes for granted in making demonstrations (as I will explain). But, beyond this, my suspicion is that such overlap occurs in the case of astronomy (and astronomy alone) because of:

13 Lennox [2008, 170] suggests that practitioners of the more natural sciences differ from mathematicians in that they specify what they separate in thought "as features of a particular kind of natural phenomenon". Though it is certainly true, as Lennox states, that one cannot discuss rainbows and eclipses without such specification, this does not, I think, capture the contrast between the geometer's making his investigation of a line but not *qua* natural and the optical theorist's studying the mathematical line but *qua* natural and not *qua* mathematical [194a9–12].

14 In these chapters of the *De caelo*, Aristotle either mentions astronomy explicitly [291b21–23, 297a3–6] or adduces visual or perceptual evidence [291b18–19 διὰ τῶν περὶ τὴν ὄψιν, 297b23–24 διὰ τῶν φαινομένων κατὰ τὴν αἴσθησιν] that is of concern to the astronomer.

15 Simplicius [Diels 1882–1895, 290.3–291.20] maintains that both the mathematician and the natural scientist speak of the same thing, viz. the accidents of natural bodies. But his account does not preserve Aristotle's distinction between μαθηματική and τὰ φυσικώτερα τῶν μαθημάτων, ignores the problem of idealization in mathematical argument, and makes the questionable assumption that *x* conceived as a property of *y* is semantically the same as *x* conceived with no regard for *y*.

(a) its reintroduction of change (locomotion) into abstractions from the heavens themselves, and
(b) the uniqueness of the heavens and its internal structure.

To be sure, in optics, which is about seeing, the theorist treats geometrically the lines, planes, and points separated in thought from a very large and diverse class of phenomena. But this class only includes and is not in fact limited to natural objects. Consequently, he is like the geometer, not the astronomer, in that, so far as what he says must be consistent in kind or manner for all his objects, his discourse will be removed from that of the φυσικός. The same holds for harmonic science: it will perhaps be enough to notice that, if harmonic science is the science of melody or tunefulness, its object is not a natural body but a product of human invention understood apart from the means of its production and so will concern the φυσικός remotely at best.[16]

Now, one might object that this explanation of how it comes about that the astronomer and the φυσικός say the same thing necessitates that astronomy be a part of the science of nature. But this does not follow because of how the astronomer separates in thought the objects of his study from natural bodies. That is, even if astronomers separate in thought a circle from the observed path of a celestial body, and even if they treat this circle as the trace of a point on the surface of a rotating sphere, they neither regard this circle or the sphere as properties of a natural body nor endeavor to connect them to that internal source of motion by virtue of which any natural body is natural. Thus, while it is true that both the astronomer and the φυσικός may say the same thing about the rotation of the celestial sphere, for example, the differences between what they say and how they construe this object will ensure that astronomy is not part of φυσική.

It is important to notice that, for Aristotle, astronomical arguments can only support an argument in φυσική that reaches the same conclusion. Indeed, though arguments may be demonstrative within astronomical science, they are not probative in φυσική beyond showing that some thesis is, or is not, consistent

16 At no point does Aristotle really give sufficient information to determine what the cognitive separation in harmonic science entails, that is, what is separated and how it is treated "naturally". All we have are programmatic remarks to the effect that one branch of harmonic science explains the facts perceived in the other, which is "empirical". Consequently, there is little to say about why Aristotle regards ἁρμονική as one of the more natural sciences beyond the claim that it relies on perception in dealing with something heard. For an account of how Aristoxenus' *Harm. elem.* stands in relation to the arguments of Aristotle's *An. post.*, see Barker 1991. For Aristotle's rejection of the idea of a cosmic ἁρμονία, see *De caelo* 2.9.

with the perceived facts. That is, for example, the demonstration in astronomy that the Earth is a sphere at the center of the cosmos, though reaching the same conclusion as the demonstration in φυσική from the natural motion of earth downward to the center of the cosmos, has no real bearing on the truth of the latter. Furthermore, as Aristotle would have it, it is in fact subordinate because knowledge of why something is the case is superior to knowledge that something is the case. That is, for Aristotle, arguments in astronomy typically account for the fact that something is the case (τὸ ὅτι), e.g., that the Earth is located at the center of the cosmos, whereas arguments in natural science give this fact as a conclusion in an argument explaining why it is so (τὸ διότι), e.g., why the Earth is situated at the center of the cosmos [*An. post.* 1.13].[17]

The reader of Aristotle's *Analytica posteriora* and *De caelo* will recall yet another instance when the astronomer and the φυσικός say the same thing, that is, when the astronomer posits something that he does not prove but proceeds to rely on as a first principle in his argumentation. To understand this, we must consider astronomy as though it were a fully axiomatized demonstrative science, a view outlined in the *Analytica posteriora* and essential to the Aristotelian conception of astronomy as a body of knowledge.[18] Of course, the problem here is not the fact that there was no demonstration of these positings *within* astronomy: for Aristotle and his followers, this is inevitable since, as they argued, no demonstrative science demonstrates its own starting-points or first principles (ἀρχαί). Thus, for them, there is no argument in astronomy that concludes, for instance, that

(a) the cosmos is finite and unique,
(b) the cosmos is spherical in shape,
(c) the heavens as a whole (κοσμός) rotate about the cosmic center, and
(d) the seven planets are carried on circles rotating about this same center.[19]

Still, as they saw it, such propositions that something exists or is the case were deemed fundamental to any science. Consequently, the problem is that astronomy itself could count as a body of knowledge only if such starting-points or,

17 This is not to deny that there can be demonstrations of why something is the case in astronomy, as Aristotle indicates in *An. post.* 1.13 when discussing a planet's not twinkling and the sphericity of the Moon.

18 See Barnes 1975 for the argument that Aristotle's aim in this treatise is to present a "formal model of how teachers should *present and impart knowledge*" [77], not to show how astronomical knowledge is, or ought to be, gained.

19 I am casting this claim in terms that Aristotle would approve: the "astronomer" might prefer to say instead that the planets move on circles about the cosmic center rather than that they are carried by these circles.

as they were termed, hypotheses (ὑπόθεσεις), were true. But to know that they were true—and hence, that astronomical demonstrations were not just valid but sound—would thus require argument in φυσική.

Accordingly, we may infer, given the proofs and resources to be found in the *De caelo*, the potential for difficulty here was not realized.[20] That is, for Aristotle, the astronomer's positing and leaving unproven such hypotheses in his theorizing about the heavens was not a matter of concern: the standing of the astronomy of his age as a proper science constituting real knowledge was secure, since not only were the objects that it concerns—the cosmos, the fixed stars, the seven planets and their motions, and the Earth—well defined and understood, its hypotheses posed no real challenge that could not be met in φυσική.

In sum, as Aristotle would seem to have it, astronomy posed no special problems: it was a duly established science that lays hold of, and articulates, truth. This was not so certain, however, for Aristotle's readers in the early first century BCE.

2.2 *Two Changes after Aristotle*

The late second and first centuries BCE saw two changes that gave special urgency to the idea that astronomy would not count as a body of knowledge unless its hypotheses were shown to be true in φυσική. The first change came with the realization sometime during the second century BCE that the five planets (Mercury, Venus, Mars, Jupiter, and Saturn) make stations and retrogradations [see ch. 4.1, p. 63], a realization that apparently came with the influx of Babylonian astronomical theory into Greco-Roman culture [see p. 71n3]. This recognition of hitherto unknown planetary phases spawned new ways of accounting for the motions of all seven planets, ways that departed from Aristotle's reliance on the rotations of homocentric spheres made of a fifth element, aether, the nature of which was to move in a circle about the center of the cosmos. Chief among these new ways was the use of epicycles revolving on deferent circles that rotated about either the center of the cosmos or some point eccentric to it.

The second change was the return in philosophical circles to Aristotle's esoteric treatises, that is, to treatises such as the *Analytica*, *Physica*, *De caelo*, and *Meteorologica*. This return involved not only Posidonius (*ca* 135 – *ca* 51 BCE)

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20 Finitude of cosmos: *De caelo* 1.5–7. Uniqueness of cosmos: 1.8–9. Sphericity of cosmos: 2.4. Rotation of heavens: *Meteor*. 339b16–19; *De caelo* 1.2–4, 2.1, 2.8. Rotational motion of planets: 2.11 with 2.8.

and perhaps his teacher, Panaetius,[21] two Stoics from Rhodes, but also their fellow countryman, the Peripatetic Geminus (first century BCE),[22] who tackled Posidonius in his own work. Regrettably, we do not know the timing of their engagement with Aristotle in relation to Sulla's confiscation of Apellicon's private library of esoteric Aristotelian and Theophrastean works or to his taking this library to Rome in 86 BCE, where it was "organized" in part by Tyrannio, a scholar (*grammateus*) and admirer of Aristotle (φιλαριστοτέλης), and then made public along with a catalog prepared by Andronicus of Rhodes even later in the first century BCE.[23]

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21 See *PHerc.* 1018.col.61; Cicero, *De finibus* 4.79. Just how Panaetius engaged or was influenced by Aristotle is controversial: see Falcon 2015, 11n16.

22 Nothing really speaks against the tradition that Geminus was born in Rhodes [Evans and Berggren 2006, 15–17]: it is the question of where he wrote his *Introductio astronomiae* that is controversial. Any identification of Geminus' philosophical allegiance is admittedly a matter of inference from rather slender hints. On the availability of Aristotle's esoteric works in Rhodes at the time of Posidonius (a Stoic Aristotle-izer [Strabo, *Geog*. 2.3.8]), see Pajón Leyra 2013. Geminus certainly addresses philosophically minded readers in his *Intro. ast.*: in 12.1–19, he attacks the theory found in Plato's dialogues that the planets do not really, but only apparently, move eastward by virtue of their falling behind (ὑπόλειψις) the sphere of the fixed stars; in 16.2–23, he criticizes the Stoic Cleanthes for locating Ocean in the zone between the tropic circles; and in 17.32–35, he criticizes poets and philosophers for holding that Sirius is responsible for the intensification of heat during summer. That he is a Peripatetic (but *only* in the manner of Peripatetics of his time) is a possibility suggested by his preparing a summary exposition of a treatise by Posidonius that takes its starting-points from Aristotle [see §2.3, p. 80]. The complication here is that it is not made clear whether the reliance on Aristotle evident in this summary exposition as it has come down to us is due to Geminus or to Posidonius or to both. Still, Geminus' standing as a Peripatetic does seem to be indicated by his acceptance of the existence of the fifth element, aether, as the constituent material of the supralunary domain [16.29]—his "whether the stars are fiery or made of aether" at 17.15, 33 indicates neither doubt nor agnosticism: it simply serves to establish that the stars are all made of the same thing (whatever that is) and so must have the same power (δύναμις) and, thus, no effect on Earth. The same is indicated also in his recommending that one should follow the Peripatetic Boethus of Sidon, a younger contemporary who taught Strabo Aristotelian philosophy [Falcon 2012, 12; 2015, 4], in setting up a *parapegma* [see ch. 5.2 §3, p. 198] that grounds the signs of changes in the weather in natural causes [17.48], the sorts of signs used by Aristotle and Eudoxus [17.49]. For Eudoxus' philosophical views and their interest in the early Peripatos, see Aristotle, *Meta*. A.991a14–19; *Eth. nic*. 1.1101b27–31, 10.1172b9–18: cf. Lasserre 1966, 12–14.

23 On the story of the disappearance and reappearance of Aristotle's esoteric works, and their organization into a canon, see Strabo, *Geog*. 13.1.54: cf. Plutarch, *Vita Sullae* 26; Porphyry, *Vita Plotini* 24. On Andronicus' date and edition, see Falcon 2012, 18n31; on his role in this story, see Hatzimichali 2016. The point of this ancient story was to explain the decline of the Peripatos after Theophrastus and its re-emergence in the first century BCE. There are, however, numerous indications that Aristotle's esoteric works were indeed known, though not widely, in the interval from Theophrastus' death to their publication in the first cen-

By itself, however, this return to Aristotle was important but only as it bore on how his esoteric texts were actually read. Centuries later, readers of Aristotle would proceed on the assumption that his writings were a source of truth to be understood by those eager to follow him to that truth. But, in the interval from Posidonius to Alexander of Aphrodisias (*flor*. early third century CE), there was no such commitment: being a Peripatetic did not entail adhering to fixed doctrine. Instead, Posidonius and Geminus, like other readers of Aristotle's works, saw his writings as an important starting-point and interpreted them closely in order to formulate their own responses to contemporary arguments and claims. Thus, while Aristotle became an authority in the sense that he was to be taken seriously, there arose among Peripatetics an efflorescence of diverse, critical readings that were often inconsistent with what Aristotle meant as well as with each other. Yet these readings were still Peripatetic, not because of their doctrinal content, but because they started with Aristotle and proceeded *more Aristotelico* [Falcon 2012, 21–25; 2016a].

As for the Stoics, it is clear that not all Stoics followed Posidonius in his use of Aristotle's works [Strabo, *Geog*. 2.3.8], which thus raises more generally the question of Stoic engagement with Aristotle and the Peripatetics. This question is difficult not only because there is uncertainty about which of Aristotle's works were accessible prior to Andronicus and in what form but also because there are few works from either the early Stoa or the Peripatos that have survived. To address this question, then, one has to rely on citations by later writers and the parallels with extant Aristotelian writings that they suggest, a precarious business at best.[24]

This belief that Aristotle was a worthy thinker and starting-point, combined as it was with a willingness to take issue with him whether one was a Peripatetic or a Stoic, brought to light a new problem: How was one to justify the new hypotheses being explored in contemporary astronomical theorizing? Would it suffice to update Aristotle or would some entirely new approach be necessary?

2.3 *Posidonius, Geminus, and the New Astronomy*

This question comes down to us in a text cited in Simplicius' commentary on Aristotle, *Phys*. 2.2.[25] This text, so Simplicius asserts, presents (with some

tury BCE [see Falcon 2015, 1–3]. For conjecture about which of Aristotle's esoteric works were accessible prior to Andronicus in Rhodes, see Pajón Leyra 2013.

24 For discussion of this problem and some tentative conclusions, see Bénatouïl 2016.

25 For an annotated translation and detailed discussion of this text, and of its role in Simplicius' commentary on *De caelo* 2.10–12, the main burden of which is to defend Aristotle against Philoponus' polemic, see Bowen 2013a, 3–15, 27–72, 91–93.

evident omissions [Bowen 2013a, 45–46, 48–49]) a very careful quotation by Alexander of Aphrodisias (presumably in his now lost commentary on Aristotle's *De caelo*) of a particular passage from the summary exposition by Geminus of Posidonius' *Meteorologica*, a passage which takes its starting-points from Aristotle.[26] The closing lines of the quotation,

> That, then, is how Geminus—or rather Posidonius [cited] in Geminus—transmits the distinction between physical theory (τῆς φυσιολογίας) and astronomy, and he takes his starting-points from Aristotle.
>
> KIDD 1988–1999, F18.42–52 ≈ DIELS 1882–1895, 292.23–31

which repeat the opening remark about the dependence on Aristotle, show that, for Simplicius, the words and substance of the quotation derive from Posidonius. This appears, however, to be an inference that potentially overlooks the question of any role played by Geminus in summarizing Posidonius' account—after all, summarizing a treatise *can* be a creative enterprise. Moreover, Geminus' *Introductio astronomiae* itself takes a position that is consistent with the major claims reported in Simplicius' citation [Bowen 2007, 331–334: see ch. 4.3 §2.2, p. 98]. Still, the same claims are also essential to the argument in the *Caelestia* by Cleomedes, a Stoic writing some time after Geminus and before no later than the mid-third century CE;[27] and this treatise, while it does acknowledge a heavy debt to Posidonius [Todd 1990, 1.8.157–162, 2.6.228–231; Bowen and Todd 2004, 15–17], makes no mention of Geminus. So rather than prejudge this difficult question of the source of the text that Simplicius reports, I will write either of the author reported by Simplicius or, following Ian Mueller [2004, 66–72], of Posidonius/Geminus.[28]

The quotation, which plainly draws on Aristotle's *Physics*, especially 2.2, and his *Analytica posteriora*, focuses on the relation of natural science (or the science of nature) and astronomy. The first part[29] distinguishes natural science (φυσική) and astronomy (ἀστρολογία) by means of their subject matters. The essential points are:

26 On the text, Diels 1882–1895, 291.21–23 ≈ Kidd 1988–1999, F18.1–3, and the title of the work by Posidonius, see Bowen 2013a, 41nn12–13.

27 On Cleomedes' date, see Bowen and Todd 2004, 2–4.

28 Cf. Lloyd 1991, 265–268 and Evans and Berggren 2006, 49–58, which treats Geminus as the source by ascribing to him the substance of the text that Simplicius cites. Yet, it is hardly required that Geminus believe Posidonius in any or every detail to summarize what the latter had written; nor does it follow that Geminus' summary reflects accurately or fully what Posidonius meant. In both instances, argument is required.

29 Kidd 1988–1999, F18.5–32 ≈ Diels 1882–1895, 291.23–292.15: see Bowen 2013a, 41–46.

(1) Natural science is concerned with the nature of the heavens and celestial bodies, and with what follows from this, that is, their power and quality, and whether they come into being and cease to exist. Astronomy is concerned with the shapes, sizes, and distances of the celestial bodies as well as with their spatial and temporal configuration. This is why astronomy makes its claims on the basis of the quantitative sciences, arithmetic and geometry.

(2) While natural scientists and astronomers may speak of the same things, they do this using different procedures (ὁδοί). The natural scientist makes causal demonstrations by looking to the celestial object's nature; its contribution to, or role in, some context; and the causative power by virtue of which celestial objects are what they are and do what they do. Astronomers, focused as they are on quantity, make their demonstrations either

  (a) by looking to the extrinsic, incidental features (both spatial and temporal) of celestial objects and their motions, or

  (b) by arguing on occasion (ἄλλοτε) from some hypothesis (ὑπόθεσις) which is adapted in various cases so that, *if the adaptations are the case*, the phenomena will be saved [Bowen 2013a, 43nn22–24, 44–45: see §4, p. 94].[30]

(3) The term «ὑπόθεσις» here does not simply mean a proposition that something exists or is the case, a proposition that the astronomer uses as a starting-point or first principle (ἀρχή) and that is, therefore, undemonstrated in astronomy itself. As «ἄλλοτε» suggests and Posidonius/Geminus quickly makes clear, Aristotelian usage is here being refocused to mean such a proposition that is undemonstrated not only in astronomy but also in natural science.

The next part[31] turns abruptly from the remark about the astronomers' use of hypotheses and their adaptations to a question that has serious consequences: "For example, why do the Sun, the Moon, and the planets appear to move unsmoothly (ἀνωμάλως)?" [F18.32–35]. In other words, why do the Sun and Moon appear to cover equal arcs of their circuits in unequal times and why do the five planets appear to slow down in their direct or prograde motion, stop, go backward, stop, and then speed up in returning to their direct motion?

30 Posidonius/Geminus has in mind, say, the adaptations or modes (τρόποι) of an epicyclic hypothesis that account for the first morning visibility of each of the five planets. For Posidonius/Geminus, a phenomenon or what one sees is saved when it is explained away, viz. proven to be apparent only and not real. This notion of saving the phenomena figures importantly in Simplicius' commentary on *De caelo* 2.12.

31 Kidd 1988–1999, F18.32–39 ≈ Diels 1882–1895, 292.15–20: see Bowen 2013a, 46–48.

Given the preceding distinction of φυσική and ἀστρολογία, it is clear that this why-question is addressed to the natural scientist, that is, to the philosopher *qua* natural scientist, and not to the astronomer. The reason for asking it is, apparently, that astronomers differ in their accounts of this unsmooth motion (ἀνωμαλία) or anomaly, some proposing to save the phenomena by means of eccentric circles and others by means of epicycles. As Posidonius/Geminus sees it, insofar as each astronomer claims to save the phenomena by his hypotheses, each claims that his hypothesis is actually the case, which means that such dispute among astronomers is ultimately about the underlying *realia* and so can be resolved only in natural science. For Posidonius/Geminus, however, there was in hand no argument in natural science that could show definitively why one (if any) of the current astronomical hypotheses was really the case. Thus, as Posidonius/Geminus points out, in the absence of an answer to the why-question, the best that the natural scientist can do in accounting for planetary anomaly is to offer a systematic listing of each hypothesis and its adaptations. Accordingly, this answer will amount to no more than a simple-minded compendium of all the solutions proposed by astronomers for each planet. Now a sceptic such as Aenesidemus would take this to mean that, given the plethora of accounts available, there is no sense in any search for a single causal explanation. But for dogmatic philosophers, this plurality of divergent accounts would be intolerable. And so Posidonius/Geminus poses a pressing challenge to natural science, namely, to explain why the planetary motions are unsmooth or anomalous.

The consequences for astronomy of this challenge are drawn out in the concluding section of Simplicius' report:

> For, in general, it is not for astronomers to know what is by nature at rest and what sort of things are moved. Instead, by introducing hypotheses (ὑποθέσεις) of some things' being stationary, others in motion, they investigate by which hypotheses the phenomena in the heavens will follow. But astronomers should take as first principles[32] from natural scientists that the motions of the heavenly bodies are simple, smooth and orderly, and through these [principles] they will demonstrate that the choral dance of all [those bodies] is circular, with some revolving in parallel circles, others in oblique circles.
>
> KIDD 1988–1999, F18.42–49 ≈ DIELS 1882–1895, 292.23–29: see BOWEN 2013a, 50

32 F18.46 ≈ Diels 1882–1895, 292.26: These starting-points are ἀρχαί, not ὑποθέσεις, because they are demonstrated in natural science.

But this emphasis on the dependence of astronomy on natural science for the soundness of its demonstrations only highlights the importance of the challenge to natural science. Indeed, exactly what propositions is the natural scientist to provide the astronomer so that the latter can take them as his first principles in demonstrating the celestial "choral dance", especially when this dance involves appearing to stop and go backward? How is the natural scientist to save astronomy from its hypotheses and thus safeguard the science itself?

2.4 *Ptolemy's Response*

Not everyone agreed that there really was a pressing need for philosophers *qua* natural scientists to come up with a theory that would allow demonstrations of first principles that could replace the current hypotheses and serve in the astronomer's accounting for the unsmooth motions of the seven planets. Strabo, a Stoic himself [Mueller 2004, 75], says only:

> So much for Posidonius, since many [of his claims] meet with due criticism in my detailed [remarks] so far as they concern geography. But, so far as they pertain more to natural science, I must investigate them elsewhere or not even consider them, since in [Posidonius] there is much to do with stating causes (τὸ αἰτιολογικόν) and Aristotle-izing, the very thing which our [school] avoids because of the obscurity of the causes (αἰτιῶν).
>
> *Geog*. 2.3.8: cf. BÉNATOUÏL 2016, 64–65

Likewise, Seneca, also a Stoic, generalizes the claim that astronomy is dependent on philosophy for its first principles to the claim that, while the liberal arts (Posidonius' *artes pueriles*), notably, the study of music (*musica*) and mathematics (represented by geometry), may demonstrate that such-and-such is the case, philosophy, which is itself independent and self-sufficient, not only knows why it is so but also provides these arts with their first principles [*Epist*. 88.21–28].[33] But he does this not to make the challenge discerned by Posidonius/Geminus more important but to dismiss it on two grounds. First is that, while the liberal arts make one receptive to philosophy and supply means for pursuing it, they are in truth not part of it or relevant to it because none of them involves knowledge of virtue, which is the goal of philosophy [88.1–20].

33 Posidonius is named at 88.21: his division of the arts frames Seneca's contention that the pursuit of philosophy must be freed of any concern with the liberal arts, a contention that echoes at several points the language of the passage from Posidonius/Geminus.

Second is that there are simply too many philosophical questions to address in pursuing this goal to permit spending time on the liberal arts [88.29–46].[34]

It was Claudius Ptolemy, however, who offered the most forceful response by denying the core thesis of the challenge, namely, that astronomy is dependent on natural science for its being a proper body of knowledge. To the contrary, for Ptolemy, astronomy was the paradigmatically self-sufficient body of knowledge.

To address the question of the relation of natural science and astronomy in *Almagest* 1.1, which is in effect a preface to this treatise, Ptolemy begins by distinguishing philosophy (φιλοcοφία) into its practical and theoretical parts, and by affirming that he thought it fitting to devote himself for the most part to intellectual pursuits (cχολή) in order to teach theoretical studies (θεωρήματα) which are numerous and beautiful, especially those that are termed "scientific" («μαθηματικά») [Heiberg 1898–1907, 1.4.7–5.7]. Next, he divides theoretical philosophy into three parts: the natural, the scientific, and the theological [Heiberg 1898–1907, 1.5.7–10]. Though Ptolemy cites Aristotle [*Meta.* 6.1.1026a16–23] as an authority for this tripartition, it quickly becomes clear that Ptolemy is neither responding to nor following Aristotle specifically. Instead, he is using Aristotle as a means to distance himself from the conception of astronomy held by philosophers of his day, the Stoics [cf. Wolff 1988, 498–502 (esp. 499n31), 543–544].

Ptolemy explains the tripartite division as follows:

> All things that exist have their being from matter, form, and motion; and each of these cannot be observed but only thought of separately (that is, without the others) in a subject. In consequence of this, if one should take the primary cause of the primary motion of the universe[35] without qualification, one would consider it an invisible and unmovable god (θεόc) and the kind (εἶδοc) [of theoretical philosophy] which can inquire into this [primary cause] as theological because such an actuality can only be thought of as up somewhere around the highest parts of the cosmos, and because it is absolutely separate from perceptible beings. The kind [of theoretical philosophy] which can investigate material and ever changing quality (ποιότηc) and which engages with the white, the hot, the sweet, the soft, and things like this, one would call natural (φυcικόν) because such being abides among things that can for the most part cease

34 For further discussion of this letter, see Bowen 2009.

35 *scil.* the daily rotation.

> to exist (that is, it abides below the lunar sphere). But one would define as scientific (μαθηματικόν) the kind [of theoretical philosophy] which can make statements about quality in respect of shapes (εἴδη) and in respect of motions from place to place (μεταβατικαὶ κινήσεις) because it can inquire into shape, quantity, size, and, further, into place, time, and the like. Such being falls, as it were, between those [other] two not only because it can be thought of through sense-perception[36] and apart from sense-perception,[37] but also because [such being] is a property of absolutely all things that are both mortal and immortal. [And this is the case] because it alters (συμμεταβάλλεσθαι) along with those things that are ever altering (μεταβάλλειν) with respect of their inseparable form,[38] whereas for things that are eternal, that is, of an ether-like nature, it preserves unchanged (ἀκίνητον) the [aspect] of their form that cannot be altered (ἀμετάβλητον).[39]
>
> HEIBERG 1898–1907, 1.5.10–6.11

Ptolemy then argues that only scientific theoretical philosophy constitutes real knowledge.

> We reasoned from this that one should describe the other two kinds (γένη) of the theoretical [division of philosophy] more as conjecture (εἰκασία) rather than as apprehension which can yield knowledge (κατάληψις ἐπιστημονική)—the theological because of its utterly non-evident and ungraspable [character], and the physical because of matter's unstable and unclear [character]—with the result that, for this reason, philosophers can never expect to agree about them. [We also reasoned] that, if one approaches it rigorously, only the scientific [kind of theoretical philosophy] can provide knowledge that is sure and incontrovertible (εἴδησις βεβαῖα καὶ ἀμετάπιστος) to its practitioners because its demonstration must be through indisputable procedures (ὁδοί), namely, arithmetic and geometry.[40]

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36 *scil.* as it is in astronomy, for example.

37 *scil.* as it is in arithmetic and geometry.

38 Heiberg 1898–1907, 1.6.8–9 κατὰ τὸ εἶδος ἀχώριστον: thus, for instance, Socrates, whose inseparable form is his being a man, is always changing in shape, configuration, and position.

39 Cf. Aristotle, *De an.* 1.2–4.

40 Heiberg 1898–1907, 1.6.19–20. If arithmetic and geometry are procedures, then it would seem that they are tools of scientific theoretical philosophy and not branches of it coor-

> In consequence of this, we were convinced to cultivate in the first place all theory like this in accordance with our ability, and especially (ἐξαιρέτως) the [theory] which understands divine, that is, celestial, things. For this [theory] alone busies itself with the investigation of things that are always in the same state; and, for this reason, in respect of its own apprehension, it can itself also be always in the same state (which is neither unclear nor disordered)—this is a characteristic feature of knowledge[41] —and it can contribute to the other [kinds of theoretical philosophy] no less than they themselves.[42] Indeed, this [theory] in particular paves the way for the theological kind [of theoretical philosophy] in that it alone can in fact make proper inferences about the unmovable and separate actuality on the basis of its nearness to the properties of perceptible beings that are, on one hand, both causes of motion and moved, and, on the other, eternal and impassive (that is, in respect of their locomotions and the arrangements of their motions). And to the natural kind [of theoretical philosophy] it can make a significant contribution. For the universal characteristic of material being is more or less made known from the distinctive manner of its motion from place to place. So, the perishable itself and the imperishable [are made known] from motion in a straight line and circular motion, and the heavy and the light (or the passive and the active) from motion to the center and motion from the center.[43]
>
> HEIBERG 1898–1907, 1.6.11–7.17

The force of this argument is telling. Ptolemy effectively uses ideas in Stoic epistemology to propose that astronomy, that part of scientific theoretical philosophy which studies the visible, eternal motions that are ever the same, is a surer guide to reality than what the Stoics call natural science or, in his terms,

dinate with astronomy. In other words, it appears that, for Ptolemy, scientific theoretical philosophy is comprised of those sciences that Aristotle calls more natural.

41 Heiberg 1898–1907, 1.7.1–2 περὶ τὴν οἰκείαν κατάληψιν: the point is that one apprehends what is eternally the same when one apprehends either the subject matter of this special scientific theory or the theory itself—a typical instance in which the study of a subject matter is said to take on the character of its subject matter.

42 Heiberg 1898–1907, 1.7.4 πρὸς τὰς ἄλλας οὐχ ἧττον αὐτῶν ἐκείνων συνεργεῖν. Though by itself this line might suggest that τὸ μαθηματικόν contributes as much to τὸ φυσικόν and τὸ θεολογικόν as they do to τὸ μαθηματικόν, the next lines [Heiberg 1898–1907, 1.7.5–17] indicate that Ptolemy's point here is that τὸ μαθηματικόν contributes as much (or as significantly) to the development of the other branches of theoretical philosophy as they do to their *own* development.

43 Cf. Wolff 1988, 499n31.

natural theoretical philosophy. To press the point home, Ptolemy then explains how scientific theoretical philosophy, in addition to being master of its own domain, contributes significantly to the other divisions of theoretical philosophy; and, after that, he adds the argument first made known in Plato's *Republic* and *Timaeus* that it also contributes to practical philosophy [Heiberg 1898–1907, 1.7.17–24].

Ptolemy's elevation of scientific theoretical philosophy, specifically, astronomy, in cognitive status entails that the scientist's arguments for key propositions previously taken as belonging to natural theoretical philosophy (i.e., natural science to Aristotle and Posidonius/Geminus) will by themselves be sufficient to establish the truth of these propositions and that they will in fact be the best kind of argument possible. These arguments as they are found in the *Almagest* typically involve recourse to phenomena. Thus, for example, in *Alm.* 1.6, Ptolemy argues that the Earth has the ratio of a point to the distance of the celestial sphere on the basis of three considerations (τεκμήρια, σημεῖα):

(1) that the sizes and distance of the fixed stars are observably the same no matter where on Earth the observer is located,
(2) that the gnomons of sundials and the centers of armillary spheres set up anywhere on Earth appear to function as though they were at the center of the Earth, and
(3) that the horizon for any observer on Earth seems to bisect the celestial sphere.

Moreover, in *Alm.* 1.7, which is devoted to the proposition that the Earth does not move away from the center of the celestial sphere, Ptolemy recalls the arguments in *Alm.* 1.5 that the Earth is located at the center of the celestial sphere—arguments to the effect that only if it were at the center would the phenomena be preserved—and affirms the thesis of 1.7 on the basis of the arguments given in 1.5. Then, he adds that

> consequently, for my part, I think it superfluous for someone to inquire into the causes of the motion to the center, at least once the fact that the Earth occupies the center of the cosmos and that all heavy bodies move toward [the Earth] is so very evident from the phenomena themselves.
>
> HEIBERG 1898–1907, 1.21.14–19

In sum, the scientific division is sufficient to establish its own starting-point or first principles.[44] That is, for Ptolemy, the Stoic search for a theory in natural sci-

44 In his *De iud. fac.*, Ptolemy lays out his view of the contributions made by sense and intel-

ence of the celestial motions is misguided and even otiose, if one expects such a theory to constitute knowledge, be it superior to, or independent of, astronomy. Scientific theoretical philosophy when directed to the heavens, the domain of objects in motion that are perceptible and eternal, that is, astronomy, is capable on its own of yielding cognitive apprehension or knowledge.[45]

For Ptolemy, the governing principles of astronomical theory are reached by reflection on the phenomena, not by reflection on the nature or substance of the underlying objects. The theory itself advances by way of what the Stoics called cognitive sense-presentation (φαντασία καταληπτική)—this is what underlies Ptolemy's unique concern with instruments, their construction, and the certification of other observers [Goldstein and Bowen 1999: see also ch. 6.4, p. 246]—where these sense-presentations or observations are used to quantify geometrical (Ptolemy's term) numerically, hypotheses which, once properly adapted, permit one to account for the phenomena in breathtaking detail since they enable one to determine the configurations of the heavens at any time for any observer.[46]

From the Stoic standpoint, Ptolemy's response to the problems raised by the new understanding of the phenomena of planetary motion that came with the introduction of Babylonian horoscopic astrology exacts a high price. Gone is the idea that any such causal knowledge that we may hope to have of why the celestial bodies move as they do is superior to, prior to, or even relevant to, what is known in astronomy. All one can know, according to Ptolemy [*Tetr.* 1.1–2], are the positions of the celestial bodies at any time for any observer; and this knowledge is to be attained through observation and mathematical demonstration [Heiberg 1898–1907, 1.6.17–21]. The generalizations governing the significance of these configurations for creatures on Earth and the related

lect to knowledge. The key idea for understanding the character of scientific theoretical philosophy is that, though intellect depends on the senses for its primary input, both must work together if there is to be knowledge: see Long 1989, 151–154 with 172n11 (on the authenticity of this treatise).

45 It is important to keep in mind Geoffrey Lloyd's point [1991, 269–270] that Ptolemy does not accept hypotheses solely on the ground that they save the phenomena [cf. Wolff 1988, 499n31]. The reason is that, as subsequent observational experience may show, the hypotheses should be modified or even abandoned [see below]. As for what Ptolemy means when he says that a hypothesis saves the phenomena, his planetary hypotheses explain stations and retrogradations away as merely apparent, for example, but account positively for planetary positions as real. The question to ask, then, is Which phenomena?

46 A similar epistemological strategy underlies Ptolemy's *Harmonica*: see Bowen 1999, 304–311 on *Harm.* 1.1–2.

predictions, though dependent on this knowledge and still part of astronomy, are less certain because they involve material qualities.[47]

Thus, when confronted with Babylonian celestial science and the efforts of his predecessors to deny or assimilate it, Ptolemy focuses on the question of what can be known of the heavens and how. In so doing, he completely changed the intellectual landscape. How extensive this change was may be glimpsed in the opening lines of the *Hypotheses planetarum*, Ptolemy's cosmological treatise:[48]

> Syrus, we have treated the hypotheses (ὑποθέϲειϲ) of the celestial motions in the books of our *Mathematical Syntaxis* [*scil. Almagest*] by demonstrating through arguments for each [hypothesis] what is reasonable and wholly consistent with the phenomena in order to indicate (πρὸϲ ἔνδειξιν) the smooth, circular motion that must belong to [bodies] which share eternal, orderly motion and which can in no way admit the more and the less.
>
> HEIBERG 1898–1907, 2.70.1–11

For, what he here calls a hypothesis is not a proposition but a quantified geometrical model which is used mathematically to yield results that are consistent with observations. Moreover, such use of this model has the purpose of indicating the truth of what was earlier called a hypothesis, namely, that celestial bodies, which are of necessity eternal and orderly, move smoothly in circles. And so the question emerges: How are these new hypotheses utilizing the geometry of smooth, circular motion known to be true or the case, given that they are to be derived somehow from the phenomena (which they save) and not from reflection on the nature of things?

The answer to this depends in good measure on how one understands the *Almagest* itself. If, as Kremer maintains [see p. 215], the *Almagest* is not "a working notebook showing how Ptolemy developed his hypotheses over time" nor "an observational notebook recording all the 'raw data' of the observations" nor "a theoretical treatise simply describing kinematic hypotheses for celestial motions" but

47 Note that Ptolemy does not tend to present these configurations as visible signs by which the gods communicate with men but rather as significant geometrical arrangements of the aethereal celestial bodies that determine the quality of the power (δύναμιϲ) emanating from them: but see Hübner 1998, 1.208–216, 1.233–240, 1.259–266.

48 The cosmology that Ptolemy develops in this treatise belongs to the scientific division of theoretical philosophy: cf. Heiberg 1898–1907, 1.7.5–10; Kidd 1988–1999, F18.8–14.

> a pedagogical work, aimed at demonstrating how to pursue mathematical astronomy to a precision of minutes with a minimum of empirical inputs to confirm the geometry of the hypotheses and set the parameters

and how to modify this geometry when circumstances warrant, then the question of how Ptolemy proposes to establish his hypotheses will point us to a very new conception of science itself. On this basis, astronomical hypotheses, though they function as models and are not hypothetical in the sense that Posidonius/Geminus meant, still merit and should retain this name. In this, Ptolemy would seem to return to Aristotle's notion of a hypothesis as a starting-point for demonstration. But where Ptolemy departs from Aristotle and the Stoics is in holding that such hypotheses are to be shown as true not in natural science but in astronomical science itself. This demonstration is to consist in a process of improvement and eventual confirmation involving iterated observation and computation over ever increasing lengths of time, where the first iteration is already on display in the *Almagest* and his other writings in the very development of the planetary hypotheses.[49]

3 A Modern Misreading

Just more than a century ago, Pierre Duhem [1908] set out to understand what he claimed was a perennial question about physical theory and its relation to metaphysical explanation. In his view, astronomy was the only premodern science in which this question was raised, since it alone had what amounts to the modern idea of physical theory, that is, to a mathematical science with an apparatus sufficient to enable predictions that could be verified by measurements made through precise, direct observation. As he saw it, the perennial question

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49 On the development of lunar theory, see ch. 4.4 §4, p. 117. On the development of latitude theory in Ptolemy's *Almagest*, *Canones manuales*, and *Hypotheses planetarum*, see ch. 4.4 §5, p. 121. On Ptolemy's iterative procedure, see ch. 5.2 §5, p. 208.

If this is how Ptolemy envisages the validation of his hypotheses, then there is a problem in the case of the Sun, since there are two mathematically equivalent hypotheses, one eccentric and the other epicyclic, that each account fully for the same observational data [*Alm.* 3.4]. Of course, one might suppose that, in the course of time, the observational data will enable resolving this problem in that these data can be accounted for by a single hypothesis alone, be it one of these two or some other. But, for the time being at least, the best that Ptolemy can do is to prefer the eccentric over the epicyclic hypothesis on the basis of a mathematical criterion—its relative simplicity [Heiberg 1898–1907, 1.232.5–17].

of the relation between physical theory and metaphysics was in ancient times that of the relation between a mathematized astronomy and what the Greeks called φυσική. In pondering this, Duhem discovered a history of conflict dating from Plato to medieval times about the nature of astronomical hypotheses. On one side of this conflict were the "instrumentalists", who maintained that the astronomer's planetary hypotheses were merely contrivances that succeeded if and only if they saved the phenomena, and who denied that they shed any light on the *realia* of the planetary motions or that they should be constrained by any understanding of what these motions must be like. Thus, for them, to resolve any conflict of two hypotheses that were equipollent in saving the phenomena, it was sufficient to identify the one that was mathematically simpler. On the other side were the "realists", who held instead that the astronomer's hypotheses about the planetary motions had to be true and that their truth was to be demonstrated by the natural scientist (φυσικός) in his study of the nature of celestial bodies.[50]

There is no need here to review the sustained criticism that Duhem's analysis of Classical and Hellenistic Greek astronomical hypotheses and his attendant history of Greco-Roman astronomy have received.[51] To the reader of this chapter and the next [ch. 4.3, p. 95], it is worth noting that Duhem's analysis of Greco-Roman astronomy is predicated on a misunderstanding of the passage discussed in §2.3, p. 80.

To begin, he does not consider how it serves to frame Simplicius' defense of the Late Platonists' preference for Ptolemy's account of the planetary motions, in spite of the fact that this account contravenes Aristotle's strictures about the nature of the heavens and their motions, strictures that they embrace. As one might guess, Simplicius' defense entails some very "creative" readings of Aristotle and has no real worth as objective history [Bowen 2013a]. Specifically, one should not rely on it, as Duhem does, as an explanation of the homocentric spheres in *Meta.* Λ.8 [Heiberg 1894, 488.3–498.1: see p. 71n3].[52] What is worse,

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50 Duhem does not use such terms as "instrumentalist"/"instrumentalism" and "realist"/"realism" in characterizing the conflict. The former are especially problematic, given their history in philosophy. Stanley Jaki, in his essay prefacing the translation of Duhem 1908 into English [Dolan and Maschler 1969], writes of "formalists" and "formalism", which is not much better given the use of these terms in the recent history of the philosophy of mathematics.

51 For telling criticism, see, e.g., Lloyd 1978.

52 The interpretation of this text has tended historically to overlook the fact that its discourse belongs to metaphysics, specifically, that it is directed to the question of how many unmoved movers there must be to sustain the eternal motions observed in the heavens. In overlooking this, historians have wrongly pressed the text for astronomical detail.

however, is that Duhem misconstrues a key sentence in this passage. Thus, where the text reads

> ἄλλοτε δὲ καθ' ὑπόθεσιν εὑρίσκει τρόπους τινὰς ἀποδιδούς, **ὧν ὑπαρχόντων** σωθήσεται τὰ φαινόμενα.
>
> KIDD 1988–1999, F.18.30–32 ≈ DIELS 1882–1895, 292.13–15

> At other times, [astronomers] make determinations in accordance with a hypothesis by setting out some modes [of accounting for the phenomena] and, **if these are the case**, the phenomena will be saved.
>
> BOWEN 2013a, 43 and nn22–24

Duhem has

> Dans d'autres cas, il croit devoir poser certaines manières d'être, à titre d'hypothèses, **une fois admis**, les phenomènes soient sauvés.

But «ὑπαρχόντων» is a present active participle; and, in a philosophical context colored by Aristotle's thought, it typically means "to exist", "to exist in reality", "to be actual", "to be real", and the like, including my "to be the case". In any event, the verb «ὑπάρχω» does not have in its semantic field, as LSJ *s.v.* ὑπάρχω II proposes, a meaning that is synonymous with «ὑπόκειμαι» in the sense "be taken for granted": certainly, none of the passages listed in support of this proposal requires it and GS *s.v.* ὑπάρχω rightly omits it. As a result of his misconstruing «ὧν ὑπαρχόντων», Duhem misinterprets the sentence and thus does not realize that, as Posidonius/Geminus would have it, the astronomer's hypotheses (and their adaptations) must be real if they save the phenomena.

Equally important is that Duhem does not distinguish in his sources texts in which astronomy is discussed or taught and texts in which astronomy is practiced. That is, he does not distinguish practicing astronomers [see p. 73n8] from the philosophers, intellectuals (such as Pliny and the authors of *PMich.* 149, *PSI* 1492, and *PCarls.* 32), and/or teachers who interpret (and sometimes try to stipulate) what practicing astronomers do. But, given this distinction, one may well doubt that Posidonius/Geminus is correct to hold that any astronomer's claim to save the phenomena entails a claim that his hypotheses are the case. Indeed, it is well worth bearing in mind more generally the question of what the Greco-Roman astronomers actually thought of what the philosophers and so on called their hypotheses. Regrettably, any inquiry into how practicing astronomers understood their hypotheses or their science will be problematic if its focus is on astronomy in the Hellenistic Period, since the only astronomer of this era who presents his work with an eye to his broader intellectual context is Ptolemy (whom Duhem miscasts as an "instrumentalist" [see §2.4, p. 84]). Still, the question, say, of how the Greeks and Romans who composed or used tables for planetary positions that are structured by Babylonian arithmetical schemes or adaptations of those schemes understood their tables is admittedly tantalizing, yet as tantalizing as it is precarious. For not only will this question incur the danger of constructing what amount to mere arguments from silence, it will also be plagued by the doubt that, as historians, we really advance our understanding by attributing philosophical positions to those who do not articulate philosophical claims.

4 Conclusion

This chapter sets forth a brief history of the use of the term «ὑπόθεϲιϲ» ("hypothesis") as it appears in Greek and Latin texts concerning the planetary motions that reflect on the status of astronomical theorizing as knowledge. This brief history, which turns out to be a history of different conceptions of how astronomy is to be scientific, is predicated on a working hypothesis that has three parts. The first, which is well attested, concerns the introduction of Babylonian planetary theory into the Greco-Roman world, beginning in the late second and first centuries BCE as part of horoscopic astrology. The second, equally well attested, is the desire to provide an account of these motions that is in accord with classical notions deemed fundamental of the heavens and of what is to count as scientific knowledge. The third, explored here, is that the origin of these notions was in the diverse, critical readings of Aristotelian texts in the first century BCE. Of course, each part needs, and will benefit by, further contextualization that focuses on the socio-religious, scientific, and philosophical developments in the Hellenistic Period of the Greco-Roman world. Only in this way can this working hypothesis make its full contribution to a new understanding of the history of Hellenistic astronomy.

CHAPTER 4.3

Some Early Hypotheses in Greco-Roman Astronomy

Alan C. Bowen

1 Introduction

The preceding chapter [ch. 4.2] concerns the use of the term «ὑπόθεϲιϲ» in writings broadly about the sense in which astronomy is a science and narrowly about conflicting mathematical representations of the planetary motions. These writings are, however, not the only ones about astronomy and planetary theory in the Greco-Roman world during the interval from the late fourth century BCE to the time of Ptolemy. There are also texts focusing on planetary theory that endeavor to represent the planetary motions geometrically. Such work is not reflective in the sense that it worries about hypotheses and what counts as knowledge. To the contrary, it is typically dogmatic in that it involves putting forward a single account without questioning its truth. This remains the case even in those instances when the aim is to interpret tabular data available at the time by means of geometrical configurations. That is to say, in these instances, the dogmatic texts say nothing about the existence of different tables for a given planet's motions and how this difference is to be understood.

2 The Pre-Ptolemaic Hypotheses

This distinction among texts—not authors!—is not hard and fast. There are exceptions and qualifications. Still, it will serve as a heuristic device to frame the following discussion of some early geometrical representations of the planetary motions. Moreover, in the interest of clarity and as a means of drawing attention to what those who worried about astronomical hypothesis were confronting, I will, in accordance with usage in other texts, term these geometrical representations hypotheses.

The first systematic presentation of planetary hypotheses is found in Ptolemy's *Almagest* [see ch. 4.4, p. 112]. Its ostensive aim is to enable computation of the position of any planet at any time. The earlier texts are more diverse in their aims: what they share is the fact that none presents its account as a basis for

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computing planetary positions. Indeed, they offer purely qualitative geometrical descriptions of this planetary motions, and this even when their authors try to accommodate contemporary tabular data for the planetary motions that were intended to facilitate computation. Such early planetary hypotheses are, nevertheless, worthy of attention in that they show how diverse was the response to the transmission of Babylonian planetary theory as this theory was taken up in both Greek and Latin. So, let us turn now to a sampling of the texts that reveal the numerous strategies brought to bear on the question of how to account for the anomalous motions of the planets.

2.1 *The* De mundo *on the Motion of the Seven Planets*

The first, the *De mundo*, a plainly un-Aristotelian treatise addressed to Alexander the Great, is a forgery ascribed to Aristotle perhaps out of respect [Furley 1978, 337–341]. The date of its composition is uncertain. Scholars have for various reasons dated it to anywhere from the first century BCE to the mid-second century CE. David Furley, however, gives good reason to hold that it was written before or shortly after the publication of Aristotle's works by Andronicus of Rhodes in the first century BCE.[1] But David Sider [2015] has more recently drawn attention to its stylistic features or literary form and argues that it was written "to flatter Alexander the Great, probably in the last decade of his life". The upshot is that there is ground for taking the *De mundo* to be a very early Hellenistic work.

So far as the seven planets are concerned, the author of the *De mundo* supposes that each is an aetherial body moving on its own circle at its own velocity in a direction opposite to the daily rotation of the celestial sphere, that these circles are of different sizes, and that the higher circle contains the lower [2.392.13–31: see Figure 1, p. 97]. In effect, given the fact that the planets are each made of undifferentiated aether, we have the very simple claim that the planets each move at the same *linear* speed on homocentric circles about the Earth, which is at the center of the cosmos [3.392b31–34]. This means that the hypothesis for each planet can at best account for that planet's period. Indeed, since the god (θεός) that is said to create, organize, and preserve the cosmos [c. 6] sets the planets into motion [6.398b6–10] in accordance with their distances and the constitution (κατασκευή) of each, these periods will differ solely because

1 The issue in dispute for Furley is in part how much of, and by what means, Aristotle's thought was actually known in the period from Theophrastus' death to the publication of Andronicus' edition. See also p. 79n23.

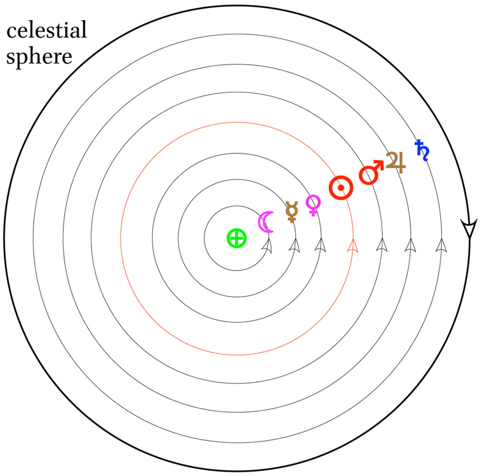

FIGURE 1 An early homocentric hypothesis

the circles traversed are of different sizes [6.399a1–13].[2] Finally, one should not suppose that these circles are the traces produced by rotating aetherial spheres, whether one in number or many. After all, the author might well be drawing on the cosmology of Plato's *Timaeus* [cf. *Resp*. 10, the Myth of Er].

In any case, the absence in the *De mundo* of any explicit acknowledgment of, or means of accounting for, the stations and retrogradations of the five planets is striking.[3] It is also important since it means that the theory of planetary motion presented in the *De mundo* was most likely not viewed *originally* by anyone as hypothetical. But was this still true by the time of the subsequent translation of this treatise into Latin?[4] Indeed, though it is easy enough to point out the persistence of such pre-Hellenistic views alongside accounts that are far more capable in their explanatory power, the pressing question is why the planetary theory in the *De mundo* persisted. Though there are doubtless several ways to explain this, it is worth keeping in mind that the effort to account for the planetary motions was largely one to "save the phenomena" of their stations and retrogradations known from Babylonian astronomy by explaining them away on the basis of early Greek philosophical and cosmological contentions

2 If s is the linear distance that each planet travels in time t, then its period Π is $(2\pi r)/s$, where r is the radius of its circle. This means that Π varies directly as r, that is, $\Pi_1{:}\Pi_2 :: r_1{:}r_2$.

3 For criticism of the view that Plato was aware of planetary stations and retrogradations, see Bowen 2013a, 232–240.

4 The attribution of this translation to Apuleius (second century CE) is disputed.

[see ch. 4.2, p. 71]. Given this project, there was, in fact, good reason to preserve the old. After all, such theories are readily viewed as preliminary trials in need only of some adjustment or elaboration. As Simplicius (sixth century CE) notes in asking for a renewal of the philosophical project initiated by Plato and Aristotle and advocated by Posidonius/Geminus [see ch. 4.2 §2.3, p. 80],

> the true account [of the planetary motions], of course, which accepts neither their stations or their retrogradations nor the additions or subtractions of the numbers in their motions (even if they evidently move in this way),[5] does not admit hypotheses as being the case. Rather, by drawing inferences from the substance [of the planets] it demonstrates that the heavenly motions are simple, circular, smooth, and orderly.
>
> BOWEN 2013a, 135–136

2.2 *Geminus on the Motion of the Sun*

After locating the solstices and equinoxes in the zodiacal circle and defining the astronomical seasons [*Intro. ast.* 1.9–12], Geminus notes that these seasons are unequal in length [1.13–17] and then, given that the solstices and equinoxes divide the zodiacal circle into equal quadrants, wonders why the Sun, which always moves at the same speed (ἰcοταχῶc), traverses equal arcs of the zodiacal circle in unequal time-intervals [1.18]. To explain this, Geminus begins by noting that “it is hypothesized for astronomy as a whole (ὑπόκειται γὰρ πρὸc ὅλην τὴν ἀcτρολογίαν) that the Sun, Moon, and five planets [each] move at the same (linear) speed on a circle and in a direction opposite to the [rotation of] the cosmos” [1.19].[6] He expounds this by remarking that, since it would be impious to attribute any lack of order (τάξιc) such as the stations and retrogradations to the five imperishable, planetary stars, the task accordingly set forth for astronomers is to explain how to account for the appearances (τὰ φαινόμενα) by means of smooth, circular motions (δι’ ἐγκυκλίων καὶ ὁμαλῶν κινήcεων) [1.19–21].[7] In effect, Geminus treats the Sun’s unsmooth motion or anomaly as well as the stations and retrogradations of the five planets as apparent only and

5 Simplicius is alluding to tabular numerical data that records the positions of the planets and the times when they occupy those positions, and, in particular, to the corrections of mean values for their daily progress.

6 Here, as often, «ὑπόκειμαι» serves as the passive form of «ὑποτίθημι», the verb from which the noun «ὑπόθεcιc» is derived.

7 For Geminus, motion at the same speed (ἰcοταχήc) is smooth (ὁμαλήc), that is, free of any variation or disorder.

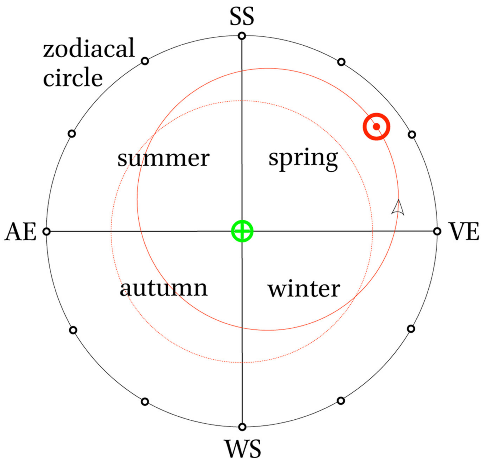

FIGURE 2 Geminus' solar hypothesis

proposes to explain them *away* by showing how what one sees follows from a proper understanding of the imperishable nature of the planets [1.21] and their motions.[8]

Next, Geminus argues that, if the Sun actually moved among the zodiacal constellations, that is, on the zodiacal circle, the time-intervals from one solstice to the next equinox would always be equal [1.31], given that the Sun traverses equal arcs in equal times. The same would be true, he notes, if the Sun moved on a circle that was lower (*scil.* closer to Earth) than the zodiacal circle but still had the same center and so was homocentric [1.32]. In this case too, the seasons would be of equal length [1.33].[9] But, if this solar circle is *not* homocentric with, but eccentric to, the zodiacal circle [see Figure 2, p. 99], the diameters dividing the quadrants of the zodiacal circle will no longer divide the solar circle into equal quarters [1.34]. Moreover, if this circle is displaced to the spring quadrant, its longest arc will extend from Aries 0° to Gemini 30°(= Cancer 0°) and the shortest arc will be from Libra 0° to Sagittarius 30°(= Capricorn 0°)—which accords with the fact that spring is the longest season and autumn is the shortest [1.35–39] (94½ and 88⅛ days, respectively, by Geminus' reckoning [1.13–17]). Of course, it follows that the interval spent by the Sun in each zodiacal sign will vary as well [1.40–41].

8 This explaining away of the appearances is, in other astronomical texts, called "saving the phenomena": see p. 82 and n30.

9 See the dotted circle in Figure 2, p. 99. This circle is divided in the same way as the zodiacal circle by the lines joining the solstices and the equinoxes.

Geminus' solar hypothesis is qualitative, not quantitative: thus, for example, he does not use the season-lengths to determine the eccentricity and the apsidal line of his solar hypothesis.[10] Though he postpones explaining the planetary stations and retrogradations to another occasion [1.22], it is clear that the eccentric hypothesis that Geminus develops to explain the solar anomaly is incapable of serving by itself for that purpose, given its assumption of smooth, circular motion.

2.3 *Vitruvius and the Motions of the Five Planets*

In book 9 of his *De architectura*, after introducing the 12 zodiacal signs (*dodecatemoria*)[11] and the daily rotation of the heavens from east to west, Vitruvius[12] lists the seven planets, mentions their direct or prograde motion from west to east [see ch. 4.1, p. 63], states the tropical periods of the Moon and the Sun, and affirms that

> the stars of Mercury and Venus, as they circle with their courses round the rays of the Sun as a center, make their backward retreats and their retardations; then, moreover, on account of their revolution, they delay at stations in the intervals of the zodiacal signs.
>
> *De arch.* 9.1.6

In effect, to account for the stations and retrogradations of Mercury and Venus, Vitruvius claims that each moves on its own epicycle that has the Sun at its center and the circuit of the Sun as its deferent [see Figure 3, p. 101].[13] As proof of this hypothesis in each case [9.1.7 *id autem ita esse maxime cognoscitur*], Vitruvius points to the fact that neither planet strays far from the Sun.

Next, Vitruvius remarks that Mercury and Venus do not spend an equal amount of time in each zodiacal sign [9.1.7], states their zodiacal periods [9.1.8–9], and then gives those of Mars, Jupiter, and Saturn [9.1.10].

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10 For that, see Ptolemy, *Alm.* 3.4: cf. ch. 6.4 §1, p. 246 with Figure 2, p. 247.

11 These are confused with zodiacal constellations in 9.1.3.

12 Vitruvius was an architect and military engineer who served C. Iulius Caesar (100–44 BCE). His *De arch.* was written presumably after the battle of Actium in 31 BCE and is addressed to Augustus, Caesar's great nephew and adopted son. The subject of book 9 is the construction of sundials, a topic which permits Vitruvius a brief excursus about the celestial sphere, the zodiacal band, and the motions of the seven planets.

13 The phrase, "circa radios…uti centrum" eliminates the possibility that the center of each planetary epicycle is merely on the straight line from the Earth to the Sun.

The idea that Vitruvius is here confounding his excursus by introducing heliocentrism, that is, by shifting without regard for consistency to a cosmology in which the Sun and not the Earth [9.1.2–3] is at the center of the universe has nothing to commend it.

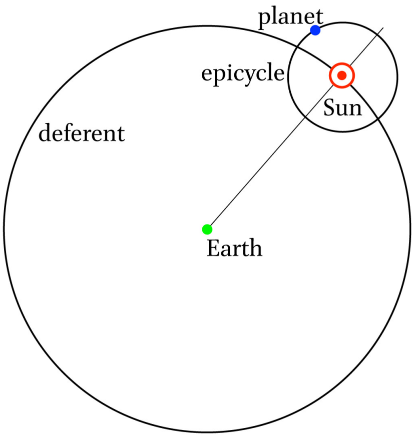

FIGURE 3 Vitruvius' inner planets

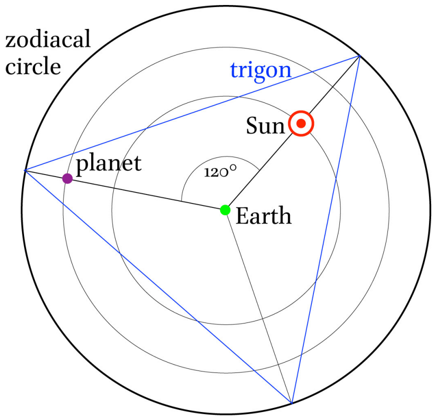

FIGURE 4 Vitruvius' outer planets

Vitruvius then turns to why the planets that are always above the Sun [9.1.11] slow down in their direct or prograde motion, stop, go retrograde, slow down, stop, and then speed up as they resume their prograde motion, thus spending unequal intervals in each zodiacal sign as they make their overall course around the heavens. To explain this behavior, he draws on prognosticatory astronomy and affirms that, when a planet, the Sun, and the Earth are in a trigon aspect, the attractive force or action (*impetus*) of the Sun slows and eventually stops a planet that it follows and then, when it leads, speeds the planet up [*De arch.* 9.1.9, 11–13: see Figure 4].

There are several points to notice about Vitruvius' account of the planetary motions. To begin, he deploys an epicyclic hypothesis only to explain the stations and retrogradations of Mercury and Venus, the two planets immediately below the Sun. He does not adapt this hypothesis to account for the motions of Mars, Jupiter, and Saturn. In fact, so far as the three outer planets are concerned, it would seem that he accepts the simple hypothesis of circular motion about the Earth as center. Next, to explain the planetary stations and retrogradations of the planets above the Sun, Vitruvius turns to natural science. Specifically, he identifies the cause of such behavior as the *impetus* of the Sun on each when it and they are in a trigon configuration. This explanation, which may well be Vitruvius' own,[14] cannot, of course, be extended to the planets below the Sun

14 See 9.1.11 *id autem nonnullis sic fieri placet, quod aiunt…nobis vero id non videtur….*[*9.1.12*] *ergo potius ea ratio nobis constabit…*[*9.1.13*] *fortasse desiderabitur quid ita sol…ergo quemadmodum id fieri videatur exponam.* The concluding lines,

Concerning the belt of the 12 signs, the contrary action and course of the seven plan-because Mercury and Venus are never 120° from the Sun. Moreover, it wrongly entails that each of the planets above the Sun may make more than one retrogradation during the solar year.

But to focus exclusively on such deficiencies is to miss the fact that Vitruvius offers without comment two distinct and incompatible accounts of the planetary motions, one astronomical and the other physical.[15] In the first, he effectively explains away the stations and retrogradations of the inferior planets as mere appearances. Yet, in the second, Vitruvius implicitly allows that the irregularities in the motions of the outer planets are real, regularly occurring events. Such confusion is hard to explain. Suffice it to say that, however inconsistently, Vitruvius does present an account of the anomaly of the outer planets which, while rooted in natural science, dispenses with the requirement of smooth, circular motion.

2.4 *Pliny's Epicyclic Hypotheses*

Somewhat later than Vitruvius, Pliny (23/4–79 CE) offers yet another account of the five planets and their motions. This account in book 2 of his *Naturalis historia* plainly draws on numerous sources no longer extant and is at times, when it is not just wrong, either very confused or maddeningly confusing. Part of the problem is Pliny's terminology: since his sources were in Greek and much of the technical terminology had no counterpart in Latin, he was obliged to use common Latin words, which thus introduces ambiguity. His use of "altitudo", in particular, is troublesome: the challenge for his readers is to determine at its

---

> ets, the causes and numbers according to which they pass from sign to sign, and their revolution, I have set out my account in accord with the way that I have learned from my teachers (*uti a praeceptoribus accepi*). [9.1.16]

do not exclude this possibility.

15 But see 9.1.9, where, in a section devoted to Venus' zodiacal period, the text has

> *Veneris autem, cum est liberata ab impeditione radiorum solis*,…
>
> But Venus, when it has been freed from the hindrance of the Sun's rays.…

The clause "cum est…solis" is either a slip on Vitruvius' part or, more likely, given his recognition that the maximum elongation of Mercury and Venus from the Sun is less than 120°, a later intrusion into the text.

As for the comparison of the planets to ants moving along concentric channels on a potter's wheel in the opposite direction to the wheel's rotation, this metaphor is limited to explicating the fact that the angular velocity of the planets increases with their proximity to Earth (even if they have the same linear velocity) [9.1.14–15]. That is, if the linear velocity v is the same for all planets, then, in time t, $r_1 \cdot \theta_1 = r_2 \cdot \theta_2$, where ϑ is the angle traversed and r is the radius of the circle. Thus, if $r_1 < r_2$, that is, if planet$_1$ is closer to the Earth than planet$_2$, $\theta_1 > \theta_2$ and so $\omega_1 > \omega_2$, where $\omega = \theta / t$ is angular velocity.

various occurrences whether he means the distance to the Earth or the variation between the apogee and perigee points on an epicycle—a variation in what is normally called βάθος (depth) but occasionally ὕψος (height) in Greek. Still, one must also recognize Pliny's outright failure at times to comprehend the subject. Granted, his remarks on the heavens do start out well enough when he presents what he has learned about the Sun and Moon [2.43–58]. (All we need note on this score is that he neither defines nor declares any hypotheses for them.) The problems arise quickly, however, when he comes to the motions of the five planets.

If we put aside the effort to make sense of everything that Pliny writes and to explain where he goes wrong in the numerous way that he does, we can extract the following from his account:

(a) There are five epicyclic hypotheses, one for each planet, and each hypothesis has a deferent that is eccentric to the Earth [2.63–64].[16]

Regarding the outer planets [2.68–71]:

(b) It would appear that the deferents of Mars, Saturn, and Jupiter lie inclined to the zodiacal circle. Pliny's remark that it is important whether the Sun's rays come from above or below [2.71] is compatible with this. Moreover, his assertion that the planets (in general) are nearest (*proximae*) to the Earth at their evening setting (Ω, LA),[17] in both *altitudo* (*scil.* distance to Earth) and *latitudo* [2.68] would likewise seem to indicate that the deferent circles are inclined to the zodiacal circle. Granted, the idea that a planet can be near the Earth in latitude is very odd. Still, I suspect that Pliny's "proximas esse terrae…latitudine" means "nearest to the plane of the zodiacal circle" and will proceed accordingly on this assumption.

(c) The epicycles of the outer planets are also inclined to their deferents and, given that
    (1) "latitude" means "distance to the zodiacal circle",
    (2) the outer planets are nearest the Earth in latitude at their evening settings, and
    (3) the planet will arrive at the evening setting point on its epicycle several times before the center of the epicycle traverses the deferent circle,

16 Pliny uses "apsis", which he says is to render the Greek term «ἀψίς» ("circle"), for both the deferent [2.63] and the epicycle [2.64 *igitur a terrae centro apsides altissimae sunt…*, 2.65 *quoniam a suo centro apsidas altissimas habent…*, 2.72–73]. Such usage is not found in any surviving Greek source.

17 On the planetary phases and the *sigla* for them, see ch. 4.1 §3, p. 66.

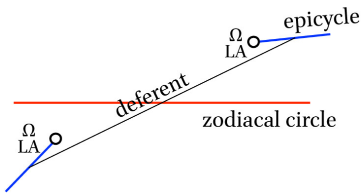

FIGURE 5 Side view of Pliny's epicyclic hypothesis for the outer planets

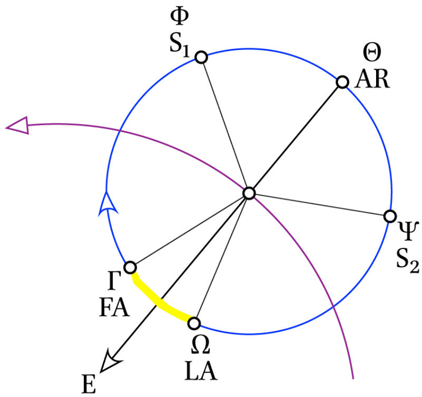

FIGURE 6 The phases of Pliny's outer planets

their epicycles are inclined to their deferent circles at angles that are less than the inclination of their deferents to the zodiacal circle so that the evening setting points are above the deferent [see Figure 5].[18]

(d) The motion on the epicycles of these planets is in the direction opposite to that on their deferents, which means that their retrogradations are incorrectly put near opposition, that is, at the acronychal rising (Θ, AR) or apogee points on their epicycles [see Figure 6].[19]

(e) At opposition, when there is an acronychal rising (Θ, AR), the planet appears smallest and its daily progress is least.[20]

(f) The epicyclic hypotheses for the outer planets are apparently insufficient in Pliny's estimation to account either for the stations of the outer planets or for their changes in latitude. For these, he adduces the fiery force of the Sun's rays and proposes that, when the planet and the Sun

18 2.68 *stationes in mediis latitudinum articulis* (the stations are in between the nodes of their latitudes). Again, this is very awkward. The nodes are better seen as the two points where the epicycle intersects the deferent or where the planet's motion in latitude crosses the deferent. Pliny, however, presents them as the two points where the planet's latitude (*scil.* distance to the zodiacal circle) is the same as that of the deferent. Given that the stations occur when the planet's elongation from the Sun is 120° [2.59], this means that the stations are in the half of the planet's course that is above the deferent.

19 On the phases of the outer planets, see 2.59–60 and Figure 6: cf. ch. 4.1 §3.1, p. 67.

20 When the unaided human eye looks upward at point sources of light in the heavens, it construes their brightness as a matter of size. (To appreciate the distinction between brightness and size, a distinction which was not actually made until the invention of the telescope, just look at the heavens through a pinhole.) Pliny's account exhibits this confusion.

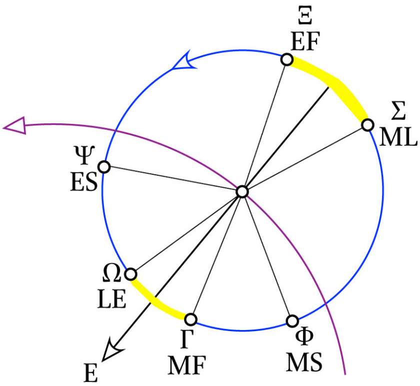

FIGURE 7 The phases of Pliny's inner planets

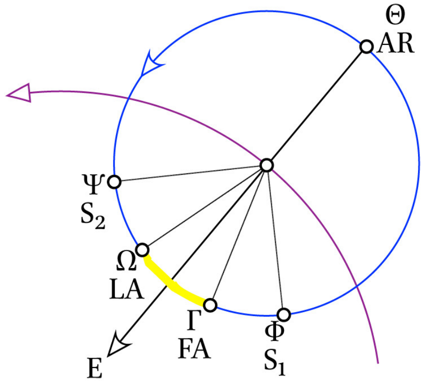

FIGURE 8 The phases of the outer planets

are in a trine configuration, that is, when the planet is 120° from the Sun and, as he would have it, at its stationary points, the rays *appear* to bring the planet to stop as it drives the planet upward and away from the Earth at first station (Φ, S_1) but downward and toward the Earth at second station (Ψ, S_2) [2.69–71]. Thus, Pliny introduces a natural cause not to maintain that stations are real but to show that they are still only apparent.

Regarding the inner planets:

(g) The motion on the epicycles of Venus and Mercury is in the same direction as that on their deferents [2.74], which means that stations and retrogradations occur when the planet is near Earth [see Figure 7].

(h) The epicycles of the inner planets are likewise inclined to their deferent circles.

(i) These epicycles figure in an explanation of why the inner planets are limited in their elongation from the Sun, an explanation which is followed by an unsuccessful attempt at explaining why these planets do not always reach their maximum elongation [2.72–73].

(j) The epicyclic hypotheses of the inner planets seem to suffice in Pliny's view for explaining their stations and retrogradations: at least, the inner planets cannot be in trine aspect with the Sun [2.72–73] and so cannot be affected by the Sun's rays.

While Pliny reports many numbers, he is interested mainly in the qualitative features of the motions of the five planets: he makes no computations to determine parameters and does not quantify the hypotheses that he describes, even though he mentions tabular data for them [2.69]. In presenting the planetary phases, he does get them in the right order but does not reflect on the direction of motion on the epicycles to determine whether he has these phases in the right places.[21] Still, one of the striking features of his presentation is the repeated claim that, with changes in a planet's *altitudo*, there will be changes in its motion or speed and its latitude. Pliny's talk of motion in depth and its effects, however ambiguous, is important because it points to a period in Greco-Roman astronomy when theorists were attempting to interpret arithmetical tables in the light of their geometrical hypotheses for the five planets.[22] As Jones [1991c, 157–159] has explained, papyrus sources dating from the third century CE and before suggest that, in dealing with the five planets, the effect of motion in depth was reckoned using tables of numbers, the heart of which was what Jones calls a template. These templates appear to have listed the planet's daily motion or progress in longitude and the argument of latitude for one period of anomaly in tables that were constructed using not trigonometry but arithmetical schemes deriving from Babylonian astronomy.[23]

2.5 *Pliny's Sources*

Given the importance of this in our understanding of the history of the planetary hypotheses and impact of Babylonian astronomy on its Greco-Roman counterpart, let us consider a summary description of what Pliny is currently thought to have found in the sources which he was attempting to report. This account, which is much indebted to Jones 1990c and, especially, 1991c, will focus on the outer planets alone because Pliny's remarks about the inner planets are less detailed and, at times, egregiously incorrect.

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21 For the phases of the inner planets as they should be in an epicyclic hypothesis if one is to compute planetary positions and get them right, see Figure 7, p. 104; for the phases of the outer planets, see Figure 8, p. 105.

22 Though Alex Jones suggested some years ago that "these tables use arithmetic sequences derived ultimately from Babylonian astronomy, although they apparently profess to represent the behavior of geometrical models" [Jones 1991c, 158], his current view is that papyri such as *PSI* 1492 and *PCarls.* 32 show something different, namely, the attempt to interpret the tables in light of geometrical hypotheses [private communication, 2017].

23 See, e.g., *PSI* 17.1673, a fragment of a template table for Saturn in effectively three columns. Column 1 gives the number of degrees that Saturn has moved since the preceding day; column 2, the number of days since epoch (day_0); and column 3, the total number of degrees traveled since epoch. The daily motion (column 1) is governed by a Babylonian System A scheme for Saturn [see ch. 4.6, p. 135]. All that is needed to determine the position of Saturn at any time is an epoch-table giving the dates of successive $days_0$. The fragment itself covers Saturn's motion from first appearance (Γ, FA) to first station (Φ, S_1), both morning phases.

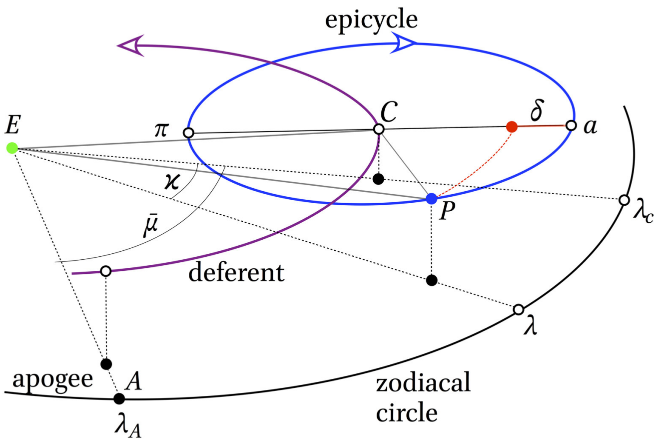

FIGURE 9 Pliny's sources on motion in depth and longitude for an outer planet

The relation of motion in depth and in longitude is rendered graphically in Figure 9.[24] As the planet P advances on its epicycle, it moves closer to and farther from the Earth E between two limits, the epicyclic perigee π and apogee a, respectively. Its distance from the apogee point is measured by δ. At the same time, as δ increases and decreases, there is a similar variation in the planet's deviation from the longitude of C, that point on the deferent which is the center of the epicycle. In other words, as the planet moves closer to and farther from Earth, it goes ahead of, and behind, its mean position. This mean position C moves in longitude with the planet's mean velocity or mean daily progress (m), which means that, if Π is the planet's tropical period,

$$m = 360^\circ/\Pi.$$

Thus, at any time, the planet's longitude will be

$$\begin{aligned}\lambda &= \lambda_A + \bar{\mu} \pm \varkappa, \\ &= \lambda_c \pm \varkappa,\end{aligned}$$

24 Pliny assumes that the motion on the epicycle of the outer planets is in the direction opposite to the motion on the deferent, an assumption actually found in *PMich.* 149 and shared perhaps by other sources too. Accordingly, in discussing Pliny's sources for his account of the outer planets, I will present the geometrical hypotheses of his sources with the phases at the incorrect positions as well.

where $0 \leq \varkappa$ and $\bar{\mu} = m \cdot \Delta t$ when Δt is the time elapsed since the planet was at its geocentric apogee λ_A. Tabulating this by adapting a Babylonian arithmetic scheme (typically, a scheme in System A) would be fairly straightforward: for each day of the synodic period in question, the table would correlate the daily values of δ with the daily values of the planet's longitude, thus showing how δ governs the planet's unsmoothness or anomaly in longitude. Given a supplementary table of epochs, that is, a list giving the dates of successive days_0 and the planet's longitudes on those days, one could compute where the planet will be at any time. The main limitation would be the effectiveness of the arithmetical scheme itself.

Of course, in the case of the five planets, the anomaly in longitude, that is, the variation in the planet's daily progress in longitude, is more complex because these planets also make stations and retrogressions. To account for this, Pliny's sources apparently used an arithmetical scheme of the following sort for the increases and decreases in what Pliny terms the planet's motion (*motus*). In Figure 6, p. 104, the planet's motion increases from Ω (LA) to Γ (FA), since they are the neighborhood of Earth [2.69],[25] and then decreases by constant differences from Γ (FA) to Φ (S_1), where it is 0. From Φ (S_1), this motion again increases by constant differences but the numbers are subtracted from the total elongation accumulated since epoch because the planet has begun retrograde motion.[26] When it reaches Θ (AR), the planet's retrograde motion is fastest. After Θ (AR), the motion decreases by constant differences until it returns to Θ at Ψ (S_2). Though Pliny does not mention it, the motion decreases by constant differences from Ψ (S_2) to Ω (MS).

The dependence of latitude on motion in depth effectively makes the planet's latitude primarily dependent on its longitude. For though, at first glance, one might think that Pliny is using "latitudo" for «πλάτοϲ», signifying latitude *simpliciter*, that is, the planet's angular distance above the zodiacal circle, this would not be consistent with what Pliny actually writes.[27] Instead, he is using "latitudo" for «πλάτοϲ» signifying the argument of latitude, that is, the elongation of the planet *in longitude* from the point on its deferent called the northern limit, where the deferent reaches its greatest latitude. Accordingly, in Figure 10,

25 In *PSI* 1492, the motion between Ω (LA) and Γ (FA) is constant [Jones 1991c, 158].

26 Professor Jones has very kindly clarified this in private communication. For an example, see *PSI* 1492, which tabulates the motion of Saturn from first appearance (Γ, FA) to first station (Ω, S_1).

27 When an outer planet is at its evening setting (Ω, LA), it is not nearest to Earth, i.e., nearest to the plane of the zodiacal circle [2.68]. Nor does latitude, so construed, begin at the morning rising (Γ, FA) [2.69].

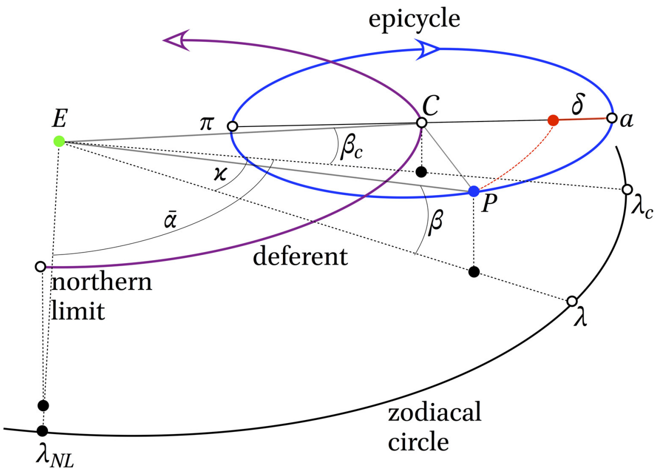

FIGURE 10 Pliny's sources on motion in depth and the argument of latitude for an outer planet

the planet's latitude (β) clearly depends on α, the argument of latitude, which will vary in accordance with δ, the planet's depth.

3 Conclusion

In this sampling of early planetary hypotheses, we have yet to find any account giving a hypothesis for each of the seven planets that aims to explain away as a mathematical outcome of smooth, circular motions any lack of smoothness or anomaly in their apparent motions. Granted, the homocentric hypothesis succeeds, I suppose, but only by failing to admit stations and retrogradations. Likewise, the eccentric hypothesis, though it can serve to account for departure in daily progress from the mean, is not sufficient by itself to account for stations and retrogradations either. Indeed, any attempt that draws only on a homocentric or an eccentric hypothesis in explaining a planet's stations and retrogradations will necessarily entail the introduction of some natural cause for the planet's behavior, viz. the action of the Sun in the instances given above.[28] Further, Pliny at least did not understand the potential of his epicyclic hypotheses

28 The eccentric and epicyclic hypotheses are mathematically equivalent only in the case of the Sun [see Ptolemy, *Alm*. 3.4; ch. 4.3 §2, p. 95], which does not retrogress. For the planets that do retrogress, the requirement that the real planetary motions be smooth and circular entails that these hypotheses are not interchangeable in reality. On when the ancients were aware of this mathematical equivalence, see Bowen 2013a, 46n28, 244–247.

or of the significance of a causal account, as his introduction of solar influence to account for the *appearance* of stoppage in the course of an outer planet's course shows.

At the same time, we should notice that none of the hypotheses described thus far comes with any attempt to determine its fundamental parameters or to tabulate planetary motions, even when it is evident that their proponents were drawing on sources that did include such tabulation and even trying to interpret such tabulation on the basis of these hypotheses. Since it is not possible to determine the position of a planet at any given time without such parameters or such tabulation, we may infer that none of the authors mentioned thus far had any real interest in prognostication, that is, in the details of establishing the planetary tables needed for casting a horoscope. Just why these authors were interested only in qualitative accounts of the planetary motions is another worthwhile question but one that we must put aside for now after noting only that even this qualitative interest can be very limited indeed: Vitruvius, for instance, does not even specify the direction of motion on his epicycles.

A version of the epicyclic hypotheses for planetary motions similar to Pliny's is found in *PMich.* 149.[29] In this papyrus, which is dated to the second century CE by its handwriting, we finally find an account that posits for each of the seven planets an epicyclic hypothesis in which the motion on the epicycle is in the direction opposite to that on the deferent. Such theoretical uniformity suggests a systematic coherence that would please Aristotle, who held that what is true of one planetary body is true of all [cf. *De caelo* 2.11]. Yet *PMich.* 149, though it too rests content with a qualitative account, also lists values for the parameters of the seven epicyclic hypotheses;[30] and, as Asger Aaboe [1963] has shown, if one adopts these parameters, the hypotheses for Venus and Mercury fail because they cannot account for their stations and retrogradations. Still, *PMich.* 149 differs from our other sources in its introducing data for the planetary hypotheses, albeit in order to facilitate its *melothesia* or assignment of planets, zodiacal signs, decans, and so on to parts of the body, a technique of astrological medicine [see ch. 9.3 §4.3, p. 372], and its definitions of numerous astrological concepts.

29 There are important differences: *PMich.* 149 has the deferents concentric about the Earth [col. 13.34–36] and makes no mention of motion in latitude.

30 Col. 1.8–25 epicyclic radii, col. 2.8–36 mean motions in longitude, cols. 10.25–11.4 phases of Mercury and Venus (greatest elongation: 22° and 48°, respectively), 11.5–26 phases of outer planets (first appearances (Γ, FA) at 15° from Sun, stations at 120° from Sun), 13.38–42 apogee/perigee of the Sun, Venus, and Jupiter (properly distinguished from their exaltations: see col. 16.23–35).

It is Ptolemy who finally established eccentric and epicyclic hypotheses that can actually serve in the correct determination of where all seven planets are at any given time [see ch. 4.4, p. 112]—and this, by using trigonometry [see ch. 3.2, p. 54].

CHAPTER 4.4

The Ptolemaic Planetary Hypotheses

James C. Evans

1 Introduction

The astronomical hypotheses (ὑποθέϲειϲ) bearing on planetary motion typically involve a circle (homocentric or eccentric to the Earth) or a combination of circles (homocentric, eccentric, epicyclic) intended to account for the motion of the Sun, Moon, and five planets. These geometrical structures, which first appear around 200 BCE, were subsequently refined until they became quantitatively predictive and reasonably accurate (which was not necessarily the goal of the first to consider them). The final, influential forms of these planetary hypotheses are found in the works of Claudius Ptolemy of Alexandria (second century CE), most crucially in his *Almagest* but also in his *Inscriptio Canobi*, *Canones manuales*, and *Hypotheses planetarum*.

2 Solar Theory

Of all the celestial bodies that move in the zodiacal band or zodiac, the Sun has the simplest motion and, therefore, the simplest theory. The Sun completes a trip around the zodiacal circle in a tropical year (the time from one spring equinox to the next), a bit less than 365¼ days (according to Ptolemy, 365 + ¼ − 1⁄300 days). This motion is almost but not quite uniform. That the Sun slows down and speeds up in the course of the year is clear from the inequality in the lengths of the seasons. If the Sun moved uniformly on a circle centered on the Earth, we would expect all four seasons to be of the same length. But the longest season (which was spring in Antiquity) exceeds the shortest (fall) by a bit more than 6 days, according to Hipparchus and Ptolemy.

Following Hipparchus, Ptolemy accounts for the inequality in the length of the seasons by postulating that the Sun does indeed move around a circle at constant speed but that the center of the circle is slightly displaced from the Earth. In Figure 1, p. 113, *O* (for the observer) represents the Earth. The center *C* of the Sun's circle is slightly displaced from (or eccentric to) *O*. VE, SS, AE, and WS represent the location of the Sun at the moments of vernal equinox, summer solstice, autumnal equinox, and winter solstice. The solstices

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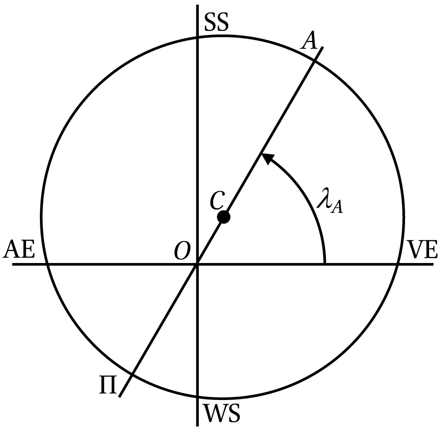

FIGURE 1 The eccentric solar hypothesis

and equinoxes are separated by equal intervals of 90°. With *C* placed in the spring quadrant of the Sun's circle as in Figure 1, the spring arc of the circle (from VE to SS) is longer than the fall arc of the circle (from AE to WS). Thus, we see how the Sun, although moving at constant speed, would take longer to run through the summer quadrant. At its apogee *A*, the Sun is farthest from the Earth; and at its perigee (Π), it is closest. Two key geometrical parameters are the eccentricity of the Sun's circle, which is distance *OC* divided by the radius *CA*, and the longitude of the apogee, which is the angle marked λ_A. These may both be determined from the lengths of the seasons.

Rather remarkably, there was a second form of the solar theory that was geometrically equivalent to the eccentric-circle theory. In Figure 2, p. 114, the Sun (⊙) moves around an epicycle, whose center *K* moves around a deferent circle concentric with the Earth *O*. In this Figure, we are looking down on the plane of the system from above the north pole of the zodiacal circle. So viewed, *K* moves counterclockwise with $\angle\alpha$ increasing uniformly with time. The Sun moves in the opposite sense (clockwise) on the epicycle but at the same rate, so that we always have $\angle\beta = \angle\alpha$.

That these two versions of the solar theory are mathematically equivalent may be seen in Figure 3, p. 114. Since $\angle\beta$ is always equal to $\angle\alpha$, *K*⊙ remains parallel to *OZ*. So, if we choose to make the radius *K*⊙ of the epicycle in the second hypothesis equal to the off-centeredness *OC* of the eccentric circle in the first hypothesis, then *COK*⊙ in Figure 3, p. 114 will be a changing parallelogram with *C*⊙ = *OK*. Thus, the path traced out by ⊙ is the off-centered circle shown in dashed line.

It is possible that the equivalence of the epicycle-plus-concentric-deferent hypothesis to the eccentric-circle hypothesis was proven already by Apollo-

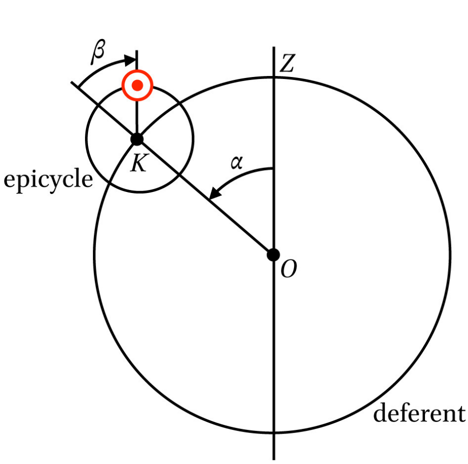

FIGURE 2 The epicyclic solar hypothesis

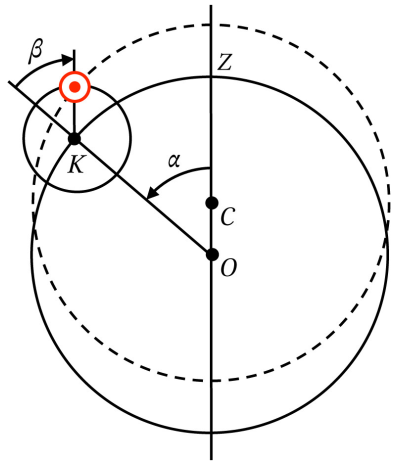

FIGURE 3 The equivalence of the solar eccentric and epicyclic hypotheses

nius of Perga.[1] In any case, proofs survive in Theon of Smyrna and Ptolemy.[2] Although these two hypotheses are geometrically equivalent, there was nevertheless a debate in Antiquity about which really corresponds to nature. According to Theon, Hipparchus preferred the epicycle-plus-concentric, saying that it was probable that the celestial bodies are placed uniformly with respect to the center of the world [*Exp*. 3.34: Dupuis 1892, 304–305]. Ptolemy, however, expressed a preference for the eccentric-circle hypothesis, saying that it was simpler in that it involved one motion rather than two [*Alm*. 3.4: Heiberg 1898–1907, 1.232; Toomer 1998, 153]. According to Theon, Hipparchus also remarked that it was worth the attention of the mathematical astronomers to investigate the explanation of the phenomena by means of hypotheses that are so different [*Exp*. 3.26: Dupuis 1892, 268–269].

3 Theory of Planetary Longitudes

In Hellenistic planetary theory, the retrograde motion of a planet is usually accounted for with the use of an epicycle. The simplest version of the theory

1 Neugebauer 1959. But see Bowen 2013a, 244–247.

2 Ptolemy, *Alm*. 3.3: Heiberg 1898–1907, 1.220–229; Toomer 1998, 145–149. Theon of Smyrna, *Exp*. 3.26: Dupuis 1892, 270–279. From Theon's remarks, it seems that he has taken his proof from a work by Adrastus (of Aphrodisias).

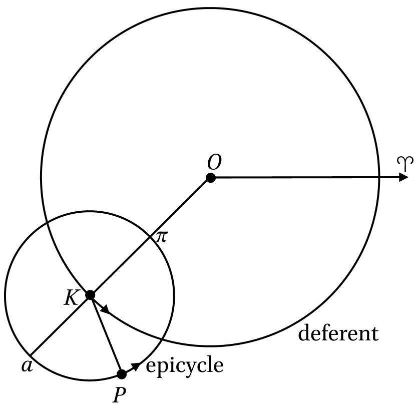

FIGURE 4 A simple epicyclic planetary hypothesis

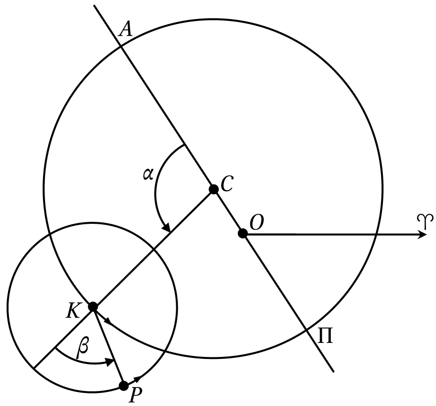

FIGURE 5 A planetary hypothesis with epicycle and eccentric deferent

is shown in Figure 4. The planet *P* travels uniformly around the epicycle, going from the epicyclic apogee (*a*) back to this apogee in one synodic period, the interval of return to the same phase [see ch. 4.1 §3, p. 66]. Meanwhile, the center *K* of the epicycle travels uniformly around the deferent circle, going from the spring equinoctial point (♈) back to spring equinox in one tropical period. Retrograde motion occurs when the planet is near the perigee (π) of the epicycle, when the backward motion on the epicycle is enough to overcome the forward motion of *K*. This hypothesis accounts in a general way for how the planets could move uniformly in circles, in accordance with the accepted physical principle of uniform motion in circles, while appearing occasionally to stand still and to reverse directions. But it will not work in a quantitative way to explain the details of planetary motion. For example, the actual retrogradations of a planet are not uniformly spaced in longitude around the zodiacal circle. In the case of Mars, the inequality in spacing is striking. In some parts of the zodiacal circle, the centers of Mars' successive retrograde arcs are only 35° apart, while in the diametrically opposite part of the zodiacal circle, they are separated by 70°.

In the second century BCE—to judge by Ptolemy's remarks in *Alm.* 9.2 about Hipparchus' criticisms of the planetary theories of his predecessors—Greek astronomers had already made some attempt to account for the unequal spacing of the retrograde arcs around the zodiacal circle by making the deferent circle eccentric to the Earth, as in Figure 5. But even this will not suffice to give a thoroughly accurate hypothesis, for there is a second complication: the widths of the retrograde arcs also vary around the zodiacal circle. Again, the situation is most striking with Mars, whose retrograde arcs vary in width from about 10° to about 20°. It is not possible to account for both the variation in the spacing of the retrograde arcs and the variation in their widths simply by making the deferent eccentric.

In *Almagest* 9.2, Ptolemy refers to the difficulty of constructing a theory that will account for two anomalies with two different periods.[3] The synodic anomaly (or the anomaly with respect to the Sun) is manifested in the very fact of retrogradation and it is clearly connected with the Sun, since the outer planets retrograde when they are in opposition to the Sun, whereas the inner planets retrograde when they are in conjunction with the Sun. Thus, the length of the synodic period is determined by the planet's successive returns to the Sun. The zodiacal anomaly shows up most clearly in the unequal spacing of the retrogradations around the zodiacal circle. (Sometimes the zodiacal anomaly and the synodic anomaly are called the first anomaly and the second anomaly, respectively.) Thus, a planet "knows" when to retrograde by its relation to the Sun but the character of the retrogradation is determined by where the planet happens to be in the zodiacal circle when the retrogradation occurs. Ptolemy remarks that one can try to account for the phenomena by using an eccentric circle or an epicycle or even an eccentric and epicycle in combination; but none of the attempts before his own time had been satisfactory. He hazards the guess that the difficulty of the problem is why Hipparchus (who had produced good theories of the Sun and the Moon) did not attempt a planetary theory.

The solution adopted by Ptolemy requires separating the center of uniform motion from the center of the deferent circle. In Figure 6, p. 117, C is the center of the deferent circle and O, the Earth as before. But now there is a third center, E (in later astronomy called the equant point), which serves as the center of uniform motion. The epicycle's center K moves around the deferent in such a way that its angular motion is *uniform as viewed from E*. Thus, $\angle\alpha$ increases uniformly with time. This results in a motion of K that is physically nonuniform: K travels faster (in miles per hour) when it is near Π and more slowly when it is near A. Meanwhile, the planet P moves uniformly on its epicycle, so that $\angle\beta$ increases uniformly with time.

Ptolemy's introduction of the equant made it possible, for the first time in history, to predict planetary phenomena accurately using a geometrical theory.[4] The Babylonians had earlier achieved predictive capacity but their

3 An anomaly is an irregularity in the motion of a planet, a departure from the way in which the planet would move if its angular motion about the Earth were uniform.

4 For several different views of Ptolemy's approach to the equant, see Evans 1984; Jones 2004a; Swerdlow 2004a; Duke 2005a. For hints based on survivals in Indian astronomy that Greek astronomers between Hipparchus and Ptolemy experimented with nonuniform motion, see Van der Waerden 1961; Duke 2005b.

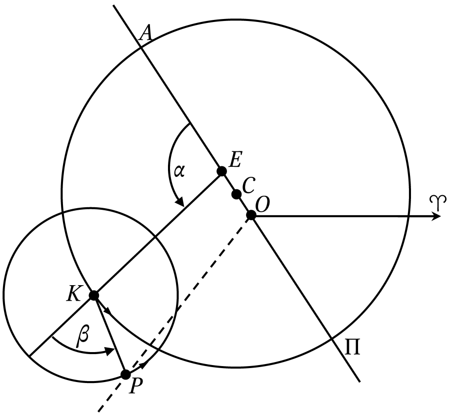

FIGURE 6 Ptolemy's theory of longitude for Venus and the outer planets

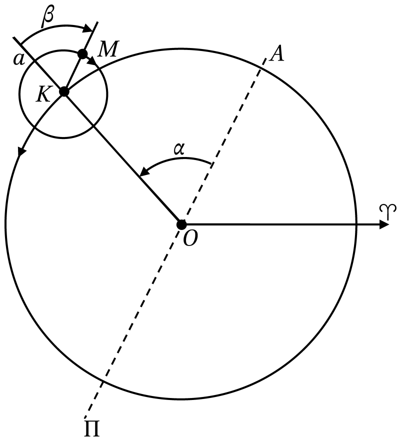

FIGURE 7 The simple lunar hypothesis attributed to Hipparchus

methods were based on arithmetical rules rather than geometrical hypotheses. Although there is some evidence for Greek experimentation with nonuniform motion in the period between Hipparchus and Ptolemy, the first treatment of the equant point known to us is in Ptolemy's *Almagest*. The theory of longitudes shown in Figure 6 was applied by Ptolemy to Venus, Mars, Jupiter, and Saturn. (Only for Mercury were there some extra complications, too intricate to describe in the space available here.) Ptolemy's theory is, in principle, quite good—though everything depends on the accuracy with which the parameters are determined.

Nevertheless, Ptolemy was criticized for his equant point in the Middle Ages and Renaissance by Ibn al-Haytham and Copernicus, among others. The complaint was not that the equant led to an inaccurate theory but that it violated the accepted philosophy of nature, which prescribed uniform, circular motions for the celestial bodies, since *K* does not move uniformly on the deferent circle about *C*, the center of this circle.

4 Lunar Theory

In his discussion of the lunar theory in the *Almagest*, Ptolemy moves through a sequence of three hypotheses of increasing sophistication. The first and simplest version is similar to his solar theory. The Moon moves eastward around the zodiacal circle at a variable speed, completing a circuit in about a month. The variation in speed can be represented either by making the Moon's circle eccentric to the Earth or by using an epicycle. We shall use the epicyclic hypothesis shown in Figure 7, p. 117. The Moon M moves clockwise around an epicycle, while the center K of the epicycle moves counterclockwise (eastward) around the zodiacal circle. If the two motions took place at the same rate, so that $\angle\beta = \angle\alpha$ always, then the Moon's apogee would be fixed in space in the direction of A. (This was the case with the Sun.)

The Moon, however, displays an extra complication: the place in the zodiacal circle where it moves most rapidly is not fixed but itself moves forward; that is, it moves in the direction of increasing longitude, around the zodiacal circle, completing a circuit in about 9 years. Thus, if in a certain month the Moon moves most rapidly when it is in Aries, then about 9 months later it will begin to move most rapidly when it is in Taurus. In Figure 7, p. 117 this is accomplished by letting $\angle\alpha$ increase slightly more rapidly than does $\angle\beta$.

It is anachronistic but helpful conceptually to ask how these features of the ancient lunar theory correspond to modern celestial mechanics. We may think of the epicycle as producing some of the features of Kepler motion: from the modern point of view, the Moon does speed up and slow down in the course of the month as it moves on its eccentric elliptical orbit, obeying Kepler's law of areas, namely, that the radius vector (pointing from the Earth to the Moon) sweeps out equal areas in equal times. The combination of the mean motion of K around the Earth and the departures from mean motion produced by the motion of M on the epicycle, results in a reasonably accurate representation of the angular motion of the Moon. If the Moon and the Earth were the only objects in the universe, the orientation of the Moon's apogee would be invariable. But, of course, the Sun is present in the system as well. The Sun's gravitational attraction disturbs the Moon's motion in many ways. One of the most important is that it causes the Moon's apogee to advance with time. Thus, two essential features of lunar motion are already explained by the simple hypothesis of Figure 7, p. 117—the Moon's variable angular speed and the progressive advance of the apogee. These features of lunar motion were also handled quantitatively by Babylonian astronomers using arithmetical procedures rather than the geometrical hypotheses of their Greek neighbors and successors.

To see how the advance of the apogee works in a Greek geometrical theory, let us consider A as the instantaneous direction of the apogee for the moment represented in Figure 7. We regard the dashed line through A as fixed in space. When $\angle\alpha$ has increased to 360° so that K is on the apsidal line through A, M will not quite have reached the apogee a of the epicycle (since $\angle\beta$ will be a little less than $\angle\alpha$, i.e., than 360°). We will, therefore, have to wait a little longer for the Moon to reach apogee. Thus, the new line through the instantaneous apogee will be rotated counterclockwise a little from the dashed line. The rate (in degrees per day) at which the apogee advances will be equal to the difference between the rates with which $\angle\alpha$ and $\angle\beta$ increase.

Hipparchus studied a hypothesis like that shown in Figure 7, p. 117 and determined its parameters. These include the periods, which he based on Babylonian values, as well as the radius of the epicycle (taken in relation to the radius of the deferent). The hypothesis depicted in Figure 7 works well in predicting eclipses, when the Moon is either new (solar eclipse) or full (lunar eclipse). But Ptolemy found that at other times of the month, the radius of the epicycle seemed to be too small. So he adopted an ingenious crank-mechanism that would cause the epicycle to draw nearer the Earth at other times of the month. This would cause the epicycle to *appear* larger at just those times (e.g., the quadratures) when the Moon was at 90° from New or Full Moons, that is, when it needed to be increased in size.

When modern readers first hear about this feature of the lunar theory, it may strike them as complicated and artificial. But Ptolemy's crank-mechanism was his way of dealing with another genuine irregularity of the Moon's motion: in modern theory, this is called evection and it results from the Sun's causing the Moon to speed up and slow down as the Moon moves around its orbit. This is in addition to (and smaller than) the main speeding up and slowing down associated with Kepler motion. Moreover, this extra correction due to the action of the Sun depends on the angle between the Sun and the Moon (the Moon's elongation).

To understand how Ptolemy's crank-mechanism works, consider Figure 8, p. 120. The Moon *M* still moves clockwise around its epicycle, while the center *K* of the epicycle moves counterclockwise around the deferent. But now the center *D* of the deferent is off-center from the Earth *O*. Moreover, *D* itself moves around on a small circle: thus, the location of the deferent's center is constantly changing. The radius *DK* of the deferent is constant; so, as *D* moves around *O*, it alternately pulls the epicycle in closer to *O* and pushes it farther out.

Now, as we have noted, the aim is to have the epicycle farthest from *O* when the Moon is New or Full and closest to *O* when the Moon is in quadrature with the Sun. This is accomplished in the following way. As the mean Sun S' (the Sun stripped of the nonuniformity of its motion) moves steadily eastward, $\angle \Upsilon OS'$ increases uniformly with time. Angle θ_1 is the mean elongation of the Moon (its mean angular distance from the Sun), an angle that goes through 360° in one synodic month. If the motion of *D* on its small circle is such that $\theta_2 = \theta_1$ always, then $\angle DOK$ (which equals $2\theta_1$) will go through 360° in half a synodic month. So if *K* coincides with S' (mean New Moon), $DOK = 0$, which means that *K* is as far from the Earth *O* as it can be: at that time, $OK = DK + OD$. And

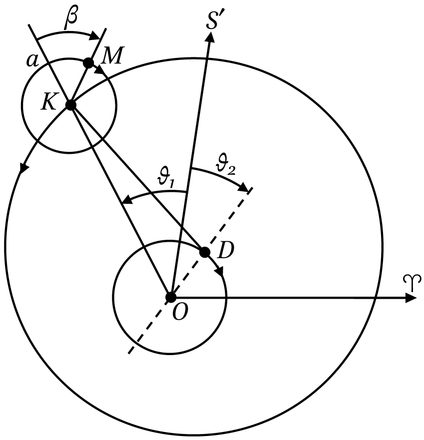

FIGURE 8 Ptolemy's second lunar hypothesis

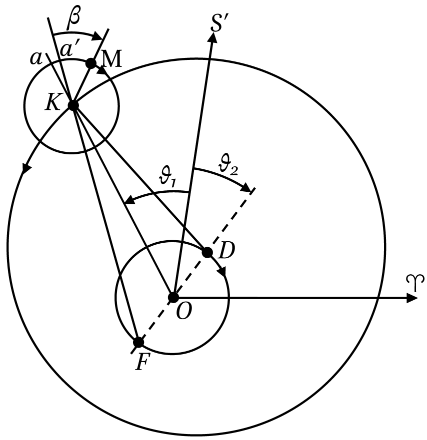

FIGURE 9 Ptolemy's third lunar hypothesis

if *K* is opposite *S′* (mean Full Moon), $DOK = 360°$, so that *OK* is again at its maximum value of $DK + OD$. On the other hand, when $\theta_1 = 90°$ (mean Moon in quadrature with mean Sun), then $DOK = 180°$ and the distance *OK* takes on its minimum value, $DK - OD$.

Ptolemy's third lunar hypothesis [see Figure 9, p. 120] was motivated by his observation that, while his second hypothesis worked well at New and Full Moons, and also when the Moon and Sun were in quadrature, there was still a small discrepancy at the octants—when the Moon is about $\pm 45°$ from quadrature. This he believed he could fix by letting the uniformly increasing $\angle\beta$ be measured, not from the true apogee *a* of the epicycle but from a sort of mean apogee a'. If we extend the diameter of the small circle and let *F* be located opposite *D*, then the line from *F* through *K* will cut the epicycle at a', which is now to be used as the zero point for the measurement of β. With this extra refinement, Ptolemy's lunar theory was complete.[5]

As an instrument for predicting the angular position of the Moon, Ptolemy's lunar theory was reasonably accurate. In the process of refinement, however, he spoiled its ability to represent the distances accurately. The problem is the crank-mechanism. The maximum possible distance between the Earth and the Moon is $DK + OD + KM$, while the minimum possible is $DK - OD - KM$. Inserting Ptolemy's parameters, we find that these two distances stand as

5 Dennis Duke [2004] has provided a large number of animated computer models of Ptolemy's planetary theories (and some later ones as well) at https://people.sc.fsu.edu/dduke/models. The animated model of the Moon is especially recommended.

78.8/41.2 = 1.9. That is, on some occasions, the Moon must be nearly twice as far from the center of the Earth as it is on others. This nearly 2:1 variation in distance is a large exaggeration, since the real ratio of greatest to least distance is about 1.12:1.00. Ptolemy passes over this defect of his lunar theory in silence, even though a 2:1 variation in angular diameter could have been easily observed.

5 Cosmological Hypotheses

In the *Almagest*, the geometrical hypotheses discussed above account for the motions of the planets. These theoretical constructs enable Ptolemy to calculate a position for any planet for any date required. The question of how these hypotheses might be physically realized is not addressed explicitly. In a separate work written after the *Almagest*, however, Ptolemy turns directly to the question of physical representation. Astronomers before Ptolemy's time, including Theon of Smyrna, his near contemporary, had asked how the real bodies of planets could be carried on incorporeal circles [*Exp*. 3.31: Dupuis 1892, 288–289]. The circles of these hypotheses had, therefore, to be interpreted in full three-dimensionality to be credible. Theon had shown how eccentric circles and epicycles could be realized physically. The general idea was to think of each planetary circle as inscribed on or embedded in a three-dimensional sphere. Usually, each circle was to be thought of as an "equatorial" circle of the sphere on which it is inscribed. The notion of nested planetary spheres with multiple parts goes all the way back to the homocentric spheres discussed by Eudoxus, Callippus, and Aristotle. The homocentric spheres were abandoned as a planetary theory within a century or so of Aristotle's death (322 BCE) and replaced by the more flexible and successful theory of eccentrics and epicycles. But the system of nested spheres that Aristotle ascribes to Eudoxus continued to exercise a profound influence in cosmological thinking all the way down to the Renaissance.

In the *Hypotheses planetarum*, Ptolemy's purpose is to show how the circles of mathematical planetary theory (as presented in the *Almagest*) may be incorporated in a spherical cosmos—that is, as a real, physical entity. Ptolemy, in fact, presents two different versions. In one, the shells that carry the planets are full spheres. In the other, the caps of the spheres are "sawn off" to make tambourine-like constructions called *prismata*. Ptolemy points out that since the caps play no role in the astronomy, one can dispense with them. But it is likely that he still intended the tambourines to provide the basis for realizable, functioning hypotheses.

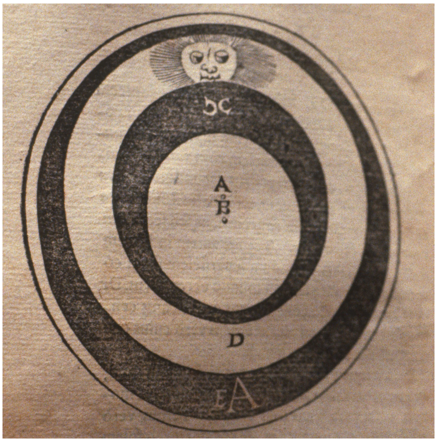

PLATE 1 Ptolemy's solar hypothesis in spherical form
PEURBACH 1553, 6

PLATE 2 Ptolemy's Venus hypothesis in spherical form
PEURBACH 1553, 61

Plate 1 shows a woodcut of the three-dimensional form of the solar theory. It is taken from Erasmus Rheinhold's edition of Georg Peurbach's *Theoricae novae planetarum* [1553], which provided Renaissance European astronomers with an introduction to the hypotheses in solid (spherical) form. Peurbach seems to have learned about them, not directly from Ptolemy's *Hypotheses planetarum*, but from a Latin translation of an Arabic text descending from Ibn al-Haytham's *On the Configuration of the World*. Nevertheless, the three-dimensional hypotheses described by Peurbach do go back to Ptolemy.

In Plate 1, the Sun is imbedded in the white spherical shell *D*, which turns around once a year, carrying the Sun around the zodiacal circle. This shell may be thought of as resembling a thin layer of onion. The Earth *B* is the center of the cosmos. But the turning spherical shell *D* carrying the Sun is centered at point *A*, slightly eccentric to the Earth. The black orbs marked *E* and *C* are stationary spacers. *C* has its inside surface centered at *B* and its outside surface centered at point *A*. We should imagine the mechanisms for Venus, Mercury, and the Moon nested in the interior spherical cavity. Spacer orb *E* has its inner surface centered on *A* and its outer surface centered on *B*; it restores concentricity with the Earth. The mechanisms for Mars, Jupiter, and Saturn are to be stacked outside *E*.

Plate 2, drawn from the same work, shows the systems for both the Sun and Venus. The three solar orbs, all marked *A*, are as in the previous figure. Three orbs for Venus are all labeled *B*—two black spacer orbs and the white revolving spherical shell that carries the epicycle. The epicycle can be thought of as a bowling ball fitted into a spherical cavity. Venus can be seen at the sur-

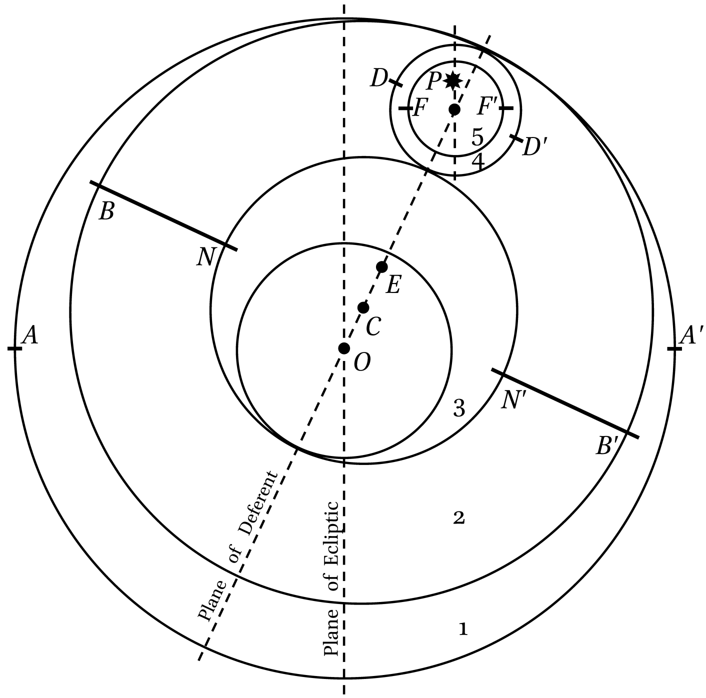

FIGURE 10 The spherical version of Ptolemy's hypothesis for an outer planet

face of the epicycle sphere. Points *D, C*, and *H* are the Earth, the center of Venus' deferent, and Venus' equant point. Plate 2 does not, however, show all the necessary detail.

So, in Figure 10, we have a more detailed view of Ptolemy's three-dimensional theory of an outer planet as described in his *Hypotheses planetarum*. *O* is the Earth; *C*, the center of the planet's eccentric deferent; and *E*, the equant point. The hollow spherical shell 2 turns around axis *BB′* (which passes through *C*) thus carrying the planet's epicycle around the zodiacal circle. Of course, this motion must be uniform as viewed from *E*. The stationary spacer orb 3 restores centrality with respect to *O*, so that the mechanisms for the lower-lying planets may be inserted in the hollow space inside 3. Similarly, the stationary spacer orb 1 also restores centrality so that the higher-lying planets may be stacked outside of 1. Orb 2 has a spherical hollow into which is inserted a spherical shell 4, into which, in turn, is inserted the sphere 5, which is the physical representation of the epicycle. The planet *P* is embedded in the surface of sphere 5.

6 Planetary Latitudes

Since (in the modern view) the orbits of the other planets about the Sun do not lie in the plane of the Earth's orbit, we observe that any given planet is sometimes north of, and sometimes south of, the zodiacal circle. The planet's angular distance out of the plane of this circle is called its latitude [see ch. 1 § 4.1, p. 16]. The theory of latitudes was the least refined part of planetary theory that Ptolemy had received from his predecessors. He continued to tinker with it during his astronomical career and presented three different latitude theories in the *Almagest*, the *Canones manuales*, and the *Hypotheses planetarum*.[6] In many parts of his astronomy, Ptolemy adapted and systematized what his predecessors had initiated. But the successive improvements in his latitude theory provide clear evidence that he was not merely an adept textbook author (as some have claimed) but also a creative and original thinker. The final version of the latitude theory in the *Hypotheses planetarum* is not only simpler but also better than the original version in the *Almagest*.

Let us examine the latitude theory of an outer planet in the *Hyp. plan.*, referring once again to Figure 10, p. 123. The plane of the deferent circle makes a fixed angle (different for each planet) with the plane of the zodiacal circle, as shown. Axis BB' (the axis of rotation of body 2) is inclined to axis AA', which passes though the Earth O and the poles of the zodiacal circle. In Ptolemy's theory of the superior planets, the plane of the epicycle is parallel to the plane of the zodiacal circle. Ptolemy provides spherical shell 4, rotating about axis DD', to "cancel out" the rotation about the tilted axis BB'. Thus, DD' is parallel to BB'. Sphere 4 rotates about DD' at the same rate as 2 rotates about BB' but in the opposite direction. The result is that sphere 4 is carried about axis BB' in a circular translation, that is, without rotation. Sphere 5, which carries the planet P, rotates about axis FF', which is parallel to AA'. The latitude theories of the *Almagest* are more complex as well as less satisfactory in terms of representing the phenomena.[7]

6 A clear account of the planetary latitude theory of the *Almagest* is available in Pedersen 2011, 355–386. For the three latitude theories of Ptolemy's successive publications, see Swerdlow 2005.

7 For example, in the *Almagest*, the plane of the outer planet's epicycle does not remain parallel to the zodiacal circle but oscillates.

CHAPTER 4.5

The Hellenistic Theory of Eclipses

Clemency Montelle

1 Introduction

"Nothing at all is unexpected; nothing may be sworn to be impossible, or even astonishing", wrote the Greek poet Archilochus (*ca* 680–640 BCE), "since Zeus, the father of the Olympians, has concealed the light of the blazing Sun and made night of out noon-day, and…fear has come upon mankind" [Rankin 1977, 24]. Literary references to eclipses, such as Archilochus' mention of a solar eclipse, testify to the importance of eclipses in society at large in Classical Antiquity and the ominous effects that they signaled. Greek and Roman authors alike took advantage of the visual brilliance of eclipses in their writing and often linked them with events of catastrophic proportions. From the earliest times in written record, they were seen as signs from the divine realm presaging happenings of great significance in the mundane realm. Given these sentiments, the Greek culture of inquiry had strong incentives to refine its ability to explain and later to predict the circumstances and details of eclipses. Most directly, eclipses were a key aspect of astrology and divination. In addition, these phenomena provided a practical occasion for the application of more abstract mathematical research. Eclipse-phenomena were also inspirational in other respects. For instance, their visual impact provided analogies for philosophers contemplating the very nature of reality [see, e.g., Plato, *Phaedo* 99d].

Naturally, then, eclipse-reckoning became a prominent component of astronomical research in the Hellenistic Period. Greek and Roman astronomers sought to understand better the mechanisms that caused eclipses as well as to predict their occurrences. Diagrams in copies of astronomical works shed some light on the ways in which astronomers conceived of the celestial configurations required for eclipses to occur. For instance, Plate 1, p. 126 reproduces a diagram from one of the extant manuscripts of Aristarchus' *De magnitudinibus*, written in the third century BCE. This particular diagram depicts the conditions that cause a lunar eclipse by displaying the alignment of the Sun, the Earth, and the Moon, along with the resulting conical shadow cast by the Earth responsible for the eclipse itself.

While the image is certainly visually arresting, it points to something more significant about Greek eclipse-reckoning by this time. Key to the accounting

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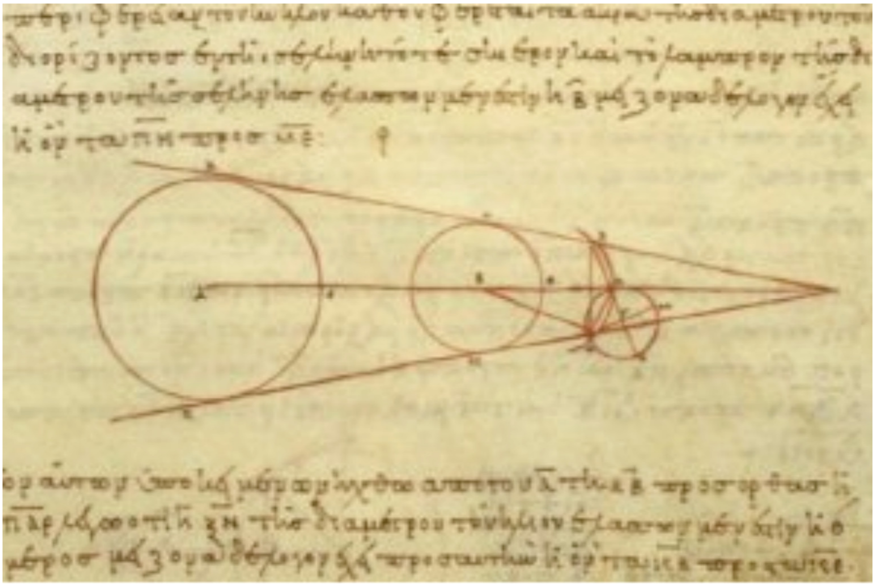

PLATE 1 A lunar eclipse as shown in a 10th-century copy of Aristarchus' *De magnitudinibus* Note the alignment of the Sun, Earth, and Moon and the path of the Moon.

of astronomical phenomena was a geometrical kinematic description of the heavenly configurations and motions. This feature, along with the quantitative particulars detailed some centuries later in Ptolemy's *Almagest*, produced a means of successfully predicting both lunar and solar eclipse-possibilities and their circumstances, as well as many other celestial phenomena. With these eclipse-possibilities, Ptolemy gives a range of criteria for which an eclipse will actually be visible. Ptolemy was not solely responsible for this accomplishment but championed an approach to astronomical phenomena that had been gradual in its realization. The roots of it can be traced back to the sixth century BCE and inspiration came from outside of the Greek culture of inquiry as well as within it. It was made by theoretical insight, practical ingenuity, as well as from the influence of other earlier and contemporary astronomically active cultures, particularly in the ancient Near East. It was in many senses a culmination of diverse disciplines, guided by some of the very best Greek mathematical achievements of generations past, shaped by philosophical preoccupations, and informed by insights in natural science. It served the demands of astrologically active communities and other intellectual traditions besides. Ptolemy's resulting astronomical theory proved so robust that it was to remain the essence of eclipse-reckoning until the 16th century.

2 Early Eclipse-Reckoning: Aristarchus and Archimedes

Testimonia by later authors in Greek Antiquity suggest that thinkers as early as the sixth century BCE were deliberating over the causes and circumstances of eclipses. Reckoning at this early stage appears largely concerned with cosmological design. The relative shapes and sizes of the celestial bodies, the causes of their illumination, and their placement in space with respect to each other were compelling subjects for many early thinkers. Many creative ideas were proposed and, while many were far from what would in time become accepted, they were markedly rationalistic in their approach. For instance, Anaximander (*ca* 610–546 BCE) is said to have argued that the igniting and smothering of internal fires on the luminaries were responsible for the eclipsing effect. He also posited that the disk of the Sun and the Moon were 28 and 19 times larger than the disk of the Earth, respectively. Eventually, speculation of this sort produced the first coherent cosmological picture to account correctly for the cause of eclipses although it is unclear to whom this should be attributed. The second century CE doxographer Aëtius claims that Anaxagoras (*ca* 510–428 BCE) was the first to enunciate this, namely, that the Moon receives its light from the Sun and lunar eclipses are caused by the blocking of this light by the Earth when the three bodies are in the correct alignment, although others credit Parmenides (*flor.* fifth century BCE) as well as other unnamed Pythagoreans for promoting this point of view [Graham 2013].

Regardless of the exact details of the individuals who should be accorded priority for such insights, by the advent of the third century BCE, the relative positions of the luminaries and the sources of their light was understood and subsequent advancements in eclipse-reckoning focused on the relative sizes of these bodies and their distances to one another. The work of Aristarchus (*ca* 310–230 BCE) was crucial in this respect. In his only surviving treatise, *De magnitudinibus et distantiis solis et lunae* (*On the Sizes and Distances of the Sun and the Moon*), he opened a new avenue of research. In the absence of precise or direct observational data and astronomical period-relations whose lengths were often longer than a lifetime, he relied instead on mathematical inference to generate claims about the celestial phenomena. In this way, he championed a new direction for astronomy to take. This so-called mathematical astronomy was characterized by a reliance on mathematics to advance astronomical speculation so that the amount of empirical data (which was often difficult to establish with certainty or precision) required for theorizing was reduced.

Aristarchus' work opens with several hypotheses (such as that the orbit of the Moon is smaller than the orbit of the Sun and that the radius of the Earth's shadow is twice the apparent radius of the Moon) and proceeds in a deductive way to demonstrate various propositions. Some of his conclusions are good (e.g., about the Sun's apparent size) and some are poor (such as his assumption entailing that the apparent diameter of the Moon is 2°). However, regardless of the actual results, Aristarchus is more important for his approach which explicitly combines basic assumptions with geometry to derive ranges with limits (and notably not direct measurements) within a deductive framework.

Archimedes (286–212 BCE) continued likewise in his own reckoning of eclipse-phenomena. His *Arenarius* (*Sandreckoner*) contains a passage on the sizes and distances of the Sun and the Moon. He too gives limits for the solar diameter and claims that the diameter of the Sun is about 30 times that of the Moon. More broadly, Archimedes, like Aristarchus, reveals that, at the beginning of the Hellenistic Era, the sizes and distances of the celestial bodies were now being considered from a geometrical point of view, even if these first attempts were in some respects unsuccessful. Poor observational data meant that many of their ratios were rather rough or inaccurate; and yet, their efforts look forward to the new direction that Greek astronomy was taking.

3 The Culmination of Eclipse-Reckoning: Hipparchus and Ptolemy

Up until the second century BCE, planetary hypotheses could reproduce the celestial motions qualitatively but lacked quantitative and predictive ability. The first to demand such quantitative significance seems to have been Hipparchus of Nicaea (*ca* 190 – *ca* 120 BCE), who was influenced by Babylonian arithmetical models. He introduced Babylonian parameters and period-relations which can be traced back to the so-called Systems A and B of the astronomical texts in cuneiform [see ch. 4.6 §3, p. 128], so that for the first time in Greco-Roman astronomy, astronomical hypotheses coupled with kinematic geometrical hypotheses could function as an accurate basis for prediction. All of Hipparchus' works are lost save his commentary on Aratus' *Phaenomena*; such knowledge as we have of his achievements in reckoning eclipses and other phenomena comes to us through the writings of Ptolemy (*ca* 100–175 BCE) in his monumental work, the *Almagest*. Ptolemy's work represents the pinnacle of Greek mathematical astronomy and was not to be replaced substantially for over a millennium.

Eclipse-observations derived from earlier sources or made in Ptolemy's time were fundamental to his determining many key parameters. Select trios of eclipse-observations made over a known period of time and their measurements were crucial in determining such key parameters as the argument and

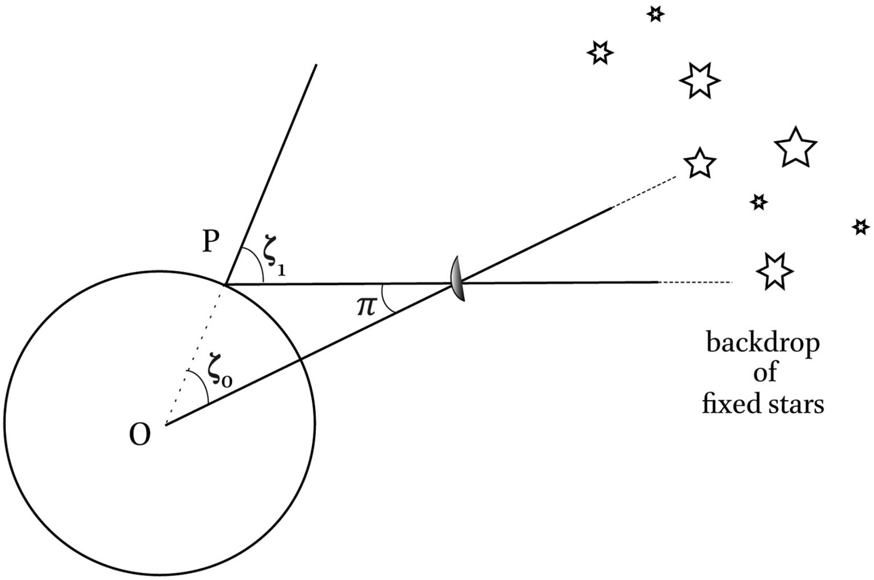

FIGURE 1 Parallax (π)
Parallax or the displacement of a celestial body when it is observed from the Earth's surface (P) and not from its center (O)—O being the point from which the body's position is to be computed—causes bodies close to the Earth, such as the Moon, to appear lower in the sky with respect to the backdrop of fixed stars. In this instance, if ζ is the zenith-distance, $\pi = \zeta_1 - \zeta_0$.

equation of lunar anomaly [see, e.g., *Alm.* 4.6].[1] But the reckoning of eclipses and their circumstances are also the focus of much of the *Almagest*. Their treatment is found in the last half of book 5 and all of book 6.

Ptolemy's eclipse-reckoning begins with an account of parallax. Parallax is the displacement in position due to the fact that an observer is on the surface of the Earth rather than its center [see Figure 1]. This effect has the result that the apparent positions of the Moon and the Sun are lower in the sky than the true positions computed on the assumption that the observer is at the Earth's

1 Lunar anomaly by itself is the irregularity or lack of uniformity in the Moon's motion in longitude. Such anomaly is a phenomenon independent of any astronomical hypothesis [see ch. 4.2, p. 71: cf. ch. 4.4 §3, p. 114]. Ptolemy proposes two hypotheses that are equivalent, the eccentric and epicyclic. In these hypotheses, there is an *argument of anomaly* and an *equation of anomaly*. In the eccentric hypothesis, the argument of anomaly is measured from the lunar apogee to the Moon about the center of the eccentric circle; in the epicyclic hypothesis, the argument of anomaly is measured on the epicycle from the line connecting the center of the deferent and the center of the epicycle. The equation of anomaly is the difference between the mean and true positions of the Moon.

center. In terms of eclipse-reckoning, the application of parallax to the positions of the Sun and the Moon is crucial. In a solar eclipse, the variation in position due to parallax can lead to prediction of eclipses that do not occur and to failure to predict eclipses that do occur.

Greek astronomers were the first to recognize explicitly the effects of parallax and were thus in a better position to predict the occurrences of solar eclipses than their predecessors had ever been.

The successful prediction of eclipses requires a consideration of the time of syzygy (conjunction or opposition of the Sun and the Moon); the sizes of the Sun, the Moon, and the terrestrial and lunar shadows; as well as the inclinations of the lunar and solar orbits. Ptolemy's treatment works through these as follows. He presents a table of all possible syzygies beginning from his epoch or starting-point, Nabonassar year 1 Thoth 1 (which corresponds to 26 Feb 747 BCE) along with the first lunar anomaly and lunar latitude (the Moon's distance above or below the apparent path of the Sun [see ch. 1 §4.1, p. 16]). The latitude determines the eclipse-limits, that is, the elongation of the Moon's position from a node—one of the two points 180° apart at which the lunar orbit intersects the zodiacal circle—within which an eclipse is possible. Accordingly, Ptolemy offers information about these eclipse-limits so that when one enters the table with these limits, one can determine those syzygies for which an eclipse is possible.

Next, details about the sizes of the celestial bodies produce information on the characteristics of the eclipse, such as its magnitude and duration. Ptolemy's values for the sizes of the celestial bodies are determined through observational results of careful selected pairs of eclipses: two close to apogee (when the bodies are farthest away from the Earth) and two close to perigee (when the bodies are closest to the Earth). He concludes that the ratio between the diameter of the Earth's shadow to that of the Moon is 1:2⅗ (which he comments is slightly too small). Following this, he uses these apparent diameters to determine the maximal latitudinal difference for which an eclipse can occur and from this in turn the distance from the node, allowing for parallax in the case of a solar eclipse.

With all this information at hand, Ptolemy completed his lunar eclipse tables [*Alm.* 4.7–8], which tabulate the magnitude and duration of an eclipse using the Moon's position with respect to the node [see Table 1, p. 131 with Table 2, p. 132] as its argument. His lunar eclipse tables, for instance, are divided into two pairs of five columns. The first set of five columns tabulates data when the Moon is at its apogee (or greatest distance) and the second set at perigee (or least distance). The first two columns give the "argument of latitude", here the distance to either side of the node for which a lunar eclipse is possible. The

TABLE 1 An excerpt from the table in Ptolemy's *Alm.* 6.8 to compute the magnitude and duration of lunar eclipses [Heiberg 1898–1907, 1.520–521]

σεληνιακῶν ἐκλείψεων μεγίστου ἀποστήματος					σεληνιακῶν ἐκλείψεων ἐλαχίστου ἀποστήματος				
α′ πλάτους	β′ ἀριθμοί	γ′ δάκτυλοι	δ′ ἐμπτώσεως μόρια	ε′ μονῆς ἥμισυ	α′ πλάτους	β′ ἀριθμοί	γ′ δάκτυλοι	δ′ ἐμπτώσεως μόρια	ε′ μονῆς ἥμισυ
οθ ιβ	σπ μη	ο	ο ο		οζ μη	σπβ ιβ	ο	ο ο	
οθ μβ	σπ ιη	α	ιϛ νθ		οη κβ	σπα λη	α	ιθ θ	
π ιβ	σοθ μη	β	κγ μγ		οη νϛ	σπα δ	β	κϛ με	
π μβ	σοθ ιη	γ	κη μα		οθ λ	σπ λ	γ	λβ κ	
πα ιβ	σοη μη	δ	λβ μβ		π δ	σοθ νϛ	δ	λϛ νγ	
πα μβ	σοη ιη	ε	λϛ ϛ		π λη	σοθ κβ	ε	μ μβ	
πβ ιβ	σοζ μη	ϛ	λθ α		πα ιβ	σοη μη	ϛ	μγ νθ	
πβ μβ	σοζ ιη	ζ	μα λδ		πα μϛ	σοη ιδ	ζ	μϛ νγ	
πγ ιβ	σοϛ μη	η	μγ ν		πβ κ	σοζ μ	η	μθ κε	
πγ μβ	σοϛ ιη	θ	με μη		πβ νδ	σοζ ϛ	θ	να μ	
πδ ιβ	σοε μη	ι	μζ λε		πγ κη	σοϛ λβ	ι	νγ λθ	
πδ μβ	σοε ιη	ια	μθ θ		πδ β	σοε νη	ια	νε κε	
πε ιβ	σοδ μη	ιβ	ν λα		πδ λϛ	σοε κδ	ιβ	νϛ νθ	
πε μβ	σοδ ιη	ιγ	μ λε	ια θ	πε ι	σοδ ν	ιγ	με μζ	ιβ λδ
πϛ ιβ	σογ μη	ιδ	λζ κη	ιε κ	πε μδ	σοδ ιϛ	ιδ	μβ ιε	ιζ ιζ
πϛ μβ	σογ ιη	ιε	λε λ	ιη ιβ	πϛ ιη	σογ μβ	ιε	μ β	κ λβ
πζ ιβ	σοβ μη	ιϛ	λδ ϛ	κ κβ	πϛ νβ	σογ η	ιϛ	λη κη	κβ νη
πζ μβ	σοβ ιη	ιζ	λγ ζ	κβ ο	πζ κϛ	σοβ λδ	ιζ	λζ κ	κδ μθ
πη ιβ	σοα μη	ιη	λβ κγ	κγ ιδ	πη ο	σοβ ο	ιη	λϛ λζ	κϛ α
πη μβ	σοα ιη	ιθ	λα να	κδ η	πη λδ	σοα κϛ	ιθ	λε νε	κζ ιγ
πθ ιβ	σο μη	κ	λα λβ	κδ μγ	πθ η	σο νβ	κ	λε λδ	κζ μβ
πθ μβ	σο ιη	κα	λα κβ	κε α	πθ μβ	σο ιη	κα	λε κβ	κη ιβ
ϙ ο	σο ο	τέλεια	λα κ	κε δ	ϙ ο	σο ο	τέλεια	λε κ	κη ϛ
ϙ ιη	σξθ μβ	κα	λα κβ	κε α	ϙ ιη	σξθ μβ	κα	λε κβ	κη ιβ
ϙ μη	σξθ ιβ	κ	λα λβ	κδ μγ	ϙ νβ	σξθ η	κ	λε λδ	κζ μβ
ϙα ιη	σξη μβ	ιθ	λα να	κδ η	ϙα κϛ	σξη λδ	ιθ	λε νε	κζ ιγ
ϙα μη	σξη ιβ	ιη	λβ κγ	κγ ιδ	ϙβ ο	σξη ο	ιη	λϛ λζ	κϛ α
ϙβ ιη	σξζ μβ	ιζ	λγ ζ	κβ ο	ϙβ λδ	σξζ κϛ	ιζ	λζ κ	κδ μθ
ϙβ μη	σξζ ιβ	ιϛ	λδ ϛ	κ κβ	ϙγ η	σξϛ νβ	ιϛ	λη κη	κβ νη
ϙγ ιη	σξϛ μβ	ιε	λε λ	ιη ιβ	ϙγ μβ	σξϛ ιη	ιε	μ β	κ λβ
ϙγ μη	σξϛ ιβ	ιδ	λζ κη	ιε κ	ϙδ ιϛ	σξε μδ	ιδ	μβ ιε	ιζ ιζ
ϙδ ιη	σξε μβ	ιγ	μ λε	ια θ	ϙδ ν	σξε ι	ιγ	με μζ	ιβ λδ
ϙδ μη	σξε ιβ	ιβ	ν λα		ϙε κδ	σξδ λϛ	ιβ	νϛ νθ	
ϙε ιη	σξδ μβ	ια	μθ θ		ϙε νη	σξδ β	ια	νε κε	
ϙε μη	σξδ ιβ	ι	μζ λε		ϙϛ λβ	σξγ κη	ι	νγ λθ	
ϙϛ ιη	σξγ μβ	θ	με μη		ϙζ ϛ	σξβ νδ	θ	να μ	
ϙϛ μη	σξγ ιβ	η	μγ ν		ϙζ μ	σξβ κ	η	μθ κε	
ϙζ ιη	σξβ μβ	ζ	μα λδ		ϙη ιδ	σξα μϛ	ζ	μϛ νγ	
ϙζ μη	σξβ ιβ	ϛ	λθ α		ϙη μη	σξα ιβ	ϛ	μγ νθ	
ϙη ιη	σξα μβ	ε	λϛ ϛ		ϙθ κβ	σξ λη	ε	μ μβ	
ϙη μη	σξα ιβ	δ	λβ μβ		ϙθ νϛ	σξ δ	δ	λϛ νγ	
ϙθ ιη	σξ μβ	γ	κη μα		ρ λ	σνθ λ	γ	λβ κ	
ϙθ μη	σξ ιβ	β	κγ μγ		ρα δ	σνη νϛ	β	κϛ με	
ρ ιη	σνθ μβ	α	ιϛ νθ		ρα λη	σνη κβ	α	ιθ θ	
ρ μη	σνθ ιβ	ο	ο ο		ρβ ιβ	σνζ μη	ο	ο ο	

TABLE 2 Computation of the magnitude and duration of lunar eclipses. Excerpted from Ptolemy's *Alm.* 6.8 [Toomer 1998, 307]

Greatest distance					Least distance				
1 Arguments of latitude	2	3 Digits	4 Minutes of immersion	5 Half totality	1 Arguments of latitude	2	3 Digits	4 Minutes of immersion	5 Half totality
79 12	280 48	0	0 0		77 48	282 12	0	0 0	
79 42	280 18	1	16 59		78 22	281 38	1	19 9	
80 12	279 48	2	23 43		78 56	281 4	2	26 45	
80 42	279 18	3	28 41		79 30	280 30	3	32 20	
81 12	278 48	4	32 42		80 4	279 56	4	36 53	
81 42	278 18	5	36 6		80 38	279 22	5	40 42	
82 12	277 48	6	39 1		81 12	278 48	6	43 59	
82 42	277 18	7	41 34		81 46	278 14	7	46 53	
83 12	276 48	8	43 50		82 20	277 40	8	49 25	
83 42	276 18	9	45 48		82 54	277 06	9	51 40	
84 12	275 48	10	47 35		83 28	276 32	10	53 39	
84 42	275 18	11	49 9		84 02	275 58	11	55 25	
85 12	274 48	12	50 31		84 36	275 24	12	56 59	
85 42	274 18	13	40 35	11 9	85 10	274 50	13	45 47	12 34
86 12	273 48	14	37 28	15 20	85 44	274 16	14	42 15	17 17
86 42	273 18	15	35 30	18 12	86 18	273 42	15	40 2	20 32
87 12	272 48	16	34 6	20 22	86 52	273 08	16	38 28	22 58
87 42	272 18	17	33 7	22 00	87 26	272 34	17	37 20	24 49
88 12	271 48	18	32 23	23 14	88 00	272 0	18	36 37	26 1
88 42	271 18	19	31 51	24 8	88 34	271 26	19	35 55	27 13
89 12	270 48	20	31 32	24 43	89 8	270 52	20	35 34	27 52
89 42	270 18	21	31 22	25 1	89 42	270 18	21	35 22	28 12
90 0	270 0	entire	31 20	25 4	90 0	270 0	entire	35 20	28 16
90 18	269 42	21	31 22	25 1	90 18	269 42	21	35 22	28 12
90 48	269 12	20	31 32	24 43	90 52	269 8	20	35 34	27 52
91 18	268 42	19	31 51	24 08	91 26	268 34	19	35 55	27 13
91 48	268 12	18	32 23	23 14	92 0	268 0	18	36 37	26 1

third column gives the digits of obscuration, a linear measure by which the Moon is divided into 12 such digits. The fourth column gives the minutes of immersion or the half-duration of the eclipse and the fifth column the amount of the half-duration of totality or half the time that the Moon spends completely obscured by the shadow in the case of a total eclipse. This last column does not have a value for every entry as not all eclipses have a period of totality. Ptolemy also presents another table [*Alm.* 6.8], which converts this linear measure of obscuration into an actual area, largely, he relates, for astrological purposes. An additional feature that he tabulates is the so-called *prosneusis* (inclination), which is related to the direction of "impact" of the eclipsed body with respect to the eclipsing body at key instants during an eclipse [*Alm.* 6.12–13]. This tradition stems back to Mesopotamian sources. Ptolemy comments that this direction of impact measurement is for astrological purposes as well.

Some time later, Ptolemy collected the tables that he had created in the *Almagest* and compiled them in a single work. The resulting work was called *Canones manuales* (*The Handy Tables*) [Heiberg 1898–1907, vol. 2] as they provided astronomers with a "handy" reference for their astronomical predictions. Many changes have been made in these tables. For one, the epoch of the tables is later. Furthermore, most tables have been simplified with respect to the precision of the data or the number of entries tabulated. Another notable change in the context of eclipses is that lunar and solar parallax have not been tabulated separately but rather have been combined. This shows that Ptolemy may have intended his table of parallaxes to be applicable only for the purpose of computing solar eclipses.

4 After Ptolemy

Major revisions or innovations to this were not proposed for a significant amount of time after Ptolemy. Rather, later authors tended to summarize and synthesize his work, to write technical or expository commentaries, or to make small corrections from contemporary observational data. For instance, Theon of Alexandria (*ca* 335 – *ca* 405 CE) wrote a *Commentarium magnum* (*Great Commentary*) [Tihon 1991] and a *Commentarium parvum* (*Little Commentary*) [Tihon 1978] on Ptolemy's *Canones manuales*, in which he provided instructions on how to use the tables as well as explanations concerning the computations which produced the numbers that fill them. Another author who is important for revealing the scope of eclipse-reckoning in the Greco-Roman Period is Cleomedes (*ca* 200 CE). His work the *Caelestia* [Todd 1990] is a detailed summary of more technical astronomical details, largely, it appears, for teaching purposes. He combines the technical details of Hipparchus (although he seems unaware of Ptolemy's contributions) with the ideas of the Stoic philosopher Posidonius (second century BCE).

Eclipse-reckoning was maintained in other disciplines outside astronomy. One important strand is the so-called omen literature. An examination of this literary genre reveals some of the practical details that practitioners found important to take account of in their determination of the ominous significance of eclipses. For instance, Hephaestio of Thebes (*flor. ca* 415 CE), an author of Late Antiquity, wrote a work on signs titled the *Apotelesmatica*, which contains several sections devoted to eclipse-phenomena. Omens that include eclipse-phenomena in the protases or "if"-clauses concern the color of the eclipsed body, the occurrence of wind, shooting stars, halos, lightening and rain, the direction of impact, the timing and instants of eclipses, as well as their position in the sky. The protases of the omens can be directly traced back to the Mesopotamian tradition, including the large compendium *Enūma Anu Enlil*.[2]

2 It is worth noting too that the Antikythera Mechanism is now regarded as including references to the color and size of the Sun at eclipse: see Antikythera Mechanism Research Project 2016 and ch. 9.2, p. 340.

CHAPTER 4.6

Hellenistic Babylonian Planetary Theory

Mathieu Ossendrijver

1 Introduction

Babylonian mathematical astronomy is preserved in about 450 tablets dating between 380 and 45 BCE, a period covering the late Achaemenid, Seleucid, and early Parthian Eras. All originate from Babylon and Uruk, two main centers of Babylonian scholarship during this period.[1] A wide range of algorithms for predicting planetary, lunar, and solar phenomena are attested in the tablets. A common feature is their use of the zodiacal circle as a coordinate system for computing celestial positions. After the introduction of the zodiacal circle by Babylonian astronomers, probably near 400 BCE, mathematical astronomy developed in a relatively short period of time.[2] Probably some time before the end of the Achaemenid Era (330 BCE) but no later than 320 BCE, even the complex lunar algorithms had been finalized, with only scarce evidence of any subsequent change. [3] Since nearly all tablets were written after that, the genesis of the algorithms is difficult to trace. In this chapter, only a selection of planetary and lunar algorithms in their final stage of development is discussed.[4]

Tabular texts form the bulk of the corpus. They can be divided into synodic tables (230), template tables (50), daily motion tables (30), and auxiliary tables (20). Synodic and daily motion tables are the final products of Babylonian mathematical astronomy. In synodic tables, consecutive rows correspond to successive occurrences of a synodic phenomenon. Template tables represent some intermediate stage in the production of synodic tables. In a daily motion

1 For ancient non-Mesopotamian sources of Babylonian mathematical astronomy, see ch. 4.7, p. 147.

2 On the date of the introduction of the zodiacal circle near 400 BCE, see Britton 2010.

3 The earliest complete synodic table of lunar System A dates to year 5 of Philipp Arrhidaeus (319/318 BCE). Developments in mathematics, medicine, and hermeneutics confirm the overall impression that the Achaemenid Era was a particularly innovative period for Babylonian science, more so than the following Seleucid Era.

4 For the underlying mathematical concepts and systems of measurement, see ch. 3.1, p. 41. For the practitioners and other contextual aspects of mathematical astronomy, see ch. 12.2, p. 472.

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table, the rows correspond to successive days or *tithis* [see Glossary, p. 652]. Some synodic tables are computed with the help of numerical coefficients from auxiliary tables.

About half of all the tables are concerned with the Moon; the other half, with the planets Mercury, Venus, Mars, Jupiter, and Saturn, apart from a few daily motion tables for the Sun. The remaining 110 tablets are procedure-texts with verbal instructions mainly aimed at computing and verifying the tables.[5]

However, some procedure-texts transcend these practical purposes in that they engage with various aspects of the algorithms on a more theoretical level. The Babylonian astronomers were not content with having one single predictive method. For each planet and the Moon, several distinct, more or less coherent "computational systems" are attested, e.g., lunar Systems A and B, Mercury System A_1, and Jupiter System B (see below). They form two main families referred to as type A and type B. Procedure-texts are usually devoted to a single system for the Moon or one planet, although some cover various different systems for several planets.

2 Planetary Algorithms

About half of the texts are devoted to the planets. Apart from synodic phenomena [see ch. 4.1 §3, p. 66], their main topic, several dozens of texts deal with the motion of a planet in between the synodic phenomena at intervals of 1 day or 1 mean *tithi*. A few procedure-texts contain algorithms for a planet's distance to the zodiacal circle but that quantity is not represented in any tabular text. A synodic table comprises up to six pairs of columns, each pair containing successive times (*T*) and zodiacal positions (*B*) of a different synodic phenomenon. Column T mentions the year number, month, and date, the latter expressed in mean *tithis* (0–30). In column B, the position of the planet is expressed as a zodiacal sign and a number of degrees (0–30) measured from the beginning of the sign.[6]

Some synodic tables also include columns for the corresponding differences, the synodic time and the synodic arc. This was probably done in order to store potential initial values for subsequent tables and to make checking the computations easier. After writing down the initial values in row 1, the rest of the table was filled by updating all quantities from one occurrence of the synodic

5 For the procedure-texts, see Ossendrijver 2012.

6 For the Babylonian calendar and the units of time and celestial position, see chs 3.1 §2, p. 42; 3.1 §4, p. 46.

phenomenon to the next. Two complementary methods were used for this. For some phenomena, the coordinates are updated from one occurrence to the next by means of the synodic arc and the synodic time. For others, the coordinates are computed from those of a different, immediately preceding phenomenon by applying "pushes". Planetary positions in the daily motion tables were updated to the next day or mean *tithi* by adding the daily displacement v.

3 Algorithms for the Synodic Arc and the Synodic Time

A central concept of Babylonian mathematical astronomy is the synodic arc (modern symbol: $\Delta\lambda$), the net displacement of the planet, the Moon, or the Sun along the zodiacal circle in between two successive occurrences of the same synodic phenomenon.[7] The corresponding time difference is the synodic time Δt. With these quantities, the coordinates of the phenomenon can be updated as

$$B_i = B_{i-1} + \Delta\lambda \text{ and } T_i = T_{i-1} + \Delta t.$$

Here i is the event-number, which corresponds to the rows of a synodic table. Note that the total distance along the zodiacal circle covered by the planet, the Moon, or the Sun, also referred to as the total synodic arc, may differ from $\Delta\lambda$ by a multiple of 360°. The two most commonly used algorithms for the synodic arc are the zigzag- function, characteristic of type-B Systems, and the step-function, which is unique to type-A Systems. Both can be tuned so as to reflect the periodically varying speeds of the planet and the Sun in their apparent motion around the Earth.

The modern term "zigzag-function" denotes an algorithm whereby a quantity varies periodically between a minimum and a maximum with a constant difference. In the Babylonian texts, this algorithm is formulated in terms of arithmetical operations without any graphical connotation, as illustrated by the following procedure for Jupiter System B:[8]

> Positions: for setting [LA], appearance [FA], station [S_1], rising [AR], and second station [S_2] you add and subtract 1;48 until 38;2, the largest value. That which exceeds 38;2 you deduct from 1,16;4 and put down. (Simi-

7 Note that in Ossendrijver 2012, the synodic arc is represented as σ, the synodic time as τ.

8 Ossendrijver 2012, no. 37. The tablet probably originates from Seleucid Babylon. For the template underlying this procedure, see Ossendrijver 2012, 43 (ZZ.B.1).

larly) until 28;15,30, the smallest value. That which is less than 28;15,30 you deduct from 56;31 and put down.

As is often the case, the meaning of the instructions may not be immediately obvious without consulting the corresponding synodic tables.[9] The zigzag-function for $\Delta\lambda$ is updated by adding or subtracting a difference, $d = 1;48°$, depending on whether $\Delta\lambda$ is increasing or decreasing, i.e., $\Delta\lambda_i = \Delta\lambda_{i-1} \pm d$. The updated value is final if it is between $m = 28;15,30°$ and $M = 38;2°$, the extrema of the zigzag-function. If it turns out to be greater than M or less than m, the result is modified. In the former case $\Delta\lambda_i$ is replaced by $2M - \Delta\lambda_i$, i.e., $\Delta\lambda_i - M$, the excess above M, is subtracted from M. In the latter case, it is replaced by $2m - \Delta\lambda_i$, i.e., $m - \Delta\lambda_i$, the excess below m, is added to m. The tables imply that this also triggers a reversal of the additive or subtractive sense of d. Having updated the synodic arc, the position of the planet is updated as $B_i = B_{i-1} + \Delta\lambda_i$ but this is not explicitly mentioned in the example.

Some properties of the zigzag-function accurately reflect the observable behavior of the planet. This is usually true for the mean synodic arc, $\mu = (m + M)/2$, which equals 33;8,45° for Jupiter System B, close to the empirical value 33;7°. Furthermore, the parameters $\Delta = M - m$, the amplitude of the zigzag-function, and d define a period-relation $\Pi \cdot d = Z \cdot 2\Delta$. Here Π is the whole number of events after which the zigzag-function returns to the same value for the first time and Z is the corresponding whole number of zigzag oscillations. For Jupiter System B, we obtain $\Pi = 391$ and $Z = 36$. A less obvious but very important feature is that Π and Z also characterize the positions of the planet. This is because μ is always tuned in such a way that the relation $\Pi \cdot \mu = Z \cdot 360$ is also exactly or nearly satisfied. Therefore, Π (mean) synodic arcs amount to Z full revolutions of the synodic phenomenon.

Both Π and Z, called turn in Babylonian, are frequently mentioned in the procedure-texts. Also mentioned is the corresponding number of revolutions of the Sun, i.e., the number of years, Y. For Jupiter, Y is obtained as $Y = \Pi + Z$, which equals 427 years for System B.[10] This period-relation,

Π repetitions of the synodic phenomenon = Z revolutions = Y years,

9 Neugebauer 1955, Texts 620; 620a + Steele 2010, Text M; 620b; 621; 622; 622a + Steele 2010, Text N; 623–629.

10 The relation between Y, Π, and Z is not the same for each planet: see Neugebauer 1975, 388–390 or Ossendrijver 2012, 60.

belongs to the empirical core of any planetary system. In modern textbooks, the Babylonian algorithms are often characterized in terms of $P = \Pi/Z$, which equals 10;51,40 for Jupiter System B. This period represents the number of synodic events corresponding to one oscillation of the zigzag-function or, equivalently, one revolution of the synodic phenomenon. However, P is in general not a terminating sexagesimal number and it is only rarely mentioned in the Babylonian texts.

The main alternative algorithm for the synodic arc is the step-function, which involves a division of the zodiacal circle into a number of "zones" ranging from two (e.g., Moon System A) to six (Mars System A). In each zone, the synodic arc assumes a constant value, at least initially. The following example illustrates the formulation of this algorithm in a procedure for updating the position of Mercury's MF according to System A_1:[11]

> Procedure for these appearances. Eastern appearance (MF) to eastern appearance.
>
> From 1 Leo until 16 Cap you add 1,46. (The amount) by which it exceeds 16 Cap you multiply by 1;20.
>
> From 16 Cap until 30 Tau you add 2,21;20. (The amount) by which it exceeds 30 Tau you multiply by 0;40.
>
> From 30 Tau until 1 Leo you add 1,34;13,20. (The amount) by which it exceeds 1 Leo you multiply by 1;7,30.

In other words, if MF of Mercury occurs between 1° Leo and 16° Cap, in the first of three zones, then $\Delta\lambda = 106°$. If, however, the position thus updated lies beyond 16° Cap, in zone 2, the excess of $\Delta\lambda$ beyond 16° Cap is multiplied by 1;20, the so-called transition coefficient (r). In zones 2 and 3, the algorithm proceeds analogously. As a result, the synodic arc deviates from the initially assumed constant values in certain transition regions adjacent to the zonal boundaries. This interpretation is confirmed by the positions of MF in a synodic table [Neugebauer 1955, no. 301] preceding the procedure on the same tablet. As with the zigzag-function, the positions satisfy a period-relation involving Π, Z, and Y. In particular, it can be shown that if α_j denotes the length of zone j, i.e., $\alpha_1 = 165°$ (that is, from 1° Leo to 16° Cap), and similarly $\alpha_2 = 134°$ and $\alpha_3 = 61°$, then Π and Z are defined by the expression $\Pi/Z = \Sigma_j \alpha_j/\Delta\lambda_j$ [Neugebauer 1975, 377; Ossendrijver 2012, 51].

11 Ossendrijver 2012, Text 1, P1.a. The tablet originates from Babylon and was written near 177 BCE. For the template underlying this procedure, see Ossendrijver 2012, 48 (STEP.A.1).

In the present case, Mercury returns to the same position after $\Pi = 2673$ occurrences of MF, during which it performs exactly $Z = 848$ revolutions around the zodiacal circle, as does the Sun ($Y = Z = 848$). As it turns out, the transition coefficients of a step-function always equal $r_j = \Delta\lambda_{j+1}/\Delta\lambda_j$, the ratio of the synodic arcs in the involved zones. It can be shown that this subtle feature is essential for ensuring that the positions strictly satisfy the mentioned period-relation.

The same tablet also preserves this instruction for updating the times of Mercury's MF:

> The distance from appearance to appearance you compute, 3;30,39 you add to it and you add it to the "day" of appearance.

The synodic tables confirm that the synodic time, Δt, is computed from the synodic arc ("the distance from appearance to appearance") by adding 3;30,39, i.e., $\Delta t = \Delta\lambda + 3;30,39$ mean *tithis*. After that, the time ("day") of MF is updated as $T_i = T_{i-1} + \Delta t$. The same approach but with different constants C, i.e., $\Delta t = \Delta\lambda + C$, underlies nearly all planetary systems. As usual, no justification is given for this algorithm; but van der Waerden has identified the assumptions from which it was derived.[12] Note that the values of T in a planetary table are nearly always rounded, whereas the zodiacal positions in column B are usually given to full precision.

4 Pushes and Subdivision of the Synodic Cycle

Numerous procedure-texts are concerned with the intervals in time and position between different phenomena within the synodic cycle, commonly referred to by the modern term "pushes". One important application of the pushes occurs in planetary systems where certain phenomena, say Ph_2, are treated as satellites of other phenomena, say Ph_1. With the help of pushes, say δB and δT,[13] the coordinates of a satellite phenomenon can be computed from those of the preceding parent phenomenon:

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12 First, the so-called Solar-Distance Principle, which implies that the Sun travels the same net distance along the zodiacal circle as the planet between two synodic phenomena; second, the Sun moves at its mean velocity [Van der Waerden 1974].

13 In Ossendrijver 2012, the pushes are denoted by "$\delta\Sigma$" and "$\delta\tau$".

$$B(\mathrm{Ph}_2) = B(\mathrm{Ph}_1) + \delta B,$$
$$T(\mathrm{Ph}_2) = T(\mathrm{Ph}_1) + \delta T.$$

Since Ph_1 precedes Ph_2, δT is additive; but δB can be additive or subtractive, depending on whether the planet moves forward or backward along the zodiacal circle. As an example, consider again System A_1 of Mercury, which treats ML and EL as satellites of MF and EF, respectively. To that purpose, the procedures on the tablet mentioned earlier list values of δB and δT from MF to ML, and similarly from EF to EL [Ossendrijver 2012, Text 1, P1.e–h]. For each push, 12 values, one for every zodiacal sign, are provided. The coordinates of ML and EL in the synodic table also written on the mentioned tablet confirm that it was the position of the parent phenomenon, MF or EF, that determined which value was picked. In Jupiter System A and some other systems, the coordinates of all synodic phenomena are updated with the synodic arc and the synodic time. Hence, there would appear to be no need for procedures concerning pushes in these systems; nevertheless, quite a few deal with this topic. They were probably used for constructing initial values for the synodic tables, many of which cover different phenomena. For instance, in order to compute a table with FA, S_1, AR, S_2, and LA for Jupiter System A, only initial values for the coordinates of FA were needed, while those for the other phenomena could be derived with the help of pushes. After writing down these initial values in row 1, each column could be individually updated with the algorithm for the synodic time or the synodic arc.

Many of the procedures for the subdivision of the synodic cycle provide or imply values for the planet's "daily" displacement along the zodiacal circle, v. This quantity was used for computing daily motion tables. Usually v is assumed to be constant within each push, but some procedures and daily motion tables contain algorithms whereby v changes linearly or even quadratically from mean *tithi* to mean *tithi*. In these tables, the zodiacal positions have a quadratic or cubic dependence on time [Huber 1957; Neugebauer 1975, 413–418; Ossendrijver 2012, 63–68].

However, for numerous procedures concerning the subdivision of the synodic cycle, no corresponding tabular texts have been discovered and it is not always clear how they are connected to the known planetary systems. Conversely, for certain planetary systems, the subdivision of the synodic cycle is accessible only through the tabular texts.

5 Lunar Algorithms

The main concern of the lunar texts is to predict New Moon (when the Moon and Sun are in conjunction), Full Moon (when they are in opposition), and several associated phenomena, namely, eclipse-magnitude and the Lunar Six intervals. The last are time-intervals between the rising or setting of the Moon and the rising or setting of the Sun around New Moon or Full Moon [ch. 5.2]. Beyond that, daily motion tables and some procedure-texts deal with the Moon's position or other lunar quantities at intervals of 1 day or 1 *tithi*. Synodic tables, numbering about 150, form the largest class of lunar texts, followed by template tables (40), daily motion tables (12), and auxiliary tables (10). Some 50 lunar procedure-texts contain instructions for updating or verifying the tables or other computations. A typical synodic table contains predictions for 1 calendar-year, with the New Moon data written on the obverse and the Full Moon data on the reverse. All data in one row pertain to the same lunation. Aside from their content, these tables are unusual due to their highly elongated format, which accommodates up to 20 columns. Each column contains successive values of a different lunar quantity. Even more so than the planetary tables, the lunar tables must be viewed as tabular representations of algorithms. That is, they not only store "final" quantities (eclipse-magnitude and Lunar Six intervals) but also numerous auxiliary quantities needed for computing them. Nearly all lunar texts belong to Systems A and B, with few exceptions.[14] They exhibit many of the same concepts and elementary algorithms known from the planetary systems but their cumulative complexity is far greater. Since it is impossible to describe either system in the available space, only a few important features are addressed here, with a focus on System A.[15]

Lunations, that is, the lunar months, are determined by the motion of the Moon and the Sun. Hence, the lunar functions reflect periodic variations originating from both bodies. An innovative aspect of the Babylonian algorithms is that irregularly varying quantities are construed as the sum of elementary periodic contributions. The three periodic contributions that were acknowledged are, in modern terms, the zodiacal (or solar) variation, the lunar variation, and the nodal motion. The former concerns quantities that exactly repeat when the Sun and Moon return to the same zodiacal position to produce a new lunation. The period of this return is always close to 12;22,8 synodic months,

14 A third lunar System, dubbed K, underlies one early Seleucid procedure-text [Ossendrijver 2012, Text 52]. System K is concerned with the same phenomena as lunar Systems A and B but appears to reflect an earlier stage of development.

15 For more details and for System B, see Neugebauer 1955, 1975; Ossendrijver 2012.

a good approximation of the year. The lunar variation concerns quantities that vary in the same manner as the lunar velocity. Its characteristic period is the anomalistic month of about 27;33,16 days. Because the lunar orbit is not fixed with respect to the stars, functions controlled by the lunar variation do not repeat when the Moon returns to the same position in the zodiacal circle. Since this rules out the step-function, they were modeled as zigzag-functions of the lunation-number. Finally, the nodal motion denotes the slow retrograde rotation of the lunar orbit along the zodiacal circle, which completes one revolution in 18.6 years. This component is embedded in the algorithms for the Moon's distance to the zodiacal circle and the eclipse-magnitude.

The zodiacal position of the Moon (column *B*) is updated from one lunation to the next by adding the synodic arc. Each lunar position thus computed also implies a solar position: at New Moon they coincide and at Full Moon they are diametrically opposite. Hence, the synodic arc is the common net displacement of the Moon and the Sun. But note that the Moon carries out one additional full revolution each synodic month. The same methods known from the planetary systems, i.e., step-functions and zigzag-functions, are used for modeling the synodic arc in lunar Systems A and B, respectively. They also incorporate algorithms for the synodic month with which the time of the lunation (*M*) is updated. The latter is expressed in time-degrees with respect to the preceding or following sunset or sunrise. The synodic month varies rather irregularly around a mean value of 29;31,50 days. In Systems A and B, it is construed as the sum of two periodic terms reflecting the lunar variation (*G*) and the zodiacal variation (*J*). Both Systems include an interpolation algorithm whereby the duration of daylight (*C*) is computed from *B*. Embedded in each algorithm is a different convention for the vernal equinox. In System A, it occurs when the Sun is in 10° Ari, as opposed to 8° Ari in System B.[16] The significance of these conventions is unclear. If the Moon is sufficiently close to the zodiacal circle, a solar eclipse may occur at New Moon, a lunar eclipse at Full Moon. In order to predict eclipses, Systems A and B incorporate algorithms for the Moon's distance to the zodiacal circle (function *E* in System A) or a related eclipse-measure (Ψ′, Ψ″, etc.). Eclipses were considered possible if these quantities are within a certain range of values. However, the largest computational effort was reserved for the Lunar Six algorithms, one of the most impressive achievements of Babylonian astronomy [see §6, p. 144; 5.1 §2, p. 172].

16 In lunar System K, the vernal equinox is probably anchored to 12° Ari.

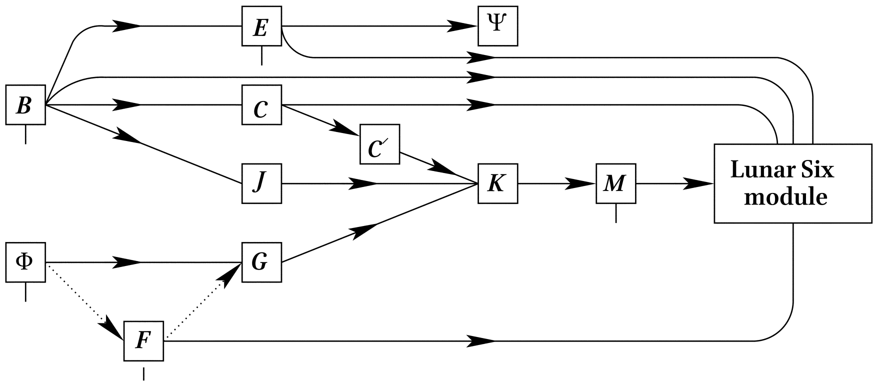

FIGURE 1 Flow chart for updating a synodic table for lunar System A
A vertical dash below the box indicates that the function must be initialized.
OSSENDRIJVER 2012, 123

6 Some Elements of Lunar System A

The sequence of operations necessary for updating a synodic table for lunar System A can be represented in a flow-chart [Figure 1, p. 144]. Lunar System A is considered to be more ingenious and mathematically coherent than System B. This ingenuity is particularly apparent in columns Φ and *G* and in the Lunar Six module. The values in column Φ form a straightforward zigzag-function of the lunation-number (i). However, the astronomical interpretation of Φ_i is surprisingly complex: it is the amount, expressed in time-degrees, by which the varying duration of the 223-month interval between lunations i and $i + 223$ exceeds 6585 days. The interval of 223 months, also known as the Saros, is a keystone of the Goal-Year method for predicting eclipses and Lunar Six intervals [see ch. 5.1 §2, p. 172]. However, in System A, the only role of Φ is to serve as a source-function for *G*, the duration of the synodic month. In other words, the varying duration of 1 month is computed from that of 223 months—a remarkable approach whose origin has not been fully explained.

Note that Φ is probably one of the oldest components of lunar System A and that there is no analogue of Φ in System B, where *G* is computed as a self-contained zigzag-function. The interpretation of Φ is complicated further because its period, P =13;56,39,…synodic months, is that of the lunar variation, i.e., Φ models only the lunar contribution to the varying duration of the Saros. However, the period of the empirical variations of the Saros is dominated by the solar variation. The difficult problem of how the Babylonian astronomers succeeded in extracting the lunar contribution to the Saros is a matter of ongoing investigations [see ch. 5.1 §4, p. 176]. In any case, the period of Φ carries over to *G*, which is, therefore, the lunar contribution to the varying synodic month. As mentioned, a second periodic contribution to the synodic month resulting from the solar variation is modeled by *J*, which is computed from *B*. By the same token, all other quantities computed from Φ or *B* [Figure 1] inherit their respective periodic behavior. Only the nodal motion, which is embedded in *E*, is not represented by its own column in the synodic tables. In lunar System B, analogous but different constructions are employed for modeling the same periodic contributions.

Some of the functions up to *M* serve as input for the so-called Lunar Six module, of which there is one version for the New Moon intervals (KUR, NA_1) and another one for the Full Moon intervals (SU_2, NA, ME, GI_6). Each of the 13 sub-algorithms into which the module may be subdivided are described in the procedure-texts [Ossendrijver 2012] but most of them are not represented by a column in the synodic tables. The module entails a rigorous and fully consistent analysis of the Lunar Six intervals in terms of the different astronomical and geometrical effects that control their variations. Lunar System B incorporates its own version of the Lunar Six module, which has not been fully reconstructed but is known to differ in some details.

7 Purpose and Applications

The purpose and applications of mathematical astronomy can only be addressed by considering the wider context of Babylonian astral science, which witnessed fundamental changes between 750 and 400 BCE. Mathematical astronomy shares the core of its subject matter—synodic planetary phenomena, eclipses, and Lunar Six intervals—with the far more numerous astronomical Diaries and related texts, which are attested from the seventh century BCE onward. By 600 BCE, Goal-Year type methods existed for predicting most of these phenomena [see ch. 5.1 §4, p. 176]. They operate by projecting past phenomena recorded in the Diaries onto a future date using the appropriate period. Note: the Goal-Year method was never abandoned but continued in use after 400 BCE. Putting aside the daily motion tables, mathematical astronomy must, therefore, be viewed, by and large, as an alternative tool for predicting exactly the same phenomena using the Goal-Year method.

This raises two questions:

(1) Why were these phenomena predicted in the first place? and,

(2) What motivated the development of mathematical astronomy as an alternative?

Fully satisfactory answers to these questions cannot be given yet. With regard to the first question, note that eclipses continued to be viewed as ominous phenomena of concern to rulers. The Lunar Six interval NA_1 was important for calendrical purposes since it determines when the new lunar crescent will be visible, which defines the beginning of the Babylonian month. The reason for predicting some of the other Lunar Six intervals and the synodic phenomena of the planets is less obvious since they play no role in the calendar and are rarely mentioned in celestial omen-texts. However, innovative astrological texts from the Achaemenid and Seleucid Eras and the Diaries themselves imply that the Babylonian understanding of how astronomical and terrestrial phenomena are correlated had evolved with respect to traditional omen divination. Instead of the old notion that celestial phenomena in the present signify the will of a god to affect future events on Earth, Babylonian astrology now appears to proceed from the assumption that future events on Earth are more or less mechanically correlated with the celestial phenomena predicted for that date. In particular, astrological procedure-texts contain detailed rules for predicting weather-phenomena and market prices on the basis of the synodic phenomena of the planets [see ch. 12.2 §1, p. 472]. This could explain not only why weather-phenomena, market prices, and other terrestrial data were reported in the astronomical Diaries but, arguably, also why so much effort was put into reporting and predicting the synodic phenomena of the planets.

With regard to the second question, it may be relevant that mathematical astronomy has a significant practical advantage in that it yields arbitrary long sequences of predictions setting out from a few initial values, as opposed to the Goal-Year method, which requires for every single prediction a reported observation of the same phenomenon. Finally, various forms of zodiacal astrology also emerged near 400 BCE. Babylonian horoscopes contain positions of the planets, the Moon, and the Sun for the date of birth of a child. The daily motion tables are the likely source of these data.

CHAPTER 4.7

The Babylonian Contribution to Greco-Roman Astronomy

Francesca Rochberg

1 Introduction

Babylonian astronomy had enormous cultural capital throughout the ancient Near East since the second millennium BCE. Scholarly texts in the form of celestial omens and the astronomical knowledge associated with them were widely disseminated to other ancient cultures, both near and far. In this early period (*ca* 1500 BCE), the Hittites imported celestial divinatory texts in Akkadian, translating them into Hittite and copying the Akkadian originals for their own archives [Koch-Westenholz 1993; Rutz 2016]. *Enūma Anu Enlil* [see ch. 12.2 §3.1, p. 479] was also imported by the Elamites to the east of Babylonia [Rochberg-Halton 1988a, 31–35; Farber 1993]. The circulation of knowledge of the heavens within the worlds of the Near East and Mediterranean during the Hellenistic Period, therefore, rested on a long-established tradition. Intellectual communities from the Mediterranean to the Indus Valley participated in this circulation and adaptation of Babylonian astronomy. As a consequence of the Hellenistic transmission, preservation of Babylonian astronomy is discernible in Arabic science (through Sanskrit as well as Greek and Middle Persian sources) and in Medieval European science (through Greek, Latin, and Arabic sources), reflecting in turn the extent and longevity of the cultural and intellectual capital of Hellenistic astronomy in its various forms. Whereas the Indian reception occurred as early as the mid-second century CE, the impact of the Sanskrit tradition upon Arabic astronomy began in the eighth century of our era, by which time Indian astronomy represented a hybrid of Babylonian and Greek traditions. In addition to the Babylonian contribution to Arabic science *via* India, Ptolemy's *Almagest* was another significant vehicle for the transmission of Babylonian astronomy to the Islamic world and all the places where his treatise was known.

"Transmission", a term that tends to connote a one-way delivery-process and generally conjures a picture of a transmitting and a receiving entity in actual contact, is inadequate to our historiographical program. Neither can, as A. I. Sabra also argued [1987, 225], "reception" be the terminological antidote. Sabra

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has also cautioned against conceiving of the receiving culture as a necessarily passive recipient of knowledge. Clearly, there were various reasons for the movement of knowledge within and around the ancient Near East as well as the Eastern and Western Mediterranean areas. In the early period of the circulation of Babylonian cuneiform scholarship, the practice of writing in cuneiform, and the fact that Akkadian became the international *lingua franca* for the ancient Near East during the Late Bronze Age explain in part why divination and knowledge of the heavens came to scribal centers outside Mesopotamia proper. In the Hellenistic Period, the Seleucid Empire encompassed an even broader cultural and political scope, where Greek and, later, Roman *literati* learned and adapted what was useful to them from the ancient cultures of the East, i.e., Babylonia (Chaldea), Egypt, and Persia.

Surely one of the most prominent bodies of knowledge that came to the attention of Greek intellectuals was that of Babylonian astronomy. Babylonian astronomical units (the sexagesimal system, the measure of time and arc, units of length and magnitude in cubits and fingers, *tithis* [see Glossary, p. 652], and zodiacal coordinates), parameters (such as period-relations for lunar, solar, and planetary phenomena, and values for the length of daylight), observations (derived from the Babylonian astronomical Diaries), and arithmetic methods (Systems A and B of Babylonian mathematical astronomy and methods for computing the rising-times of the zodiacal signs) were incorporated into later Greco-Roman astronomy.

The use of late Babylonian methods of astronomical calculation, as well as the parameters at the basis of these calculations, is manifest in the transformation of the qualitative kinematic models of early Greek astronomy into the theoretical and predictive science of Greek astronomy of the second century BCE and later. Some speculate that a key role in this transformation is attributable to Hipparchus (*flor*. second century BCE) [e.g., Toomer 1988], who somehow had access to Babylonian materials, perhaps in the form of a translated digest of records. The specifics of the second-century transmission from Babylonia to Greece, however, remain unknown. Nevertheless, a brief accounting of some of the evidence for the Babylonian contribution to Greek planetary astronomy that focuses on astronomical units, observations, parameters, period-relations, and arithmetic methods can be outlined here.[1]

1 Further details are available in the works of Neugebauer [1975], Pingree [1997, 1998], Toomer [1988], and, especially, Jones [1983, 1990a, 1990c, 1991a, 1991b, 1993, 1996, 1997, 1999a, 2002, 2004c, 2015].

2 Astronomical Units

Astronomical phenomena in Greek astronomy were calculated from the third century BCE onward by Erathosthenes, Aristarchus, Hipparchus, and Hypsicles [Neugebauer 1975, 590–591], and were carried out in the Babylonian sexagesimal (base 60) system, the origins of which may be traced to Sumerian administrative bookkeeping in the early third millennium Temple of Eanna in Uruk.

Eventually, units of measure for time and arc in the Babylonian system resulted in the division of the circle into 360°, a division deriving from the fact that the Babylonian day was counted as a total of 12 DANNA (Akkadian *bēru*) units, each subdivided into 30 UŠ («UŠ» has no known Akkadian reading). For, given that the day is the equivalent of one rotation of the heavens from sunrise to sunrise (or from sunset to sunset), the circle was thereby divided into 360 UŠ units or *degrees*. This convention, along with the use of sexagesimal notation, is attested in Greek astronomy by the mid-second century BCE, in the time of Hipparchus [Toomer 1988, 353–362] and Hypsicles [De Falco and Krause 1966; Neugebauer 1975, 590].

The cubit (KÙŠ = *ammatu*, πῆχυς), with its subdivision the finger or digit (ŠU.SI = *ubānu*, δάκτυλος), was a unit of length in Babylonian metrology with an astronomical application for measuring angular distances in the heavens between, e.g., fixed stars and the meridian[2] or between planets and zodiacal stars, and also for measuring eclipse-magnitude. The equivalence

$$1 \text{ cubit} = 24 \text{ fingers} = 2^\circ$$

was used in Babylonian mathematical and non-mathematical astronomy [Steele 2003, 283–286; 2007b, 297]. In the second part of his commentary *In Arat.*, Hipparchus used the digit for distances between fixed stars and the meridian [Neugebauer 1975, 592]. The digit and the cubit are also used in the reports of third-century observations recorded in the *Almagest*, e.g., from years 245 and 237 BCE,[3] where Ptolemy cites Hipparchus' observations of fixed stars using the digit. *Alm.* 9.7 [Toomer 1998, 541] gives a Babylonian observation of the distance in digits of Saturn from a Normal Star [see Glossary, p. 650] in the evening (from 229/228 BCE) with dates given in Babylonian lunar months (translated into Macedonian month names) and Seleucid Era years (counted from 311 BCE). *Alm.* 4.6, 9, 11; 5.14; and 6.9 [Toomer 1998, 191–192, 206, 208,

2 The meridian is the great circle that passes through the north and south celestial poles and the observer's zenith.

3 See *Alm.* 5.7.1 with Toomer 1998, 322–323 and n5; and 9.7 with Toomer 1998, 452–453 and n70.

211–213, 253, 309] cite Babylonian eclipse-reports, giving the time of the onset of the eclipse, a statement of the time of totality, time of mid-eclipse, and direction and magnitude of greatest obscuration in digits, all in the manner of earlier cuneiform eclipse-reports.[4] These observational reports attest to Greek awareness of the Babylonian astronomical Diaries and related observational and predictive texts[5] or of translated digests of the Diaries and their derivatives. The Babylonian cubit is also used in Strabo, *Geog.* 2.1.18.

The lunar day or *tithi*—the cuneiform texts use the term "day" («UD»/«ūmu»)—the equivalent of 1⁄30 (a *tithi*) of a mean synodic month, is fundamental to Babylonian mathematical astronomy. The difference-sequences between dates of the ephemerides are computed in *tithis* (τ) because the division of one mean synodic month into 30τ serves better when computing than do civil days, since the number of days in any given true lunar month varied month by month. For planetary phenomena, *tithis* substituted well enough for calendar dates and enabled the coordination between progress in longitude (number of degrees between consecutive phenomena) and time (number of *tithis* between consecutive phenomena).[6]

Cuneiform texts of the late fifth century BCE attest to the standardization of the zodiac as a band or belt in the heavens consisting of 12 parts of 30° each in width. The motion of the Sun and planets was then reckoned by means of such degrees of celestial longitude. Greek reception of the Babylonian zodiac before the Hellenistic Period is uncertain but Autolycus' *De sphaera* and *De ortibus* and Euclid's *Phenomena* already assume both the zodiacal circle and the zodiacal band. The earliest unequivocal Greek evidence for the use of the division of the zodiacal circle into 360° is found in Hypsicles' *Anaphoricus* in the second century BCE [De Falco and Krause 1966, 47; Neugebauer 1975, 590]. Somewhat later than Hipparchus, or around 100 BCE, this division is also found in the stone inscription known as the Keskintos inscription [Jones 2006a, 108; 2006b].

Pliny's claim [*Nat. hist.* 2.31] that a certain Cleostratus was responsible for introducing the concept of the zodiacal circle to the Greeks around 500 BCE is suspect, given the date of the introduction of the 12 zodiacal signs in Mesopotamia a century later. Neugebauer [1975, 596] doubted the introduction of the degrees already in the fifth century (Meton) or the fourth century (Eudoxus), as

4 See Pinches and Strassmaier 1955, 1413–1430 (lunar eclipse-reports); 1458–1476 (solar eclipse-reports): for texts, see Huber and de Meis 2004.

5 For discussion, see ch. 5.1, p. 171: for texts, see Sachs and Hunger 1988–1996; Hunger 2001–2012, vols. 5–6.

6 Later, Indian astronomy applied the unit to 1⁄30 of the true lunar months, thereby reintroducing the complex variation in month length precluded by the Babylonian *tithi*.

might be implied by the claim made by Columella (first century CE) that Meton and Eudoxus normed the zodiacal circle at 8° Aries, which was the Babylonian System B norming point for the vernal equinox. Neugebauer dismissed these claims as a later attempt to lend weight to the tradition of the Roman calendar makers. Indeed, the Babylonian System B norm came to be widespread in the Greco-Roman literature and continued into the Middle Ages in some well-known compendia by Isidore of Seville, Martianus Capella, Johannes Scotus Eriugena, and others less well known, the latest being a computus from 1400 [Neugebauer 1975, 596–597].

The assimilation of the Babylonian zodiacal coordinate system is also reflected in the astrological devices of the Egyptian decans and Indian *nakshatras*. Greek and Demotic documents attest to the use of the zodiacal signs and degrees beginning in the second century BCE.

There has been some discussion about the extent to which the Babylonians used zodiacal coordinates of longitude and latitude. John Steele has argued that they did not [2007b, 320]. In reference to celestial longitude, he explains that "for the planets there is nothing in the mathematical astronomical theories which necessitates a link between the centre of the paths [of each planet through the zodiacal signs] and the sun" [2007b, 318]. The conception of celestial latitude, therefore, also differs from Babylonian to Greek astronomy. Steele suggests that just as each planet (Sun, Moon, Saturn, Jupiter, Mars, Venus, Mercury) had its own path through the zodiacal band, they also had their individual maximal heights and minimal depths from a middle of this band, on the order of what we now call latitude. This has profound implications for how the Babylonians imagined the frame of reference for celestial phenomena [Britton 2010: see ch. 1 §4, p. 16].

3 Observations

From Late Antiquity come stories of an alleged fourth-century transmission of Babylonian observational data to the Greeks. Simplicius (sixth century CE), for one, tells of the historian and contemporary of Alexander the Great, Callisthenes, bringing observations to the Greeks following the Alexandrian conquest of the Near East. In his commentary on Aristotle's *De caelo*, Simplicius also claimed that Porphyry reported on Babylonian astronomical observations preserved for 31,000 years [Bowen 2013a, 169, 295]. Aristotle [*De caelo* 291b34–292a9] said the Egyptians and Babylonians "made observations from a very great number of years" and had provided "many reliable data for belief about each of the planets". In the first century BCE, in his *Bibliotheca histor-*

ica [2.31.9], Diodorus of Sicily assigned a value to this "great number of years", saying (in the translation of Oldfather 1933):

> As to the number of years which, according to their statements, the order of the Chaldeans has spent on the study of the bodies of the universe, a man can scarcely believe them; for they reckon that, down to Alexander's crossing over into Asia, it has been four hundred and seventy-three thousand years since they began in early times to make their observations of the stars.

Roughly a century later, Pliny [*Nat. hist.* 7.193] invoked Epigenes as an authority on the antiquity of Babylonian astronomical observations, saying that they went back 720,000 years. Pliny also claimed that Critodemus, a name associated with Greek horoscopes of the first and second centuries CE, had direct access to Babylonian sources. In book 7 of the *Nat. hist.*, Pliny mistakenly placed him in the third century BCE on the assumption that he was a student of Berossus, the Hellenistic writer of the *Babyloniaca*, who was (rightly or wrongly) associated with astrology and with a school on the Island of Cos [Geller 2014a]. Pliny's claim was that Critodemus agreed with Berossus that Babylonian astronomical observations went back 490,000 years. The material, if however obliquely referred to in these Greek attributions to the Babylonians, was no doubt the Diaries archive of nightly lunar and planetary positions compiled in Babylon from 747 BCE until the mid-first century BCE. What is significant about these references is that the Greeks of the Hellenistic Period found the idea of keeping many centuries of records of celestial observations to be new and important.

Observations of lunar eclipses in the *Almagest* "from those observed in Babylon" are found in *Alm.* 4.6 [Toomer 1998, 191, 211–213], namely, eclipses of 19/20 Mar 721 BCE, 8/9 Mar 720 BCE, and 1/2 Sep 720 BCE. These eclipses are dated to regnal years of King Mardokempad (Marduk-apla-iddina) but in months of the Egyptian calendar. The contents of the eclipse-reports, just as in Babylonian eclipse-reports, concern the time when the eclipse begins, the time of greatest obscuration, and the magnitude of the eclipse (given in digits or in terms of the lunar disk, as in "more than half"). More eclipse-reports are given in *Alm.* 5.14 from 621 and 523 BCE [Toomer 1998, 253], dated in regnal years of Nabopolassar and Cambyses, respectively, and Egyptian calendar-months. The reason for these reports is given in *Alm.* 4.2, where it is explained that Hipparchus aimed to establish a lunar theory that would account for "the mean motions of the moon in longitude, anomaly and latitude" [Toomer 1980, 100]. From eclipses observed by Babylonian astronomers and those observed in his own time, Hipparchus derived an eclipse-cycle of 126,007 days (+1 equinoctial hour), using pairs of eclipses to confirm his period.

For the earliest of dated observations made by a Greek astronomer, one finds those ascribed to the astronomer Timocharis of Alexandria (early third century BCE) in *Alm.* 7.3 [Toomer 1998, 334–335], which include three lunar occultations and a Venus observation [Goldstein and Bowen 1989].

4 Parameters and Period-Relations

Part of the Babylonian legacy to Hellenistic astronomy is found in astronomical parameters and period-relations. The earliest example of a period-relation is the Babylonian lunisolar period 19 years = 235 synodic months.[7] This relation was employed for the Babylonian calendar from at least *ca* 500 BCE, somewhat earlier than the date associated with Meton of Athens (432 BCE) [Bowen and Goldstein 1988]. The earliest use of the 19-year cycle can be traced to a text of the early seventh century BCE from Uruk that gives dates of solstices from the reign of Nabopolassar in 625 BCE to the reign of Cyrus in 530 BCE [Britton 2007b, 93]. The length of the solar year that derives from the 19-year cycle is 1 year = 12;22,6,20 months [Neugebauer 1975, 355, 358, 365]. A modification of this parameter for the length of the solar year (12;22,8 months) underpins calculations for the planets and the Moon in Babylonian mathematical astronomical texts.[8]

Kugler [1900, 23–24] was the first to recognize that underlying the eclipse-cycle attributed to Hipparchus (4267 synodic months = 4573 anomalistic months = 126,007 days) is the Babylonian value for the mean synodic month of System B (29;31,50,8,20 days) [Aaboe 1955; Toomer 1980, 98–99]. He also identified the reduction of Hipparchus' relation to 251 synodic months = 269 anomalistic months as the period-relation at the basis of System B's columns F (lunar progress in degrees of longitude) and G (first approximation of the variable length of the synodic month assuming constant solar progress of 30° per month). Hipparchus' use of these lunar parameters as well as the period-relation for the Moon's motion in latitude (5458 synodic months = 5923 draconitic months) further implies Greek knowledge of the canonical System A Babylonian relation: 1 year = 12;22,8 synodic months [Neugebauer 1975, 311, 365,

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7 In Greek literature, this cycle, known as the Metonic Cycle, is 19 years = 235 months = 6940 days [Bowen and Goldstein 1988, 42–44]. See chs 5.2 §4, p. 201; 9.2 §3, p. 345.

8 Britton [2002, 33] discusses the standardization of the 19-year cycle in the Babylonian calendar. The subject of intercalation is also taken up in Stern [2012, 71–124].

531]. These parameters, Toomer has argued, were borrowed directly, not derived by comparing eclipse-observations [Toomer 1980, 99; 1988].

Babylonian lunar parameters and period-relations are directly traceable in Geminus, *Intro. ast.* 18.4–19. There, Geminus attributes the value 13;10,35° for the Moon's daily mean motion in longitude to the Chaldeans (18.9) [Bowen and Goldstein 1996; Evans and Berggren 2006, 229; Jones 1983, 23–26]. In his treatment of the Moon's daily anomaly, Geminus utilizes a Babylonian linear zigzag-function (which Neugebauer termed F* [1965, 480–481]) related to System B and attested in cuneiform astronomical texts [1955, §§190–196]. The parameters of this function for the Moon's daily motion are given by Geminus [18.19] as follows:

d (constant increment/decrement) = 0;18°
M (maximum value of the function) = 15;14,35°
m (minimum value of the function) = 11;6,35°
μ (mean) = 13;10,35°.

The resulting period-relation, 248 days = 9 anomalistic months, and the value for the anomalistic month of 27;33,20 days also are noted in Geminus, *Intro. ast.* 18.11. These parameters and the 248-day schema appear elsewhere in ancient astronomy, showing the wide circulation of the Babylonian mathematical astronomical tradition in India and the Greek and Greco-Roman worlds [Jones 1983]. Hipparchus also gives a set of parameters constituting the *exeligmos*, an eclipse-cycle that is three times a Babylonian Saros Cycle, with the following relations:[9]

669 synodic months = 717 anomalistic months
= 19,756 days
= 723 sidereal rotations + 32°.

Finally, Ptolemy [*Alm.* 5.3] attributes the 248-day period for the lunar anomaly to Hipparchus, which indicates yet again Hipparchus' knowledge of Babylonian System B,[10] more precisely, of the function F*. Jones points out that knowledge of Babylonian planetary theory of the kind characteristic of the mathematical ephemerides also emerges in Hipparchus' *In Arat.* 1.9 [Manitius 1894, 88–90]. There, Hipparchus reasons that if there were solar lati-

9 Neugebauer 1975, 586; Toomer 1980; Jones 1983, 24; Bowen and Goldstein 1996, 161–167.
10 For further detail, see Toomer 1980, 108n12; Jones 1983, 24–27.

tude, then the lunar eclipse-predictions by the ἀςτρολόγοι (meaning Babylonian astronomers/astrologers), which do not presume solar latitude, should not be as accurate as they are, coming within no more than two digits of more contemporary predictions [Jones 1991a, 449].

Period-relations for the planets based directly on observations are also given by Ptolemy [*Alm.* 9.3: Toomer 1998, 423–424] and attributed to Hipparchus. These are the Babylonian Goal-Year periods, attested in the so-called Goal-Year Texts [Pinches and Strassmaier 1955, §§1213–1367) and derived from the Diaries as follows:[11]

> Saturn makes 57 synodic revolutions (or revolutions in anomaly) and 2 zodiacal revolutions (+ 1; 43°) (or revolutions in longitude) in 59 (tropical) years (+1¾ days).
>
> Jupiter makes 65 synodic and 6 zodiacal revolutions in 71 years (−4⁹⁄₁₀ days).
>
> Mars makes 37 synodic and 42 zodiacal revolutions (+3⅙°) in 79 years (+3;13 days).
>
> Venus makes 5 synodic and 8 zodiacal revolutions (−2¼°) in 8 years (−2;18 days).
>
> Mercury makes 145 synodic and 46 zodiacal revolutions (+1°) in 46 years (+1⅓₀ days).

Planetary period-relations from the Babylonian ephemerides turn up in much later astronomy, e.g., in the Indian astronomy of Varāhamihira's *Pañcasiddhāntikā*, ch. 17 from the sixth century CE [Neugebauer and Pingree 1970–1971].

Ptolemy refers to an estimate by "even more ancient [astronomers]" of the 18-year eclipse-cycle which he called The Periodic and which is now known as the Saros, defined as

6585⅓ days = 223 synodic months
= 239 anomalistic months
= 242 draconitic months
= 241 sidereal months + 10⅔°
= 18 sidereal years + 10⅔° [Toomer 1998, 175].

11 See Toomer 1988. Jones 1993, 81 points out that the corrections may not be original to Hipparchus.

The Babylonian formulation did not give the length of the period in days, nor did it correct for longitude. However, cycles of 223 months (18 years) were employed in the computation of eclipse-possibilities, both lunar and solar.[12] Although Ptolemy does not identify Hipparchus' essential lunar parameters as Babylonian in origin, Kugler discovered that they indeed were [Kugler 1900, 20–21; Toomer 1980]. When Hipparchus introduced Babylonian numerical parameters into Greek astronomy, he helped to establish a quantitative basis for the Greek kinematic hypotheses for the Moon and planets.

The ratio of the longest daytime to the shortest daytime at a given location (M:m) was another important parameter in the later inheritance of Babylonian astronomy. Since the length of the daytime increases as geographical latitude increases, the ratio of longest to shortest daytime will be an indication of local latitude. The ratio 3:2 for Babylon was the value accepted in Babylonian computations of the length of daytime, although the ratio does not correspond to the actual geographical latitude of Babylon. This conventional, albeit incorrect, Babylonian value was adopted by Greek geographers, resulting in their misidentification of the latitude of Babylon by several degrees and a consequent distortion of the eastern part of the world in early maps.

5 Arithmetic Methods

Evidence for Babylonian arithmetic methods in Greek astronomy after Hipparchus, as well as in Indian and Demotic texts later, attests to the widespread nature of the Babylonian transmission. For example, a diagnostic scheme of System A, in which the synodic motion of Mars is divided into six zones of the zodiacal circle, appears in the Stobart Tables from Roman Egypt [Jones 1994, 25–29]. While these are based on Babylonian methods, they were adapted to an entirely different set of requirements for Hellenistic astrology: tabulating the dates of planetary entries into zodiacal signs rather than dates of synodic phenomena as in the Babylonian tables [Neugebauer 1975, 456; Jones 1993, 82]. A six-zone scheme for the synodic motion of Mars, the treatment of the retrograde arc of Mars, and a System A-type scheme for Mercury are also attested in the *Pañcasiddhāntikā* [Neugebauer 1975, 456, 473].

In 1988, Neugebauer published a Greek papyrus fragment from Roman Egypt containing a sequence of sexagesimal numbers forming a zigzag-function with parameters familiar as column G of the System B lunar ephemerides. This text

12 Aaboe, Britton, Henderson, Neugebauer, and Sachs 1991.

was a preview to many more astronomical papyri from Oxyrhynchus [Jones 1999a, 2002], which showed in a more complete way how Babylonian ephemerides were reproduced in Greek and demonstrated that Greek knowledge of Babylonian lunar theory in the Hellenistic Period went beyond isolated period-relations or observations of eclipses. As Britton and Jones stated,

> of the fifteen planetary epoch-tables that have so far come to light, nine turn out to have been computed using models that are identical in structure and parameters to the models in the cuneiform texts, the only adaptation being an adjustment in the method of calculating the dates of the phenomena that was necessitated by the substitution of the Egyptian calendar for the Babylonian lunar calendar.
>
> BRITTON and JONES 2000, 349

More fragmentary tables are not so definitively Babylonian in structure. But a scheme employed for Jupiter [*POxy.* 4160 + *PBer.* 16511] offers a more complex reflection of Babylonian astronomical methods. As the editors have written,

> we have in the scheme underlying this papyrus evidence of a surprisingly sophisticated and successful extension of Babylonian methods, which reflects a complete and intimate familiarity not only with the conventional applications of System A, but also its underlying fundamentals. It is the first example we have of a table of planetary phenomena calculated according to the strict conversion rule, as well as the first example of a consistent four-zone System A model for Jupiter. Furthermore, despite a seemingly impractical virtuosity, it is remarkably accurate and clearly reflects—less than a century before Ptolemy—an active engagement with the contemporary empirical record, all within the context of purely Babylonian methods.
>
> BRITTON and JONES 2000, 372

Explicit Greek identification of the Babylonian inheritance is indicated, albeit in fragmentary context, in an Oxyrhynchus papyrus concerning lunar periods [*POxy.* 4139], which not only contains the earliest reference to a lunar parameter of the Babylonian System A lunar theory (6695 anomalistic months in the period-relation for lunar anomaly) but also mentions Orchenoi[13] or people of Uruk, the same group identified by Strabo as "astronomical Chaldeans"

13 *POxy.* 4139, l.8, again in broken context.

[*Geog.* 16.1.6]. Uruk is indeed one of the two principal Mesopotamian cities from which archives of mathematical cuneiform texts have come.

Among the astronomical papyri are table texts; those termed "epoch-tables" by Jones [1999a] are formatted on the model of Babylonian ephemerides. Of the 15 planetary epoch-tables, only 4 were not computed by means of a Babylonian scheme or a variant of one. Attested in the papyri are a System A scheme for Mercury (first and last visibilities) [Jones 1996a, 147–148] and for Mars, a version of System A′ (itself a variant of System A) for Jupiter, and a System B scheme for Jupiter and Saturn. Also rooted in Babylonian astronomy are adaptations of that methodology in so-called template texts, which produce daily positions of the Sun, Moon, Mercury, Mars, Jupiter, and Saturn [Jones 1996a, 147–148].

Finally, a method for computing the rising-times of the zodiacal signs found its way into later Greek astronomy. In Babylonia, a scheme for computing the length of daytime was based on the notion that the length of daytime equals the rising-time of the half of the zodiacal circle to rise and set with the Sun on a given day of the year at the geographical latitude of Babylon (32.5° north), i.e., from λ_{Sun} to (λ_{Sun} + 180°). Two sets of rising-times (Systems A and B) were chosen for the 12 zodiacal signs to form arithmetic progressions such that the extremal values in both would obey the conventional ratio 3:2 for longest to shortest day at Babylon. These rising-times were adopted by the Greeks to accommodate other geographical latitudes (10 different latitudes are given in the table in Ptolemy's *Alm.* 2.8). The originally Babylonian method of computing rising-times can also be traced in Manilius (early first century CE), *PMich.* 149 (*ca* second century CE), and Vettius Valens (*ca* 150 CE). As Neugebauer has observed,

> the historical significance of the Babylonian scheme for the rising-times reaches far beyond their applications in the solar and lunar theory. Since Greek mathematical geography characterized the latitude of a locality by its maximum daylight *M* the Babylonian method of finding the function C(λ) of daylight depending on the solar longitude was properly modified, but under preservation of the arithmetical types A or B for the rising-times. The geographical system of the "seven climata" preserved vestiges of the Babylonian oblique ascensions until deep into the Middle Ages. On the other hand one finds the unaltered set of Babylonian rising-times of System A in Indian astronomy of the sixth century CE without any consideration for India's far more southern position. Rising-times and related patterns have thus become an excellent indicator of cultural contacts, ultimately originating in Mesopotamia.
>
> NEUGEBAUER 1975, 371

6 Conclusion

All evidence presented in the foregoing makes clear the depth of the astronomical achievement of Babylonia and the critical impact it had upon Hellenistic astronomy. In addition to the material preserved in Greek treatises, such as those by Geminus and Ptolemy, Jones [1996, 142–144] has shown that another key factor for understanding the connection between Babylonian and Greek planetary theory is that of the relation between Babylonian texts and later Greek papyri, especially those from Oxyrhynchus in the Roman Period [Jones 1999a]. The papyri also show the importance of astrology in the process by which scientific knowledge was transmitted and adapted. Nor was there the same distinction between astronomy and astrology throughout the period, as is evident in the modern era. Clearly, the idea and even the formulation of horoscopes in Babylonia had a significant impact on Greek practice and many elements of Babylonian astrology are found in Greco-Roman horoscopy [Rochberg-Halton 1988b; Jones and Steele 2011; see ch. 12.1, p. 443].

From a cultural point of view, Babylonian astronomy in the context of its surrounding ideas and world system—including Babylonian celestial divination, mathematical astronomy, and astral theology—came to be of acute interest within a Hellenistic intellectual culture with its own multiplicity of ideas about the cosmos and especially about the heavenly regions, its luminaries, and their relation to the divine. The evidence from both sides of the Mediterranean attests to the cultural dynamism of astronomy. Cultural dynamics determined that the forms taken by astronomy were a function not only of the observable celestial phenomena of interest but also of religion, philosophy, or cosmology. Equally so, the reasons for transmission and reception are bound up with the dynamics of intercultural contact—the borrowing and exchange between the eastern and western parts of the ancient Mediterranean—that intensified in the Hellenistic age.

CHAPTER 4.8

Hellenistic Egyptian Planetary Theory

Micah T. Ross

1 The State of the Evidence

Due to the circumstances of archaeological preservation, Egyptian papyri and inscriptions often record funerary and religious literature, but relatively few primary sources reflect the development of astronomy in Egypt. Otto Neugebauer and Richard Parker collected the bulk of the limited Egyptian astronomical corpus in three volumes [1960–1969] but a handful of sources have appeared after this collection. In particular, the coordination of reports and predictions of the heliacal rising of Sothis (Sirius) with the beginning of lunar months[1] and a schema for lunar eclipse-prediction postdate this collection [Neugebauer, Parker, and Zauzich 1981]. Although classical literature reports Egyptian observations of lunar occultations of planets and comets [Aristotle, *De caelo* 2.12; *Meteor.* 1.6] and ascribes an eponymous comet to the apocryphal King Typhon [Pliny, *Nat. hist.* 2.23], Egyptian astronomy rarely merited or permitted inclusion into Greek analyses. Whatever Egyptian observations or planetary theories may have once existed, several factors have hampered their dissemination and citation.

First, Egypt did not conduct a systematic program of observation. The organized Mesopotamian observations of the astronomical Diaries began with Nabonassar and earned him his position as the first figure in Ptolemy's king list. Even if a similar contemporary project had existed in Egypt, the tumultuous Third Intermediate and Late Periods of Egypt disrupted the continuity of chronology necessary for astronomically useful observations.

Second, Egyptians lacked a standard celestial coordinate system [see ch. 1 §4, p. 16]. Although several Greek astrological sources preserve the Egyptian system of decanal stars used to mark nocturnal hours, the Egyptian decans were better suited to mark hours than to locate other phenomena.[2]

1 For the contemporary state of the debate about this, see Long 1974. For a more recent assessment, see Spalinger 2002.

2 The decanal belt comprised a wide band of stars south of the zodiacal circle. Likewise, more than one star could mark a decan: see Neugebauer and Parker 1960–1969, 1.97–100. *Pace* Locher 1992; Belmonte 2002; and Conman 2003. See chs 7.1 §4, p. 264 and §7, p. 267; 12.1 §5, p. 448 and §10, p. 458.

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Finally, the few Egyptian records that do survive use idiosyncratic metaphors rather than standardized technical terms for celestial phenomena. For example, the verb «prỉ» ("to go out") denotes heliacal risings in the Middle Kingdom but the verb «ḫ͗ʿ» ("to appear") indicates the same event in at least one Demotic text of the Roman Period.[3] Variation also marks the terminology for eclipses: the general Middle Egyptian term for "eclipse" cannot be stated absolutely but Demotic uses the phrase «ỉr ꜣbꜣ» ("to make dark") and Coptic also invokes the metaphor of darkness through different words—«ειρε κακε» ("to make dark") [Parker 1959, 8; Ray and Gilmore 2006].

2 Astronomical Readings

Given the lack of strictly defined technical terms, some modern researchers have attempted to interpret prosaic accounts in light of celestial phenomena. The tantalizing expression, «n ʿmꜣ pt ỉʿḥ» ("though the sky did not swallow the Moon"), appears in the ninth-century inscription now called the *Chronicle of Prince Osorkon*. This chronicle describes political events, not astronomy. Egypt erupted into revolt "even though the sky did not swallow the Sun" [Caminos 1958, 88–90].[4] The same metaphor «ʿmꜣ tꜣ pt pꜣ ỉtn» ("the sky swallowed the [lunar] disk"), appears in the seventh-century economic complaint of a priest [*PBer.* 13588: Smith 1991] and in a fourth-century magical papyrus [*PLou.* 3129, J] which states, «ỉmỉ knḥ ỉtn…ỉmỉ ʿmꜣ pt ỉʿḥ» ("let not the [solar] disk be dark…let not the sky swallow the moon") [Schott 1929, 123.11–12].[5] A parallel spell [BM 10252] preserves a negative aorist, «bw ir tꜣ pt ʿmꜣ ỉʿḥ» ("the sky cannot swallow the Moon"). Curiously, all the lunar phenomena employ «ʿmꜣ» ("swallow") and the two solar phenomena use «knḥ» ("darken"). However, the ambigu-

3 The *Wörterbuch der Aegyptischen Sprache* does not distinguish astronomical uses from religious uses: *s.v. prỉ*, F: "Hervorkommen, Erscheinen von Gestirnen und Göttern". The heliacal rising of Sothis discussed in *PBer.* 10012 clarifies the technical use [Clagett 1989–1999, 2.321–333], while *PCair.* inv. 31222 clarifies the Demotic term for "heliacal rising" [Hughes 1951]. The change of verb may have resulted from an attempt to render the Akkadian logogram «IGI» ("nanmurtu": "appearance") used to denote heliacal risings. In both cases, the semantic range of the terms is broad and the two terms overlap significantly.

4 Caminos outlines the variety of potential interpretations, including lunar and solar eclipse and the possibility of a partial eclipse. To these might be added the possibility of a predicted eclipse which did not occur.

5 Even the terms for the Sun and Moon vary in Egypt. *PLou.* 3129, J clarifies «ỉtn» by writing «ỉʿḥ» with a lunar determinative. The use of «ỉtn» in *PBer.* 13588 has prompted discussion [von Lieven 2001c]. Demotic eclipse-omens preserve the same distinction [Ross 2007b].

ous phrasing of *PBer.* 13588, the lack of a clear calendar date, and the ongoing identifications of the eclipse in the reigns of different pharaohs all highlight how far this record diverges from an astronomical observation [Depuydt 1995, 53n50].[6] Ideally, astronomical chronology offers scientific certainty in dating. This certainty depends on the accuracy and clarity of the description of the astronomical phenomenon. In the case of Egypt, the reports of celestial phenomena preserve few clearly understood astronomical details and remain just one element among many other chronological indicators.

Nor does this ambiguity and difficulty of interpretation characterize only the earliest examples of Egyptian astronomy. Ambiguous astronomical records appear even after Egypt had adopted Babylonian techniques under Greek rule. The circular bas-relief of zodiacal iconography in the ceiling of the pronaos of the Temple of Dendera depicts two disks—one containing a goddess holding an animal by the tail, the other containing the *wḏꜣt*-eye—near the zodiacal constellation of Pisces. These disks have been paired with a lunar and solar eclipse, respectively [Aubourg 1995]. Both the Setian pig and the Eye of Horus invoke associations appropriate to eclipses; the identifications account for all the astronomical images. The date of these two proposed eclipses, though, derived from the positions of the planets among the zodiacal signs—an arrangement which also corresponds to an astrological association of planets with particular zodiacal signs, well-known as their *bīt niṣirti* (secret house) from Mesopotamian sources and surviving in modified form as the astrological exaltations [see ch. 12.1 §10, p. 458]. The zodiacal decoration on the ceiling of the pronaos of Dendera falls short of an astronomical observation by omitting dates or a textual explanation of the images. Thus, the image may preserve either a record of eclipses or evidence of the transmission of Babylonian astrological doctrines.

3 Mathematical Planetary Theory

Despite these difficulties, the descriptions of planets permit some non-mathematical understanding of the Egyptian views of the planets and their motions. Obviously, the interpretation of these views demands caution and the caveat that any given view may not have been adopted in all Egyptian sources. For example, the tomb of Senmut omits Mars from the list of planets. Unlike the Babylonians, who characterized each of the planets as benefic or malefic, Egyp-

6 Ryholt 2012, 136n101 summarizes the development of the interpretations.

tians deleted only Mars; Saturn passed without comment. Presumably, the Egyptian characterization of the planets was unrelated to, but later compatible with, the Babylonian characterization.

The names of the planets suggest an Egyptian familiarity with the distinction between inferior and superior planets. The superior planets Mars, Jupiter, and Saturn embodied manifestations of Horus distinguished by a descriptive element—Horus-the-Red, Horus-the-Secret, and Horus-the-Cow, respectively—while the inferior planets Mercury and Venus had independent names («sbg» and «ḏꜣ», respectively, although variations exist).[7] The tomb of Ramses VI (*ca* 1137 BCE) adds a gloss to Mercury: “Seth in the evening, a god in the morning”. Just as Mesopotamians personified Venus differently as a morning star and an evening star [Reiner 1995, 6] and early Greeks called Venus Phosphorus in the morning and Hesperus in the evening, Egyptians differentiated the inferior planets by their time of appearance. This distinction is most explicit in the case of Mercury, to which the tomb of Ramses VI (*ca* 1137 BCE) adds a gloss: “Seth in the evening, a god in the morning”. Likewise, the «bꜥḥ» and «bnw» birds seemingly served as the morning and evening manifestations of Venus [Clark 1949], but no equally explicit primary source had yet established this association. Notwithstanding these descriptions, Greek sources ascribe the discovery that the morning star and evening star of Homer (*scil.* 700 BCE) [*Iliad* 22.317, 23.226] are the same celestial body to either Parmenides [Diels 1965, 2.15.7; Diels and Kranz 1951, 28A40a; Diogenes, *Vitae* 9.23] or to Pythagoras [Jacoby 1923–1958, 244F91; Pliny, *Nat. hist.* 2.37]. The presumption that Homer was ignorant that Mercury and Venus appear in the eastern and western horizons precludes the possibility that he borrowed not only Babylonian constellations [Pingree 1998, 129–130] but also Egyptian techniques for naming planets.

Other Egyptian sources refer to the planets collectively. An Egyptian ostracon [Neugebauer 1943, 121] names the planets «pꜣ(!) siw ꜥnḫ» (“the five living stars”) and reports a correspondence of Egyptian months and zodiacal signs appropriate from 370 until 250 BCE. Here, the meaning of the phrase is clear. However, references to a single “living star” («𓇼𓋹») appear as early as the Pyramid Texts 468 [Sethe 1908, 507.904c: see Plate 1, p. 164], although the phrase may permit other, non-astronomical interpretations. Nor was the usage geographically limited: knowledge of the five living stars appears among the Egyptian graffiti of the Temple of Dakka in Lower Nubia [Griffith 1916]. The phrase also constitutes one of the few translatable portions of Meroitic, the language of

7 The Temple of Ramesses II at Luxor violates this generalization and names Mercury «Ḥr-ḥknw» (“Horus-the-Praiser”).

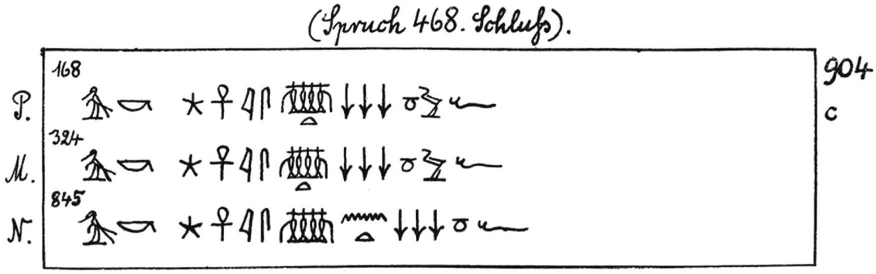

PLATE 1 Pyramid Text 468.904c

ancient Nubia. In fact, the phrase appears to be Egyptian in origin. Possibly Aristotle had such Egyptian wisdom in mind when he declared the heavens to be ἔμψυχος (endowed with a soul) and, thus, debatably alive [*De caelo* 285a29–30] in that they were animate, which implies life and that being ἔμψυχος is a quality of living beings.[8]

4 The Babylonian Heritage

The Stobart Tables and *PBer.* 8279 constitute the preeminent documents of Egyptian mathematical planetary theory in the first century CE. When Neugebauer elucidated these lists of dates on which each of the five planets entered a zodiacal sign, he framed their historical importance in light of the question: "Are those texts purely of Egyptian origin or written under Greek influence?" [1942a, 229]. Neugebauer concluded that they were "merely Hellenistic science in Egyptian disguise" [1942a, 235], in part because of the presence of the zodiacal signs, a Babylonian element.

The recent identification of sign-entry tables among Greek astronomical papyri better elucidates the origins of these texts. While some Greek papyri directly parallel the Stobart Tables and *PBer.* 8279, two undated texts [*POxy.* 4197, 4198] reveal the probable method of constructing this type of text. These two "perpetual sign-entry tables" compute the year and day of a Babylonian Goal-Year period at which a planet enters a zodiacal sign [Jones 1999a]. The Babylonian Goal-Year periods relate an even number of years to an even number of passages through the entire zodiacal circle. By repeated extension from a known epoch, an astronomer could roughly calculate planetary position. The

8 Admittedly, Aristotle may contradict himself. The notion that the stars were alive was embraced by Platonists and Stoics. The prevalence of the idea in the West has been traced to Origen [Scott 1991], and an Egyptian precursor seems likely.

earliest Goal-Year Texts appeared in Babylon during the third century BCE. Thus, the Stobart Tables and *PBer.* 8279—like the zodiacal signs—reveal "Babylonian techniques in an Egyptian context" more than Greek science[9]. Greek scientists had disparaged these specific techniques since Hipparchus [Ptolemy *Alm.* 9.2], although they remained in use by Greek-speaking Egyptians until the third century CE.

5 Conclusion

Still, Egyptian planetary theory remains elusive. In the earliest eras, Egyptians apparently did not redact their observations and explanations to the standards of Babylon. The possible legacy of Egyptian planetary theories appears murky through the lens of time and linguistic barriers. Even when Egyptians did adopt Babylonian standards, these labors risk characterization as Greek. In evaluating the standards of Egyptian sciences, care must be taken neither to assume obvious achievements such as the observation of eclipses, nor to dismiss indigenous labors as derivative.

9 Another more developed Babylonian technique of planetary theory appears in ODem. 483 and ODem. 525+732+763 [Ossendrijver and Winkler 2018].

PART B

Observations, Instruments, and Issues

Observational Foundations

CHAPTER 5.1

The Observational Foundations of Babylonian Astronomy

Lis Brack-Bernsen

1 Introduction

Of the excavated Mesopotamian astronomical cuneiform tablets, a small fraction utilizes advanced mathematical algorithms to calculate astronomical quantities. This corpus comprises about 450 tablets and fragments, which were found in the ancient towns of Babylon and Uruk. Scientific excavation produced the material from Uruk, while the Babylonian tablets were obtained through the antiquities-market. The texts, which were written during the period 450–50 BCE, are classified as the corpus of Babylonian mathematical astronomy. This corpus consists of two different types of texts: tabular texts and procedure-texts.

Tabular texts contain computed astronomical quantities arranged in rows and columns, while procedure-texts instruct how to calculate those astronomical quantities for the Moon, the Sun, and planets. This chapter discusses the empirical foundation of this corpus. In order to do this, however, we must take into consideration older astronomical texts, since these texts may give hints as to the observations and astronomical conceptions that the Babylonian astronomers had at their disposal, which will in turn shed light on how the mathematical algorithms were likely to have been developed. The earliest known cuneiform texts concerned with astronomy date back to the beginning of the second millennium BCE.

Since 1955, when Neugebauer's *Astronomical Cuneiform Texts* was published, we have known fairly well what the Babylonian astronomers calculated and how. They utilized elegant numerical functions representing different astronomical quantities, such as the synodic arc or angular displacement of the Sun, the Moon, or a planet from one synodic event to the next or the changing length of daytime or of nighttime throughout the year.

Note the way in which Babylonian astronomy differs from ours: we calculate the positions of celestial bodies as continuous functions of time, whereas the Babylonians concentrated on isolated events (synodic phases), for which they calculated the positions in the zodiacal circle and the times when they

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were expected to occur [see ch. 4.1 §3, p. 66]. In the case of the Moon, the days around the New and Full Moons were of special interest. For these phases, not only the day of the event but also the time between the rising and setting of the Sun and Moon were observed, predicted, and calculated. These time-intervals, although rather complicated from a theoretical point of view, are visually obvious and thus easy to observe.

The procedure-texts give quite abbreviated instructions on how to calculate the tabular texts. They do not explain or indicate how the algorithms were developed or give any information regarding their theoretical or empirical foundation. But the two types of texts, the tabular and the procedural, helped in the original modern decipherment of the cuneiform astronomical texts. Our knowledge of Babylonian mathematical astronomy has been extended by numerous papers published after 1955 and lately deepened by a monograph by Ossendrijver [2012], which provides new editions of the procedure-texts and a semantic, mathematical, and astronomical analysis.[1] Nevertheless, we know relatively little about how this elegant and efficient mathematical astronomy was developed; nor do we know in detail what sorts of observations provided its foundation.

2 Babylonian Astronomical Observations

The earliest hints about astronomical observations are found in early omen-texts, which seem to connect observed lunar eclipses with the death of kings perhaps in the Ur III dynasty (*ca* 2100 BCE); another omen-text gives the dates of the first and last visibility of Venus observed in the years of the Old-Babylonian king Ammiṣaduqa. Later, probably starting around 747 BCE, the Babylonians observed the sky regularly over the course of many hundreds of years, recording this “regular watching” on cuneiform tablets. All such tablets known to us have been published by Sachs and Hunger in their *Astronomical Diaries* [1988–1996]. The earliest surviving Diary dates from 652 BCE; the latest, from 61 BCE. Hunger estimates that only 5% of the written Diaries have been found. Other collections of observed and predicted quantities are published in Hunger 2001–2014.

Along with weather, prices, river levels, and historical events, a typical Diary contains information on the Moon, planets, solstices and equinoxes, Sirius-phenomena, meteors, and comets. With these ancient records of observations,

1 For an excellent introduction to Babylonian astronomy, see Ossendrijver 2012, 1–53.

we know what Babylonian astronomers observed[2] and we are able to check the accuracy of their observations. The movements of the Moon and planets were traced by means of their passings by some special so-called Normal Stars [see Glossary, p. 650] for the purpose of establishing the positions of their synodic phenomena. The following planetary phases were observed:

– their first and last visibilities,
– stationary points, and the
– acronychal risings[3] of the outer planets.

Only by means of solar and lunar eclipses, which were recorded carefully, were the conjunctions and oppositions of the Sun and Moon observable. Since, normally, such syzygies cannot be observed directly, the Babylonians observed the risings and settings of the Sun and Moon in the days around New and Full Moon.

Six time-intervals, called the Lunar Six, were measured and recorded together with the day on which they were observed:

NA_1 = time between sunset and the first visible setting of the new crescent.

At Full Moon the Babylonians regularly measured the following time-intervals, known as the Lunar Four:

ŠÚ = time from moonset to sunrise, measured at last moonset before sunrise.
NA = time from sunrise to moonset, measured at first moonset after sunrise.
ME = time from moonrise to sunset, measured at last moonset before sunset.
GE_6 = time from sunset to moonrise, measured at first moonrise after sunset.

Toward the end of a month, they also recorded:

KUR = time from last visible moonrise before conjunction to sunrise.

Note that it is exactly those synodic phenomena of planets and of the Moon observed and recorded in the Diaries that were calculated in the tabular texts. Before the methods evident in the texts collected in Neugebauer 1955 were

2 For further details, see the introduction in Sachs and Hunger 1988–1996, 1.11–27. See also Hunger 2012.

3 The opposition of a planet cannot be observed directly, so the Babylonians observed its rising at sunset, i.e., its acronychal rising, instead. See ch. 4.1 §3.1, p. 67.

developed, the Babylonians had found an easy and elegant method for their prediction by means of earlier observations.

There have been several attempts to reconstruct the numerical functions of the tabular texts by means of observations, but we are still far from a comprehensive reconstruction. We must keep in mind that a reconstruction only shows that we have been able to derive the astronomical parameters of a numerical function from Babylonian observations. It does not prove that this was how the Babylonians did it; there may be other ways to construct the same algorithms from observations. Thus, each reconstruction should be confirmed by other means. Strictly speaking, we can only determine the empirical basis of the numerical systems when we know how they were constructed in the first place. Here the non-mathematical astronomical tables that show us earlier stages of the developing astronomy and reveal astronomical concepts and methods for predictions are of great help.

3 Preconditions for Practicing Mathematical Astronomy

The Babylonian scribes were aided in their development of astronomy by a well-functioning writing system and their mathematical training in a sexagesimal number system [see ch. 3.1 §7, p. 51] in which the standard calculations were easily carried out. In addition, the Babylonian calendar and the division of the zodiacal circle into segments of 30° or signs offered a suitable frame for recording times and positions of astronomical events. The empirical basis of this frame is quite well known.

The Babylonian calendar itself is very old: it is attested in texts dating from 2600 BCE. It was determined by lunar phases and by the solar year: the day began at sunset; the first day of a new month began on the evening when the new crescent became visible for the first time after conjunction. This event took place either 29 or 30 days after the previous first visibility. However, the sequence of 29- and 30-day months is highly irregular and, hence, troublesome to handle. The normal year had 12 months but 12 synodic months are some 10.88 days shorter than the solar year. Therefore, on average, an intercalated 13th month was necessary roughly every three years in order to keep the months in tune with the seasons.

This calendar evidently was formed empirically by observations of sunset, the new crescent, and the positions of the Babylonian months within the solar year, whereby a shift of the lunar months with respect to the seasons would show the need for intercalating a 13th month. Period-relations between lunar months and solar years helped to organize the intercalations. John Britton

[2007a, 119–130] analyzed the patterns of the intercalations in early texts and of the solar longitude at the beginnings of Babylonian years. He shows that such period-relations improved from 750 to 484 BCE, after which time intercalations were systematically governed by the 19-year cycle in which 19 years = 235 synodic months. (The simplest way to discover this cycle would be to notice that eclipses separated by 235 months recur at the same place in the sky.)

Before the intercalations were regulated, the need for an extra month could be indicated by the date of the heliacal rising of a bright star like Sothis (Sirius). Other indicators were the points at the horizon where the Sun rises or sets. Since early times, the Babylonians knew that the rising point of the Sun changes throughout the year; they regulated their calendar such that the day at which the Sun rose straight east (spring equinox) took place in month XII or month I. Such observations may also have been used to find and improve the intercalation cycles. The problem of intercalation was settled in the early fifth century BCE before the tabular texts, called ephemerides in Neugebauer 1955, had been developed; the trouble with the variable length of lunar months remained but eventually it was elegantly solved.

The Babylonians had, from the earliest bureaucratic texts (3000 BCE) onward, an easy way to cope with the irregular length of the month: each month was reckoned as 30 days independently of its actual length. This "schematic year" with 12 months of 30 days was a practical approximation to the irregular Babylonian lunisolar year. In the later mathematical astronomical texts, we find traces of this schematic year in the useful unit *tithi* (= 1/30 synodic month) [see Glossary, p. 652]. The schematic year was used in early astronomical schemes (from around 1100 BCE) to record how the rising point of the Sun, the length of daytime, and the time of the Moon's first visibility changed throughout the year.

In this period, the movements of the Sun, the Moon, and the planets were traced along some 17 constellations called the "path of the Moon". Later, around 450 BCE, that path was divided into 12 sections of 30°. I presume that this division was conceived in analogy to the schematic year, the reason being that several crude astronomical schemes identify the schematic year with the 12 zodiacal signs of 30°. This corresponds to the fact that the Sun travels roughly 1° per day and 30° per month. Huber 1958 points to the fact that some bright stars are situated at the beginnings of zodiacal signs, implying that these were the stars used to define the boundaries of the signs.

This abstraction of the Moon's path facilitated the computations in the tabular texts. But the positions of the Moon and planets on the zodiacal circle or ecliptic cannot be observed directly. In the Diaries, the movements of the Moon and planets were surveyed by means of their passings by Normal Stars. A newly edited text gives the zodiacal positions of the Normal Stars [Roughton, Steele, and Walker 2004]. In this way, observed positions could easily be converted to positions in the zodiacal circle. The Diaries also note how much above or below the Normal Stars the passing took place. Such observations were also used to survey movement in latitude—or, more precisely, to find the positions of the Moon or the planets within the "zodiacal band". Steele 2007b shows that the zodiacal band was identified by Normal Stars. For each of these special stars, the Babylonian astronomers knew the interval of 6 cubits or 12° (= 6 × 2°) within which the variation in lunar latitude took place and they knew the smaller central path within which eclipses took place.

To summarize, the days of the synodic phenomena of the Moon and planets were observed directly, while their positions within the zodiacal band (longitude and latitude) were found by converting their observed positions relative to Normal Stars. Evidently, such observations constituted the empirical basis of all functions capturing movement in longitude and latitude. Note that the Babylonian conception of the zodiacal circle or ecliptic differs from ours: for them, its starting-point is fixed with respect to the stars; whereas, for us, its starting-point is the vernal or spring equinoctial point, which moves slowly backward (to the west) along the zodiacal circle [see ch. 1 §7, p. 22].

4 Methods of Astronomical Prediction

Eclipses played an important role in Mesopotamia. They occur when the Moon in its full or new phase passes the middle of the zodiacal band. This happens at intervals of six or sometimes five months. Eclipses were predicted by means of the Saros, an eclipse-cycle of 223 months, which equaled 18 years plus 11 days. The Babylonians named the cycle "18" and identified 38 months within each cycle in which eclipses could possibly occur [Steele 2000b]. We call such "dangerous" months eclipse-possibilities (EPs). Since EPs repeat after 1 Saros, they can be arranged in a matrix-like scheme of columns and lines by which all future EPs may be predicted.

Each column covered 1 Saros, listing its 38 EPs. The next column listed the EPs of the next Saros, and so did each line of the scheme, giving a series of EPs situated 1 Saros apart. The largest eclipse scheme comprised 24 cycles, covering the time from 747 BCE to 333 BCE. We do not know exactly when such Saros-schemes for predicting eclipses were developed—probably by the seventh century BCE. From then on, the months, but not the times, of future EPs were known beforehand. When the time of an eclipse also was known, the times of the EP expected 1 Saros later could be predicted [Brack-Bernsen and

Steele 2005]. The basis for such predictions would be the observed eclipses recorded in the Diaries. Here the years, months, days, times, and other details of eclipses are recorded; however, the measured times were only accurate when the eclipses took place near sunset or sunrise.

The empirical basis of Babylonian mathematical astronomy is certainly to be found in the Diaries. But we have the problem that only about 5% of all such texts are at our disposal, so it is on a thin basis that we evaluate the quantity and quality of observed events. In addition, the Diaries do not tell us which kind of practical experience and knowledge the Babylonian astronomers possessed. In planetary texts, one often finds notes such as this:

> Month VIII, the 25th, Jupiter's first appearance in Scorpius, 3½ cubits behind alpha Scorpii; rising of Jupiter to sunrise: 11°; (ideal) first appearance on the 24th.
>
> HUNGER 2001–2014, 6.263

The interval of 11° of time between the risings may have played a role for finding the ideal date but we do not know exactly how. Often the Diaries give days and times between the risings of the Sun and a planet or the Moon in addition to comments like "clouded over", "I did not watch", and so on.

In the case of the Moon, we know how such missing data were reconstructed by means of the Goal-Year method. In the case of the planets, we do not know the details.

Goal-Year Texts are collections of earlier observations, presumably excerpts from the Diaries, that were used for the prediction of astronomical events in a particular year, *Y*, the "Goal-Year". The Goal-Year table for year *Y* would collect the synodic phenomena of Jupiter from year $Y - 71$ and Jupiter's passings by the Normal Stars from year $Y - 83$. Evidently, the Babylonians knew the 71- and 83-year periods of Jupiter, and they probably had ways to adjust the days of the phenomena to year *Y*.

In the case of the Moon, the Goal-Year tables collected lunar data from year $Y - 18$, that is, the Lunar Sixes and eclipses of that year. Lunar Six data were skillfully used to predict their expected values for year *Y* by means of the Goal-Year method [Brack-Bernsen 1997, 1999; Brack-Bernsen and Hunger 2002]. This method is easy and very accurate—and it was known at least since the sixth century BCE. The times $\check{S}\acute{U}_i$ and NA_i for a month *i* could be found by easy calculations from the data $\check{S}\acute{U}_{i-223}$ and NA_{i-223} of month $i - 223$, that is, 1 Saros earlier, measured on two consecutive mornings:

$$\check{S}\acute{U}_i = \check{S}\acute{U}_{i-223} + \frac{(\check{S}\acute{U}+NA)_{i-223}}{3}$$
$$NA_i = NA_{i-223} - \frac{(\check{S}\acute{U}+NA)_{i-223}}{3}$$

These rules for prediction are based on elegant combinations of the following empirical considerations:

(1) After 1 Saros, the time of opposition with respect to sunrise is shifted by ⅓ of a day.

(2) The sum ŠÚ + NA is connected to how fast the Full Moon moves with respect to the Sun. It is the setting time of the Moon's movement relative to the Sun on the day of the Full Moon. Analogously, ME + GE_6 is its rising-time.

(3) The sums ŠÚ + NA and ME + GE_6 repeat after 1 Saros. When the difference for finding NA (or other Lunar Six) became negative, the calculations were revised and the day of the phenomenon changed.

The Goal-Year method thus provided a means to determine the length of the month in advance [Brack-Bernsen and Hunger 2008; Brack-Bernsen 2011].

5 The Tabular Texts: The Planets

The sequence of synodic phenomena for the inner planets is different from that of the outer planets but the numerical methods are similar. I shall, therefore, present one planet, Jupiter, as an example. The five characteristic synodic phenomena of an outer planet are:

Ω disappearance,
Γ appearance or heliacal rising,
Φ first stationary station,
Θ opposition, and
Ψ second station [see ch. 4.1 §3, p. 66].

A complete tabular text gives in separate columns the times and zodiacal positions of these five synodic phenomena for consecutive synodic periods 1, 2, 3, and so on [Table 1, p. 179]. In most cases, the column tabulating position (in longitude) was calculated separately[4] by means of the synodic arc $\Delta\lambda$, that is, the angular distance between successive events of the same sort:

4 Sometimes, the data of one phase were used to find those of the next by means of some pushes [see ch. 4.5 §4, p. 133]. A decent value for the angular distance between the phases can be found by observation.

TABLE 1 The structure of a typical planetary ephemeris

	$t\,\Gamma$	$\lambda\,\Gamma$	$t\,\Phi$	$\lambda\,\Phi$	$t\,\Theta$	$\lambda\,\Theta$	$t\,\Psi$	$\lambda\,\Psi$	$t\,\Omega$	$\lambda\,\Omega$
1	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.

Columns 1 and 2 tabulate times and positions (longitudes) of the planet's consecutive appearances or heliacal risings. Columns 3 and 4 tabulate times and positions (longitudes) of its first stations, and so on. Each line follows the planet through one synodic period, with the next period given in the line below.

$$\lambda_\Gamma(i+1) = \lambda_\Gamma(i) + \Delta\lambda_i,$$

whereby the Babylonians utilized two main types of numerical functions to determine the synodic arc $\Delta\lambda$:

System A calculates $\Delta\lambda$ from a step-function of its position in the zodiacal circle. The synodic arc $\Delta\lambda$ of Jupiter is, for instance, approximated to be 36° on one part of the zodiacal circle and 30° on another.[5] When a step of the functions is passed, the value of $\Delta\lambda$ is found by linear interpolation.

System B gives the synodic arc through a linear zigzag-function of the number of the phenomenon: $\Delta\lambda$ varies linearly between a maximum M and a minimum m with the amount of $\pm d$ from one line to the next.

For the corresponding times of the events, a similar calculation was used:

$$t_\Gamma(i+1) = t_\Gamma(i) + \Delta t_i.$$

In most cases, Δt_i was derived from $\Delta\lambda_i$ by the following (surprising) connection, which was used for all planets:

$$\Delta\lambda + C = \Delta t,$$

where C is a constant with λ measured in degrees and the time, in *tithis* [see ch. 3.1 §2, p. 42]. Van der Waerden called this feature the "Sonnenabstands-

5 Evidently, the Babylonians had noticed that the angular distance between successive Γ-phenomena was smaller on one part of the zodiacal circle and larger on the other part, and they had developed numerical methods to describe this variation.

prinzip" ("The Solar-Distance Principle"). It allows for the fact that the Sun travels 1° per day and that 1 day ≈ 1 *tithi*.

Such a connection may have been found by observation, for example, of acronychal risings of Jupiter or Saturn and then transferred to the other synodic phases of the planet. It might even have been extended to other planets, once the constant was adjusted. I do not, however, see the principle as a basic concept according to which the functions were constructed by means of dynamic models of solar and planetary movements. Note that the conversion $\Delta t_i = \Delta\lambda_i + C$ is far more suitable for acronychal rising than for heliacal rising and that the same system was used for all phenomena of Jupiter.

The numerical functions in both Systems A and B were constructed such that they satisfy a period-relation, tying them to actually occurring phenomena quite well, even over a number of centuries. A number Π was determined such that the planet after Π synodic periods would return to the same position in the zodiacal circle. Such a period corresponds to an integer number *Z* of sidereal revolutions of the phenomenon in question (i.e., to the number of times that the phenomenon returns to the same star) and to a whole number *Y* of revolutions of the Sun (i.e., to the number of times that the Sun returns to the same point on the zodiacal circle as calculated in the Babylonian scheme at use) and, therefore, also to *Y* years. Most of the Jupiter texts are based on the following period-relation:

391 synodic occurrences = 36 sidereal rotations = 427 years.

The exact period-relations were not the result of observations over hundreds of years but were—no doubt—constructed from shorter periods by means of corrections to these periods. From Goal-Year tables we know approximate periods for all planets and we presume that the Babylonians used Goal-Year data from earlier periods in order to fill in non-observable data in the Diaries. This means that, in the case of Jupiter, the scribes compared observations some 71 and 83 years apart and that they knew how to adjust the data from the Goal-Year tablets to the actual year, presumably by some knowledge of the shift in date and location after 71 and 83 years.

Precisely such empirical data can be used to find the period-relations on which the numerical functions of Systems A and B are based. Once the period-relation was determined, other parameters could be fixed. System B is determined by the period-relation and one additional parameter, for example, the maximum *M* of the linear zigzag-function. System A step-functions are more flexible in that they are determined by more than one parameter besides the period-relation. There is some freedom in choosing the number and length of the arcs (into which the zodiacal circle was subdivided) together with the respective synodic arcs of the planets.

The constant C, which enabled converting synodic arc into synodic time and *vice versa* using $\Delta\lambda + C = \Delta t$, was determined such that the sum of the synodic arcs over Π periods equals $Z \times 360°$ and that the sum over the synodic times over Π periods equals *Y* years. Given the numbers Π, *Z*, and *Y* and the length of the year measured in *tithis*, one can find the constant *C* for each planet as the difference between the mean values of Δt and $\Delta\lambda$. Lunar tables of System A contain implicitly two different values for the year: the column recording the dates, where intercalations are regulated in the 19-year cycle, have a year-length of 6,11;3 *tithis*, while the velocity function of the Sun[6] in the same system gives the length of the year to be 6,11;4 *tithis*. Barring one procedure-text [Neugebauer 1955, no. 813 (pp. 286, 412)], the Babylonians utilized the latter value to determine *C* for the planets.

There have been several attempts to construct the numerical functions in the ephemerides from observations. Asger Aaboe [1958] compared positions and times of planetary events (calculated in the Babylonian tabular texts) with modern astronomical calculations. In some cases, the positions of the events showed a good fit but not the times; and sometimes *vice versa*. Therefore, Aaboe proposed that some might have been constructed from the positions of consecutive phenomena, others by the times of their occurrences. For System A for Mars, he found a nearly perfect agreement with synodic arcs derived from the longitudes of opposition.

Later [1964], Aaboe showed that the Babylonian step-function for calculating consecutive positions of one synodic phenomenon results in an uneven distribution of the events in the zodiacal circle. This corresponds to reality. Aaboe thus proposed that a simple counting of the numbers of events taking place within different zones of the zodiacal circle could lead to the Babylonian step-function. He also showed that, next to the desire to reproduce a planet's behavior, purely arithmetic considerations and demands of the models co-determined the choice of numbers in the period-relation.

The texts in Neugebauer 1955 exhibit a variety of numerical methods for determining the synodic arc (procedure-texts for Jupiter bear witness to eight variations of Systems A and B), showing how the scribes tried different way of finding good "fits" to observational experience through their elaboration of the methods of Systems A and B and the choice of numbers. These arithmetic

6 The velocity of a celestial body is the daily displacement in its position on the zodiacal circle during a given time-interval; it is typically assessed in degrees per day.

schemes deliver a phenomenological numerical description of periodic phenomena. For Jupiter, for instance, the same function for the synodic arc could be used, and was in fact used, for all characteristic phenomena, providing a good fit.

This was not the case for Mercury, for which the different phenomena were fitted individually by different functions for $\Delta\lambda$ or Δt. The ephemerides in Neugebauer 1955 are not the result of one man's work: an entire group of scribes was involved that no doubt utilized different types of observations for their fits. What they shared were the observations, the arithmetic methods, and a number of conceptions based in practical knowledge, for instance, on how to predict by means of the data collected in the Goal-Year tablets.

Noel Swerdlow's *The Babylonian Theory of the Planets* [1998] gives a solid analysis of all systems of planetary computation and of the planetary data as recorded in the Diaries. Since the dates of the phenomena were given with much more precision than the positions in the zodiac,[7] Swerdlow investigated whether the dates might have been the empirical basis of the numerical functions and he presented a detailed reconstruction of all schemes based on observed dates. For the planetary phases, he determined "observed" synodic times in two ways:

(1) from recordings in the Diaries and
(2) through modern computation of first or last visibility.

He then compared these data with the synodic times of the Babylonian numerical functions, exhibiting substantial deviations. It was consequently not evident how the parameters of the models were determined from "observed" values. Further know-how was needed. Therefore, Swerdlow presented a reconstruction of all the planetary systems based on observations of the times of the phenomena, starting with "well-chosen" values of Δt. In a later paper [1999a], Swerdlow showed that computer-simulated dates of acronychal rising fit the numerical functions much better than dates of heliacal rising, which he had used in the first reconstruction. He thus proposed that the functions for the outer planets were constructed from the dates at which the acronychal rising of the planets had been observed.

Since the tabular texts establish a fixed connection between synodic arc and synodic time ($\Delta\lambda + C = \Delta t$), it is possible that the synodic times were calculated first and the synodic arcs were found by means of C or *vice versa*. The Babylonians utilized the connection in both directions. I believe that the Babylonians

7 The month, day, and zodiacal sign was noted for Γ, Φ, Θ, and Ω, but not the position within the sign. Only the date is found with Θ.

first developed their systems from the positions of Jupiter and Saturn, as Aaboe first proposed. Later, they may have applied the methods to data of observed times and may thus have been able to construct the numerical functions, for example, of the irregular planet Mercury, as reconstructed by Swerdlow. In either case, more precise data or some extra know-how is needed than what we find in the Diaries.

It is, however, not too serious that only the zodiacal sign was given for Γ, Φ, Θ, and Ω. The passings by Normal Stars were also recorded, so it is quite possible that the Babylonians could find the positions of the phases more precisely, for example, by estimating the planetary movement in its different phases. They were excellent observers and much more experienced than what we find in the Diaries. On the basis of an early observation text for Mars, Britton [2004, 33–55] showed how ongoing observations of planetary phenomena were improved and systematized during the time from 668 BCE to around 600 BCE, when planetary observations included nearly all elements reflected in the later observation texts, showing that a motion of ¼° was perceptible to sixth-century observers.

6 The Lunar Systems

The lunar ephemerides are the most remarkable achievement of Babylonian astronomy. They skillfully combine the effects of all variables that determine the synodic lunar phenomena and succeed in calculating the Lunar Six time-intervals near New or Full Moon and eclipses. A typical table will have 12 or 13 lines, one for each lunation within a year, and up to 13 or 19 columns recording the numerical functions necessary for the calculation of, for example, the day when the new crescent was visible for the first time together with NA_1, the time from sunset to its setting. NA_1 is a quite complicated quantity. It depends on the position of the Moon in the zodiacal circle, its latitude, the time from conjunction to the sunset in question, the length of daytime, and the lunar velocity. Each of these variables was taken into account in separate columns and then combined elegantly to find NA_1. Neugebauer identified the columns by the following letters:

T, Φ, [A], B, C, [D], E, Ψ, F, G, J, C′, K, [L], M, [N, O, Q, R], P.

The tabular lunar texts focused on New or Full Moon. Correspondingly, the astronomical quantities in the different columns are calculated for the moment of New and Full Moon.

The lunar texts are grouped into Systems A and B. The columns in square brackets are only present in System B texts, while columns Φ and C′ are specific to System A. Column T records the year and month of the lunation in question, the intercalations being regulated by means of a 19-year cycle, where 19 years = 235 synodic months. This means that Column T implicitly has the year-length of 12;22,6,19 synodic months, an excellent approximation to the tropical year, the period of the Sun's return to the vernal equinoctial point. However, the Babylonians did not distinguish between the tropical and the sidereal year. Column B was based on another year-length.

Column B calculates the position of the Moon $\lambda_☾$ at conjunction or opposition. In System A this calculation is made by means of a step-function, while System B uses a linear zigzag-function. At conjunctions, the position of the Sun ($\lambda_\odot$) equals $\lambda_☾$; at opposition, it equals $\lambda_☾ + 180°$. Surprisingly, the synodic arc $\Delta\lambda$ depends heavily on the solar velocity, while the lunar contribution is negligible. Therefore, observations of positions of new crescents or Full Moons may have served as bases for the construction of Column B [Bernsen 1969]. Such data could have been combined with the empirical knowledge of the lunar movement in elongation and with the exact position of the Moon observed at eclipses. Function B of System A has the period P = 12;22,8 months, reckoning the excess of the year over 12 months as 0;22,8 synodic months = 11;4 *tithis*.

This value is used heavily in both Systems A and B in spite of the fact that the period of B in System B is 12;22,13,20 months. That different values of the length of the year were used within each system indicates that the numerical functions were numerical approximations to astronomical phenomena and not derived theoretically from one basic model. A newly published procedure-text [Britton, Horowitz, and Steele 2007] shows how the Babylonians in the late second century BCE seemingly aimed at minimizing such small inconsistencies within System B. In comparison to the values known from tabular texts, some more precise parameters for the daily movement of the Sun and Moon are recorded here.

Column Φ belongs to System A and is connected to the lunar velocity. Column C gives the length of daytime at the beginning or middle of the month, respectively. Column E approximates the lunar latitude and F its momentary velocity, i.e., the velocity of the Moon measured at New or Full Moon. The length L of the synodic month is approximated by 29 days + G + J, where G is the contribution due to the varying lunar velocity, while J gives the solar contribution. K gives the time of conjunction (or opposition) with respect to sunset; and, finally, Column P contains the calculated value of NA_1 and the day on which it occurs.

Column C approximates the actual length of daytime with a "sine-like" curve. The lengths of daytime and nighttime equal the rising—and setting—time of the arc on the zodiacal circle between $\lambda_{\odot}°$ and $(\lambda_{\odot} + 180°)$; therefore, they are connected to rising-times of arcs on the zodiacal circle. By means of Babylonian methods, these can be found easily from the partial sums of the Lunar Four, ME + GE_6 or ŠÚ + NA, which were observed and collected regularly.

7 Some Complications

In System A, all functions accounting for the lunar velocity were derived from the numerical function recorded in the second Column Φ. Also of interest is a series of variable time-intervals that were also recorded in System A: time-intervals at 1, 6, and 12 synodic months. These time-intervals depend on the velocities of the Sun and Moon, and the Babylonians calculated them, correctly, as a sum of two terms: one depending only on the solar velocity and the other only on the lunar anomaly.[8] The solar component was deduced from Column B, while the lunar component was derived from Column Φ.

The burning questions are how the Babylonians were able to separate lunar and solar anomaly on the basis of their observed data and how Φ was derived from observations. Column Φ can be interpreted as the lunar contribution to the length of the Saros, a cycle of 223 lunar months. I have called its duration $\Delta^{223}t$, indicating that it is the difference in time between the beginnings of 2 months, situated 223 months apart. In the case of $\Delta^{223}t$, it is the solar contribution that dominates. Observed values of $\Delta^{223}t$ vary with the period of the year and not with the period of the lunar velocity, but no Babylonian estimate for the solar contribution had yet been found. Without that, Φ cannot be derived from observations of, for example, eclipses situated some *n* Saroses apart [Brack-Bernsen 1980].

Some other lunar observations must have been used: this is why, in my own research, I have focused on the Lunar Six time-intervals, because they incorporate the lunar velocity and investigated whether it is possible to find the period of Φ from the Lunar Six. It turns out that the sum of the Lunar Four, Σ = ŠÚ + NA

8 The amplitudes of the two variables, that is, the differences between their highest and lowest values, were well determined in all cases. See Brack-Bernsen 1980. A modern mathematical analysis of interference patterns resulting from the superposition of two periodic functions with slightly different periods, here $P_{\odot}$ and $P_{☾}$, shows how to separate the two dependences graphically.

+ ME + GE_6, indeed, oscillates with the period P_Φ of Φ. Each of the partial sums, ŠÚ + NA or ME + GE_6, oscillates in tune with the year. The reason is that they measure the setting- and rising-times, respectively, of the Moon's movement relative to the Sun within one day. Such rising- and setting-times depend heavily on the momentary angle of the zodiacal circle at the eastern and western horizons, respectively.

This dependence is reduced effectively by adding the two, so that their sum Σ oscillates in tune with the lunar velocity and, hence, with Φ. The function Σ is quite noisy (i.e., it exhibits an irregular pattern) but it repeats nicely after 1 Saros; and the linear zigzag-function Ẑ, which approximates it, has the same period, amplitude, and phase as Φ. This has led to the hypothesis that the numerical function Φ was derived empirically from the sum Σ of the Lunar Four. In the meantime, a function giving the solar contribution to the Saros has been found [Brack-Bernsen and Hunger 2002, 80–85; Brack-Bernsen and Steele 2005]. Thus, on this basis, the former identification of Φ as the lunar contribution to $\Delta^{223}t$ can now be accepted. The question still is, however, how Column Φ was constructed and how it still holds that the period P_Φ, which equals the period of the lunar velocity, was derived from horizon observations of the Lunar Four.

Britton worked intensively with the astronomy of the texts in Neugebauer 1955 and presented his reconstruction of the lunar systems in two major papers [2007b, 2009]. His starting-point was two ancient cycles, the Saros (= 223 months) and the 19-year calendar cycle (= 235 months). He suggested that System A was the work of one very clever author who, in addition to the ancient cycles, assembled the following empirical elements necessary for the construction of System A functions:

– an accurate anomalistic period-relation,
– estimates of the extremes and amplitudes of key eclipse-intervals, and
– an improved estimate of the length of the mean synodic month.

The next and crucial theoretical step consisted in building a mathematical model of the amplitude of 235 months in units equal to the change over 223 months due to lunar anomaly in the length of 223 months [Britton 2007b, 86].

In order to derive the different values for the length of the year, implicitly given by period-relations of Systems A and B, Britton postulated that the Babylonians used the positions of the Moon with respect to Normal Stars observed at eclipses. Well-chosen eclipses that had taken place 334, 335, and 804 months apart could lead to the estimate that after 19 years, the position of the Moon with respect to the Normal Stars would be shifted by 0;15° = ¼. This insight implies that:

(1) the variation of 235 months was due solely to lunar anomaly (uniquely among intervals bounded by eclipses), and
(2) the sidereal year was of 12;22,8 months, the period of Column B in System A.

In order to reconstruct the exact parameters of those functions accounting for the variable lunar velocity, Britton started with simple period-relations between synodic months m and anomalistic months m_a: $14m = 15m_a$ or $223m = 239m_a$. The Babylonians may have recognized that these were only approximate and so tried to find more accurate relations of the form $14k - 1m = 15k - 1m_a$. In order to determine k, Britton analyzed Lunar Four data and utilized the mean values of their sum Σ taken over 7 months and got the estimate: $17.85 < k < 18.25$. The value of k determined as 17;55,12 leads to the period-relation of Column Φ in System A, while $k = 18$ gives the period-relation of F in System B.

In his reconstruction, Britton then determined extremes and amplitudes of the following time-intervals: 6, 12, 223, and 235 synodic months, which all occur as intervals between lunar eclipses. To this end, Britton utilized computer-simulated observations of times and positions of the eclipses arranged according to the Saros-scheme mentioned above. In Britton 2009, the reconstruction of how the effects of lunar and solar anomaly were separated was based on one crucial insight: that the variation of the 235-month eclipse-interval is solely due to lunar anomaly. Its amplitude can be found from Britton's Saros-scheme, whereby the amplitudes of 223 and 12 months could be deduced by an elegant mathematical model.

Britton was right in his insistence that Column Φ is closely connected to lunar eclipses, and his reconstruction is one possibility. I would prefer a reconstruction that grows directly out of the Goal-Year method and proceeds without our heavy tool of algebraic notation.

That the numerical functions giving the length $\Delta^{235}t$ of 235 months show nice symmetries may simply be the result of the way they can be constructed from two versions R and S of Φ. We still do not know which kind of concept or what consideration determined the use of versions R and S of Φ, shifted by 1, 6, or 12 months, respectively, in order to find the lunar component of $\Delta^{1}t$, $\Delta^{6}t$, and $\Delta^{12}t$. Britton's reconstruction is based heavily on the structure of the Saros-scheme into which quite accurate times of the EPs are added.

Two questions arise: Did the Babylonians have access to such a complete list of timed eclipses? and, if so, How did they know which special eclipses, situated far apart, they should pick in order to determine their parameters? Ptolemy approached the problem in that way but it is not evident that the Babylonians did. We still do not know with any certainty how all the columns associated with lunar velocity were developed. A method more closely related to the Goal-Year method, which is applicable to every month, seems to be preferable from a historical standpoint. This method was used by the Babylonians and it automatically gave them a means of comparing Lunar Six values of each syzygy with that of 1 Saros earlier.

8 Conclusion

Some years ago, Otto Neugebauer wrote:

> For the cuneiform ephemerides we can penetrate the astronomical significance of the individual steps, as one may expect with any sufficiently complex mathematical structure. But we have no concept of the arguments, mathematical as well as astronomical, which guided the inventors of these procedures.
>
> NEUGEBAUER 1975, 348

Much has been achieved since that time. Aaboe and Swerdlow have shown how the planetary schemes can be reconstructed from Babylonian observations. Hunger has in six volumes edited the astronomical Diaries and related texts, so that we now have all the Babylonian observations which have survived on cuneiform tablets at our disposal. The edition by Roughton, Walker, and Steele of a text on Normal Stars has given us insight into how observed positions of the Moon and the planets with respect to Normal Stars could be transferred into positions in the zodiacal circle. This means that Babylonians had many more accurate planetary positions at their disposal than just the location given by zodiacal sign in the Diaries. We understand now how the movement of the Moon through the zodiacal band was surveyed by means of Normal Stars, and Ossendrijver's edition of procedure-texts includes many insights. There has also been progress in the reconstruction of Babylonian lunar theory. Britton has shown how one could construct many period-relations and numerical functions using Babylonian lunar data. His analyses have brought new insight as well. Still, I remain convinced that we have not yet found the final solution. The insight that observed eclipses could not be used for the construction of column Φ has led me to concentrate on the only other Babylonian observations which contain information on lunar velocity, the Lunar Six time-intervals, which until then had not been investigated. This has proved very fruitful. All reconstructions of column Φ and F are in a crucial step based on the sum Σ. But more important is that the research on Lunar Six has led to the discovery of the Goal-Year method and the edition of the early procedure-text TU11 containing many rules for prediction. These give us insight into the methods, empirical knowledge, and astronomical concepts that guided the Babylonian scribes in developing their astronomy.

CHAPTER 5.2

Experience and Observation in Hellenistic Astronomy

Richard L. Kremer

1 Introduction

Was Hellenistic Greek astronomy an empirical science? This depends, of course, on what we mean by "astronomy", "empirical", and "science". In one of the earliest classical texts, Hesiod (*ca* 700 BCE) wrote:

> At the rising of the Atlas-born Pleiades,
> Begin the harvest, and you should plough when they set.
> …
> Fifty days after the solstice,
> at the arrival of the end of the season of weary heat,
> that is the time for mortals to sail…
> Then are the winds orderly and the sea propitious.
>
> LEHOUX 2007, 5, 6

Hesiod knew about cyclically recurrent patterns visible in the sky, the seasons, the Sun's movement as it rises and sets along the horizon over the course of the year—he may have coined the phrase "turning of the Sun", which Latin writers rendered by "solstitia" and we designate by "solstice" [*Op*. 479, 564, 663]—the annual risings and settings of named stars[1] (i.e., the dates on which they rise just before sunrise or set just after sunset), and the lunar phases. And he knew about terrestrial events regularly correlated with the recurrent celestial patterns marking out the year. This knowledge appears to be empirical, quantitative (to a granularity of days), predictive, and even prescriptive. Hesiod does not explain, however, why the patterns occur or how he acquired knowledge of them. Does his poem *Works and Days* suggest the existence of an astronomy or an empirical science in seventh-century Greece?

1 Hesiod's names for certain stars and catasterisms—Arcturus, Sirius, Orion, the Bear, the Pleiades, the Hyades—are among the earliest attested in Greek. See Lorimer 1951.

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Rather than answering such questions directly, I will here briefly survey Hellenistic Greek astronomical texts, starting late in the fourth century. We will look for knowledge presented as if it had been acquired *via* sensory experience and will consider the roles played by this knowledge in the elaboration of astronomical systems. Our goal is not to fit that astronomy into a taxonomy driven by today's philosophy of science or by assumptions about monolithic cultural traditions. And our goal is not to claim that Hellenistic Greek astronomical theory had its sole foundation in empirical observation and measurement [Goldstein and Bowen 1983; Bowen and Goldstein 1988].

2 Frames of Reference

Naming and mapping the stars and constellations was a complex cultural process, the development of which has provoked considerable discussion among modern scholars. Experience and observation contributed to, but certainly did not exhaust, this process.

Babylonian constellations are known from a variety of of types of cuneiform texts: star-lists, early Babylonian astronomical texts, such as the "Astrolabe" [Horowitz 2014] and MUL.APIN [Hunger and Pingree 1989], divinatory or celestial omen-texts, and Late Babylonian astronomical texts such as the ephemerides and the Diaries. Recorded in lists of star-names such as in the so-called *Three Stars Each* tablets, the Mesopotamian constellations presented stars as visual images, not as coordinates in a geometrical scheme. Quantitative data appear first in MUL.APIN (*ca* 1000 BCE) as dates of the heliacal risings of the constellations [Rogers 1998: see chs 2 §3, p. 29; 6.3, p. 240].

The Babylonian zodiacal constellations and four additional animal-shaped constellations were adapted into the Greek sky that eventually would be comprised of 48 constellations. By considering precession [see Glossary, p. 648] and the southern limits of the Greek constellations, some historians have suggested that the 32 non-Babylonian Greek constellations were invented at a particular time and place, i.e., that the system was designed according to a single plan. Most historians of astronomy, however, favor what Frank [2015] has called a gradualist model in which various ancient cultures organized bits and pieces of the nighttime sky in an unplanned evolution stretching over centuries. In naming stars and constellations, realizing that they move together through the night sky from the east to the west, and noticing that different groups of stars become visible over the course of the year, the early Greek constellation-makers surely combined direct observations, received traditions, and various cultural assumptions about the cosmos.

Around 270 BCE, the king of Macedonia asked Aratus of Soli to write a summary of the *Phaenomena* of Eudoxus of Cnidos, a text in prose that was composed a century earlier [see ch. 10.1, p. 383]. Eudoxus' text is now lost. Aratus' *Phaenomena*, a poem in the dactylic hexameter of Homer, is the oldest surviving description in Greek of the constellations. Combining stories and legends with descriptions of figures defined by stars, Aratus presented 48 constellations, probably a synthesis of material gathered at least by the fifth century, and described their risings and settings.[2] Most striking is his organization of those constellations on the celestial sphere. Eudoxus' spherical cosmos is that of the Greek philosophers, starting perhaps with Parmenides and canonized by Plato and Aristotle. Aratus located the constellations qualitatively with respect to the zodiacal circle, tropical circles, and the celestial equator and pole.

> Day in, day out, innumerable mixed
> And scattered stars process above us. Fixed
> Forever, never bending, an axle pins
> Earth in the center of all; around it spins
> Heaven on opposing poles, the axle's ends.
> Though one cannot be seen, the other extends
> Over the north.
>
> ARATUS, *Phaen.* 19–24: POOCHIGIAN 2010, 1

Eudoxus' placement of the constellations relative to the equator accords with an epoch around 2000 BCE. Although the sources for this much earlier placement remain unclear, it seems obvious that neither Eudoxus nor Aratus relied simply on their own observations to situate the constellations on the sphere.[3]

The earliest known set of quantitative Greek stellar observations date from slightly before Aratus. Attributed to Timocharis, Aristyllus, and the "school of Timocharis" in Alexandria, these data were known to Hipparchus and used by Ptolemy to confirm Hipparchus' rate for precession [see chs 1 §7, p. 22; 6.3 §2.4,

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2 Aratus himself offered an etiology for the constellations, even as he included conflicting versions of some of the myths, implying a distrust of stories about origins.

> Some one of those no longer living found
> A way to lump stars generally and call
> A group one name…he devised a frame for clustered stars…
> And thus the heavens were marshaled into order. [*Phaen.* 384–392: Poochigian 2010, xx–xxi]

3 See Proctor 1877, 339: cf. Roy 1984, who speculates that Eudoxus had borrowed his data from a Minoan star-globe prepared *ca* 2000 BCE as a navigational tool for sailors. No such Minoan star-globe, however, is extant.

p. 243]. The reported observations include four lunar occultations with dates (295 to 283 BCE) and times (seasonal hours) with no positions specified, and 18 undated stellar declinations, all recorded by Ptolemy [*Alm.* 7.3] to thirds, fourths, fifths, or sixths of a degree. Timocharis and his school presumably did not know about precession; the Greek lunar theory known in the third century was inadequate; and no instrument for measuring angles is attested in archaeological or in literary records dating to that century. So how did Timocharis and his school make these measurements and why?

We may dismiss the suggestion that Hipparchus invented these data to strengthen his claim about precession. If we analyze Timocharis' and Aristyllus' measured declinations for 281 BCE and drop one outlier (α Boö), the errors scatter randomly between ±12′ of arc (correlated neither with declination nor right ascension) and their average error is less than a minute from the geographical latitude of today's Alexandria (31; 07°N).[4] The standard deviation in the errors is about 8′ of arc. Goldstein and Bowen have wondered whether these observers may have used a circle divided to degrees, set in the meridian, to measure these declinations. Yet, no archaeological evidence exists for such a device in the third century. The Antikythera Mechanism [see ch. 9.2, p. 340] does contain disks divided to degrees [Carman and Evans 2014] but not until Heron of Alexandria (first century CE) do we find a literary description of a device for measuring angles, the *dioptra* [see chs 6.1 §2, p. 222 and §11, p. 229; 6.4 §8, p. 256], that could have measured declinations, as Goldstein and Bowen have noted. Just as the Antikythera Mechanism suggests the existence of a sophisticated metalworking craft and acquaintance with astronomical theory, so too do Timocharis' and Aristyllus' observations of declinations imply the existence of a group of Alexandrian skywatchers who had learned to measure angles in the sky to a precision of 8′ of arc (about ¼ the apparent width of the Moon).

Noting that Ptolemy's reports of the occultations are written in the literary style of Babylonian materials, Goldstein and Bowen [1989, 1991] have speculated that Timocharis and Aristyllus were perhaps seeking to establish period-relations like those of Babylonian astronomy, in this case, the length of the sidereal month. Jones, on the other hand, doubts that the Alexandrians would have been measuring periodicities since they lacked "a body of significantly older observations" against which to compare their own observations; they may rather have been engaged in a "programme of recording a wide range of phenomena analogous to the Babylonian one" [Jones 2006c, 276–278]. Goldstein

4 For a similar analysis, using the minimum standard deviation to date Timocharis' observations to 291 BCE and Aristyllus' to 261 BCE, see Maeyama 1984, 290.

and Bowen further considered whether the Alexandrians measured the 18 stellar declinations in order to locate stars and the constellations on the celestial sphere as had Aratus and Eudoxus. Yet mapping stars requires two measured coordinates, not just declinations. Goldstein and Bowen thus suggested that Timocharis might have measured arc distances between pairs of stars for the second coordinate, data that Ptolemy (and perhaps Hipparchus before him) dropped as irrelevant to the question of determining the rate of precession [1991, 98].

A simpler explanation might be that Timocharis and Aristyllus were interested only in declinations because such lists could be used in conjunction with local observations of the same stars to map terrestrial latitudes. Timocharis' and Aristyllus' 18 stars include 7 of the 15 brightest stars that Ptolemy would designate as first magnitude; their remaining 11 stars are second magnitude in Ptolemy's catalog [*Alm.* cc. 7–8].[5] Their stars extend across the sky from 40° to 270° in right ascension and from −18° to 68° in declination and distribute fairly uniformly across that space. Interestingly, the earliest extended Greek description of the coasts of the Mediterranean and Black Seas dates from the end of the fourth century BCE. This text reports distances in stades or days' voyages; it does not employ concepts like latitude and was intended less as a work of cartography than as a descriptive geography. However, the traveler Pytheas of Massalia, writing about the same time (*ca* 330 BCE), did record the elevations of the Sun at the solstices (measured with a gnomon) and the lengths of longest daytimes, suggesting knowledge of parallels of latitude. Perhaps Timocharis and Aristyllus measured stellar declinations to contribute to a terrestrial cartography?[6]

A century and a half later, Hipparchus wrote his commentary on the *Phaenomena* of Eudoxus and of Aratus, a commentary that has survived. Hipparchus [Manitius 1894, 1.5–6] criticizes both for their erroneous epoch, justifying his intervention as an empirically driven corrective.

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5 One star described by Timocharis as "middle of the Pleiades" (η Tau) does not appear in Ptolemy's catalog. Four of the first magnitude stars in Ptolemy's catalog, which were not observed by Timocharis and Aristyllus, have declinations exceeding −40°, well south of the swatch of sky containing the stars of Timocharis and Aristyllus; the remaining four of Ptolemy's bright stars also missing in their observations span that swatch, viz. β Ori, α CMi, β Leo, and α Lyr.

6 See Shipley 2011; Dicks 1970, 180, 185–187; Aujac 1987, 150–151. Note that around 300 BCE Timocharis' and Aristyllus' stars would have been highest in the Mediterranean sky from November through June. If they had measured the declinations for cartographic purposes, we might wonder why they included none of the stars that would have been prominent in the late summer sky.

> Since my reading of Aratus reveals in most and the most important points contradictions between the data recorded there and the phenomena and the actual celestial constellations, while the other interpreters, even Attalus, seem to recognize them without hesitation as valid, I have decided, for the satisfaction of your desire for knowledge and for the general benefit of others, to discuss everything that I consider to be incorrect in a special treatise.... My intention is...to prevent you and all others desirous of knowledge from uncritically taking over ideas which are incompatible with the scientific conception [θεωρία] of the phenomena of the cosmos.
>
> GRAßHOFF 1990, 52

With Hipparchus we find an elaborate, cartographic interest in the stars. Using the zodiacal circle to map positions to a precision of ½° and defining phenomena for the horizon of Rhodes, Hipparchus listed the degrees of the zodiacal circle (divided into 12 equal signs) that rise and culminate simultaneously with the rising of the easternmost and westernmost stars of each constellation. At the end of his text, Hipparchus named stars near each of the 24 hour-circles (i.e., at equal right ascensions) that could be used, he indicated, for telling time at night, marking the times of eclipses, and "other astronomical observations". Hipparchus nowhere specified longitudes for the stars that he described, preferring equatorial or mixed coordinates [see ch. 1 §4.2, p. 17]. But he did, for the first time, define longitude, counting degrees from the vernal equinox.

From these data, Heinrich Vogt in 1925 was able to construct pairs of "Hipparchan" coordinates for 122 stars and to sort their dates of observation into several groups, ranging from 157 to 131 BCE [Graßhoff 1990, 53–66, 117–121]. Hipparchus' commentary thus provides the earliest set in Greek of systematically measured stellar positions, quantitatively located on a coordinate system and neither copied nor updated from earlier sources.[7] Writing a century later, Pliny [*Nat. hist.* 2.95] described Hipparchus' contribution as follows:

> ...he did a bold thing, that would be reprehensible even for God—he dared to...tick off the heavenly bodies by name in a list, devising instruments [*organa*] by means of which to indicate their several positions and magnitudes, in order that from that time onward it might be possible easily to discern not only whether stars perish and are born but whether

7 For a list preserved in a single manuscript written in 1431 of 68 stellar longitudes that date to Hipparchus' time and are recorded to a precision of degrees, see Neugebauer 1969, 68–69; Graßhoff 1990, 67–72; Hübner 1995b.

> some are in transit and in motion, and also whether they increase and decrease in magnitude—thus bequeathing the heavens as a legacy to all mankind, supposing anybody has been found to claim that inheritance.
>
> RACKHAM 1949, 1.238–239: cf. JONES 1991c, 148

The 48 Greek constellations would receive their fullest elaboration in the *Almagest*, where they are presented in a list of magnitudes, longitudes, and latitudes for the individual stars, to a precision of ⅙° or ¼°. Using an astrolabe, an armillary instrument that he describes in considerable detail,[8] Ptolemy tells his readers that "we observed as many stars as we could sight down to the sixth magnitude" [*Alm.* 7.4]. He also indicates that he used zodiacal or ecliptical coordinates [see ch. 1 §4.1, p. 16] so that, with precession, latitudes would remain unchanged over time [see chs 1 §7, p. 22; 6.3 §2.4, p. 243]. To prove that stars remain fixed with respect to each other over time, he compared several dozen of his own straight-line alignments among stars, observed presumably by stretching a string between one's hands, with similar observations attributed to Hipparchus in a text no longer extant. Ptolemy concluded:

> If one were to match the above alignments against the diagrams forming the constellations on Hipparchus' celestial globe, he would find that the positions of the [relevant stars] on the globe…are very nearly the same as at present.
>
> *Alm.* 7.1

Ptolemy thus presented the fixity of stellar positions as an empirical fact, tested across a span of roughly 260 years.

To confirm Hipparchus' value for precession of 1° in 100 years, Ptolemy quoted from another now lost text by Hipparchus, comparing his measurements of the longitude of Spica (in degrees) with those by Timocharis 160 years earlier. To buttress this claim, Ptolemy analyzed eight observations of lunar occultations of stars (i.e., their dates and times, usually listed to the nearest hour) recorded by Timocharis of Alexandria (291 BCE), Hipparchus (129 BCE), Agrippa of Bithynia (92 CE), and Menelaus of Rome (98 CE). For each, Ptolemy computed a stellar declination (based on his lunar theory), compared a star's movement over periods ranging from 12 to 391 years between pairs of observations, and found in each case a movement of the celestial sphere against the equinoxes of 1° in 100 years. From these comparisons Ptolemy concluded: "we

8 The classic study of Ptolemy's instrument remains Rome 1927. See ch. 6.4 §5, p. 250.

have confirmed that the sphere of the fixed stars…has a movement toward the rear with respect to the solstitial and equinoctial points" rotating around the poles of the zodiacal circle [*Alm.* 7.4]. Ptolemy's language is unambiguous; he presents his knowledge of the stellar coordinates and precession as empirical, derived from his own observations and those of his predecessors. Yet the empirical content of those coordinates is derived from the robustness of Ptolemaic lunar theory.

Ptolemy's star-catalog with its rhetoric of empiricism quickly became canonical in the later Greco-Roman world and, by the ninth century, in the Arabic world as well [see ch. 6.3, p. 240]. Not until Tycho Brahe's discovery that Ptolemy's stellar longitudes are systematically too small by 1° would the star-catalog begin to face critical scrutiny. The astronomers J.-J. Lalande (1764) and J. B. Delambre (1821) suggested that Ptolemy had copied Hipparchus' positions rather than observing them independently, a charge that has been vigorously debated over the past century. We need not enter this debate here beyond indicating that most historians now agree that Ptolemy greatly exaggerated the independence of his stellar positions.[9] Nonetheless, most would agree that both the Babylonian and Greek astronomers experienced the starry sky as patterned into constellations, that Hipparchus and Ptolemy added quantitative precision not only in naming but also in locating stars on the celestial sphere by degrees in a coordinate system,[10] and that by comparing quantitative observations, made at widely separated time-intervals, Hipparchus discovered the phenomenon of precession. Those stars, mapped in zodiacal coordinates, would provide the spatial frame for subsequent astronomy.

Some, but not all, of this knowledge was observational. Some of the instruments and procedures developed also found application in terrestrial cartography. Although stars did not feature as prominently in horoscopic astrology as did the planets and the major luminaries [but see Evans and Berggren 2006, 125–136], stars nonetheless became part of Hellenistic Greek and Roman predictive practices, to be considered in our next section.

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9 Cf. Kunitzsch 1975, 9–27; Newton 1977; Maeyama 1984; Graßhoff 1990; Swerdlow 1992; Britton 1992, 77–98; Jones 2005a.

10 Ptolemy in his *Geography*, of course, also presented coordinates of latitude and longitude for every location that he assembled for the known world, thereby enabling readers to create their own maps. See, most recently, Berggren and Jones 2000.

TABLE 1 Lines from the Miletus-*parapegma*

● Capella sets acronychally according to both Philippus and the Egyptians.
● Capella sets in the evening according to the Indian Callaneus. ●
● Aquila rises in the evening according to Euctemon.
● Arcturus sets in the morning and there is a change in the weather according to Euctemon. ● On this day Aquila rises in the evening also, according to Philippus.

LEHOUX 2007, 155 (PHOTOGRAPH), 225

3 Correlating Weather and the Heavens

Stars have significance beyond their names or their spatial positions mapped onto the celestial sphere. They also have temporal dimensions: although fixed in space with respect to each other, their visibility in the nighttime sky shifts over the course of the seasons. In this sense, stars, like the Moon, have phases. To mark these passages, early Greek star watchers began making and using *parapegmata*, physical artifacts that track cyclical phenomena by means of a moveable peg that can be fitted at regular time-intervals into a sequence of holes in a tablet of marble, sandstone, clay, wood, and the like. Pegs could track phenomena such as days of the week, seasonal weather-patterns, entry into zodiacal signs, and phases of the Moon or the fixed stars. *Parapegmata* are also preserved in literary form, often combined with agricultural texts, wherein solar calendars replace the physical holes. The first *parapegma* to be found, a stone fragment excavated in 1902 in Miletus, displays holes (●) and an inscribed text formatted as shown in Table 1. This tablet, dated to 111 BCE, links days, stellar phases, and weather and cites its sources. The longest and most detailed *parapegma* known is Ptolemy's *Phaseis* [Lehoux 2007, 261–309]. Nearly 60 *parapegmata* are extant, dating from the fifth century BCE into the Latin Middle Ages. We have here, writes their modern cataloger, "a tradition that would have been familiar to pretty much anyone in Antiquity, from poets to farmers, and from scholars to sailors" [Lehoux 2004, 230].

Parapegmata embed a type of empirical knowledge that Bowen and Goldstein have called "data of common lore, that unscientific repository of local experience and convention" [1988, 56]. Lehoux has distinguished two types of such knowledge that he calls foundational and practical. As in the example quoted above, many *parapegmata* justify correlations between stellar phases and weather by appeal to earlier authorities.[11] But how did those authorities acquire this information? Rather than making discrete observations of a heliacal rising and weather on a given date, the authorities, Lehoux conjectures, had first schematized the annual sequence of stellar phases for their latitude (i.e., established a foundational stellar calendar). At some later point, they loosely slotted experienced meteorological events, Lehoux's practical knowledge, into this sequence. Making *parapegmata* would thus have been an empirical but not necessarily a precisely observational process with discrete, dated records. Lehoux also emphasized that using a *parapegma* did not entail direct observation of celestial phenomena. To extract a weather prediction, one need not look at the sky but only at the position of the peg on the tablet, presuming that it had been properly advanced each day. Yet if no other calendars were available, a user would have to observe a given stellar phase to know how to set the peg initially, i.e., to calibrate the mechanism.[12]

The logical structure of the *parapegmata*, viz. the correlations that could be expressed as "if-then" conditional clauses, is similar to that found in the earlier Mesopotamian omen literature. For example, in a Jupiter omen of *Enūma Anu Enlil*, we have: "If Jupiter becomes steady in the morning, enemy kings will become reconciled" [Reiner and Pingree 2005, 40.1]. Although a literal reader might find here two correlated events, Rochberg has argued that this omen derives from a semantic analogy between the protasis (Jupiter as Marduk's star denotes rulership and stability) and the apodosis (peace among rulers). Other Akkadian omens work from literary allusions, onomatopoeia, or logical exhaustion (e.g., celestial bodies in evening/midnight/morning, in East/West/North/South) [Rochberg 2010a]. In turns out that in both the *parapegmata* and the Babylonian omens, many of the astronomical protases are schematic or "theoretical": they are not empirical claims grounded in particular, dated observations. And whether such predictions were ever tested or whether the testing of predicted knowledge by observation was an epistemic value for the science of this period is, of course, unlikely.

On the other hand, many of the apodoses in the *parapegmata* are phrased as discrete, empirical phenomena. Ptolemy's *Phaseis* predicts, for example, "east winds blowing", "mist and burning heat", "bad air and rainy at sea", "west wind

11 For example, in the *Phaseis*, Ptolemy's cited sources include Dositheus, Philip, Callippus, Euctemon, Meton, Conon, Metrodorus, Eudoxus, Caesar, Democritus, Hipparchus, and "the Egyptians". See Lehoux 2007, 261–309.

12 Lehoux 2007, 55–64. Lehoux's claim that "observation is basically superfluous in the day-to-day use of a *parapegma*" [64] ignores the question of how a peg is initially placed in the tablet.

or south wind", or the more generic "change in the weather" [*Phaseis* 283–285]. Geminus, who may have authored a *parapegma* himself in the first century BCE, explained the origin of the *parapegma* as follows:

> The predictions from the weather signs that occur in the *parapegmata* are not [made] from particular, definite precepts, nor are they treated methodically by a particular science, nor do they involve a necessary result. Rather, taking whatever was concordant from that which generally arises through daily observation, they inserted it in the *parapegmata*. The compilation and observation came about in this way: They took the beginning of the year, having observed in which sign the Sun started at the beginning of the year, they recorded against the degree [of each zodiacal sign], day by day and month by month, the important changes that occurred in the air, winds, rains, and hail; and they placed these beside the positions of the Sun reckoned by sign and by degree. Having observed these things for more years, they recorded in the *parapegmata* the changes that occur *for the most part* around the same places of the [zodiacal circle], not taking the record from any particular science or from a definite method, but rather taking from experience whatever accorded most closely.
>
> *Intro. ast.* 17.6–8: EVANS and BERGGREN 2006, 218

For Geminus, the weather signs were empirical but not "scientific". They were not an art undergirded by rules or principles, a τέχνη wielded by experts:

> The weather signs in the *parapegmata*…have been recorded in a general way, not treated by a particular science or compelling method, but rather recorded from continuous observation. This is why they are often wrong. Therefore one should not reproach the astronomers if they miss the mark with the weather signs. If one is wrong in foretelling an eclipse or the heliacal rising of a star, then…the practitioner…will with good reason be deemed worthy of reproach. For all that is treated methodically by means of science [τέχνη] is bound to have a decision free of error. But matters connected with weather signs give grounds neither for praise when they succeed…nor for reproach when they miss the mark. For this particular part of astronomy is not scientific (ἄτεχνον)….
>
> GEMINUS, *Intro. ast.* 17.23–25: EVANS and BERGGREN 2006, 221–222

The *parapegma* thus combined a conditional, if-then correlation between celestial and terrestrial phenomena with a calendar and a lived experience of weather through the seasons (Bowen's and Goldstein's common lore). Experience and observation must have informed the making of *parapegmata*. Indeed, as Geminus would have it, they would inform a *parapegma* grounded in the natural causes of changes in the air, where the actions and effects of these causes are correlated with "signs given to us by nature" [*Intro. ast.* 17.45–49; Evans and Berggren 2006, 225–226].

4 "Scientific" Observations of the Sun, Moon, and Eclipses

We turn next to discrete observations of the positions of the Sun and Moon at particular dates and times, and to the way in which such data were represented by Greek astronomers.[13] Like the star-catalogs, our sources here are problematic. Few unmediated "observational records" have survived. Authors reporting on their predecessors are difficult to interpret without knowing something about their generally unspecified practices of citation and their views of "observation" in astronomy.[14] In many texts, we may learn more about rhetorical practices than about observational techniques, data, or data reduction, to use modern descriptive terms.

Neugebauer [1975, 615–674] divided early Greek astronomy of the luminaries into five types of phenomena:

(1) lunisolar cycles;
(2) solar theory, length of the seasons, and the displacement of the equinoxes and solstices with respect to the stars;
(3) sizes and distances of the luminaries;
(4) eclipses;
(5) "steps".[15]

In each case, empirical information fed into the development of what Neugebauer simply called a "theory" or what Jones more neutrally has called a "scheme". And in each case, the aim was to generate predictions, although the precision of their expression could vary considerably.[16]

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13 I ignore here eclipse-reports preserved in non-scientific texts: see Bowen and Goldstein 1988, 40.

14 For one end of the interpretative spectrum, see Goldstein 1997, 1:

> As a matter of principle, I do not simply take authors as reliable in reporting on their predecessors without strong corroborating testimony from sources contemporary with those predecessors.... I consider this principle valid for all historical periods....

15 These are a late development that I shall ignore here.

16 Babylonian astronomical theory, of course, similarly interacted with empirical information. See ch. 5.1, p. 171.

It was once thought that the fifth-century Athenian Meton was "the first Greek of whom one could say with certainty that he undertook serious astronomical observations" [Toomer 1981b, 338]. No texts by Meton are extant. So, what can we say about his astronomical efforts? First, several Greek authors associate him with the introduction of the 19-year lunisolar cycle, that now bears his name. He probably borrowed the basic relation (19 years = 235 synodic months) from Babylonian sources; but unlike the latter, Meton's cycle was said to have specified its length as 6940 days. Yet this day-count could well have been derived from assumptions about the lengths of the months, not new observational data.[17] Second, Ptolemy [*Alm.* 3.1] and several others explicitly attribute to Meton an observation of the date of summer solstice in 432 BCE, the epoch of his first 19-year cycle. The Athenian historian Philochorus, in a witty commentary on Aristophanes' play, the *Birds*, suggests that Meton had erected an instrument (*heliotropion*), some type of sundial, on the hill of the Pnyx, presumably to detect solstices.[18] However, Meton's date for the solstice is in error by more than a day. Bowen and Goldstein [1988, 64–72] have suggested that Hipparchus might have calculated this date or that Meton could have extracted it from his Babylonian sources. Archaeologists have debated what Meton's *heliotropion* might have been, and Bowen and Goldstein [1988, 74] have further suggested that it may have been used to mark an alignment against the horizon once a date already was known, i.e., to calibrate pegs in a *parapegma*.[19] Finally, a fragmentary text from the second century BCE records the unequal lengths of the seasons (in days) as determined by Euctemon (usually linked to Meton, whose name is not mentioned), Eudoxus, Democritus, and Callippus [Blass 1887, 25]. The text says nothing about observation and Bowen and Goldstein [1988, 59–61] have noted that differing seasonal lengths might have been modeled on the Babylonian System A, which has the Sun moving at different velocities in different parts of the zodiacal circle. Hence, although Meton need not have made direct observations to obtain the astro-

17 Geminus, *Intro. ast.* 8.51, indicates the number of days but does not associate Meton with the cycle. See Evans and Berggren 2006, 183–184. For conjecture that the Babylonians or Meton could have computed the 19-year cycle as 6940 days, see Bowen and Goldstein 1988, 50–51.

18 For details, see Jacoby 1923–1958, *s.v.* Philochoros of Athens fr. 122. Aristophanes makes fun of Meton, having him wear effeminate clothes and measure out, with some elaborate geometrical instrument, a star-shaped city in the air. In the *Birds*, Meton "fit…the comic stereotype of the arrogant intellectual" [Dunbar 1995, 551]. See Sommerstein 1987, 120–125.

19 Lehoux 2007, 90–97, 212–213, is not convinced that Meton (or the associated Euctemon) ever developed a *parapegma*.

nomical knowledge attributed to him, Greek and Roman authors frequently did associate him with quantitative information that could be understood as empirically derived.

The next solstice listed in *Alm.* 3.1, also borrowed from Hipparchus, was observed in 280 BCE by "the school of Aristarchus" (in the next paragraph, Ptolemy mentions only Aristarchus). Ptolemy provides only the year, not a day or time, for this observation. Goldstein and Bowen again doubt the authenticity of this report, wondering whether Hipparchus himself may have computed the date [1991, 122]. Better attested is Aristarchus' determination of the relative sizes and distances of the Sun and the Moon, another of Neugebauer's basic phenomena for Hellenistic astronomy of the luminaries. In his treatise, Aristarchus offers several geometrical constructions using Euclidian propositions and techniques of proof to show how the sizes and distances can be computed from three empirical "measurements": the elongation of the bisected Moon from the Sun, the apparent lunar and solar angular diameters during a solar eclipse, and the ratio of the width of the Earth's shadow cone at lunar distance to the lunar diameter during a lunar eclipse [Heath 1913; Neugebauer 1975, 642–643; van Helden 1985, 5–9]. Scholars generally have assumed, however, that Aristarchus selected convenient numbers for these empirical inputs. Aristarchus, like Meton, probably made no "precise" measurements.[20]

Hipparchus, who developed the first Greek solar theory is an astronomical observer for whom we must rely on Ptolemy for reports of those activities. *Alm.* 3.1 attributes 24 observed times of solstices or equinoxes to Hipparchus, for dates ranging from 162 to 128 BCE. Britton, who has carefully studied these times, argues that they were derived from midday solar altitudes measured with a meridian circle graduated to ⅕° and from the local geographical latitude.[21] Hipparchus generally specified solstice times to the nearest ¼ day. By comparing these times with modern values, Britton found a systematic error of about 7 hours, which he explains by suggesting that Hipparchus drew on earlier sources to set the interval between spring and fall equinoxes to 187 days,

20 Archimedes, Hipparchus, and Posidonius of Rhodes (first century BCE) also wrote texts about the sizes and distances of the luminaries, treatments also more geometrical than empirical. Ptolemy uses a similar procedure for the Sun. For the Moon, he determines its parallax (i.e., the angular difference in its position due to whether it is determined from the Earth's surface or from the Earth's center [Figure 1, p. 113]) by comparing its theoretical zenith-distance with a single zenith-distance that he measured in 135 CE with a parallactic instrument, which he describes in some detail in *Alm.* 5.12–13. See Carman 2009.

21 The meridian circle [see ch. 6.4 §2, p. 247] is an instrument not unlike that used by Timocharis to measure stellar declinations.

adjusting his latitude to yield this result in the observations [1992, 12–24].[22] Britton's Hipparchus would thus have deployed earlier astronomical knowledge to calibrate his own empirical measurements. According to Ptolemy [*Alm.* 3.1], however, Hipparchus also critically evaluated his own and earlier solar observations, worrying that he had "committed errors" in the solstice timings (where the daily change in solar declination is very small) and especially naming those observations that were "very securely determined".

More important for our purposes is Hipparchus' program of determining the numerical parameters for his solar theory (the length of the tropical year, mean solar velocity, eccentricity, and position of the apogee) on the basis of his own and earlier observations. As is well known, Ptolemy's solar theory was essentially taken from Hipparchus and Ptolemy's procedure of setting parameters in astronomical hypotheses from a few, carefully selected observations also recapitulates Hipparchus' [see ch. 4.3 §2, p. 95]. For both astronomers, an "observation" need not always entail a discrete experience unmediated by previous theory or observations. For example, Hipparchus probably compared several of his own solstice- or equinox-observations with those of earlier observers (Ptolemy quotes only one example, spanning 145 years) and probably did not find the same value for the tropical year. Swerdlow has shown that Hipparchus may have derived his tropical year-length (365¼ – 1⁄300 days) from his lunisolar calendrical cycle of 304 years and a Babylonian value for the length of the synodic month [1980, 293–300]. In this case, Hipparchus would have used his own observations to confirm rather than derive a parameter.

For Ptolemy's own solstitial and equinoctial observations—he reports only four made between 132 and 140 CE—the astronomical practice becomes even more complex. Ptolemy briefly describes his instrument, a ring fixed to the plane of the celestial equator which at the instant of a daytime-equinox would be equally illuminated on both sides by sunlight [see ch. 6.4 §4, p. 249]. In perhaps the earliest discussion of instrumental error, Ptolemy [*Alm.* 3.1] remarks that errors could arise if the ring were not well aligned to the equator or had over time (many years) gradually shifted in position. He also reports "sometimes" seeing on his own brass ring at Alexandria two equinoctial events on the same day, a puzzling result that Ptolemy does not seek to explain. Despite these potential problems with his instrument, Ptolemy asserts that his equinox-observations agree with those of Hipparchus. From this agreement, he con-

22 The 187-day interval between equinoxes appears in Geminus' *parapegmata*, where it is attributed to Callippus (*ca* 340 BCE). See Evans and Berggren 2006, 231–240.

cludes that the length of the tropic year remains constant, i.e., that it has the length determined by Hipparchus, and that the Sun has only a single anomaly.

However, as has long been known, Ptolemy's equinoctial and solstitial times, which he describes as "very securely" observed, are all roughly one day later than the modern computed times. Britton has shown that atmospheric refraction—apparently known to Ptolemy [*Alm.* 9.2]—could indeed produce double, or even triple, equinoxes on an equinoctial ring over the course of a day.[23] But neither this problem nor misalignment of the ring, Britton argues, could produce the error-pattern in Ptolemy's four observations. Instead, it appears as if Ptolemy computed his "observed" equinoctial and solstitial times from Hipparchus' times and length of the tropical year. Perhaps, Britton speculates, Ptolemy realized that his equatorial ring, with its intrinsic limitations, could not yield reliable times and thus decided that he could not improve on Hipparchus' values. Or perhaps for each observation he realigned his ring to get values that confirmed a constant year-length, a single solar anomaly and, hence, a simple solar theory. Ptolemy "may well have chosen to sacrifice the accuracy of his [observed] equinox for theoretical clarity" [Britton 1992, 37: cf. Jones 2005a, 18–27]. In any case, the rhetoric of the *Almagest* obfuscates the matter. Ptolemy obviously wants his readers to believe that he had directly observed the equinoxes and that their times were "securely" or "very securely" determined [*Alm.* 3.1]. Since the equinox serves as the reference point for all celestial longitudes, Ptolemy could not have measured positions of other celestial bodies (stars and planets) without a solar theory. His error of 1 day in the equinoxes thus introduced an error of 1° into all the other longitudes that he reportedly measured.

Hipparchan and Ptolemaic lunar theories are considerably more complex than their solar theory, since they could only measure lunar positions by observing the times of eclipses and using solar theory to compute the positions.[24] As with his presentation of the solar theory, we find Ptolemy telling a story about deriving numerical parameters for geometrical hypotheses from eclipse-observations. Historians, however, have found that the empirical foundations of these reported eclipse-observations are complicated.

As outlined in *Alm.* 6.2, the Ptolemaic and Hipparchan Moon has three mean motions, one in longitude, one in anomaly, and one in latitude. To determine each, so Ptolemy reports, Hipparchus adduced from pairs of widely separated

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23 Note that the effects of refraction are much reduced on a meridian ring such as the one that Hipparchus employed.

24 In *Alm.* 4.1, Ptolemy explains that parallax can be ignored for lunar, but not for solar, eclipses, which makes the former much more suitable for "measuring" lunar longitudes.

lunar eclipse-observations the time-intervals required for the eclipsed Moon to return to an identical eclipse for each of these motions [Neugebauer 1975, 71–73]. In 1900, the Assyriologist Franz Kugler showed that Hipparchus had derived his period-relations not from observations but from well-attested Babylonian lunar parameters. The pairs of eclipse-observations would thus have been used to confirm, not to derive, the mean motions, a Hipparchan computation that Ptolemy does not present in the *Almagest*.[25]

Ptolemy does describe, however, Hipparchus' simple epicyclic (or equivalent eccentric) lunar hypothesis and the six lunar eclipse-observations that he used to fix the relative sizes of its epicycle and eccentricity [*Alm.* 4.11].[26] Worrying that Hipparchus' derived parameters differed significantly from those he himself had derived from a different set of six eclipse-observations [*Alm.* 4.6], Ptolemy repeated Hipparchus' computations and found that the latter had erred in determining the time-intervals between the various eclipses. When correctly computed, Ptolemy concluded, Hipparchus' six eclipse-observations confirm his own parameters, "agreeing closely with our hypotheses" [*Alm.* 4.11].

Ptolemy reports a total of 19 lunar eclipse-observations in the *Almagest*, the earliest 10 of which he attributes to the Babylonians (ranging from 721 to 382 BCE) and presumably borrowed from Hipparchus. As is well known, late Babylonian astronomical texts are filled with eclipse-records, both computed and observed, each with a distinctive terminology. Babylonian scribes aggregated these materials into Eclipse Texts, lists of consecutive eclipse-possibilities and observations arranged in Saros Cycles [see ch. 5.1 §4, p. 176]. Three tablets have been found that, when complete, would have covered 24 Saros Cycles from 747 to 315 BCE. Hipparchus apparently had access to many of these early eclipse-records. Steele has found that the accuracy of the Babylonian eclipse-timings reported by Ptolemy is comparable to the accuracy of such timings in the overall cuneiform record (about ½ hour), from which he concludes that "the observations are indeed genuine". Steele found a similar accuracy in the five early Greek observations listed by Ptolemy (years from 201 to 141 BCE) but also noticed a systematic error of nearly ½ hour that he could not explain. In Ptolemy's own eclipse-observations (only 4, from 125 to 136), Steele found a similar systematic error and an accuracy of about ¼ hour (if one outlier is dropped) [2000c, 100].

25 For a reconstruction of two such pairs of eclipse-observations that Hipparchus might have used for this confirmation (although not attested to in any known sources), see Toomer 1980.

26 For more details and an attempt to reconstruct Hipparchus' solar theory, see Jones 1991b.

All these eclipse-observations record only times in seasonal hours that were presumably determined by naked-eye observations of the stars. No instruments were required. *Alm.* 5.3–4 does include, however, four observations of the luminaries (one by Ptolemy, three by Hipparchus) when they were not at syzygy, which are recorded as times and longitudes to fractions of a degree. For one of these, Ptolemy writes, "Hipparchus records that he observed the Sun and the Moon with his instruments in Rhodes." Presumably some kind of instrument for measuring angles placed in the plane of the zodiacal circle was used for these elongations.[27] Now, aligning any longitude-measuring device to Aries 0° is difficult; yet, in a careful study of Hipparchus' solar longitudes, Jones has found that at least one, and probably all three, of Hipparchus' solar longitudes was indeed measured rather than computed [1991b, 116–117].

As was suggested long ago, Hipparchus and Ptolemy undoubtedly had access to many more reports of eclipse-observations than those listed in the *Almagest*. Britton and others have argued that they employed some form of averaging of (and/or selection from) a larger pool of empirical data to obtain "reasonable" values for the parameters in their lunar theories. Emphasizing that the *Almagest* was "not intended to be a historical account but rather a pedagogical treatise", Britton observes that Ptolemy

> may reasonably have concluded that the interests of clarity and rigor were better served by examples of how his results were obtained than by a lengthy, and necessarily non-rigorous, discussion of his procedures for obtaining parameters from discordant observations.
>
> 1992, xiv

The only other Hellenistic eclipse-observations known are recorded in a Demotic papyrus excavated in Middle Egypt. It lists 23 successive dates for possible lunar eclipses or observations of eclipses from 85 to 74 BCE. Six of these records include times or details such as the visibility of planets or the entrance angle of the shadow that could only have come from direct observation. Such a mixture of content is similar to that of the Babylonian Eclipse Texts. Steele has suggested that these astronomers in Egypt probably based their predictions on some kind of eclipse-cycle but he could not determine which Babylonian cycle might have generated the predictions in the papyrus. Steele also notes that some of the observational records mix future and past verb tenses, which

27 Toomer suspects that Hipparchus used a *dioptra* rather than an armillary sphere [see ch. 6.4 §5, p. 250] or that perhaps he used one instrument for the solar position and another for the elongation [1981b, 219; 1998, 227].

he attributes to confusion on the part of the scribe [2000c, 86–91: cf. Parker and Zauzich 1981; Neugebauer, Parker, and Zauzich 1981].

The astronomical papyri from Oxyrhynchus contain no observational reports and only one fragment that may have been part of a list of eclipse-predictions [see chs 12.1 §3, p. 445; 13.4 §2, p. 572]. As Jones has noted, the material best represented in this corpus are ephemerides, positions computed at regular intervals for use by astrologers [1999a, 1.87–94, 175]. Apparently, the astrologers' needs were being met by the available astronomical tables. If they observed and recorded positions of the Sun and Moon, those records have not been preserved.

5 Observing Planetary Motions

The corpus of dated planetary observations made before Ptolemy and recorded in Hellenistic Greek and Roman sources is small but, as Jones recently has shown, exceedingly interesting.[28] The *Almagest* contains 11 dated planetary observations from before the mid-second century CE and these are extracted from three sources:

(1) Timocharis (see above) for 273 BCE,
(2) unknown with dates "according to the Chaldeans [*scil.* Babylonians]" from 245 to 229 BCE, and
(3) unknown with dates "according to Dionysius" [Egyptian] from 272 to 241 BCE.

Each of these reports specifies the distance of the planet from a designated star in units of lunar diameters, cubits, fingers, or in one case redacted by Hipparchus, in degrees.[29] Ptolemy used this material in conjunction with more recent observations to set the rates of mean motion for his kinematic planetary hypotheses.[30] But why did his predecessors, who had no kinematic hypotheses or tables for predicting planetary motions, measure planetary positions?

28 Jones 2006c. The following several paragraphs draw from this study.

29 *Alm.* 9.2 claims that Hipparchus

> did not even make a beginning in establishing theories for the five planets.... All he did was to make a compilation of the planetary observations arranged in a more useful way, and to show by means of these that the phenomena were not in agreement with the hypotheses of the astronomers of that time.

It is not clear to what hypotheses or astronomers Ptolemy refers here. Perhaps to Babylonian mathematical schemes?

30 Ptolemy complains, however, that the ancient observations "have been recorded in a way

The Babylonian reports follow a format often found in cuneiform texts in recording the observed close passages of planets by one of 30+ bright zodiacal stars known as “Normal Stars”[see Glossary, p. 650]. Such records go back to the mid-seventh century BCE, long before Babylonian astronomers developed mathematical schemes for planetary motion, and, as noted by Jones, show no interest in “catch[ing] a planet in a theoretically interesting situation such as a station or opposition” [2006c, 276]. Rather, the Babylonian sky watchers recorded a broad range of celestial and terrestrial phenomena (including river levels and commodity prices) in their search for correlations and patterns. It appears as if Timocharis and the Dionysian observers followed a similar program of naked-eye observation, perhaps at quite frequent intervals: Ptolemy twice lists ancient observations of the same planet made only four days apart. Third-century Greeks thus made Babylonian-like planetary observations, a finding not especially surprising given the ever-expanding body of evidence indicating that Babylonian sources were known to Hellenistic Greek astronomers.

The only other known Hellenistic planetary observation dating before Ptolemy appears in an unusual papyrus fragment from Oxyrhynchus, which Jones has called a “treatise on planetary theory” [1999a, 1.69–80, 2.205: cf. 1999d]. The text gives the observed distance in 104 CE of an unnamed body, shown by Jones to be Jupiter, in lunar diameters from several named stars and reports that this body had been in a similar position with respect to those stars 344 years earlier in 241 BCE. Unlike the 11 ancient planetary observations in the *Almagest*, this pair of Jupiter-positions, as Jones shows, bristles with theoretical concern. Both observations took place near opposition and near the same longitude and could have been used to estimate the anomalistic period of Jupiter or the location of its nodal line. Jones conjectures that this treatise was authored by Menelaus of Alexandria, two of whose lunar observations, made in 98 CE, were included in *Alm.* 7.3.

Ptolemy refers to 13 ancient and 30 of his own planetary observations dating from 127 to 141 CE, as he demonstrates how to derive the mean motions and parameters of his planetary hypotheses. As has long been known, he undoubtedly had assembled a much larger set of observations from which he selected those which located the bodies at strategic places (e.g., at opposition to, or maximum elongation from, the mean Sun) for the development of his theories.[31]

which is difficult to evaluate, and crude” [*Alm.* 9.2]. For an argument that Ptolemy probably did not “tamper with” or otherwise adjust any of these ancient observational reports, see Jones 2006c, 282–284.

31 Ptolemy himself notes that he changed values of some of his parameters in the lunar the-

For each planet, the number of observations reported is the minimum required for Ptolemy's geometric derivations.[32] Hence, it is not surprising to find that the finished kinematic hypotheses and parameters given in the *Almagest* generally serve to predict longitudes that match the reportedly observed longitudes to $\pm5'$ of arc or less.[33]

How Ptolemy presents his derivation of the hypotheses in the *Almagest* and how he actually derived the parameters for those hypotheses need not coincide. We cannot pursue all the details that scholars have uncovered on this issue. To illustrate how Ptolemy worked with ostensibly empirical data, I shall consider several examples, beginning with the planetary mean motions recently studied by Jones and Duke.

In the *Almagest*, Ptolemy outlines an iterative process by which he deduces the parameters for each planet's hypothesis. He begins, not mentioning any observations, with approximate mean motions "computed by Hipparchus", which, as we now know, are Babylonian values. He then derives the other parameters from recent observations using the Babylonian mean motions. With those parameters, he next derives from one ancient and one recent observation "corrected" mean motions, which presumably he then uses to go back and recompute the other parameters, generating finally the hypotheses and

ory "because we later got more accurate observations" [*Alm.* 4.9]. Cf. Jones and Duke 2005, 231.

32 The superior planets each have four independent parameters, which require a minimum of five observations (two are required for the mean motion in longitude). The inner planets have more parameters and Ptolemy reports more observations—11 for Venus, 17 for Mercury.

33 For the observational reports in the *Almagest*, see Pedersen 2011, 408–422. Times are specified in equinoctial or seasonal hours, "dawn", "evening", or by the culminating degree of the zodiacal circle. Usually, the computed position of the mean Sun at the time is also stated. Computing with the solar theory of the *Almagest*, I have determined in all cases the time of observation to be 0;05h. Computing longitudes for those times with the planetary theories of the *Almagest*, I have also matched the reportedly "observed" planetary longitudes $\pm5'$ of arc for 30 of the 43 cases (including 8 ancient cases). Larger deviations between the computed and observed longitudes occur only for the inner planets (88′, 44′, −38′, and −44′ of arc for Pedersen 2011, nos 76, 79, 57, and 93, respectively). Each of these observations was near a time of maximum elongation from the mean Sun (a computed, not observed value), where the variation in longitude is small over a span of a considerable number of days. My results recapitulate the tables and computational procedures of the *Almagest*, with no internal rounding. Presumably, Ptolemy's practices of rounding account for the lion's share of the differences between our computed longitudes. To compute modern positions, I have used the JPL Horizons ephemerides for planets and for stars: see Graßhoff 1990, 275–316.

TABLE 2 Ptolemy's reported observations of Venus' elongation from the mean Sun

Pedersen number[a]	Observational procedure[b]	Ptolemaic error[c]		Relative error[d]
		Longitude	Maximum elongation	
18 (A)[e]	Occultation (0°)	1′		−6′
19 (A)	Near conjunction (5°)	−3		−9
56	Conjunction (1°)	−9	−20d	14
57	Near conjunctions (4°)	−38	−10	−49
61	Near conjunctions (−1°)	5	−14	25
66	Astrolabe (59°)	−5	+1	63
76	Near conjunctions (6°)	88	+28	80
77	Conjunction (0°)	−12	−10	48
80[f]	Astrolabe (40°)	1		−5
90	Astrolabe (−29°)	5	+1	25
93	Conjunction (0°)	−44	−15	−79

a See Pedersen 2011, 408–422.

b Ptolemy used two observational procedures to determine these elongations. For occultations and conjunctions, he reports naked-eye estimates of the separation in longitude (given as degrees in the parentheses) between a planet and reference-body whose longitude was known. For greater separations between planet and reference, Ptolemy reports that an astrolabe was used to measure the separations.

c These errors are the differences in minutes of arc between observed longitudes and those computed by Ptolemy's own theories and the difference in days between the date of the observation, presumed to be at maximal elongation, and the date predicted by Ptolemy's theories for maximal elongation.

d These errors, which are the differences between observed longitudes and those predicted by modern theory using the JPL ephemerides, indicate how accurately Ptolemy's reported observations matched the sky. Since his assumed positions for the reference-bodies usually contain slight errors, I have removed the latter so that "relative errors" designates the error in longitude relative to the reference-body.

e "A" stands for "ancient".

f In Pedersen 2011, 420, no. 80, Ptolemy describes two observations, one with Spica as the reference star (used for my computation), one with respect to a line between β Sco and the Moon, which is not used here so as to avoid the complication of introducing a lunar position generated by Ptolemy's theory. Both observations yield the same longitude for Venus.

parameters written up in the *Almagest*. However, Ptolemy invariably finds identical—“practically the same”, “very nearly the same”—mean motions from the pairs of observations, which suggests that he “manipulated” those observations or that his reduction or analysis of them to confirm the (Babylonian) values which he earlier had provisionally accepted.[34]

On the other hand, there is reason to doubt that claim if we examine the relative errors (i.e., the differences between the modern and the observed longitudes, with the error in the reference-body removed) in the 10 observations that Ptolemy deployed for his “corrections”. Seven of these observations show relative errors of 8′ of arc or less, scatter that we might well expect for naked-eye estimates of positions of planets judged against nearby stars or against more distant stars by means of an astrolabe (two cases here). Only the pair of observations of Mars (relative errors of −59′ and +29′ of arc) and one observation of Mercury (+46′ of arc) might have been adjusted to match the previously derived mean motions. And all 10 of these observed longitudes match, ±3′ of arc, those predicted by the *Almagest* hypotheses. Ptolemy's control over the empirical and theoretical content of his planetary hypotheses here seems robust.

To explore further the empirical content in Ptolemy's planetary observations, we may consider his reported measurements of the elongations of the inner planets from the mean Sun [Table 2, p. 211 and Table 3, p. 213]. At maximal elongation, the elongation changes very slowly with time. For the greatest elongations, Ptolemy reports the date and time of observation; measures the longitude of the inner planet relative to some nearby star (angles presumably estimated by naked eye) or more distant star (angles measured, he says, with an astrolabe); computes the position of the mean Sun at that time; and thereby determines the elongation. Although reputedly measured, these greatest elongations rest on Ptolemy's solar theory (in error by about 1° during the 130–140s CE), on star-positions precessed (in error by 14″ of arc per year) from his star-catalog with its epoch of 137 CE, and on estimated or measured angular separations between those stars and Mercury or Venus. The measured elongations always combine theoretical and empirical knowledge [Neugebauer 1975, 166].

34 See Jones and Duke 2005, 232. For the “correction” chapters, see *Alm.* 9.10, 10.3, 10.9, 11.3, 11.7. Pedersen 2011, 290, terms these ostensible tests of the mean motions “nothing more than a pedagogical trick”. For a more recent study of Ptolemy's reception of earlier planetary observations, see Jones 2016a; for a survey of Ptolemy's views on various sources of observational error, see Lloyd 1982.

TABLE 3 Ptolemy's reported observations of Mercury's elongation from the mean Sun

Pedersen number[a]	Observational procedure[b]	Ptolemaic error[c]		Relative error[d]
		Longitude	Maximum elongation	
20 (A)[e]	Near conjunctions (2°)	2′		−4′
21 (A)	Near conjunctions (2°)	16		4
22 (A)	Conjunction (0°)	6	+1.5d	−12
23 (A)	Near conjunctions (0°)	3	+5	34
24 (A)	Conjunction (−3°)	−5	−2	−118
25 (A)	Near conjunction (10°)	7	−1.5	65
26 (A)	Conjunction (0°)	6	+4	−22
28 (A)	Conjunction (0°)	−11	0	0
58	Conjunction (4°)	0	−1	27
60	Astrolabe (−72°)	4	0	94
67	Conjunction? (6°)	−19	+2	−79
68	Astrolabe (48°)	−5	−1	66
71	Astrolabe (−8°)	0	+1.5	69
79	Astrolabe (−26°)	44	+6	84
84	Astrolabe (−45°)	0		46
87	Astrolabe (37°)	−2	−4	−22
94	Astrolabe (61°)	2	+3	−69

a See Pedersen 2011, 408–422.

b Ptolemy used two observational procedures to determine these elongations. For occultations and conjunctions, he reports naked-eye estimates of the separation in longitude (given as degrees in the parentheses) between a planet and reference-body whose longitude was known. For greater separations between planet and reference, Ptolemy reports that an astrolabe was used to measure the separations.

c These errors are the differences in minutes of arc between observed longitudes and those computed by Ptolemy's own theories and to the difference in days between the date of the observation, presumed to be at maximal elongation, and the date predicted by Ptolemy's theories for maximal elongation.

d These errors, which are the differences between observed longitudes and those predicted by modern theory using the JPL ephemerides, indicate how accurately Ptolemy's reported observations matched the sky. Since his assumed positions for the reference-bodies usually contain slight errors, I have removed the latter so that "relative errors" designates the error in longitude relative to the reference-body.

e "A" stands for "ancient".

In Tables 2 (p. 211) and 3 (p. 213), the shaded rows indicate observed longitudes of the inner planets when not at greatest elongation. For these entries, Ptolemy's measured longitudes match quite well the predictions based on his finished hypotheses for those planets and of modern ephemerides for those dates after correcting for errors in the reference-bodies (i.e., relative errors).[35] For the greatest elongations, the measured longitudes match Ptolemy's hypotheses less well and the relative errors are much larger. For both planets, the astrolabe-measured errors relative to the Ptolemaic predictions are smaller than those in the conjunction-measurements, which might suggest that Ptolemy "corrected" the more difficult angular measurements using the astrolabe with his theory.[36] Yet the errors relative to the reference-bodies are roughly similar in the greatest elongations measured either by an astrolabe or *via* a conjunction. Since it seems implausible that Ptolemy misjudged small separations between the planets and nearby stars, we might suppose that instead he adjusted the purported dates of these observations to achieve coherence in the parameters for the inner planets. The third columns in Tables 2 and 3 show the difference between the reported dates and the dates of greatest elongation as predicted by the planetary hypotheses of the *Almagest*. Toomer suggests that Ptolemy may have lacked observations for dates closer to the predicted greatest elongation and that he may have selected dates near greatest elongation that also offer the mean Sun at convenient positions with respect to Venus' apsidal line for working out the geometry [1998, 469]. However, the pattern of relative errors in these data also suggests that some of the observational dates may have been shifted.[37]

35 Only one astrolabe-measurement of Mercury when it is not at greatest elongation [Pedersen 2011, 420, no. 84] shows a large relative error of +46 minutes of arc. Did Ptolemy shift the measured angle so that the planet's longitude exactly matches the value predicted by his theory for Mercury?

36 Of the nine measurements with an astrolabe, only one yields a longitude that differs significantly from Ptolemy's computed value [Pedersen 2011, 419, no. 79]. Toomer 1998, 449 suggests that an astrolabe could not have yielded "valid" observations when measuring differences of longitude exceeding 70° [Pedersen 2011, 417, no. 60], the greatest angle measured by an astrolabe that is reported in the *Almagest*.

37 As can be seen in Table 3, p. 213, 10 of the 17 reported observed longitudes for Mercury match longitudes computed with the *Almagest* hypotheses $\pm 5'$ of arc. Four differ by more than $\pm 10'$ of arc. Recent studies of the *Inscriptio Canobi* have shown that its parameters represent the earliest versions of Ptolemy's planetary hypotheses. For Mercury, the apogee given in the *Insc. Can.* is 4° less than the one in the *Almagest* and the eccentricity and radius of its small crank circle is 2;30 parts rather than 3;00. Might some or all of Mercury's observed longitudes as reported in the *Almagest* have been computed with the hypothesis of the *Almagest* and the parameters of the *Insc. Can.*? Re-computation with the *latter* parameters (both changes or only the shifted apogee) fits the observed longitudes less well

Presumably Ptolemy iterated between a larger set of observed elongations, preliminary values for parameters derived therefrom, predicted longitudes generated by those parameters, and "adjusted" observations confirming parameter values before settling finally on the hypotheses, parameters, and date-adjusted measurements recorded in the *Almagest*. Ptolemy appears to have treated both the ancient (marked by "A" in Tables 2 and 3) and his own observations in this manner. Some scholars have denounced such observational reports as "fraudulent" or "fudged". For our purposes, the 43 planetary observations reported in the *Almagest* demonstrate Ptolemy's practice of displaying the geometry of finished planetary hypotheses built on both theoretical and empirical foundations. The *Almagest* is not a working notebook showing how Ptolemy developed his hypotheses over time; it is not an observational notebook recording all the "raw data" of the observations; and it is not a theoretical treatise simply describing kinematic hypotheses for celestial motions. We prefer to follow Britton in calling it a pedagogical work, aimed at demonstrating how to pursue mathematical astronomy to a precision of minutes with a minimum of empirical inputs to confirm the geometry of the hypotheses and set the parameters [Pingree 1994b; Jones 1999e; Gingerich 2014; Bernard 2014].

In Greco-Roman astronomy after Ptolemy, we find very little observational activity of any kind.[38] The astronomical texts of Late Antiquity that remain extant are dominated by ephemerides and commentaries on Ptolemy's work, beginning early in the third century. The major commentators, Pappus, Theon of Alexandria, and Proclus, did not challenge Ptolemy's approach to mathematical astronomy.[39] As Jones has observed, these authors attended to "Ptolemy's mathematical reasoning at the small scale, that is, the individual geometrical and numerical demonstrations" [1999e, 165]. Only one "observational test" of Ptolemaic prediction [Rome 1952, 212; Steele 2000c, 103–104; Jones 2012; Steele 2015] appears in the commentaries, viz. Theon's observation of a solar eclipse on 16 Jun 364 CE. In his commentary on the *Almagest*, Theon computes the eclipse, comparing Ptolemy's methods of the *Almagest* and the *Handy*

than does re-computation with the *Almagest* parameters, so we cannot use the Mercury parameters of the *Insc. Can.* to explain the deviations in Table 2. Cf. Hamilton, Swerdlow, and Toomer 1987; Jones 2005b.

38 For a survey of astronomical activity from Ptolemy to the seventh century, see Neugebauer 1975, 942–1058.

39 Bernard 2014, 113:

> …something essential of Ptolemy's spirit died with late commentators, namely the notion that one should continue and complete astronomical observations and determination of parameters in the way Ptolemy and his predecessors had done.

Tables—they differed by no more than 5′ of time—and reports the times of the beginning, middle, and end of the eclipse that he had "observed with the greatest certainty" [Fotheringham 1920, 114: cf. Tihon 1976–1977; Steele 2000c, 103–105]. Although this text, book 6 of Theon's commentary, has not been critically edited and Camerarius' edition of 1538 introduces some confusion, Rome wrote that Theon concluded that the calculated times "conform" to his observed times, i.e., that in the fourth century Ptolemy's eclipse-predictions still adequately matched celestial phenomena.[40]

Proclus' *Hyp. ast.*, composed in the mid-fifth century CE, describes in considerably more detail than does the *Almagest* Ptolemy's observational instrument, the *astrolabon*. Concluding that "…this instrument is earnestly recommended as highly useful for observations of the Moon and stars that can be made in no other way…", Proclus does not explain why readers might want to make such observations. He writes nothing about testing Ptolemy's parameters or theoretical hypotheses.[41] Indeed, the only known observational reports from Late Antiquity were ("accidentally" according to Neugebauer) placed in several of the earliest extant codices containing the *Almagest* and related material: seven naked-eye observations, made in Athens and Alexandria between 475 and 510 CE, of occultations or near conjunctions when the Moon or a planet passed close to a star or another planet. Although several of these observations were compared with positions computed from the *Almagest* and the *Handy Tables*, Jones has concluded that "it is difficult to discern in them any systematic effort to check the tables' accuracy" [1996b, 103].[42] Such efforts would not be launched until the advent of Arabic astronomy several centuries later.

6 Conclusion

Many of the extant texts of Hellenistic Greek astronomy present the enterprise as a synthesis of observational and theoretical knowledge. The best known of

40 Camerarius 1538, 337–339; Rome 1952, 212; Tihon 1976–1977, 49. According to Steele 2000c, 102–103, Theon's observed times are early by about ½ hour in comparison to modern computations.

41 Manitius 1909, 198–213. Interestingly, Proclus [Manitius 1909, 110–111] considered Ptolemy's parallactic instrument sufficiently explained in *Alm.* 5.12, thus making "superfluous" any further discussion of its construction or use. Apparently Proclus considered Ptolemy's similarly detailed presentation of the *astrolabon* [*Alm.* 5.1] inadequate for this more complicated device with its seven concentric rings turning on different axes.

42 Cf. Neugebauer 1975, 1037–1041; Jones 2005b, 81–83, 91–95. In one case, an astrolabe was used to record the seasonal hour of the time of observation.

these astronomers, Hipparchus, Geminus, and Ptolemy, each portray mathematical astronomy as the formulation and then use of a set of predictive schemes derived from geometrical principles and from discretely determined times and positions, often reported as if measured to the minute. They also described some of the instruments by which such measurements could be made. Although none of these observing instruments has survived—how many shipwrecks remain to be found?—archaeologists have located many early sundials [see ch. 9.1, p. 323]. In a work on the genres of mathematical writing, Geminus offers three subdivisions for astronomy: gnomonics (sundials), meteoroscopy (armillary spheres), and dioptrics (the sighting, angle-measuring *dioptra*), all related to instruments [Gibbs 1976; Evans and Berggren 2006, 43–48]. Few would be so churlish as to deny that Hellenistic Greek astronomers had tools for celestial observation.

Over the past century, however, historians of astronomy increasingly have challenged the claims found in the major Hellenistic Greek astronomical texts about their empirical practices. More than a few of the numerical parameters for the kinematic Greek astronomical hypotheses undoubtedly derived from earlier Babylonian sources and not from new observations. Positional astronomy based on zodiacal rather than sidereal coordinates, a decision made by the Babylonians and followed by the Greeks, inextricably ties any measured positions to solar and precessional theories. Naked-eye observations of occultations or near conjunctions likewise involve theories about the movements or positions of the reference-bodies. Empirical knowledge invariably rested, in part, on theoretical claims.

Even more fundamentally, defining the elements of kinematic geometrical theories, items such as anomalies of motion, lines of apogee, the bisected equant, or links between the mean Sun and the planetary hypotheses, must have involved a complicated interconnection between geometrical and empirical knowledge. Constructing kinematic hypotheses for celestial motions must have required an implicit theory of error to deal with discrepant data or to evaluate the robustness of data—recall Ptolemy's reference to "improved" parameters for the Moon, Saturn and Mercury in *Alm.* 4.9. It also must have required a set of expectations for defining an acceptable fit between "data" and "theory" as in Ptolemy's "corrections" chapters. And in cases where two geometrical arrangements are equivalent mathematically (the eccentric and epicyclic hypotheses), criteria of choice are required that might derive from complex mixtures of philosophical, empirical, or physical commitments. In any case, regardless of how Hipparchus or Ptolemy may have sought to position their approach to mathematical astronomy, the judgment as to whether Greco-Roman astronomy in Hellenistic times was, or was not, an empirical science is anachronistic either way. It is historiographically more sound to emphasize the deeply interconnected nature of observation and theory in ancient astronomical science.

Astronomical Instruments

CHAPTER 6.1

Hellenistic Surveying Instruments

Tracey E. Rihll

1 Introduction

The same intellectual and physical tools are required to establish one's location in relation to either the heavens or the Earth. For this reason, the same people performed activities of interest to both astronomy and geography, for example, the explorer Pytheas noted the height of the Sun wherever he was at the equinoxes and the solstices, while the astronomer Ptolemy also wrote a geography. Those intellectual and physical tools were used in ordinary life in Antiquity to survey land, to establish bearings, and to measure distances and estimate heights for planning, public works, and monumental architecture across cities and the countryside [Adam 2005, 8]. Those with an interest in the heavens used the *dioptra* with sighting tube [see §§2, 5, 12], for example, to determine the angular distance between celestial bodies or the elevation of such a body above the horizon. They also relied on surveying in general to specify positions on Earth and the distances between them [see §10]. Still, the primary or common use and context of these tools was in terrestrial surveying.

Lewis [2001] has identified three key surveying instruments in use in Greek and Roman societies during the Hellenistic Period: the *dioptra*, the *libra*, and the *groma*. Simpler or less fundamental tools that might be present in ancient surveyors' kits and that were adequate for relatively small or straightforward applications were the sighting tube, the staff or measuring rod, the cord, the water-level, the A-frame, and the *chorobates*. The hodometer is of special mechanical interest but may have had limited application off-road. We will introduce these in turn below. To complete the set of instruments with which the ancients performed these operations, we need to add portable sundials [see ch. 9.1, p. 323], folding rulers (usually 1 Roman foot long), compasses, dividers, inkpots, and *styli*, all of which have been found with surveyor's tools in Pompeii and elsewhere [Plate 1, p. 222; Dilke 1971, 73].

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PLATE 1 Folding ruler and wedge-tightened dividers

2 The *Dioptra* and Staff

The Greeks' principal surveying instrument was a simple sort of *dioptra* [see ch. 6.4 §8, p. 256]. The developed *dioptra* consisted of a disk, which could be hung vertically from a stand by a ring on its edge or mounted horizontally on a stand [Figure 1, p. 223]. The disk was marked with two straight lines at right angles to one another, from edge to edge through the center of the disk. One of the lines was aligned with the suspension ring. The center of the disk was pierced by an *alidade*, i.e., a bar with a sight set perpendicularly at each end, which could turn through 360°. The rim was calibrated when the instrument was used for astronomical sightings but probably not for terrestrial sighting, for which it was irrelevant [Lewis 2001, 51, 97; Coulton 2002]. The variety described by Heron in his treatise of the same name is a more sophisticated version of the standard *dioptra*, incorporating gears for fine adjustment and a water-level in place of the *alidade* when it was being used for leveling.

When suspended vertically from a stand, the *dioptra* acted as its own plumb bob and could be used for leveling or measuring relative heights. In practice, a temporary windbreak would normally need to be erected upwind to stop the device from swinging. The *dioptra*'s main use when mounted horizontally was

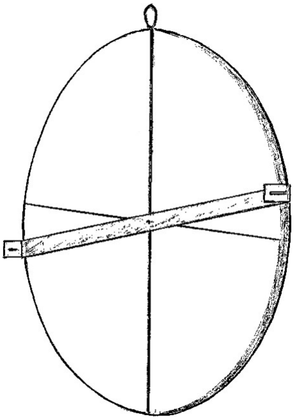

FIGURE 1 A standard *dioptra* hung vertically

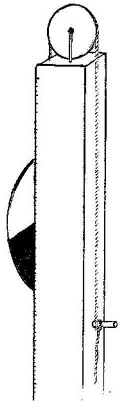

FIGURE 2 The staff

to observe and set out lines on the ground. A graduated staff was an essential accessory, as this is what the surveyor actually spots when using the *dioptra*.

A developed form of staff is described by Heron in *Dioptra* 5 [Figure 2]. It was about 10 cubits high, 5 fingers wide, and 3 thick. A round target, of 10–12 fingers in diameter, was attached *via* a groove such that it could move up and down the length of the staff at the front of it. The target was divided into upper and lower halves, one painted white, the other black. A cord attached to the target passed over a pulley at the top of the staff and ran down the back of the staff, so that if the cord was pulled, the target would rise up the staff. The side of the staff was divided into cubits, palms, and fingers along its length. On the back of the target, a lead plate was affixed and a pointer level with the horizontal line dividing the black and the white halves, which indicated the reading on the scale. On the other side of the staff was hung a plumb bob to enable the surveyor to ensure that the device was vertical in use.

3 The *Libra*

The *libra* was a Roman leveling instrument with no Greek antecedent. It may have been a relatively large version of a builder's A-frame [see §7, p. 225], since the small version was commonly known as a *libella*. But Lewis [2001, 109–113] argues that it may have consisted of a balance, specifically the beam of a weighing balance without pans hanging from each end [Figure 3, p. 224]. His speculative design for a reconstruction was based on what he thought achievable by an ancient Roman smith and its apparent simplicity belies brilliance in that

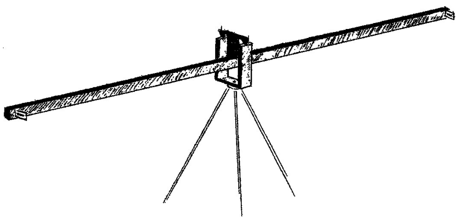

FIGURE 3 The *libra*

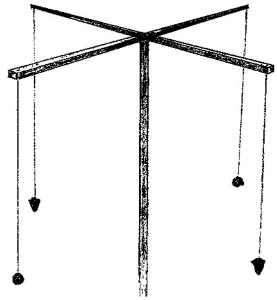

FIGURE 4 The *groma*

the 6-foot-long iron beam literally balances on a knife edge, and "is so sensitive that a fly settling on one end affects the reading on the staff" [Lewis 2001, 116]. In practice, this showed itself to be as accurate as modern equipment, achieving an error margin of 1 in 24,000 when the sightings were performed in a hurry and an astonishing 1 in 57,667 when an average was taken of three results each involving two-way sightings over 173 meters. However, "that it works is no proof that it is correct" as Lewis himself emphasizes [2001, 119]. The *libra* was used to find levels, principally for aqueducts—hence, its name "libra aquaria", a level for water, not a water-level [Lewis 2001, 110].

4 The *Groma*

The *groma* [Figure 4, p. 224] was the Romans' preferred instrument for sighting and setting out straight lines and right angles, and it became the trademark of surveyors to the extent that it might feature on their tombs in the same way doctors were indicated with medical kits or builders were indicated with A-frames. Examples survive in contemporary illustrations and in the archaeology, including a depiction on the tombstone of the freedman surveyor Lucius Aebutius Faustus in Eporedia [*ILS* 7736] and a specimen from the house of the instrument maker and seller Verus in Pompeii. But no surviving text describes one, which has led to difficulties and disputes about its reconstruction [Guillaumin 2015]. It consisted of a horizontal cross with arms at right angles and mounted on a stand. Plumb bobs hung from the four corners of the cross. It used to be thought that the cross was offset so that the vertical support did not interfere with sighting the plum lines across the device; but Schiøler [1994] has argued cogently against the existence of the bracket, citing a variety of pieces of evidence. Considering all the arguments and evidence surviving on the instrument, and the functionality it must have had, both Guillaumin and Lewis conclude that insoluble problems remain, and that as a result "none of the alternatives…is satisfactory, and until more evidence should emerge we have to admit that we do not know the answer" to the question whether it did or did not have a bracket to offset the cross.[1]

5 The Sighting Tube

The sighting tube could be made of any opaque material to whatever size desired. Its function was to eliminate peripheral vision. It helped users see better by cutting out distractions. It is mentioned as early as Aristotle [*De gen an.* 780b19–781a12].

6 Cords, Rods, and Pacers

The cord was the usual measuring device in Greek surveying. Made of rush rope or other fibers, 100 cubits was probably the standard length. The rope was treated to minimize, if not prevent, shrinkage and stretch in use. Metal chains were an expensive and heavy alternative. Wooden rods, 10-feet long, were preferred by Roman surveyors [Lewis 2001, 19–21]. Surviving endpieces have flat circular ends to facilitate the alignment of two rods, which is useful when measuring horizontally, and were sometimes calibrated in inches or digits [Dilke 1971, 73]. The third alternative was to use trained pacers, who counted their regular steps: this was what Alexander the Great used on his Asian expedition and may be what Eratosthenes relied on for his calculation of the circumference of the Earth [Lewis 2001, 22].

7 Water-Levelers

The water-leveler is surprisingly difficult to find in the surviving evidence, if Lewis' interpretation of the *libra aquaria* is correct (as I think it is). Although it needs very little observation and thought to realize that water finds its own level, it needs rather more thought to continue to the idea that water may, therefore, be used as a leveling tool and, crucially, it needs a good deal more

1 See Lewis 2001, 126–132, quotation at 132.

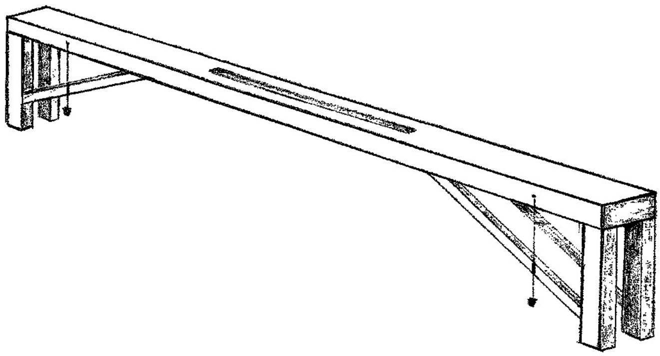

FIGURE 5 The *chorobates*

again to come up with a method for so using it in practice. Surface tension interferes, especially at the small scale, and capillary-action would draw water up the sides of a glass tube of the type attached to Heron's *dioptra* (forming a meniscus). Clear glass tubes were probably a novelty when Heron wrote, after more than a century of experiments and developments since "the first trial inflation of a heat-softened glass tube" [Stern 2008, 536]. Before then, no material existed that could be made into a sufficiently clear tube as appears on Heron's *dioptra* in place of the *alidade*. Thus, the unwieldy *chorobates*, which incorporates a water-level within it, may have been the best available solution to the problem when Vitruvius was writing. His detailed description[2] indicates its novelty at least to his intended audience, and asserts the role of the water-level as supplementary and secondary—something to fall back on when it is too windy for leveling by plumb lines.

The *chorobates* was another leveling instrument [Figure 5] and was sufficiently uncommon in Vitruvius' circles to warrant a description, unlike the basic surveying instruments, knowledge of whose appearance and use he assumed of his reader. It consisted of a very long beam supported at its four corners on perpendicular legs, with a narrow channel (1 finger wide, 1½ fingers deep) excavated from the central 5 feet of it. The legs were braced, each brace was marked with a precise vertical line, and a plumb line hung from a point directly above each line. If it was too windy to use the plumb lines, the central channel could be filled with water and, when the water uniformly touched the lips of the channel, the instrument was level. Lewis [2001, 3–35] argues that at 20 feet long and on four nonadjustable legs, this instrument would be much more appropriate for a fixed location, such as a large building site, than in use

2 See *De arch.* 8.5.1–3, originally with illustration, since lost.

PLATE 2 The A-frame

crossing the countryside to find a route for an aqueduct. Vitruvius' description may have been based on a lost Greek source of the early second century BCE by Carpus.

8 The A-frame

The A-frame, another leveling device [Plate 2], consisted of three pieces of wood: two at a right angle and the third bracing them across the diagonal, about halfway along their length, resembling the letter "A". The feet of the inclined timbers were trimmed so it would stand unaided. A plumb line hung from the apex. The halfway point on the brace was marked with a perpendicular line. When the plumb line coincided with the line on the brace, the A-frame was level. Metal sheathing might be added to sharpen and protect edges and joints. The A-frame could be made any size; and the larger it was, the more accurate it was.

9 The Hodometer

The hodometer was a significantly more complicated device, consisting of a two-wheel cart that mechanized the measurement of distance, ideally on a road already built. It was possibly invented about 240 BCE to measure the newly constructed Appian Way.[3] A description is preserved by Vitruvius [*De arch.* 10.9.1–4] and Heron [*Dioptra* 34, 38]. In Vitruvius' version, which is the earliest surviving and uses Roman measures, the wheel's diameter was 4 feet, so that its circumference was 12½ feet. This was 1⁄400 of a mile, so when the wheel had undergone 400 rotations, 5,000 feet (i.e., a Roman mile) would have been covered.[4] To the hub of the road wheel was fixed a single tooth, which engaged with a 400-tooth gearwheel mounted on the cart. Each revolution of the road wheel advanced the cart gearwheel by 1⁄400, and 400 revolutions of the road wheel turned the cart gearwheel through one full revolution.

The hodometer's gearwheel was furnished with a single additional small projecting tooth that engaged another gearwheel, which governed the recording mechanism. This third gear was to be pierced with as many holes as the number of miles the instrument might be expected to cover in a single journey. Into each hole was put a smaller round stone. In the lower surface of a sleeve on this gearwheel was a hole through which the stones dropped into a bowl, one by one, as they became aligned, giving an audible signal of another mile passed. At the end of the journey, the number of stones in the bowl gave the number of miles covered.

10 A Multifunction Tool

Finally we should consider a small stone fragment that came to light in Budapest in 1990 and is inscribed on both sides with, variously, lines, scale, arcs, and place-names. It has been associated with surveyors' equipment [Plate 3, p. 229] and interpreted as a unique multifunction tool by which one could establish the cardinal points of the compass, one's latitude, and possibly one's longitude.

3 See Sleeswyk 1979, with illustration: cf. Lewis 2001, 137–138.

4 These Roman measures are given in the *Corpus agrimensorum romanorum de agris* [Campbell 2000, 272–273]. The manuscripts actually have 4⅙ feet for the diameter of the wheel, giving a value of 3 for π in order to produce the presumed circumference of 12½ feet. Some editors prefer 4 feet, giving a value of 3½ for π. It probably did not matter to a legionary carpenter constructing a hodometer out of wood.

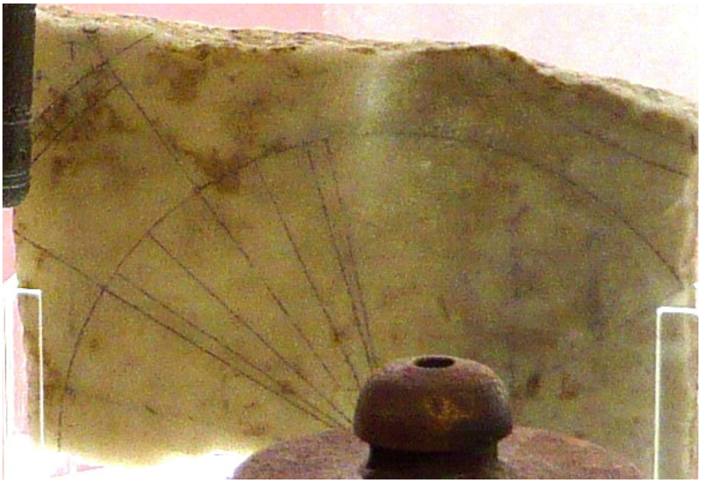

PLATE 3 A multifunction tool

With that information, one could use the other side of the same stone to construct an accurate sundial for that location, among other things [Madarassy 1993; Noéh 1993].

11 Surveying Triangles

Much ancient surveying utilizes similar triangles. If their angles are similar, then the lengths of their sides are in proportion. Thus, heights could be found from lengths and *vice versa*. Surveying involved sighting a distant object together with a nearby staff or gnomon using the *dioptra* or other instrument and then creating similar triangles and computing figures. The same method was used to find the height of the Sun and, thus, the latitude of the observer [Lewis 2001, 26].

12 Use of the *Dioptra*

Heron's treatise on the *dioptra* is our principal source of information on the instrument and preserves its actual and prospective uses according to that author in the first century CE. But an appropriate context for its development was found around the end of the third and the first half of the second centuries BCE; and Lewis has identified 200 BCE as a plausible date around which to locate its invention [2001, 101–105].

The *dioptra* was used first and foremost to determine the difference in height between places. Foundations of buildings required no height difference, while the route for irrigation channels or pipes to convey water by gravity required a gentle gradient, for example. Laying out aqueducts, walls, harbors, and "every sort of structure" lead Heron's sales pitch in a long list of possible uses, before measuring the distances between stars and studying the size, distances, and eclipses of the Sun and Moon [*Dioptra* 2]. Military commanders contemplating a siege could use the *dioptra* to find the height of a city wall at a distance beyond the range of whatever missiles the defense could deploy, or the depth of a ditch, or the width of a river. Other uses proposed by Heron vary in their practicality and plausibility, and were not obviously superior to alternative existing, simpler, methods. These include plotting a straight line between two points not mutually visible, calculating the length and direction of a straight line between two points at a distance, establishing in which direction to dig a tunnel from both ends, establishing where to sink shafts to connect with a tunnel (including remedial works after a cave-in), and staking out for earth-shaping activities such as building mounds and banks [e.g., Rihll and Tucker 1995].

13 Use of the *Groma*

The *groma* was used by the Romans for a variety of key tasks in newly conquered territories: marking out parcels of farmland for veterans and colonists, surveying roads to connect the area together (especially forts therein) and to the rest of empire, and establishing the layout for new forts or grids for towns. For example, Vitruvius' *De architectura* describes all aspects of planning for such and envisages the architect rather than *agrimensor* (land-surveyor) or *mensor* (surveyor) choosing and laying out a new colony. New land was typically divided into plots of 200 *iugera*, about 50 hectares, which was then subdivided into 100 small holdings. The surveyors were also responsible for making multiple records of their work in the form of maps, one to be kept locally, one to be sent to the archive in Rome. Sometimes their maps were also recorded on stone. Three still survive in part at Orange in the south of France [Plate 4, p. 231]. In already settled areas, surveyors dealt with disputes over land law and boundaries [Cuomo 2007, ch. 4].

PLATE 4 A surveyor's record on stone

14 Conclusion

Location-finding tools and techniques were developed for a variety of terrestrial uses, especially military, and a few of these were found to be useful for astronomical purposes too. In the first century BCE, Vitruvius assumed that his readers knew what a *dioptra* was and how to use it. Moreover, the Roman army trained relatively large numbers of personnel in how to make and use their preferred versions of surveying instruments, personnel who then disseminated that knowledge across the empire and who, in due course, retired from the army into civilian life. As a result, the technical skills required to make and to use surveying instruments may have been relatively widespread during the centuries either side of 1 BCE.

CHAPTER 6.2

Hellenistic Maps and Lists of Places

Klaus Geus

1 Introduction

To the modern reader, maps are essential to understanding places both on Earth and in the heavens. A map is a two-dimensional, graphical display of spatial knowledge, in which distance is presented according to some scale and some method of projection, and employs a standardized way of expressing place and other features. So one central question is, Did the ancients have maps?[1]

If we consider the ancient languages Greek and Latin, we see that the usual Greek term for map is «πίναξ» ("pinax": literally, "plank", "platter", "board"); the Latin term is "forma". But both words have much wider connotations and only the contexts of their usage allow us to understand whether the few ancient sources in question refer to maps proper or related forms such as drawings, diagrams, pictures, or (geographical) lists. In particular cases like the so-called Agrippa map, the exact meaning is ambiguous and, therefore, open to debate [e.g., Arnaud 2007–2008]. Similar ambiguity attaches to other terms relating to maps in Greco-Roman Antiquity. The word "tabula", nowadays known mainly in connection with the famous medieval *Tabula Peutingeriana*, was quite rare in Antiquity [Cicero, *Ep. ad Att*. 6.2.3; Propertius, *Eleg*. 4.3.37]. Moreover, «γῆϲ περίοδοϲ» (literally, "voyage around the Earth"), which was used in early Greek sources to describe all kinds of geographical and topographical texts, also meant "map" [Aristophanes, *Nub*. 207; Herodotus, *Hist*. 4.36; Aristotle, *Meteor*. 2.5]; whereas "mappa", a Punic word according to Quintilian's *Inst. orat*. 1.5.57, evokes the medieval and premodern "mappamundi" ("map of the world") but did not have this meaning in Antiquity. Instead, it meant "napkin" or "flag". The Greek word «διάγραμμα», from which the English word "diagram" is derived [*LSJ* 391 *s.v.*], may designate a figure, a geometrical proposition, a horoscope, a list, a register, an inventory, an ordinance, or a regulation. But the specific notion of "map" is not attested before the letters (10) of the emperor

1 For discussion of the concept of a map and of mapmaking in Antiquity, see Rochberg 2012, 9–14.

 | DOI:10.1163/9789004400566_024

Julian (*reg*. 361–363 CE). Rarely, and far from exclusively, the Latin “orbis terrarum” (literally, “sphere (or disc) of the Earth”) was used to denote a map [cf., e.g., Vitruvius, *De arch*. 8.2.6]. In other words, in Antiquity, there was no unambiguous term for what we call a map.

2 Physical Objects and Uses of Maps

No object from Antiquity that fulfills the requirements of the definition of “map” given above has survived. Only maps of the inhabited world or *oikoumene* (οἰκουμένη) produced by cartographers in and for scientific circles show some concern for the problems of scaling and projection. Indeed, some map-like objects came down to us, such as diagrams, drafts, cadastral registers, mosaics, tables, and boards of *climata*.[2] We hear about maps in literary texts as well [Brødersen 2014]. But there is no denying the fact that these were rare objects in Antiquity.

This absence of maps, which is in stark contrast to their prominence in modern culture, can be attributed to a number of factors:

(1) The ancients relied widely upon a non-cartographic mode as the master model of spatial perception and description, the so-called hodological presentation.[3] That is, instead of maps, texts, and especially lists of places (serving like flow charts) were used to navigate from one landmark to another and to describe routes.

(2) In addition, technical difficulties in manufacturing and copying maps, the high price of papyrus (the most common scribal material before the parchment), the availability of spatial information, and the high level of geographical literature such as Ptolemy’s *Geographia* made maps precious and expensive objects [Rathmann 2011].

(3) Furthermore, maps in Antiquity did not have any practical value. They were neither used for traveling (for orientation or navigation) nor available in public schools.[4] Instead, ancient maps had a propagandistic (e.g., the “Agrippa map”), an aesthetic (e.g., the so-called Shield of Dura-Europos), a touristic (e.g., the Vicarello cups), and, in particular, a scientific

2 Cf. especially Janni 1984 and Brødersen 2003. For a well-balanced overview of ancient cartography, see Prontera 2001.

3 For a thorough revision of Janni 1984, see Poiss 2014.

4 The few exceptions attested in ancient sources also point to scientific circles: see, e.g., Diogenes, *Vitae* 5.51 on the world maps in the Peripatetic school at the time of Theophrastus.

> function. Most records concern the “world maps” of the eminent scholars Hecataeus of Miletus, Eratosthenes of Cyrene, or Claudius Ptolemy.

The ordinary Greek and Roman probably never saw a map in his or her lifetime.

3 Military Maps

Surprisingly, it is even unclear whether maps were drawn for military purposes.[5] Sources, which could be interpreted as military maps, are very rare and late [esp. Pliny, *Nat. hist.* 6.40; Vegetius, *Epit.* 3.6]. As a rule, generals in Antiquity possessed no maps of any strategic or tactical importance. In fact, they lacked cartographical awareness. Normally, ancient generals and officers obtained geographical and topographical information *via* reconnaissance and intelligence during their military campaigns [Bertrand 1997]. At least, we know of the presence of land-surveyors (*mensores*) in the Roman army who had both the knowledge and the experience to transfer topographical information into diagrams (or real maps) [Sherk 1974, 546–551]. And we hear of the body of βηματισταί (step-counters) in the armies of Alexander the Great and Hellenistic kings.[6] But even if they did produce maps in a modern sense instead of merely compiling lists of toponyms, distances, and the like, such objects were uncommon and did not help to advance a “two-dimensional” worldview. The heuristic potential of maps was not recognized by ancient armies—or, for that matter, by administrations, which also relied mostly on lists and some schematic cadastral plans [Talbert 1999, 306].

4 Astronomical Maps

If someone wants to map the heavens, there are basically two options: the construction of a three-dimensional image such as a star-globe or a two-dimensional star-map, traditionally called a *planisphaerium*.[7] The common feature of all ancient copies is that they do not show single stars (*stellae*) but figures of constellations (*sidera* or *signa*). Hence, the ancient *planisphaeria* are not maps in the strict sense but rather charts and pictures. Interestingly, celestial globes seem to have played a bigger role than star-maps in research and literature. The

5 *Pro*: Brødersen 2003. *Contra*: Sherk 1974.

6 The fragments of the step-counters are collected in Auberger 2005, 43–61.

7 For this section, see esp. Stückelberger 1994, 27–46 and Dekker 2013.

Hellenistic poet Aratus described the heavens in his *Phaenomena* (*ca* 276 BCE) according to the treatise of the same name by Eudoxus of Cnidus, a treatise written perhaps with an eye on a celestial globe [see ch. 10.1, p. 383]; and the famous polyhistor and chief librarian of Alexandria, Eratosthenes of Cyrene, probably did the same in his *Catasterismi*.[8]

While we do not have copies of *planisphaeria* before the medieval manuscripts of Aratus, there are at least—next to the famous Farnese Atlas—two fully preserved celestial globes (the Mainz Globe and the Kugel Globe) and a globe fragment (now at the Staatsbibliothek Berlin).[9] The so-called Planisphaerium Bianchini, a marble shrine with the zodiacal constellations, and the Planisphaerium of Dendera are not star-maps in the strict sense. The many *planisphaeria* depicted in the manuscripts raise the question of additional ancient predecessors. Hints in Vitruvius' *De architectura* and Ptolemy's *Planisphaerium* reinforce this assumption. But the same holds true here as with the geographical maps: the number of star-maps was probably quite limited and their use was restricted to certain circles, mainly to scientists and intellectuals interested in astronomy and astrology.

5 Portable Sundials and Lists of Latitudes

If we allow for a certain freedom in the definition of a map, we find an interesting group of objects that seem to contravene the rule of the "absence of maps" discerned above, at least at first sight. This group comprises approximately two dozen portable sundials.[10] These sundials are inscribed with lists of peoples, regions, and cities, two of them with no fewer than 36 names. Like most topographical lists, these tables of inscribed toponyms are organized according to *climata*. They shed light on the geographical awareness and worldview of their makers and owners. But geographical misconceptions can be detected in almost every single list. Certain biases—a sundial from Mérida, Spain, e.g., mentions all three Iberian provinces—support the view that these portable sundials were private instruments despite the fact that owners of portable sundials were obsessed with latitude. The practical purpose seems to be secondary. The object itself was the main attraction. In all probability, portable sundials were not produced by astronomers or specialists with advanced knowledge in

8 Cf. Eratosthenes, *Cat.* 6.28 with the commentary of Pàmias and Geus 2007, 216n7, 236n115.

9 See Dekker 2013, 49–115, which also discusses the photo of the now lost Larissa Globe.

10 The 16 Roman portable sundials are now ably discussed in Talbert 2016.

gnomonics but by craftsmen versed in iron and miniatures, who basically used samples, models, or simple diagrams (for each of the seven *climata*) [Schaldach 1998b].

Despite some similarities, a direct connection between the latitudes marked on the sundials and those listed in Ptolemy's *Geographia* can hardly be proven. Most numbers differ and Ptolemy's fractional degrees are more accurate than the ones on the sundials. In my view, the numbers on the sundials derived from lists that circulated independently in Antiquity. We hear of some of these in Vitruvius, Strabo, and Pliny [p. 236n13].

6 Place Lists and Their Use for Astronomy and Cartography

Ancient astronomers and geographers were able to determine the geographical latitude of a place by means of gnomons or σκιοθήρια (shadow-chasers). The angle between the Sun's rays and the shadow of a gnomon at noon on the day of the equinox is equal to the geographical latitude. The famous measurement of the Earth attributed to Eratosthenes employed this fact. But there was another approach to measuring the geographical latitude of a place, namely, by means of the number of hours of the longest daytime at that particular location.[11]

Computing such maxima requires spherical trigonometry. For the sake of convenience, Ptolemy in his *Geographia* prepared a table listing 23 parallels, the length of the longest daytime on those parallels, and the important cities associated with those parallels.[12] If we compare his latitudes with modern values, we notice an astonishing accuracy. If we compare Ptolemy's values with similar data from Antiquity, we also notice a nearly perfect consensus [Pliny, *Nat. hist*. 6.212–218]. The reason for this is quite simple. Ptolemy did not carry out his own measurements, at least not large-scale measurements over the entire *oikoumene*. Rather, he relied on older lists of geographical data whether observed or computed.

At least since the end of the fourth century BCE, lists of latitudes based on observation and on computation circulated among scientific groups as well as among craftsmen. Traces of such lists and tables can be found in the works of Vitruvius, Strabo, and Pliny the Elder.[13] In addition, Marinus of Tyre, Ptolemy's

11 This method is described in full by Ptolemy in *Alm*. 2.3.

12 Ptolemy, *Geog*. 1.23. Cf. also Strabo, *Geog*. 2.5.39: Radt 2002, C134.

13 Pliny, *Nat. hist*. 6.212–218; Strabo, *Geog*. 2.5.34–43 with 1.4.4: Radt 2002, C132–136 with 63; Vitruvius, *De arch*. 9.7.1.

predecessor in the field of cartography, attached such a table to his work [*Geog.* 1.6.2, 1.15.5, 1.15.6, 1.18.5]. Since such tables listed latitudes but not longitudes, they enabled the cartographer to plot only the *climata*, that is, stripes or belts running from east to west, onto which he placed important cities. For accurate drafting, a map with such tables of latitudes was a difficult task. Anyone who also wanted to learn about the longitudes of places had to find and consult another list, which Ptolemy describes as a list of opposite places (τῶν ἀντικειμένων τόπων) [*Geog.* 1.4.2]. As Ptolemy himself mentions [*Geog.* 1.17.1], such tables of longitudes were not always available; moreover, given the difficulty in determining longitude, they were probably far less comprehensive. Ptolemy seems to be the first cartographer to come up with the idea of combining both tables and producing a full catalog of places. This makes his *Geographia* an even more impressive masterpiece in the history of science.[14]

7 Geographers and Astronomers

"Geography" in modern times is a term that covers several sub-disciplines, all of which concern themselves with "space" or "environment". In ancient times, the definition of geography was much more limited. Geography aimed at the production of a map of the *oikoumene* and a geographer was basically a cartographer. The famous scientist Ptolemy defined geography in the first sentence of his *Geographia* [1.1.1] as "imitation through drafting of the entire known part of the Earth, including the things which are, generally speaking, connected with it". In contrast to chorography, geography uses only "lines and labels in order to show the positions of places and general configurations" [*Geog.* 1.1.5]. Therefore, according to Ptolemy, a geographer needs a μέθοδος μαθηματική (a mathematical method or procedure) as well as ability and competence in mathematical sciences, most prominently astronomy, in order to draft a map of the *oikoumene*.

Given this close connection between geography and astronomy, it is not by default that nearly all ancient "geographers" (in the limited sense of the term)

14 Geography arose as part of cosmological reasoning. It did not emerge as a distinct scientific discipline before Hellenistic times, when—and this needs more discussion—more data became available. The dependence of earthly phenomena on these celestial phenomena was called into question and an environmental awareness and concern developed. This question of spatial hierarchy is one raised, e.g., in both common almanacs (or *parapegmata*) and scientific treatises.

also stood out as astronomers and mathematicians: among them, Eudoxus, Eratosthenes, Hipparchus, Posidonius, and Ptolemy are the most illustrious.[15]

Apart from certain topics such as latitudes, meridians, circumpolar circles, and so forth, ancient geography also took over from astronomy some methods such as the determination of the size of the Earth or of celestial and terrestrial distances. The geographers Eudoxus, Hipparchus, Posidonius, and Ptolemy even constructed instruments for measuring, observing, and calculating such as the gnomon, sundial, astrolabe (zodiacal armillary sphere) [see §5, p. 250] or the meteoroscope [Lewis 2001; see §5.1, p. 252].

This kind of "astronomical" or "cartographical" geography is to be distinguished from the "descriptive" geography pursued by authors such as Strabo, Pomponius Mela, or Dionysius of Alexandria and often called *chorography*[16] in ancient times (e.g., by Ptolemy, as we have just seen).[17]

Between geography and chorography (or between astronomical and descriptive geography or between geography in the ancient and modern senses), there were differences not only in the requirements in the knowledge of mathematics but also in their aims, contents, methods, and implementation.[18] Such differences are very hard to define in detail for astronomical geography because the "cartographical" works of Eudoxus, Eratosthenes, Hipparchus, and Posidonius, which would shed some light on this matter, are nearly completely lost. Some doxographical notions and fragments are preserved but the narrative and historical contexts are normally missing. What is more, authors such as Strabo, Mela, and Pliny, who transmitted the bulk of information on astronomical geography, did not have a mathematical background. Hence, they often misunderstood and misrepresented the arguments and results of their "astronomical" counterparts or presented them only as "distillates" from secondhand

15 Though nothing from Anaximander has survived, one should note Strabo's remark [*Geog.* 1.1.11: Radt 2002, C7] that, according to Eratosthenes, Anaximander introduced the gnomon and was the first to publish a geographical map (γεωγραφικὸς πίναξ). Cf. Diogenes, *Vitae* 2.1.1: Müller 1882 2.471 (Agathemerus), 2.428.7–8 (Scholiast in Dionysius Periegetes), 2.208.91/17 (Eustathius).

16 Cf. also the titles of the works of Pomponius Mela and Pappus of Alexandria.

17 Strabo's *Geographica* is an exception only at first sight. Even Strabo could not deny that the geographer needs to have astronomical and mathematical knowledge, although he tried to play it down. Cf. *Geog.* 2.1.41 with 8.1.1: Radt 2002, C94 with 332.

18 The fact that Ptolemy's *Geographia* has survived as the sole specimen of mathematical or astronomical geography would suggest that we need a different categorization of ancient geographical literature. Thus, the Berlin Excellence Cluster TOPOI has proposed the concept of "common sense geography", which classifies spatial literature according to the degree of rationalization of the phenomena into "naive", "canonical", and "(fully) reasoned" geography: see Dan, Geus, and Guckelsberger 2014.

accounts. In other words, in Antiquity, geographers—much like astronomers (a group comprising mathematically skilled scientists as well as *aficionados* in stargazing and poets interested in mythography)—were far from constituting a homogenous group.

8 Conclusion

The last three millennia have witnessed a noticeable change in cartography. Maps nowadays play an essential role in modern life. As we have seen, the same does not hold true for ancient times. Geographical and astronomical maps were rare objects. Especially striking is the fact that astronomical knowledge (despite the advances made by Eratosthenes and Ptolemy) was not employed to a larger extent to produce maps. Most latitudes and longitudes of cities were, so far as we know, measured and mapped along routes hodologically, not astronomically [Janni 1984: cf. Prontera 1997]. This fact was lamented by Ptolemy in the introduction to his geographical treatise:

> Astronomical observation is self-sufficient and less subject to error, while surveying is cruder and incomplete without [astronomical observation].
>
> *Geog*. 1.2.2: BERGGREN and JONES 2000, 59

CHAPTER 6.3

Star-Lists from the Babylonians to Ptolemy

Gerd Graßhoff

1 Introduction

Star-lists date back to the beginning of the second millennium BCE in Mesopotamia, when they were used to classify groups of fixed stars relevant to the celestial omen series *Enūma Anu Enlil*. The names given to the stars by the Babylonians were for individual stars such as MUL.LUGAL (= *Šarru* or King), which is identifiable as Regulus, or for stars grouped into constellations such as the True Shepherd of Anu (MUL.SIPA.ZI.AN.NA = *Šitadallu*), identified as Orion. In Babylonian astronomy, lists of stars seem to have a primarily classificatory function: MUL.APIN tablet I lists 60 stars in the "paths of Enlil, Anu, and Ea" plus an additional 6 circumpolar stars. There is also a list of culminating (*ziqpu*) stars that number 14[1] and the "gods in the path of the Moon" number 17.[2]

While the Babylonians focused on the risings and settings of the fixed stars, they never depicted or described the visual spectacle of the nightly motion of the stars on a rotating sphere. However, there was much interest in identifying the stars that rise and set on the horizon before sunrise and after sunset. During the course of a year, the Sun appears to move across the sky, tracing the path of a great circle known as the zodiacal circle or ecliptic. In the northern hemisphere, the inclination of this circle to the celestial equator leads the Sun to move higher above the horizon in summer than in winter, which is why the Earth has seasons. Knowledge of the seasons was of great importance to the agriculturally based economies of the time, with its consequences for state taxes and thus everyday life. The so-called heliacal risings and settings of the stars allowed ancient astronomers to determine each day in a calendar year, solely on the basis of the first visible rising of a star before sunrise or its last visible setting after sunset, without the need of additional instruments. A star has the same longitude as the Sun only once a year, during which time it is not visible to the naked eye. As the Sun moves away

1 In the Late Babylonian Period, this list increased to 26 *ziqpus*. See chs 3.1 §3, p. 44; 7.2, p. 272.

2 see chs 5.1 §3, p. 174; 12.2 §2, p. 475.

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from the star, the star will rise at dawn just before the Sun and is thus visible to the attentive observer for a few moments before the light of the rising Sun drowns out the light of the star. This moment, the heliacal rising, was considered to be a sign of particular seasonal phenomena. Even the earliest civilizations—across all cultures—used the heliacal risings and settings, together with the azimuth of the rising Sun [see ch. 1 §4.3, p. 18] to establish agricultural and weather-guidelines. In the extensive literature of cuneiform omen-texts, additional factors, such as periodic planetary positions, or many terrestrial events, such as the behavior of animals or the observation of the exta of a sacrificed sheep, formed complex signs from which one could predict important events that were relevant to kings, the state, and sometimes the individual.

Thus, besides the position of the Sun in the zodiacal circle and the motions of the Moon, the long-term weather-patterns of the solar year, the different phases of the Moon, and the culminations of selected bright stars could all be used to establish the time at night. Only the brightest stars were named (such as Sirius and Regulus); other stars were classified by the constellations into which they had been grouped. In the first millennium BCE, star-lists were used almost exclusively to forecast the seasons and for divination.

2 Mapping the Heavens

2.1 *Aratus*

Over the centuries, constellations were used to describe celestial phenomena and this information was transferred in a similar manner to neighboring cultures. In the third century BCE, Aratus (*ca* 315–240 BCE) described the constellations in a poem, the influential *Phaenomena*, a medium through which stellar configurations could be easily memorized and communicated [see 10.1, p. 383]. The pictorial representations of the constellations had a mnemonic function and people were able to identify a group of stars through the use of just one word.

Following the Babylonians, Greek astronomers had posited a central belt about the zodiacal circle, the zodiac, and divided this circle into 12 zodiacal signs of 30° each that is surrounded by northern and southern zones. Aratus' poem, which is based on the writings of Eudoxus (408–355 BCE), provides the names of constellations and their configurations at setting and rising without referring to specific stars. Each description of a constellation concludes with the number of its stars. Aratus' *Phaenomena* was followed by a compilation called the *Diosemeia,* in which Aratus links stellar phenomena with meteorological knowledge and traditions. In the *Catasterismi*, Eratosthenes (*ca* 276 – *ca* 194 BCE) describes the figurative patterns of the constellations, including a summary of all the known bright stars.

2.2 *Hipparchus*

In the second century BCE, qualitative star-lists were quantitatively enhanced by Hipparchus of Nicaea (*ca* 190 – *ca* 120 BCE). In the second book of his commentary *In Arati et Eudoxi phaenomena*, Hipparchus describes, in a strictly schematic fashion, the simultaneous risings, culminations, and settings of bright stars along with the respective degrees of the zodiacal circle. The stars selected were those positioned at the boundaries of their constellation figures. Hipparchus thus mentions those stars in respect to the rising and setting of the constellation and also selects important degrees of culmination. Hipparchus' objective was not to create a comprehensive star-catalog but rather to write a quantitative criticism of Aratus. However, Hipparchus probably derived the data in his commentary with the aid of a celestial globe and not by carrying out numerical calculations. Presumably, the underlying observational data for the star-positions were the meridian-observations of the right-ascensions or the culmination-times and polar distances, namely, the declinations, of the stars. These observational records have, however, not survived.

2.3 *Ptolemy's Star-Catalog*

The only extant star-catalog of Greek Antiquity can be found in books 7–8 of the *Almagest* by Claudius Ptolemy (100 – *ca* 170 CE). The catalog contains 1,028 entries of stars or nebulas, of which three have been entered twice and another three are star-groups or asterisms. The stars have been grouped into 48 constellations: 21 northern constellations at the beginning of the catalog followed by 12 zodiacal constellations and 15 southern constellations. Each entry of the catalog has four columns for:

(1) the name of a star as belonging to a particular constellation figure,
(2) the star's longitude [see ch. 1 §4.1, p. 16] for the beginning of the reign of Antoninus, which, as this was the date Thoth 1 of Nabonassar 885, corresponds to day 137 (July) in 20 CE,
(3) its latitude [see ch. 1 §4.1, p. 16], and
(4) the numerical magnitude of the star's brightness, ranging from 1 to 5 (and faint).

Overall, the catalog rarely places individual stars outside their actual constellations. Unlike in modern catalogs, there are no abbreviated names for most of the stars. In order to identify stars, astronomers were expected to know the basic patterns of the constellations.

The spherical coordinate system that forms the basis of the catalog was introduced to the field of astronomy by Ptolemy. Besides citing a few older sources for the positioning of stars—a few declinations were provided by Aristyllus (*flor. ca* 26 BCE) and Timocharis (*ca* 320–260 BCE)—most of the information came from Hipparchus, "our chief source for comparison" [Toomer 1998, 321]. Hipparchus' values were presumably available to Ptolemy in degrees up to a fraction of ⅙°. Ptolemy noticed that, due to what he construed as the precession of the celestial sphere [see Glossary, p. 648], these values had changed since Hipparchus had recorded them more than 260 years earlier [see ch. 1 §7, p. 22]. Ptolemy credits the discovery of this phenomenon to Hipparchus. For example, in Cancer, Ptolemy cites three stars lying almost in a straight line. The central star (β Cnc) is "½ digits to the north and east of the straight line joining the two end ones" [Toomer 1998, 322], while the common distances between each of the stars remain the same.

Ptolemy records such alignments for all the zodiacal constellations and stresses several times that he obtained this information from Hipparchus. The use of "digits" or "fingers" derives from an original Babylonian source (no longer extant) that found its way into the *Almagest* through Hipparchus [see ch. 3.1 §4, p. 46]. In the final evaluation of the alignments, Ptolemy came to a significant conclusion: the alignments with the drawings and diagrams that Hipparchus deduced from the celestial globe were identical to Hipparchus' writings. Since Ptolemy quoted star-positions that are not in the coordinate system of the zodiacal circle, we can assume that he was the first to transform Hipparchan star-positions to the zodiacal or ecliptic coordinate system [see ch. 1 §4.1, p. 16].

2.4 *Ptolemy and Precession*

Ptolemy chose this particular coordinate system so that he could carry out the corrections needed to account for the precession of the fixed stars at different dates [see ch. 1 §7, p. 22]. As this precession, which is an eastward motion about the poles of the zodiacal circle, affects the longitude of the stars by little more than 1° in 100 years, one can easily convert the coordinates of the stars to another epoch. However, Ptolemy's value is too small by a third. Hipparchus had given a value of at least 1° per century for the effect of precession; Ptolemy took the lower end of this value to transform the data.

Since, according to Ptolemy, the sphere of the stars revolves slowly about the poles of the zodiacal circle, the intersection points of the celestial equator with the zodiacal circle (and thus the origin of the zodiacal coordinate system) move slowly westward. These points of intersection determine the spring and autumn equinoxes of the annual motion of the Sun. Traditionally, the vernal equinox was associated with the zodiacal sign of Aries. Due to precession, the constellations shift relative to the zodiacal circle in the direction of the Sun's annual motion. Ptolemy defined the position of the zodiacal signs as arcs of 30° and put the vernal equinoctial point at Aries 0°. For Ptolemy, this meant that in the passage of time the zodiacal signs will no longer coincide with the same constellations.[3]

3 Comparison of the Hipparchan and Ptolemaic Star-Lists

The celestial map [Figure 1, p. 245] shows Ptolemy's star-catalog (in blue) using the coordinates of the stars for the year 127 BCE on the zodiacal circle. The stars from Hipparchus' commentary are depicted in green. The positions are based on modern computations of up to a magnitude of 4.2. The bright stars not mentioned by Ptolemy or Hipparchus are plotted in white. The stars in configurations have been grouped into minimum convex polygons. Ptolemy's (blue) star constellations cover larger celestial areas than those of Hipparchus, owing to the different intentions of the astronomers: Ptolemy's aim was to provide a comprehensive description of the stars, whereas Hipparchus only referred to star-lists in his observations of horizon-related phenomena.

In the zodiacal coordinate system, the celestial equator is depicted as a curved line that begins at the vernal equinox. The areas of the constellations become detached from the map projection's surface when the constellations extend to the edges of the projection. The brighter southern stars (in white), which neither Ptolemy (in the *Almagest*) nor Hipparchus mentioned, are, owing to their southern declinations, invisible from places north of Alexandria in latitude. Although the polygons do not cover the entire sky, Ptolemy's constellation boundaries only fail to capture a few of the bright stars. With a few exceptions in the northern hemisphere, almost all Ptolemy's and Hipparchus' brighter stars are included in the areas along the zodiacal circle and the celestial equator.

3 In modern times, it has become customary to hold that it is the equinoxes which precess rather than the fixed stars. In this account, it is the zodiacal circle and, hence, the equinoctial points that rotate about the poles of the zodiacal circle and they do so in a westward direction, that is, in the direction opposite to the Sun's annual motion along the zodiacal circle. See Evans 1998, 245–246, 259–262.

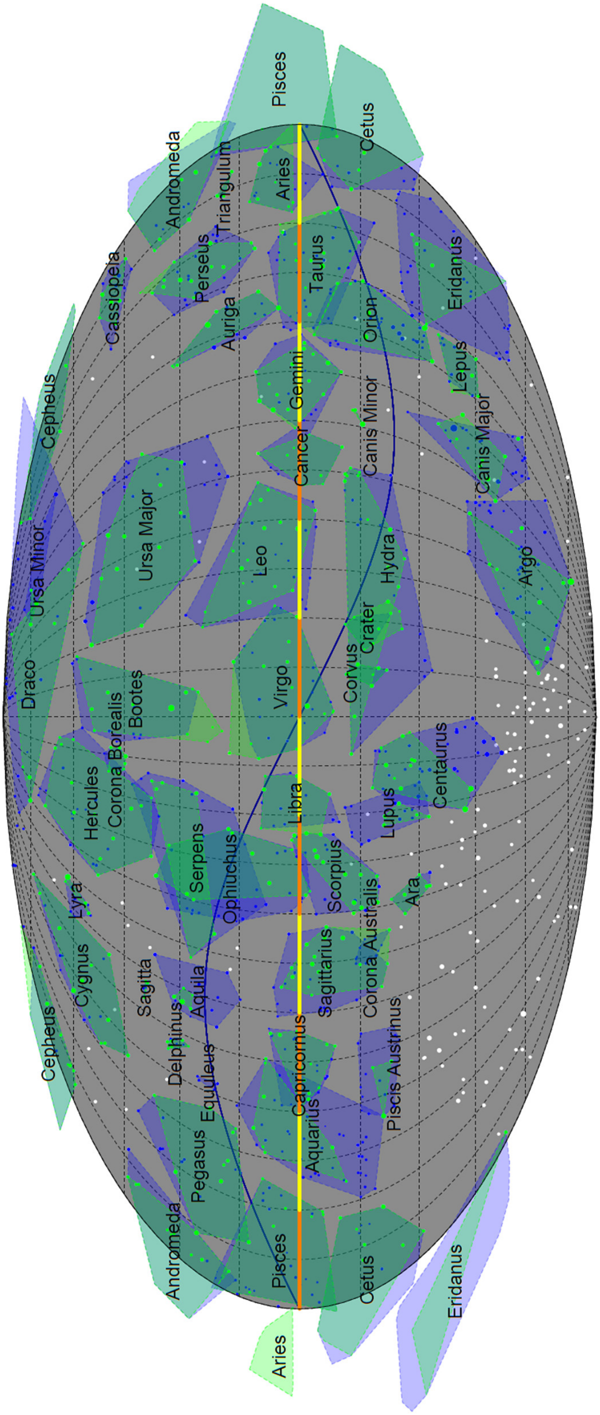

FIGURE 1 The constellations of Hipparchus (in green) and Ptolemy (in blue)
The bright stars not mentioned by either are plotted in white.
MAP GENERATED USING MATHEMATICA WITH ASSISTANCE BY SUSANNE M. HOFFMANN

CHAPTER 6.4

Ptolemy's Instruments

Dennis W. Duke

1 Introduction

Although the *Almagest* is primarily a book about astronomy as proposed by Ptolemy at the beginning of the first millennium CE, it is not surprising, but in fact necessary, that Ptolemy also discusses various astronomical instruments. Ptolemy's general approach to astronomy is:

(1) to assume some general framework, in this case a cosmos filled with various rotating celestial spheres carrying stars and planets, and then

(2) to suppose definite geometric hypotheses that specify precisely the sizes, speeds, and arrangements of these spheres.

The numerical values associated with these elements are at the outset all unknown constants that cannot be surmised from any kind of first principles but instead must be determined by trigonometrical analysis of carefully selected empirical observations. Thus, the instruments that Ptolemy discusses and the observations made with them are crucial supporting components of his theoretical program. And since one of the main goals of the *Almagest* is to be a handbook for future generations of astronomers, completeness requires that Ptolemy inform his readers of the instrumental aspects in his program. The discussion below will discuss Ptolemy's instruments but not his observations with those instruments or his use of those observations to establish his hypotheses, both topics requiring a much more complex analysis [Britton 1992].

Book 2 of the *Almagest* is concerned with the mathematics of spheres rotating about axes that are oblique to one another. The first two instruments that Ptolemy describes are closely related and are used primarily to determine the altitude or its complement, the zenith-distance [see ch. 1 §4.3, p. 18], of the Sun at noon when it is crossing the southern meridian [Figure 1, p. 247]. When these measurements are made at the summer and winter solstices—the times of maximum positive and negative angular distance or declination from the celestial equator—subtracting one distance (z_s) from the other (z_w) and dividing the result by 2 will give the angle of the zodiacal circle to the equator—usually called the obliquity (ε) of the zodiacal circle—and thus determine an important parameter in Ptolemy's hypothesis of rotating oblique spheres. In addition,

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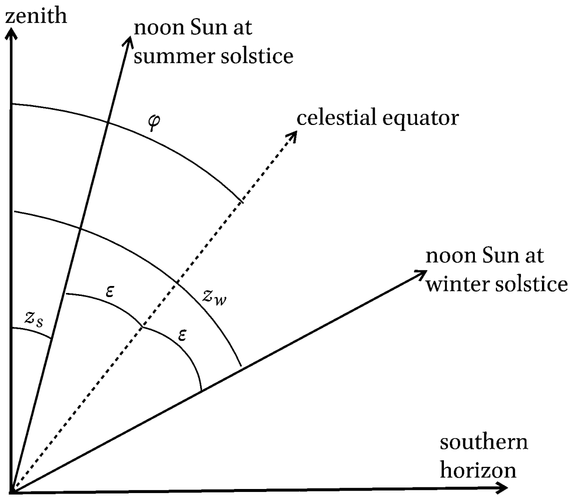

FIGURE 1 The obliquity ε of the zodiacal circle and the latitude ϕ of the observer with the zenith-distances z_s and z_w of the Sun along the southern meridian at summer and winter solstice

the average of the two zenith-distances gives the geographical latitude (ϕ) of the observer.

2 The Meridional Armilla

The first instrument is given no name but it might be called a meridional armilla [see Figure 3, p. 248]. It is a pair of concentric, circular bronze rings, the inner ring fitting closely inside the outer ring so that it does not fall out but is able to rotate smoothly. The outer ring is inscribed with marks that correspond to the 360° of the circle and any marks for fractions of a degree that might fit if space is available. The inner ring is fitted with two diametrically opposed plates with small pointers attached to their centers. Thus, by rotating the ring until the shadow cast by the upper plate is centered on the lower plate, the altitude of that object—or its complement, the zenith-distance—can be determined from the scale on the outer ring. The plane of both rings is adjusted to be both vertical and parallel to the meridian.

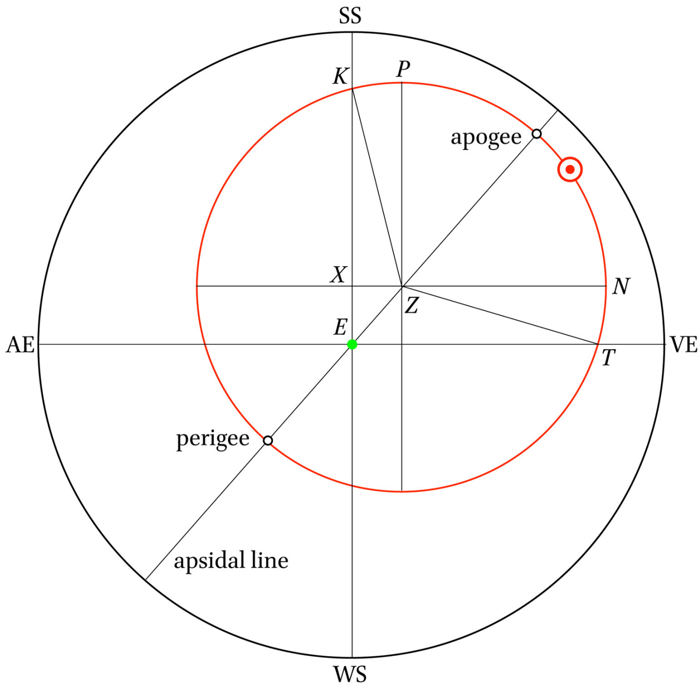

FIGURE 2 Parameters of solar motion
Earth is at E, the center of the celestial sphere, but the Sun's orbit is eccentric and centered at *Z*. From the season-lengths of spring and autumn, we can determine ∠*TZN* and ∠*PZK*, and simple geometry gives the eccentricity *EZ* and the direction of the apsidal line *EZ*.

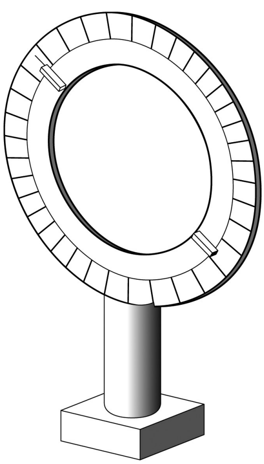

FIGURE 3
The meridional armilla

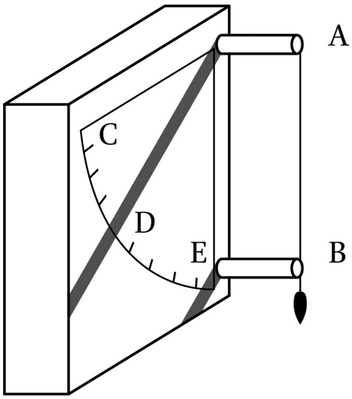

FIGURE 4 The plinth

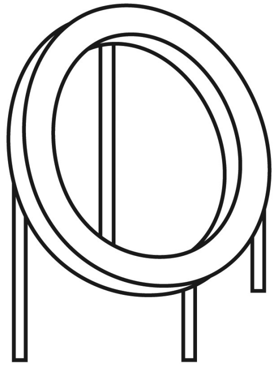

FIGURE 5 The equinoctial ring

3 The Plinth

Ptolemy next describes an alternative instrument, again unnamed but usually called a plinth, which he claims is "even handier", presumably because it is simpler to construct and use. One takes a square block of stone or wood with at least one face accurately planed flat and inscribes on this plane a quadrant of a circle with its center near the plane's top toward its southern edge and with marks for degrees and fractions of a degree on the curve as described above. Two pegs are inserted perpendicular to the plane on a vertical line, one peg at the center of the circle and the other at the bottom of the quadrant. Once again the plane is adjusted to be both vertical and in the plane of the meridian. When the Sun is on the meridian, the shadow cast by the upper peg can be used to determine its altitude and its zenith-distance.

4 The Equinoctial or Equatorial Ring

When Ptolemy comes to the hypothesis for the Sun in book 3, he needs to establish values for the length of the tropical year in order to determine the mean motion of the Sun and the length of the seasons, which will serve to determine the eccentricity and apsidal line of the Sun's orbit [Figure 2, p. 247]. To these ends, he introduces a third and even simpler instrument, which we might call an equinoctial or equatorial ring. This instrument is a bronze ring permanently mounted and adjusted so that it is in the plane of the celestial equator. Thus, when, and only when, the Sun is at an equinox, and so simultaneously on both the zodiacal and the equinoctial circles, the shadow cast by the part of the ring facing the Sun will fall upon the inner edge of the opposite part of the ring, thus determining the moment of equinox.

5 The Zodiacal Armillary Sphere

In book 4 of the *Almagest*, Ptolemy uses lunar eclipses to find the parameters of his lunar hypothesis at syzygy, that is, at conjunction and opposition. Most of the eclipses that he uses are from historical records, so no instruments are mentioned. For his contemporary eclipses, the only instrument needed is a clock to establish the time and he offers no guidance on how his timings were determined. But to determine the parameters of his hypothesis when the Moon is away from syzygy, the first major topic of book 5, he introduces the most elaborate of all his instruments, the zodiacal armillary sphere or astrolabe for short, which is not to be confused with the planar astrolabe popular with astrologers. The modern way of thinking about this instrument is to see it as an analog computer that allows a direct conversion of the local horizon-coordinates (altitude and azimuth) of any celestial object into the zodiacal coordinates (longitude and latitude) [see ch. 1 §4.1, p. 16].

Ptolemy's astrolabe has in total seven concentric rings. Let us number the rings 1 through 7 in order of increasing size [Plate 1, p. 251]. The instrument in Plate 1 was built at Florida State University in 2002 following Ptolemy's instructions as given in book 5 of the *Almagest*. The outer meridian ring is 24 inches in diameter and the inner sighting ring is 15⅝ inches in diameter. The markings on the two graduated rings are at ½° intervals. In this instrument, the geographical latitude of the observer is adjustable and the obliquity of the zodiacal circle is adjustable between 23° and 24°.

The two largest rings are essentially the same as those described above for the meridional armilla. An adjustable inner ring 6 slides smoothly but securely inside a larger outer ring 7, which is attached to a mount for the whole device. Inside these two rings is a nest of five rings that revolve as a group around the equatorial axis by adjusting ring 6 so that pivoting pegs connecting rings 4 and 6 are pointing toward the equatorial pole, and so at an angle to the vertical corresponding to the observer's geographical latitude. Thus, the pivoting of the entire nest of five rings accounts for the daily rotation or prime movement of the cosmos.

Rings 1 and 2 are a concentric pair, like rings 6 and 7, with ring 1 sliding smoothly inside ring 2. Two rotating pegs are inserted into ring 4. This creates an adjustable axis of rotation that is the pole of the zodiacal circle, at the angle

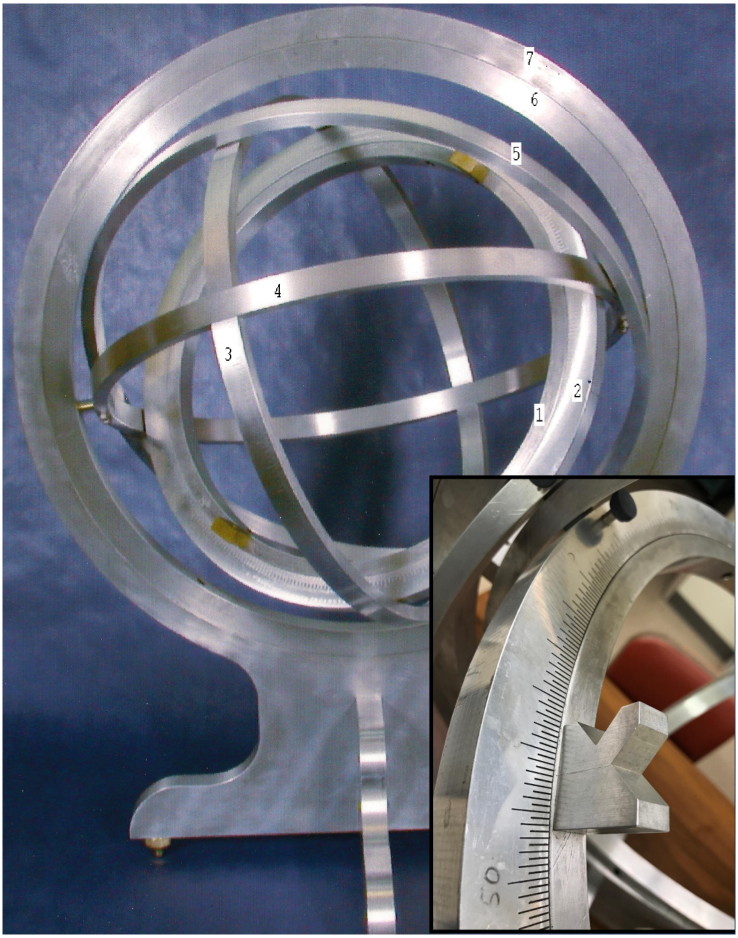

PLATE 1 A zodiacal armillary sphere
PHOTOGRAPHS: DENNIS W. DUKE AND JAMES C. EVANS (INSET)

determined in book 2 as the obliquity of the zodiacal circle. Rotating on these pegs are rings 1 and 2 on the inside of ring 4, while ring 5 rotates on the outside. A ring 3, which is the same size as ring 4, is mounted on ring 4 so that its plane is perpendicular to the axis of the zodiacal circle. Rings 3 and 2 are both inscribed with marks indicating the degrees and, in the words of Ptolemy, "as small subdivisions of a degree as was practical" [Toomer 1998, 218]. A pair of diametrically opposed ferules or peep sights is mounted on ring 1, so that a target object may be sighted by rotating ring 1 inside ring 2 and sighting through the ferules. In order to use the instrument to determine the longitude and latitude of an object, the assembly of rings 1–5 must be rotated so that the plane of ring 3 is in the zodiacal circle. If the Sun is well above the horizon, this can be accomplished by rotating the rings until the shadow of ring 3 falls on its inner, trailing surface—as happens with the equinoctial armillary mentioned above. If the Sun is not available, the rings can be rotated until the longitude of some object of known longitude, perhaps the Moon or a bright reference star, is indicated by rings 3 and 5. In either case, once ring 3 is known to be in the plane of the zodiacal circle, rings 1 and 2 are adjusted so that the target is seen through the sights and its longitude and latitude can be read from rings 3 and 2, respectively. In addition, whenever ring 3 is in the plane of the zodiacal circle, one can read off from the intersection of ring 3 and ring 6 the degree of the zodiacal circle that is culminating, that is, crossing the meridian to the south, and using this and a theory of the Sun, determine the local time.

5.1 *The Meteoroscope*

Closely related to the zodiacal armillary sphere is the meteoroscope mentioned in Ptolemy's *Geog*. 1.3. This instrument, which Ptolemy described in a lost work that is known to us only in references by Pappus and Proclus, was like the zodiacal armillary sphere except that, while the latter had seven rings, the meteoroscope had nine—three for determining positions in relation to the zodiacal-circle, three for positions in relation to the equinoctial circle, one for sighting, and two more rings for positions in relation to the horizon.

6 The Question of Accuracy

In order to get a sense of how accurate these instruments must be, let us consider the determination of the time of an equinox or a solstice. Ptolemy mentions a number of such determinations by Hipparchus that are all rounded to a ¼ day or 6 hours. That might sound a bit large but Ptolemy points out that, if there is an error of only $\frac{1}{10}°$ in the measurement of the Sun's zenith-distance, the resulting error in its longitude will be ¼°, which is about 6 hours in time for the moment of equinox or solstice.

There are a number of factors that in practice limit the accuracy of any measurements made with the instruments just described:

(1) All of them must be free of warped components and must remain so during their useful life. This fact then limits their size, since if they are too big and heavy they will bend under their own weight. Three of them have one or more metal rings and these will be subject to thermal expansions and contractions throughout the day and the seasons that might well lead to nonuniform errors due to stresses and other imperfections in the metal.

In addition, the larger the component parts, the more likely in general are imperfections due to manufacturing, for example, lack of planarity, lack of circularity, and lack of uniform thickness.

(2) Beyond the issue of imperfections in the components, all four instruments must be carefully aligned and adjusted. The appropriate axes of each instrument must point very close to the zenith and be parallel to the north-south line of the meridian. One might address the former with a plumb line and the latter with a series of determinations by means of the shadow of a gnomon. Both efforts, however, present many opportunities for error; so some degree of error is unavoidable. Unless the instrument is permanently and securely mounted, the need to realign the axes each time the instrument is used introduces the chance of additional errors.

(3) The instruments should not be too small or they will be unable to supply the precision required for the desired measurements, usually angles in one or more celestial coordinate systems that must be determined to some fraction of a degree. It is straightforward to get a reasonable estimate of the size required to achieve a given level of precision in these instruments. For example, if graduations of ½° are desired and the marks are 2 mm apart, so that estimates might be made to ¼° or smaller, then a ring so graduated must be at least 1,440 mm in circumference, or about 46 cm (about 18 in) in diameter.[1] Graduated rings of about this size, 1 cubit (about 18 in), are in fact mentioned by Pappus; and a 2-cubit equinoctial ring (probably ungraduated) is mentioned by Theon [Rome 1926, 11]. The two graduated rings of the FSU armillary sphere are also about the same size (one is 18¾ in, the other is 17¾ in). This graduation of the rings is simple enough for us to estimate but it would probably not have been so easy to manufacture accurately in Antiquity. Imagine, for example, how one might go about marking the divisions on a ring. Presumably one would find four marks 90° apart, then bisect these angles, and then bisect them again, so as to get 16 marks that are 22½° apart. But the positions of the remaining marks would have to be estimated somehow and this will inevitably produce a nonuniform distribution of errors around the entire ring. In the case of the zodiacal armillary sphere, there are two pivots and there would very likely be some play in them that would introduce errors.

Using the instruments discussed above and getting measurements accurate to a fraction of a degree is, in practice, not at all straightforward.

1 For comparison with an instrument that has survived, graduated rings on the Antikythera Mechanism have 1° marks spaced about 1.2 mm apart [Price 1975]. On the date of the Mechanism, see ch. 10 §4, p. 345.

Consider the equinoctial ring when one is estimating the moment when the shadow of the ring falls on its back inner edge:

(a) half the equinoxes occur during the night and so cannot be seen at all;
(b) atmospheric refraction will severely distort results of measurements taken near sunrise and sunset;
(c) even when the Sun is well above the horizon, the sky must be fairly clear or there cannot be a useful shadow; and
(d) since the apparent diameter of the Sun in the sky is about ½°, the shadow cast by the edge of the ring will generally not be particularly sharp and specifying the moment when it appears centered on the rear of the ring can be problematic.

In the case of the meridional armilla and the plinth, the measurements are taken only at noon, so a clear sky is required at a very specific time. For the first instrument, the shadow cast by the upper plate will be poorly defined as it falls on the lower plate: since the angular size of the Sun is ½°, the Sun will almost certainly shine both above and below the upper plate and the shadow cast will have not only an umbra but also a very noticeable penumbra. (The same thing happens with a gnomon—the shadow never has sharp edges). That fuzziness will make an accurate determination of the solar altitude problematic at best. In the case of the plinth, the angle of the shadow cast by the peg must be measured just before noon, thus inviting some error unless mitigating steps are taken [Britton 1992, 1–11]. In both cases, errors in manufacturing and in alignment would make unbiased and accurate measurements difficult. Of course, if the measurements were meant to simply verify some prior expectations, then that is another matter entirely. In the case of the armillary sphere, there are two graduated rings of different sizes and this will further compound the effect of errors in the graduation marks. In addition, the complicated multiring design introduces several other problems:

(a) There is a substantial amount of material in the instrument that inevitably blocks the view in some directions—for example, directly toward the zenith, toward the south, and toward the north—objects with low latitude being prime examples.
(b) Experience shows that sighting stars, and especially dim stars, through the ferules on the inner latitude ring 1 is difficult at best and literally impossible for some mechanical configurations of the rings—to say nothing of the problem of parallax regarding the placement of the eye in the sight line through the ferules.
(c) Besides the alignment with the zenith and the meridian plane, there are two other angles in the instrument that must be accurate: the geographical latitude of the observer and the obliquity of the zodiacal cir-

cle. In Ptolemy's case, neither of these angles is specified correctly in the *Almagest* and it is likely that one or both angles would also be misspecified to some extent by most other users in Antiquity.

(d) The objects that need to be sighted are moving, which implies the need for carefully moving the rings and making the readings of reference and target objects close together in time.[2]

To complete his discussion of the Moon, Ptolemy has to determine its distance in units of Earth radii, since that distance is small enough that the parallax of the Moon must be corrected for in most lunar observations. In order to do this, he needs observations of the Moon in very special circumstances, namely,

– when it is crossing the meridian, and
– when it s at the same time very near one of the solstitial points in longitude (i.e., near 90° or 270°).

When such circumstances arise, which is not very often, a measurement of the Moon's apparent zenith-distance can be compared with the zenith-distance predicted by Ptolemy's hypothesis; and the difference of those two values, that is, the parallax, is enough to determine the Moon's distance from the Earth in units of Earth radii.

7 The Parallactic Instrument

Measuring the zenith-distance of the Moon is similar to measuring the zenith-distance of the Sun using the meridional armilla discussed earlier, except that even a Full Moon will not cast an adequate shadow. Therefore, in *Alm.* 5.12, Ptolemy replaces the plates with sighting ferules similar to those found on ring 6 of the astrolabe; and in addition he builds a new, and much larger, parallactic instrument to carry these ferules [see Figure 6, p. 256]. This structure has two rectangular rods of measured length—Ptolemy says the lengths should be no less than 4 cubits, so about 6 feet—one of which is mounted vertically with one face parallel to the meridian (like the plinth). At the top of this rod is a peg on which the second rod rotates and at the two ends of the second rod the sighting ferules are attached [Figure 6, p. 256]. When the Moon is in position on the meridian, it is sighted through the ferules and the distance between the bottom of the first post and the bottom of the second post is noted with the aid of a third rod. Given the lengths of both posts and this measured distance, simple trigonometry gives the desired angle at the top of the triangle, which is the

2 The best modern account of observing with an zodiacal armillary sphere is Włodarczyk 1987.

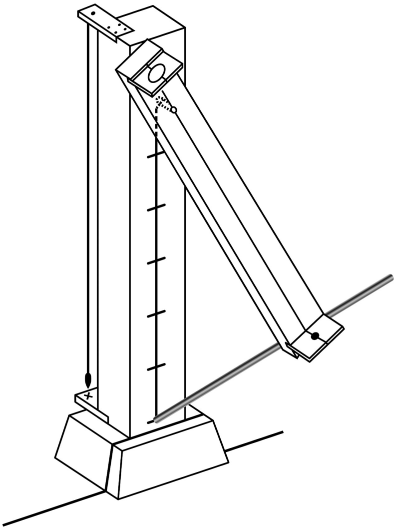

FIGURE 6 The parallactic instrument

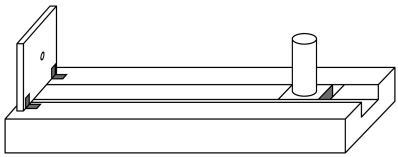

FIGURE 7 The dioptra

zenith-distance of the Moon. Clearly, this instrument will be subject to a number of potential sources of error similar to those discussed above.

8 The Dioptra

The final instrument, which Ptolemy presents in *Alm*. 5.14, is the *dioptra*, an instrument which he says was also used by Hipparchus [see chs 6.1 §2, p. 222; 6.1 §11, p. 229]. The *dioptra* is a long rectangular rod with two sighting plates. One of the plates is fixed at one end and has a small sighting hole; the other plate is allowed to slide along the base rod until the sliding plate, as seen through the fixed plate, just covers a target such as the Sun or Moon. Then the angular size of the object can be determined from the length of the rod and the size of the sliding plate. Ptolemy mentions a rod of 4 cubits (about 6 feet), which would imply a sighting plate of about 16 mm in size. Ptolemy uses the dioptra to determine that the Sun and Moon have the same angular diameter at maximum lunar distance. But he decides that determinations of the angular diameter of either object with the dioptra are too uncertain and eventually finds those values using a pair of lunar eclipses.[3]

3 See Carman 2009 for a thorough account of *Alm*. 5.13–15.

9 Displaying the Planetary Hypotheses

In the opening paragraph of his *Hypotheses planetarum*, Ptolemy expresses an interest in instruments to display arrangements of the various spheres of his planetary hypotheses, especially their motions leading to the anomalies that we observe and that the hypotheses are meant to explain, namely, their variation in speed around the zodiacal circle, the periodic occurrence of retrogradations, and their motions in latitude. These motions of the spheres in these instruments could result either from adjustment by hand or by some mechanical device, presumably some arrangement of gears. Unlike the instruments for measurement described above, there is no indication that Ptolemy ever built or even saw any of these instruments for demonstration. But he clearly hopes that some might be built to improve on the more common sphere-making that displays craftsmanship but not the fidelity to nature that interests him.[4]

10 The Planisphere

Ptolemy's *Planisphaerium* develops the mathematical construction needed to project onto a plane the principal components of the celestial sphere, i.e., the equator, the zodiacal circle, and some circles of declination and latitude [Sidoli and Berggren 2007]. Ptolemy shows that once this projection is made it is possible to solve many of the problems that he solved in books 1 and 2 of the *Almagest* using spherical trigonometry, e.g., the rising-times of the zodiacal signs at some geographical latitude. Ptolemy makes it clear that the purpose of this construction is to guide instrument-makers in making physical *planisphaeria* (planispheres). In this way, there is a similarity with the aim of the *Hypotheses planetarum*. While there is no evidence that Ptolemy himself ever used a *planisphaerium*, such instruments were eventually constructed a few centuries later.

11 The *meta-helikon*

Finally, in the *Harmonica* Ptolemy describes another instrument for demonstration that he probably did build, this time to deliver to the ear the sounds of the theoretically constructed tonal scales that are one of his principal inter-

4 See Hamm 2011 for a thorough review of Ptolemy's *Hyp. plan.* 1.

ests in the *Harmonica*. This *meta-helikon* is a soundboard with a set of movable strings and an adjustable bridge, thus enabling the user to play scales with many different sets of theoretically specified ratios of string-lengths [Barker 2009]. Although it is not strictly an astronomical instrument, to Ptolemy astronomy and harmonics were so closely related that the final part of his *Inscriptio Canobi* is a set of such ratios of tones [Swerdlow 2004b].

12 Conclusion

Ptolemy's instruments for observing the heavens and the program given in the *Almagest* for using specially selected observations to fix the parameters of astronomical hypotheses were both influential for the next 15 centuries, first in Islam and later in Europe. The instruments especially were improved several times over, usually by making them bigger and thus allowing measurements that were both more precise and more accurate. In particular, the faulty parameters for Ptolemy's solar hypothesis were all replaced by much better values. On the other hand, the stellar coordinates listed in the star-catalog of *Alm.* cc. 7–8 were not measured again until the 1400s, when Ulugh Beg established a magnificent observatory in Samarkand. Still, there was no significant improvement in either the stellar coordinates or the parameters of his planetary hypotheses, except for a much better value for the constant of precession [see Glossary, p. 648].[5] The real breakthrough for all of these empirical measurements was made in the mid to late 1500s by Tycho Brahe, who was able to design and build instruments that were truly great improvements over Ptolemy's and enabled measurements whose accuracy was limited primarily by the limits of resolution of the unaided human eye [Thoren 1991].

5 See Sayili 1960 for an excellent overview of the development of instruments and observations in Islam.

Thematic Questions

CHAPTER 7.1

Issues in Hellenistic Egyptian Astronomical Texts

Anthony Spalinger

1 Introduction

This chapter aims to outline the major issues concerning Egyptian astronomical sources, centering upon their intrinsic nature as well as the applications of the source material to dating, both ancient and modern.[1] It illuminates the Hellenistic Period because, in Egyptian astronomy, owing to its conservative outlook, we find that old concepts are not abandoned but remain. This is particularly noticeable in the persistence of age-old waterclocks. In addition, new ideas were added to the older parameters, especially in religiously oriented texts.

2 Lunar Dating

The extant historical data from ancient Egypt provide helpful benchmarks. The absence of secure eclipse-records is balanced by a relatively large number of lunar-oriented events, many of which are also set within the Egyptian civil calendar [see ch. 2 §5, p. 24]. Thus, we possess two overlapping methods of historical positioning. The following hypothetical schema illustrates the usefulness of these records with "double dates" [Depuydt 1997].

> Regnal Year X, month Y, day Z under the majesty of Pharaoh PN; lunar day *psḏntjw*.

The Egyptian lunar month began with the absence of the Moon from the morning sky. In the case above, I have chosen the first day of the month. The date is described in two ways. The first is the king's regnal year plus the month and the day. Besides the day is a lunar equivalent. In festival calendars, there was a preference for the first day as well as for the 15th, which in the scheme was the day of the Full Moon. Now, knowing the general time frame during which this

1 See Clagett 1989–1999, vol. 2; Neugebauer 1969, 80–91; ch. 4.8, p. 160.

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hypothetical king lived, it is relatively easy to identify the astronomical parameters for the sighting made on this particular first lunar day.

Ludwig Borchardt [1935] established this method of determining absolute dates for pharaonic Egypt. He showed how frequent such lunar sightings were, even though, as Parker, R. Richard Parker later commented [1950], his analyses tended to be questionable. Parker, in fact, may be credited as the first Egyptologist to explain fully and clearly the Egyptian method of astronomical sighting.

Egyptian lunar events were determined by the complete invisibility of the Moon, that is, by the first day after the last appearance of the waning lunar crescent. It was in the east, then, that the Egyptians concentrated their energies. Not only was the lunar monthly cycle based on a first eastern "nonevent" or "nonappearance" before sunrise, the first sighting of the important star Sirius (Egyptian Sothis) after its period of invisibility, that is, its heliacal rising, also involved a nonevent, this time, the Sun's absence as it lies below the eastern horizon [Krauss 1985]. We shall cover the significance of Sothis later [see §4, p. 264] but for the moment it is sufficient to emphasize the eastern orientation of the Egyptians' observations.

Lunar events seen in the east and determined by the invisibility of the Moon are particularly vulnerable to statistical error. Parker [1950, 13–15] figured that between 17 and 30 hours could pass during the interval from the Moon's last visibility in the morning to its first visibility in the evening, when the Sun's light makes it invisible. The number of hours that could be indicated by the Egyptian record of *psḏntjw* (lunar day 1) amounted to 1 day, of course. However, 60 hours could pass between seeing the last crescent in the west and its reappearance in the east on *ꜣbd* (New Crescent Day), the name of the second lunar day. The third day was called *mspr* (Arrival Day). Given the time-interval of about 84 hours between the last waning crescent and the new waxing one, it is easy to conclude that most lunar conjunctions occurred on the first Egyptian lunar day, though they could occur either one day before or one day after when the first sighting of the crescent is allowed a greater delay to cover Egyptian *mspr*.

Egyptologists have often tried to establish working cycles of lunar days. One example is based on the well-known demotic papyrus *PCarls.* 9 (dated *ca* 144 CE), which covers 25 Egyptian civil years (each of 365 days) in which every first civil day was given a lunar equivalent.[2] Unfortunately, the origin of the papyrus is uncertain and its applicability to Egyptian time-reckoning is unclear. Was it Babylonian in derivation? Were modified versions of its cycle employed in the Ptolemaic Period?

2 For a most recent discussion of this papyrus, see Krauss 2009.

Other scholarly attempts have relied upon chance and the infrequent mention of closely identifiable Egyptian lunar days. With these, too, exact determinations of absolute dates are impossible.

There are major statistical problems associated with any Egyptian lunar date. Naked-eye sightings are highly individualistic. When the challenge was to observe the absence of any crescent Moon, it is easy to realize that inaccuracies could occur. There must have been instances in which the native contemporary viewer made an error when he set *psḏntjw* on a specific day. Indeed, there was no regularly devised method in ancient Egypt of determining when a lunar month had 30 days and when it had 29 days. Furthermore, Bradley Schaefer's sophisticated unbiased investigations, carried out through his Moon-watch program, have demonstrated that humans are not reasonably adept at near perfect accuracy when identifying the advent of a lunar crescent (or lack thereof); rather, mathematical formulae must be applied.

It is not that Egyptologists have consulted outdated computer programs or that they have run ones readily available but simplistic that renders their lists of first lunar days questionable. More seriously, it is that they have not applied statistical methods to their calculations. The use by Ronald Wells [2002] of Schaefer's research has demonstrated the imponderable nature of exact dating when the accuracy of Moon-sighting is around 73%.

3 The Origins of the Civil Calendar

There has been much scholarly disagreement about the origins of the Egyptian civil calendar, in which there were 12 months, each possessing 30 days, all set within 3 seasons, and 5 extra days (called epagomenal).[3] Otto Neugebauer [1939, 1942b] sought a physical explanation by advocating that the year originally began when the flooding of the Nile coincided with the season called Inundation and that the year-length was reached by averaging the day-count between Nile floods, whereas Parker [1950, 52–53] argued that there was an averaging of lunar years of 12 and 13 months to arrive at a mean number (or average) of 365 days per year. R. W. Sloley [1948] disagreed and proposed that the interval to be averaged was that between the migrations of birds. However, it appears better to argue for the establishment of a specific date, that of the heliacal rising of Sothis, as the epoch of the civil calendar.[4]

3 See Spalinger 1994; Harrison 1994; and Devauchelle 2005.

4 See Spalinger 2010, partly following Berlev 1999 but revising Gardiner 1906 and 1955; Parker 1957; Sauneron 1962; Depuydt 1999 and 2003.

Indeed, Parker [1950, 53] later claimed that the number of days between successive heliacal risings of the star Sothis would effectively account for the year-length.

Once the Egyptians transferred their timekeeping into this simple method of calculation, the influence of Moon-oriented events radically diminished. The first sighting of the Sothic heliacal rising for calendrical purposes is now placed in *ca* 2768 BCE, following Parker.

4 The Heliacal Rising of Sothis

The Egyptians turned east to make their observations. The annual heliacal rising of Sothis is perhaps the best known event in their astronomical writings [Krauss 1985]. Their term was «prt Spdt», the "going forth of Sothis" after a period of invisibility of 70 days. In 139 CE, Censorinus wrote concerning the fundamentals of this event. Both the primary observers and modern scholars have been at pains to set any "Sothic date" within a template, that is, as a Julian date (modern) or a day in the pharaoh's reign (ancient).

The importance of this event was emphasized by its "ideal" temporal position when the inundation began in mid-July (day 19 in the Julian calendar to be exact). Needless to say, everything was assumed to have its rebirth then: the year, a king's reign, prosperity, and so on. Very few Sothic dates are preserved. Many of them have been discussed repeatedly owing to their importance. Whenever an exact date for this event can be determined in the Julian calendar, accurate Egyptian chronological measurements are possible. (Naked-eye sightings are liable to error and one must use an aneroid barometer to measure the atmospheric pressure to determine the time when Sothis rises heliacally.)

Middle Kingdom temporal reckoning is presently based on the heliacal rising of Sothis.[5] In one significant example, the date given is IV *prt* 16, which signals a time around 1870 to 1840 BCE, plus or minus one decade. A key reference in the contemporary Illahun papyri contains the same date and the reign is that of Sesostris III.

Normally, Egyptian interest in recording the heliacal rising of Sothis was singular and solely concentrated upon the auspicious event itself. Only when a complete Sothic cycle[6] was at an end would the hallmark of that Great Year be indicated.

5 For a detailed discussion, see Luft 1992.

6 Given that the year is 365¼ days in length, the heliacal rising of Sothis in July (Julian) will

The Egyptians used the risings of certain star-groups in the east, called decans, to measure the hours of night. Joachim Quack has presented cogent reasons for thinking that this method was first used during the Old Kingdom.[7] By the 12th dynasty (*ca* 1990 BCE onward), the date of the extant private coffins on which the decanal system was painted, a revision would have had to occur because of the gradual movement of these star-groups in relation to the fixed Egyptian calendar of 365 days. Should we therefore assume that in the late 12th dynasty there was a revision of the older decanal system of stars seen at night, the ones painted on private coffins, given that they present the date of IV *prt* 16 [see ch. 12.1 §4.2, p. 446]?

5 The Beginning of the Calendrical Day

Two major proposals regarding the Egyptian calendrical day have repeatedly been offered to scholars and the public alike [Krauss 1993; Spalinger 2006]. Considering the eastern orientation of their lunar perceptions in combination with the heliacal rising of Sothis, it seems reasonable to argue that the Egyptian calendrical day, which began in the morning, commenced either at dawn or at morning twilight. In their vast discussions of the primary sources, both sides of this position have argued their case with success. Frequently overlooked, however, is the situation of the star Sothis. Its heliacal rising presupposes a period of time that is relatively short but nonetheless sufficient for this object to be seen *before* the actual appearance of the first sliver of the Sun in the east. Hence, *prt Spdt* implies a moment that precedes sunrise. For this reason alone, it is justifiable to decide that the epoch of the calendrical day in ancient Egypt started in the early morning twilight.

5.1 *Division of the Calendrical Day*

Parallel to this arrangement was the early system for the hours of nighttime [Spalinger 2012]. The diagonal star-clocks on Middle Kingdom coffins indicate that the interval of night was divided into 12 hours of darkness. A depiction of a shadow-clock in the Seti I cenotaph at Abydos also shows that daylight included 1 hour of morning twilight and 1 hour of evening twilight.

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advance by 1 day every 4 years in the Egyptian calendar of 365 days. Thus, in $(365 \times 4) + 1 = 1461$ years, it will complete 1 Sothic cycle and return to the original date in the Egyptian calendar.

7 For discussion of the instruments of time-reckoning, see Spalinger 2010.

The early shadow-clocks, however, marked 4 hours preceding noon and 4 hours following. Hence, there were originally 8 hours—of unequal length throughout the year, of course—during the interval of day. Owing to this arrangement, it seems likely that the definition of this interval excluded morning twilight, during which Sothis could first be seen after 70 days of invisibility, and evening twilight.

Thus, 2 hours included twilight. In a sense, this tripartite sequence of morning twilight, "day", and evening twilight resembles the division of the interval of night into evening, middle, and early morning, as known from other sources.[8]

5.2 *A* caveat

One final point needs to be stressed. The absolute chronology of Egypt differs depending upon whether it is based upon sunrise or morning twilight as the beginning of the ancient Egyptian calendrical day. Unfortunately, some have followed one chronology unwittingly or have chosen it without forethought. It is a desideratum for resolving which diurnal cycle was in force during pharaonic Egypt.

6 The Heavens in the Old Kingdom

We rely solely upon the archaic spells labeled Pyramid Texts (first half of the third millennium BCE) for our reconstruction of the oldest phases of Egyptian astronomical thought. The Egyptians divided the heavens into a northern and a southern sector delineated along the zodiacal circle, which they named the *kha*-canal. The ferryman Mekhentiu, associated with this sinuous waterway, is presumed to be the Moon, which waxes and wanes in different sectors of the sky. The northern or upper locality was called the Field of Offerings and the southern, the Field of Reeds. Kurt Locher [1992] has argued that the decanal belt, known from Middle Kingdom coffins, was already in existence as a topographic entity in 2500 BCE [Locher 1992]. Rolf Krauss [1993] has identified other details that the Egyptians of this time applied to their night sky. The basic result of his research, however, is the definitive solution to the significance of the *kha*-canal and the dating of the earliest evidence for knowledge of the zodiacal circle to the middle of the third millennium BCE.

8 For example, as recorded in the cosmological text, *PCarls.* 1, a late demotic papyrus dated to the second century CE, the Sun-God Re is born before sunrise and enters the mouth of his mother, the sky goddess Nut, during the first hour of the evening [von Lieven 2007].

The stellar objects north of the zodiacal circle were called the Imperishable Stars (*ikhemu-sek*, *jḫmw-sk*) and those to the south of the zodiacal circle were called the Unwearying Stars (*ikhemu-wered*, *jḫmw-wrd*). The former were visible every night of the year, whereas the Unwearying Stars would disappear for days or months at a time. Stars from both sides of the zodiacal circle were present in the solar bark of Re. Egyptologists formerly assumed the Imperishable Stars to be the circumpolar stars.

Among the familiar Imperishable Stars was Capella, a major celestial body with a very bright magnitude. Although located north of the zodiacal circle, it appears relatively close to the constellation of Orion (Egyptian Sah, Sꜣḥ), which is to the south of that dividing line. Orion was considered to be the male counterpart of Sothis. In later depictions of the sky, Orion always preceded Sothis. Their appearance presaged the commencement of the Ideal New Year. As a star, their son was called Horus, Horus-in-Sothis. The Crown of Sah is equivalent to the Greek girdle and sword of Orion. The Egyptians also stressed the presence of a Great Star near to and west of Orion. So far it has not been identified but Aldebaran (+1.1 magnitude) has been proposed.

7 The Decanal System and the Ramesside Star-Clocks

The oldest system of telling time in the evening was based on the risings of star-groups in the eastern horizon after sunset. Not all of these configurations have been identified. Neugebauer and Parker denied any final resolution, whereas Locher's proposals have met some acceptance, especially for stars north of the zodiacal circle, for example, the "constellations" of the Sheep, the Bird, and the Lion between Two Crocodiles. He has also argued that the decanal belt was already a topographic entity about 2500 BCE.

The original method was to locate certain cohorts—now called decans—of stellar objects and then use them to mark 12 hours of the night, which consisted of complete darkness, not the twilight after sunset or before sunrise. The stars corresponded to the ends and not the beginnings of their respective hours. Every 10 days the star markers had to be moved, hence the term "decan" [see §§4, p. 264 and §7, p. 267; ch. 12.1 §5, p. 448].

Because this method was based upon a week of 10 days, Neugebauer and Parker concluded that the decanal system was invented after the civil calendar. While much of our data for this arrangement of timekeeping come from private coffins of Dynasty XII, evidence adduced by Quack [2002] indicates that the decanal system began hundreds of years earlier. The purpose of the decanal system was to arrange a relatively standard series of night-hours that would play a role in Old Kingdom cultic practices.

By the Middle Kingdom, there was a switch in orientation. A new method of determining the decanal hours was introduced. The Egyptians abandoned their eastern orientation and adopted a fundamental change in localization. The new method was to wait for designated stars to cross the meridian to mark the beginning of each hour of the night.

The Ramesside star-clocks constituted a third way to count the hours of night (complete darkness). Despite its name, this method was in use in Dynasty XVIII (roughly *ca* 1480 BCE onward). It revised Egyptian global celestial observations in that it relied upon a different series of star-groups. There were just 13 of them in 24 tables. Some of these stars lay within the decanal belt but most were outside of it. Although Sothis and even Orion had places, we cannot identify any of the other star-clock members with certainty. The same difficulties remain as with the earlier decanal groups.

The newer method employed the meridian as well as lines before and after it. Its series of star-groups was different from the earlier decanal arrangement. And whereas the decanal-star hours remained fixed in length, those of the Ramesside star-clocks frequently varied in length. All of the native Egyptian systems were cemented into the hours of complete darkness and thus were not the same as the later Greek seasonal hours that stretched from sunset to sunrise.

8 The New Inventions of Timekeeping

Sometime in the early XVIIIth Dynasty, the waterclock was introduced into Egypt (*ca* 1520–1500 BCE). Although there is no artifact preserved, this object is mentioned in the private tomb of Amenemhet, a warrior who is often said to have invented the first Egyptian *clepsydra*, although there are better reasons to presuppose borrowing from the East, that is, from Babylon *via* Syria. Complete darkness was again at its basis but there is the possibility that the short intervals of morning and evening twilight were included.

A shadow-clock copied on a wall in the Osireion cenotaph at Abydos and dated to Seti I (1290–1279 BCE) is definitely of an earlier date. Twilight belonged to the "day-hours".

Thus, by Dynasty XVIII, notwithstanding the Ramesside star-clocks, the decanal systems had been replaced by a more artificial way of regarding and counting the hours of night.

Some have argued that the *clepsydra* was the basis for those star-clocks but there is no apparent reason that a cumulatively third method of sighting night-stars would have depended upon a less empirical method. Stated simply, at present the extant data reveal at least three different means of timekeeping for the night:

(1) Ramesside star-clocks,
(2) waterclocks, and
(3) shadow-clocks.

One particular shadow-clock, the first, might be the earliest of these instruments—but only if the Sothic reference in the Ramesside star-clocks alludes to the introduction of the other type of device. It may not be so. In any case, the waterclock, if arriving from the east, has to be considered separately from the shadow-clocks. Yet all three of the aforementioned newer systems imply that both daytime and nighttime were now amalgamated into a unity. The chores of regular nightly observation and memorization came to be superseded by the customary employment of small, often ritual, objects for the evening and a technical apparatus for the hours of "day" [von Lieven 2016].

9 Nature of the Egyptian Source Material

If one were to assemble the extant written and pictorial evidence concerning the Egyptians' perceptions of the heavens, with very few exceptions the material belongs to a priestly or cultic context. Granted that cosmological papyri such as *PCarls.* 1 reflect a perception that was not fully sacerdotal, they nevertheless indicate a cultic setting. Indeed, only the practical water and shadow-clocks seem less than sacred; but even then, the secular connection is often vitiated by their original locations among reliefs on temple walls or as votive clocks in a religious setting. (It must be remembered that the separation between the cultic and the secular is a modern one.)

The data that we rely upon to reconstruct ancient Egyptian astronomy are for the most part produced for reasons other than those which we would call scientific today. The inherently religious setting of the star-clocks of the Ramesside royal tombs, not to mention the overtly religious orientation of the Pyramid Texts, are facts to be taken into consideration. The inscribed Middle Kingdom astronomical decans that are painted on private coffins may ultimately be derived from some temple archive. Another sizable amount of the material has a royal bias.

The necessity of updating, in fact changing, a previously held astronomical system is an indication that the ancients realized the limitations of their calculations. Why, for example, was the horizon-system of the early decans thrown away for a newer one based on the transiting of the meridian? The reason was that the eastern horizon has always been a difficult place from which to evaluate heavenly phenomena, day and night. The later system achieved greater accuracy. By the time the shadow-clock was invented, the hours of "day", at least, could be organized with relative success. When the waterclock was adopted, it, similarly, aided the determination of hours of night or complete darkness. Additional progress was made in the New Kingdom, notably with the establishment of the ratio of the longest daytime to the shortest night-time, although this achievement may have involved intellectual borrowings from Babylon.

10 Northern Constellations and Planets

Advances in attribution have been made concerning the decanal-star groups, even though the constellations represented on various monuments remain unclear [Leitz 1995; Krauss 1993]. Egyptologists lay great emphasis upon the Senenmut ceiling, even though it depicts an underlying earlier version of the northern heavens. The conglomerations of Hippo (Restful-of-Feet), Crocodile, Man, An, Sak (a crocodile), Lion, and Serket (Scorpion) occur. Only one, Meschetiu (Msḫtjw), is certain: it is the asterism the Big Dipper, the original depiction of which was the foreleg of an ox. Hippo may have a crocodile on her back. She and Meschetiu remain standard and essential in all Egyptian celestial pictures. The former, probably named Djatmut (Ḏꜣt Mwt, "The One Who Ferries across the Mother" [?]), was equated with Isis. Perhaps the related expression, "The Festival of Heaven", refers to Isis as Sothis at the starting-point of the Great (Sothic) Year in which all of these constellations are presumed to have had their original stationary points. Otherwise, does the phrase merely indicate the commencement of an annual cycle?

The Foreleg constellation was tied to two mooring posts of flint and entrusted to (Isis) as Hippo, which guarded it. Hence, Meschetiu was permanently fixed and prevented from going into the Duat, the afterworld or, in this case, the "counter-night" below.

All but one of the known planets were associated with Horus. Mercury was Seth and in one Ramesside text he is called "Seth in the evening twilight, a god in the morning twilight" [Krauss 1993, 2009]. Horus was Venus the morning star and Horus-the-Older was Venus the evening star. Both were eventually merged and simply called Horus. An early epithet for this planet, "Star of Horus, the First of Heaven", was later replaced by the name "Phoenix" («Bnn»). The later name of Mars, "Horus-the-Red", was straightforward. Its second epithet, "who-travels-backward", alludes to that planet's retrograde motion. The large and remotely distant outer planets of Jupiter and Saturn were less significant to the Egyptians. Both were called stars, with the first labeled "Southern Star of the Sky" and the second, as "Eastern Star" or "Western Star".

Mercury and Venus played a great role in the perceptions of the Egyptian heaven-gazers. For example, both planets show up in a Ramesside calendar of lucky and unlucky days, a list of 365 daily prognostications in which Mercury was Seth and Venus, the Eye of Horus.

It has been presumed that the connection of the four gods Osiris, Isis, Horus, and Seth with, respectively, Orion, Sothis, Venus, and Mercury proves beyond a doubt the *original* mythological "Osirian Circle" [Krauss 1993]. This hypothesis remains subject to further study.

CHAPTER 7.2

The Texts and Aims of Babylonian Astronomy

Hermann Hunger

1 Introduction

The study of celestial phenomena in the ancient Near East antedates the upper limits of the Hellenistic Period and original documentation in cuneiform astronomical texts ends within the first century CE. Knowledge of the tradition continued for many centuries: there are Greek papyri containing fragmentary Babylonian tables that have been found in Roman Egypt [Jones 1999a; Neugebauer 1988].

By the Hellenistic Period, Babylonian astronomy had reached its technically most advanced stage.[1] For its purposes and contexts of use, one will also have to look to preceding centuries, when the principal kinds of texts were first developed. There are, however, no Babylonian treatises that discuss questions in astronomy. It is from both the answers inherent in astronomical texts themselves and such texts as the celestial omens, letters, reports, ritual texts, and horoscopes that we can try to find out what the reasons were for studying the heavens.

Babylonian texts know no difference between astronomy and astrology, neither in terminology nor in concept. There was only knowledge of the heavens and that was used in several ways. For modern people, trying to see in the sky warnings of future events is completely separated from scientific astronomical observation and understanding of the movements and appearances of celestial bodies; however, both endeavors were part of the Babylonian knowledge of the heavens. Different approaches to the study of heavenly phenomena led to different text types. There is a large corpus of celestial omens from Babylonia and many sources for their application and interpretation [Rochberg 2004b, 2016]. Of the more narrowly focused astronomical texts, some contain observations of the celestial bodies, while others deal with the regularities detected in such observations. Among the latter, those that use mathematical methods for predicting celestial phenomena stand out as a special group [Ossendrijver 2012: see ch. 3.1, p. 41].

1 For the claim that Babylonian mathematical astronomy was developed in the period from 450 to 350 BCE, see Ossendrijver 2012, 1. See also ch. 4.6, p. 135.

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In the Neo-Assyrian correspondence of the king with experts in divination (seventh century BCE), on a few occasions scribes are attested with the title "scribe of *Enūma Anu Enlil*" («ṭupšar Enūma Anu Enlil»), where «Enūma Anu Enlil» is the title of the collection of celestial omens. The same people are in most letters just given the designation "scribe" («ṭupšarru»). Moreover, on tablets of *Enūma Anu Enlil* itself, the writer is never called a *ṭupšar Enūma Anu Enlil*. In the Hellenistic Period, «ṭupšar Enūma Anu Enlil» is applied to some but not all scribes writing mathematical astronomical texts. Conversely, the same scribes are given different titles, such as «kalû» ("chanter") or «āšipu» ("incantation-sayer"), on other tablets of the same kind [Rochberg 2000].

2 Observational Texts and Their Derivatives

The main groups of observational texts are
(a) the astronomical Diaries,
(b) the Goal-Year Texts, and
(c) the Almanacs and Normal-Star Almanacs. [2]

The Diaries' ancient name means "regular observations", which fits their content very well. Goal-Year Texts were labeled "First days, appearances, passings, and eclipses which are established for year *x*"; the ancient name of the Almanacs from Babylon was "measurements of the zodiacal sign-entrances (*lit.* reachings) of the planets of year *x*" and in those from Uruk simply "measurements of year *x*".

The observational texts and their derivatives are sometimes called, for want of a better term, non-mathematical astronomical texts (NMATs).

2.1 *The Diaries*

Most numerous are the Diaries; more than 1,500 fragments are preserved. Almost all of them come from Babylon, a few come from Uruk and possibly from other places. The findspots in Babylon are for the most part unknown,[3] although it is usually assumed that the Diaries were found in an area related to a temple.[4]

The earliest Diary found so far can be dated to 652 BCE; the latest, to 61 BCE. There is evidence that systematic observations existed earlier in a compilation of Mars-observations reaching back to the reign of Esarhaddon (680–669 BCE)

2 These terms were coined in Sachs 1948.
3 For the few tablets that were from controlled excavations, see Pedersen 2005, 279–283.
4 See §4, p. 278, on astronomers employed by temples.

[Britton 2004]. Tabulations of eclipse-possibilities begin with eclipses in the eighth century [Hunger 2001–2012, 5, nos 1–3; see Steele 2000c, 390–399]. Note too that Ptolemy uses eclipse-observations from the eighth century, which he attributes to the Babylonians [*Alm.* 4.6].

The Diaries contain the following information [Sachs and Hunger 1988–1996, 1.11–36]:

> For the Moon, at the beginning of each monthly section, there is a statement about the length of the preceding month (29 or 30 days). Next, the time-interval between sunset and moonset on the first evening of the month, when the lunar crescent became visible for the first time, is noted. Around Full Moon, one finds the time-intervals between the rising and setting of the Moon and the Sun before and after opposition. Toward the end of the month, the date of the morning of the last visible crescent is recorded, together with the time-interval from moonrise to sunrise [Brack-Bernsen 1997: see ch. 5.1, p. 171].
>
> Also recorded are lunar and solar eclipses, with duration and magnitude, the planets that were visible during the eclipse, weather-conditions, and so on.
>
> For the outer planets Mars, Jupiter, and Saturn, the Diaries give the dates of first and last visibility, of the stationary points, and of acronychal rising. For first and last visibility, the zodiacal sign is also recorded. For the inner planets Venus and Mercury, we find the dates and zodiacal signs of first and last visibility as a morning star and as an evening star.
>
> The dates of the equinoxes and solstices and the visibility of the star Sirius are given according to a schematic computation, not from observations [Neugebauer 1975, 357–365].
>
> In addition to these phenomena, the conjunctions (literally, “passing by”) of the Moon and the planets with certain stars (Normal-Stars)[5] near the zodiacal circle are recorded. The distance of the Moon and the planets from these stars is expressed in cubits and fingers, which correspond approximately to 2° and 5′ of arc, respectively.

5 The term “Normal Stars” was introduced to designate stars near the zodiacal circle that were used as points of reference for planetary movements.

The Diaries frequently mention weather conditions, especially clouds, which prevented seeing the stars or the planets. But we also find wind, rain, lightning and thunder, rainbows, and so on reported.

At the end of each monthly section, the prices of some basic commodities, for example, barley and dates, are given. If the prices changed in the course of the month, this is described in detail.

Most Diaries from Babylon also give the level of the river Euphrates during the course of the month.

Finally, for each month, events or rumors of such events are reported. These can be of only local interest, such as an outbreak of fire in some part of Babylon, or the events can be of historical significance, such as the death of kings or the overthrow of Seleucid rule by the Parthians. Unfortunately, the poor state of preservation of the tablets leaves many details in these historical reports uncertain.[6] Since the Diaries can be dated by their astronomical contents, the information about historical events can also be dated securely.

2.2 *Goal-Year Texts*

Goal-Year Texts [Hunger 2001–2012, vol. 6] contain materials for the prediction of planetary and lunar phenomena for a certain year, the Goal-Year. Planetary phenomena recur after a certain number of years at almost the same calendar date within a Babylonian year. Every planet and the Moon has a separate section in the Goal-Year Texts. The planetary phenomena are collected from a year that is earlier by one period than the Goal-Year. So the first section contains the phenomena of Jupiter from a year that preceded the Goal-Year by 71 years. In a similar way, data for the other planets and for the Moon are presented, in each case earlier than the Goal-Year by one period. The periods are 71 or 83 years for Jupiter, 8 years for Venus, 46 for Mercury, 59 for Saturn, 79 or 47 for Mars, and 18 for the Moon.

The Goal-Year Texts were most likely excerpted from the Diaries. They use exactly the same expressions and even contain remarks about bad weather that prevented an observation, as do the Diaries. It must have been a lot of work to get the information contained in Goal-Year Texts out of the Diaries [Sachs 1948, 288ff.]: for each planet, one had to use a different Diary because

6 For improved readings of many of these passages, see Pirngruber 2012.

the periods are of different length. Also, the data for a given planet are not all at one point in a Diary but spread throughout the text because the Diaries are arranged chronologically. So the Goal-Year Texts could only be produced using a reasonably complete archive of Diaries.

One purpose of the Goal-Year Texts was most likely the production of predictive texts like the Almanacs [§2.3].

2.3 *Almanacs and Normal-Star Almanacs*

Almanacs are calendar-like previews of lunar and planetary phenomena for a whole Babylonian year in 12 or 13 sections, one for each month. At the beginning of each monthly section, the length of the preceding month, 29 or 30 days, is given. Next follows a summary of where the five planets were at the beginning of the month. The remaining data are then arranged chronologically. For most of the planetary phenomena, the zodiacal sign in which they occurred is mentioned. It is also indicated when a planet moved from one zodiacal sign into another. Also listed are the calendrical dates of solstices and equinoxes and of the appearances of Sirius, computed according to the same scheme that provided these data in the Diaries.

The Almanacs also contain data for eclipses, which were predicted by means of the so-called Saros Cycle [Neugebauer 1975, 502–505]. This cycle of 223 lunar months provides all eclipses, not just those visible in Babylon, for a few centuries. The small deviations of the cycle from nature require an adjustment [Beaulieu and Britton 1994, 78–83]. For lunar eclipses, the Babylonians were able to say whether they would be visible, that is, when the Moon would be above the horizon, sometimes with an indication of their magnitude. If a solar eclipse is considered possible, the Almanacs add the remark "to be watched for". Since the Babylonians did not know the shape of the Earth or their location on it, they could not predict when a solar eclipse would be visible locally, even if the cycle indicated one.

The Normal-Star Almanacs contain, in addition to the data mentioned above, the dates when the planets passed one of the Normal Stars.

In the Almanacs, there are no remarks about weather. From this and the remark about solar eclipses, it appears that the Almanacs are predictive, not observational. The predictions were most likely made with the help of Goal-Year Texts [Gray and Steele 2008].

3 Relations of the NMATs

The Diaries are the basic observational material, collected over at least seven centuries. From them, the Goal-Year Texts were derived. The Goal-Year Texts in turn provided the material from which to construct Almanacs and Normal-Star Almanacs.

Extant Diaries run from 652 BCE to 61 BCE; Goal-Year Texts, from 260 BCE to 56 BCE;[7] Normal-Star Almanacs, from 293 BCE to 78 BCE; and Almanacs, from 220 BCE to 75 CE. This distribution roughly corresponds to the relationship among the types of text listed above.

4 The Babylonian Observational Program

There are numerous questions yet to be answered about the NMATs. For instance: Who initiated and supported such an observational program, which continued with remarkable consistency for more than 700 years in spite of political upheavals and economic disasters? Who needed or used this astronomical program? Perhaps the intellectual foundation for the development of Babylonian astronomy is to be sought in earlier times when the project was begun or designed.

Again, what could be expected from the Diaries? It has been suggested that they provided a database from which periodic recurrences not only of celestial events but also of weather, prices, river-level, and maybe even historical events could be found and checked. This would explain the detailed weather-reports. We know that there were attempts to predict the weather by means of periods [Hunger 1976a]. Prices predicted by means of periods are not attested, although omens announcing high or low prices based on planetary phenomena are known [Hunger 1976b, no. 94]. And some of the events reported in the Diaries are clearly in the style of omen protases (e.g., malformed animals).

In view of this, it would seem that establishing period-relations could well have been one of the chief goals of Babylonian astronomy as represented in the NMATs. On a deeper level, the NMATs can also be seen as a continuation or development of the attempts to predict those events in the sky that were considered omens [Brown 2000b, 164–168].

7 But note that compilations of phenomena of single planets [Hunger 2001–2012, 5, nos 52–103] reach farther back in time than the Goal-Year Texts.

5 Mathematical Astronomical Texts

Tables of numbers to describe phenomena in the sky are attested relatively early [Hunger and Pingree 1999, 44–50]. But these tables are very schematic and cannot be used for predicting the phenomena accurately. It is only in the second half of the first millennium BCE that sufficiently accurate computation is developed. The preserved tablets were written either in Babylon or Uruk. On average, the Uruk-texts are older than the Babylon texts but this is due to local history rather than separate development.

The same texts can be grouped according to the mathematical method used for basic parameters [see chs 3.1, p. 41; 4.6, p. 135] as belonging to System A or System B. In the lunar tables, System A is preferred in Babylon; System B, in Uruk. The division according to systems is less clear-cut in planetary tables [Neugebauer 1955, 10].

The mathematical astronomical texts can also be subdivided into tables or ephemerides and procedure-texts [Neugebauer 1955, 1]. For the outer planets, the tables provide dates and positions of first and last visibilities, stationary points, and acronychal risings. For the inner planets, only first and last visibilities are computed. For the Moon, the tables calculate the date of appearance of the first crescent or the Lunar Six [Brack-Bernsen 1997: see ch. 5.1 §2, p. 172]. In addition, the dates (and the times) of eclipses can be calculated.

The procedure-texts [Ossendrijver 2012] give rules for how to compute the tables but do not present any "theory" behind these rules. There are also a few tablets with calculations of daily positions of planets [Neugebauer 1955, 326–328, 353–356; Ossendrijver 2012, 63–67]. Such procedures could have provided the positions of planets listed in some horoscopes.

John Steele [2000a] has found that a text listing planetary phenomena was most likely produced with the help of astronomical tables.

While many tablets can be easily grouped with either the tabular texts and their procedures or with observational texts, many others (mostly fragmentary) do not conform to these categories.

6 Context of Astronomical Texts

There are only a few places where and times when we can identify a context for astronomical activities.

In the letters and reports from Assyrian and Babylonian scholars of the seventh century to the Assyrian kings [Parpola 1993; Hunger 1992], we find astronomy in the service of the interpretation of celestial omens. These omens usually concerned the whole country and especially the king. They did not announce an immutable fate but were warnings from the gods. So the experts counseling the king tried to avoid imminent dangers by counteracting the misfortune announced. This could be done by various rituals. The most impressive example of these is the Substitute-King Rite: if an omen announced the death of the king, another person was put on the throne and dressed in royal garb while the true king was kept out of sight as much as possible. Of course, the substitute had no real power and it was expected that he would die (be put to death) within 100 days. If this did not happen by itself, it was effected in some way by command of the king [e.g., see Parpola 1993, nos 347, 351, 352].

In Hellenistic times, an elaborate ritual was still preserved and performed by lamentation-priests (*kalû*). The text [Linssen 2004, 306–320] offers tantalizing details on what was done during such a ritual, such as lighting a brazier, singing, and making funerary offerings; wailing and mourning for the eclipsed Moon; pouring out a circle of flour; beating the copper kettledrum; chanting Sumerian incantations; performing the Bull-in-Its-Fold Ritual when the disc is ⅓ eclipsed and again when it is ⅔ eclipsed, and adding the lamentation "Alas and woe your heart!"; and leaving the brazier lit until the eclipse clears [Parpola 1983; Brown 2000b].

Eclipses and their predictions continued to be of importance until Hellenistic times. Even when there was no king anymore in Babylonia who had to be protected against the danger announced, eclipses were still considered bad omens, as the Hellenistic eclipse-ritual discussed in Linssen 2004, 109–117 attests. The prediction of eclipses, which had already been attempted in the seventh century, would have continued and was later improved. For the purpose of omens, prediction does not need to consider all the details of an eclipse that could be computed today: the very fact of a total eclipse was sufficient. In partial eclipses, the eclipsed part of the Moon provided information on the region that would be afflicted.

We get a glimpse of the practical application of astronomy in eclipse-prediction from the records of the Temple of Eanna in Uruk in the sixth century. It seems that when an eclipse was predicted, the chanters (*kalû*s) in Uruk and in neighboring Larsa performed the appropriate ritual, especially one involving the playing of a kettledrum. But according to one of two depositions made in Uruk (presumably in the Temple of Eanna) concerning this eclipse, it did not occur after all. Paul-Alain Beaulieu and John Britton [1994] consider it likely that the erroneous prediction was made using the Saros Cycle, which allows prediction of the possibility of an eclipse but not its visibility.

The late eclipse-ritual seems to have been expanded compared to its earlier versions. David Brown and Marc Linssen [1975, 155] propose to explain this by the greater reliability of eclipse-prediction: since most lunar eclipses could be announced correctly, the considerable expense for the ritual would (most likely) not be wasted on a wrongly expected eclipse.

In Uruk, astronomical texts were found mostly in the Rēš sanctuary [Oelsner 1986, 180–186]. The colophons of these Uruk-texts show scribal families involved in the production of astronomical tables [Ossendrijver 2011a: see ch. 11.2, p. 426].

In Babylon, an expert in knowledge of the sky—called *ṭupšar Enūma Anu Enlil* (scribe of *Enūma Anu Enlil*)—received rations from the temple-administration at Esangila as early as the fourth century BCE [Beaulieu 2006]. It is not stated what kind of work they were doing.

In the second century BCE, scribes of *Enūma Anu Enlil* were demonstrably employed by the temple Esangila.[8] In an official document, the temple assembly agreed to accept the request of the son of such an astronomer to take over his father's position (and salary) and to deliver certain texts to the temple. The designations of these texts correspond to subscripts of astronomical texts preserved elsewhere. We can identify them as astronomical tables, Diaries, and Almanacs. So while we do not know how the tables were derived from the observational texts, it is clear that the same group of people worked on both. Another document from Esangila concerns two scribes of *Enūma Anu Enlil* who are also to be supported by the temple. These documents also mention the names of other such scribes as being engaged in the same work. Some of the persons called scribes of *Enūma Anu Enlil* additionally held titles related to the cult; this may have been their connection with the temple in the first place.

Astronomy lived on in the context of the temple(s) in the Hellenistic Period but we can only guess why.

7 Motivation and Purpose of Astronomical Texts

Regarding the question of the purpose of the astronomical tables, it is true (and perhaps a truism) that their purpose is their results, that is, the calculated dates and positions of the phenomena. But this hardly explains why Babylonian mathematical astronomy started in the first place or why it continued and developed as it did. Mathieu Ossendrijver [2012, 2f.] states that the purpose of the mathematical astronomical texts has not been established in a convincing

8 These documents have been discussed by van der Spek 1985 (with previous literature). See also Rochberg 2000, 369–372; she translates one of them on pp. 373–375.

manner, and that only their applications can be discerned, that is, the results of calculations as described above [see ch. 4.6, p. 135]. Nevertheless, some considerations may be offered.

7.1 *Celestial Omens*

Celestial omens have been suggested as an incentive to calculate and predict the phenomena of stars and planets. Eclipses could be especially important omens. Attempts to predict lunar eclipses were attested in the correspondence of scholars with the Assyrian kings as early as the seventh century [Parpola 1993]. From these letters, it appears quite clear that advance knowledge of an eclipse made it easier to arrange for the rituals and other measures required to avert the catastrophe that it announced [Hunger 1992, xix].

David Brown [2000a, 197–207] considers such predictions of celestial phenomena (not only eclipses) a change of “paradigm” that began in the seventh century and involved moving away from just interpreting omens to using period-relations (and other computational methods) to predict them.

We do not know whether the scholars responsible for the interpretation of celestial omens had anything to do with the compilation of the Diaries that is attested as early as the seventh century. The data collected in the Diaries would have provided the period-relations necessary for predictions after about two centuries of observation. A direct application of such period-relations is the Goal-Year Texts; however, they happen to be preserved only from Hellenistic times. Mathematical methods were developed from the fifth century onward and could do the same job even more accurately. We do not know whether the goal-year method or the mathematical tables were preferred for specific purposes.

There are more uncertainties in discerning the purpose of the Diaries. Although the Diary-archives seem to have had their inception in the middle of the eighth century, no Diaries have been found in Assyria so far: all are Babylonian. We can assume that after the breakdown of the Assyrian Empire at the end of the seventh century, the Babylonian “colleagues” among the royal astronomers continued and developed further the work done previously for the king of Assyria on their own. Any speculation about this is hampered by the lack of a royal correspondence of the Babylonian kings of the Chaldean dynasty and by our general ignorance of the organization of astronomy during the sixth to fourth centuries BCE when the king was a member of the Achaemenid dynasty and no longer a correspondent of Babylonian scholars. At some point, patronage of astronomers moved from the court to the temples [Rochberg 2004b, 224–228].

7.2 *Time-Reckoning and the Calendar*

Time-reckoning and creating the calendar are other purposes of astronomy that have been proposed [see, e.g., Neugebauer 1975, 353, 474]. It is true that the astronomical tables provide *inter alia* the date of the first visibility of the lunar crescent, which determined the beginning of the Babylonian month. But most tables, which calculate other planetary phenomena, have no relevance for the calendar.

Steele [2007a, 143] assumes that in Hellenistic times the beginning of the month was calculated in advance by means of Goal-Year periods. There are a number of Babylonian texts related to the measurement of time [see chs 2, p. 24; 9.1, p. 323]. It has to be noted that we know little about measuring time in Babylonia. Daytime and nighttime were divided into three watches, obviously of varying length, in the course of the year. Measures of constant length were UŠ and *bēru*, corresponding to 4 and 120 of our minutes, respectively. Schemes for the length of daytime and nighttime in Hellenistic astronomical texts are based on a ratio of 3:2 of longest to shortest daytime (or nighttime).

Two tablets [Pinches and Strassmaier 1955, nos 1494 and 1495] describe the construction of a kind of sundial. Due to their broken state, however, there has of yet been no convincing interpretation.

Time-measurement at night could be accomplished by means of *ziqpu*-stars, of which there are several lists.[9] The *ziqpu*-stars culminate high in the sky so that they are visible even when atmospheric conditions make horizon observations difficult. The actual use of *ziqpu*-stars to define a moment in time is proven by eclipse-records and other events in the Diaries as well as by letters from the seventh century.

Time-measurement may have been needed occasionally in the cult in the Hellenistic Period, when the timing of cultic activities was prescribed in a ritual [Linssen 2004, 27]. Cultic events were related to celestial situations in a loose way: offerings had to be brought at certain times of day or feast days were connected to specific calendar dates.[10]

7.3 *Horoscopes*

Horoscopes [see ch. 12.2, p. 472] are rather close to Almanacs [Rochberg 1998]. Horoscopes could, therefore, have been an incentive to produce the Almanacs. But there are data in the horoscopes that were not available in Almanacs and so

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9 See Hunger and Pingree 1999, 84–90; Roughton, Steele, and Walker 2004; and Steele 2014.

10 For an argument that changes in month-length sometimes led to changing the date of certain religious ceremonies, see Beaulieu 1993, 78–80.

other sources must have been used as well [Rochberg 2004b, 156]. Some horoscopes contain planetary positions by degrees within zodiacal signs, for which they may have relied on tables of daily motion.

The tools developed in astronomy opened up new possibilities in the realm of omens and medical procedures [Reiner 1995]. The zodiacal circle of 12 signs of 30° each, which was certainly developed in parallel to the schematic year of 12 months of 30 days, could have been used as a new tool of astrology.

8 Conclusion

From the seventh century on, and certainly in Hellenistic times, it became important to predict events in the sky correctly. For this, establishing and refining periods was the best tool available to Babylonian astronomers. Such periods underpin the mathematical astronomical tables of the second half of the first millennium BCE. Within the corpus of observational texts, the Goal-Year Texts made use of periods to predict the phenomena of the planets. Methods used for deriving lunar phenomena were reconstructed in Brack-Bernsen 1997, 2011, and Brack-Bernsen and Hunger 2002, 2008. It is not evident that different "theories" were compared to observations and refined accordingly, as would be done today. Different methods of calculating celestial phenomena existed side by side, such as those of the Goal-Year Texts and the ephemerides, and we cannot discern preferences for particular methods among the Babylonian astronomers.

CHAPTER 7.3

Issues in Greco-Roman Astronomy of the Hellenistic Period

Alan C. Bowen

1 Introduction

The question What were the issues in Hellenistic astronomy? is perhaps more complicated when asked of the Greco-Roman world than of any of its contemporaries or immediate predecessors, not because of its intrinsic nature but because of the accidents of history itself. The reason is that, in addition to what we have today of Greco-Roman astronomy, and this is substantial, we have evidence of all sorts that allows us to consider it in diverse contexts. This means that to answer What were the issues in Hellenistic astronomy? when asked of the Greco-Roman world, we not only can, but must, ask To whom? and Why?

For example, to certain philosophers of the Stoic, Aristotelian, and later Platonist schools, *the* issue in Hellenistic astronomy was whether there were hypotheses that could actually save the phenomena, where the phenomena were the planetary stations and retrogradations and, thus, qualitative. By this was meant whether there were geometrical starting-points that could serve not only to account for, or explain away, the planetary stations and retrogradations as merely apparent but were also themselves sanctioned in natural science (φυσική) by demonstrative argument from independently established conclusions about the nature of the bodies in the heavens and their motions. For some, of course, this was never in doubt: all one had to do was turn to the works of Plato and Aristotle to find them. To these philosophers, the challenge was to elaborate these hypotheses in a way that could account for the planetary phenomena known at the time [see ch. 4.2, p. 71; Bowen 2013a]. In either case, what was at stake was their understanding of astronomy as a body of knowledge and, ultimately, their accounts of the natural world.[1]

Again, those who held political power were concerned primarily with prognosticatory astronomy or astrology. In early Hellenistic times, for them it was

1 For Plotinus' analysis of what must underpin celestial motion, an analysis that focuses on the daily rotation of the heavens, see ch. 14.2, p. 619.

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crucial that they take advantage of the belief shared by many throughout the Hellenistic world that the heavens were authoritative in the course of human affairs in order to secure and warrant their power. At the same time, it was also crucial to prohibit any practice of astronomy that threatened or diminished this power.[2]

When we look at Hellenistic astronomy in the Greco-Roman world and its practitioners, that is, to the philosopher/astronomer Ptolemy, his commentators, those who copied and sometimes adapted Babylonian arithmetical schemes for planetary positions, and perhaps even to Pliny [see ch. 4.3 §2.4–5, p. 102], as well as the astrologers,[3] however, we see that one defining feature of this science was its ambition to determine the positions of the heavenly bodies at any time past, present, and future; and that this effort was predicated on solutions to a number of problems both technical and practical.

In general, such mastery of time and space, as it were, in a science that could specify where any celestial body was at any time as well as the significance of its being there for the course of human events and lives required:

(1) the selection of a calendrical cycle that would be accurate over very long intervals of time and the means to specify moments within a calendar constructed in accordance with this cycle; and
(2) systematic, tabular data that effectively quantified suitably established geometrical constructs of the various celestial motions.

Let us consider these requirements to get a sense of what was at stake. This overview will be conceptual: its aim is to draw out the issues involved and their connections without great concern for the details of when they were actually taken into account or their subsequent treatments through time.

2 The Mastery of Time

2.1 *The Calendrical Cycle*

To establish any calendrical cycle in the Greco-Roman world, one had first to define three fundamental units: the year, the month, and the day. Since these units are periodic, it sufficed to identify their epochs or starting-points. Thus, for example, the day was defined as the interval from one sunset to the next; the month, as the interval from one first lunar appearance after invisibility to the

2 Barton 1994b, 27–71; 1994a, 32–80. See also chs 10.2, p. 398; 8 §§4–5, p. 304; 12.3 §3.5, p. 506.

3 Here again "astronomy" includes prognosticatory astronomy.

next; and the year, as the interval from one vernal equinox to the next. These definitions facilitate assigning to any day a date by identifying the day-number, month, and year in which it occurs.

The next step was to identify a calendrical cycle equating or synchronizing some number of years with some number of months and some number of days. (If the months are lunar, the cycle is lunisolar; if they are not, it is solar.) One such lunisolar cycle, termed Metonic and used in Greco-Roman astronomy, posited

$$19^y = 235^m = 6940^d,$$

where 7 of the months are intercalated in order to keep the end of the lunar year near the vernal equinox. Another cycle, termed Callippic, spanned 4 Metonic Cycles and had

$$4 \cdot 19^y = 4 \cdot 235^m = 4 \cdot 6940^d - 1^d \quad \text{or} \quad 76^y = 940^m = 27759^d.$$

There was, of course, a plethora of calendrical cycles put forward throughout the Greco-Roman world in early Hellenistic times. These could differ not only in their definitions of the day and month but also, as we have just seen, in their overall length (and, hence, in the values effectively assigned to the length of the year and month). Moreover, even when the Egyptian calendrical cycle

$$1^y = 12^m \cdot 30^d + 5^d$$

gained ascendance, there was not one but many Egyptian calendars in which different dates were assigned to the same day [see ch. 2 §§3–4, p. 29].

2.2 *The Division of the Day*

The interval of a day was divided by sunrise and sunset into daytime and nighttime. These latter intervals were again subdivided in various ways. For instance, they could each be divided into 3 watches or into 12 seasonal hours. But, given that the daytimes and nighttimes differ in length among themselves and from each other during the course of the year, the equinoctial hour was preferred. These hours are equal during both nighttime and daytime on the day of equinox. That is, each such hour is 1⁄24 of the length of the day of equinox.

There follows from this an important refinement. It is a fact that the Sun's motion along the zodiacal circle, that is, its daily progress, is not the same each day. The ancient Greeks and Romans were aware of this solar anomaly and that the revolutions of the heavens from one sunset to the next vary in length. If one's standard is the day of equinox, then it follows that most days are not 24 equinoctial hours in length, that some are longer and some are shorter. To account for this, Greco-Roman astronomers added to, or subtracted from, the 24 equinoctial hours some small periodic difference, which is called the equation of time, to get the day-length of a given day.

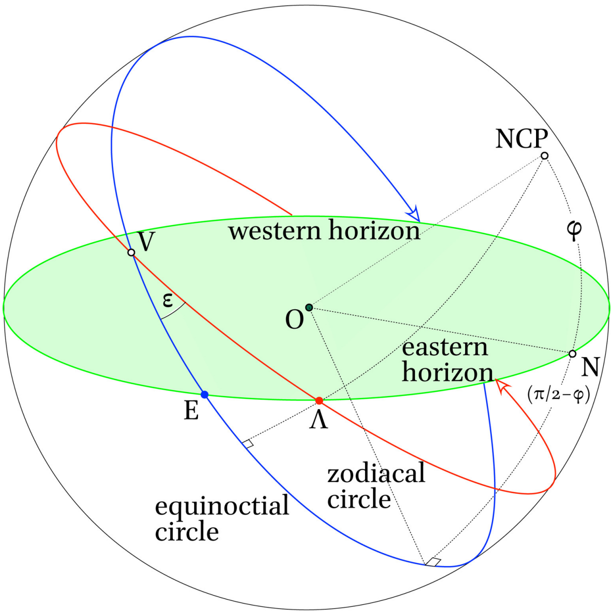

FIGURE 1 The rising-time of an arbitrary arc *V*Λ of the zodiacal circle
ε = the obliquity of the zodiacal circle; φ = the observer's latitude; E = the horizon's East Point; N = the horizon's North Point; NCP = North Celestial Pole; O = observer

The real problem for the astronomer, however, was how to measure time in equinoctial hours during daytime and nighttime. Now, it was generally known that during each nighttime six zodiacal signs rise and six set. This means that the length of nighttime depends on the times that it takes the six zodiacal signs to rise, times that differ throughout the year. This variation in the length of nighttime could, of course, be quantified in an arithmetical scheme for the rising-times (or oblique ascensions) of the zodiacal signs that was typically of Babylonian origin, such as one finds in Hypsicles' *Anaphoricus* [Montelle 2016].

But, after Menelaus in the first century CE, it became possible to compute the length of a given nighttime trigonometrically [ch. 3.2, p. 54].[4] This computation requires specifying where the Sun is on the zodiacal circle at the immediately preceding sunset, identifying the 180°-arc of the zodiacal circle that rises during the nighttime following that sunset, and computing the length of the arc on the equinoctial circle that rises in the same interval. This entails determining the rising-times of the individual zodiacal signs and parts thereof. The same technique also allowed one to compute the rising-times of individual degrees of the zodiacal circle, which was necessary in astrology for establishing the ὡροσκόπος or Ascendant at the time of a child's birth [ch. 12.1 §2, p. 443]. In Figure 1, p. 287, arc *VE* is the time that it takes the arbitrary arc *V*Λ to rise (or ascend obliquely) above the eastern horizon. The time itself is measured in degrees of time or hours, where

$$1^d = 24^h = 360^\circ$$

and the day in question is equinoctial.[5]

The ability to determine the intervals in which arcs of the zodiacal circle rise can also serve in ascertaining the time of daytime in equinoctial hours. For example, it would be sufficient to know:

(a) the epoch of the day;
(b) the date in a calendar that will permit good inferences about where the Sun is on the zodiacal circle, since, given this information, one can determine the 180°-arcs of the zodiacal circle that rise during daytime and nighttime on that date; and
(c) the seasonal hour as measured on
  – a sundial [see ch. 2 §6, p. 36] or a waterclock [see Vitruvius, *De arch.* 9.8.4–15: Lewis 2000, 364–365], or
  – as computed from the Sun's azimuth and altitude [see ch. 1 §4.3, p. 18], given that the seasonal hours of daytime are 1⁄12 of the interval that it takes the 180°-arc of the zodiacal circle that rises during daytime to rise and the seasonal hours of nighttime are 1⁄12 of the interval that it takes the 180°-arc of the zodiacal circle that rises during nighttime to rise.

4 Note that arithmetic methods continued in use long after the introduction of trigonometry and were especially popular among astrologers.

5 The trigonometric argument is given in Ptolemy, *Alm.* 2.7: see Pedersen 2011, 110–113.

3 The Mastery of Space

Thus far, our account of what was involved in determining where the celestial bodies are at any time has focused on the calendar and timekeeping. The next step involves identifying period-relations and using them and a geometrical hypothesis to generate tables.

Let us take the simplest case, that of the Sun, since its motion has but one anomaly. Period-relations in general correlate numbers of diverse cycles. So far as the Sun is concerned, the period-relation identifies one revolution—in this case, called a year—with a number of days. Ancient instances include:

$$\begin{aligned} 1^{y} &= 365\tfrac{1}{4}^{d}, \\ &= \left(365 + \frac{1}{4} - \frac{1}{300}\right)^{d}, \text{ which is} \\ &= 365;14,48^{d}, \end{aligned}$$

where the year is tropical (or seasonal) and the day is equinoctial. If we suppose that the Sun revolves about the Earth, it is an observable fact that there are differences in the lengths of the astronomical seasons,[6] which means that the Sun's motion (φορά, κίνηϲιϲ) is not smooth (ὁμαλή). To the contrary, as seen from Earth, the angular distance that the Sun travels each day is not constant. Now, Greco-Roman astronomers characteristically analyzed such lack of constancy or anomaly as a periodic or regularly recurrent departure from some mean motion. In other words, for them, the Sun's true position on a given day was to be determined by a correction to its mean position on that day.

To define the Sun's mean daily motion or progress, they took a period-relation for the Sun and computed, for example,

$$\frac{360}{365;14,48} \approx 0;59,8,17,13,12,31^{\circ/d}.$$[7]

But to interpret this daily motion of roughly 1°, it would hardly suffice to suppose simply that the Earth lies at the center of the Sun's circular course. For if it did, it would follow that the four astronomical seasons are of equal length.

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6 The year is divided into four astronomical seasons by the cardinal points of the zodiacal circle: spring (vernal equinox to summer solstice), summer (summer solstice to autumnal equinox), autumn (autumnal equinox to winter solstice), and winter (winter solstice to vernal equinox).

7 Knowing a period-relation does not entail knowing a mean motion: computing a mean motion is a distinct step.

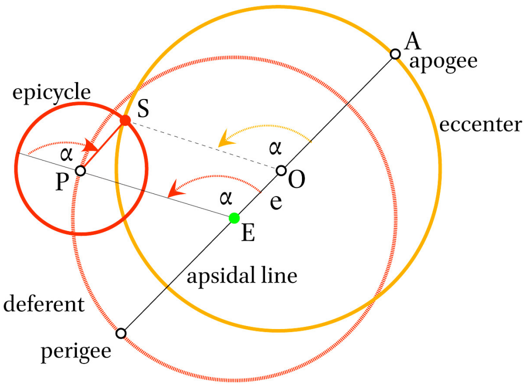

FIGURE 2 The equivalence of the solar epicyclic and eccentric hypotheses

In fact, there are two geometrical hypotheses put forward in the Hellenistic Period concerning the Sun's course through the heavens and, in each, the key step is to construe the Sun's true and mean positions as directions to the zodiacal circle. In the first, the Sun travels along a circle eccentric to the zodiacal circle, that is, along a circle that does not have the Earth (E) at its center. In the second, the Sun is carried on a rotating circle (the epicycle) with its center on a second circle (the deferent) that is homocentric to the zodiacal circle and rotates at the same speed (viz. the Sun's mean motion) in the opposite direction. These particular hypotheses are mathematically equivalent[8] and so either can serve in computing the correction to the Sun's mean motion that is needed to determine its true position at any time.[9]

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8 See Figure 2. Both hypotheses place the Sun at *S*. The key is the parallelogram *OPSE* where $OE = e$ (since the eccentricity of the eccentric circle is $e = OE{:}OA$ and *OA* is the unit circle); the radius of the epicycle is $PS = e$; and the radius of the deferent is $EP = OS = OA$.

9 The direction to the vernal equinox (VE) and the mean motion are centered on the observer and independent of either hypothesis.

In the eccentric hypothesis [see Figure 3, p. 291], the argument of anomaly is $\alpha = \bar{\lambda} - \lambda_A$, where $\bar{\lambda}$ is the mean longitude and λ_A is the longitude of the apogee. The equation of anomaly (i.e., the correction to the mean longitude $\bar{\lambda}$ that is needed to get the Sun's true longitude) is $q = \angle OSE$.

In the epicyclic hypothesis [see Figure 4, p. 291], as in the eccentric hypothesis, the argument is $\alpha = \bar{\lambda} - \lambda_A$ and the equation is $q = \angle POS$.

To use either hypothesis, begin with $\bar{\lambda}$ and λ_A. For Ptolemy, $\bar{\lambda} = \bar{\lambda}_0 + \mu \cdot t$, where $\bar{\lambda}_0$ is the value of $\bar{\lambda}$ at some epoch (i.e., starting-point of his tables for mean motion); μ, the mean motion; and t, the time since the epoch. Since, for Ptolemy, λ_A is fixed, subtract it from $\bar{\lambda}$ to get α. Then, enter the table of corrections with α and find q opposite it. To find the Sun's true

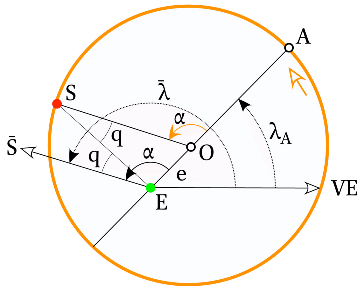

FIGURE 3 Mean and true longitude in the eccentric solar hypothesis

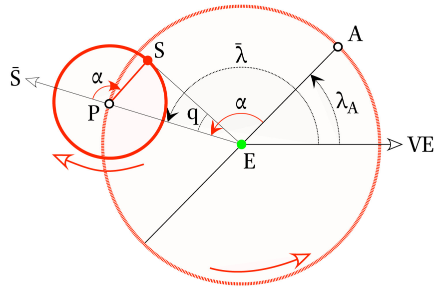

FIGURE 4 Mean and true longitude in the epicyclic solar hypothesis

The motions of the Moon and five planets are substantially more complicated and, consequently, so are the geometrical hypotheses for them. The reason is that, unlike the Sun, the Moon not only moves in latitude, that is, above and below the plane of the zodiacal circle, the nodes where its path crosses this plane also change position [see ch. 4.4 §4, p. 117]. As for the five planets, though like the Moon they too move in latitude, unlike the Sun and Moon, they also make stations and retrogradations [see ch. 4.4 §§3, 5–6, p. 114]. Yet, to account for the position of the Moon and the five planets at any time, the fundamental challenge remains the same:

(1) determine the period-relations by counting the appropriate phenomena over a given time,
(2) compute the mean motions from these period-relations,
(3) interpret the derived mean motions using a geometrical hypothesis,
(4) compute the corrections needed to specify the true positions of these phenomena, and
(5) present these corrections in tabular form.

4 Precession

There remains one important refinement for the calendar as well as for any reckoning of celestial position. One must also account for the fact that the positions of the stars change over time with respect to the vernal equinox (VE). For Ptolemy, this motion or precession occurs because the stars (which remain

longitude λ, add (or subtract) q from $\bar{\lambda}$. Ptolemy spares the user the need to solve $\triangle OES$ or $\triangle OPS$ by offering a table that only requires linear interpolation between adjacent entries to find the correction q corresponding to the given α.

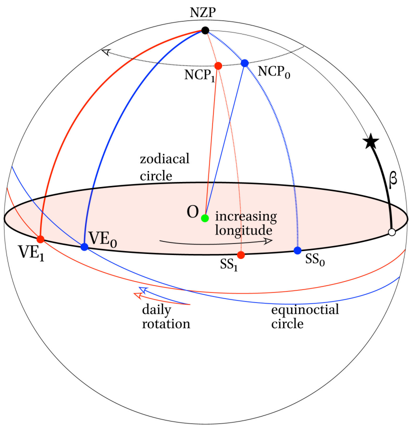

FIGURE 5
Precession
As the North Celestial Pole (NCP) revolves in the direction of decreasing longitude (westward) about the North Zodiacal Pole (NZP), so does the Vernal Equinox (VE).

fixed in relation to one another) make a slow revolution eastward (that is, in the direction of increasing longitude) about the poles of the zodiacal circle. There were apparently others, however, who held that it was due to the slow motion westward (this is, in the direction of decreasing longitude) of the equinoctial points, those points where the equinoctial circle crosses the zodiacal circle [see Figure 5]. Its period is roughly 1° in 72 years. In the zodiacal coordinate system [see ch. 1, §4.1 16], the effect of precession is to change the longitude (λ) of any celestial body but not its latitude (β).

5 Subsidiary Issues

The account thus far of the fundamental issues or concepts in Greco-Roman astronomy of the Hellenistic Period readily points to numerous issues that are conceptually subsidiary. For example, in that this account has focused on astronomy in its capacity to predict where things are at any given time, one might rightly ask What were the issues that governed the actual development of Greco-Roman prognosticatory astronomy?, a question that I must leave for others to address. But, even recognizing that, there still remain many issues subsidiary to the project of determining the position of any celestial body at any time.

Plainly, this project of predictive astronomy does not spin out of sheer speculation; it must have an observational or experiential basis on which it is undertaken.[10] Given that the phenomena at issue occur over very long stretches of

10 For discussion of the various ways in which experience and observation figure in Hellenistic Greek astronomy, see ch. 5.2, p. 190.

time, it follows that the relevant observational data must come from different eras and individuals, typically, in different cultures. This means that working such data up to a point where it can be used may entail the problems of

(a) converting from one calendar to another, which usually involves finding an event dated in each, and
(b) identifying the location in which the data are defined or collected.

Thus, not only will there be the challenges of identifying different calendars and assessing their value for astronomical work, there will also be a need to certify observers [Goldstein and Bowen 1999]. In addition, astronomers may also have to specify precisely places and distances on Earth, which will thus bring them to the nexus of astronomy and geography.[11] Again, when the observer's position on Earth is important, as in reports of solar eclipses, there will also be a need to account for parallax [see ch. 4.5 §3, p. 128], that is, the difference between seeing a celestial object from the Earth's surface and "seeing" it from the Earth's center [see Figure 1, p. 113].

All this and more will be involved in using observations made by others. But perhaps more fundamental are the observations that one makes on one's own. So far as these are concerned, there are the crucial questions of what instruments to use and how to use them[12] as well as the need for clarity about what is to count as a proper observation or determination. Settling such matters will help in testing observations made in the past and in certifying other observers.

In sum, the issues addressed by astronomers in Greco-Roman astronomy are plainly numerous and rich in their complexity and scope.

11 For an account of Greco-Roman instruments used to determine distances on Earth, see ch. 6.1, p. 221.
12 For an account of the instruments that Ptolemy uses, see ch. 6.4, p. 246.

PART C

Contexts

CHAPTER 8

The Professional Ἀϲτρολόγοϲ

Wolfgang Hübner

1 The Sources

There are only a few sources reflecting directly on the practice of Hellenistic astrologers,[1] perhaps because they practiced an often proscribed art. It is true nonetheless that there are many extant astronomical and astrological papyri,[2] several poems on astrology,[3] and handbooks written by expert astrologers.[4] But the majority of Greek and Latin astrological texts concern theory rather than practice. Such theoretical texts inform us about the methods of constructing horoscopes,[5] but horoscopic documents reveal almost nothing about the practice of consultation.

Historians, for example, Suetonius, the authors of the *Historia Augusta,* and Cassius Dio, sometimes shed anecdotal light on astrological practice [Gury 1996, 234–235]. Philosophical works such as Cicero's *De div*. and *De fato*,[6] laws and legal texts, and even some poetic satires and satiric epigrams cast their own light on the *milieu* of astrology as it was experienced.[7] Thus, Propertius [*Eleg*. 4.1.71–150] introduces a ridiculous astrologer named Horus, son of the Baby-

1 Gury 1996 is the best documented study: see Evans 2004, 3.

2 See Neugebauer and van Hoesen 1959; Baccani 1992; Jones 1999a. There is an updated list in Heilen 2015. On the scarcity of information, see Baccani 1992, 49, 53–54. Cf. Turner 1984, 171.

3 In Greek, the authors are Nechepso-Petosiris (second century BCE), Dorotheus (Neronian times), Anubio (perhaps first century CE), and the anonymous *Manethoniana* (the nucleus of which was written under the reign of Hadrian). In Latin, there is only Manilius' *Astronomica*, written under the reigns of Augustus and Tiberius. See Boehm and Hübner 2011.

4 In the second century CE, Vettius Valens, *Anth*. and Ptolemy, *Apo*. Later sources may give valuable information about earlier times. The great gap between the last horoscope in Valens (188 CE) and the first of Hephaestio (380 CE) [Neugebauer and van Hoesen 1959, L188, L380] corresponds to the decline of the Roman Empire in the "dark" third century CE.

5 Barton 1994a, 71–94 makes only a few remarks about the method of casting horoscopes: she says nothing about the negotiations between astrologers and their customers.

6 Varro's *De astrologia* is lost but left some traces in Late Antiquity.

7 See the works of Horace and Juvenal. In Plautus' *Rudens*, the prophetic prologue is spoken not by an astrologer but by Arcturus, a personified storm-bringing constellation.

 | DOI:10.1163/9789004400566_031

lonian Orops;[8] in Lucan, *De bell. civ*. 1.638–672, the Neopythagorean Nigidius Figulus utters a horrible prognostication [Getty 1941 on Housman's "Astronomical Appendix" [1926]]; and in Petronius, *Sat.* 35, 39, the blusterer Trimalchio proudly displays his astrological expertise.[9] The most vivid image of a foreign professional astrologer is painted by Apuleius [*Meta.* 2.12–15]. The Alexander-Novel reveals astonishing details of horoscope casting. In the fifth century CE, Nonnus of Panopolis invents an astrologer, Astraeus, who, with the assistance of his servant Asterion, calculates a horoscope for Demeter concerning the wedding of her daughter Persephone [*Dion.* 6.58–104].

First of all, we have to be clear about our terminology. The strict distinction between ἀστρολογία and ἀστρονομία did not arise until the 18th century [Hübner 1989]. The less common and curious term «ἀστρονομία» appears in Pythagorean and Platonist contexts and was perhaps influenced by the double sense of «νόμος» as "law" and as "melody", with respect to the harmony of the planetary spheres; whereas Aristotle turned back to the natural Presocratic term ἀστρολογία. The person-related substantive "astronomus" appears less frequently than "astrologus". Astrologers are said to have been called ὡροσκόποι or ὡρολόγοι in Egypt [Clement, *Strom.* 6.4–35.4; Porphyry, *De abst.* 4.8]. The professional astrologers could not, however, dismiss astronomy, they needed it in particular to determinate the exact point of the Ascendant.

In addition to its use of astronomy, the more synthetic goals of astrology involved many other aspects of nature, such as plants, animals, and regions of the inhabited world, the four elements, and whatever else was related to them. Astrology's universalizing tendency encompassed the whole world from the heavens down to everyday life.[10]

Knowledge of astronomy was needed as an auxiliary discipline by makers of sundials and waterclocks, and by land-surveyors. As for the lower classes, farmers, sailors, land surveyors (*agrimensores, gromatici*), geographers, and clockmakers needed to know the motion of the stars. Nevertheless, the astronomical observer remained limited in his goal of calculating the movements of the heavenly bodies.

In Antiquity, astronomers (practitioners of predictive astronomy) could be called ἀστρολόγοι and ἀστρονόμοι as well, whereas astrologers (practitioners of prognosticatory astronomy) were rarely called *astronomi*. To distinguish them from astronomers, they were designated according to their origin as *Chaldaei*

8 See Dieterich 1900; Montanari Caldini 1979; Gury 1996, 154; Hübner 2008. An astrologer named Horus is hidden perhaps in Pliny, *Nat. hist.* 1.37 *ex…Oro*.

9 See Gundel and Gundel 1966, 195–197; Pérez Jiménez 2002, 129–131.

10 Manilius, *Astr.* 3.67–74. On Firmicus Maternus, see Barton 1994a, 162. See also Hübner 1984, 228 on Manilius, *Astr.* 4.159.

or, more frequently from the end of the first century CE onward, as *mathematici* [Cramer 1954, 244; Stramaglia 2013, 86][11] and their practice was called judicial astrology.

Often astronomy was only one discipline among many treated by universal-minded scholars, e.g., Eratosthenes at the beginning of the Hellenistic Period and Ptolemy toward its end [Hübner 2018]. Ptolemy divided his astral sciences into an astronomical part (*Syntaxis* or *Almagest*) and the later-written astrological work (*Apotelesmatica*). Many other erudite scholars dealt with astrology, such as Varro, Nigidius Figulus,[12] C. Fonteius Capito [Weinstock 1950; Cramer 1954, 67ff.], Thrasyllus, Balbillus, Chairemon, and even Cicero, who describes the Chaldean planetary system in *De re pub*. 6.17 [Gury 1996, 254].

As in many other sciences, the language of astrology remained Greek down to the third century CE, as we know from numerous papyri. Only a few handbooks are written in Latin. Varro's lost *De astrologia*[13] (one of his nine *disciplinae*) must have been a mixture of astronomy and astrology, which we can conclude from the traces that we find in Augustine, Martianus Capella, and Cassiodorus [Cramer 1954, 65–57].[14] The astrological handbooks were written in Greek, although the only one preserved was written by Firmicus Maternus and it was preserved because the author converted to Christianity.

We cannot judge to what extent all these authors of works devoted to the heavens practiced horoscopy since our sources are not forthcoming on this point. For Vettius Valens and Hephaestio, this is the case, while whether Firmicus Maternus practiced horoscopic astrology has been questioned [Dickie 2001, 150]. The distinction between theory and practice became important in Roman law of later times, since the principate punished astrological practice but never barred astrological studies and theoretical research.[15]

2 The Wanderings of Astrologers

Astronomical observation as well as astrological prognostication were important in Babylonia and Assyria, where priest-scholars specializing in divination

11 The distinction between "astrologus" and "mathematicus" attempted by Straub 1970, 259ff. is not convincing. See Hübner 2004–2010. For the Greek term «μάντις» in the sense of "astrologer", see Cramer 1954, 123.

12 On this learned man, see Cramer 1954, 63–65.

13 For the title, see Cramer 1954, 67; Tester 1987, 115–123; Hübner 1990b.

14 L. Tarutius Firmanus seems to have published his horoscope of Rome in Greek: cf. Pliny, *Nat. hist.* 1.18. See Heilen 2007.

15 *UlpMos.* 15.2 [Lenel 1889, 2.975]; Julius Paulus, *Sent.* 5.21.3: cf. Cramer 1954, 229, 247; Straub 1970, 252, 267; Gury 1996, 259.

and astrology belonged to the royal court. The fate of the entire country was implicated in the fate of the king, so inevitably astrologers were engaged in politics. According to Diodorus, Chaldean astrologers are said to have warned Alexander the Great not to enter the city of Babylon (the Chaldeans negotiated indirectly with him *via* Nearchos). Alexander first obeyed and set up his camp at a distance from the town; but, convinced later by philosophers that divination was not pertinent in this case, he finally entered Babylon [Diodorus, *Bib.* 17.112.2–5; Seneca, *Suasor.* 4: see Stramaglia 2013, 16]. Individual horoscopy arose only later, together with Stoic philosophy, when Alexander had created his universal empire. Hence, we have the difference between global predictions for towns and countries, if not for the whole world (γένος καθολικόν), and forecasting for individuals (γένος γενεθλιακόν) [Bouché-Leclercq 1899, 327–457; Cramer 1954, 279ff.; Fögen 1997, 278–281].

It is presumed that Babylonian astrology was transmitted during the period of Alexander's successors. It was at this time that Berossus, a priest of Bēl, is said to have founded a school on the isle of Cos, where Babylonian tradition was translated for a Greek audience [Frommhold 2004, 3f.: cf. Geller 2014a]. His Greek fellows were Antipater, Achinapolus, and Critodemus [Schnabel 1923; Cramer 1954, 14]. According to Pliny and Vettius Valens, other authorities on Babylonian astrology of this time were Sudines in the court of Antigonus I at Pergamon and Kidenas, Apollonius of Myndos, and Epigenes from Byzantium. At the beginning of the Hellenistic Period, Ptolemy I Soter moved the center of scientific scholarship from Athens to the Museum (Μουσεῖον) of Alexandria.[16]

In Egypt, the Babylonian and Greek astral scientific traditions were integrated into a characteristically Hellenistic system.[17] What Boll [1950, 4] referred to as the "bible" of Hellenistic astrology was written—at least partly—in Greek iambic verse and attributed to the legendary king Nechepso and the priest Petosiris [Heilen 2011], though perhaps the iambs were imbedded in prose as in Martianus Capella's *De nuptiis*. The less known and more fanciful "Babylonian" Teucer probably came from the Egyptian district named Βαβυλῶν. Teucer must have lived at the end of the first century BCE, since he influenced Manilius' poem [Hübner 1995b, 92; 2010, 10–16].

When Rome subjugated Egypt in 31 BCE, astrology penetrated their empire [Jones 1994]. At Rome, it began to meet other forms of traditional divination,

16 The role in this played by Demetrius of Phaleron is not quite clear: see Pfeiffer 1968, 87–104.

17 See Kroll 1923, 213, 219; Hübner 1984, 136–137; the importance of Egyptian elements is emphasized by Jones 1994, Greenbaum, and Ross 2010.

such as the Etruscan haruspicy, the interpretation of prodigies, in particular, of comets (which were excluded from astrology in the strict sense). In the early principate, during the first and second centuries CE, astrology reached its apogee in Antiquity [Cramer 1954, 233: cf. Straub 1970, 250–251].

3 Priests and Astrologers: Their Social Rank and Prestige

Vettius Valens and Firmicus Maternus [*Math.* 2.30.2, 3.*praef.*1] celebrated astrology as worshipping the Sun, Moon, and planets or the divine Hermes Trismegistus.[18] [Harpocration] writes that he owes his wisdom to Asclepius. Astrologers sometimes claimed to be priests of the heavenly bodies, even assuming a godlike status [*CCAG* 8.1.3, 136.31 (*De planetis*): cf. Manilius, *Astr.* 1.50, 2.30.1].[19] and thus were more esteemed, presumably, by believers [e.g., [Quintilian], *Decl.* 4.3.4: cf. Stramaglia 2013, 99–100]. There may have been prayers to the planets or other astral divinities,[20] and Vettius Valens engaged his pupils by oath [*Anth.* 4.11.11, 7.*praef.*3, 7.6.23].[21]

From this conception of their task came the aspiration to live a purified life and have moral integrity [Valens, *Anth.* 6.*praef.*15] and thus to nourish the immortal soul, an ideal that resembles that of mystical cults. But although this aspiration was demanded in the handbooks, it seems to have been seldom realized. Whether or not some of the astrologers also practiced magical arts [so Dickie 2001, 111][22] cannot be proved.

Writing his *L'Égypte des astrologues* [1937], Franz Cumont was inspired by the Latin *Liber Hermetis*, which had been uncovered and published one year earlier by Wilhelm Gundel [Feraboli 1994, c. 25; Hübner 1995b]. Following the lead of Wilhelm Kroll's “Kulturhistorisches aus astrologischen Texten” [1923], Cumont conjectured that astrological texts reflected the society of Ptolemaic Egypt and assumed a common source written by astrological priests of the temples in the Nile valley [1937, 124–131]. Louis Robert protested immediately,

18 See [Quintilian], *Decl.* 4.16.1; Gury 1996, 232.

19 The astrologer Balbillus was at the same time the supreme priest of the Temple of Hermes at Alexandria [Cramer 1954, 114].

20 Prayers to all planets: [Manetho], *Apo.* 5[6], 29–34. Firmicus, *Math.* 1.10.4 (inspired by Cicero, *De re pub.* 6.17); see Hübner 1988, 40n9. Neugebauer and van Hoesen 1959, no. 137c mentions the seven gods at the very beginning. Other prayers were directed to the Sun, the Moon, or Mars [cf. Evans 2004, 12] or to the female Ἄρκτος: *PGM* 1.116–118.

21 See Cumont 1908: but not Critodemus as proposed in Riley 1987, 253.

22 Cf. Tertullian, *Idol.* 9.3.7; Gury 1996, 255. We find astrological elements in the *Defixionum tabella* no. 15.8–9 [Audollent 1904, 22]; Ovid, *Ibis* 207–214.

saying that the texts are not limited to Ptolemaic Egypt but reflect the life of the entire Greco-Roman world, the later empire included [1938, 77–86: but see Barton 1994a, 159–160]. Ignoring this principal objection, Daniela Baccani has tried to corroborate Cumont's idea so far as it relates to the ostraca excavated at Medinet Madi [1992, 50–51].[23] Finally, James Evans has traced out a lively picture of the temple astrologers in Egypt in the second century CE, defining them as priests of Serapis [2004, 27–37, against Kroll 1923, 213]. This may be convincing for Ptolemaic Egypt; but under the Lagides, the astrological lore had been secularized and globalized. Throughout the whole Roman Empire, many astrologers were not settled but traveled across countries, as Vettius Valens relates about himself [*Anth.* 4.11.4:, 9.15.11].

Not all of the frequent contemptuous utterances against astrologers [Gury 1996, 232n17] in Roman literature can be related to priests. Contemporaneously to the first expulsion of astrologers from Rome in 139 BCE, the moralist Cato warned the overseer of a farm to refrain from consulting all kind of charlatans [*De agr.* 5.4].[24] In such enumerations, astrologers are often associated with augurs [see, e.g., Lactantius, *Epit.* 23.5][25] or the Etruscan *haruspices* [Weinstock 1950, 48]. Both kinds of professional forecasters pursued their task either by public or by private charge.[26] The astrologer Regulus consulted a haruspex after casting the horoscope of the ill Verania and found his results confirmed [Pliny, *Epist.* 2.20.3]. Some such interpreters were named by Cicero pettifoggers (*vicani haruspices*) [*De div.* 1.132: cf. Wissowa 1912, 547 "Winkelharuspices"]. But unlike *haruspices*, astrologers never joined guilds (*collegia*) nor do we know of any astrological professorial circles. In Babylon and Egypt, astrologers were scribes in temples and, in Egypt at any rate, they seem perhaps to have conducted introductory schools as well [Cumont 1937, 124–125; Baccani 1992, 51–53]. However, we do not have similar information for what happened in Roman times. Astrologers mentioned by Roman historians and in the literature are very different personalities. They are not always simple charlatans or money-starved knaves [Gury 1996, 243 with n121]; on the contrary, some of them were highly educated thinkers. Yet, Vettius Valens came from the lower population of Antioch, where the social rank of astrologers is comparable to that of scientific experts in modern democracies, especially physicians. In the *Iatromathematica* of Nechepso-Petosiris and the *Salmeschiniaka* of the

23 The fact that zodiacal bands are depicted on the ceilings of Egyptian temples does not prove that astrology was practiced in the temples, as suggested in Evans 2004, 24–25.

24 See Columella, *De re rust.* 11.1.22, which does not explicitly mention astrologers.

25 The term "haruspex" can also designate astrologers: Stramaglia 2013, 16.

26 On the *haruspices*, see Wissowa 1912, 547–549.

so-called Hermes, astrology and medicine were closely linked.[27] Medical practitioners such as Thessalus [Cramer 1954, 123; Pingree 1976a][28] and Antigonus of Nicaea [Cramer 1954, 188–190; Heilen 2015] covered both disciplines and even Hippocrates emphasized the medical usefulness of astronomical knowledge [*De aer*. 2]. The disciplines used similar methods, that is, prognostication after observation, stochastic conjecture, and a dressing of casuistic typologies. Moreover, both types of practitioner had to be discreet concerning personal data. Finally, their art could be lucrative. Like physicians, professional astrologers did not often enjoy high repute in Antiquity. They worked in hidden places, for example, near the Circus Maximus.[29]

The terms "astrologi", "Chaldaei", and "mathematici" appear in disparaging catalogs listing *augures*, *magi*, *haruspices*, *harioli*, *coniectores*, *sortilegi*, *interpretes somniorum*, *vates*, and *vaticinatores*, not only in comedy[30] but also in philosophical literature,[31] technical literature,[32] and the works written by Christian apologists.[33] In legal texts such catalogs fulfilled the juridical aim of exhaustive completeness.[34] In such enumerations, the limits between the different kinds of soothsayers often faded away, as may have been the case in real life. In literature, astrologers were often ridiculed, as in the works of Petronius and Apuleius. Lucillius' epigrams reveal a sarcastic scepticism of their lore. Tacitus condemned them in his famous verdict on the Neronian court astrologers [*Ann*. 1.22.1].[35] Vettius Valens complained that astrology was ill-reputed [*Anth*. 6.*praef*.7].

27 The disciplines are compared by Ptolemy, *Apo*. 1.2.10, 1.3.18–21; see Fazzo 1991, 230, 241–243; Barton 1994a, 168; 1994b, 185–191; Hübner 2008, 338–344; Komorowska 2009. In the Renaissance, the connection became even stronger: see Hübner 2013, 11f.

28 On his doubtful identity with the famous Thessalus of Tralles, see Gundel and Gundel 1966, 153n31.

29 Livy, *Ab urbe* 39.16.8 (186 BCE); Cicero, *De div*. 1.132. See Pease 1921 *ad loc*.; Kießling and Heinze 1886–1898, 1.6.113 on Horace; Juvenal, *Sat*. 6.588.

30 Plautus, *Miles* 693: cf. Cato, *De agr*. 5.4. As for the relationship between the new comedy and astrology, see Hübner 1984, 188–190; 2010, 53–54, 282–288 on Manilius, *Astr*. 5.473–476. See p. 303n31.

31 Cicero, *De nat. deor*. 1.55; *De div*. 1.132 modeled perhaps after Ennius; *Telamo* cited after that [see Pease 1955–1958 *ad loc*.].

32 Quintilian, *De inst*. 5.7.36: see Cumont 1937, 124n5.

33 Tertullian, *Apol*. 35.12, 43.1; *De praescr*. 43.1; Arnobius, *Adv. nat*. 1.24: Jerome, *Ad Iovin*. 2.15, *In Ezech*. 6.20.

34 *UlpMos*. 15.2.1 [Lenel 1889, 975] (*senatus consultum* a.16); Julius Paulus, *Sent*. 5.21.3; CodTh. 9.16.4 [a.357 = CodIust. 9.18.5]; CodIust. 9.16.6. There are similar catalogs in the indexes of the Catholic Church.

35 The epithet "fallax" here is used in both senses: active ("deluding") and passive ("deluded").

Still, knowledge of astrology could sometimes bestow a high reputation, as seen for the uneducated Petronian freedman Trimalchio, who wanted to impress his guests by a sophisticated interpretation of a zodiacal dish.[36] Some astrologers, indeed, enjoyed an extended reputation, for example, a certain Pammenes[37] and this was deplored even more *après coup*, if their prognostications failed.[38]

4 Court Astrologers

According to sources written in Greek, during the reign of Alexander and the successors, celestial diviners/astrologers maintained their reputation and continued to influence political decisions. The Seleucids, Lagids, and Attalids surrounded themselves with court astrologers. King Antigonus I, despite his general scepticism, followed their advice out of respect for their experience [Diodorus, *Bib*. 19.55.8]; and his foe, Seleucus I Nicator, consulted astrologers by means of catarchic horoscopy [Appianus, *Syriaca* 58.299–306: cf. Cramer 1954, 11]. The well-known Conon, serving Ptolemy III, set among the stars the "Hair of Berenice". Attalus I Soter employed the astrologer Sudines. So astrology continued to be intimately linked with politics.

The political function of astrology persisted in the Roman Period, when astrologers investigated the fortune of Roman emperors as indicative of the destiny of the whole country.[39] Octavius and Agrippa consulted the astrologer Theogenes at Apollonia in their youth [Suetonius, *Aug*. 94.12]. From Tiberius until Domitian, almost all emperors were believed to have obtained predictions of imperial power [Cramer 1954, 168] and they employed court astrologers. The first and the most famous court astrologer was the Alexandrian grammarian Thrasyllus, whom Tiberius knew during his first *nesiarchia* at Rhodes and whom he employed starting in 2 CE.[40] Thrasyllus' son Balbillus [Cramer 1954, 11, 108–139; Gundel and Gundel 1966, 151–153] served Claudius, Nero, and

36 He represents himself as a *vir Mercurialis*, a skillful interpreter, who was born under the sign of the multipedal and amphibious Cancer [Petronius, *Trim*. 39.8]: see Hübner 2003b; 2011, 34.

37 The rivalry between colleagues, observed in Riley 1987, 251–254 and following him Gury 1996, should not be overestimated.

38 See the epigraph *CIL* 6.4.2675, no. 27140. A certain Telephus grieves because his child has died at only four years old. There are similar epigraphs in Cramer 1954, 97.

39 On credulous Roman emperors, see the very detailed chapter in Cramer 1954, 81–146.

40 For further discussion, see Cramer 1954, 99–104; Gundel and Gundel 1966, 148–151.

Vespasianus [Tacitus, *Hist.* 2.78.1].[41] Caligula consulted an astrologer named Sulla, who is said to have foretold exactly his imminent death [Suetonius, *Calig.* 57.2: cf. Cramer 1954, 112; Gundel and Gundel 1966, 177]. The philosopher and astrologer Chaeremon was called from Alexandria to Rome by Claudius for the instruction of Nero [Gundel and Gundel 1966, 354f.]. The younger Agrippina is said to have looked by means of catarchic astrology for the most favorable moment for installing her son Nero on the throne [Tacitus, *Ann.* 12.68], as perhaps advised by Balbillus. Poppaea Sabina employed Ptolemaeus Seleucus [Cramer 1954, 129f.],[42] who served Otho as well. As for the credulous Domitian, no court astrologer is known; but he eagerly studied the horoscopes of prominent people [Cassius Dio, *Epit.* 67.15.6] and looked anxiously toward the hour of his death, which was predicted to him in his youth [Suetonius, *Dom.* 14.1]—and his fear allowed conspirators to slay him [Cramer 1954, 142–145]. Hadrian believed in astrology.[43] Septimius Severus and Caracalla also held court astrologers. The former is said to have married the Syrian Julia Domna after comparing several horoscopes [*Hist. Aug.*: *Sev.* 3.9: cf. *Geta* 3.1], to have studied the unfavorable horoscope of his second son, the unfortunate Geta [*Hist. Aug.*: *Geta* 2.6–7], and even to have published his own horoscope in his youth, which was illegal. He was accused of this but escaped punishment for political reasons.[44] Alexander Severus consulted the astrologer Thrasybulus, who was his friend [*Hist. Aug.*: *Alex.* 66.2]. Caesar and Augustus had some knowledge of astrology.[45] The crown prince Germanicus translated Aratus' *Phaenomena* and substituted the second, metrological part with *Prognostica*.[46] Tiberius even practiced astrology by himself [Tacitus, *Ann.* 6.21; Cassius Dio, *Hist. Rom.* 57.19.3: see Cramer 1954, 106, 131, 145]. Following the *Historia Augusta*, Hadrian [*Hist. Aug.*: *Hadr.* 16.7, *Aelius* 3.9], Septimius Severus [*Hist. Aug.*: *Sev.* 3.9] and Alexander Severus [*Hist. Aug.*: *Alex.* 27.5][47] are also said to have been expert in astrology; but this must be viewed with suspicion [Kuhlmann 2002,

41 We do not know whether Balbillus also worked for Titus, who is said to have had his horoscope cast [Suetonius, *Titus* 9.2].

42 It seems that the two names belong to the same astrologer [Cramer 1954, 82; Gundel and Gundel 1966, 177].

43 *Hist. Aug.*: *Aelius* 16.10 mentions astrologers among many other professionals. See also the critical remark in Cramer 1954, 174, 248, which Straub 1970, 258 accepts.

44 Perhaps in 180 CE [*Hist. Aug.*: *Sev.* 4.3: see Cramer 1954, 209, 269].

45 The former wrote the work *De astris* [Cramer 1954, 74–80]. Alexander's expertise in astrology is legendary [Cramer 1954, 10].

46 Montanari Caldini 1973, 1976. On the widespread fame of Aratus' *Phaenomena*, cf. Hübner 2005a. See also ch. 10.1, p. 383.

47 See Cramer's take on this [1954, 230], which Straub 1970, 257 questions.

105]. At least for Hadrian, this seems to be likely.[48] In the later period, we have to include Julian the Apostate [Ammianus, *Res gest.* 21.2.4]. Augustus is even said to have published his own horoscope but this was probably only his rising sign, Capricorn.[49]

We also have the horoscopes of some other rulers. While Cramer [1954, 164] could cite only the horoscope of Hadrian—the most detailed horoscope we possess from Antiquity[50]—we now know of 15 nativities of regents, princes, usurpers, and high functionaries [see Heilen 2015, 2.150ff.], to which we may add the horoscope of Nero, which has been investigated independently by several scholars.[51] Astrologers were also consulted by those who opposed the emperor and members of conspiracies, so they could be dangerous to emperors. Ironically, Tacitus, *Hist.* 1.22.1 evokes the persistence of horoscopic practice despite so many permanently renewed legal prohibitions.

5 The Prohibition of Astrology

Astrological practice was strictly controlled and frequently prohibited by law.[52] The first edict against astrologers known to us was issued for the year 139 BCE. This edict, which was valid only for the city of Rome and only for that year, was announced by the *praetor peregrinus* because it was a part of foreign policy.[53] This measure also ordered the expulsion of the worshippers of Jupiter Sabazios [Valerius Maximus, *Facta* 1.3.3]. It is only in this early edict that reasons are given, namely, doubtful interpretation of the sidereal data and moneymaking. Later laws gave no justification. The next measure came 100 years later and was promulgated by Marcus Agrippa when he was in exile in 33 BCE. Once again, the measure concerned only the city of Rome.

The fundamental edict was that of Augustus in 11 CE [Cassius Dio, *Hist. Rom.* 56.25.5].[54] It concerned, in particular, prognostication for the death of individuals. It regarded horoscopy for the ruler as *crimen laesae maiestatis* (lese-majesty) or *curiositas* (περιεργία). Further prohibitions were constantly issued.

48 Cramer 1954, 162–178: “Hadrian: another astrologer on the throne”; Heilen 2015, 1.17–20.

49 Suetonius, *Aug.* 94.12. We have several coins and other architectural pieces. See Schmid 2005; Terio 2006.

50 For a more detailed discussion, see Heilen 2015.

51 Neugebauer and van Hoesen 1959, no. L37. See Hübner 2005b, 14 with n12.

52 This has been treated very carefully in Cramer 1954, 232–248, with table on p. 234.

53 It is not clear whether this was done to protect the indigenous Etruscan *haruspices*, as supposed by Dickie 2001, 155f.

54 On this edict and its repeated application, see the detailed study in Cramer 1954, 251–181.

After the first expulsion of astrologers, 14 further expulsions occurred until 205 CE. Tiberius chose to effect this in the form of a senatorial decision in his two measures of 16 CE. In 212 CE, all people throughout the empire were granted Roman citizenship, so the juridical distinction between Rome and the provinces no longer made sense. Consequently, in 294 CE, the proscription against astrology was expanded to the whole empire. Christian emperors repeated and reinforced the worldwide prohibition [Straub 1970, 261–264]. The law by which Alexander Severus allowed liberal profession to astrologers seems to have been an exception as part of an apologetic strategy against Christian repression [*Hist. Aug.*: *Alex.* 27.5].[55]

It must be noted that not only astrologers but also their clients were accused, whereby the *crimen laesae maiestatis* was often accompanied by other forms of incrimination.[56] Some of the examples known to us concern wives.[57] The Augustan edict, first of all, forbade casting horoscopes for the moment of death, in particular for the emperor. But there is a curious contradiction. On the one hand, it was strictly forbidden to cast a horoscope for the emperor [Firmicus, *Math.* 2.30.3]; on the other, the emperor was said to be exempt from heavenly influence [*Math.* 2.30.5].[58]

The punishment for astrological forecasting—either by law or by the command of the emperor—was quite variable. Tiberius ordered two astrologers to be executed [Tacitus, *Ann.* 2.32: see Cramer 1954, 249]. The jurisprudent Julius Paulus reported a decree that threatened the same penalty [*Sententiae* 5.21.3: cf. *UlpMos.* coll. 15.2 [Lenel 1889, 2.975]]. But the astrologer Apollonius, who is said to have rightly foretold the death of Caligula, escaped from the punishment because the execution had been postponed [Cassius Dio, *Hist. Rom.* 59.29.4; see Cramer 1954, 111f]. The astrologer Pammenes, however, did not undergo capital punishment as Gundel and Gundel 1966, 177, claim, although two of his clients actually did [Tacitus, *Ann.* 16.14; see Cramer 1954, 130f.]. Vitellius expelled astrologers or furiously [Suetonius, *Vit.* 14.4] ordered them to be executed; Domitian arranged to kill Ascletarius [Suetonius, *Dom.* 15.2;

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55 Straub 1970, 261–272 expresses doubts on this.

56 Cramer 1954, 248–270. One instance in the later period was Parmenius, the prefect of Egypt [Libanius, *Orat.* 14: see Bouché-Leclercq 1899, 569].

57 (a) Aemilia Lepida [Tacitus, *Ann.* 3.22: see Cramer 1954, 255f.]. (b) Lollia Paulina [Tacitus, *Ann.* 12.22: see Cramer 1954, 259–261]. (c) Vibia, the mother of Furius Scribonianus [Tacitus, *Ann.* 12.52: see Cramer 1954, 261f.]. But there was no astrological consultation in the case of Claudia Pulchra [Tacitus, *Ann.* 4.52: see Cramer 1954, 256f.] or Domitia Lepida [Tacitus, *Ann.* 12.65: see Cramer 1954, 263f.] or Barea Soranus and his daughter [Tacitus, *Ann.* 16.30; Dio Cassius, *Epit.* 62.26.3: see Cramer 1954, 164f. and n171].

58 On this contradiction, see Cramer 1954, 280.

Cassius Dio, *Epit.* 67.16.3];[59] Caracalla did the same for the astrologer Serapion,[60] who had prognosticated for him a short life.[61] Tiberius is said to have required astrologers on the isle of Capri to prognosticate their own futures. If he judged them to be untrustworthy, he ordered them to be thrown down from the rocks into the sea [Tacitus, *Ann.* 6.21; Suetonius, *Tib.* 14; Cassius Dio, *Hist. Rom.* 55.11.1f.]. Thrasyllus escaped this fate, whereas the supposed model of this story, Nectanebo—the legendary last indigenous pharaoh/astrologer of Egypt and supposed father of Alexander—is said to have been questioned in the same way by his son and killed by a 12-year-old boy after he predicted that he would die at the hand of his own son.[62]

There are also examples of self-justice. A sarcastic epigram of Lucillius derides the suicide of an unlucky astrologer named Aulus, who, after having reckoned the hour of his own death, hanged himself; when the fatal hour was over, though he was still alive, he considered himself guilty, "ashamed of Petosiris" [*AnP* 11.164].[63] Another case of self-justice was constructed in [Quintilian], *Declam.* 4 (*ca* 200 CE):[64] it was foretold that someone would slay his father. To prevent this crime, Aulus prepared to commit suicide but his father pleaded against it.

6 Astrologers and Their Work

According to Latin sources, astrologers made their predictions either spontaneously or on demand. One may compare the traditional Roman distinction between *auguria impetrativa* and *auguria oblativa* and the ritual of "counter-announcement" (*obnuntiatio*) [Wissowa 1912, 529–534]. A *haruspex maximus* warned Caesar in vain to cross to Africa. Perhaps it was the same Spurinna who rightly warned him to be cautious on the Ides of March [Cicero, *De div.* 1.119, 2.52 with Pease 1921]. Cramer's remark [1954, 77] that "astrology, or at least astrometeorology was the likelier source of such a prediction", is doubtful, as

59 For the different names of this person, see *CCAG* 8.4 and n101; Cramer 1954, 273f. and nn273–275.

60 On the different astrologers named *Serapion*, see Denningmann 2009.

61 Cassius Dio, *Hist. Rom.* 79(78), 4.4f.: see Cramer 1954, 215; Gundel and Gundel 1966, 284 and n13.

62 For a Latin version, see Julius Valerius 1.14: see Weinreich 1911, 16f. On the parallelism of the two stories, see Krappe 1927.

63 The poet was also deluded by erroneous prognostications [11.159]; the only true one from the astrologer Hermocleides came *post eventum*.

64 See the recent treatment by Stramaglia 2013.

seen in Propertius *Eleg*. 4.1.150, where the half-comic Horus adopts the traditional prohibitive role of Apollo.[65] A spontaneous prognostication is given, for instance, by the Chaldeans to the king Antigonus Nicator and by the senator Nigidius Figulus "practicing some forbidden art" after the birth of Octavianus [Suetonius, *Aug*. 94.5; Dio Cassius, *Hist. Rom*. 45.1.3–5: cf. Cramer 1954, 63]. But in general the charts were requested, especially in catarchic horoscopy.

Astrologers were consulted by believers of all classes. Little is known about the relation of soldiers to astrology.[66] The lower classes are rarely mentioned by the historians[67] but the literature and original horoscopic texts as well pay more attention to them than does history [Barton 1994a, 160–162; Gury 1996, 240]. Women of the lower classes in particular were susceptible to belief in astrology, as Juvenal reports in his sixth satire [*Sat*. 6.588]. Several of the persons accused of having consulted astrologers were women. Among the proper names of the customers of astronomical papyri, we find several wives.[68] It sometimes happened that several members of a family cast horoscopes together [Baccani 1989, 74]. Although we know two literary instances in Plautus of female *hariolae* [*Miles* 693, *Rudens* 1139: cf. *TLL* 6.3c.2535.65–70] and one for a *haruspica* [*Miles* 693, *Rudens* 1139: cf. *TLL* 6.3c.2549.11–13; Dickie 2001, 150, 163]—by Etruscan heritage—there is none for an "astrologa". Nevertheless, a woman could attain enough expertise to no longer need consultation with professional astrologers and could even be consulted by others [Juvenal, *Sat*. 6.574f.].

In the later Imperial Period, many astrologers traveled across the Roman Empire, for example, Vettius Valens [Pingree 1986, 4.11.4] and the Apuleian astrologer Diophanes. Vettius Valens studied astrology in Egypt [Pingree 1986, 4.11.4] and reports that he had disciples.[69] He also addressed the last books of

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65 See Wimmel 1960, 280, which compares the Apollonian Sibyl in *Tib*. 2.5: cf. Hübner 2008, 355–358. See also Neugebauer and van Hoesen 1959, no. 3.16 φυλάττου.

66 In the republic, people were rather resistant to superstition [Cramer 1954, 49]. One example is in Baccani 1995, nos 9 and 10: Πάτρων and his wife Ταρικᾶς. Another doubtful example can be compared from *POxy.* 31.2557.2 [Baccani 1992, 54, 168].

67 See Cramer 1954, 2; on p. 145 he confines himself to upper-class society.

68 Neugebauer and van Hoesen 1959, nos 150.1 γένεςις Φιλόης, 227.2 γένεςις Πτολεμαΐδος, 244.1 Διονυςία, 283.1 "nativity of Pichine", 351.1 γένεςις Ἑρμειόνης, 376a.11 γένεςις Ἰωάννης "Joannes (or Joanna?)", 385.1 γένεςις Νηςτία ἢ καὶ Ἀπολλωνία. Neugebauer and van Hoesen 1964, nos 304 [= Baccani 1992], 174.13 (with 177) γένεςις Θεονίς [cf. Pape and Benseler 1884 594]. See also Jones 1999a, nos 4258.1 γένεςις Ἀπίας, 4297.1 Θοώνιος; whereas in the *catarche* of marriage, no. 4270.2 γένεςις Ἀμμωνᾶς may concern a male person, as Jones [1999a, 1.277] conjectures. For further examples, see Baccani 1989 and 1995.

69 Valens [Pingree 1986, 3.13.16] admits that his writings were rather simple. Firmicus, *Math.* 2.*praef*.2 assumes the role of a teacher.

his *Anthologiae* to a certain Marcus [Pingree 1986, 7.6.230.al].[70] Others, such as Paulus Alexandrinus and Theophilus of Edessa, wrote their handbooks in the typical Roman tradition of *praecepta ad filium*, transmitting their experience and wisdom to the younger generation.[71]

6.1 *The Proper Names and the Religious Status of Astrologers*

The astrological papyri mention the names of several customers[72] either at the beginning or at the end of the horoscopic data but never those of the astrologers who cast them. We know but one name from an original papyrus, the author of *PLond.* 130 (after 81 CE), Titus Pitenius.[73] In one case [Jones 1999a, no. 4266.col.1.12 (with 1.272)], it is not clear whether «ὁ γράψας Διάπαλος» means that Diapalus was the astrologer who cast the horoscope or the scribe who copied it out. In historiography and other literature, astrologers are mentioned often but by the indefinite plural ἀστρολόγοι/*astrologi*; we know only a few proper names.[74] Moreover, we find many pseudonyms, either theophoric ones—such as Ammon, Anubion, Asclepius, Asclepiades (of Myrleia), Orpheus, Hermes (Trismegistus), Horus, Petosiris (i.e., Given by Osiris), Pythagoras, Serapis (Sarapis) [Petronius, *Sat.* 76.10], Serapion—or Zoroaster. Other names were taken directly from the stars or constellations esteemed as divine beings, as often even in modern times: for example, Orion [Maass 1898, 47.14; Pingree 1986, 3.2.20] and, in later times, Leo [*CCAG*, 12.156.2][75] and Centaurus [*CCAG* 11.1.85].

6.2 *The Meeting Points of Astrologers and Clients*

There were various meeting places other than temples. Agrippa and Octavius consulted an astrologer in a pergola at Apollonia in Illyria [Suetonius, *Aug.* 94.12]; Septimius Severus, in his homeland, Africa [*Hist. Aug.*: *Sev.* 2.8.] At Rome, astrologers practiced near the Circus Maximus, although Firmicus warned that

70 In book 4, his addressee is simply an ἀδελφός [Pingree 1986, 4.11.11].

71 Paulus Alexandrinus to his son Cronamon, Theophilus of Edessa to his son Deucalion.

72 When Baccani deplores that the name has often been omitted, one has to consider that a name could have fallen out or been truncated, mostly at the beginning of the fragments.

73 Neugebauer and van Hoesen 1959, no. 81.col.8.185–189 Τίτος Πιτήνιος ἐψήφισα (homonymous with the emperor Titus), col.2.38. See Boll 1903, 388f.; Baccani 1992, 44. The index of personal names in Jones 1999a, 2.455 is, however, rather small.

74 From Belephantes onward, who was said to have negotiated with Alexander the Great at Babylon [Diodorus, *Bib.* 17.112.3]. Even many court astrologers are buried in oblivion [Cramer 1954, 82].

75 Cf. the pseudonym "Alan Leo" of William Frederick Allen, born 7 Aug 1860, when the Sun stayed in the zodiacal sign Leo. See Howe 1995, 84. As for Teucer, see Hübner 2010, 1.17 and 2.170 on Manilius, *Astr.* 5.298 *Teucro*.

a cautious astrologer should keep himself away from the games, not only to avoid seduction by the sensual delights (*voluptates*) but also to appear as non-partisan and objective [*Math.* 2.30.12]. (The problem here is that the course of the charioteers in the circus-arena was likened to the movement of the planets and the colors of the charioteers' factions to the planets' colors [Wuilleumier 1927; Le Boeuffle 1989, 111f.].) Since the Sun was also regarded as a planet, the *spina* could be marked by an obelisk, an ancient and renowned object of Sun-worship.[76] In the Circus Maximus, there was even a Temple of Sol. The greedy astrologer Nectanebo cast a horoscope in the house of Olympias to determine the best moment for the birth of Alexander; the legacy-hunting astrologer Regulus, in a spontaneous action, cast the horoscope of Verania on her sickbed [Pliny, *Epist.* 2.20.2–6]. It was also possible for there to be no meeting at all. The quite successful and famous astrologer Pammenes was consulted in his exile by his former clients and friends by courier or correspondence [Tacitus, *Ann.* 16.14: see Cramer 1954, 130; Gury 1996, 241].

6.3 *The Negotiation between Astrologers and Clients*

When the astrologer first met with his client, a sort of negotiation started. First, the client had to reveal the day and the hour of his nativity.[77] For a more exact calculation, even the geographical latitude (κλίμα) of his birthplace was needed,[78] though in the papyri we find only one such special indication [Neugebauer and van Hoesen 1959, 81.col.9.201–207 (with 26f.): cf. Baccani 1992, 44]. The situation resembles a patient who must unclothe himself before a doctor. Octavianus, when he consulted an astrologer at Apollonia, at first refused to reveal his birth data, being afraid that his nativity would yield a result less favorable than that of his friend Agrippa, who was born first.[79] After the astrologer was given the personal data, he was the first to know the results; so discretion was necessary. Thus, Vettius Valens required from his pupil an oath of secrecy.[80]

76 Generally for all obelisks, see Pliny, *Nat. hist.* 36.64; for the oldest, highest, and heaviest item, now standing in Piazza del Laterano, see Ammianus, *Res gest.* 17.4.12. Cf. Tertullian, *De spect.* 8; *AnL* 197. See Wuilleumier 1927, 193f.

77 Cf. Julius Valerius 1.4 (Nectanebo invites Olympias); Neugebauer and van Hoesen 1959, 284.1–3. Cf. Baccani 1992, 41.

78 See Honigmann 1929, 42. Mostly, people calculated with the second *clima*, that of Alexandria, because it presented a minimum of fractions. Cf. Hübner 1984, 148.

79 Suetonius, *Aug.* 94.12: cf. [Quintilian], *Decl.* 4.3.4.

80 Pingree 1986, 4.11.11, 7.6.231, 9.12.2; 9.15.11: cf. Bouché-Leclercq 1899, 268f.; Barton 1994b, 82–85.

It is for this reason that almost all individual horoscopes that come down to us in great quantity, be it in either papyri or astrological handbooks, do not reveal the name of the astrologer, with only one exception. Some literary writers published their own horoscopes—e.g., [Manetho], who did so explicitly in a *sphragis* [see p. 494n22] to his didactic poem,[81] and Aelius Aristides.[82] But some did not, e.g., Vettius Valens, who concealed his [Neugebauer and van Hoesen 1959, no. L120.II].[83] A special case is the *Apotelesmatica* of Hephaestio of Thebes, which existed in several different versions or excerpts. Whereas in the so-called main text the author frankly reveals his own horoscope, saying "I was born" («ἐγὼ ἐτέχθην»), one of the excerpts gives the cryptic text "Someone was born" («ἐγεννήθη τις»).[84] This difference must go back to different versions of the text that reveal a certain ambivalence on the part of the author. The anonymity of horoscopic data has invited modern scholars and astrologers to a veritable horoscope hunt to identify, with more or less success, the concealed individuals.[85]

It has been supposed that anonymity underlined a certain scientific distance [Potter 1994, 19], but it was more important to protect the private sphere and the personality of both the astrologer and the client. Discretion was needed most of all in horoscopes for rulers.[86] Under the Christian emperor Valens, an astrologer was caught holding the nativity of a certain Valens. He was accused

81 [Manetho], *Apo*. 6[3], 738–750 [= Heilen 2015, gr. 80.V.27–28] and Aelius Aristides *Sacred Discourses* 6.26 [= Heilen 2015, gr. 117.XI.25].

82 Aristides, *Sacred Discourses* 6.26 [= Heilen 2015, gr. 117.X], 11.26. The horoscope of Proclus is transmitted by his biographer Marinus in his *Vita Procli* [= Heilen 2015, gr. 412.II.7]: cf. Saffrey and Segonds 2001, 185–201; Hübner 2017.

83 It is mentioned 21 times and has been identified as his own horoscope by Pingree [1986, v]. See also Komorowska 2004, 17, 398, 413.

84 Pingree 1973–1974, 1.91.27, 2.187.15 [= Heilen 2015, gr. 380.XI.26]: cf. Hübner 2011, 35.

85 In the chronological order of the investigation: the emperor Hadrianus (76 CE), the grammarian Pamprepius (440 CE), Nero (37 CE), Cronamon, the addressee of Paulus Alexandrinus [see Holden 1989], Domitianus (51 CE). In Latin texts, we find Ceionius Rufius Albinus (303?), and perhaps even Sulla (139/138 BCE ?), which would be the oldest known horoscope. See Hübner 2005b, 14–15; 2011, 39; Heilen 2015, lat. −138.V.22–23.

86 Nevertheless, some emperors promulgated details of their nativity (or other important moments of their reign) by propaganda in coins and architectural sculpture or building: Antiochus I of Commagene had the constellation Leo inscribed on a monument near his tomb [Heilen 2015, gr. −61.VII.6–7; Augustus published his birth-sign Capricorn: Cassius Dio, *Hist. Rom*. 56.25.5 mentions the complete διάταξις [Terio 2006]. Various hypotheses about Tiberius, Trajanus, and Septimius Severus (ceiling of his palace and Septizonium) are, however, more or less speculative. See Hübner 2011, 40–51.

but undertook to defend himself: the Valens in question was not the emperor but the accused's deceased brother. Before he could prove this, however, the astrologer was killed [Ammianus, *Res gest*. 29.2.27].

As with modern experts, astrologers had to maintain impartiality [Firmicus, *Math*. 2.30.12] and, especially, fidelity [*Math*. 2.30.9]. It is clear from history, however, that this moral maxim, which the handbooks demanded, was violated quite often by fraudulent prognostication.[87] An astrologer could not only make a mistake, he could also make a false prognostication intentionally, as is seen, for example, in case of the foundation of the city Seleucia on the Tigris: for political reasons, and in favor of the old capital Babylon, the Chaldeans fabricated a negative prognostication if any troops entered the city. But when the soldiers of Antigonus Nicator started the battle, the astrologers changed their unfavorable prognostication into a positive one.[88] Thrasyllus gave Tiberius ten years to live in order to protect presumptive successors from execution [Cassius Dio, *Hist. Rom*. 58.27.3]. But to spare Nerva from being executed by Domitian, another astrologer forecasted that Nerva had only a few days left to live and by this trickery rescued the successor [Cassius Dio, *Epit*. 67.15.6]. In the sixth century CE, the Christian Zacharias Scholasticus reported one delicate case in his description of the life of Severus, patriarch of Antioch [Krugener 1904, 66f.].[89] The astrologer Leontius was once asked by a client about the sex of the child to which his wife would give birth. The astrologer replied that she would have a boy. As he left, he informed the woman doorkeeper that it would be a girl but that he was refraining from upsetting the father in advance, since he wanted a boy. After the wife gave birth to a girl, the father was irritated and made Leontius come to him to convict him of lying but the latter saved himself with the testimony of the doorkeeper. This story shows two things: there were horoscopes of complaisance; and astrologers, when they carried out foul play, hedged.

All these examples suggest that there was a justifiable distrust on the part of the client. The Petronian Trimalchio tested the astrologer Serapa by asking him what he had eaten the day before [*Cena Trim*. 76.11]; he knew that he still had 30 years, 4 months, and 2 weeks to live. The astrologer was well informed and answered correctly. But distrust was mutual. The emperor Septimius Severus was suspected by the astrologer whom he consulted in Africa

87 Martial, *Epig*. 9.82.2; [Quintilian], *Decl*. 4.22.2. In Apuleius, *Meta*. 2.14.5, Milo wishes for Lucius that "the Chaldean will tell you the truth." In general, Cicero, *De div*. 1.2: cf. Gury 1996, 252f.

88 Appian, *Syriaca* 57, 300–307: cf. Brødersen 1989, 165–167.

89 Cf. Gundel and Gundel 1966, 393n6. Quoted without source by Barton 1994a, 177f.

of having submitted the nativity of another person [*Hist. Aug.*: *Sev.* 2.8: cf. Maass 1902, 142; Cramer 1954, 209]. The astrologer refrained from foretelling a potentially important event and made his client swear that his information was authentic.

6.4 *Casting Horoscopes with Instruments*

Astrologers typically used their fingers and hands.[90] Clement of Alexandria [*Strom.* 6.4–35.4] described the procession of the priests coming out from the temple: after the musician (ᾠδός) came the astrologer (ὡροσκόπος), who carried in one hand a sundial (ὡρολόγιον) and in the other a palm branch (φοίνικα). Clement adds that he had to learn by heart the four books of Hermes. In Martianus Capella's *De nuptiis* 6.581, the personified Geometria and her full sister Astrologia[91] hold in their hands similar instruments: Geometria, a pointer (*radius*) and a *sphaera solida* [6.580]; Astrologia, a yardstick (*cubitalem fulgentemque mensuram*) and a book showing in different colors the movements of the planets before observation [8.811]. Both authors emphasize the use of written materials, that is, tables (πίνακες) with data obtained not by observation but by extrapolation (by addition to the values of former data) [Gundel and Gundel 1966, 149 with n117] such as we now have in numerous primary tables or kinematic "handy tables", ephemerides, and almanacs,[92] in addition to handbooks[93] and introductions to horoscope collections such as Vettius Valens' *Anthologiae* [cf. Pingree 1986, 2.*praef*.1][94] and the treatises by Ptolemy,[95] Hephaestio, Firmicus Maternus, Paulus Alexandrinus, as well as the fragments of Rhetorius.

But there were also portable or standing instruments as well as a table covered by ashes, on which diagrams could be drawn.[96] The planets could be designated by different colors as in the very precious board (πίναξ) for casting horoscopes described in the Alexander-Novel.[97] This board was made with ivory, ebony, gold, and silver and showed 3 zones with the 36 decans, the 12

90 As Regulus in Pliny, *Epist.* 2.20.3 and as Astraeus in Nonnus, *Dion.* 6.61–63: cf. Gury 1996, 233.

91 On the sister-metaphor, see Hübner 1989, 49f.; on her name, see Hübner 1990b.

92 See the various types of written material in Jones 1999a, 1.113–245, 2.2–369. Cf. the foreseer Olympus in Lucillius, *AnP* 11.163.4.

93 Cf. the superstitious woman in Juvenal, *Sat.* 6.578.

94 Valens collected more than 140 horoscopes cast by himself concerning individuals born between 50 and 173 CE and one prognostication for 184 CE.

95 His *Apotelesmatica* is quite different from the other ones, being more philosophical: Fazzo 1991, 216.

96 Astraeus in Nonnus, *Dion.* 6.19–23. On drawing in the sand, see Claudian, *Pan.* 16.126f.

97 Julius Valerius 1.4. On the Greek version, see W. Gundel in Boll and Bezold 1931, 196–198.

zodiacal signs, and the 2 luminaries (Sun and Moon). On it, one moved little colored stones representing the 7 planets and the Ascendant of the corresponding metals (λιθοτέχνων μετάλλων), taken from a precious chest of ivory.[98] Such instruments appear to have been used by priests and royal astrologers as well as perhaps by some wealthy owners.

Other instruments used by astrologers were sundials,[99] waterclocks [Ptolemy, *Apo*. 3.3.2: cf. Baccani 1992, 78], a staff or yardstick, *parapegmata* [Rehm 1949; Rüpke 2000], and two different types of globes, as distinguished by Cicero in *De re pub*. 1.21f.[100] The first was the *sphaera solida* showing the celestial sphere with the constellations of the fixed stars; the second, the more sophisticated revolving *sphaera armillata*, representing the orbits of the seven planets with bronze rings [Schlachter 1927, 48–54]. A servant helped the Nonnian astrologer Astraeus to operate his precious globe.[101] Surpassing all these instruments was the *astrolabium*, which was unknown to the Western world until the 11th or 12th century.[102]

All of the astrologer's instruments bestowed upon the act of casting a horoscope a kind of theatrical revelation [Gury 1996, 255f.].

98 There is advice for using such an instrument in a Washington papyrus [Packman 1976, 1988]. The Tabula Bianchini and the marble plate from Daressy are the examples to which the tablets from Grand (in the east of France) may be added: Gury 1993, 126–132. A typology of the different boards and diagrams is given in Evans 2004, 4–12.

99 Vitruvius, *De arch*. 9.8.1 mentions 9 different types of concave hemispherical dials. There are some images in Gundel 1992, 57. On one special type of the *skaphe*, see Geus 2002, 231f.

100 The victorious Marcellus transported an example of each item made by Archimedes from Syracuse as booty to Rome. On the conserved fragments of *sphaerae solidae*, see Schlachter 1927, 42–46. The mostly fragmentary items of the solid sphere known until a little while ago were merely decorative objects, such as the famous Atlas Farnese. The only scientific example coming from the East (150–220 CE) appeared only 15 years ago; it is now kept in the Römisch-Germanisches Zentralmuseum in Mainz. Cf. Künzl 1997–1998, 2000. On another recently discovered exemplar from Turkey (Kugel collection), see Dekker 2013, 57–59, 112–115.

101 Nonnus, *Dion*. 6.64–57. The instrument is kept in a sort of box [6.87 κοιλάδι κίστῃ]. See Stegemann 1930, 94–100. It is not likely, however, that astrologers used globes constructed so as to permit consideration of the precession of the equinoxes (described by Hipparchus) [Schlachter 1927, 37f.] or any type of computing instrument such as the sophisticated Antikythera Mechanism [see ch. 9.2, p. 340]. Since we have no literary sources on the use of such instruments, they must have been known and used only by a few astronomical specialists.

102 The oldest description, which is no longer extant, was given by Theon of Alexandria. See Neugebauer 1949; 1975, 877–879. The oldest extant description is by Johannes Philoponus (*ca* 520–550 CE). See Kunitzsch 1996, 402.

6.5 *Special Methods of Casting Horoscopes*

Sometimes people compared several nativities, for example, when they wanted to marry.[103] In the Alexander-Novel, Alexander's mother Olympias asks Nectanebo to compare her nativity with that of her husband. But the keen astrologer compared it with that of his own in order to seduce her [Julius Valerius 1.4]. Septimius Severus, looking for a second wife, is said to have gathered the horoscopes of several maidens. We have already seen a case of horoscope comparing in the common consultation of Agrippa and Octavius at Apollonia [see p. 304].

Some astronomical papyri contain and compare two or more (up to five) horoscopes.[104] Astrological handbooks collect many nativities. In one special case, Vettius Valens compares the horoscopes of six individuals who escaped the same shipwreck.[105] The case of the shipwreck was one of the strongest arguments against astrology—complementary to the well-known twin argument—because it seemed impossible that individuals of different nativity could all die at the same moment.[106]

Another astonishing practice is mentioned in the same Alexander-Novel: when Olympias was about to give birth to Alexander, the royal astrologer and her lover Nectanebo stood beside her observing the stars, and twice he inhibited the birth because the most favorable moment had not yet arrived.[107]

6.6 *The Subject Matter of Prognostications*

The subject matter for which consultation was desired varied. One principal interrogation was for the length of life and the moment and the manner of death but weddings[108] and children (gender and number) were also important. The universality of astrology is reflected in the variety of actions described in

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103 Likewise, in Martianus' *De nuptiis* 2.101–104, the bride Philologia compares her own name with that of Mercury (Θωυϑ) by *isopsephia*.

104 See the list in Baccani 1992, 17 and 55 on the "quadernetto de Hermesion" and the astronomical papyri edited by Jones 1999a, II.376f., no. 4240 and II.390f., no. 4252.

105 Julius Valerius, 7.6.127–160, in Heilen 2015, 249–263; the horoscopes cover the years from 114 until 133 CE. However, veritable archives of horoscopes, as affirmed by Gury 1996, 252, are not documented.

106 After a collective baptism in the fourth century CE, the Christian neophytes asked the bishop Zeno Veronensis how so many individuals with various nativities could be reborn *in Christo* altogether at the same moment. The Christian bishop, adopting the role of an expert astrologer, responded by adapting the zodiac, sign by sign, to Christian lore [Zeno, *Tract.* 1.38]. See Hübner 1975; 1983b, 63f.

107 [Callisthenes], 1.12 and Julius Valerius 1.12: see Boll 1950, 351–356; Gundel in Boll and Bezold 1931, 153, 196f.; Cramer 1954, 10 (Bibl.); Frommhold 2004, 17 with n59.

108 See, e.g., Cumont 1916, 21n3: cf. the horoscope for Persephone [Nonnus, *Dion.* 6.48–104].

the didactic poems of Manilius [*Astr.* esp. cc. 4–5]; Dorotheus, *Carm.* c. 5 on catarchic horoscopy; some parts of the vast material preserved in book 3 of Hephaestio, *Apo.*; [Manetho]; and in the astrological handbooks, especially in chapter 4.4 of Ptolemy's *Apotelesmatica* and chapter 25 of the *Liber Hermetis*. The variety of zodiacal signs, planets, and extra-zodiacal constellations represents a variegated panorama of everyday life. In catarchic horoscopy (which sought the most favorable moment for the beginning of a certain action), the social interaction was determined by the four *cardines* of the daily rotation augmented with the 12 "houses" of the *dodecatropos* [Hübner 2003a: see ch. 12.1, p. 443]. So, for instance, the Ascendant signified the accuser; the Descendant, the defendant; the upper culmination (Upper Midheaven), the judge; and the (hidden) lower culmination (Lower Midheaven), the result, still unknown at the moment of consultation.

People also consulted astrologers for their home and its parts (especially the bed), the parts of the human body [see Hübner 2013], animals, ships (with very detailed specification) [Komorowska 2001; Pérez Jiménez 2007], pregnancy,[109] sacrifice and prayers, sports,[110] and games (in particular chariot racing), banquets [Pérez Jiménez 2000 and 2002], and, with regard to social interrelationships, for renting and lending, all kinds of treatises, testaments, lawsuits, learning, diseases, illnesses and healing [Hübner 2002a], how and where to find a thief [Cumont 1916, 21n1; see Kudlien 1988], and at which moment to emancipate a slave or—rather often—where to regain an escaped one.[111] They even asked about mortal punishment. Very often one posed questions about voyages [Hübner 2002b], especially by ship [Dagron and Rougé 1982; Krugener 1904, 66f.]. As for public affairs, the change of rulership, despotism, and warfare; the search for escaped soldiers; and the foundation, inauguration, siege, destruction, and rebuilding of cities are all attested. In sum, horoscopy encompassed all actions of everyday private life and all ranks of private and public society.

A special case of catarchic horoscopy was the investigation of the most favorable moment for casting a horoscope. This may be hidden in the hitherto unedited chapter of the Greek translation of Abū Maʿšar, *Myst.* 2.183 [*CCAG* 11.1.85 περὶ πάσης ἐρωτήσεως].

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109 Since the time of conception was very difficult to determine, it was calculated backward from the birth: Frommhold 2004, 70–172, "the rule of Petosiris".

110 Cf. Lucillius, *AnP* 11.161: a boxer; 11.163: three sportsmen.

111 *CCAG* 1.97–99 (Timaeus); 1.101 (Serapion). See Kudlien 1988, 1991, 81–91; Hübner 2003a, 191–209; Wolff 2011.

6.7 *Presentation*

The raw data of the preserved original horoscopes written on papyrus are rarely accompanied by interpretation.[112] Hence, one must conclude that the interpretation was given orally [Evans 2004, 3].

We know two horoscopes in heroic hexameter (in the oracular tradition): one is a *sphragis* in [Manetho]'s didactic poem of [see p. 494n22] and the other is uttered by a ghost (*imago*) who tells Julian the moment of the death of Constantius II in a dream.[113] But they are exceptions: most of the horoscopes found in papyri are lists with phrases in prose.

6.8 *Payment*

We know very little about the payment of astrologers. Generally, astrologers were suspected of being greedy for money [cf. Valerius Maximus, *Facta* 1.3.3]. It has been suggested that the cost varied according to the interpretation's minuteness of detail [Baccani 1992, 55] but this cannot be proved by explicit testimony. In Neronian times, the astrologer Pammenes received an annual private salary from a certain Publius Anteius [Tacitus, *Ann.* 16.14] but this seems to be an exception. The Apuleian astrologer Diophanes, described as an efficient businessman, lost his loan by funny trickery [Apuleius, *Meta.* 3.13.1]. Only Alexander Severus is said to have given public remuneration to the astrologers (and other scientists) but even this has been contested.[114]

7 Astrologers in Astrological Texts

Astrologers also cast horoscopes for themselves, like the unlucky Aulus and Nectanebo in the Alexander-Novel, who was compelled to do so by Alexander, and Thrasyllus, whom Tiberius compelled. Nectanebo was slain but Thrasyllus escaped harm. Under the reign of Domitian, the astrologer Ascletarius made a self-fulfilling prediction and actually died [Suetonius, *Dom.* 15.3: see Cramer 1954, 143f., 273–274]. We know that there were even prognostications that a native would be an astrologer [Cumont 1937, 124n5]. For this, Mercury was the most responsible candidate among the planets,[115] especially when in

112 See the examples given by Neugebauer and van Hoesen 1959, 16–75. Cf. Baccani 1992, 159; *POxy.* 36.2790.16f., in Jones 1999a, 1.247–295, 2.371–447.

113 Ammianus, *Res gest.* 21.2.2: Jupiter in Aquarius and Saturn in Virgo 25°. This fits the year 360/1 CE exactly [Neugebauer and van Hoesen 1964, 66f.; Jones 1999a, 1.346]. Gury 1996, 254 quotes Plutarch, *De Pythiae oraculis* 407c but does not mention astrologers.

114 *Hist. Aug.*: *Alex.* 44.4, which is contested by Straub 1970, 269.

115 Mercury had some traits of the Egyptian Thoth [Manilius, *Astr.* 1.30]. The astrologer Aes-

trine aspect to Jupiter.[116] So, the middle and temperate planets of both the internal and the external triad on both sides of the central Sun worked together.[117] The poet Dorotheus adds as a supplementary condition the ninth house named θεός.[118] As for the zodiacal signs, Mercury's day-house (Virgo) is responsible for general wisdom; its night-house (Gemini), for astrology in particular.[119] Moreover, besides the influence of Mercury, we find some single degrees of Libra and the man-shaped Sagittarius.[120]

Teucer of Babylon (in Egypt) detected the figure of the astrologer amid the heavenly constellations, interpreting the enigmatic Ἐγγόνασιν (Hercules), who appears in an inverted headforemost figure (κατακέφαλα) as *Uranoscopus*.[121] Ophiuchus (Serpentarius) in an upright position is pressing Scorpio down with his feet, while Hercules (oriented in the opposite direction) is stepping on the polar constellation Draco, thus forming a perfect symmetry, as, for instance, can be seen on the Kugel Globe [see Plate 1, p. 320]. This arrangement was taken to represent the fundamental, reciprocal interrelation between mortal mankind and the godlike constellations, an interrelation which the human mind invented although it already was antecedently dependent on it:

> *terraque composuit caelum*[122] *quae pendet ab illo.*
>
> And Earth fashioned the heavens on which it depends.
>
> MANILIUS, *Astr.* 2.38

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culapius asserted that he owed his *Myriogenesis* to this god [Firmicus, *Math.* 5.1.36: see Hübner 1984, 262–268; 2003b].

116 Dorotheus arabus [Pingree 1976a, 2.14.12 ≈ 2.14.13]: cf. the synoptic edition of the fragments in Stegemann 1943, 126f. Mercury and Venus: [Manetho], *Apo.* 4.210–211. Mercury with Venus and Saturn: [Manetho], *Apo.* 6[3].473; *Liber Hermetis* [Feraboli 1994, 34.29]. Mercury and the Moon in Virgo and Scorpio: Ptolemy, *Apo.* 4.4.10 [= Hephaestio, *Apo.* 2.1.19]: μάγους, ἀστρολόγους (together with Taurus, Capricorn, and Cancer: μάντεις). All the zodiacal signs mentioned are female ones.

117 On the symmetry of the two planetary triads, see Hübner 1988, 14; on the relationship between Jupiter and his youngest son, see Hübner 1988, 16 with n6.

118 Dorotheus in Vettius Valens, app. 1.140, hitherto falsely attributed to Anubio: see Schubert 2015, cxliv n241 [*CCAG* 2.172.9 = Stegemann 1930, F58a]:

ἄλλοι δ' αἰθερίων ἄστρων ἐπιίστορές εἰσιν.

The following text is written in prose: εἰκὸς δὲ τοῦτο γίνεσθαι, ὅταν ἐν τῷ θ' τόπῳ τὸ σχῆμα γένηται. On the ninth house, see Kroll 1923, 216f. On the 12 houses of the δωδεκάτροπος in general, see Bouché-Leclercq 1899, 280–284; Hübner 1995a.

119 Manilius, *Astr.* 4.159–160. See Hübner 1982, 544f.; Abry 2002.

120 Firmicus, *Math.* 8.25.10 (Libra 30° together with Boötes), 8.27.9 (Sagittarius 9°).

121 Teucer, 1.8.2 (Scorpio 5–7°); Hübner 1995b, 1.120f. with 1.64f. and similarly 1.9.7 (Sagittarius 2<4>–26°), with 2.75. For more detail, see Hübner 1990a, 2002c.

122 For the transmitted "caelum", which Housman unnecessarily conjectured should be "mundum", see Hübner 2002c, 68.

PLATE 1 The *Uranoscopus* on the Kugel Globe
DEKKER 2013, 57–69

In the latest stage of the Hellenistic Period, all Eastern religions that had penetrated Rome adopted more or less important astral elements [Cumont 1906] and "scientific" astrology was replaced by ever increasingly magical and theurgic practices in which professional astrologers were no longer involved. Finally, Christian rulers issued the total, empire-wide ban of astrology and all Eastern religious heresies.

Hellenistic Astronomy in Public Service

CHAPTER 9.1

The Sundial and the Calendar

Robert Hannah

1 Introduction

Chapter 2 [see p. 24] emphasized the centrality of the celestial sphere to an understanding of ancient methods of reckoning time. It showed how that sphere could be reduced to a physical representation in the form of a carved sphere decorated with the constellations, as with the Farnese Atlas, or abstracted to a simple skeletal framework of intersecting great circles in the form of an armillary sphere. This same perception of the cosmos as a sphere underlies the further representation of the celestial realm in the form of most ancient Greek sundials, whether they are of the spherical, conical, or planar variety. These serve a direct functional purpose, namely, to tell time through the day, the seasons, and the year. Before we investigate these sundials and how they were used to tell time, let us first consider the most basic form of time-telling machine used by people: the human body.

2 Shadow-Tables

A fragment of a play by the comic poet Euboulus illustrates the method well:

> There are among our guests invited to dinner two invincibles, Philocrates and Philocrates. For even though he is one, I count him as two, great ones…three, even! They say he was once invited to dinner by some friend, who told him to come whenever the shadow (στοιχεῖον) measures 20 feet, and from dawn he immediately measured as the Sun was rising and when the shadow was greater than by 2 feet he arrived. Then he said he had come a little earlier because of business, though he came at daybreak!
>
> ATHENAEUS, *Deip.* 1.8b–c

A character has been invited to dinner when his shadow was 20 feet long but he has arrived too early because he had been misled by a shadow of similar length cast by the Sun at dawn [Gibbs 1976, 94–95n15]. Assuming the play by Euboulus was produced at a spring festival, say at the end of March, a 20-foot shadow on

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a person notionally "six feet" tall (i.e., six of their own feet) would correspond to about 16°40′ for the Sun's altitude, which would occur at 4:47 pm, roughly an hour and a half before sunset. Philocrates mistakes the equivalent morning shadow, or rather one that is 2 feet longer still, for the one he should use. A 22-foot shadow corresponds to 7:13 am, an hour and 20 minutes after sunrise (exactly 20 feet computes to 7:21 am) [Bilfinger 1886, 16]. The joke arises from an unrealistic expectation of how early one should get to dinner but the exaggeration is magnified to the point of including almost the whole day. So Philocrates was ready to dine all day long—hence Euboulus' characterization of him as "invincible".

About 20 Greek shadow-tables survive, demonstrating the practical use of such a rudimentary mechanism for telling the time. Of these tables, only two are antique; the former dates to *ca* 200 BCE; the other, to Roman times. The rest are Byzantine and derive from the 12th to the 16th centuries. But these and other tables, which survive from the Late Antique and Medieval Periods, probably derive from the same Greek prototype [Neugebauer 1975, 736–746]. The tables fall into two main types: those that organize the seasonal shadow-lengths according to the zodiacal months[1] and those that group them by calendrical month. These two methods of organization of the data make the origin of the tables Hellenistic at the earliest because the zodiacal month is an invention after *ca* 300 BCE, and the calendrical months—Julian or Alexandrian—are later still.[2]

The table dating to *ca* 200 BCE provides an illustration of the type in general. It is extremely fragmentary but enough survives to deduce the form and the underlying arithmetical scheme. The reconstructed shadow-lengths, in feet, are shown in Table 1, p. 325.

As far as the form is concerned, the table provides shadow-lengths at the end of hours 1 to 11 in the day, once per zodiacal month of the year. The day is divided into 12 hours—the shadow at the end of hour 12 would stretch out to the horizon and so is not measured. These must be seasonal hours, which increase and decrease in size with the length of daytime through the year, being longer in

1 I.e., the interval in which the Sun traverses a zodiacal sign, each of which is 1⁄12 of the zodiacal circle.

2 Cf. Neugebauer 1975, 737–739, who regarded the zodiacally organized version as the earlier, followed by the calendrical (Alexandrian and Julian). At the end of the second century BCE, Miletus was using a *parapegma* (παράπηγμα) organized into zodiacal months [Miletus I 109/8 BCE, Berlin, Pergamonmuseum inv. no. SK1606: Lehoux 2007, 180–181, 478–480], which could later metamorphose fairly readily into the Julian calendar's "solar" months [Hannah 2005, 132–133].

TABLE 1 An early shadow-table

End of hour	**Zodiacal sign/month**						
	Cancer	**Leo Gemini**	**Virgo Taurus**	**Libra Aries**	**Scorpio Pisces**	**Sagittarius Aquarius**	**Capricorn**
1	22	23	24	25	26	27	28
2	12	13	14	15	16	17	18
3	8	9	10	11	12	13	14
4	5	6	7	8	9	10	11
5	3	4	5	6	7	8	9
Midday	2	3	4	5	6	7	8
7	3	4	5	6	7	8	9
8	5	6	7	8	9	10	11
9	8	9	10	11	12	13	14
10	12	13	14	15	16	17	18
11	22	23	24	25	26	27	28

summer and shorter in winter. In contrast, if the hours were equal (or equinoctial), there would be more than 12 from the spring equinox through to midsummer and less than 12 from the autumn equinox to midwinter.[3] Equinoctial hours were used in the Hellenistic Period as the measure for all hours throughout the year but not commonly. Astronomers used them; so the use of them on an early sundial from Oropos in the fourth century BCE is remarkable, since the cultural context is not a scientific one but a theatrical or cultic one. It may be that equinoctial hours were initially used to divide the day on sundials but gave way from the third century BCE to seasonal hours.[4] Stone sundials tended to replicate the apparent spherical form of the sky either directly in spherical sundials or through projection in conical and planar sundials, and these naturally gave seasonal hours. Some shadow-tables in the calendar-month mode also used equinoctial hours [Neugebauer 1975, 738].

According to the arithmetical scheme of the table, the lengths of the shadows change by the hour within each zodiacal month. In any given month, the

3 So in Athens, in midsummer, there are just over 14 equal hours in daytime; but in midwinter, just over 9.

4 See Schaldach 2016, 68–69, fig. 3–5a, 5b; 2006, 4, 23n27, 116–121, 196–198; Hannah 2009, 122–126.

shadows decrease in length from the end of the first hour to midday by 10, 4, 3, 2, 1 feet, and conversely they increase by 1, 2, 3, 4, 10 feet from midday to the end of the 11th hour. Midday shadows increase by 1 foot per month from midsummer in Cancer to midwinter in Capricorn and then decrease by the same amount as the year progresses again to midsummer. This is an artificial scheme which does not represent reality in any of the locations in the Eastern Mediterranean, from which the table might have stemmed.

The table prioritizes the hours of the day and then states what the length of the shadow is at those hours through the year. This might suggest that activities had come to be tied to particular hours of the day and the development of formal sundials will have helped in this regard. Comic playwrights indicate as much, if we may trust their jokes against the tyranny of sundials:

> The gods damn that man who first discovered the hours, and—yes—who first set up a sundial here, who's smashed the day into bits for poor me! You know, when I was a boy, my stomach was the only sundial, by far the best and truest compared to all of these. It used to warn me to eat, wherever—except when there was nothing. But now what there is, isn't eaten unless the sun says so. In fact town's so stuffed with sundials that most people crawl along, shriveled up with hunger.
>
> AULUS GELLIUS, *Noctes* 3.3.5, attributed to Plautus

But it is not clear from our literary evidence how shadow-lengths were originally used in a world before the concept of "hours". Indeed, it would seem to stand to reason that without a concept of an hour, the shadow ruled instead and that a particular length of shadow may have governed the timing of the same activity through the course of the year. Thus, a mealtime could take place at a fixed shadow-length through the year, which would translate to a different hour of the day in both seasonal hours and equinoctial hours. The shadow, therefore, would become a flexible "event-marker" through the day and the seasons. If we take a 20-foot shadow as a gauge of how this could have played out in ancient Athens, in midwinter it would mean 2:53 pm (in local sundial/solar time), while in midsummer it would signify 5:40 pm. The variation could match the changes in people's circadian rhythms that would be brought on by the very changes in the seasons in the temperate climates of the Mediterranean. The different summer and winter mealtimes posited here in fact lie proportionally at much the same distance from sunset at those times of year, both being almost at the 10th seasonal hour. So mealtime would have been literally a movable feast.

3 Meridian-Lines

At some stage, a type of instrument was developed that showed the passage of the Sun, *via* the shadow of a fixed gnomon, into each of the 12 zodiacal signs in the course of a year. By the fifth century BCE, a set of 12 constellations had been marked out along the path that the Sun appears to pass through in the course of a year: Κριός in Greek (Aries in Latin), Ταῦρος (Taurus), Δίδυμοι (Gemini), and so on [see Table 1, p. 12]. The system came from Babylonia [Koch-Westenholz 1995, 163–164; Bobrova and Militarev 1993]. For calendrical and astrological purposes, the full circuit of the zodiacal band was divided up into 12 equal divisions (*dodecatemoria*) of 30° each, which were named after their associated constellation. The distinction between actual zodiacal constellations of varying size and these artificial, normalized zodiacal regions centered about the zodiacal circle and 30° in width is not attested in extant Greek texts before the third century BCE [Bowen and Goldstein 1991, 233–254]. It is, therefore, probably only from about 300 BCE at the earliest that we could expect evidence of sundials organizing the year according to the zodiacal months.

It is possible that the first instruments to show the Sun moving through the zodiacal band were similar to a vertical meridian-line found on Chios and dating between *ca* 150 and 50 BCE.[5] This is just a small noontime line engraved into the planar face of a block of stone oriented to the south. The winter and summer solstices are marked by lines at top and bottom, respectively, as are the divisions between the 12 zodiacal signs along this line. The gnomon's shadow marked the passage of the midday Sun through these solar months. How useful is this one? The gnomon appears to have been 12.4 cm (4.8 in) in length. The change in shadow-length from midday 24 Mar (the time of the spring equinox and of the entry of the Sun into the zodiacal sign of Aries at the time of the instrument's construction) to midday 24 Apr (the time of its entry into Taurus) was 8.9 cm (3.5 in), a visually perceptible movement. However, at the latitude of Chios (38°22′N), the shadow measured by this gnomon changed too little to help in distinguishing one day from the next: between midday 23 Mar and midday 24 Mar, for example, the difference in shadow-length was a mere 2.3 mm (0.09 in). Even with a human-sized gnomon of, say, 1.50 m height, the change would be only 1.6 cm. At other times of the year outside the equinoxes, the movement of the shadow would be even smaller. The Chios meridian, then, is of use as a calendar over monthly, not diurnal, periods.

5 See Schaldach 2011; Hunt 1940–1945, 41–42. These are noted in Gibbs 1976, 7, 94n12 but not included in the catalog.

Given this imperceptible daily change, a meridian-line displaying the shift of the noontime shadow would be useful on a daily basis only if it were much taller than a human figure. A gigantic form of such a line would be much more useful and may be imagined from the remains of an inlaid bronze meridian-line in the Campus Martius in Rome. Its gnomon was an obelisk more than 30 m (98.5 feet) tall brought from Egypt by the emperor.[6] The obelisk bears at its base a dedicatory inscription which details the particular political offices held by the emperor Augustus at the time. This enables the monument in its Roman setting to be dated to 10/9 BCE.

Such is the scale of the meridian-line that each day of each zodiacal month is marked off along its length. It now seems likely that although the cannibalized obelisk obviously served a highly visible propagandistic purpose, namely, to commemorate the Roman takeover of Egypt in 30 BCE, its associated meridian-line was used to help correct the Julian calendar in 10/9 BCE. This calendar, under which we effectively still live, had been introduced by Julius Caesar in 46 BCE; but his assassination in the following year seems to have led to a mistake being made by the priestly officials in charge of the calendar with respect to the insertion of the new leap-day. Instead of adding the extra day every four years, they inserted it every three and this discrepancy led to the calendar falling out of synchrony with the Sun over the next 36 years. By then, 12 leap-days had been inserted instead of nine. This is not a large difference. But something must have triggered an awareness of it among the officials and astronomers, and it would have been possible to observe the error *via* an instrument as large as the meridian in the Campus Martius. Thereafter, Augustus delayed the next insertion of a leap-day for several years until calendar and Sun were back in synchrony from 8 CE.

4 Sundials

The passage of the Sun through the zodiacal months is also found on fully developed sundials in the Hellenistic Period. A spherical sundial found in Aï Khanum in Afghanistan and datable to the third century BCE or first half of the second century BCE before the city's sacking is inscribed with a network of lines indicating the daily hours and the boundaries between the zodiacal signs. Three of the latter serve also for the solstitial and equinoctial lines [Hiebert and Cambon 2008, 125; Veuve 1982, 23–36].

6 See Haselberger, Auber, Alföldy, Fillwalk, Frischer, Hannah, Heslin, La Rocca, Leonhardt, Pollini 2014; Frischer, Auber, Dearborn, Fillwalk, Kaja, and Floris 2017–2018.

The spherical type of sundial was the most labor intensive and difficult to construct, as it entailed carving out initially a hemisphere but usually a quarter sphere of stone. It was, however, theoretically the simplest to mark out because it captured the celestial dome inversely on a matching concave surface (although in practice carving regular curves on the interior surface would never have been easy). Its gnomon hung out over the hollow part sphere. The earliest surviving spherical dial is a fragmentary example from the Greek colony of Istros on the Black Sea coast in Romania, which has been dated to the third century BCE on epigraphical grounds [Gibbs 1976, 69, 158, no. 1044; Edwards 1984, 12].

It is generally assumed that Vitruvius [*De arch.* 9.8.1] is referring to this spherical type of sundial when he writes about the *scaphe* or *hemisphaerium*—the latter name particularly recommends the identification. He ascribes its invention to Aristarchus of Samos, an attribution which would place the invention in the early third century BCE, since Aristarchus (or his "school") is associated with a summer solstice-observation in 280 BCE [Ptolemy, *Alm.* 3.1].[7] The type probably existed long before Aristarchus' time, though it may have been "introduced" to Greece several times [Edwards 1984, 12–13].

Vitruvius [*De arch.* 9.8.1] lists 14 types of sundials along with their supposed inventors, the earliest being Eudoxus in the fourth century BCE. The spherical, cylindrical, conical, and planar types dominate surviving examples. There are other types known, including eventually small, portable ones, which were functional over much of the Roman Empire—a remarkable feat, considering that the dials were sensitive to latitude [Talbert 2016].

The conical type of sundial is a variation on the spherical. The two are the most popular types that survive. The conical dial is intimately related by geometry to the spherical type and represents a simplification in construction terms of the latter. The basic steps in the design of both types are demonstrated in the following analemma [see Figure 1, p. 330], the presentation of which is based on Vitruvius, *De arch.* 9.7.[8]

To explain:

(1) Draw a line on a planar surface. Mark on it a point A. Call this line the horizon.

(2) Draw out a circle centered on A with a radius of 9 units.

7 Cf. Toomer 1998, 137n19 on the relationship with Aristarchus.

8 Vitruvius' numbering system is confused in the surviving manuscript tradition; he does not use a notation for degrees or trigonometric functions. My presentation of the analemma seeks to simplify a complex situation and to express it in modern terms in the interests of emphasizing the interconnectedness of the designs of the spherical and conical sundial types.

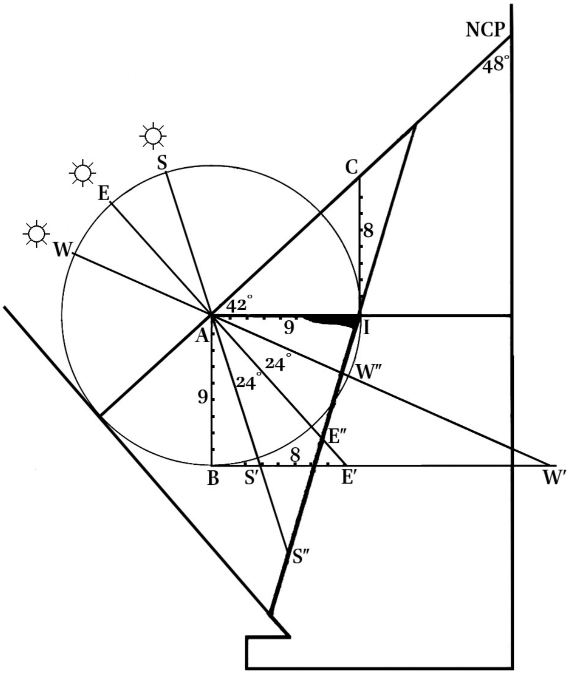

FIGURE 1 An analemma for the section of a spherical and a conical sundial for the latitude of Rome
DRAWING: R. HANNAH

(3) Mark out one radius along the horizon. Call the end point I.
(4) Drop another radius below and perpendicular to the horizon. Call the point where it intersects the circle B.
(5) Draw a line perpendicular to AB (and so parallel to AI). Mark out 8 units along this line. Call the end point E′.
(6) Draw a line from E′ to A and extend it outward to E.
(7) Similarly, draw a line up from I perpendicular to AI (and so parallel to AB). Mark out 8 units along this line. Call the end point C.
(8) Join AC and extend this line outward. This is the *axon* (ἄξων).
(9) Another approach, once E′AE has been drawn in step 6, is to extend a line perpendicular to E′AE from A, thus creating the *axon*, and then to draw a line from I perpendicular to AI to intersect the *axon* at C. It will be found that IC is 8 units long. The angles created, ∠BAE′ and ∠IAC, are also by definition the same, belonging to equal triangles.
(10) Vitruvius [*De arch* 9.7.1] says that at the time of the equinoxes in Rome, a gnomon of 9 units will cast a shadow of 8 units. This is the principle underlying the construction of △ABE′, in which AB would be the gnomon

of 9 units on the planar-sundial and BE′, the noontime shadow of 8 units. This principle may be based on empirical evidence but the theoretical and more general underpinning is easier to see from △AIC, which is equal to triangle ABE′. In △AIC, AI is the horizon. ∠IAC is generated by the sides of 8 and 9 units, and is 41.6° in size by measurement or by trigonometry (cot 8/9 = 41.6°). By geometry, a line that points at the celestial pole makes an angle with the horizon that is equal to the latitude of the place where the line is installed. The actual latitude of Rome is 41.9°. So AC must point in the direction of the North Celestial Pole and ∠IAC and ∠BAE′ represent (in practical terms) the latitude of Rome. By the same token, line E′AE, being perpendicular to AC, must represent the celestial equator, on which the equinoctial points sit.

(11) To either side of AE′ mark out an angle of 24° to represent the angular separation of the zodiacal circle at the solstices. Draw the lines of these angles to intersect BE′ at S′ and BE′-extended at W′. These represent the shadows cast at noon at the times of the summer (S′) and winter (W′) solstices.

(12) Arc BI represents the noontime line or meridian of a simple spherical sundial. It is also now crossed by the solstitial and equinoctial lines. The two arcs thus created on either side of the equinoctial point are equal.

(13) Line AC (the *axon*) may be treated as the axis of a cone. Its base will be constructed parallel to the equatorial/equinoctial line EAE′. In the diagram, I have arbitrarily set the base simply as a tangent to the circle and then given an angle of 60° to the side of the cone.[9]

(14) AW′ intersects the side of the cone at W″, and AE′ at E″, while AS′ is extended to intersect at S″. W″E″ is, therefore, shorter than E″S″.[10]

(15) The equinoctial arc that will run through point E″ on the dial is circular since it is formed by a section through a right cone that is parallel to the base and perpendicular to the axis. But the solstitial arcs will be elliptical since they are formed by sections that are angled more or less than perpendicular to the axis.

(16) It would be possible to construct the cone so that its side is perpendicular to the line AW′, thus making the winter solstice arc parabolic. But other than making the end product seem more elegant geometrically, I see no real advantage in this.

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9 This matches examples in Gibbs 1979 but there appears to be no mathematical underlying principle; perhaps it depended on external factors, such as the size of the block of stone or the desired sculptural form of the sundial.

10 This inequality is found in all but one example in Gibbs 1979.

The earliest surviving example of a conical sundial is from Heraclea ad Latmum in Turkey and dates probably to the second quarter of the third century BCE.[11] This might be very close to the period of the type's invention. The work by Apollonius (*ca* 200 BCE) on the theory of conic sections suggests that he may have had something to do with the exploration of sundials, given that one of the main types is conic and that from them he may have derived the theorems for conics.[12] The popularity of the conical type may occasion some surprise, given the apparent complexity of its theory and the greater difficulties in marking out the requisite interior lines, as these are now projected onto an awkwardly shaped curved surface—theoretically, for instance, the hour-lines should be double curved and sinuous. But it is likely that the conical dial was much easier to construct in stone because its generating line was straight, not curved as for a spherical dial, while its theoretical underpinning was kept to a minimum—and indeed obviously simplified or even not understood by many of the makers, to judge by their inaccuracies.[13]

The planar type of sundial, which occurs usually in horizontal or vertical forms, is the easiest to construct but technically the most difficult to mark out. The difficulty arises from the projection of the hemispherical dome of the sky onto a completely flat surface. A shadow, which tracks the movement of the Sun through the year, is cast by a gnomon, which is usually stuck perpendicularly into the flat surface of the sundial. The vertical plane-dials on the eight sides of the Tower of the Winds in Athens, built by Andronicus from Cyrrha in Macedonia, are now dated to the second century BCE [Plate 1, p. 333].[14] They

11 See Gibbs 1976, 62–63, 73, 268–269, no. 3049G; 1979, 44, fig. 3; Schaldach 2016, 68–71, fig. III.6. Edwards [1984, 10] discusses detail the evidence for the date, which derives from a dedicatory inscription on this dial to a King Ptolemy—he presumed that this was one of the Ptolemies between Ptolemy III Euergetes, who took control of several cities in Asia Minor in 246–241 BCE, and Ptolemy V Epiphanes, who lost them in 203–201 BCE: Gibbs 1976, 63 presents a different pair of Ptolemies, based on Rayet 1875, and Vitruvius' attribution of the invention of this type of dial to a certain Dionysodorus, perhaps of Kaunos in Caria in Turkey, who was a contemporary of Apollonius of Perga, who was active *ca* 200 BCE. Schaldach argues for Ptolemy II.

12 Cf. Neugebauer 1948, which proposes a link between the actual discovery of conic sections *ca* 350 BCE by Menaechmus, a pupil of Eudoxus, and a type of sundial that he has difficulty exemplifying from the archaeological record, with only London BM 2546 [= Gibbs 1976, 363–365, no. 5022G, pl. 59] presenting itself for comparison. Cf. Gibbs 1976, 62.

13 See Mills 2000, 64; Cam 2001, 160–162, fig. 12 for a template for making a conical sundial that is based on Rayet 1875; Gibbs 1976, 17, 74–75, 77.

14 On the Tower of the Winds in general, see Kienast 2014; Bonnin 2015, 286–294. For the surviving roofed spherical dial designed by Andronicus and now in Tenos [Archaeological Museum, no. A139], see Gibbs 1976, 71, 373–375, no. 7001G. On Andronicus, see Müller 2001.

PLATE 1 A planar sundial on the Tower of the Winds, south-east side
PHOTOGRAPH: R. HANNAH

are, therefore, among the earliest surviving examples of the vertical plane-type but their complexity and accuracy suggest an older ancestry.[15] Two equatorial planar sundials, from Olympia and Oropos, dated to the fourth century BCE, confirm this suspicion [Schaldach 2016, 63–69, figs. III–2, III–5A,B].

Even among miniature portable sundials, there is complexity. Some of these dials are simply very small versions in limestone of the spherical or conical types.[16] On one of the smallest and earliest of such miniatures, an ivory conical

15 For explanations of the mathematics of these sundials, see Schaldach 2006, 68–83; Gibbs 1976, 342–344, no. 5001; Delambre 1817, 487–503.

16 Two examples from Akradina, perhaps no more than 10 cm high, and one from Neapolis, only about 5 cm high, are on display in the Museo Archeologico “Paolo Orsi”, in Syracuse, Sicily.

dial only 2.8 cm in height dating probably to the first century BCE, the accuracy of the hour-lines is remarkable: it was made for a latitude of 33°, which corresponds reasonably well with the latitude of its provenance, Tanis in Egypt, at 31° [British Museum EA 68475; Evans and Marée 2008]. It was found in the private house of perhaps an official who worked at the nearby Temple of Amun. Fixed in place, the dial "may have kept the owner abreast of time in between his duties at the temple, averting tardiness whenever he had to return to them" [Evans and Marée 2008, 13]. It seems that not all portable dials were intended to be taken far.

Taxonomies of time-instruments remain necessary, as new finds add considerably to older lists. Gibbs 1976, 4 records 256 sundials; Schaldach 1998b, 40 lists over 340 sundials of different kinds; Bonnin 2015, 387–401 has 586 sundials; and now about 650 Greek and Roman sundials have been entered into a new database within the Edition – Topoi research platform. The sundials are classified into six types and more than 30 subcategories at http://repository.edition-topoi.org/collection/BSDP/. The increase is due to a mixture of newly excavated sundials and newly identified ones in museum collections.

5 Abstraction from Nature

The proliferation of sundials in a wide variety of geometrical forms from the late Classical Period onward is indicative of an increasing abstraction in the way time was measured and perceived. The distancing from bodily nature which we witnessed in the skits of Greek and Roman satirists—the body's needs no longer governed the timing of activities but sundials did—is matched in the very forms of the instruments which were used to mark the passage of time. It becomes harder and harder to see the natural in the end products, which become less representative of the natural world in their construction. Yet, as Cassiodorus indicated much later [*Epist.* 1.46.2], this distancing comes to be seen as a mark of civilization, something that distinguishes humans from animals.

There was an increasing tendency to look to the heavens for telling the time. While human needs may still have governed in practice when people performed some activities through the day such as eating or sleeping, these too are a function of the circadian rhythm, which is controlled by sunlight. The Sun itself can help to mark out the time of day. We can see this even into the Modern Period in Greece, where daybreak is known as the "etching", when the outlines of features are first seen against the light sky; the Sun "bursts" like buds in spring at its rising; it is "full" by mid-morning; the afternoon is "after the fullness", and the Sun "leans" toward the west, where it "finishes" ("shrivels", even) at dusk [du Boulay 2009, 39].

But whether from patterns on the ground based on the human shadow or from mirror-images of the celestial dome designed to recapture the apparent movement of the Sun across the sky, the development of Greek and Roman sundials followed a route which distanced their users further and further from the original means of measuring time.

The degree of abstraction which was quickly achieved by Greek dialers is well illustrated in the contrast between the two broadly contemporary sundials found at Aï Khanum, the Greek city founded at the extreme east of the Hellenistic world in Afghanistan. These were certainly in use in the mid-second century BCE, in the last phase of the city before its destruction, but they may have been manufactured earlier, in the third century [Hiebert and Cambon 2008, 125; Veuve 1982, 26–27, 36].

The spherical dial has already been mentioned because of its network of lines dividing the day into 12 hours and the year into 12 zodiacal months. The concave form of the dial still recalls the apparent domical form of the sky above, while the inscribed lines track the observable path of the Sun through the day and the year *via* the shadow of the gnomon. Nature is not very distant from the mind of the dialer here. With the cylindrical sundial from the same site [see Figure 2, p. 336], on the other hand, we encounter a form which is highly unusual in the literary and archaeological records, and which is clearly a considerable conceptual distance from the natural world. This sundial consists of a block of marble, taller than it is wide, out of the center of which a cylindrical hole has been carved. The inner surface of this hole has been graduated with two sets of straight lines, a set emanating from each of the broad faces of the slab and radiating toward the interior of the hole. The stone is of unequal length on its front and back faces and bevelled at its base so that it did not stand upright but was set at an angle. Measured from the vertical, that angle is 37°4′, which is practically the latitude of Aï Khanum (37°10′). With the slab's longer face set toward the north and its shorter to the south, the angular fix causes the stone to be parallel to the celestial equator. This means that the Sun would have shone into the southern aperture of the cylindrical hole from the autumn equinox, through the winter solstice, and on to the spring equinox, and then into the northern interior of the hole from the spring equinox, through the summer solstice, and on to the autumn equinox. Because the dial surface is set parallel to the celestial equator, the stone would have borne no shadow at all on the days of the two equinoxes themselves. The lines inscribed within the hole then told the time of day in hours but they signaled the season of the year only with regard to the solstices and equinoxes, which marked the inner and outer

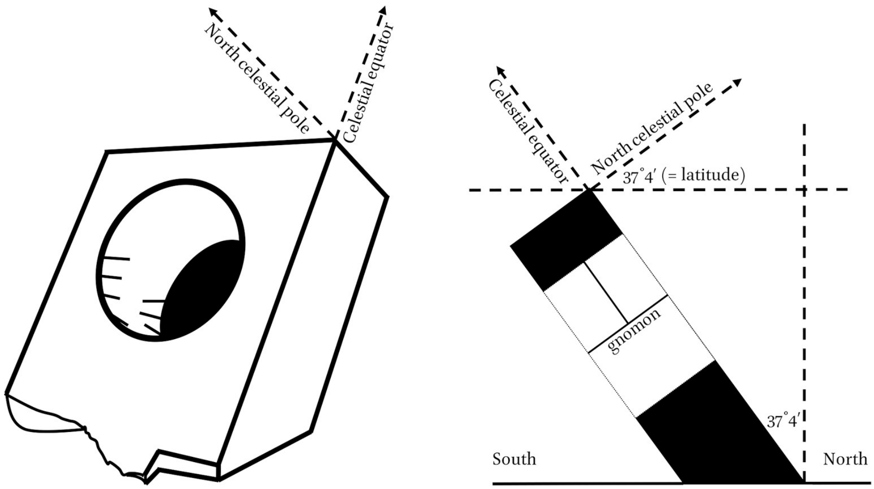

FIGURE 2 The cylindrical dial from Aï Khanum
DRAWN BY THE AUTHOR AFTER VEUVE 1982, 36, FIG. 7, 39, FIG. 1

extremities, respectively, of the interior lines. In that sense, it was a less precise calendar than its spherical cousin, even though it was a more complex form of dial.

Both of the sundials at Aï Khanum were discovered in the gymnasium. There they could have been used to assist in telling the time for various activities, not just what we would term "gymnastics" or physical exercise but including the teaching of astronomy, a core subject in ancient education, as gymnasia in Antiquity were much broader educational facilities than their modern equivalent [Veuve 1982, 23–25].

In these cases, the sundials still served primarily secular functions but, in other instances, we find dials closely associated with religious sanctuaries. A large sundial at Klaros in western Turkey was set up beside the Temple of Apollo by a public official, the ἀγοράνομος.[17] In Delphi inscriptions indicate that sundials were also set up on columns at that sanctuary of Apollo [Veuve 1982, 24 and n4]. What is happening here is an actualization, through the cultic furniture, of the identification of Apollo with Helios the Sun-God, an identification

17 Gibbs 1976, 270, no. 3015G; Akurgal 1993, 139; Martin 1965, pl. XV.4. This is one of the largest surviving conical dials, with a width of 1.10 m (misprinted in Gibbs as 110 mm) and a height of 78.85 cm, second only to the one that overlooks the Theater of Dionysus in Athens. It is no longer *in situ* and appears to have been moved offsite completely; its present whereabouts have proved impossible to discover. I am grateful to Professor Juliette de La Genière for information on this sundial and related finds from Klaros.

that developed from the late fifth century BCE onward.[18] Within that context, it was then deemed appropriate to provide a timekeeping instrument that is intimately connected with the Sun. Throughout the Greek and Roman worlds, the popularity of sundials extended to both public and private contexts: not only religious and civic centers afforded access to these ancient clocks but private individuals also had them at home. One of the earliest surviving of all Greek sundials comes from a private house in Delos and dates to the third century BCE [Gibbs 1976, 78, 324–325, no. 4001G, pl. 52]. The second-century Tower of the Winds in Athens, with each of its eight faces and an annex decorated with vertical sundials, survives still in its original, public situation near the later Roman Agora.[19] On architectural grounds, eight of the external sundials, one on each outside wall, are now accepted as an original element of the design, despite the absence of any mention of them by Varro [*De re rust.* 3.5.17] or Vitruvius [*De arch.* 1.6.4–7]—an omission that once led to the suspicion that they may have been added afterward.[20] Also surviving *in situ* is one of the largest conical dials, long known in the archaeological record since its publication by Stuart and Revett in the late 18th century, which is above the Theater of Dionysus on the south slope of the Acropolis in Athens [see Plate 1, p. 26].[21]

A lack of care or comprehension of the underlying theory of sundialing is well illustrated by a well-known conical sundial from Alexandria. This dial was found in 1852 at the foot of the obelisk now known as Cleopatra's Needle; both were transported to London [British Museum 1936.3–9.1: Gibbs 1976, 304–305, no. 3086G, pl. 48; Mills 2000, 9, 66]. The original placement of the gnomon on the sundial is clear, even though it has disappeared, because of the remains of its hole: it was set horizontally over the face of the dial and its original length can, in theory, be determined either graphically or mathematically from the seasonal day-curves on the dial-face.[22] Three curved, seasonal, lines are engraved on the face's surface, and both literary instructions and inscribed examples that have survived would suggest that these should represent the

18 The identification of Apollo with Helios is first attested in literature in Euripides, *Phaethon* fr. 781. 11–12 [Kannicht 2004, 817].

19 See Hannah 2008, 753–754; Schaldach 2006, 60–83; von Freeden 1983; Gibbs 1976, 342–345, no. 5001; Noble and de Solla Price 1968.

20 See Delambre 1817, 487–503 and now Kienast 2014.

21 Stuart and Revett 1762, 29, 33 pl. I; Schaldach 2006, 91–93, no. 2, 184; Gibbs 1976, 74, 227–228, no. 3008G, pl. 28. Other sundials from the Theater of Dionysus are Athens, National Museum 3157, 3158, and 3159 [Gibbs 1976, 224, no. 3005G, 220–221, no. 3001G, pl. 26; Locher 1989]. On the early history of the discovery of sundials beginning in the Italian Renaissance, see Turner 1993, 208.

22 For the graphical method, see Valev 2004; for the mathematical, see Gibbs 1976, 4–5, 77.

solstitial and equinoctial lines for the latitude of the site where this dial was intended to work [Gibbs 1976, 75]. But in reality, they do not match where we would place the solstitial and equinoctial lines for the latitude of Alexandria, which other measurements indicate is where the sundial was intended to operate.[23] As it is, if the sundial stood in Alexandria and the shadow cast by the gnomon struck the presumed equinoctial line at the time of the equinoxes, then at the time of the winter solstice the shadow would never have reached the upper (winter solstice) line and it would have overshot the dial completely beyond the lower (summer solstice) line at the time of the summer solstice. While the lower line just might signify a day in the year other than the summer solstice, such as a day just before or after that date,[24] any confidence that this may be so is undermined by the fact that the upper line can serve absolutely no calendrical role since the gnomon's shadow could not reach it at this latitude. In fact, one gets the impression that one or both "solstitial" lines were cut more as guidelines for carving the separate hour-lines, since the upper, "winter-solstice" curve is dotted with evenly spaced holes that mark the top ends of the hour-lines.[25] So it appears that the dial was intended for Alexandria; yet, of its engraved seasonal lines, only the equinoctial serves its purpose accurately [Hannah 2009, 127–133].

We may contrast this situation with that of the cylindrical sundial from Aï Khanum. Its hour-lines have been calculated as more suitable for a latitude of 23°N, rather than that of Aï Khanum's 37°N. Although the dial was accurate in Aï Khanum at noon every day and through the day at the equinoxes, it was up to an hour astray by the time of the solstices. The discrepancy in latitude would make the dial more suitable for places like Syene in Egypt or even Indian Ujjain, both of which lie at 23°N and had strong associations with astronomy in Antiquity. Given the ingenuity of the design of the sundial, an error due to ignorance in setting the hour-lines seems unlikely. Instead, it has been argued that the dial

23 As Gatty noted, "The inclination of the face of the block appears to correspond with the latitude of Alexandria" [1890, 388]. See Gibbs 1976, 77: cf. 33–35, 74–75:

> On a dial constructed with the aid of an analemma, the best measure of the latitude intended by the dial-maker is the angle between the top and front surface; the next best indication of the intended latitude is provided by the relative distances on the meridian-line; measurements taken on day-curves give the least reliable indication of the intended latitude.

24 See Valev 2004, 55n3 regarding the commemoration of an emperor's birthday on Roman sundials.

25 Mills [2000, 9, 65] found a "triad" of holes on the seasonal lines that he believed served as markers for the hour-lines. But such triplets of holes were not obvious to me when I studied the dial in 2005.

may have provided scientific demonstrations of the effects of varying latitudes on the reading of time [Veuve 1982, 23–25; Hiebert and Cambon 2008, 125–126].

The association of the sundial from Alexandria with an obelisk is suggestive: the former tells the time from the Sun, while the latter was a recognized symbol of the Sun [Pliny, *Nat. hist*. 36.64]. The curiosity is that, as far as we can tell, obelisks were not used by the Egyptians as parts of sundials themselves [Symons 1998, 30–31], however useful others found them for similar uses. We noted earlier how the emperor Augustus made outstanding use of one on the Campus Martius in Rome [Pliny, *Nat. hist*. 36.72], as the gnomon for a huge meridian-line at least.

CHAPTER 9.2

The Antikythera Mechanism

James C. Evans

1 Introduction

The Antikythera Mechanism is an astronomical model and computing machine that was retrieved from an ancient shipwreck in 1901. It is named for the island (between Crete and the southern end of the Peloponnesus) near which the wreck was discovered. The Mechanism survives in 5 large fragments and some 77 smaller ones at the National Archaeological Museum in Athens and is remarkable for its gears, 30 of which remain.[1] Ancient texts discuss the theory and use of gears but all the devices described are quite simple [e.g., Pappus, *Coll.* 8; Hero, *Mech.*]. No one would have guessed from these texts that a machine of such complexity could have been built in the ancient world. Nearly all the surviving parts of the Mechanism are devoted to modeling solar and lunar phenomena. But Greek inscriptions on the Mechanism mention the planets as well as planetary phenomena (stations and greatest elongations), so it is likely that the device originally included another 20 gears or so.

According to Cicero [*De re pub.* 1.21–22],[2] Archimedes built a model that replicated the motions of the Sun, Moon, and planets and even foretold eclipses. This wonderful prize was taken back to Rome by Marcellus after his capture of Syracuse in 212 BCE. Cicero tells this story in a philosophical dialogue set several generations before his own time and he never expressly says that he himself had seen Archimedes' machine. Some scholars therefore doubt the details reported by Cicero—perhaps Cicero has supplied details from the machine built by his teacher, Posidonius, around 70 BCE. In any case, σφαιροποιία (sphere-making)—the art of constructing models of the cosmos ranging from globes and armillary spheres to geared mechanisms such as the Antikythera Mechanism—was a recognized branch of the mechanical arts.[3] According to Pappus [Hultsch 1876–1878, 3.1027; Ver Eecke 1933,

1 For Fragments A and C, see Plates 1 and 2, pp. 341–342.

2 Unfortunately, the manuscript breaks off in the course of the discussion. Cicero mentions Posidonius' recently constructed machine in *De nat. deor.* 2.88.

3 For an introduction to sphere-making, see Evans 2014; Evans and Berggren 2006, 43–48, 51–53.

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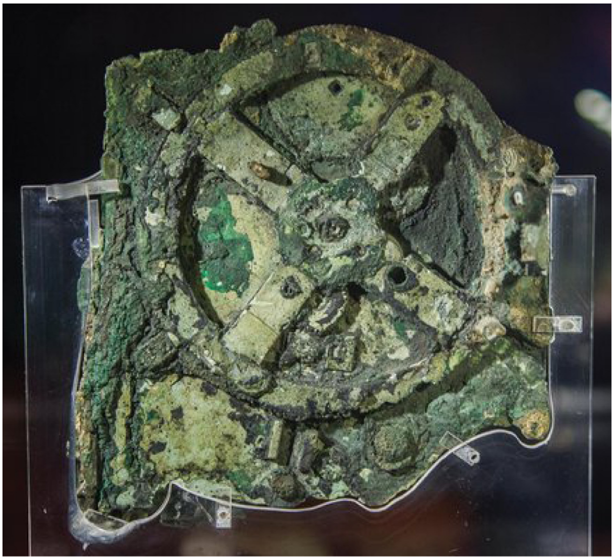

PLATE 1 Fragment A of the Antikythera Mechanism
This fragment contains 29 of the 30 surviving gears. It is dominated by the large, four-spoke wheel, whose rotation represented the solar year. [©Hellenic Ministry of Education and Religious Affairs, Culture and Sports/Archaeological Receipts Fund]
NATIONAL ARCHAEOLOGICAL MUSEUM, ATHENS

2.813–814], citing Carpus of Antioch, Archimedes wrote a book on this subject (now lost). In the second century CE, both Theon of Smyrna [*Exp.* 3.30] and Ptolemy [*Hypoth. plan.* 1.1: see Hamm 2011, 45] mentioned sphere-making. So, whatever one thinks of the details of Cicero's account, it seems that the art of sphere-making was practiced at least from the late third century BCE to the mid-second century CE. In Greek, an individual device such as the Antikythera Mechanism was also called a σφαιροποιία or sometimes simply a σφαῖρα (sphere).

The Antikythera Mechanism was about the size of a large shoe box. The enclosure was made of wood and the front and back faces, as well as the working parts, were of bronze. Two doors or covers could be closed to protect the Mechanism when it was not in use. The blank space on the interiors of the doors, as well as on the front and back faces of the Mechanism, was covered with inscriptions describing the features of the device.

PLATE 2 Fragment C showing a portion of the zodiacal circle The inner ring is engraved with names of the zodiacal signs and the outer ring with month-names from the Egyptian calendar. A portion of the *parapegma* has slipped out of place and become fused to the scales, thus obscuring portions of them. [©Hellenic Ministry of Education and Religious Affairs, Culture and Sports/Archaeological Receipts Fund]
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2 The Front Face

The front face [see Plate 3, p. 343] was dominated by a circular zodiacal scale surrounded by a ring representing the Egyptian calendar. This portion of the Mechanism is described in one of the inscriptions as the "cosmos" [Freeth and Jones 2012]. It constituted a working model of the universe. The user turned a knob to advance the gear-work. Markers indicating the positions of the Sun and Moon advanced around the zodiacal circle. A ball, half-silver and half-black, turned around once a month to show the changing phases of the Moon [Wright 2006]. Along the zodiacal circle occur key letters, Α, Β, Γ,.... When the Sun-marker reached Σ, one could look for the Σ in the accompanying *parapegma* [see ch. 2 §3, p. 29] to read "Σ Arcturus sets in the morning" [Antikythera Mechanism Research Project 2016].

PLATE 3 Modern reconstruction of the front of the Mechanism
Pointers carry gold and silver balls representing the Sun and Moon, respectively. The Sun pointer also indicates the day in the Egyptian calendar. The Moon ball rotates to show the changing phase of the Moon. All this is activated by turning the knob at right. Most scholars believe that there were also moving pointers representing the planets but these have not survived.
ARISTOTLE UNIVERSITY: ANTIKYTHERA MECHANISM, MODEL V.2. [PHOTO COURTESY OF JOHN H. SEIRADAKIS]

2.1 *The Display of Lunar Anomaly*

A surprising aspect of the Mechanism is its way of representing the lunar anomaly [see p. 129n1; ch. 4.4 §4, p. 117]. The Moon speeds up and slows down as it goes around the zodiacal circle. A modern astronomer would think in terms of motion on an ellipse according to Kepler's laws. But ancient Greek astronomers usually represented the Moon's varying motion using either

(1) a circle eccentric to the Earth or

(2) an epicycle plus a concentric circle.

Their Babylonian predecessors and neighbors represented the lunar anomaly not by a geometrical model but by arithmetic rules. According to Babylonians, the Moon's daily motion increases by equal increments from one day to the next until it reaches a maximum, after which it decreases by equal increments in a sort of linear zigzag pattern [see ch. 4.6 §3, p. 137]. In any of these theories, the zodiacal location in which the Moon has its greatest speed is not fixed but itself advances around the zodiacal circle with a period of about nine years. So, if in one particular trip around the zodiacal circle, the Moon moves fastest when it is in Aries, nine months later it will move fastest in Taurus.

In the Antikythera Mechanism, this feature of the Moon's motion is modeled by a four-gear assembly riding on a larger gear that goes around in nine years. And the four-gear assembly incorporates an ingenious pin-and-slot mechanism whereby uniform circular motion is turned into nonuniform circular motion about the same center. The key feature of this assembly is a pair of gears, one riding on the other but with its axis mounted slightly off-center; a small pin on the driving wheel fits into a slot in the driven wheel. A uniform input motion is thus turned into a nonuniform output motion.[4]

The ancients were aware of the equivalence of an eccentric circle to an epicycle plus a concentric circle. Extant proofs are given by both Ptolemy and Theon of Smyrna, and the demonstration possibly goes back to Apollonius of Perga.[5] A remarkable circumstance is the quasi-equivalence of the pin-and-slot device used by the maker of the Antikythera Mechanism to the geometrical constructions discussed by the theoretical astronomers. It is a *quasi-equivalence* because the pin-and-slot device gives the same motion in angle as does the epicycle but suppresses the motion in depth (i.e., the Moon's varying distance from the Earth). None of the extant astronomical texts breathes a word of the pin-and-slot device. It appears, then, that this mechanical solution to the problem of nonuniformity of motion was employed in a craft tradition that was largely ignored by astronomers, such as Theon and Ptolemy, who rooted their own work in an acceptable philosophy of nature. There is perhaps a reference to this by Ptolemy, in his *Planetary Hypotheses*, when he criticizes σφαιροποιία, as usually practiced, for displaying the phenomena rather than the underlying reality. If Ptolemy had peeked inside the Antikythera Mechanism, he probably would have disapproved: instead of proper epicycles and eccentrics, he would have seen unnatural pin-and-slot devices.

2.2 *The Display of Solar Anomaly*

The solar anomaly seems to be represented on the Mechanism by a much simpler scheme. On the extant portions of the graduated scales of the front face, 30° of the zodiacal circle consistently lines up with 29½ days of the calendar scale, which is a synodic month. Now, in the simplest form of the Babylonian

4 See Freeth, Bitsakis, Moussas, Seiradakis, Tselikas, Magkou, Zafeiropolou, Hadland, Bate, Ramsey, Allen, Crawley, Hockley, Malzbender, Gelb, Ambrisco, and Edmunds 2006.

5 But see Bowen 2013b, 244–247.

solar theory, the Sun has a fast zone in the zodiacal circle (in which it travels 30° per synodic month) and a slow zone (in which it travels 28⅛° per synodic month). It happens that the preserved portion of the zodiacal scale lies entirely in the Babylonian fast zone. Thus, it appears that the solar anomaly was handled simply by nonuniform division of the zodiacal scale [Evans, Carman, and Thorndike 2010]. In this case, a single pointer would indicate both the date and the position of the Sun. However, some scholars hypothesize that there were separate *mean Sun* and *true Sun* pointers, the former indicating the date on the calendar scale and the latter indicating the position of the Sun in the zodiacal circle [Wright 2002; Freeth and Jones 2012].

3 The Back Face

The back face [see Plate 4, p. 346] of the Antikythera Mechanism was dominated by two spiral dials [Wright 2005]. The upper spiral indicated the month in a Greek lunisolar calendar. The underlying principle is the Metonic Cycle: 235 months by the Moon equal 19 years by the Sun. The inscribed month-names best fit the Corinthian family of calendars—either Corinth itself or one of its colonies. These colonies include Syracuse and a number of cities in northwestern Greece. Syracuse is tantalizing but the calendar on the Mechanism is probably not that of Syracuse [Freeth, Jones, Steele, and Bitsakis 2008; Iversen 2017]. The lower spiral was an eclipse-predictor based on a Babylonian eclipse-cycle (today called the Saros) of 223 months [Freeth, Jones, Steele, and Bitsakis 2008].

4 The Date of the Antikythera Mechanism

There are several approaches to dating the Mechanism. Radiocarbon dating of the ship's timbers gives a date between 211 and 40 BCE, with 85% probability.[6] But this only tells us when the trees that were used to construct the ship were felled. Dating by the styles of the everyday pottery found onboard suggests a date in the second quarter of the first century BCE [Davidson Weinberg, Grace, Edwards, Robinson, Throckmorton, and Ralp 1965, 4]. When Jacques Cousteau's crew re-excavated the shipwreck in the 1970s, they found some coins that can be dated to a reasonably narrow range and provide a *terminus post quem* for the

6 Professor Andrew Wilson, Oxford University, personal communication.

PLATE 4 Modern reconstruction of the back of the Mechanism
The top spiral indicates the month in a Greek lunisolar calendar. The small supplementary dial inside and to the right indicates the place of the current year in the four-year cycle of Olympic games. The other small dial (conjectural) indicates the place of the currently running Metonic Cycle in the Callippic cycle consisting of four Metonic Cycles. The bottom spiral is an eclipse-predictor, showing the months for which eclipses are predicted and their times of day during one Saros-Cycle. The small supplementary dial inside shows the corrections to be applied (0, 8, or 16 hours) to the eclipse times according to the place of the currently running Saros inside an *exeligmos* consisting of three Saros-Cycles.
ARISTOTLE UNIVERSITY: ANTIKYTHERA MECHANISM, MODEL V.2 [PHOTO COURTESY OF JOHN H. SEIRADAKIS]

wreck. The coins and pottery are consistent with a wreck in the decades around 60 BCE. But this tells us nothing directly about the Mechanism itself. Some of the other cargo consisted of marble statues that had been made recently but some of the bronze statues were 200 years old at the time of the wreck [Kaltsas, Vlachogianni, and Polyxeni 2012]. Paleographical dating of the letter forms in the inscriptions on the Mechanism has been said to suggest a best fit around 125 BCE[7] but the uncertainty involved in this procedure may be about ±100 years.

The eclipse-predictor of the Mechanism provides the only possibility for a precise astronomical dating. The eclipses recorded on the Mechanism best fit an 18-year Saros-Cycle that began in 205 BCE and ran till 187 BCE. The next few Saros-Cycles would also be permissible, although the fit becomes progressively worse [Carman and Evans 2014: cf. Freeth 2014]. The epoch of 205 BCE appears to be confirmed by a study of the Metonic calendar and associated dials leading to a "start-up date" for the Metonic calendar scale also in 205 BCE [Iversen 2017]. A third piece of evidence points in this same direction. Next to the zodiacal scale is a small radial mark at about 18° or 19° of Libra. It has been argued, originally by Price [1974], that this was a calibration mark, showing where to set the first day of Thoth (of the Egyptian calendar ring) for the starting year of the Mechanism. Now, Thoth 1 would occur when the Sun was at the 18th or 19th degree of Libra also in the low 200s BCE [Evans and Carman 2014]. Thus, three different lines of evidence converge on an epoch of 205 BCE. (Because of damage to the calendar ring, not all scholars agree that the calibration mark is really a deliberately made mark.) Of course, it does not necessarily follow that the machine was built this early—the maker might, for example, have used an eclipse-table designed for an earlier period. Some scholars argue that the Mechanism was probably made within a few decades of 205 BCE, for the eclipse-predictor would have functioned poorly after that [Evans and Carman 2014; Freeth 2014]. Others argue for a construction date closer to the time of the shipwreck [Jones 2017, 157].

The patterns in the times of day for which the eclipses were predicted also permit one to say something about the underlying lunar and solar theories. Thus, the departures of the Moon and Sun from uniform motion were more likely governed by arithmetic rules (linear zigzag-functions) modeled on Babylonian theories than on Greek epicyclic theory. The method of eclipse-prediction on the Mechanism represents an ingenious Greek adaptation of Babylonian methods.

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7 See Freeth, Bitsakis, Moussas, Seiradakis, Tselikas, Magkou, Zafeiropolou, Hadland, Bate, Ramsey, Allen, Crawley, Hockley, Malzbender, Gelb, Ambrisco, and Edmunds 2006, 7 (Supplementary Information).

5 The Display of Planetary Motion

Although the Mechanism probably included displays of planetary motion, these have not been recovered. Scholars have suggested several ways in which planetary motions might have been represented. Intriguingly, it would be possible to model the planets' direct and retrograde motions using the same sort of pin-and-slot mechanisms that are known to have been used to represent the Moon's anomaly.[8] Whether it was actually done this way remains unknown.

6 Conclusion

The Antikythera Mechanism has an affinity with other displays of astronomical knowledge. Examples include the Tower of the Winds in Athens (roughly of the period of the Mechanism) as well as an *Astronomy of Eudoxus* (Ἀcτρολογία Εὐδόξου), which was written on whitened boards and presented to the Temple of Good Fortune on the island of Delos. The text itself does not survive, but its existence is known from a preserved inventory of the temple's goods that was inscribed on stone [Dürrbach and Roussel 1935, no. 1442B.41–42]. The Mechanism also has an affinity with the "wonder-working art"—the construction of devices intended to amaze or amuse driven by steam-pressure or other contrivances. Hero of Alexandria describes many such devices, including mechanical singing blackbirds. The Antikythera Mechanism, with its workings hidden from view, would certainly have seemed marvelous. Finally, we cannot discount a sense of awe or religious wonder as motive. Ptolemy dedicated his *Canobic Inscription* (which displayed the parameters of his planetary theories) to the Savior God (which in his time and place probably meant Sarapis) [Heiberg 1898–1907, 2.149].

The Antikythera Mechanism had no practical applications to navigation. Conceivably, it could have been useful to an astrologer; there are, however, no mentions of astrology in the extant inscriptions and, if the Mechanism is as early as the eclipse-predictor implies, it comes from the period before astrology had widely permeated the Greek world. One can imagine the Antikythera

8 Proofs that the pin-and-slot device can model retrograde motion for the outer planets were given in Carman, Thorndike, and Evans 2012 as well as in Freeth and Jones 2012. For the inner planets, see Evans and Carman 2014. For a short film showing retrograde motion produced by a metal pin-and-slot device, go to http://www2.ups.edu/faculty/jcevans/Pin%20and%20slot%20movie%20compressed.wmv.

Mechanism being used to illustrate a teacher's course in astronomy or as an offering placed in a temple or as the property of a wealthy patron.

The engineering of the Antikythera Mechanism is remarkable and radically changes our view of what was possible in the Hellenistic Period. By contrast, the astronomy is not hugely surprising for its period. If the dating by the eclipse-predictor should turn out to be valid, it would show Greeks predicting eclipses quantitatively somewhat earlier than was previously known. A number of the astronomical features of the Mechanism also help resolve some scholarly debates. For example, it has been doubted whether the ancient Greeks ever adopted the Metonic Cycle as the regulating principle of their civil calendars. The Mechanism shows us that, at least by the time of its construction, the Metonic Cycle was definitely being used in this way [see p. 33]. A second example involves the full (30-day) and hollow (29-day) months. In a Greek civil calendar, these roughly alternate (with a few more 30-day months). Geminus [*Intro. ast.* 8.53–56] claims that all months are temporarily assumed to be of 30 days and that the days to be removed to create the 29-day months are distributed as uniformly as possible across the entire 19-year cycle. Thus, the day to be removed is not always day 30 but could be day 5, or 22, and so on, of a month. Scholars had doubted whether such a complicated practice could really have been followed. But there it is, inscribed on the calendar spiral of the Antikythera Mechanism.

CHAPTER 9.3

Hellenistic Astronomy in Medicine

Dorian Gieseler Greenbaum

1 Introduction

Astronomy has several roles to play in ancient medicine. When I use the words "astronomy" and "astrology" I am not, of course, proposing anachronistically to separate disciplines: in Antiquity, they were subsets of the same subject, later called by Arabic writers "the science of the stars (*ʿilm al-nujūm*)" or "celestial science".[1] Astronomy, insofar as it measured and recorded celestial bodies and events, did so in large part in the service of what we would call astrology today, that is, a means for humans to understand how events in the heavens could connect with life on Earth. To clarify the roles that astronomy plays, however, it will be advantageous to divide ἀστρολογία/*astrologia* into astronomy and astrology in what follows, where astronomy is the division that serves to predict celestial phenomena and astrology the division that serves to prognosticate human lives and events in them on the basis of the former.[2]

Hellenistic physicians depended on both astronomical and astrological information. In Mesopotamia, celestial events were correlated with human events in the practice of medicine and even more generally. The same was true in the Greco-Roman world. Neither Babylonian nor Greek medical practice depended only on astronomy/astrology, but both were an important component of medicine in both civilizations. Although this chapter will focus primarily on astronomy and astrology in Greco-Roman medicine, the Babylonian material provides an important precursor and counterpart to the Greek material and, thus, will also be treated here.

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1 As in the title of Abū Maʿshar's work on this topic, the *Kitāb al-mudkhal al-kabīr ilā ʿilm aḥkām al-nujūm* (*Book of the Introduction to the Science of the Judgment of the Stars*). A new critical edition by Charles Burnett and Keiji Yamamoto has now been published [2019].

2 See ch. 0 §1, p. 1 and §§2–3, pp. 3– 5, Glossary, *s.v.* Astronomy, Hellenistic: names. Isidore of Seville (d. 636) was the first to codify a distinction between the terms "astronomia" and "astrologia": see *Etym.* 3.24, 27 [Barney, Lewis, Beach, and Berghof 2006, 99]. See Pines 1964; Hübner 1989. Ancient writers, though, could and did use the words interchangeably, with context determining meaning. This practice continued up to the time of Copernicus [French 1994, 33–34].

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The natural cycle of the seasons due to the Sun's apparent annual motion and the natural phenomena due to its apparent daily motion (such as day/night) and the Moon's motion (such as the month) all influenced earthly life. The courses of the planets, as well as celestial phenomena such as eclipses and meteorological phenomena such as the formation of clouds, rain, and comets (understood as sublunary phenomena) were influential as well. In medicine, Greek physicians employed the doctrine of humors (χυμοί: blood, phlegm, bile, black bile), which could also be correlated with seasonal cycles and the planets, as well as the elements (cτοιχεῖα: earth, air, fire, water) and qualities (ποιότητεc: hot, cold, wet, dry) discussed, e.g., by Empedocles and Aristotle. When a healer considered natural celestial phenomena in the cause and treatment of disease, he[3] made interpretations and conclusions from the natural conditions that doctors perceived as influencing the courses of disease and the maintenance of health.[4]

Within this practice, we also find the application of astrological doctrines and principles, which tended to be applied in an individual way to a particular patient. These could include the casting of horoscopes to interpret the cause, progress, and resolution of disease—a practice called decumbiture (κατάκλιcιc, *decubitus*) [see ch. 12.1 §5.3, p. 449]—and the use of astrological techniques in prescribing a therapeutic regimen. The use of astrology in Hellenistic Greco-Roman medical practice is mentioned by Pliny the Elder in his *Historia naturalis* but it likely developed earlier.

In a chapter such as this, it is impossible to ignore the towering figures of Hippocrates, the inspiration of the collection or corpus of works attributed to him, and Galen. Yet, it is also important to take account of what has not had so much attention, at least in modern scholarship: ἰατρομαθηματική or medical astrology, how it works with astronomy, and how it was used in actual practice in the Greco-Roman Period up through Late Antiquity. Thus, I shall present the main components of Greek medicine and its connections with the heavens; but I shall also bring in the practices of the medical astrologers (ἰατρομαθηματικοί) i.e., those who use astrology in the practice of medicine. This will include coverage of practices used in diagnosis and treatment such as decumbiture and *melothesia*, practices which show the intersection of astrology and medicine in their focus on critical days, conception and birth, as well as the relationship between plants, stones, animals, deities, and the heavens. The approach will

3 Very few women practiced medicine at this time, although they were lay practitioners: see Nutton 2013, 101–102.

4 This may also be called natural astrology. In this period, it would not have been distinguished from *astronomia*.

be generally thematic rather than chronological, although I shall begin with a short survey of Babylonian astral medicine and then proceed to the connections of Greek medical practices with the heavens.

2 Astronomy and Astrology in Mesopotamian Medical Practice

Recent scholarship on medicine has delved into the question of cultural transmission or exchange between the Mesopotamian and Greco-Roman cultures, showing practices in each that have some remarkable similarities and also some differences.[5] It complements work on the Mesopotamian roots of Hellenistic astrological methods [e.g., Rochberg-Halton 1984 and 1988b; Reiner 1993; Jones and Steele 2011]. The following brief discussion of astral medicine in Mesopotamia will place in context the kinds of astral medical knowledge important to that culture. When we move to the Greco-Roman world, it will be easier to see the continuities in medical traditions that allow us to understand how developments in medicine do not arise in a vacuum but relate to, and build on, earlier practices, especially those involving medicine's intersections with astronomy and astrology.

2.1 *Beginnings of Astral Medicine*

The practice of medicine in Mesopotamia is attested from the late third millennium BCE onward, although the greatest documentation appears in the first millennium BCE [Scurlock 2005, 302].[6] The observation of the heavens and the interpretation of celestial events as omens for human life are important features in Mesopotamia from the third millennium BCE as well. The combination of the two in applying celestial phenomena understood as omens to medicine is attested as early as the Old-Babylonian Period (2000–1600 BCE) [Reiner 1995, 49; Heeßel 2008, 2].

2.2 *Practitioners*

Practitioners of Babylonian medicine, like other medical practitioners, dealt not only with diagnosis and therapy but also with prognosis. Since this could be achieved through astronomical means, it will be useful to briefly describe their functions.

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5 See, e.g., Stol 2004; Thomas 2004; van der Eijk 2004; Scurlock 2004; Geller 2004 and 2014b, 15–25, 69–71; Asper 2015.

6 General surveys of Babylonian medicine include Scurlock 2005 and Geller 2010a.

There were three main practitioners: the *āšipu*, the *asû*, and the *bārû*.[7] Though there is some debate about exactly what the first two of these did,[8] we can say that the *āšipu*, who was a priest, is sometimes likened to a physician [Scurlock 2004, 16] but other times to a kind of exorcist [Scurlock 1999; Geller 2010a, 43–44] or "conjuror" [Stol 1991–1992, 42; Finkel 2000, 146; Rochberg 2016, 64, 67], that is, someone who treats disease by "medico-magical means" [Finkel 2000, 146; Geller 2009, 4], with an emphasis on incantation and ritual. However, as illustrated in medical texts, his job was to find a cause, diagnose, and provide prognosis in treating illness [Stol 1991–1992, esp. 61–63; Rochberg 2004b, 93–95 and 2016, 68], by whatever methods that have been seen to work empirically. These could be either physical remedies or incantations and rituals. Thus, to all appearances, he fulfills the functions of a typical (modern) physician [Scurlock 1999, 76–77].

The *asû*, on the other hand, is likened to a pharmacist, apothecary, or medicine dispenser, that is, to someone dealing in physical remedies [Scurlock 1999, 78; Geller 2010a, 43], although he or she [Worthington 2009, 49n.11] is also described as a physician.[9] His primary role was taken on after diagnosis, when treatment was the next step in the process of healing [Scurlock 1999, 77–79 and 2005, 305–306]. As Scurlock 1999, 78–79 affirms, his function is like the old-fashioned pharmacist, who effectively treated disease with tested remedies once it had been identified. Thus, in cases of chronic illness with periodic episodes, one might imagine that the patient could go straight to the *asû* for the usual remedy. However, the point to take away here is that both the *āšipu* and the *asû* cooperated in the practice of medicine.

The third player on the medical team, the *bārû*, was a diviner [Stol 1991–1992, 56–57; Geller 2010a, 50–51]. His job was prognostication; thus, he provided a timeline for recovery (or not) [Scurlock 1999, 77]. All three medical practitioners would, of course, use every means available for curing disease in their work, including those of an astronomical or astrological nature.

2.3 *Disease and Healing from the Stars*

Evidence dating to the first half of the second millennium BCE shows that some diseases were thought to have come from the sky [Reiner 1995, 59; Wasserman 2007, 44–46; Heeßel 2008, 2–3]. Diseases caused by the stars could also be cured by the stars: setting medications at night "under the stars (*ina kakkabī*

7 See Scurlock 1999 and 2005, 303–306, 310–311; Finkel 2000, 146–148.

8 See Scurlock 1999; Geller 2009, 2–4; Böck 2009, 109–110; Geller 2010a, 45–52.

9 See Stol 1991–1992, 42, 59–61; Scurlock 1999, 69; Finkel 2000, 146; Geller 2010a, 43, 52; Rochberg 2016, 64.

tušbāt)" is a well-attested therapeutic practice.[10] Many examples show the popularity of this practice.[11] Medications placed under the stars at night, which, as Scurlock mentions [2014, 502], has the effect of a cold steep in darkness, demonstrate the faith in astral efficacy.[12] As Heeßel points out [2008, 2], the gods have a cosmic connection with the celestial bodies and stars, thus showing their ultimate responsibility for such diseases—and thereby the means to heal them astrally. A star often mentioned in such texts is the Goat-Star (the constellation Lyra), which is associated with the Babylonian goddess of healing, Gula.[13]

In addition, a star may be importuned to alleviate an illness and to judge the medical case lawfully:

> Oh star, august divinity, the evil which exists…like kiln slag, [bring it] to an end.
>
> *BAM* 480.3.42–44

> You, star that brightens…within the heavens, surveyor of the regions, I am so-and-so, son of so-and-so. On this night, I kneel before you. Judge my case, apply the law to my situation. May these plants undo my evil.
>
> e.g., *BAM* 480.3.52–54[14]

This example, with its uncommon implication that a star is also a judge, shows that the god (in this case, perhaps the star *as* god) can be appealed to in order to right a situation and to prevent (further) damage.[15]

2.4 *Hemerologies*

Although not strictly astronomical/astrological, texts called hemerologies noted certain days as favorable or unfavorable for performing certain actions,

10 See Reiner 1995, 48–59; Heeßel 2008, 3–5; Wee 2014, 23–24. Heeßel translates the entire phrase as "you let (the preparation) spend the night under the stars" (first attested in *BAM* no. 393). Reiner also translates "under the stars" but explains that the preposition is literally "in". Wee is more literal and has "in the stars".

11 E.g., DPS Tablet 31, 35′–39′, 46″–49″; *BAM* 480.2.4–9, 59.21–28, 575.3.51–54: cf. Scurlock 2014, 229, 321–322, 636–637.

12 This does not necessarily assume or imply a physical influence: see Rochberg 2010b, 16. But see Wee 2014.

13 See Heeßel 2008, 4; Böck 2014, 181. Examples in Scurlock 2014, 229, 499, 520, 543.

14 Both texts are in Scurlock 2014, 326–327. See also Reiner 1995, 58; Heeßel 2008, 3.

15 On the concept of law and judgment in Mesopotamian divination and omens, see Lehoux 2006, 110–111.

including medical rituals or treatments,[16] or warned of days for possible illness [Stol 2009, 37]. These hemerologies, as Geller points out [2014b, 41–42, 47], were precursors of similar texts arising in the Persian Period, in which the days have either been replaced by zodiacal signs or those signs have been added to correspond with the days. The innovation of correlating the zodiac and days of the month in texts such as *BRM* 4.19 and 4.20 is an important development for medical practice and astronomy/astrology generally.[17]

It should be noted that Egyptian hemerological concerns also stand as precursors to Hellenistic astrological doctrines.[18] Herodotus remarks that the Egyptians could tell by someone's birthday what his or her fortune, longevity, and character would be [*Hist.* 2.82.1].

The interesting word «adannu (UD.DA.KAM)» is used in relation to hemerologies and favorable days for rituals.[19] It has been variously translated as "critical time or fixed time" [Geller 2014b, 22], "usual time" [Geller 2014b, 47], "appointed time" [Rochberg 2010b, 115], "appointed, fateful time", and "favorable time" [Bodi 2013, 47]. This idea of a "right" time for a ritual is fascinatingly similar to the Greek notion of καιρός (right time, season, opportunity) [Bodi 2013, esp. 52–56], which is in turn linked both to Greek medicine [see §3.4, p. 362] and to catarchic astrology.[20] The use of «adannu» in medical texts, as Stol points out, could be an early use of this word in a medical astrological context [1991–1992, 58]. The word could also be related to the concept of critical days or days of crisis in illness that compel decision. Geller mentions the 3-day crisis period occurring in some Babylonian texts [2014a, 22]. When looking for a remedy against sorcery, Stol says, the fifth month and specifically days 1, 7, 14, 21, and 29 are preferred [1991–1992, 58]. The third day, and multiples of 7, plus what is essentially the last day of the lunar month, indicate important days of the lunar phases.[21]

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16 See Reiner 1995, 59, 96; Livingstone 1998, 63–64; Brown 2006, 83–85; generally Livingstone 2013; Geller 2014b, 57, 68, 83–84.

17 See Koch-Westenholz 1995, 163–164; Heeßel 2005, 20; Heeßel 2008, 3, 5; Geller 2014b, 41, 57.

18 E.g., OḤor 3 (second century BCE) portends fortunate events for the birthday and anniversary of the king [Ray 1976, 21, 23, 25–26; Greenbaum 2016, 53].

19 See Stol 1991–1992, 58 and nn100–101; Rochberg 2010b, 115; Bodi 2013; Geller 2014b, 22, 47, 89.

20 See Greenbaum 2016, 40–42, 247–248; 2020. See chs 12.1 §5.3, p. 449; 12.4, p. 509. One of the meanings of the verb «κατάρχω» is "begin the sacrificial ceremonies" or "begin the rite" [LSJ *s.v.*].

21 For the use of critical days in astrological texts and medical astrology, see Heilen 2012b. For the last days of the month as unfortunate in Egyptian culture, see Greenbaum 2016, 121.

2.5 *Menologies*

Menologies, which are based on lunar observations, were also used in Babylonian medical practice [Langdon 1935; Labat 1939; Reiner 1995, 112]. When the zodiacal band was introduced, it was tied to the lunar months of the Babylonian calendar. Three important texts document earlier usage of the month and day [*STT* 300] and later usage [*BRM* 19–20] in regard to the zodiacal band.[22] These texts contain some directions for apotropaic rituals dealing with medical matters. Both *STT* 300 and *BRM* 4.19, in particular, use the word «UD.DA.KAM/adannu» or the "appropriate day" for reciting a spell and, in the case of *BRM* 4.19, concern a particular zodiacal sign and a particular day, the idea being that certain days/zodiacal signs are propitious or unpropitious for such rituals. This text has been compared with lunaria of Late Antiquity and the Middle Ages [Reiner 1993, 21; 1995, 112]. There are also Babylonian medical astrological texts that specifically correlate the Moon's being in certain zodiacal signs with illness, e.g., Pinches and Strassmaier 1955, 1597,[23] and 1598 [Geller 2014b, 73–75, 80–82].

2.6 *Babylonian* melothesia

Melothesia, the assignment of body-parts to celestial counterparts, has been documented in two forms: planetary and zodiacal. Erica Reiner [1993, 21–22; 1995, 59–60] has demonstrated that 11NT4 [Civil 1974, 336–338], a Neo-Babylonian source, connects the spleen to Jupiter and the kidneys to Mars. John Wee [2015; 2016, 215–222], following on research by Reiner [1993, n26; 1995, 59], Heeßel [2000, 112–130, 468–469; 2008, 11–14], and Geller [2010b, esp. 74–80, 85–86; 2014b], has shown that a very late cuneiform tablet, which is "Hellenistic…or even Parthian" [BM 56605 rev.: Heeßel 2008, 11] did contain a zodiacal *melothesia* with the typical assignments to body-parts from head (Aries) to feet (Pisces). For more on this, see §4.3 and Table 1, p. 369.

2.7 *Plants, Stones, and Trees*

Related to *melothesia* in that it correlates zodiacal signs with earthly materials is the doctrine of plants, stones, and trees. These items are linked to months, zodiacal signs, and propitious days for therapy. It arose in the fifth century BCE [Heeßel 2005; 2008, 9–11; Rochberg 2016, 85–88]. For more on this, see §4.6.

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22 See *BRM* 4.19, 20: Reiner 1995, 108–112. For texts, translations, and commentary, see Scurlock 2005–2006; Geller 2010b, 25–54 and 2014b, 28–46, 47–57.

23 Reference to the Moon is assumed here on the basis of similar texts: see Geller 2014b, 80 and n5.

2.8 *The Zodiacal Band and Medicine*

More than one scholar of Babylonian medicine has remarked that the development of astral medicine in Babylonia takes a different turn in the Persian Period.[24] This "seismic change" [Geller 2010a, 163] is connected with the introduction of the zodiacal band and such doctrines as that of plants, stones, and trees, which, as Heeßel says, can be described as "an "astrologisation" of late Babylonian medicine" [2008, 16]. The correlation of the zodiacal signs with months and days and of the movements of the planets with sequences of positions on the zodiacal circle allows a development in Babylonian medicine that could not have been possible in the earlier periods.

In Greco-Roman culture too, and largely due to Babylonian influence, there was a similar turn in medical practice from the strictly astronomical indications of disease and methods of healing, to the potential for and realization of astrological interpretation and therapy as an aid in healing. In short, the two aspects of this celestial knowledge, astronomy and astrology, likewise influenced the developing practice of medicine in the Greco-Roman world.

3 Astronomy and Astrology in Greco-Roman Medical Practice

3.1 *Elements, Qualities, and Humors*

These three concepts play a significant role in Greek medical practice. Developed by Presocratics such as Empedocles as well as Aristotle [*De gen. et corr.* 2.3] and the Stoics [Galen, *De nat. fac.* 2.4.92, 1.3.8; Sambursky 1959, 3], they take on both philosophical and medical importance. The three are connected: each element was associated with one or two qualities and with a humor. For example, fire can be hot (Stoic) or hot and dry (Aristotelian) and links to the choleric humor (bile). Air can be cold (Stoic) or hot and wet (Aristotelian), linked to the sanguine humor (blood). Earth can be dry (Stoic) or cold and dry (Aristotelian), linked to the melancholic humor (black bile). Finally, water can be wet (Stoic) or cold and wet (Aristotelian), linked to the phlegmatic humor (phlegm). While the medical value of these concepts seems clear, their relevance to the use of astronomy/astrology in Greek medicine may not be as obvious. However, all three—elements, qualities, and humors—also became incorporated into Greco-Roman astrology and were linked to planets and zodiacal signs. Their connections to the day, month, and season were dependent

24 See, e.g., Koch-Westenholz 1995, 163–164; Heeßel 2008, 3; Geller 2010a, 163 and 2014b, 47, 68.

on the cycles of Sun and Moon. In the following sections, the context of their involvement in the doctrines of medicine and astrological medicine will be examined.

3.2 *Microcosm and Macrocosm*

Greek philosophy from very early times embraced the idea that human beings are a “microcosmos” that reflects the “macrocosmos” in their makeup [Diels and Kranz 1951, 68B34]. This idea is very important in the development of both astronomy/astrology and medicine. If humans are made of the same stuff as the cosmos and ordered like the cosmos—«κοςμός» can also mean “order”—this puts them in relation to things of the macrocosm. In effect, there is a correlation of such cosmic things as stars and planets with parts in the human being. Thus, humans both reflect the macrocosm and are affected by it. This means, for example, that a disease associated with the planet Mars, which is associated with fire or the hot and dry, can be cured by an antidote to what is Mars-like, namely, the cool and wet.[25] This doctrine had enormous implications for medical practice.

3.3 *Hippocrates: Humors, Astronomy, and Critical Days*

> ὁ βίος βραχύς, ἡ δὲ τέχνη μακρή, ὁ δὲ καιρὸς ὀξύς, ἡ δὲ πεῖρα σφαλερή, ἡ δὲ κρίσις χαλεπή.
>
> *Aph.* 1: LITTRÉ 1839–1861, 4.458

> Life is short, but the craft is great, the opportune moment fleeting, experimentation perilous, discernment difficult.[26]

This famous quotation (mostly in its truncated Latin version “ars longa, vita brevis”), the first line in the *Aphorisms*, sums up the Hippocratic conception of the healer’s practice. Notable are the designation of medicine as a craft or art (τέχνη) and that it involves both experience/experimentation (πεῖρα) and judgment (κρίσις) from «κρινέω» meaning “I discern or judge”.[27] The notion of the *right* time (καιρός) is also critical. Each of these tenets is further elaborated in the Hippocratic corpus and, in terms of astronomy, “seasonal time” (another meaning for «καιρός») is important in medical practice.

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25 Following the dictum in the Hippocratic *Aph.* 2.22 that “in general contraries are cured by contraries” (…καὶ τῶν ἄλλων ἡ ὑπεναντίωσις) [Jones 1931, 113].

26 Unless otherwise noted, translations from Greek and Latin are the author’s.

27 Each of these terms is readily applicable to the practice of astrology.

Hippocrates of Cos (b. *ca* 460 BCE) or, more accurately, the Hippocratics (that is, Hippocrates and his followers),[28] took the ideas of various Presocratic writers about the elements (fire, air, earth, water) and qualities (hot, cold, wet, dry), especially those of Empedocles, and applied them to the human body.[29] The Hippocratic model extends Empedocles' roots (i.e., fire, earth, air, and water) to the human body in the form of humors or fluids (χυμοί) in the body, particularly, yellow bile, black bile, blood, and phlegm (χολή, μέλαινα χολή, αἷμα, φλέγμα). This scheme is first articulated in the treatise *De nat. hom.*[30]

> The human body has within itself blood, phlegm, yellow and black bile, and these are the nature of this body, and through these it suffers illness or is of sound health. A human being is most healthy when it has these evenly proportionate to one another by mixture, power, and quantity; and they are the most well mixed up.
>
> *De nat. hom.* 4.1–5: LITTRÉ 1839–1861, 6.38–40

Thus, a balance of humors is essential for the best health, indicating the theoretical importance of the even mixing of qualities. But no one is naturally balanced and we are living in a world where we are also affected by other things made up of elements and qualities in that physical world. In addition, each humor becomes associated with a season during which it is predominant and so the various humors ebb and flow during the year. This early use of humoral theory in connection with disease and health, the idea of a bal-

28 There is substantial debate about the ascription of the treatises in the corpus to Hippocrates.

29 The author of *De prisc. med.* mentions Empedocles by name at c. 20.1 in the course of refuting those who were inspired by Empedocles' view of nature (φύϲιϲ): see Schiefsky 2005, 30–31, 55, 100–101. Schiefsky [2005, 302] notes that attributions to ancient authors are rare in the Hippocratic corpus. But, as Kingsley 1995, 229–230 points out, the mention of Empedocles in this passage shows that, for the Hippocratics, Empedocles' "knowledge of cosmology and nature was meant to have a practical application, especially in the sphere of healing" and so would have been of crucial interest to others working in this vein. In addition, Kingsley says that Empedocles' concern with these things was in a "magical…sense" [1995, 229] as well, citing Mauss' definition of magic:

> [it is] not only a practical art, it is also a storehouse of ideas. It attaches great importance to knowledge—one of its mainsprings. In fact as far as magic is concerned, knowledge is power.… It is a fact that certain branches of magic, such as astrology and alchemy, were called applied physics in Greece…the word *physikos* was a synonym for magic. [Mauss 1972, 143]

30 On the development of humoral theory in Hippocratic writings, see Jouanna 2012, 229–232.

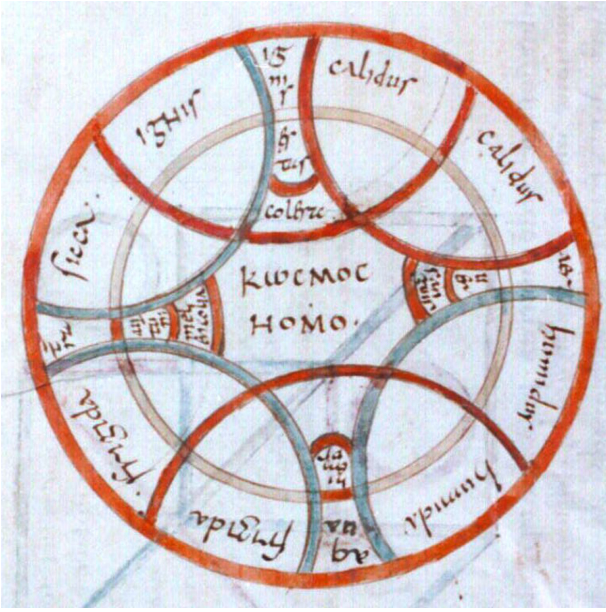

PLATE 1 Κωcμoc Homo
Depicting the relationship of the world, the year, the human being, the elements, the qualities, and the humors.
COLOGNE, HS83^{II}, 131V (798 CE) [ISIDORE OF SEVILLE, *DE NATURA RERUM* C. 11.3] HTTP://WWW.UNI-KOELN.DE/AHZ26/EDITION/START1B.HTM

ance of humors to restore health, and assigning certain medical conditions to an excess of a humor all contribute to the subsequent development of a theory of humors and temperaments in both a physical and psychological dimension. Discovering the proportion of the humors in each person and applying an ideal scheme for them eventually leads to the concept of choleric, melancholic, sanguine, and phlegmatic temperaments. Temperament or mixture (κρᾶcιc) eventually became part of astrological medical practice that correlated qualities, elements, and humors with planets and zodiacal signs, as we shall see.

The connection of the seasons to medicine naturally brings in the yearly cycle of the Sun. Each season was linked to elements, qualities, and humors. Spring was naturally sanguine, airy, hot, and moist; summer, choleric, fiery, hot, and dry; autumn, melancholic, earthy, cold, and dry; and winter, phlegmatic, watery, cold, and wet. But these operate on a continuum, with increases and decreases of qualities throughout the season and throughout the year. As *De natura hominis* tells us:

> All these [substances], then, are always present in the body. But, as the year goes round, they become now greater and now less, each in turn and according to its nature. For just as every year has its share in all of them, the hot, the cold, the dry, and the moist—none in fact would last for a moment without all the things that exist in this universe, but if one were to fail all would disappear, since they are all mutually interdependent; in the same way, if any of these primary bodily substances were absent from a human, life would cease. In the year, sometimes the winter is most powerful, sometimes the spring, sometimes the summer, and sometimes the autumn. So too in a human sometimes phlegm is powerful, sometimes blood, sometimes bile, first yellow, and then what is called black bile.
>
> *De nat. hom.* 7.34–47: LITTRÉ 1839–1861, 6.48–51: trans. JONES 1931, 20–23 modified

These seasonal fluctuations, brought about by the solar cycle, are what cause disease:

> The transitions of the seasons especially engender diseases, and in these seasons the great changes are from either cold or heat, and so on according to the same rationale.
>
> *Aph.* 3.1: LITTRÉ 1839–1861, 4.486

Additionally, different humors are associated with the different ages of human beings:

> As for the seasons in spring and early summer, children and young people enjoy the greatest well being and good health; in summer and part of autumn, the aged; for the remainder of autumn and winter, the middle-aged.
>
> *Aph.* 3.18.1–5: LITTRÉ 1839–1861, vol. 4, 494: trans. JONES 1931, 128–129[31]

The Moon and its phases were also important for the Hippocratic authors, especially in pinpointing the critical days of an illness and its prognosis. The structure of the doctrine of critical days seems to be based on the week and the month, showing its dependence on the Moon (though some critical day schemes are difficult to match to the lunar cycle). “Acute diseases come to a crisis in fourteen days”, says the Hippocratic aphorism, suggesting a time cor-

31 See also *Aph.* 3.2; *De nat. hom.* 15.

responding to the lunar phase of opposition to the Sun at the Full Moon [*Aph.* 2.23: Littré 1839–1861, 4.476: trans. Jones 1931, 113]. The aphorism does not mention the Moon or its phase; but that this crisis point matches the lunar phase of opposition implies that the crisis at the 14th day is analogous to the Full Moon (when the Moon is at its greatest size as seen from Earth): the time of crisis and the time of month (i.e., the phase) have the same quality. Though a *quid pro quo* should not be assumed, there is a connection here, as in Babylonian medicine, between heavenly and earthly events.

3.4 *Overt Use of Astronomy in the Hippocratic Corpus*

> For knowing both the changes of the seasons and the risings and settings of the stars, in what manner each of these occurs, [the doctor] may foreknow what kind of year is going to come to pass. Thus, someone who has searched out and perceived the seasonal times beforehand would know quite well about each of these concerns, and would have both the greatest of health and carry it correctly, in no small measure, into the [medical] craft.
>
> *De aere* 2.10–15: LITTRÉ 1839–1861, 2.14

This important passage appears near the beginning of the Hippocratic text *De aere aquis locis*, which may have been written by Hippocrates himself [Jouanna 2012, 232]. It appears within the context of learning to know about disease from environmental factors, including what the author of *De prisca med.* calls meteorology—the study of things in the sky in contrast to those on the Earth.[32] An important part of these "meteorological" phenomena are the risings and settings of stars and the events associated with them. The season, humor, and astronomical event all combine to pinpoint disease. For example, typhus occurs "when the Dog Star rises, on account of bile being moved through the body" [*De aff. int.* 39.1–3: Potter 1988, 200].

The passage from *De aere* goes on in the next sentence to specify that the just-mentioned celestial phenomena belong to "astronomy":

> If someone should suppose that these things only belong to meteorology (μετεωρολόγα), he might change his mind if he comes to understand that

32 Schiefsky 2005, 137–139 explains that the author's understanding of the term encompasses "Sun, Moon, stars and planets, weather signs, clouds, thunder and lightning, winds, hail, snow, dew, the rainbow and haloes, comets, shooting stars and earthquakes".

> astronomy (ἀςτρονομίη)[33] contributes not a small, but a very great part, to medicine.
>
> *De aere* 2.15–18: LITTRÉ 1839–1861, 2.14

As the quotation emphasizes, astronomy's role is not trivial.

A number of other passages make clear that the Sun, Moon, and stars have an effect on the body in terms of regulating disease and health.[34] Even dreaming of celestial bodies can aid in diagnosis and treatment, as we see in this passage in book 4 of *De diaeta* concerning dreams:[35]

> To see the Sun, Moon, heavens and stars [in a dream] clear and bright, each in the proper order, is good, as it indicates physical health in all its signs, but this condition must be maintained by adhering to the regimen followed at the time. But if there be a contrast between the dream and reality, it indicates a physical illness, a violent contrast a violent illness, a slighter contrast a lighter illness. The stars are in the outer circuit, the Sun in the middle circuit, the Moon in the circuit next to the hollow.
>
> *De diaeta* 4.89.1–8: LITTRÉ 1839–1861, 6.644: trans. JONES 1931, 427, slightly modified

The last part about the stars, Sun, and Moon in "circuits" («περίοδοι»), reprises an earlier part of the treatise, where the three "circuits" of the soul within the body are compared to the circuits of the stars, Sun, and Moon. This is a direct analogy of the macrocosm to the microcosm.[36]

33 As Jacques Jouanna points out [1992, 306], this marks the first appearance of «ἀςτρονομίη» in the extant Greek corpus.

34 For a detailed analysis of the use of astronomy in the Hippocratic corpus, see Phillips 1983, 427–434.

35 For a comparison with Babylonian practices, see van der Eijk 2004.

36 See Jouanna 2012, 203–205, esp. n30, which compares *De diaeta* 4.9–10 to 4.89: see also Jouanna 1998. Jouanna 2012, 221–227, furthermore points out the similarities between certain passages of *De diaeta* on the circuits of the soul and passages in Plato's *Timaeus*. For analysis of the astronomical indications of dreams in 489, see Hulskamp 2008, 162–170, with a useful table on 164–166. Also note the fact that the Sun is "in the middle [circuit]" suggests a planetary order (called Chaldaean) commonly used in astrology, where the Sun's sphere lies exactly in the middle of the spheres of the seven classical planets: Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon (and the sphere of the fixed stars lies above Saturn's). Furthermore, the location of the middle circuit, as Hulskamp points out [2008, 164], is likely the heart, the organ associated with both the Sun and the zodiacal sign of Leo.

The means by which dreams are effective in diagnosis and prognosis is the soul's ability to see the inner workings of the body and announce pathology before it is outwardly apparent. The *interpretation* of the symbolism in the dream in regard to health is the province, though, of the healer. This shows that even in the supposedly "naturalistic" Hippocratic corpus, divinatory practices such as using dream interpretation to treat illness were seen as efficacious, as were prayers to the gods [*De diaeta* 89.130: Hulskamp 2008, 169–170]. The medical use of dreams and, within that practice, the interpretation of celestial events for the prognosis of the illness, continued in medicine as, e.g., in the work of the physician Rufus of Ephesus (first/second century CE), author of *Quaestiones medicinales*, a part of which is devoted to the use of dreams in diagnosis.[37]

3.5 *Galen's Use of Astronomy*

Claudius Galen (b. 129 CE [Nutton 2013, 222, 390n2]), from Pergamum in Asia Minor, is arguably the most influential physician on Western medicine up to the Modern Period. We may note, in reference to the previous section on dreams, that Galen was supposedly encouraged to study medicine by a dream in which Asclepius appeared to his father [von Staden 2003, 27 and n40; Nutton 2013, 223, 391n10]. His copious output was widely disseminated not only in Greek but in Latin and Arabic translation. Galen was hugely influenced by Aristotle and the Hippocratic corpus. His commentaries on doctrines in various Hippocratic texts updated and canonized them in medical practice. For example, his work was instrumental in popularizing Hippocratic humoral doctrine and expanding it into the doctrine of temperament. (He also wrote his own treatise, *De temperamentis*.) Galen's model for temperament, which also incorporated the Aristotelian qualities and elements, became the standard in much of medieval and Renaissance medicine. In addition to his expansion of Hippocratic humoral theory, Galen also built on the earlier corpus' doctrine of critical days, giving it a firm foundation in the phases of the Moon. In his commentaries on the Hippocratic *De aere* and *De nat. hom.* and his own treatise *De diebus decretoriis*, we find numerous examples of his use of astronomy in medicine.

Galen's views of astronomy and astrology are complex. He is generally accepting of astronomy in medical practice. He says that both doctors and astronomers, along with mathematicians and philosophers, are in the circle closest to the god Hermes [*Adhortatio* 5.4–6]. Doctors would do well to study astronomy. which, as Hippocrates claimed, is central to the study of medicine

37 See Perea Yébenes 2014: cf. Galen, *De dignotione ex insomniis*.

[Galen, *Quod opt. med.* 1: Kühn 1821–1833, 1.53.3–6]. In another comment, from a Hebrew abridgment of his *In Hipp. de aere*, he remarks that "whoever loves and desires astronomy should study it in Egypt, for no other nation knows astronomy but the Egyptians."[38] Regarding astrology, as we shall see, at times he supplies clearly astrological information as helpful for treating a disease, especially in regard to its critical days. But at other times, he is dismissive of "natal astrologers" (γενεθλιακοί, γενεθλιάλογοι), classing them with diviners like augurs and haruspices [e.g., in *In Hipp. de victu*: Helmreich 1914, 128.24–25 = Kühn 1821–1833, 15.441] or considering most of them to be poorly trained "diviners and fortune-tellers" [*In Hipp. de aere*: Toomer 1985, 199–200, 202]. As is usual with Galen, acquiring the best and most accurate knowledge of medicine and disease is the most important thing a practitioner can do. His disdain may be not so much for astrology or astrologers in general as for those who lack the proper expertise.

De diebus decretoriis supplies an example of the uses of both astronomy and astrology. The phases of the Moon provide a foundation for the usefulness of the theory of critical days in the progress of an illness. The treatise explains in detail how the critical days are derived, especially from the lunar cycle, and is plainly dependent on astronomical phenomena connected with disease and its progress.

But Galen also clearly incorporates astrological practices.[39] Following Hippocrates, who used fever to pinpoint the beginning of the illness [Kühn 1821–1833, 9.799.6–9], Galen says that the beginning of the illness is when people have taken to their beds (κατεκλίθηcαν) with manifest signs of fever [Kühn 1821–1833, 9.797.11–13]. This is equivalent to the astrological moment of decumbiture (also called κατάκλιcιc) [see §4.4, p. 374].

Then comes a section which can only be interpreted as an application of astrological doctrines to the effects of critical days, in particular the lunar squares and oppositions from the Moon's position when the illness begins. Coupled with the previous indication that he is aware of something like a

38 Trans. A. Wasserstein as cited in Nutton 1993, 23. Note that the Greek original of this text has been lost; it exists only in a complete Arabic translation (awaiting edition), the Hebrew version just cited, and a Latin translation based on it: see Toomer 1985, 193. We should remember that "astronomy" could include astrological prognostication.

39 For more on the topic of astrology in Galen, including the astrology in this treatise, see Booker 2014, 50–78, esp. 58–63. His nuanced, careful, and informed examination is in contrast to Cooper 2011b, 68–70, 340; 2011a, 130–132, where the analysis, though allowing that the passage is astrological, is flawed by a cursory knowledge of astrology and serious mistranslation: see the review in Langermann 2012. On Galen and astrology generally, see also Barton 1994b, 53–54.

decumbiture-chart, this shows, at least in this instance, that Galen's assessment of astrology is more nuanced than scholarship has usually acknowledged.[40] Galen explains, with examples, how the Moon, in its relationship to other planets and by virtue of the phases that he has previously outlined, affects the course of disease for good or ill. He then applies the doctrine to a hypothetical person's particular astrological circumstances:

> We must again take up that topic which we, having made careful observations, find always to be most true. It is what the Egyptian astronomers discovered, namely, that the Moon is disposed by nature to indicate what kinds of qualities the days will have, not only in disease but also in health. For if it is placed with the well-tempered planets, which they also call benefic, it will cause the days to be good; but if with the ill-tempered, they will turn out wretched. For example, let it be, when someone is born, that the benefic [planets] are in Aries, but the malefic ones in Taurus; this person absolutely, whenever the Moon comes to be in Aries, Cancer, Libra and Capricorn, will fare well. But whenever it occupies Taurus, one of its squares or its opposing zodiacal sign, his life at that time will be spent badly and wretchedly. And furthermore, beginnings of illnesses will be most pernicious when the Moon is in Taurus, Leo, Scorpio, and Aquarius but not dangerous and delivering recovery when it is passing through Aries, Cancer, Libra, and Capricorn. And in regard to the great alterations which we said occur at the squares and oppositions every seven days, in the destructive illnesses they [the alterations] are also destructive; but again, in good circumstances, good outcomes necessarily occur.
>
> KÜHN 1821–1833, 9.911.14–912.16

Now, though Galen introduces atypical terminology in using «εὔκρατοι» and «δύσκρατοι» for benefic and malefic planets respectively, he is familiar enough with more typical usage to correlate them with «ἀγαθοποιοί» and «κακοποιοί», respectively, as well. (Perhaps he is deliberately linking the characteristics of benefic and malefic planets with concerns of temperament.) Moreover, he is clearly following astrological ideas in tying the critical days of the lunar cycle—the conjunction, squares, and opposition—to the Moon's relationship with planets that can do good or ill.[41]

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40 Cooper's argument [2011a, 120, 123–124] that Galen mentioned astrology primarily for rhetorical reasons is unconvincing.

41 Note that Dorotheus, *Carm.* 5.31, says the same thing:

> If you want to know the condition of a sick [man] for whom death and misfortunes are

Galen tells us that the Moon is important throughout a person's life when considering health and disease. If the natal benefic planets (Venus or Jupiter) make an aspect to the Moon—again, instead of using technical astrological terminology for an aspect, Galen uses the more generic word «ἵστημι» ("set", "be placed")—as it moves through the signs, then, if a disease begins when it comes into that sign or one of its squares or opposition, the outcome will be good; but if the natal malefic planets (Mars or Saturn) are involved with the Moon, the opposite result will occur. (Obviously this does not mean that a disease is bound to occur every time the transiting Moon enters that sign.)

Galen's example of someone born with benefic planets in Aries and malefic ones in Taurus illustrates the theory—the Moon will create health when it joins these benefic planets *via* the signs of Aries, Cancer, Libra, and Capricorn. Conversely, when the Moon moves through Taurus, Leo, Scorpio, or Aquarius, it activates the malefic planets to bring about disease.[42] Whether he has actually cast a chart for the beginning of an illness (somewhat unlikely) or merely marked the Moon's zodiacal position at that time, Galen is showing how to interpret the combination of a natal chart with something akin to the astrological practice of decumbiture, with the Moon's position interacting with planets in the natal chart.

Examples such as this demonstrate why astrological medical texts such as *Prognostica de decubitu ex mathematica scientia* (*Prognostications concerning Decumbiture from the Astrological Science*) were once thought to be genuine works by Galen.

4 From Astronomical Medicine to Medical Astrology

In the history of Greek medicine, as Vivian Nutton has said, previous assumptions about the use of astrology in medicine led to a prevailing opinion that it was "an aberration, best left outside accounts of mainstream medicine" [2008, 19]. Increasing scholarship in this area is demonstrating that the use of astrology in medicine, as well as the incorporation of medical issues into astrological

feared, then at the time of his taking ill look at his nativity, in which sign[s] the benefics were and in which sign[s] the malefics were. [Pingree 1976a, 291: cf. Hephaestio, *Apo*. 3.31.12–13]

So there is a precedent for Galen's position.

42 Note that, contrary to Cooper's assumptions [2011b, 70], Galen is not casting a birth-chart of any sort here. He is merely providing, hypothetically, the relevant information to illustrate the principle. Langermann [2012, 229] has the same assessment of Cooper's interpretation.

theory and practice, gives evidence of a wider role for astrological medicine.[43] The most important components of this practice will be examined in the following sections.

4.1 *Medical Astrology* (ἰατρομαθηματική)

The word «ἰατρομαθηματικός» derives from «ἰατρός» meaning "doctor" or "healer" and «μαθηματικός», a word commonly used to mean "astrologer". Its first attestation appears to be in Ptolemy's *Tetrabiblos*.[44] Ptolemy had a clear interest in the uses of astrology *vis-à-vis* medicine. As does his contemporary Galen, he associates medical astrology with the Egyptians:

> The Egyptians have completely joined together prognostication through astronomy and the medical [art].
>
> PTOLEMY, *Tetr.* 1.3.18: HÜBNER 1998, 21.358–359

It may not be a coincidence that Alexandria in the Greco-Roman and Late Antique Periods was a magnet for both would-be doctors [Nutton 1993, 11–13] and astrologers [Fowden 1993, 178; Jones 1994, 38–41; 2007, 308–309]. For Ptolemy, what the Egyptians called their "systems of medical astrology" [*Tetr.* 1.3.16] were useful for understanding how bodies and disease were affected by «σύγκρασις» ("commixture") [*Tetr.* 1.3.15]—Ptolemy's word for temperament—and the environment, as well as for supplying the proper treatment for afflictions. He thereby applied a physical explanation (the physical qualities of temperament and the physical environment, including the celestial environment) for causes of illness in bodies. Medical conditions covered by medical astrology also included diseases and surgery.[45] The use of astrology in medical practices continued to grow after Late Antiquity, and flourished in the Middle Ages and the Renaissance.

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43 Recent examples include Akasoy, Burnett, and Yoeli-Tlalim 2008 and Booker 2014.

44 Searching the *TLG* with the string «ιατρομαθ» yields only six hits. I say "appears" because Ptolemy tells us that this is the word that the Egyptians use for their art, so we may assume an earlier usage of the term. Hermetic texts also support an Egyptian connection: see Fowden 1993, 2, 32n115.

45 For examples, see Dorotheus, *Carm.* cc. 29, 31, 38–41 (41 is a later addition); Hephaestio, *Apo.* 3.5.51–55, 31–34; Maximus, Περὶ καταρχῶν cc. 6–7. On Maximus, astrology, and medicine, see Boehm 2011.

TABLE 1 Zodiacal *melothesia*

Zodiacal sign	Babylonian	Greek and Roman							
Aries	head	head DFHMPPaV	sense organs V	eyes V					
Taurus	neck	neck DFHMPPaV	gullet V	face V	nose V	tendons P			
Gemini	arm shoulder	shoulders DFHMPPaV	arms HPV	hands V	fingers V	joints V	tendons V		
Cancer	chest	breast FHMPPaV	stomach VF	heart F	ribs H	spleen V	jaws V	mouth V	hands D
Leo	belly heart	stomach sides DMPa	breast H	heart DV	shoulder blades M	ribs VPa	loins V	tendons V	diaphragm P
Virgo	waist	belly DFHMPa	intestines V	inner pri- vate parts HV	spine D	flanks P			
Libra	insides(?)	hips V	buttocks HPPaV	kidneys FP	colon V	penis V	hind parts V	loins M	bladder D
Scorpio	female genitals	genitals HPPaV	groin M	male genitals D	buttocks D	pudenda P			

TABEL 1 Zodiacal *melothesia* (*cont.*)

Zodiacal sign	**Babylonian**	**Greek and Roman**						
Sagittarius	hip, upper	thighs	groin	knees				
	thigh	DFHMPaV	VP	P				
Capricorn	knees	knees	tendons	loin	hips			
	shins	DFHMPaV	V	P	P			
Aquarius	leg	legs	lower legs	buttocks	shoulders	tendons	joints	ankles
		DM	FHPPa	V	V	V	V	P
Pisces	feet	feet	extremities	tendons				
		DFHMPPaV	V	V				

D = Dorotheus, *Carm*. 4.1.76; H = Hephaestio, *Apo*. 3.31.11; P = Porphyry, *In tetr.*. c. 44;
F = Firmicus, *Math*. 2.24; M = Manilius, *Astr*. 2.453–465; Pa = Paulus, *Intro*. c. 2; V = Valens, *Anth*. 2.37
For the Babylonian *melothesia*, see BM 56605 rev.
WEE 2015, 220; 2016, 217

4.2 *Astrologers and Doctors*

In the opening statements of his astrological work, the *Tetrabiblos*, Ptolemy distinguishes between predictive and prognosticatory astronomy (i.e., astrology):

> Of the preparations for the goal of prognostication through astronomy, O Syrus, two are the greatest and most authoritative. One is first in order and in power, by which we comprehend, every time they occur, the configurations of the movements of the Sun, Moon and stars which happen in relation to one another and to the Earth. The second is by which, through the natural particular quality of the configurations themselves, we investigate the changes in the surrounding environment which they bring about.
>
> PTOLEMY, *Tetr.* 1.1: HÜBNER 1998, 3.32–39

Thus, astronomy must come first, though its purpose is to serve prognostication, a practice that also applies to medicine. We have already seen with both the Hippocratic writers and Galen that celestial events and the environment surrounding the Earth must be considered in medical matters. Ptolemy goes on to compare the practices of astrologers and physicians: both practice an art that he terms "stochastic" in that it cannot be classified as an exact science but must use the art of conjecture, to make judgments [*Tetr.* 1.2.7, 10, 12–13, 15–20; 3.2.6].[46] Doctors and astrologers have other points of interconnection. Both depend on finding clientele to make a living and so need a certain amount of rhetorical skill in practicing their art.[47] Both disciplines were called a τέχνη, which is usually translated as "art", though the word also means "craft". Both depended on accurate prediction (even using the very same word, «πρόγνωϲιϲ») to help their patients/clients [Barton 1994b, 134–136].

In astrological texts, doctors and astrologers are frequently categorized together, by virtue of what they do as well as, possibly, by virtue of their status in society. Mercury and the ninth place (which was known as God), is particularly associated with astrologers and doctors. For Firmicus Maternus, when Mercury falls in the ninth place, it produces doctors and astrologers as well as diviners such as haruspices and dream interpreters [*Math.* 3.7.19: Kroll, Skutsch, and Ziegler 1897–1913, 1.162.2–3]. When Mercury is in the third place, we get priests, magi, court doctors (*archiatri*), and astrologers [*Math.* 3.7.6: Kroll, Skutsch, and

46 For astrology as stochastic, see Komorowska 2009; Greenbaum 2010. For medicine as stochastic, see Ierodiakonou 1995; Boudon 2003; Boudon-Millot 2005; Schiefsky 2005, 189–190, 206–207, 368–374.

47 Cuomo 2000, 14; Barton 1994b, 139–140 and 1994a, 139, 154. For the doctor's position in the cultures of the Greco-Roman world, see Nutton 2013, 254–271.

Ziegler 1897–1913, 1.157.16–17]. Mercury in the Ascendant gives orators, court doctors, astrologers, astronomers, and haruspices [*Math.* 4.21.9: Kroll, Skutsch, and Ziegler 1897–1913, 1.263.17–18]. Saturn in the ninth, on the other hand, gives famous magi, renowned philosophers, and illustrious astrologers [*Math.* 3.2.18: Kroll, Skutsch, and Ziegler 1897–1913, 1.101.26–102.2], Saturn seemingly producing fame. When Paul of Alexandria lists the professions associated with the astrological places, the ninth place (which he says "pertains to astronomy (ἀϲτρονομικόν)") produces philosophers and mystics as well as diviners, dream-interpreters, and astrologers [Paulus, *Intro*. 24: Boer 1958, 63.5–64.9].[48]

Serafina Cuomo remarks [2000, 14] that "being an astrologer is a rather positive prospect, comparable to that of being a doctor or an orator." But such groupings more likely show that astrologers could move between the divinatory and the more "rational" arts just as healers could. The associations of doctors with magi, priests, diviners, and dream-interpreters in astrological texts may also indicate connections between Hellenistic medicine and Egyptian temple practices, which included healing [Cumont 1937, 128–129]. Healing centers were popular throughout the Greco-Roman Period. One dedicated to Apollo Grannus, in Grand (Vosges), France, has yielded remains with evidence of astrological practice [Abry 1993].

4.3 *Melothesia*

Melothesia, the assignment of parts of the body to planets, zodiacal signs, decans, and so forth has a long history in astrological medicine. One system, likely derived from the Egyptian practice of deifying the limbs [Quack 1995], developed into decanal *melothesia* (assigning body-parts to the decans, viz. 10°-portions of the zodiacal signs). Other systems of *melothesia* include the popular zodiacal and planetary ones, which are attested in Mesopotamia[49] and in the Greco-Roman world. The earliest extant Greco-Roman *melothesia* (assigned to zodiacal signs) is in Manilius, *Astronomica*. *Melothesia* also appears in the magical papyri and the Hermetica.

While zodiacal *melothesia* [see Table 1, p. 369] was arguably more prevalent, connecting body-parts to planets [see Table 2, p. 373] was also widespread (and the two systems could be employed in tandem). Babylonian antecedents for planetary *melothesia* have been discussed in §2.6, p. 356 but the assignment of the right eye to the Sun and the left to the Moon in Table 2 shows a clear Egyp-

48 For more such associations, see Cuomo 2000, 14–16.

49 For planetary *melothesia* in Mesopotamia, see Reiner 1993, 21–22 and 1995, 59–60; Heeßel 2008, 14–15; Geller 2010a, 158 and 2010b, 60–80; 2014b, 77–79. For zodiacal *melothesia* in Mesopotamia, see Wee 2015. See also §2.6, p. 356.

TABLE 2 Planetary *melothesia*

				Planets			
	Sun	**Moon**	**Saturn**	**Jupiter**	**Mars**	**Venus**	**Mercury**
Body Parts	head V	stomach PtV	legs V	thighs V	head V	neck V	hands V
	sense organs V	breasts V	knees V	feet V	rump V	face V	shoulders V
	right eye HeV	left eye HeV	sinews V	semen seed PtV	private parts genitals PtV	lips V	fingers V
	ribs V	bladder V	watery fluids phlegm PV	womb V	blood HePV	organ of smell HePtV	joints V
	heart PPtV	spleen PV	bladder PtV	liver PV	spermatic ducts PV	foreparts V	intestines V
	nerves PtV	membranes PV	kidneys V	righthand parts V	bile V	lungs PV	windpipe V
	sight PPt	marrow PV	hidden parts V	⟨teeth⟩ V	excretion of excrement V	liver Pt	hearing P
	brain Pt	taste Pt	right ear Pt	lungs Pt	left ear Pt	flesh Pt	tongue HePPtV
	belly Pt	bones Pt	arteries Pt	kidneys PPt	bile P	buttocks Pt	
	lefthand parts Pt	spleen Pt	touch Pt	veins Pt		bile Pt	

He = [Hermes], *Iatr.*; P = Porphyry, *In tetr.* c. 44; Pt = Ptolemy, *Tetr.* 3.11; V = Valens, *Anth.* 1.1. For [Hermes], *Iatr.*, see Ideler 1841, 430; Rovati 2018, 82–83.

tian origin.[50] Yet another system with Babylonian roots assigns a body-part to each roughly 2.5°-section of a zodiacal sign (called *dodecatemoria*) [Neugebauer 1983]. Vettius Valens describes a system based on the Lots of Fortune and Daimon [see ch. 12.4 §§4–5, p. 515], where Fortune designates external body-parts and Daimon, the internal parts [Valens, *Anth.* 2.37.1–5: Pingree 1986, 103.28–104.12].[51] Perhaps the oddest *melothesia* comes from a second-century

50 The right and left eyes of Horus are the Sun and the Moon, respectively.

51 Cf. Hübner 1977; Greenbaum 2016, 313–314.

Greek papyrus, in which the signs of the zodiac are assigned to "front parts" and "back parts" [Robbins 1936; Greenbaum 2016, 152–55].

The doctrine of *melothesia* was so well known that it became part of the common lore of popular culture. By the Middle Ages, we find many examples of "zodiac men" [Hübner 2013], among the most famous being that in the Duc de Berry's beautifully painted and gilded manuscript, *Les Très Riches Heures*.

4.4 *Decumbiture*

An important tool for medical astrologers is the interpretation of a chart cast for when a sick person takes to his bed (κατάκλιcιc, lit. lying-down-in-bed). «Κατάκλιcιc» was translated as *decubitus* in Latin and is known as decumbiture in English. Specific instructions for casting and interpreting a decumbiture appear in the early fifth century CE, in Hephaestio's *Apo*. 3.5.51–54, 31 but he took his cue from Dorotheus (*flor*. first century CE), who had instructed the astrologer to compare the time when the illness began with the natal chart [*Carm*. 5.31.1], as we saw above [see p. 366n41: cf. Hephaestio, *Apo*. 3.31.12–13].[52] The astrological techniques of decumbiture interpretation rely heavily on the Moon, critical days, and relationships with benefic or malefic planets. As we have seen, Galen's techniques are, interestingly, in this same continuum. One Greek text says that in the decumbiture-chart, the Ascendant represents the doctor; the Midheaven, the sick person; the Descendant, the illness; and the Underground angle (Lower Midheaven), the therapy [Ἄλλη cκέψιc: *CCAG* 1.124.2–3 = Pingree 1976a, 425.11–13].[53] But a variant assignment appears in a Greek text ascribed to Dorotheus, *From Dorotheus, on Sick People* [Pingree 1976a, 420.16–19 = *CCAG* 2.157.11–14], making the Ascendant the sick person and Midheaven the doctor. These variations may reflect two different petitioners to the astrologer, the ill person and the doctor [Hübner 2003a, 184]. Using the standard practice for an interrogation, the person asking the question would be represented by the Ascendant [e.g., Lilly 1647, 50, 123]. Thus, the medical astrologer would set the ill person as the Ascendant in one case but the doctor as the Ascendant in the other.

In practical evidence for the employment of decumbiture, we find a probable use at the healing center in Grand, France, where the remains of two

52 We are fortunate that Hephaestio of Thebes quotes Dorotheus in his *Apotelesmatica* (*ca* 415 CE), since he authenticates what is in the Arabic version of Dorotheus, corroborates astrological techniques, and gives us at least a paraphrase, along with some direct quotation, of the Greek original.

53 The same text (in Arabic translation) in Dorotheus, *Carm*. 5.41.35–36 is said to be from Qīṭrinūs the Sadwālī.

astrological boards (πίνακεϲ) made of ivory were found [Abry 1993]. These could have been used to demonstrate both nativities and decumbitures for patients on pilgrimage at the center.

The pseudo-Galenic text *Prognostica de decubitu* provides the following advice:

> It is necessary for the best doctor to heed the astrological science (ἡ μαθηματικη ἐπιϲτήμη), to examine the day and hour of the decumbiture closely. Also to pay attention to the state of the cosmos. For nothing happens apart from cosmic sympathy.
>
> c. 14: Kühn 1821–1833, 19.569.7–11; Rovati 2018, 122–123

This aligns with what can be found in the authentic Galen: he was interested in best practices for the best doctors and, as we have seen in *De diebus decretoriis*, he incorporates astrological doctrines from time to time. We may also note the emphasis on the connection of microcosm/macrocosm and the importance of the principle of cosmic sympathy.

The primary purpose of the *Prognostica*, the author of which may be one Imbrasius of Ephesus [Weinstock 1948], is to lay out interpretations for planetary aspects in the decumbiture-chart. It has a number of similarities with the Hermetic *Iatromathematica*, and an *Epitome* of Pancharius.[54]

ἐὰν δὲ τῆϲ
☾ οὔϲηϲ ἐν ♓ τοῖϲ ἀριθμοῖϲ καὶ τῷ φωτὶ αὐξούϲηϲ, ♂ ϲυνόντοϲ ἢ □ ἢ ☍, ἔϲται ἡ καταρχὴ τῆϲ νόϲου ἀπὸ πλήθουϲ, οἰνοποϲίαϲ καὶ ὠμότητοϲ. ἄρχεται γὰρ ἀπὸ τῆϲ διατρίτου ἡ νόϲοϲ αὔξειν. ἐπιτάϲειϲ δὲ νυκτὸϲ ἔϲονται καὶ πυρώϲειϲ τοῦ θώρακοϲ. καὶ παρακοπὴ τῶν λογιϲμῶν καὶ φρενῖτιϲ. καὶ περὶ τὴν κεφαλὴν ϲφήνωϲιϲ. καὶ πυρετοὶ καυϲώδειϲ, καὶ δίψα, καὶ ἐπιθυμία οἴνου, καὶ ϲφυγμοὶ ἐπηρμένοι, τούτοιϲ ἁρμόϲει ἡ τοῦ αἵματοϲ ἀφαίρεϲιϲ καὶ πάντα τὰ δυνάμενα καθελεῖν τὴν ἕξιν.

If, when the Moon is in Pisces, increasing in numbers (fast in motion) and in light (waxing), while Mars is conjoining, square, or opposing [her], the origin of the illness will be from excess, wine consumption and indigestion. For the illness will begin to increase from the third [day]. There will be increases of intensity at night, and inflammations of the chest. Also delirium of the reasoning powers and phrenitis [*scil.* inflammation of the brain]. Also stuffiness in the head. Also parching fevers, thirst

54 See Heeg 1911; Cumont 1935; Wilson and George 2006; Heilen 2015, 2.1305–1307.

ἐὰν οὖν ἀγαθοποιοὶ μὴ ἐπιθεωρήσωσι τὴν ☾, ἐν τῷ πρώτῳ □ τελευτήσει. ἐὰν δὲ ἀγαθοποιοὶ ἐπιθεωρήσωσι τὴν ☾, παραλλάξας τὴν ☍ κινδυνεύσας σωθήσεται. ἐὰν δὲ τῆς ☾ οὔσης μετὰ τοῦ ♃ ἢ ♀ ἢ □ ἢ ☍ κατακλιθῇ τις κἂν ἐν οἵῳ δήποτε ζωδίῳ κατακλιθῇ τις μέχρι τῆς α′ □ ἢ τῆς ☍ σωθήσεται. πολὺ δέ τι καὶ ἡ ὥρα συμβάλλεται ἐν τῇ κατακλίσει. [Kühn 1821–1833, 19.568.6–569.3; Rovati 2018, 118, 120]

and lust for wine, and throbbing of inflamed parts. For these bloodletting will be suitable, and all things able to destroy the condition. So if benefics do not aspect the Moon, he will die in the first quarter. If benefics do aspect the Moon, when [the sick person] has passed by the opposition, though having been in danger, he will be healed. If someone takes to his bed when the Moon is with Jupiter or Venus, or in square or opposition, although he took to bed in such and such zodiac sign, he will be healed up to the first square or the opposition. The time also contributes greatly in the decumbiture.

In the passage excerpted from *Prognostica de decubitu* on pages 375–376, the focus is the Moon as it moves through the signs: its waxing and waning, fast or slow movement, squares and oppositions to the Sun, and aspects to benefic or malefic planets especially when, at conjunction, square, or opposition, it also connects with a benefic or malefic planet. We can see in this last topic how it relates to the authentic Galen's remarks in *De diebus decretoriis*, when he mentions similar examples of the effects of benefic and malefic planets on the Moon. The emphasis here and in *De diebus decretoriis* on the critical times of conjunction, square, and opposition demonstrates that these are aspects of intensity that denote good or ill depending on the circumstances with benefic or malefic planets. It points up a difference between medical and natal astrology, where squares and oppositions are less likely to have a fortunate effect [see, e.g., Paulus, *Intro.* c. 10; Boer 1958, 24.3–25.2]. This text is purely one in astrological medicine, concentrating as it does on the astrological techniques of decumbiture and emphasizing the Moon, its cycle, and its circumstances in relationship to other planets. It also shows effectively that the decumbiture-chart was meant to be interpreted in conjunction with the movements of the Moon in real time during the illness.

4.5 *Critical Days, Conception and Birth, and Length of Life*

Astrologers as well as doctors used the theory of critical days, which, as we have seen in Hippocratic and Galenic texts, pinpoints crisis points in the course of an illness. The doctrine of critical days was employed both in interpreting a natal chart and when the Moon's current position at the time of the illness connects with the natal chart. It was also employed in charting the course of an illness [see §4.4, p. 374]. Seven-day periods were important, but the 3rd and 40th days were also critical. Vettius Valens discusses the 3rd, 7th, and 40th days of the Moon in *Anth.* 1.14. In a detailed investigation and analysis, Stephan Heilen has demonstrated the importance of, and the reasoning behind, the choice of these particular days [2015, 2.895–984]. For example, the 40th day is significant for the birth-process, both at conception and after birth, as well as being a critical day in astrological medicine generally [2012b, 186–88].

As in medicine, astrologers were also interested in conception and birth. The difficulty in finding the time of conception led to developing techniques for its discovery [Frommhold 2004]. A popular method considered the Ascendant position at birth to be the same as that of the Moon at conception, and the Moon's position at birth the Ascendant position at conception, thus relating the two events.[55] Putting aside the philosophical issue of whether a chart should be cast for a birth or for conception, most astrologers expediently used the moment of birth. Connecting the birth-process with astrology, Porphyry wrote *Ad Gaurum quomodo animetur fetus*,[56] in which he considered the role of astrology in conception, fetal development, and the birth-process [Wilberding 2011; Greenbaum 2018].

Another important concern for astrologers was determining length of life. Again, a number of different techniques existed to determine how many years someone would live. Many Hellenistic astrologers wrote about this topic.[57] In a time when death often came early, it was useful to know about how long a life might last.

4.6 *Plants, Stones, and Sympathy*

Astrological medicine could also incorporate the assignment of signs or planets to plants, stones, and other natural objects. As we saw in §2.7, p. 356, the practice is found in Babylonian medicine.[58] In the Greek corpus, these associations worked through the concept of sympathy. An important text for this doctrine is the Hermetic *The So-Called Sacred Book of Hermes to Asclepius*, the purpose of which was the creation of a phylactery to ward off disease, repre-

55 Sometimes called the "rule of Petosiris" or the "trutine of Hermes". See, e.g., Porphyry, *In tetr.* c. 38.

56 Interestingly, this text was first ascribed to Galen: see Kalbfleisch 1895.

57 For discussion of this practice, see Greenbaum 2016, 65–66, 107–108, 330–335.

58 See Reiner 1995, 130–131; Heeßel 2005 and 2008, 9–12; Geller 2014b, 82–83.

sented by each decan of a sign, using decanal *melothesia* [see ch. 11.1 §5, p. 418]. For example, the first decan of Leo was associated with the heart, so the efficacious amulet should be an agate engraved with a lion and solar rays and placed under the plant called lion's foot [Ruelle 1908, 260–261]. *De virtutibus herbarum* (*On the Powers of Plants*) [Friedrich 1968], which has been ascribed to one Thessalus, who may or may not be the first-century physician of Tralles, links various plants with signs and planets and describes their associated diseases and the herbal regimens needed to cure them [Fowden 1993, 162–165; Scarborough 1991, 154–156]. The anonymous *Cyranides* (*ca* second/fourth century CE) detailed the sympathies, antipathies, and other properties of birds, fish, plants, and stones [Festugière 1949–1953, 1.202–216; Fowden 1993, 87–89]. Though Galen would disparage such treatises,[59] they were commonly used in medical treatment.

4.7 *Ptolemy and Astrological Temperament*

Claudius Ptolemy was a near contemporary of Galen and his *Tetrabiblos* is a valuable resource for the development of Hippocratic medicine, especially in the doctrine of what would become temperament. The *Tetrabiblos* explicitly combines astrology with this doctrine. Although Ptolemy never uses the word «χυμός» ("humor"), he advocates a balance of qualities for good health. Moreover, the mixing of qualities, which he calls σύγκρασις, can be seen in the birth-chart:

> ...why can he not also perceive, for each individual person, the general quality of his particular commixture (σύγκρασις) from the surrounding environment at his creation (such as, that his body is such-and-such, and his soul such-and-such)...?
>
> PTOLEMY, *Tetr.* 1.2.11: Hübner 1998, 9.139–143

To accomplish this, Ptolemy assigns qualities to the planets, seasons, solstices, and equinoxes, the four principal lunar phases, and the cardines of the birth-chart [see Table 3, p. 379]. He astrologically determines the mixture of qualities in a human being through the Ascendant, planets in the Ascendant-sign and their rulers, the Moon, and, to a lesser degree, the fixed stars [*Tetr.* 3.12.2]. The practice of assigning qualities and elements to signs and planets occurs in other astrological works but, except for Hephaestio (who quotes Ptolemy), is not applied to the finding of a temperament.

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59 See *De simplicium medicamentorum temperamentis ac facultatibus* (*On the Mixture and Potency of Simple Medicines*): Kühn 1821–1833, 11.796.8–798.14; Barton 1994a, 53; Nutton 2013, 275.

TABLE 3 Ptolemy's astrological assignment of the qualities

	Cardines	Solstice/equinox	Lunar phase	Planet phase	Planets	Seasons
Hot	Midheaven	Summer Solstice	Full Moon	Opposition	☉ ♀ ♂ ♃ ☾ (slightly)	Spring Summer
Cold	Lower Midheaven	Winter Solstice	New Moon	Conjunction	♄	Autumn Winter
Wet	Descendant	Vernal Equinox	First Quarter	1st Station Square	☾ ♀ ♃	Winter Spring
Dry	Ascendant	Autumnal Equinox	Last Quarter	2nd Station Square	☉ ♂ ♄	Summer Autumn

FROM *TETR*. 1

4.8 *Doctor-Astrologers*

Although few examples of doctor-astrologers are recorded in the period under discussion, Asclepius, a major deity associated with healing, combines both functions. As a legendary authority, whose shrines dotted the Mediterranean area, Asclepius is cited both for his medical connections and his astrological knowledge. The mythology around his function as a god of healing is probably more widely known but his name is also linked to astrology. In a Greek horoscope for a birth in 137 CE, Asclepius is called "Imouthes, son of Hephaestus" and an "ancient sage" [Neugebauer and van Hoesen 1959, no. 137, c. 3, 6].[60] Imouthes is the Greek name for Imhotep, the legendary Egyptian sage, architect, and astrologer who was worshipped as a god of medicine starting in the Ptolemaic Period. In another Greek papyrus of the second century, Asclepius names the functions of the astrological places [*PMich.* inv. 1.149.col.9.20: Robbins 1936, 62]. A Demotic magical papyrus gives instructions for casting a chart to achieve "everything that you wish". The chart is prepared by Imhotep (the Greek Asclepius) [*PDM* 14.1–114, esp. 14.93–114.col.4.1],[61] The *thema mundi*, a symbolic chart showing the positions of the planets in signs at the "birthday of the cosmos" was said by Firmicus Maternus to come from Asclepius [*Math.* 3.1]. The name of Asclepius is often linked to Hermes in Hermetic texts, both astrological and medico-astrological.

As far as actual practitioners go, Vivian Nutton provides some examples of doctors who made predictions of lifespan and prescribed specific times for starting treatments, both of which suggest the use of astrology, as well as the

60 See also Fowden 1993, 32, 50–52.

61 See Betz 1992; Griffith and Thompson 1904–1905.

case of Crinas of Marseilles [Nutton 2008, 19–20], who made a fortune as a doctor-astrologer. Crinas is described by Pliny as follows:

> Crinas of Marseilles, who practised medicine by uniting two arts, as he was very careful and scrupulous, surpassed [Thessalus] in authority by assigning diets according to the motions of the stars from the astrological ephemerides and watching for the proper times, and recently left 10 million sesterces....
>
> PLINY, *Nat. hist.* 29.5.9

Finally, Antigonus of Nicaea (mid-second century CE), the author of an astrological manual, is probably identical with the doctor of the same name. His most famous nativity is that of the emperor Hadrian [Heilen 2012a and 2015, 1.27–31].

The connections between medicine and astrology, the first doctor-astrologers and the incorporations of medical issues by astrologers, would be put to fine use in the Middle Ages and Renaissance. Astrology came to be taught in the medical curriculum at respected universities in Europe by the end of the 13th century. Doctors commonly employed astrology in diagnosis and prescription. The association of astronomy both predictive and prognosticatory with medicine continued to inform medical practice until the 19th century, when the long collaboration came to an end.

Hellenistic Astronomy in Literature

CHAPTER 10.1

Aratus and the Popularization of Hellenistic Astronomy

Stamatina Mastorakou

1 Introduction

Historians of science long ago abandoned a narrowly internalist approach to the investigation of science. In ancient science and ancient astronomy, however, much still needs to be done to put the astronomical knowledge of Antiquity into its proper cultural and social contexts. But the problems in doing this include the technical content of extant sources, the dead languages of those sources, and, especially in the case of the Late Antique Period, the fact that some sources are not yet widely accessible but await modern editions and translations.

A good example of a source on which the limitations of our current history of ancient astronomy have had an impact is Aratus' poem *Phaenomena*. Although Aratus' work has been studied for literary purposes, not much has been done by either historians of astronomy or classicists in general regarding either the astronomical content or the contextualization of the poem. There are many reasons for this. First, among historians of astronomy, there has been a lingering assumption that as a poem its content is not compatible with scientific knowledge. Second, these same historians tend to believe that Aratus' work is merely a copy of previous sources and does not add anything new to the history of astronomy. Third, and perhaps consequently, Aratus is considered a less important figure in ancient astronomy and so he has been left out of its history, particularly from the "advanced, high-brow practices" [Cuomo 2001, 1] of astronomy in the older historiography.

In this chapter, I show that these three factors, which have kept Aratus and his work in the shadows, were not operative in the ancient world. Thus, for a history of astronomy that is not anachronistic or heedless of its ancient contexts, we should take into consideration Aratus' work and view it as the ancients did over the course of many centuries.

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2 Aratus and His Work

Aratus was from a prominent family from Soli in Cilicia, a town that produced other educated and famous people, the most well known being the Stoic philosopher Chrysippus, who was usually confused with Aratus by those outside their particular fields of endeavor. Aratus wrote many poems but his only extant work is his *Phaenomena*, an astronomical poem of 1154 hexameter lines, which was written while he was in Pella at the court of Antigonus Gonatas in the years following 276 BCE. Historians usually maintain that Aratus wrote this poem by versifying the now lost prose work *Phaenomena* by Eudoxus of Cnidos (408–355 BCE) and copying *De signis*, which was allegedly written by Theophrastus of Eresus (370–286 BCE). Eudoxus' work demonstrably included a description of the constellations in the sky, which Aratus might have used as a source for the first part of his poem. For the second part of his poem, Aratus probably used *De signis* as a work on signs for meteorological phenomena. Looking at the astronomical content of the *Phaenomena*, one finds everything that astronomers of Aratus' period dealt with, minus the movement of the planets. Aratus talks about the celestial circles and the axis of the sphere, the tropics and solstices, the 48 constellations, the Great Year, the constellations (ἄϲτρα) and individual fixed stars (ἀϲτέρεϲ) [Kidd 1997, 168–169], the risings and settings of the stars, how to tell time, haloes, parhelia, eclipses, comets, and meteors.

Aratus was extremely popular in the ancient world for many centuries. The *Phaenomena*'s prominent role is illustrated by the successive poetical traditions that replicate its style. The poem was the subject of at least 27 separate commentaries, and it is one of only a very few Greek poems to be translated into Arabic [Dolan 2017, 23]. The translations of, and the commentaries on, the *Phaenomena* constitute a whole tradition, the so-called tradition of Aratea. We are fortunate to have at our disposal several commentaries on Aratus' poem, in particular, the one by Hipparchus (190–120 BCE), as well as translations by Cicero (106–43 BCE), Germanicus (15 BCE – 19 CE), Avienus (*flor.* fourth century CE), as well as many editions of the poem and references in other works. Surprisingly, even the New Testament, where Paul is addressing the Athenians [Acts 17:28], contains verses from Aratus' *Phaenomena*. Aratus was also appreciated by his contemporaries, such as Callimachus (310/305–240 BCE) and Leonidas of Tarentum (290–220 BCE). In fact, Callimachus, in *Epig*. 29 [Mair-01 1955, 156–157] praises the newly published *Phaenomena* and its author for his "refinement in style (λεπτότηϲ)".[1] Callimachus also apparently praised Aratus

1 Aratus insinuates this quality in the acrostic «ΛΕΠΤΗ» of verses 783–787 and the anaphora of «λεπτή» in 783–784.

in a lost prose work, *Against Praxiphanes*, calling him a "very learned man and an excellent poet" [Pfeiffer 1953, fr. 460]. The poet Leonidas of Tarentum also wrote an epigram in which he ranks Aratus next to Zeus and, like Callimachus, praises him for the refinement of his style (λεπτότης) and also calls him expert (δαήμων) [Dawson 1950, 276–277].

Despite Aratus' popularity in Antiquity, little mention of his work has been made in traditional histories of astronomy. It is true, though, that in the past two decades the interest in Aratus and his work has increased. First of all, Aratus can be studied in two excellent editions with translation and commentary by David Kidd in English [1997] and Jean Martin in French [1998]. There are also numerous recent works on the *Phaenomena* but they are either philological analyses or studies of the reception of the poem and/or its relation to subsequent works.[2]

3 Didactic Poetry

The truth is that modern scholarship has been stymied by considering Aratus first and foremost a didactic poet.[3] Thus, he is said to belong to the tradition that starts with Hesiod; continues with Empedocles' *On Nature* and/or *Purifications* [Diels and Kranz 1951, c. 28] (*ca* 492–432 BCE) and Parmenides' poem [Diels and Kranz 1951, c. 31] (*ca* 515–450 BCE); and reaches his contemporary period, the Hellenistic world, together with didactic poetry like Callimachus' *Aetia*, Apollonius' *Argonautica*, Lycophron's *Alexandra*, and Theocritus' *Idyllia* [Hutchinson 1990, 5]. The didactic tradition continued during the Roman Period as well, particularly with Cicero, who paraphrased Aratus' *Phaenomena*, thereby launching poetry of this type into the Roman world. This identification of such a seemingly coherent poetic tradition is the main reason students of literature have paid Aratus so much attention [Gee 2000, 2013], with most of their analyses addressing literary and philological interests.

Although such classifications are useful, there are various issues with categorizing Aratus' poem as didactic. To begin, there is the problem with the concept of literary genre in general. Fowler, for instance, discusses the malleable nature of genre, its natural instability as a cultural category, and what this can mean

2 See, e.g., Fakas 2001; van Noorder 2009; Gee 2000 and 2013; Volk 2002; Cusset 2011.

3 The most common definition of didactic poems is that they "provide, or claim to provide, a systematic account of a subject" [Dalzell 1996, 8]. For characteristics of the didactic genre and categorizations of didactic poems, see Todorov 1970, 6; Kidd 1997, 8; Effe 1977, quoted in Dalzell 1996, 32 and in Hopkinson 1988; Gibson 1998, 68; Volk 2002, 36–56; Cairns 1972, 6.

particularly for didactic poetry [2000].[4] There is also a view in which every work of literature can be characterized as didactic, especially in Antiquity, when poets were viewed as teachers first and foremost. The most important reason, however, for abandoning such a framework is that this generic definition is anachronistic, at least for the Hellenistic Period. Importantly, when we look at ancient categories of poetry, we find in the grammarian Diomedes' work a distinction that includes didactic poetry only after the fourth century CE, although there is a first attempt at such a categorization in the post-Aristotelian Tractatus Coislinianus [Schuler and Fitch 1983, 1n11]. Using one of the few important sources that we have on ancient Greek and Roman education, the *Institutio oratoria* by Quintilian, we see that Aratus is presented as one of the most eminent *epic* poets along with Homer and Hesiod [*Inst. or*. 10.1.44, 46, 52].[5] Despite the fact that this is a Roman work, it is enlightening for the Greek Period too, if we take into consideration that to a significant extent the Romans followed the Greeks in their educational system. This seems indeed to be the case according to Quintilian himself [*Inst. or*. 1.4.1], who says that he is trying to form an educational system following the Greeks. So what is crucial here is that Aratus' work as well as Hesiod's in more ancient times are discussed under the label of "epic poetry" [*Inst. or*. 10.1.51] and put alongside the work of Nicander, Antimachus, Apollonius, and others. In short, the texts that *we* call didactic were, according to Quintilian, regarded instead as epic [Volk 2002, 29]. As there is no evidence of there being a "didactic" genre in Antiquity nor of a distinction between epic and didactic in the period close to Aratus,[6] and since didactic poetry tended to be written in the same meter as epic, namely, dactylic hexameter, it becomes clear why treating Aratus' *Phaenomena* as a didactic poem can be misleading.

There is no doubt that Aratus' poem has an educational purpose in a loose, not genre-specific way; and there is no doubt either that Aratus followed both the Homeric and the Hesiodic traditions. Nevertheless, de-categorizing Aratus'

4 For similar problems with genre as a concept in literary studies and particularly with the genre of didactic poetry, see Volk 2002, 25–43. Other problematic aspects of the notion of genre already discussed by such philosophers as Foucault [1989] and Derrida [1980] concern our understanding of a text as a class and how we can interpret a specific member of the class, since each text can be indeterminate.

5 On ancient education more generally, see, e.g., Atherton 1998, 218–219; Morgan 1998a, 245–246; Volk 2002, 29; Clarke 1971, 16; Morgan 1998b, 24.

6 In fact, there was no theory of genre as such at that time [Volk 2002, 27]. Granted, Plato and Aristotle had their own theoretical views about poetry but these seem not to have impacted the common views on the subject significantly.

work as a didactic poem[7] paves the way for a fresh look into why he wrote such an astronomical poem and what its audience thought of it. Instead of exploring the didactic connections of the *Phaenomena*, we might, for example, explore the educational system of its period. Yet, although there are general accounts of education in the Hellenistic Period [e.g., Marrou 1956; Clarke 1971; Cribiore 2001], we currently lack analyses which take into account the political and social dimensions of education and thus present the educational process as one in which the learner acquires more than just knowledge or a skill of some sort.[8]

4 Hipparchus

Returning to Aratus' *Phaenomena*, the general question remains: Is it possible for any poem to achieve the clarity and precision that we moderns normally associate with prose? Nowadays, it is usually believed that poetry is by its nature alien to discursive reason and, especially, to science. The question, however, is strictly modern. In Antiquity, there was a long-lived tradition that regarded poetry as a special source of truth as well as a tradition of thinkers who were sceptical or even polemical about this. It seems, though, that, rather than a dichotomy, there was a relationship of give and take and, as Gee puts it,

> the very persistence of that medium [poetry] testifies to its value. Empedocles' *On Nature* (fifth century BCE) and Lucretius' *De rerum natura* (first century BCE) are in verse. We should not downgrade the serious contribution of these works—the four-element theory, atomism—on the grounds of their literary form.
>
> GEE 2011, 409[9]

For the purpose of this chapter, however, it is interesting to see how Hipparchus, an astronomer of the Hellenistic Period, responded to Aratus' poem and to consider whether he thought that poetry and astronomy were incompatible. This

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7 Heath follows a similar line argument but for different reasons, suggesting that Hesiod's *Works and Days* was didactic without belonging to a formally didactic genre [1985, 254]. According to Heath, Hesiod does not intend to instruct but rather has artistic purposes, such as affording pleasure and delight [263].

8 A good example of understanding education as a multidimensional phenomenon is Yun Lee Too's work [1995, 2000] on education in classical Athens.

9 This topic has been the subject of much discussion: see the bibliographies in Frank 1986; Murray 1996; Clarke and Rossini 2011.

brings us to a second point, the misconception that Aratus merely versified Eudoxus' prose text and that his poem contains no novel astronomical content.

Hipparchus' commentary on Aratus' and Eudoxus' *Phaenomena* is Hipparchus' only extant work and it was written after at least two of his major works, *On Simultaneous Risings* and *On the Rising of the Twelve Signs of the Zodiacal Circle* [see, e.g., Dicks 1960, 1–18; Toomer 1978]. These works did not come down to us perhaps because they were eventually seen as redundant in a *fortuna* that included Ptolemy's *Almagest*. Although it may be an oversimplification, one might argue that Hipparchus' commentary on Aratus is his only surviving work because of the extreme importance of Aratus in Hipparchus' time and later. In any case, the fact that a *bona fide* astronomer like Hipparchus thought it important to compare Aratus' *Phaenomena* with Eudoxus' *Phaenomena* and *Enoptron*,[10] as well as with Attalus' commentary on Aratus, is itself testimony to the far-reaching influence of Aratus' treatise.

According to Hipparchus himself, the aim of his work was to correct the misinformation that all three—Aratus, Eudoxus, and Attalus—provide about the heavenly bodies so that one can determine with accuracy the hour of the night and understand lunar eclipses and other astronomical phenomena [*In Arat.* 3.5.1]. In his preface, Hipparchus also gives an idea of the function and the audience of his commentary: as he writes to Aischrion, his eager student and friend, he wants to correct Aratus' poem "for the sake of your love of learning and for the common benefit of others" [*In Arat.* 1.1.5]. Many people, according to Hipparchus, have been misled about the works of the universe "because the charm of poetry grants some credibility to what is said and almost everybody who interprets this particular poet associates himself with his statements" [*In Arat.* 1.1.7].

One of the reasons, then, that Hipparchus wrote his commentary was to correct misapprehensions derived from Aratus' poetry. In addition, he asserts his *bona fides*: "I charged myself with this task not because I intended to get a good image for myself criticizing others (that would be absolutely vain and ungenerous...)" [*In Arat.* 1.1.6]. It is interesting that Hipparchus was obliged to say something along those lines; perhaps he thought that he had to confess why he, a professional astronomer, was dealing with things like poetry, nonprofessional astronomers, and commentators on those nonprofessional astronomers. And yet perhaps Hipparchus does protest too much—he knew that Aratus was popular and it surely crossed his mind that by writing about Aratus, his own

10 Hipparchus says that Eudoxus wrote two books, the *Phaenomena* (*Appearances*) and the *Enoptron* (*Mirror*), that they are not very different from each other, and that Aratus followed Eudoxus' *Phaenomena* in writing his poem [*In Arat.* 1.2.2].

name would gain wider circulation among the nonprofessional astronomers and lovers of poetry from whom he is so keen to distance himself. In any case, Hipparchus' popularity in Antiquity outside small, specialist circles was due to his commentary on Aratus. There are indeed differences in Eudoxus' and Aratus' descriptions of which constellations rise and set along with the zodiacal signs, differences not only in style because one is a poem and the other a work in prose but, more importantly, in content as well. Thus, Aratus sometimes omits constellations that Eudoxus mentions or describes different parts of constellations that Eudoxus recounts.[11]

Each critic of poetry, of course, approaches his subject according to his own agenda, with views that sometimes are less than straightforward. What we can say about Hipparchus is that he puts side by side two mathematical astronomers and a poet. And if we compare how many lines Hipparchus quotes from, and paraphrases, the works of Aratus, Eudoxus, and Attalus, the result is quite striking. The lines of Aratus' poem that he mentions cover half of the whole poem and are double those that he cites from Eudoxus' treatise. It is also interesting that sometimes Hipparchus quotes the same line from Aratus two or three times at different points. Moreover, as one reads Hipparchus' commentary, it becomes clear that Hipparchus did not simply want to comment on Eudoxus' and Aratus' work; rather, he wanted to comment on Aratus' work in comparison with Eudoxus' *Phaenomena*, Attalus' commentary, and his own understanding of the heavens. Indeed, Aratus appears to be Hipparchus' main interlocutor, even his main competitor for authority in knowledge of the heavens. Moreover, it seems not only that the *Phaenomena* was addressed to everybody but that it was to be read virtually by everybody, by common people like Aischrion, by the commentators, the best being the mathematical astronomer Attalus and the other experts, including Hipparchus himself. Aratus' popularity, then, as well as his prominence in ancient astronomy are manifest in Hipparchus' own words.

Given such an introduction, one would not expect to find Aratus sometimes "correcting" Eudoxus by providing more accurate information. Indeed, in some instances, Attalus not only makes mistakes but even changes things in Aratus that are correct. Hipparchus very rarely admits that fact, as his concern is to present Eudoxus in a better light than he does Attalus, and Attalus in one better than he does Aratus, and himself in the best light of all. Further, he emphasizes that Attalus and Eudoxus are mathematical astronomers (μαθηματικοί), while Aratus is presented as just a poet and ἀστρολόγος, distinctions and statuses that

11 On the differences between Eudoxus' and Aratus' work, see Mastorakou 2018.

Hipparchus sustains [Mastorakou 2018]. Why Hipparchus should do this is a good question. If he was not trying to supplant the *Phaenomena*, perhaps one consideration was that, by establishing such authority, he wished to ensure that his corrections of Aratus' work would serve to secure continued reading and the poem itself. If so, the question is whether commentators after Attalus and Hipparchus took into consideration Hipparchus' corrections.

Here I will mention three additional instances showing how Aratus differentiated his poem from his source. The first one has to do with the North Celestial Pole. When Hipparchus reports what Eudoxus says about the North Celestial Pole, "There is a certain star that remains always in this place; this star is the pole of the universe" [*In Arat*. 1.4.1], he observes that this is wrong, as this place is empty, while three stars are close to it that form a square with the tip of the pole. Interestingly, Aratus does not mention this point anywhere in his *Phaenomena* because, I think, he realized that it was wrong in the light of contemporary knowledge. One contributor to that knowledge was Pytheas of Massilia (fourth century BCE), who lived around the same time as Aratus.[12] It is interesting that apart from Aratus, Eudoxus, Attalus, and Aischrion, Pytheas is the only other person mentioned by Hipparchus. And, while Hipparchus mentions that according to Pytheas the North Celestial Pole was marked not by a star but by an empty space between several stars, he stays silent regarding Aratus' possible endorsement of the same claim. It is typical of Hipparchus not to show that a non-astronomer could be more "truthful" than a distinguished mathematical astronomer like Eudoxus. There are, admittedly, some very few occasions when Hipparchus admits that Aratus is right while Eudoxus or Attalus is wrong, for instance, when Hipparchus comments that the simultaneous risings recorded by both Eudoxus and Aratus are more correct for the division of the zodiacal circle assumed by Aratus than for the division assumed by Eudoxus [*In Arat*. 2.2.6]. But, in general, Hipparchus does not credit Aratus for correcting Eudoxus' *Phaenomena*.

There are also two very interesting points in Aratus' poem that go against the common notion that Aratus simply versified Eudoxus' work. The first is the claim in the *Phaenomena* of that the center of the cosmos is not the center of the Earth but of the observer's eye [*Phaen*. 541]. This notion was introduced by Aristarchus of Samos, a contemporary of Aratus, in his work *De magnitudinibus et distantiis solis et lunae* [prop. 8.hyp.2]. What is noteworthy here is that Aratus draws on sources more recent than Eudoxus. The second passage in the *Phaenomena* is where Aratus talks about the 19-year cycle [*Phaen*. 748–753]. It is

12 On Pytheas' life, see Kaplan 2013; *OCD s.v.* Pytheas.

PLATE 1 Fabric with Aratus and the Muses Urania and Calliope
IMAGE KINDLY PROVIDED BY THE BENAKI MUSEUM.

obvious that he is referring to the 19-year cycle allegedly developed by Meton of Athens (*flor*. 440 BCE) [Bowen and Goldstein 1988; Kidd 1997, 435–436]. Once more, then, we see that Aratus took into consideration not only Eudoxus' text but also the astronomical knowledge of his time and earlier.

The preceding analysis makes clear the need to treat Aratus under a new light by abandoning the categorization of his work as didactic and the idea that he was a poet who merely versified material written by earlier experts. Aratus was a widely known and influential poet who brought astronomy to the general public. His popularity was and still is a challenge to experts who try to understand it but only on limited literary terms. It is, therefore, essential to explore further his popularity and to appreciate more fully how it came about.

5 Material Reception of the *Phaenomena*

The ancients left behind not only texts but also a material culture of objects and artifacts. In searching for evidence of Aratus' impact in this material culture, one finds that there is an unexpected wealth of relevant artifacts spread around the Mediterranean world. Aratus' long-lasting popularity is obvious then not only from the many translations, commentaries, and editions of the *Phaenomena* and its influence on later poetry but also from Aratus' representations in art.

The first group of objects includes depictions of Aratus along with Urania, the Muse of astronomy. A magnificent and not very well-known example is a piece of fabric—number 213 of the Coptic collection—in the Benaki Museum that dates from the second or third century CE and measures 1.55 m by 0.7555 m [see Plates 1–2, pp. 391– 392]. Aratus with a halo around his head is placed in the

PLATE 2 Detail of the fabric with Aratus and the Muse Urania
PHOTOGRAPH: STAMATINA MASTORAKOU

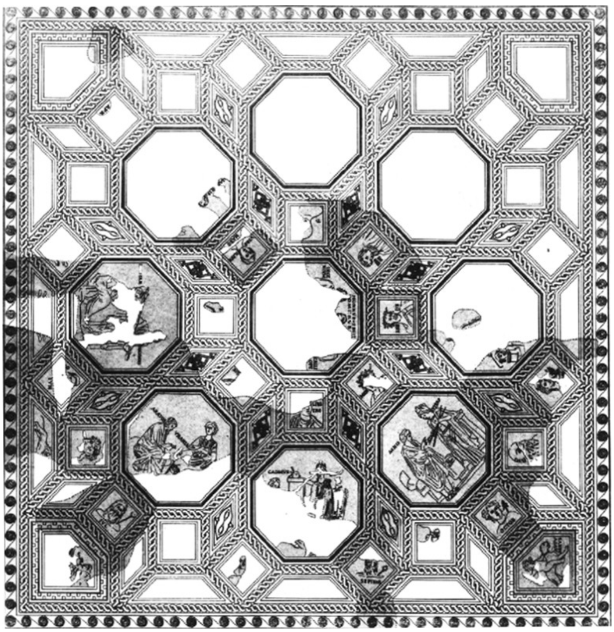

PLATE 3 The Monnus Mosaic
Aratus is seated with the Muse Urania in lower right octagon. He has «ARATOS» to the left of his head; she has «URANIA» to the right of hers.
DANIEL 1996

middle of the fabric slightly turned to the right with his head turned ¾ to the left looking up. We can be sure about the identity of this figure, as we read below it «ΑΡΑΤΟC» in white letters.

The haloed female figure on the left who is ¾-turned toward Aratus is Urania, the Muse of astronomy, as her Greek name «ΟΥΡΑΝΙΑ» below her figure makes clear. Urania is depicted checking the globe, having as her guide the book that she holds, most likely Aratus' *Phaenomena*. The second haloed female figure on the right is turned to the right, probably looking at another figure now lost; she has a halo and holds a roll. We can presume that this is Calliope, the Muse of eloquence and epic poetry, from the letters «ΑΛΛΙΟ» and hints of the letters «Κ» and «Α» as well as of some other letters after «Ο» below her figure.

The depiction of historical characters on fabric, especially in life-size dimensions, was not common in Antiquity. This is a unique example that might have been displayed in the house of a wealthy person who was a fan and admirer of astronomy or, even more, of Aratus himself. According to Apostolaki, the fabric with Aratus and the two Muses is probably a copy of a mosaic and it is unique not only because it depicts life-size persons but also because of its technique and style [1938, 8].

We find the same motif of Aratus with the two Muses on one side of a sarcophagus, while we have many depictions of Aratus only with Urania such as the one in the so-called Monnus Mosaic from Trier in Germany [see Plate 3, p. 392].[13] This mosaic consists of representations of the seasons in the extreme corners; the 12 months in the middle of the left side; eight square portraits of poets, of whom Ennius, Hesiod, Cicero, Virgil, and Menander remain recognizable and are explicitly inscribed; and eight octagons with the Muses between the corners and the central picture, in which Calliope is depicted with Homer, Ingenium. Aratus is depicted seated in one of the octagons with the label «ARATOS» to the left of his head and the Muse Urania, with the label «URANIA» to the right of hers.

In another example of the same pattern [see Plate 4, p. 394], Aratus and the Muse Urania appear on a *skyphos* from 240 BCE, which is now in Paris in the National Library.[14] Aratus wears a himation similar to the one that he wears in his herm [see Plate 5, p. 394]; he has a beard and is pointing with a stick to a globe. His whole appearance reminds us once more that the ancients represented him as a thinker, a philosopher. On the globe, which is placed on some kind of a base, there are the zodiacal circle, the sign of Scorpio, some stars, and

13 This mosaic was found in Neustraße in 1942 and measures 3.90 m × 3.40 m.

14 This is the silver *skyphos* 13, pl. 16 (after Babelon's classification) with a height of 14.3 cm, width of 17.0 cm, and weight of 578 g.

PLATE 4 Aratus with the Muse Urania
APOSTOLAKI 1938, 14

PLATE 5 A coin depicting Chrysippus on the obverse (left) and Aratus on the reverse (right)
SCHEFOLD 1997, 419

some remains of presumably some other zodiacal signs. Urania is resting her upright palm on a roll, probably *Phaenomena*, and in the background there is a lyre, which suggests that the scene also has to do with poetry.[15]

There is a second group of objects that includes herms, statues, and coins; whether these objects represent Aratus or Chrysippus is debated among archaeologists. One example is the three copies of a bronze coin that has survived from about 163/4 CE. The coins are from Aratus' birth city Pompeiopolis-Soli, as we can see from the inscription, and they portray Chrysippus on one side and Aratus on the other [see Plate 5].

15 For information on the *skyphos*, see Babelon 1916, 107; Gundel 1992, 52; Schefold 1997, 47.

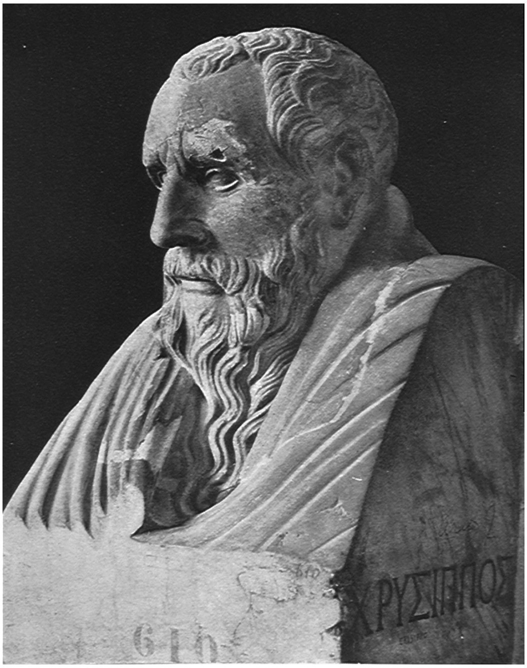

PLATE 6 A herm of either Aratus or Chrysippus
SCHEFOLD 1997, 108

Although there is a debate among archaeologists as to the identification of the heads, the consensus is that Aratus is the man with the short beard because he is looking toward the sky, as would suit the author of the *Phaenomena*, and Chrysippus is the man with the long beard, as his hand gesture matches a philosopher-type. The debate also extends to 18 statues, which according to some scholars represent Aratus and according to others, Chrysippus,[16] as well as a herm [Schefold 1997, 251: see Plate 6], a Roman copy of a bronze statue dating, according to Schefold, from 240 BCE.[17] Despite the debates among scholars about the identity of these depictions, the objects from this group show the association of Aratus with philosopher-types and especially with Stoicism, since at first sight, the last herm resembles Zeno's traditional portrait. Aratus was seen as a distinguished man of Soli, a thinker, and a prominent teacher.

16 See Bacchielli 1979, which also gives all the details concerning the debate on the confusion of Aratus and Chrysippus.

17 The name on the side of the herm, «ΧΡΥΣΙΠΠΟΣ», might be a later addition or refer to the next herm. If Schefold is right, there are 15 herms of Aratus. The argument in Bacchielli 1979, 32 that the person represented must be Chrysippus is not convincing.

6 Conclusion

It is a *topos* among scholars that in the Hellenistic Period we can detect a transition from spoken to written language. It is fair to say that this transition was not a single event or a universal and inexorable one, and that epic poetry continued to be composed and recited into the Hellenistic Period.[18] Although we cannot be sure how easy access was to Aratus' text, we can guess that, even if people did not have direct access to written copies, Aratus' *Phaenomena* could well have been spread by word of mouth. Public education is one more thing that comes to light during the Hellenistic Period [Harris 1989, 99, 137; Morgan 1999, 58], and that too might be a reason for the popularization of the astronomical knowledge in the *Phaenomena*. It is true that some historians have tried to explain the popularity of Aratus' *Phaenomena* by suggesting that in the Greco-Roman world it was used as the standard textbook of astronomy accompanied by a globe [see, e.g., Marrou 1956, 182; Cribiore 2001, 27].[19] The many commentaries and translations of the poem, and the fact that it draws on Homer's language, would facilitate its becoming part of basic education in Hellenistic Antiquity. In this context, the modifications that Aratus made in recasting his sources might constitute in part a social act. That is, the rapid increase in astronomical knowledge just before and during early Hellenistic times may have created a demand for popular versions of this new knowledge and, thus, a need for epic astronomical poetry such as Aratus' *Phaenomena*.[20] Astronomical knowledge in Hellenistic times also became a symbol of status and identity [Morgan 1998b, 23, 180]. In a world whose boundaries seemed to have expanded after Alexander the Great's campaigns, the notion of what it meant to be Greek was now inextricably linked to the notion of how one learned to be Greek. Education, in increasingly systematized forms, became the marker of social and cultural identity among peoples otherwise living under different political conditions. Astronomy and literature were the most popular subjects of the Hellenistic Period, while mathematics, although respected and admired, was for the experts and did not have a place in the common culture [Too 1995, 232]. Antigonus Gonatas, by giving patronage to Aratus at some point

18 For a discussion on the increasing use of the written word and what that meant for society, see Levitan 1979; Jensen 1980; Thomas 1989 and 1992.

19 Gee also comments on Aratus' popularity by saying, "Aratus' *Phaenomena* is a transparent substance, taking on color from the context around it. This is one of the keys to its enduring relevance" [2013, 12].

20 For this idea that scientific poetry flourished whenever there was a significant explosion of scientific knowledge, see Schuler and Fitch 1983, 29.

close to 276 BCE and sponsoring broadly educational works like the *Phaenomena*, was creating for himself the image of an educated (πεπαιδευμένος) ruler. This relation of patronage, which was probably based on the same *paideia* and Stoic leanings, is particularly interesting in a period when the political situation was not stable and cultural propaganda was so essential.

Aratus' place in the history of ancient astronomy manifests itself in many different ways: he figured importantly not only in translations, references, literary verdicts, scholia, and commentaries but also in material culture. Both ancient objects and texts indicate that Aratus and his work were very popular and influential from the Hellenistic Period well into Roman times. Aratus was the person whom the ancients associated with astronomy; his image was well known and easily recognizable from Hellenistic times onward. The *Phaenomena* engaged a range of people: mathematical astronomers, philosophers, poets, kings, emperors, artists, epigrammists, as well wealthy and common people alike. Aratus was a thinker, a person who observes the heavens and unlocks their secrets; his work was probably mainstream and praised by his contemporaries and imitated by his successors.

My aim has been to show that, because of their preconceptions, modern historians of astronomy have not fully understood how and why Aratus made astronomy popular. But having come this far, new questions arise, each requiring further research and thought. For example, with Aratus' poem, did astronomy become subject to non-technical demands? Did it then begin a process of transformation by which it ceased to be the preserve of cosmologists and philosophers? Was Aratus' poem, then, a key factor in creating the context in which the later interest in horoscopic divination was cast as a demand for changes in the traditional Greek astronomy?[21]

21 On which, see Bowen 2013a and 2002.

CHAPTER 10.2

The Authority of the Roman Heavens[1]

Alfred Schmid

1 Introduction

Giuseppe Tomasi di Lampedusa's classic novel *Il Gattopardo* (*The Leopard*) is set in the time of the fading glory of the Kingdom of the two Sicilies (which will end with the deposing of kingship by Garibaldi's troops in 1860). The story's hero, Fabrizio, Prince of Salina, finds consolation for the progressive decay of his world as an amateur astronomer. From his private observatory, he gazes at a world of lasting purity that is governed by painless numbers. The authority of the starry heavens is evoked in the novel as a metaphor for the yearnings of a dying era: the era of monarchic power that will give way to a new republican age, a world of anti-monarchical, secular, and self-regulated societies which is still our world today. And this political change of paradigms may invite us to look back to an earlier, opposite transformation. Almost 2000 years before the novel's time, Augustus inaugurated an epochal change from republic to monarchy. Rome's first emperor is a founding figure of Western monarchy and he believed so firmly in the power and authority of the stars that he made the zodiacal sign of his birth, Capricorn, into a popular logo [Schmid 2005; Barton 1995] or signet of the new kind of power that he consolidated and wielded in the wake of Julius Caesar's death in 44 BCE. This image of Capricorn, which became a favorite motif in the iconography of the principate, must mean the Lot of Fortune (*Pars Fortunae*) in Augustus' horoscope, though the issue remains debated [Schmid 2005, 19–54], thus signifying his unshakeable good luck, an apt quality for a king. Plate 1, p. 399 of the Gemma Augustea shows Augustus seated beside the Goddess Roma under the image of Capricorn.

Augustus set a trend in his public reverence to astrology.[2] After him, almost every emperor was affected in some way by astrological rumors and came into contact with the relevant experts—Greek astrologers.[3] Nor did the star–

1 The English of this chapter has been corrected and modified by my friend and colleague John Weisweiler. Any remaining oddities are due to my own stubbornness.

2 He even published his horoscope in 11 CE by edict: see Suetonius, *Aug*. 94.12; Cassius Dio, *Hist. Rom*. 56.25.5. Barton [1995, 48] was certainly correct when she wrote, "There could have been no more official endorsement of astrology."

3 There are innumerable passages in the ancient sources about the later emperors and their entanglements with astrologers/astrology. Some emperors, Tiberius and Hadrian (certainly),

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PLATE 1 The Gemma Augustea

spangled heaven appeal only to the most powerful. It became a favorite topic in Roman literature,[4] an object of religious piety,[5] and of philosophical reflection: since Plato's *Timaeus*, the ensouled sphere of the universe [Scott 1991; Moreau 1939], driven by divine intelligence,[6] had become the leading metaphor for order and intelligibility of things outside and inside the human realm. But how can we make sense of this coincidence of socially visible star-lore[7] or even a kind of star-religion[8] with a monarchy that had risen from anti-monarchic premises to the lasting condition of sociopolitical order?[9]

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and Caracalla and Titus (allegedly) were steeped in astrological lore and must have mastered the astronomical knowledge required for that [Schmid 2009, 218f.].

4 Prominent texts include the *Astronomica* of Manilius and the *Aratea* of Germanicus (himself a member of the royal family): see, e.g., Le Boeuffle 1989; Gee 2000; and ch. 10.1, p. 383.

5 See Cumont 1912a, 57–91; Gundel and Gundel 1966, 303–305 (with further literature); and Schmid 2007.

6 For the theology of a world-moving divine mind, see Krämer 1964.

7 One of the lasting monuments of this popularity of things on high is the 7-day planetary week that is not attested before Augustus [Le Boeuffle 1989, 18–19]. The order of the planets is tricky [see, e.g., Boll 1912]. That the symbolism of time and its cosmic order was a dominant subject of Augustan iconography seems obvious: see, e.g., Schmid 2005, 181–182, 305–340; Rehak 2007, 74–80.

8 See p. 399n5 and the first volume of the monumental work by A. Festugière on Hermetism [1949–1953], which forcefully suggests that a learned astral piety was older than astrology in the Greco-Roman world. Eastern influence can, of course, never be excluded but it is worth noting that the heavenly realms did not gain their dignity and sanctity in Greece before the fourth century BCE, before Plato, that is. Earlier thinkers like Anaximander or Anaxagoras and Democritus had not treated the heavenly stuff with much respect.

9 The first emperor was even said to have the constellation of Ursa Major as a birthmark on his

2 A Paradigm for Social Order

That the stars had something to do with the eternal and the divine and for this reason were interesting symbols for a rising power with claims to superior and paternalistic authority is exemplified by Roman coins dating from Feb 44 BCE, the last days of the Dictator Julius Caesar, showing his portrait on the obverse with a star behind his head.[10] But the stars had not only become signifiers of things holy. They had transformed into fully fledged gods, whose latinized names have preserved until our times the memory of Jupiter, Mars, Venus, and their relatives. Stars also came to be viewed as accomplices of Fate [Virgil, *Aen.* 4.519f., 9.429] and were associated with order, [11] with law,[12] and, not least, with rationality and coherence.[13] This respectability of the heavenly spheres is surprising, since there was no indigenous tradition of astral piety in Rome as there was none in Greece, though in both the stars were commonly held to be divine. The idea that things in heaven might serve as paradigms for social order and structure was common in ancient China, where the constellations around the polar star (which signified the monarch) were thought to be the models for the imperial bureaucracy [Needham 1974, 68 ff.; Lloyd and Sivin 2002, 223]. In Mesopotamia, the heavenly bodies were watched in the king's service [Rochberg 2004b; Koch-Westenholz 1995, 56–73; Brown 2000b, 33–52] and eclipses both solar and lunar elicited serious ritual for the king [Maul 2000]. But, in Augustan Rome, the relevance of the astronomical realm was a recent and unofficial import. Its precondition was Greek astronomy, which E. R. Dodds [1970, 123] has rightly called Hellenism's leading exact science. The latter had been affected by a "theological" concept of

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belly [Suetonius, *Aug.* 80]: cf. Ovid, *Met.* 15.816–851, where the dying Caesar is lifted up into heaven.

10 Crawford 1974, 480–485, 489 and Bechtold 2011, 141ff. The meaning of this star is controversial but it might signify nothing more than a connection with the divine that remained undefined in terms of the traditional religion of the state gods, one of which Caesar was to become himself. The star had by this time also become the hieroglyph for god (*netjer*): see Bergmann 1998, 64–65.

11 E.g., Manilius, *Astr.* 2.82–86, 4.14–16. The heavens were imagined as paradigmatic for political order and hierarchy: see Manilius, *Astr.* 5.738f. See also the critical remarks by Eric Voegelin [1974, 35, 200] on an imperial deformation of the cosmos and especially on the pseudo-Aristotelian *De mundo*, where the world is cast as an imperial giant.

12 E.g., Manilius, *Astr.* 1.671: cf. Schmid 2005, 305–335 on the cosmos as metaphor of equality and justice in the image of the equinoxes.

13 Note the famous Manilian motto, "ratio omnia vincit" [*Astr.* 4.932: cf. 1.95ff.]. On the cohesive quality (the *conspiratio mundi* or cosmic sympathy) of the universe, see §3, p. 401.

the cosmos since the days of Plato [Schmid 2005, 119–183; 2007]. Since the second century at the latest, Babylonian methods of star-reckoning for ominous purposes were adopted in Ptolemaic Egypt, leading to astrology in the sense that we are acquainted with [Pingree 1997, 21–29; Jones 1999a; Derchain 1999].

The new science must have been fashionable, when sometime between Dec 45 and Mar 44 BCE two young Roman noblemen went to consult the astrologer Theogenes in Apollonia (on the Adriatic coast of today's Albania) to have their future unveiled [Suetonius, *Aug*. 94.12]. The consulted expert, or so it was later said,[14] "jumped up" and "prostrated himself" before the young Octavius (who later would become famous as Caesar Augustus). An otherwise unknown astrologer was thus the first person to recognize and declare the sacred quality[15] of the Roman emperor, many years before the senate officially conferred upon him the name "Augustus" in 27 BCE. The same sacred quality was later also believed to inhere in the Julio-Claudian family, which was to embody hegemonic power over the world until Nero's death—a world that could be perceived as global in the very concrete sense of the celestial globe, the substantial world-sphere that was merely imitated by the spherical shape of the Earth.[16]

But what is specific about a power that can be signified, symbolized, or illustrated by the starlit outer sphere of the world?

3 A Coherent World (*mundus*)

One often quoted quality of the world (*mundus*) as conceived in ancient times was its coherence. Such togetherness or inclusive structure was symbolized by the all-embracing spherical form of the outer heaven or celestial sphere. This image of coherence or cosmic sympathy [Reinhardt 1926] was translated into Latin by the terms "conspiratio" or "consensus" and by the verb "convenire" [Manilius, *Astr*. 1.148]. Thus, the appearances of things "convene" or "come together"; they are connected and included in a wholeness of the world. Its

14 The source is not very pure as it might have its origins in the lost memoirs of Augustus himself.

15 See Schmid 2005, 2n5 with reference to nativities of gods as a subject of astrological manuals of the time.

16 For the astronomical spheres, see Lerner 1996. For the spheres as part of a conception of the world, see Schmid 2006. For the (celestial) globe as a political symbol in Rome, see Schmid 2005, 200, 248–249.

inclusive quality was also termed by Ptolemy as the «περιέχον», meaning the surrounding, astrologically relevant, zone of the world [e.g., *Tetr.* 1.1–3: cf. Plato, *Tim.* 31a, 92c].

The symbol of an ordered, intelligent cosmos (*mundus*)[17] that was astrologically powerful [e.g., Manilius, *Astr.* 1.35f.] and reliable had an obvious appeal for a society which had lived through a long period of social turmoil and civil wars, and had finally reached a new unity under the "peaceful" reign of Augustus.[18] This society lacked a mythic cosmology of social relevance such as there was in Mesopotamia and other monarchical societies. Yet, since the battle of Actium, it had better reasons than ever to regard itself as the ruling power of the whole inhabited world, the political embodiment of a new world order which in turn was embodied in the *princeps*. And the latter could regard this imperial and social fact as preordained, as did his supporters such as Virgil.[19] The appeal of what might be called a "correlative" quality of things—to employ a concept invented to describe Chinese thinking[20] where monarchy was never in doubt—is also present in the wider culture [e.g., Habinek and Schiesaro 1997] of the Augustan age, as can be seen in Virgil's *Georgica*, in the "cosmic" imagination around the *Ara Pacis*, or simply in the popularity of the symbolic connection of the *princeps* with a part of the zodiac. Poets such as Virgil and Horace laid claim to the role of a seer (*vates*) that had superior insight into the worldly order of things and their connectedness.[21] On the subject of Manilius, the Augustan author, Katharina Volk [2009, 30n39] aptly speaks of a "blurring of boundaries between science and the object of science, poetry and its subject matter, and human beings and the cosmos".

The outermost sphere of the world (*mundus*) was normative, enlightening, life-giving, and an inexhaustible source of power.[22] Everything participated in

17 For the heavenly bodies as thinking gods in Plato and later, see Karfik 2004, 128.

18 See Schmid 2005, 305–335 and Rehak 2007, 62–127 on the *Ara Pacis* (Altar of [Augustan] Peace) and its cosmic conception of peace (in combination with the alleged sundial).

19 In *Aen.* 6.791ff., the *princeps* is already announced and foreseen in mythic time; he is shown in a vision in the underworld to the mythic founder of the Julian *gens*, Anchises.

20 See Loewe and Shaughnessy 1999, Index *s.v.* correlative.

21 In Virgil's *Georgica*, with its correlation of mundane particulars under the influence of Aratus and Stoic philosophy, man is a politically innocent, piously laboring figure concerned with agriculture. See Schiesaro 1997; Hardie 1986, 16f. on Virgil as an Augustan *vates*.

22 This source of all motion is aptly described in Aristotelian terms in Lerner 1996, 53:

> ce moteur meut en tant qu'il est objet de désir et d'intellection de la part du premier ciel. Il meut comme un objet d'amour meut celui qu'il aime, c'est-à-dire à titre de cause finale, une cause à laquelle sont suspendus le ciel et la nature, et que le Stagirite, en quelques lignes admirables mais obscures, identifie à la Vie, à la Joie et à la Pensée pures.

the communality of origins[23] and the stars made this participation visible: the world (*mundus*, κόϲμοϲ/οὐρανόϲ)[24] was the ideal container of a common reality shared by anyone and everything. This was a reality with mythic qualities, if we take myth simply as a story involving the gods. The outer spheres of the stars were nearer to the divine, the origin of all things.

4 Astrology and Authority

But the cosmos was not all just harmony.[25] Or if it was, it had to overcome a fundamental paradox. Astrology propagated a subversive concept of authority on closer inspection. By taking the all-encompassing authority of the cosmos as its norm, its practitioners ignored human collectivities as the main source of state-power. Genethliacal astrology was based on the analysis of nativities, horoscopic charts that translated the moment of somebody's birth into cosmic parameters. But these individuals had a rhythm or cycle of life of their own. As Aristotle (prior to the advent of astrology) had argued against Plato's concept of global cycles of change, each organism had its own share in time. In his view, what does not begin at the same time will not change at the same time [*Pol.* 1316a14–17]; nor will it reach maturity or decline at the same time. In other words, an entity with its genesis will by nature find its end in its due time. To that extent, then, it will be independent of its social environment and norms.[26]

23 See Schmid 2007 on the "physico-theological" conception of the heavenly world-shell as an eternal presence of the Origin (*Ursprung* in German).

24 The synonymity of the terms «κόϲμοϲ» and «οὐρανόϲ» was an important theme of Plato's *Timaeus*: see Festugière 1949–1953, 1.128n2, 1.224n4.

25 Symmetry was a paramount feature of the κόϲμοϲ [Plato, *Tim.* 55a, 63a–b, 69b, 73b–c, 87a–d, 88c, 90a; Schmid 2005, 13n57]. But the cosmic model had also to mirror the disharmonic, the violent features of the inhabited world, whose generic frame it was; it had to be martial. Thus, the planets fight against the diurnal motion of the sky [Manilius, *Astr.* 1.259]. And even more: they virtually had to create war. Every discord and all misery in the inhabited world would stem from a dissension of the stars [*Astr.* 2.603–607]; not even the civil wars were ever in the hands of men alone [*Astr.* 4.84]. Hate as well as peace must be inferred from the stars [*Astr.* 4.84, 2.641]. See Schmid 2006, 148.

26 The problem of this paradox must have been recognized in astrology and its criticism: group-catastrophes (natural and political) were a problem for the doctrine of individualized fate. See Cicero, *De div.* 2.97 with the "Cannae-argument", which opens with the question of whether all the men killed together in the battle of Cannae had the same "bad" constellations. See Beck 2007, 101–111 and Komorowska 2004, 252–360 on Vettius Valens' attempt to prove that six persons affected by the same shipwreck—Valens had collected their horoscopes—must have had adverse constellations individually and independently at the same time.

A man like Augustus, who claimed that his rise had been structured by a horoscope that declared him a god among men at his birth,[27] could no longer be defined in constitutional terms. Of course, the historical facts of his birth were somewhat more mundane. The first emperor was the son of a municipal councillor, who happened to have married a niece of Julius Caesar at a time when the future Dictator had just been chosen *Pontifex Maximus* and was one of Rome's most ambitious and scandal-stricken politicians.

The stars knew better. The ominous authority of these superior beings[28] who plowed their way through the heavens under some supreme command (*imperium*) [Manilius, *Astr*. 1.496], provided Augustus with an unshakeable source of authority and even legitimacy.[29] The fact that his power had been preordained by the stars[30] went a long way toward dispelling any legal or constitutional objection to his new *régime*. It is true that the *princeps* did honor legal tradition and convention explicitly after degrading it and that this must be seen as a reverence to the enormous social power of Roman tradition (the *mos maiorum*).[31] However, more astonishing is the fact that he successfully overthrew the traditional political order and adapted it to the new monarchical reality that he represented (with due understatement when this seemed necessary). Augustus was a Roman citizen and had been so at his birth. He was part of Roman politics in its eternally successful tradition. But, at the same time, in his elevated individuality, he became the condition of all of politics in Rome and elsewhere.[32] His numinous personality[33] hovered over it and surrounded it like the sphere of heaven, thus providing an important emblem for the new

27 That the Sun near the ascending degree of the horoscope was regarded as a mark of such a royal birth is argued in Schmid 2005, 283–293. Of the emperors whose horoscopes we know, Augustus, Nero, and Hadrian are said to have been born at sunrise. I argue that the "solar-Apollonian" horoscope was the reason for Nero's reverence to Apollo—which he was the first to emphasize since Augustus—as it had been for Augustus'.

28 Cicero (interpreting Aristotelian physics) even held that the celestial bodies and mind were made of the same "quintessential" stuff [*Tusc*. 1.22, *Acad*. 2.1.7.26: cf. Moreau 1939].

29 The world, geometrically idealized as a sphere, was also the natural root of justice: see Schmid 2005, 316ff.

30 The concept of Providence (πρόνοια) had gained importance since Plato [*Tim*. 30c] and, together with related ideas and notions to denote a superiority of Fate, became part of a general Hellenistic tendency toward teleological physics, anthropology, and epistemology [Schmid 2009, 214–215] that affected even historiography.

31 In *Res gestae* 6, Augustus claims explicitly that he never accepted any official duty contravening tradition.

32 In the introduction to his *Res gestae*, Augustus claims that by his deeds he had subjected the entire inhabited world to Roman power.

33 See Pötscher 1978 on the *numen Augusti*, which also became part of the official cult.

and happy order.[34] A cosmic consensus had raised him to this lofty position. It functioned independently of any social bonds and of the internal consensus[35] of the society in which the new ruler had risen to power. And as a mediator of cosmic influence on society,[36] Augustus obtained the stature of a real king.[37]

The fact that the heavens became socially visible in the period when Rome was transformed from an anti-monarchical into a monarchical society is symptomatic of a paradigmatic re-invention of authority.[38] The new authority was as fateful as the stars. The stars (in their astrological role as rulers of Fate) served as symbols of a revolutionary process that led societies away from human autonomy to its subjugation to external agencies. In Greek tragedy, the human heroes had been confronted with the gods representing Fate's objection to a politically based human freedom. And similarly, the stars could now symbolize the new order of monarchy in an anti-monarchical culture. They represented the stern negation of autonomy in a society that could not simply abolish its glorious tradition of liberty.[39]

5 A Shift in Paradigm

The appeal to things in heaven (from Aratus to astrology) is symptomatic of a paradigm shift in the full sense of the term. This shift took place not only in the political but also in the mental horizon of the leading societies of Greco-Roman Antiquity. There was a new longing for an authority beyond the futile contingencies of willful arbitrariness. Plato introduced new gods—the star-gods—and thus started a transfer of meaning which sought to deepen the significance of those lofty areas beyond human control, the luminous outer shell of the κόσμος/οὐρανός. To this religious transformation corresponded a foundational concept of individuality.[40] Individuality might function as a potentially hege-

34 See Schmid 2005 and Barton 1995 on Capricorn, the sign presaging fortunate beginnings for the *princeps* and thus for all under his tutelage. Another favorite idea of the time was the Golden Age that was to dawn with the new order: see Schmid 2004, 91–92.

35 In *Res gest.* 34, Augustus claims that he had gained power over all state affairs by universal consent. But humans seldom reach such a consensus.

36 This is apparent on coins and monuments of the time in an iconography of astrological or more generally "cosmo-theological" allusions.

37 For the king as mediator of cosmological influence, see Schmid 2005, 65–91; 2011.

38 See Gordon 1996, 50 on the cult of Mithras under the heading of "invention of authority".

39 So the *princeps* had to claim that he was in fact the "avenger of freedom" [Augustus, *Res gest.* 1].

40 The individual here amounts to no more than an agent inside or outside a collectivity that

monic agency which resided in the depths of such socially invisible conceptions as "soul" or "spirit"—a realm not tied to collective and externally visible concepts and norms in the first place but to its own spirit or character (δαίμων). This turned out to be easily compatible with the astrologically calculated fate, with a "nativity" in the model of a horoscope where it was conceived as connected immediately to the very stuff of which the stars were made. By its life, this spirit responded to the kinetic impulse of pure and uncorrupted being. It should not be forgotten that, for Aristotle (who relied on Plato), the stars along with the invisible spheres had a theophanic quality: they marked a new visibility of the divine and as such constituted the counterparts of the new, visible gods in politics.[41]

It should be kept in mind, though, that the "Greek" stars originally did not have a political function, despite the fact that Plato's emphasis on the heavens originated in a debate about political crisis and its remedies.[42] The astronomers of China, Mesopotamia, and Egypt were part of the state authority, whereas the astrologers of Rome (whose superstars became friends of the emperors) could always be subject to expulsion, prosecution, or serious regulations [Cramer 1954; Fögen 1997]. In Rome, despite Manilius' metaphor of the stars as a republic, astral fate became political only through the individual owner of a horoscope. The political relevance of the stars thus depended on the social status or function of the owner of the horoscope.

The new interest in the appearances of heaven was coincidental in Rome with a revolutionary transformation: from anti-monarchy to monarchy. In this respect it seems meaningful that the first political usage of the term "revolutio" can be found in the early 12th-century Latin translation by Herman of Carinthia of Abū Maʿshar's great treatise on the sweeping qualities of eternal heaven, *The Great Conjunctions of Saturn and Jupiter*. [43]

As for the paradoxes of revolutionary change generated by immutable essentials, the antinomistic point of the famous proverb "If we want everything to stay as it is, everything must be changed" in the *Gattopardo* had received poetic articulation by Horace, one of the bards of the "Augustan revolution" [Syme

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could oppose it in different, heroic, scandalizing, or tragic roles. The individual could also be connected to an inner life with superior, or simply aberrant, truth-claims. Sometimes it even founded religions.

41 After Hecataeus of Abdera and Euhemerus, there were only two kinds of gods: the kings and the stars [Henrichs 1988, 147–148].

42 In Plato, *Leg*. 894d–898e, astronomers are guardians of the constitution.

43 See Yamamoto and Burnett 2000, 100.2. John of Seville translated the Arabic term using "mutatio". So "revolutio" in the sense that implies change of dynasties or new sects is especially Hermans' translation. See also Smoller 1994, 191n17; Schmid 2005, 409–410.

1939]. He was given the task of writing a hymn for the secular games, a festival conceived to celebrate the beginning of a new age. Augustus himself, the founder of the new social order, acted as the priestly authority of this new age of purity, prosperity, and youth.[44] The festival was largely a new creation but drew on ancient ritual tradition—an old prophecy was invented on the occasion and all had to be announced by a comet, which is represented on a denarius from 17 BCE [Kienast 1999, 118n129].[45] It was celebrated in early summer of 17 BCE for three nights and days at Full Moon, a fact first noticed by H. Dessau in 1910 [Schmid 2004, 96]. The Sun and Moon, "the world's brightest lights" [Virgil, *Geor.* 1.5f.], play a great role in Horace's poem. Horace appeals to the Sun:

> alme Sol, curru nitido diem qui
> promis et celas aliusque et idem
> nasceris, possis nihil urbe Roma
> visere maius.
>
> Life-giving Sun, who brings out daylight by your shining chariot
> and hides it, and is born the same and
> different, may you behold nothing greater than
> the city of Rome.
>
> HORACE, *Carm. saec.* 9–12

The Sun, nurturing and divine (revealing and hiding the day) is born anew and still the same. On the one hand, this quality of being the same and different neatly expresses the revolutionary beginning of the Augustan monarchy—a form of kingship that claimed to be the fulfillment of the honorable republican tradition that it had overturned. On the other hand, this seemingly paradoxical quality marks kingship from the oldest form in myth up to the more modern or enlightened forms. Monarchy seems to have the capacity to function as the alternative to itself: "The king is dead; long live the king!" The alternative to a king is a new king. The "individual" (i.e., mortal or temporal) base of this form of rulership is also the guarantee of its renewal. Every king is a new one, a "nativity", a new birth, and, in astrological terms, a new horoscope. A new king could

44 See Schmid 2004 (with further literature on the *ludi saeculares*). For Augustus as founder of a *novus status*, see Suetonius, *Aug.* 28.2.

45 The comet depicted might well be the Julian Star which appeared in 44 BCE on the occasion of Caesar's funeral games: see Ramsey and Licht 1997.

even be conceived as the beginning of a new era of revolutionary hopes[46]—a newborn child smiling at his mother at birth like the ominous boy of Virgil's fourth eclogue, which announced the return of Saturn's reign, of a Golden Age of peace and prosperity.

6 Conclusion

A physico-theological world, enveloped by divine spheres that were always in motion (and were the stable origin of all motion themselves) might be regarded as the natural solution of the political *Gattopardo*-paradox. It had been conceived at a time when autonomous societies (democratic or aristocratic ones) found their way to monarchy—a change of paradigms that modern scholarship has hardly noted for what it was. Since Plato, mathematically based theorizing and theologizing of the things on high was a prestigious undertaking for educated men (and sometimes women). It reached its canonical form with the mathematical astronomy of Ptolemy of Alexandria and provided the ultimate model of hierarchically structured order: a world of guided unrest. This world functioned as a symbol of authority and its revolutionary origins until the times when Galileo's telescope and Descartes' methodological attack on teleology in nature began to dissolve its theoretical glue. From that time on, the universe was no longer a model-community of being that changed restlessly and unendingly like time itself and yet never ceased to be that same old world that people lived in as did their ancestors and as would all future generations.[47] On this world, Aristotle had remarked that the eternal (and heavenly) motion that is its seminal reality [48] has always reached its goal [*Meteor*. 339a26]. Incessantly moving as the guarantor of continuous being, its unrest has always and already found its end.

46 Note the unreal expectations of many all over the empire when Caligula came to the throne after Tiberius' death [Philo, *Leg. ad Gaium* 6–20].

47 See Effe 1970, 43 on the world after Aristotle that was marked by an "eidetic continuity of being" and Moreau 1939, 73–75 on the circular motion that "conserve dans le changement le maximum de l'identité".

48 True reality or actuality is above all motion: see Aristotle, *Meta*. 1047a30–32.

Hellenistic Astronomy in the Training and Work of Priests

CHAPTER 11.1

Hellenistic Astronomy and the Egyptian Priest

Alexandra von Lieven

1 Introduction

In ancient Egypt, both before and during the Hellenistic Period, astronomy was closely linked to a learned priestly class. And during this period, astronomy and astrology remained subjects of the highest interest within the native Egyptian priesthood serving the traditional Egyptian gods. In fact, among the very last dated inscriptions in the temples of Dakka and Philae are three third-century CE graffiti recording the priestly title "prophet of Sothis, overseer of the course[1] of the Moon, priest of the five living stars [i.e., the planets], who knows the time of the eclipses of Sun and Moon".[2] Despite the fact that for these particular individuals (actually, members of the same family) an at least partially Meroitic background has to be taken into account [Török 2009, 459–461], these occupations also fit well into the traditional Egyptian priestly curriculum.

The reason for the importance of astronomy is, of course, the ancient Egyptian conception that the gods were manifested in the phenomena of (what we call) nature [von Lieven 2004; Fischer-Elfert 2008] and in those of the sky in particular. While this viewpoint might have struck a certain chord in the Hellenistic Period, when some Greek authors gave explicit interpretations of traditional myths as allegories of natural phenomena, it is nevertheless present in the oldest texts known from Egypt, the so-called Pyramid Texts [Krauss 1997][3] from the early third millennium BCE. Indeed, these texts were still relevant in the Hellenistic Period when copies of certain spells of the Pyramid Texts are attested. The libraries of the temples were thus repositories of millennia of collected knowledge concerning the gods and the phenomena.

1 Read «ỉmỉ-r' mšʿ», a title that could as a whole be understood as "general". As, however, «mšʿ» is not written with the hieroglyph of the soldier for «mšʿ» ("troop") but with the group for «mšʿ» ("travel"), the translation given here seems preferable. At any rate, the horned owl is to be read «ỉmỉ-r'», not simply «m».

2 Graffito Dakka no. 30 [Griffith 1937, 26–31, esp. 27–28], similarly with slight variants Graffito Philae nos 410, 421 [Griffith 1937, 112–113, 121–122].

3 So named by Egyptologists after their oldest preserved attestations on the walls of the pyramids of Dynasty V, despite the fact that there is nothing intrinsically linking them with pyramids.

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2 The Written Word

The practice of this tradition of knowledge implies that old texts were not deliberately withdrawn even if their views on astronomical phenomena were long superseded. Thus, a temple library of the second century CE, such as the one at Tebtunis[4] in the Fayum, contained not only many astrological treatises operating with, e.g., the zodiacal constellations, but also six copies of the age-old *Fundamentals of the Course of the Stars* (*snč šm.t n.t sbꜣ.w*). This work was a treatise on the course of the Sun, the lifecycle of the decans, and the phases of the Moon and the planets.[5] The treatise is positively attested for the first time around 1290 BCE; but given certain linguistic as well as astronomical criteria, it apparently dates originally from the third or, at the very latest, the early second millennium BCE.[6]

All the late astronomical/astrological texts that are not copies of earlier works are composed in the stage of the Egyptian language known as Demotic. However, occasionally, the priest-scholars also translated a traditional text from an older phase of the language into Demotic and then added a commentary in Demotic as well. This practice is attested for two copies of the *Fundamentals of the Course of the Stars*.[7] Interestingly, the commentary only tries to elucidate the text as it stands—including a part where the text has been jumbled for some reason in the course of transmission. It does not attempt to update the information provided in any way, at least not consciously. How faithful the late commentary is to the original intentions of the commented text is not always clear. For example, its explanation of the concept of the decans as expounded in the original work has been strongly debated in recent scholarship [Symons 2002] without, however, there emerging any plausible alternative. Until proven otherwise, it seems reasonable to assume that the late priests still understood the older outdated concepts very well.

It is also important to state that all astronomy in the older periods would have been kept in papyrus-scrolls in the library. The wealth of astral knowl-

4 For its contents, see the preliminary overview by Ryholt 2005.

5 At least three possible planetary names are mentioned in the last chapter along with further lunar mythology. Leitz [2008–2009, 17–19], however, interprets this part as referring only to the Moon.

6 Usually, the original age of a composition is evident not only from its contents but also from the character of its language [von Lieven 2007, 223–250; 2013b]. In many instances, however, despite the growing evidence in its favor, an earlier dating based on linguistic evidence is still either ignored or even denied by many Egyptologists.

7 For an edition and commentary, see von Lieven 2007: cf. von Lieven 2012 for some improvements on the interpretations. On the translation specifically, see von Lieven 2010c.

edge stored there in, e.g., the New Kingdom and earlier is at least hinted at in the autobiography of the high official Amenemhet around 1520 BCE [von Lieven 2016]. He claims to have found out the different lengths of the night during different seasons as a result of studying ancient sacred writings. This raises the possibility that Egyptian temple astronomers kept records concerning astronomical phenomena, although such records are no longer extant. The possibility of texts of this sort would lend credence to statements by Aristotle [*De caelo* 2.12] and Seneca [*Nat. quaest.* 7.3.1–2], who attribute such observations and records not just to the Babylonians but also, in particular, to the Egyptians. It is, however, not certain just what these later Greek writers were referring to in the Egyptian context.

In contrast, the numerous astronomical/astrological depictions on the ceilings of temples and in tombs, sarcophagi, and coffins,[8] although highly significant in their symbolism, were not intended to represent the state of the art of the astronomy of the time. Yet, even here, the time-honored traditional compositions were updated with new elements or even entirely supplanted by new decorative schemes in the Hellenistic Period. The gradual disappearance of the so-called Classical Sky Picture[9] in favor of zodiacal depictions is a clear case in point.

As for the libraries, while most of them are lost, it is at least possible to get an impression of their holdings from book-titles that are cited elsewhere. The Demotic commentary to the *Fundamentals of the Course of the Stars* itself cites a few other works that seem at least partially to have been astronomical or astrological, judging from titles like “Primeval Sky” («gb.t pꜣ.t») and “The Influences of Sothis” («sḫ̮n.w spṭ.t») [von Lieven 2007, 284–290]. The book-catalog in the small library of essential books in the pronaos of Edfu also contained a book titled “Knowing the Movement of the Two Lights, Ruler of the Lamps” («rḫ̮ nmt.t ḥꜣỉ.tỉ ḥḳꜣ ḫ̮ꜣbꜣs.w»).[10] The determinatives indicate that the two lights are the Sun and the Moon, and that the lamps are the stars. This fits well with the description of a procession of priests by Clement of Alexandria [*Strom.* 6.4.35.2–37.1], which states that the *horoscopus* (ὡροσκόπος, i.e., the *ỉm.ỉ-wnw.t*, or he who is in the hour) and the *hierogrammateus* (ἱερογραμματεύς, i.e., the *sẖꜣ mḏ̌ꜣ.t nčr*, or scribe of the god’s book) were supposed to know by heart several

8 For a selection that is relevant for the period treated here, see Neugebauer and Parker 1960–1969, vol. 3; the most important addition since then is Kaper 1995.

9 I.e., depictions of a type similar to Neugebauer and Parker 1960–1969, vol. 3, pls 1–13, 15–22, 24–28.

10 See Grimm 1989, 160. For the reading, see von Lieven 2000a, 49–50n172.

astronomical and astrological treatises on the fixed stars; the movements of the Sun, the Moon, and the five planets; and conjunctions and risings of stars.[11]

3 The Paramount Celestial Objects

The fundamental celestial entities relevant for traditional Egyptian astronomy were the Sun, the Moon, the planets, the decans (which included Sothis in particular), Orion, and the Big Dipper. From the third, or possibly the sixth, century BCE, the zodiacal constellation imported either directly from Mesopotamia or later *via* the Greeks as intermediaries were added to this group, implying some changes or at least readjustments of older concepts.

3.1 *The Sun*

The Sun was in all periods the most important heavenly body in Egyptian astronomical thought [Quirke 2001; von Lieven 2002b and 2010b]. It was always the most important deity and the very close tie between the Sun-God and the physical object visible in the sky is evident from the fact that from the New Kingdom onward, and particularly in the latest periods, the name of the Sun-God "Re" (literally, "Sun") is quite regularly prefixed with the masculine definite article to form "Pre" (literally, "The Sun"). A similar development cannot be pinpointed for any other deity except for Aton (literally, "Disk" or possibly "Orb"), the short-lived form of the solar deity during the two decades of the Amarna Period around 1350–1330 BCE. Aton is in fact almost always called Pa-Aton (literally, The Disk) when his much longer theological name is not used. Thus, for the Egyptians, the link between the most spectacular astronomical entity and their supreme deity was manifest. This explains why close observation of the Sun's movement during the day and its religious interpretation always occupied a prime position in priestly astronomical science.

The course of the Sun during a cycle of daytime and nighttime was interpreted in different ways. One classic concept has it as a journey by boat. Depictions like the one on the ceiling of the hypostyle of the Temple of Dendera attest to the ongoing importance of this concept in the Hellenistic Period. In fact, the late depictions elaborate on the idea even more than the earlier ones. While it was always thought that the Sun-God would have a nighttime and a daytime bark and that there would be a few other subtle changes over time,

11 Cf. Sauneron 1988, 146–147; Osing 1999, 127–140; von Lieven 2007, 297–298 (contrary to the statement there, the issue may need to be reevaluated nevertheless).

the Dendera-ceiling shows a different ensemble for each hour. Not only does the form of the Sun-God himself change with each hour, there are also variations of the bark and its divine crew. Even the enemy Apopis, shown speared below the bark's prow, is shapeshifting from one hour to the next. Similarly, each hour is personified by a goddess who has a different name for each hour. Those of the daytime wear a Sun-disk on their head; those of the nighttime wear a star instead. Thus, their headdress points to the methods of measuring time during daytime and nighttime, respectively. As the different names of the hour goddesses were a matter of priestly scholarship, it is no wonder that the Tebtunis *onomastica* [Osing 1998]—encyclopedic reference works kept in the temple library—give lists of the goddesses, not just one, but actually several according to different traditions.[12]

Similarly, the different shapes of the Sun-God himself had a long tradition of priestly interest, most notably the Ritual of the Hours [Graefe 1995, 2001–2019]. In the Hellenistic Period, there was apparently a canonical list of 12 shapes which made its way into astrological treatises in Greek, where it became known as the *dodecaoros* (δωδεκάωρος) or "the circle of 12 animals". By way of Greek translations, it made its way farther east and eventually became what is known today as the Eastern Asian zodiacal circle [von Lieven 2018].

3.2 *The Moon*

Next to the Sun, the Moon always held a high position in Egyptian theology [Derchain 1962].[13] However, in contrast to the Sun, there never was a deity Iah (Moon) with equal standing to Re (Sun). "Iah" only rarely appears isolated as a divine name and is usually an epithet of several important gods who have clear lunar traits. These, however, are not exclusively lunar but have other responsibilities as well. One of the most important lunar deities is certainly the god Thot, who was also the lord of wisdom and science and the inventor of writing. As Hermes Trismegistus, he was to have a great career, eventually transcending far beyond the boundaries of traditional Egyptian thought. That astrological treatises among other "technical" Hermetica are attributed to him is, therefore, no surprise [see ch. 13.5, p. 580]. This is clearly in line with his standing in the view of Egyptian priests, as is his epithet: "thrice-great". In Demotic, he is even sometimes called "five-times great" [Ritner 1981] which is probably an elaboration of his very ancient epithet "Greatest of Five".

12 These *onomastica* also contain many lists of important features, objects, and deities, several of which are of astronomic relevance.

13 For a complete study of the religious significance of the Moon in Greco-Roman Egypt, see Altmann-Wendling 2018.

Another deity whose lunar character was prominent in the Greco-Roman Period was Osiris, otherwise mainly known as the god of the dead [Graefe 1979]. However, he and his wife Isis rose to their highest popularity in later periods as inventors of culture in general as well. Demotic papyri from the temple library of Tebtunis detail Osiris' life in epic form [Quack 2018], and the mysteries surrounding his death were annually celebrated all over Egypt. At the same time, the missionary Isiac religion spread important aspects of this cult in Hellenized garb to the last corner of the Greco-Roman world. The lunar aspect of Osiris fitted especially well to the myth of his murder and dismemberment by his brother Seth and his subsequent reconstruction and temporary revival by his wife Isis. Thus, the lunar phases can be imagined either in light of this myth or as different deities entering the Moon and filling it with different minerals. The latter concept is depicted in many temples of the period in the form of a procession, often leading up a staircase with 15 tiers.[14] At the top is the Full Moon, guarded by Thot. Within it is sometimes shown the sound/*wedjat*-Eye of Horus—another mythological symbol for the damage (again by Seth) and subsequent restoration of the Moon.

While these mythological pictures held great prominence in the visual decoration of the temples of the period, it would be naive to think that the Egyptian priests did not know better. These depictions are merely traditional symbols that could be imbued with many layers of meaning. An interesting reflection of such a depiction—a lunar staircase combined with the mytheme of Osiris' dismemberment—is still to be found in the alchemical treatise *De compositione aquarum 1* by Zosimus of Panopolis (fourth century CE) [Mertens 1995, 35–36, 216–217; von Lieven 2000a, 131–132].

3.3 *The Planets*

The planets' importance for theological interpretation has been researched little for the older periods. They clearly are an important part of the so-called Classical Sky Picture, but apart from that they seem not to have been too prominent. However, it is possible that this impression is misleading. For example, the great Horus-myth in the Temple of Edfu clearly claims that the winged disk, which is the symbol of the particular Horus of Edfu, is the morning and evening star, i.e., the planet Venus [Chassinat 1931, 129.10–131.1].[15] In fact, there are other instances in which it can be proven that not every disk necessarily need be a solar disk [von Lieven 2001c].

14 See Labrique 1997, 1998a, and 1988b; von Lieven 2000a, 127–132, folding pl. 5.

15 For translation, see Kurth 2014, 218–220.

4 The Impact of Zodiacal Astrology

The introduction of the zodiacal signs and zodiacal astrology that relies on the position of the planets in the zodiacal circle completely revolutionized any traditional role that the planets might have held before. With zodiacal astrology as a newly dominant frame of reference, the planets became hugely important in Greco-Roman Egypt [see chs 4.8, p. 160; 12.4, p. 509: cf. ch. 12.1, p. 443]. This change in status also affected their names and their iconography, although no linear correlation between the two is observable [Neugebauer and Parker 1960–1969, 3.175–182]. A particularly striking and unique case is the iconography of Jupiter and Mars in Roman-Period Esna, which is influenced by their Greek equivalents while at the same time being stylistically fully Egyptian.[16]

The temple-ceilings of the period[17] render visible concepts that are also to be found in contemporary astrological treatises in Demotic and Greek. Thus, the planets are shown in positions of power, usually in their exaltations (ὑψώματα). In the hypostyle in Dendera, however, instead of the exaltations, the houses (οἶκοι) of daytime and nighttime were chosen, probably because this offered an elegant opportunity to allot each of two symmetrically arranged ceiling parts to astrological theories. In sum, the astronomical ceilings of temples, if they show a zodiacal circle, represent the *thema mundi*, i.e., the positions of the celestial bodies at the birth of the universe. This is an ideal situation according to astrological theories but astronomically it is not realistic. Any attempt, therefore, at dating such ceilings according to the planetary positions is futile. Occasional aberrations from this scheme are likely no more than mistakes.

On the ceilings of private tombs or within private coffins, conversely, the planetary positions in the zodiacal circle do represent the birth-horoscope of the respective owner. As horoscopes were cast by priests, it is to be assumed that such ceilings were also conceived of by priests even in the case of private funerary monuments. Moreover, the owners of such private monuments sometimes held priestly titles, so it is likely that they conceived of these ceilings themselves. A good case in point would be the so-called zodiac tomb of Athribis, which contained not only two different zodiacal circles with the horoscope of each of its two occupants on the ceiling [Neugebauer and Parker 1960–1969, 3.96–98, pl. 51] but also cult-scenes clearly derived from a temple context on its walls.[18]

16 See Neugebauer and Parker 1960–1969, vol. 3, pls 29, 43; von Lieven 2000a, 158.

17 For a monographic treatment of the one in the preserved hypostyle of Esna, see von Lieven 2000a with an important addendum in 2001a. For Dendera, see Leitz 2006.

18 See Petrie 1908, pls 36–38 (ceilings with zodiacal circles), pls 39–42 (wall decoration with Osirian cult scenes); von Lieven 2010a, 94–96.

5 The Role of the Decans

Probably the most important entities in the Egyptian sky from the point of view of theological speculation were the so-called decans [Quack 2002a]. Originally, these were a group of 36 constellations rising at certain intervals so that every 10 days one rose for the first time, while another set [Neugebauer and Parker 1960–1969, vol. 1]. Altogether, there were always 29 visible and 7 temporarily non-visible decans. This schematic template was then used for timekeeping at nighttime. Most likely because of precession [see Glossary, p. 648], over time different decan "families" were developed [Neugebauer and Parker 1960–1969, 3.105–174]. These families also differed in their iconography.[19] Their members were identified with different deities and they were believed to have a dangerous aspect, causing epidemics and the like. At the same time, however, they also could protect their devotees from precisely these dangers. Their link to the cult of the Dangerous Goddess on the one hand and to ἰατρομαθηματική (medical astrology) [see ch 9.3 §4.1, p. 368] on the other is, therefore, a longstanding one.[20]

With the introduction of the zodiacal band, the concept of the decans changed profoundly. Instead of being first and foremost constellations in their own right, they were now at least in part understood to be 10°-divisions of the zodiacal circle. Thus, each zodiacal sign was allotted three decans. While the timekeeping aspect was thus largely lost or at least strongly modified, the iatromathematical use intensified and was codified in the form of decanal *melothesia*, the practice of assigning human body parts to the decans [see ch. 9.3 §4.3, p. 372].

In the context of horoscopic astrology, the use of the decans in divination also survived. At least some Demotic astrological handbooks from Tebtunis still operate with them. Other handbooks from Tebtunis, and probably some other find-spots, also contain the more important Sothis-*omina* in particular. Sothis herself was a decan, often identified as the astral form of the goddess Isis [see ch. 7.1 §10, p. 270]. Originally, the name «Spṭ.t» meant "the pointed one", and decan lists clearly allot her three stars, namely, CMa α, δ, and ε. However, the most important of these three, Sirius (CMa α), came to be regarded as dominant; and Greek sources simply identify Sothis with Sirius.[21] The importance of Sirius-Sothis through all of Egyptian history lay in the fact that not only was she

19 See Neugebauer and Parker 1960–1969, 3.105–174; Kákosy 1979; von Lieven 2000a.

20 A particularly interesting monument in this respect is the Naos of the Decades: see von Bomhard 2008; Leitz 2010; Quack 2010.

21 Foremost among them is Plutarch, *De Iside*, 61.

the brightest star in the night sky save for the Moon, but that her heliacal rising happened at the same time as the onset of the Nile flood, so vitally important for agriculture and thus the entire livelihood of ancient Egypt. In the calendar, this event signaled the New Year as well, a fact that had divinatory uses. The long tradition of the practices attested to by the Demotic manuals from the second-century CE Fayum is evident from a comparison of the beloved woman in a New Kingdom love-song to "the star that rises at the beginning of a good year".

There are a few sources demonstrating that *omina* were not derived just from the rising of Sothis but also from some other decans. From this, one may extrapolate that all the decans were suitable for this use; but such uses are, it would seem, only attested sporadically.

6 Orion and the Big Dipper

Apart from Sothis as a form of Isis and also of the Dangerous Goddess, Orion was important, again from the earliest texts onward. Theologically, he was identified with Osiris. But while Sothis herself was a decan, Orion apparently was made up of several different decans, whose names imply identity with different body parts of Orion. As Sothis and Sirius are not always identical with each other as the Greek evidence would suggest, it also needs to be said that the Egyptian constellation Sꜣḥ is not necessarily identical with the ancient Greek (and indeed modern) constellation of Orion. The fact that different decan families contain different decans associated with different body parts of Sꜣḥ suggests that identifications must be made with care.

An asterism easy to identify is the Big Dipper (*msḫ.tı͗w*), which in Egyptian tradition is the astral form of Seth [von Lieven 2000a, 24–29]. As such, he is often depicted as a bull's foreleg (and sometimes as bullheaded) being held by a hippopotamus goddess and tethered to a chain in the middle of the northern sky. This is a standard picture and alludes to the circumpolar nature of the Big Dipper. The same fact is emphasized in inscriptions stating that thus he is prevented from harming Osiris-Orion in the southern sky or in the netherworld, respectively. Such texts, not by accident composed in classical language, are good examples for traditional concepts being repeated even on a Roman-Period ceiling (as, e.g., in Esna in the second century CE), despite the fact that the Egyptians had long been aware that due to the precession, the Big Dipper was not strictly circumpolar anymore. It is, accordingly, a clear warning against using traditional inscriptions in monumentalized form to prove any supposed lack of knowledge by the Egyptians. Monumentalized inscriptions simply served different purposes and surely were never intended to be read as repositories of astronomical knowledge as such.

In fact, the Egyptians are even to be credited with the discovery of the effects of the precession around 1200 BCE, i.e., long before Hipparchus' time. The only difference is that there the explanation is mythological, not one that is part of a strictly scientific theory. At any rate, in a magical text attested in two papyri, the fact that the Big Dipper has moved in an unexpected way is clearly remarked on and blamed on the divine trickster Thot, who supposedly loosened the pole to which he had been tethered.[22]

As an incarnation of Seth, the murderer of Osiris, the Big Dipper also played a certain part in magical rites in the Hellenistic Period. In those texts, his traditional Egyptian role is sometimes combined with a more Greek outlook as the Bear.[23] The relationship of the Greek Magical Papyri and their Demotic counterparts to the world of the traditional Egyptian temple is much debated.[24] While some rites are modeled on traditional temple-ritual, others are unrelated; and the find-context of those papyri is not clear. Even the texts following models from temple-ritual could use it as a "Black Mass" without actually having any real connection to the temple. Unfortunately, for this material, the users are not easily named.

7 The Zodiacal Circle

As for the zodiacal circle itself, it was a late introduction into Egypt. Unfortunately, it is not known whether it had already been introduced directly from Mesopotamia in the Late Period or, alternatively, in the Ptolemaic Period *via* the Greeks. As Egypt was in very close contact with Mesopotamia—first Assyria, later Persia—during the period from around 675 to 330 BCE and especially in the circulation of intellectual traditions from Mesopotamia, the former option seems more plausible; yet it cannot be proven beyond doubt.

While textually well represented in astrological manuals, iconographical representations are often to be found in the context of the astronomical ceil-

22 See *PChester Beatty* 8.3.1–2 [Gardiner 1935, pl. 40] and *PGreenfield* 70.20–23 [Budge 1912, pl. 70]; Schott 1970, 547–556. For the correct astronomical interpretation of the passage, see Quack 1996, cols. 156–157; Waitkus 2010, 179n38.

23 See, e.g., *PGM* 4.699–702. The golden shoulder of a bull nevertheless is a clear hint at the underlying Egyptian concept. This holds true for the other instances in *PGM* 4 as well. For more Greek occurrences in the Greek Magical Papyri, see Betz 1992, 184n561.

24 For a discussion of the provenance of just one group, the Theban Magical Library, see Dieleman 2005, 11–21, 40–41.

ings of temples. The individual zodiacal constellations follow more or less the Mesopotamian and Greek conventions. However, there are a few particulars that represent adaptations to the Egyptian context. One is that the Twins (Gemini) are usually shown as the divine couple Shu and Tefnut, the first sexually differentiated deities, who were also believed to have been siblings. The Crab (Cancer) is often assimilated very closely in form to a scarab, which as a form of the self-arisen Sun-God was, of course, an animal of great symbolic importance.

The most striking specialty of Egyptian zodiacal terminology and iconography, however, is Libra [Neugebauer and Parker 1960–1969, 3.207, 210]. As is well known, this sign also shifted identities in the Greco-Roman conception from the claws of the scorpion to the balance. The existence of a particular Egyptian variant is actually a good argument for an introduction of the zodiacal circle to Egypt in a period when there was not yet a fixed iconography associated with this particular sign. In Egypt, its name in Demotic «tꜣ ỉḫ̮y» ("the horizon") has nothing to do with the balance. In the preserved later Hellenistic iconography, it is indeed shown as a balance; still, a Sun-disk—and once even a horizon hieroglyph with the Sun-disk rising from it—is often associated with it. Sometimes, the solar child sits within the disk. This combination of the Sun-disk plus child and so forth with the picture of a balance attests to an awareness of the variant iconography for Libra, which gradually took over. However, the original absence of the balance from this sign can be inferred from its Egyptian name and the iconographical remnants consistent with it. This is all the more significant because balances as such had been an important symbol in the Egyptian religion for a long time. The balances were related closely to the weighing of the heart in funerary iconography but also to other issues like the city of Memphis, often called the Balance of the Two Lands. It is, therefore, a definite choice not to use the balance in the first place that clearly has significant implications for the history of the zodiacal circle and its transmission.

Moreover, the fact that the symbol for Libra to this day is actually the Egyptian horizon hieroglyph in a form closely resembling its Demotic form further speaks in favor of a genuine Egyptian form only later being supplanted with the balance. Certainly, the cursive sign as such is an Egyptian invention, as indeed are all the hieroglyph-like symbols of the zodiacal constellations still in use. Apart from their shapes, this is proven by their first attestation in Demotic Egyptian astrological texts [von Lieven 1999, 126].[25] They also appear in the Hieratic priestly *Onomasticon* 1 from Tebtunis [Osing 1998, 187, 189, pls 16–16A].

25 Unfortunately, in the table there, the Egyptian forms have erroneously been dropped in favor of medieval forms. However, the correct forms can be seen in the original publications, Spiegelberg 1910 and Neugebauer 1943.

The casting of horoscopes seems to have been an important priestly occupation until the demise of the Egyptian temple and its cultural life, as the Narmouthis-ostraca amply attest.[26] Apart from the zodiacal circle and the planets, other elements play a certain role in Egyptian horoscopes. Most can be seen as parallel to similar phenomena in horoscopic texts in Greek and Latin [von Lieven 1999, 123–124] (and indeed in Sanskrit); but there are a few elements apparently unique to the earliest Egyptian texts, namely, the *swšp* and *twr*, the latter of which is a direct transliteration of a term used in Mesopotamian texts [Ross 2008]. This is again a good argument in favor of a direct takeover from the East, without Greek intermediaries.

Moreover, the 12 places of the *dodecatropos* (δωδεκάτροπος, circle of 12 divisions) have varying names, some of which, again, by their linguistic character speak in favor of a longer native tradition, which then influenced others instead of the other way around. The four cardinal positions are in fact attested in the Pyramid Texts, making a native development even more likely [von Lieven 2007, 146–147]. Its final form might have come about, again, by the absorption of the Mesopotamian zodiacal circle.

8 The Tutelary Deities (Chronocrators)

In addition to the classical elements of zodiacal astrology, the Egyptians recognized other important entities, conceptualized as tutelary deities (chronocrators) of different time-units for each day or month and so on [Quack 2013; von Lieven 2017]. Very important among these was, for example, the *špšy.t* (noble lady). The *špšy.wt* in Demotic or *špsy.wt* in more classical language were a group of 12 tutelary goddesses of the months. In temples of the Hellenistic Period, they were often depicted as groups of hippopotamuses standing on their hind legs [Mendel 2005]. They were also differentiated in color, as each was allotted a different mineral. Similar allotments are also attested for the decans and it is to be assumed that this was not entirely fictive but was reflected in actual ritual in the temples.

The immediate relevance of the *špšy.t* for the fate of an individual is nicely demonstrated by fragments of an usurpation plus refurbishment of an elite tomb in the fourth century BCE [Jansen-Winkeln 1997]. The depictions show both of the owners, the original one as well as the later usurper/renovator,

26 See Bresciani, Pernigotti, and Betrò 1983; Gallo 1997 with a review in Quack 1999; Menchetti 2005a with a review in Quack 2006–2007; Ross 2006b, 2007a, 2009a, and 2011.

together with their tutelary goddess of the respective month of their birth. The goddesses are clearly labeled as such; so they are easily identifiable despite the fact that, for once, they are fully anthropomorphic, not hippopotamus-shaped.

9 Astronomy and the Egyptian Temple

All of these deities and their specifics had to be known by priests, together with many other subjects, including the technicalities of horoscope-casting and so forth. To achieve this, a young son of priestly descent had to attend the temple-school and learn all the relevant information. Thanks to the instructions for the head-teacher that are preserved in the so-called *Book of the Temple* [Quack 2002b]—a manual on how to build and run an ideal temple attested in at least 50 different manuscripts from Roman-Period Tebtunis, Soknopaiu Nesos, Oxyrhynchus, and Elephantine—it is possible to reconstruct the curriculum of this school. Despite its late attestation, the *Book of the Temple* was probably composed originally in the Middle Kingdom and certainly before 238 BCE.[27] The book was of the highest importance in the Hellenistic Period, as temples followed its injunctions regarding architecture and decoration closer than they had ever before that time. Moreover, the book was among those traditional texts translated into Demotic; in Oxyrhynchus, it was even translated into Greek [Quack 1997]. This latter fact, especially, leaves no doubt about its compulsory character for the period in question.

The priestly curriculum, according to the *Book of the Temple*, was to be organized in four terms (literally, occasions). How long each of them took is, unfortunately, not specified. In the first term, among other subjects, the local specifics and court-etiquette were to be learned; in the second, feast-rituals and the explanation of difficulties, i.e., commentary techniques; in the third, medicine; and in the final, fourth term, eclipse-*omina* and more specialized medico-magical knowledge. Thus, astronomical-astrological knowledge belongs among the most advanced subjects a temple-priest could learn.

Priestly offices that were in particular associated with astronomy or astrology were the *ỉm.ỉ-wnw.t* (literally, One who is within the hour) and the *ỉmw-p.t* (literally, ...[meaning uncertain] of the sky).[28] Another term for the astronomer

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27 The date of the Canopus Decree [Pfeiffer 2004], when the number of priestly *phyles* was raised to five. The *Book of the Temple* operates with four.

28 The writing of «ỉmw» in the *Book of the Temple* [Quack 2004, 16] is clearly different from «ỉm.ỉ», so it cannot be the same word. Its meaning is, unfortunately, not clear. At

was «wnwn.w», making him "one observing the movement (*wnwn*) of astral bodies".[29] The first of the three terms is especially very well attested as a priestly title. As its literal meaning implies, one of its main functions was timekeeping and the announcement of the correct times for certain rituals [Sauneron 1959]. As many temple-observances were strictly tied to certain hours of the daytime or nighttime, this was an important function; and as timekeeping was usually done by the observation of either the Sun during daytime or certain stars and constellations during nighttime, the astronomical link is also beyond question. In fact, the only Egyptian clock that does not operate with either the shadow of the Sun or the movement of the constellations is the waterclock.[30] But waterclocks were often decorated with the Classical Sky Picture and bore a standardized inscription mentioning the fact that they were supposed to be used during times when the observation of the heavenly bodies was impaired by clouds. Thus, essentially, timekeeping was conceived of as an astronomical activity.

Astronomical observations were also used to orient temple buildings according to the positions of different constellations on particular days of the year [Leitz 1991, 58–92; Waitkus 2010], the details varying from case to case according to theological considerations.

Very little is known for sure about the distinctions to the other two titles. Interestingly, though, the *Book of the Temple* specifies where in the temple-precinct the special quarters of the *ỉmw-p.t* should be located [Quack 2004, 16]. It also specifies the location of the quarters for other particular functions; for example, for the chief teacher and the master of chant, it is to be assumed that each class of priests had their prescribed living space.

As Egyptian priests of certain ranks had a right to erect inscribed memorial statues of themselves in their temples, several autobiographies of late priests who were also astronomers have been preserved. Examples from the Hellenistic Period are the statues of Harkhebi [Neugebauer and Parker 1960–

any rate, the reading **«bꜣḳ-p.t» in Sauneron 1959, 39–41 is definitely wrong. Contrary to his statements, the Berlin Wörterbuch files do also contain some evidence for a writing of «ỉm.ỉ-wnw.t» with the beautiful eye determinative, implying an observational activity.

29 For this term, compare the texts cited in von Lieven 2000a, 42 and note c. Yet another title is discussed by Černý 1963.

30 On Egyptian clocks, see Borchardt 1920; Neugebauer and Parker 1960–1969, vol. 2; Leitz 1995. Borchardt 1920 has recently been reprinted with a new foreword [Wuensch and Sommer 2013], which unfortunately misrepresents several important issues: see the review in von Lieven 2013a.

1969, 3.214–216],[31] Senti [Daressy 1919, 276–278; Birk 2014, 85], Haremhab, and Imhotep [Birk 2014, 80–85], to name just a few. Similar texts can also be found sometimes on their grave stelae.

10 Conclusion

As stated at the beginning, astronomy remained a matter of interest in the Egyptian temple until the end of its tradition as such. Its latest incarnations were to be found in fields that today would more likely be labeled astrology than astronomy. Among the most important sources are the ostraca from the temple-precinct of Narmouthis [see p. 338n23; Dieleman 2003a, 2003b]. Many of them contain horoscopes for private individuals. They are dated to the later second century CE. What makes them particularly interesting is the fact that they are written in the late Demotic language and Demotic script with inserted Greek astrological terms written in Greek script.

This is good evidence for the fact that in this period interaction with the Greek-speaking population of Egypt was intense. It can be demonstrated that the Egyptian priest-scholars (e.g., in the Fayum) already had a working knowledge of Greek in the earlier, Hellenistic Period. Therefore, it is not surprising that several Greek or Latin (translated from the Greek) astrological treatises also speak about Egyptian astronomical concepts, either the decans in particular or, more generally, certain of the constellations of the *sphaera barbarica*. Some of those mentioned there can even be identified with depictions on the zodiacal ceilings of the Temples of Dendera and Esna [von Lieven 2000a; 2000b, 150–152, 157n458; 2001b]. It is thus understandable that one of the most fascinating sources concerning Egyptian temple-culture from Late Antiquity, Firmicus Maternus (fourth century CE), wrote not only a pamphlet, *De errore profanarum religionum*, amply describing the Egyptian cults of Isis, Osiris, and other gods after his conversion to Christianity but also a bulky astrological compendium with the title “Mathesis”. The latter, among other subjects, contains information on the Egyptian decans nowhere else to be found in classical authors but clearly correct in comparison with actual Egyptian sources of the latest periods [Quack 2002a].

31 Why the contents are immediately claimed as indicative of a transmission of Babylonian knowledge instead of possible indigenous developments is not justifiable by any facts.

CHAPTER 11.2

Hellenistic Astronomy and the Babylonian Scribal Families

Mathieu Ossendrijver

1 Introduction

Between 400 BCE and 100 CE, the astral sciences were practiced by numerous Babylonian scholars. In the cuneiform texts, these scholars are referred to as "scribes of *Enūma Anu Enlil*", after the celestial omen-series *Enūma Anu Enlil* (*When Anu and Enlil*). In earlier times, *Enūma Anu Enlil* was the main composition consulted by Mesopotamian diviners for interpreting celestial signs for their king [see ch. 12.2 §3.1, p. 479]. Even though this practice was now less relevant and new forms of astral science had emerged, its practitioners continued to be called "scribes of *Enūma Anu Enlil*". Our knowledge of these scholars derives from a variety of cuneiform and classical sources.[1] The tablets with astral science often conclude with a colophon mentioning the name, paternal lineage, and priestly titles of the scholar who wrote or owned them. Astronomers also left their traces in administrative and legal documents. For an external view on Babylonian astronomers, we can turn to Greek and Roman historians such as Diodorus of Sicily and Pliny.

In the period of concern, Babylonian astral science covered an increasingly broad range of observational, predictive, computational, and interpretative techniques. Diaries and related observational reports, attested in Babylon between 650 BCE and 70 CE and more sporadically in Uruk and Nippur, are the most common type of astronomical text [see chs 5.1 §2, p. 172; 7.2 §2, p. 273]. They imply a well-organized program of observation and data-management involving numerous astronomers. Short-term reports made by different observers were evaluated and compiled into the six-monthly format of a standard Diary.[2] Various kinds of lists excerpted from the Diaries testify to an effort to analyze the data.

1 On the scribes of *Enūma Anu Enlil*, see also Rochberg 2000 and 2004b, 219–236.

2 For a partial reconstruction of the process by which a Diary was compiled, see Mitsuma 2015.

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Two predictive methods that were successively developed can be viewed as the fruits of these efforts. From about 600 BCE onward, so-called Goal-Year methods are attested, whereby most of the reported lunar and planetary phenomena could be predicted [see chs 5.1 §4, p. 176; 7.2 §2.2, p. 275]. Near 400 BCE, the 12 zodiacal signs of 30° were each introduced, after which mathematical astronomy emerged as a second predictive method [see ch. 4.6, p. 135]. New forms of astrology based on the zodiacal circle, such as horoscopes, were also invented [see ch. 12.1, p. 443]. Even in the Seleucid Period, scholars continued to copy the ancient omen-series *Enūma Anu Enlil* and produce new types of learned commentaries on it [Frahm 2011, 333–335]. However, few if any innovations appear to have occurred in Babylonian astral science after *ca* 330 BCE, as far as is known. From then on, the astronomers continued to produce the full range of observational reports and predictive texts, including the sophisticated lunar tables, in almost paradigmatic fashion. In Uruk, the latest evidence for scholarly activities dates to about 160 BCE but in Babylon some astronomical texts continued to be produced until the first century CE.

2 Centers of Babylonian Astronomy

Astronomical texts from the period 400 BCE – 100 CE have been found in Babylon, Uruk, Nippur, and, perhaps, Borsippa. The finds are very unevenly divided over these cities. Thousands of tablets covering this entire period and dealing with every known form of Babylonian astral science have been excavated in Babylon, the ancient capital. Babylon was certainly the most important center of astral science and probably the only location where Diaries and related observational reports were produced for a prolonged period of time. In Uruk, a few hundred astronomical tablets from the period 425–150 BCE have been found. They cover roughly the same textual genres as in Babylon, including mathematical astronomy, but the observational texts are strongly underrepresented. A handful of tablets with astral science from the period 425–364 BCE, including observational tablets but lacking mathematical astronomy, have been found in Nippur. These finds are consistent with a claim by Pliny the Elder (23–79 CE) that Babylon, Orchenus (Uruk), and Hipparenum (Nippur) were famous cities of Chaldean astral science [*Nat. Hist.* 6.30].[3] Beyond that, a few astronomical texts dating after 450 BCE, but no Diaries or tablets with mathe-

3 While Oelsner 1982 equates Hipparenum with Nippur, others maintain the earlier identification with Sippar.

matical astronomy, were found in Borsippa [Oelsner 1986, 229–230], home to another school of Chaldean astronomers according to the Greek geographer Strabo (*ca* 64 BCE – 24 CE) [*Geog*. 16.1.6]. A single letter, probably dating from 550–350 BCE, suggests the presence of astronomers in Ur.[4] The textual finds raise the question of whether Babylonian astronomers were divided into distinct schools, perhaps located in different cities; and, if so, whether each school followed a particular scholar. The tablets with mathematical astronomy from Babylon and Uruk provide some clues about these issues. They exhibit a multiplicity of alternative algorithms for computing the same phenomena [see ch. 4.6, p. 135]. Centuries after their invention, some of the algorithms were attributed to named scholars. Three lunar tables preserve a colophon with the phrase "computed table" followed by a personal name, which is either "Nabû-rēmanni" on a lunar table for 49/48 BCE computed with System A [Neugebauer 1955, no. 18] or "Kidinnu" on two lunar tables computed with System B [Neugebauer 1955, nos 122 (103 BCE) and 123a (≈ 170 BCE)]. These rare labels do not indicate the scribe or owner of the tablet but a scholar who is somehow connected to the table or the underlying algorithm. It has long been known that they can be identified with Naburianos and Kidenas, two Babylonian astronomers mentioned by Strabo along with Sudines, who remains unidentified.

Their clan affiliations are unknown. According to Strabo, the "mathematicians", a term which in the Greco-Roman Era designates mathematical astronomers, refers to "sects [of Chaldean astronomers] that hold to various different dogmas about the same subjects" [*Geog*. 16.1.6]. Naburianos and Kidenas might, therefore, be taken to be the creators of lunar Systems A and B, respectively. Caution is required because the attributions date two centuries after the fact and neither is attested with his own tablets. There is some evidence suggesting that Kidinnu originates from Uruk [Neugebauer 1955, no. 122].[5] Furthermore, lunar Systems A and B are unevenly represented in both cities, System A being attested earlier and more commonly in Babylon, System B more often in Uruk. But, while System A was almost certainly developed in Babylon, the evidence that System B originates from Uruk is inconclusive. One can only speculate as to whether these and other alternative algorithms were the subject of scholarly competition. The extant tablets, which were mostly written after 330 BCE, do not shed light on this. Perhaps this was true only in the formative period of mathematical astronomy (400–330 BCE).

4 See Ur Excavation Texts 4.168, a tablet which remains untranslated at the time of this writing.

5 The name "Kidinnu" may be written more fully as "Kidin-Anu", which would suggest that Kidinnu originates from Uruk, the city of Anu.

The localization of astronomers within these cities can, in principle, be reconstructed by analyzing the archaeological and archival context of the tablets. However, nearly all of the thousands of astronomical tablets from Babylon were dug up before 1890 in an unscientific manner. All that can be said is that this was done mainly in an area near the Esangila, Babylon's main temple dedicated to the supreme god Bēl (Marduk) and his spouse Bēltu. The tablets do not originate from the temple itself, which remains unexcavated, but perhaps from libraries in private houses of the astronomers or from some official building connected to the Esangila.[6]

As we shall see, the astronomers in Babylon were in any case closely connected to the Esangila. In Uruk, a few hundred tablets with astral science from the period 400–150 BCE were found in two main locations. Most of them originate from the Rēš, Uruk's main temple in this period, which was dedicated to the sky god Anu and his spouse Antu.[7] Nearly all of these tablets were written between 250 and 150 BCE. Some were excavated in a library in the southeastern gate of the temple complex. Other tablets with astral science from this period that were found nearby or whose find-spot in Uruk is unclear can also be assumed to originate from this library. Some Achaemenid and early Seleucid tablets with astral science (400–330 BCE) were excavated in a private house, which revealed two levels of occupation by scholarly families. Around 400 BCE, it was inhabited by the family of Anu-ikṣur of the Šangû-Ninurta clan and some 70 years later by the family of Iqīšâ, of the Ekur-zākir clan.

3 Families of Astronomers in Babylon and Uruk

If we count as astronomers all scholars who wrote or owned at least one tablet with astral science and all those who are referred to as "scribes of *Enūma Anu Enlil*" on scholarly or administrative tablets, then this yields approximately 70 named individuals for the period 400 BCE – 100 CE. About 50 of them originate from Babylon, 20 from Uruk. At least 10 astronomers belong to the Mušēzib clan, by far the highest number for any clan in Babylon.[8] At least seven generations of astronomers from this clan, stretching across

6 For this, the only library with astronomical tablets that was excavated scientifically in Babylon, see library N19 in Pedersen 2005; Clancier 2009, 150.

7 For this library and the scholars involved, see Pedersen 1998; Beaulieu 2000; Pearce and Doty 2000; Frahm 2002; Rochberg 2004b, 229–236; Clancier 2009; Robson 2011; Ossendrijver 2011a and 2011b.

8 For the astronomers of this clan, see van der Spek 1985 and Oelsner 2000.

the Achaemenid, Seleucid, and Parthian Eras, can be traced through their tablets. They pursued all the main forms of Babylonian astral science, including celestial omens, zodiacal astrology, mathematical astronomy, and observations.

The few Diaries and related observational texts from Babylon that are not anonymous were written by astronomers of the Mušēzib clan, which suggests that they played a prominent role in compiling these texts. Several ritual tablets, incantations, and a tablet of the Gilgamesh epic were also written by astronomers of this clan [Hunger 1968, nos 148, 417]. Other clans from Babylon, each attested with at most two astronomers, are Ea-ēpuš-ilāni, Egibi, Ēṭiru, Ile'i-Marduk, Kānik, Nabunnāya, and Nanna-utu. Except for the Ēṭiru, Kānik, and Nabunnāya clans, at least one astronomer from these clans pursued mathematical astronomy. For about half the astronomers from Babylon, there is no designation of clan.

About 20 names of astronomers from Uruk are known for the period 400–150 BCE. Most of them belong to the scholarly clans Ekur-zākir [13] and Sîn-lēqe-unninni [3], who are traditionally specialized in exorcism and lamentations, respectively. The remaining astronomers belong to the Šangû-Ninurta, Aḫûtu, Gimil-Ani, Ḫunzû, and Kurî clans. For two astronomers, the clan affiliation is unknown. Eight astronomers, all from the Ekur-zākir and Sîn-lēqe-unninni clans, are known to have pursued mathematical astronomy.

The library of Anu-ikṣur of the Šangû-Ninurta clan, an exorcist who lived around 400 BCE, contained at least 11 tablets with astral science, including Diary-type texts, along with a large collection of tablets about medicine and divination, and several sophisticated mathematical tablets.[9] The colophons suggest that these tablets were mostly written by Anu-ikṣur, his brother, and his son, who were also exorcists. About 80 years later, the family of Iqīšâ of the Ekur-zākir clan, a priest of the Rēš-temple, lived in the same house for at least three generations. Their considerable library contained at least 21 tablets with astral science, including mathematical astronomy, along with at least 100 tablets about other scholarly topics. The tablets with astral science were written by Iqīšâ, his son Ištar-šuma-ēreš, and Anu-aba-uṣur of the Kurî clan, perhaps an apprentice of Iqīšâ. The institutional affiliation of Anu-ikṣur is less clear but his obvious theological interest in the cult of Anu [Frahm 2002] suggests that he was a priest of the Anu-temple. Neither Anu-ikṣur nor Iqīšâ nor any of their relatives used the title "scribe of *Enūma Anu Enlil*".

9 For the libraries of Anu-ikṣur and Iqīšâ, see Oelsner 2000; Frahm 2002; Robson 2011; Clancier 2009; and Ossendrijver 2019.

The remaining astronomers belong to a network of scholars associated with the Rēš-temple that can be traced to between 250 and 150 BCE [Ossendrijver 2011a and 2011b]. The scholarly tablets from the Rēš stand out because they usually mention two individuals in their colophons, an "owner" and a scribe. The attestations of scribes and owners follow a systematic pattern in that these functions correspond to consecutive, non-overlapping phases in the career of any scholar. The scribes are junior scholars in an advanced stage of their education, while the owners are senior scholars who presumably supervised the production of the tablet for the library of the Rēš. A possible explanation might be that a scholar appears as owner of tablets once he has assumed a position in the temple. Interestingly, very few tablets are known to have been written by the senior scholars. The most prolific astronomer at the Rēš was Anu-aba-utēr of the Sîn-lēqe-unninni clan, whose father Anu-bēlšunu and nephew Anu-balāssu-iqbi were also astronomers.

Those of the Ekur-zākir clan belong to three different families. One scholar of the prominent Aḫûtu clan, who was mayor of Uruk, pursued some astral science along with his son. An exorcist of the Ḫunzû clan also collaborated with his son on a tablet with astral science. Since every tablet with astral science from this library documents a collaboration between two astronomers, the network of their professional interactions can be partly reconstructed [Ossendrijver 2011a and 2011b]. As it turns out, virtually all of the astronomers in Seleucid Uruk, though belonging to different clans, are interconnected through a single web of collaborations. The only exception is one astronomer of the Gimil-Ani clan, whose relation to the network remains unclear. The tablets of the Rēš with their elaborate colophons show that they were written with great care. Several of them explicitly mention that they were produced for the temple. Similar colophons mentioning pairs of scholars are very rare in the private libraries of Anu-ikṣur and Iqīšâ, for which a less rigorous procedure was apparently sufficient.

4 The Education of Babylonian Astronomers

Some information about the education of the Babylonian astronomers can be gleaned from cuneiform and classical sources but a full reconstruction of its various stages is not possible yet. In this connection, it is important to recall that Babylonian astronomy strongly relies on cuneiform writing as a means to document, organize, compile, and analyze observations, predictions, and interpretations of celestial phenomena. The ability to read and write was thus a precondition for becoming an astronomer. As in other premodern societies, this was largely confined to professional scribes. Our knowledge about Babylonian scribal education is fragmentary for the first millennium BCE; but there is no doubt that the scribal profession was passed on within scribal families along the male line, as was true for most crafts and professions. Evidence for female scribes, let alone scholars, is rare for the deeply patriarchal Babylonian society of the first millennium BCE.

The scribal education was probably conducted at home and not in the temple. In Uruk, school tablets were found in the house of the scholars Anu-ikṣur and Iqīšâ but not in the Rēš.[10] According to a recent reconstruction, it comprised two stages [Gesche 2001]. In the first phase, the pupil learned cuneiform signs and Akkadian and Sumerian words and phrases of increasing complexity by copying them from various lists. Elementary mathematical tables were also part of this phase. In the second phase, the pupil studied and copied more complex word lists and various scholarly, literary, and religious compositions. Astral science may have been taught at some phase of the scribal education during this period, as is suggested by an exercise tablet which includes part of *Enūma Anu Enlil* on eclipses [Mauer 1987]. Having finished his scribal education, the pupil was ready to make a living as a professional scribe by writing administrative documents, legal acts, and letters for customers. Only in families traditionally dedicated to the scholarly and priestly professions would he continue with a higher education in astronomy, mathematics, medicine, divination, rituals, or lamentations, depending on the specialization of his family or clan and, presumably, his talent.

These subjects were primarily taught by father to son as well. Direct evidence for this is found in astronomical tablets from the Rēš-temple, many of which were written by junior scholars under the supervision of a senior scholar who was usually the father. Some evidence suggests that scholarly topics such as astronomy were passed on more strictly within one's own family than other professions. In the manual crafts, it was not uncommon for a boy to take up an apprenticeship with a master who was not his father, as proven by so-called apprenticeship contracts, which exist until the Seleucid Era.[11] They are not attested for scribes and scholars but it remains to be seen whether this really reflects different apprenticeship practices. An unpublished letter from Seleucid Uruk concerning the apprenticeship of lamentation-priests [Hackl 2010, 712, no. 3684] implies that the practice also existed in scholarly circles. The astro-

10 For the find-spots of the school tablets from Uruk listed in Gesche 2001, see Clancier 2009.

11 On apprenticeship contracts, see Hackl 2010 and Robson 2011.

nomical tablets from the Rēš-temple also suggest this because some of them were written for a senior scholar who was not the father of the junior scribe.

By the fifth century BCE, the temples were the main and perhaps only source of employment for a Babylonian astronomer. The tablets from the library of the Rēš indicate that the temples played a role in the education of scholars. As mentioned earlier, they were written by junior scholars under the supervision of a senior scholar who appears as owner of the tablet. The former is usually the son of the latter, which clearly suggests an educational setting. Indeed, some tablets explicitly state that the scribe was an apprentice or that he wrote it "for his education" [Gesche 2001, 159, 213–216]. Some tablets were written by a junior scholar from a different family than that of the senior scholar. There is, however, no evidence that boys from non-elite clans entered the profession. The content of the tablets implies that the junior scholars of the Rēš were already very advanced, some being capable of computing the most sophisticated lunar tables of mathematical astronomy. The library of the Rēš is, therefore, a product of advanced scribal education. Perhaps the tablets were written within the temple itself, where many of them were excavated.

Diodorus, a Greek historian who lived in the first century BCE, admired the education of Babylonian scholars and compared it favorably to Greek practices:

> The training which they receive in all these matters [astrology and divination] is not the same as that of the Greeks who follow such practices. For among the Chaldaeans the scientific study of these subjects is passed down in the family, and son takes it over from father, being relieved of all other services in the state. Since, therefore, they have their parents for teachers, they not only are taught everything ungrudgingly but also at the same time they give heed to the precepts of their teachers with a most unwavering trust. Furthermore, since they are bred in these teachings from childhood up, they attain a great skill in them, both because of the ease with which youth is taught and because of the great amount of time which is devoted to this study.... The barbarians, by sticking to the same things always, keep a firm hold on every detail, while the Greeks, on the other hand, aiming at the profit to be made out of the business, keep founding new schools and, wrangling with each other over the most important matters of speculation, bring it about that their pupils hold conflicting views, and that their minds, vacillating throughout their lives and unable to believe at all with firm conviction, simply wander in confusion.
>
> DIODORUS, *Bib.* 2.29.3–6: OLDFATHER 1933, 1.447

The account is remarkably accurate in many respects but it also raises questions. The portrayal of Babylonian astronomy as an unchallenged body of knowledge lacking alternative, competing schools, as they existed in Greece, could reflect the situation of the last centuries BCE. However, even for that period it is not entirely accurate because Babylonian astronomy continued to offer a multiplicity of alternative methods and algorithms, some of which might reflect local preferences, as mentioned earlier.

5 Astronomers as Temple-Priests

For the period of concern (400 BCE – 100 CE), the Babylonian sources consistently indicate that the astronomers were by then, perhaps exclusively, employed by the temples [Rochberg 1993]. This situation contrasts with earlier periods such as the seventh century, when many astronomers received an income directly from the Assyrian king in exchange for astrological advice.[12] The Neo-Babylonian kings who ruled Mesopotamia after 612 BCE probably continued this practice but explicit documentation is lacking. The Persian conquest in 538 BCE is commonly assumed to have had several important repercussions. Chief among them is that the role of the temples changed within Babylonian society as a whole and for scholars in particular.

For native Babylonians, by then merely one community in a multi-ethnic empire, the temples became an increasingly important focus of their cultural identity and the conduit for their interactions with the authorities. Although Aramaic had replaced Akkadian as the main language of Babylonians, Akkadian cuneiform culture continued to flourish in the temples, some of which were renovated to an unparalleled size in the Seleucid Era. An administrative document from Babylon dating to the fourth century BCE lists monthly allowances of barley to 14 astronomers, which illustrates the considerable patronage of astronomy by the Esangila in this era [Beaulieu 2006]. At the same time, direct royal patronage of Babylonian scholars diminished drastically.

It is often suggested that this may have triggered several developments in the astral sciences after 400 BCE, since it provided the astronomers with an incentive to attract private customers. In particular the emergence of horoscopic astrology and perhaps even mathematical astronomy might be traced back to this incentive. However, the reality is certainly more complex than any

12 For the astrological reports that the astronomers sent to the Assyrian kings, see Hunger 1992.

simple *scenario*. It is not at all obvious that a temple-astronomer who received a regular income for his astronomical duties would feel this incentive. Moreover, even before 538 BCE, at least some Babylonian astronomers were connected to the temples [Ossendrijver 2019]. The observational project underlying the astronomical Diaries and related reports can be traced back to about 750 BCE, when it was initiated in Babylon almost certainly with royal support. The Diary tablets were excavated near the Esangila and probably written by astronomers who were associated with that temple. This institutional setting may explain the continuity of the Diary project across the changes of rule in 612, 538, 331 (Alexander the Great), and 141 BCE (the Parthians), and various other periods of unrest.

Several administrative tablets from the second century BCE, when Babylonia was under Parthian rule, inform us about the income and duties of the astronomers and the conditions of their employment by the Esangila.[13] The most illustrative example is a protocol of the temple-council concerning a young astronomer's claim to a position that was previously occupied by his father.[14] In the meantime, it had been given to a third astronomer, presumably because the father had died while the son was still too young. According to the protocol, the son demonstrated his competence as an observer to the council, upon which the position was transferred to him along with a plot of arable land and a yearly income in silver.

The tablet concludes with a list of his duties, namely, to carry out the "regular watch", the term for astronomical Diaries; to produce "computed tables", a reference to mathematical astronomy; and to make "measurements", which are Almanacs. He is also explicitly instructed to collaborate with five named and other unnamed astronomers ("scribes of *Enūma Anu Enlil*"). In another document, the council repartitions a single position that is currently occupied by three brothers, who inherited it from their father, with a fourth brother, who has now also demonstrated his astronomical competence. From these documents, we infer that the position of temple-astronomer was, in principle, passed on from father to son but that the son had to demonstrate his competence. It seems altogether possible that this practice existed in Babylon and Uruk at least since the early Achaemenid Era but there are no comparable documents from that time or from Uruk to prove this.

A precondition for pursuing activities in a Babylonian temple was the permission to enter it. This permission was formalized by the title of "temple-

13 For these documents, see esp. van der Spek 1985.

14 For a translation of this tablet, CT 49.144, see Rochberg 2000, 373–375.

enterer", which all the temple's personnel are assumed to have had. One of the few scholars for whom there is explicit evidence that he used this title is Iqīšâ—an exorcist of the Rēš-temple with many interests, including astral science. The numerous duties that had to be performed in a temple, ranging from cultic activities to the baking of bread, were organized in a system of so-called prebends, each carrying a distinct title. As was true for any profession, prebends were, in principle, passed on within families along the male line. The status of astronomers within the prebendary system and in relation to other scholarly priests is not fully clear. In Seleucid Uruk, all of the known astronomers were either a lamentation-priest (*kalû*) or an exorcist (*āšipu*), depending on the clan into which they were born. The former, at least originally, specialized in lamentations, an ancient genre of religious texts; the latter, in omens, rituals for averting their evil, and medicine.

In this period, however, both actually pursued a much wider range of disciplines, sometimes including astral science. Some of these astronomers do not appear to have been active at all in the nominal discipline of their clan. The prolific astronomer Anu-aba-utēr was officially a lamentation-priest, as were all scholars of the Sîn-lēqe-unninni clan, but most of his tablets deal with mathematical astronomy or other forms of astral science and none with lamentations. He and three other astronomers from Uruk occasionally used the title "scribe of *Enūma Anu Enlil*". Conversely, seven astronomers who wrote tablets with mathematical astronomy or Goal-Year procedures do not seem to have used this title [Ossendrijver 2011b]. It remains to be seen whether the circumstances in Seleucid Uruk can be extrapolated to earlier times and to Babylon.

6 Astrological, Other Scholarly, and Economic Activities

We can assume that a Babylonian astronomer spent a considerable portion of his working hours watching the sky, writing reports about the observations, compiling Diaries and related texts—including predictive Almanacs—and computing tables with mathematical astronomy.[15] Beyond that, many must have practiced astrology, some also celestial divination. Apart from copying or composing scholarly tablets about these topics, some offered astrological services to private customers, for example, horoscopes, which were ordered on

15 This is certain for Babylon but the extent to which the astronomers in Uruk carried out observations and produced Diaries and related texts themselves, rather than acquiring or copying such texts from Babylon, is unclear; see Steele 2016 and Ossendrijver 2019.

the occasion of a birth.[16] The extant horoscopes are anonymous but must have been written by astronomers, since they contain planetary and lunar data that were computed.

Astronomers may also have provided hemerological advice about the appropriate or inappropriate time for certain actions.[17] Procedures for predicting market prices from astronomical phenomena [see ch. 4.6 §7. p. 145] would appear to be another promising source of income for a Babylonian astronomer. But nothing is known about their use. Even the ancient art of celestial divination was maintained and occasionally put to use after 400 BCE. There is evidence that some Persian and Greek rulers, e.g., Alexander the Great, were consulted on astrological matters or participated in Babylonian rituals triggered by ominous astronomical phenomena [van der Spek 2003].

As mentioned earlier, Babylonian astronomers also pursued other scholarly topics. Not much is known about this for the city of Babylon, where relatively few scholarly tablets preserve the name of a scribe. One astronomer of the Nanna-utu clan, who was active in the Parthian Era, may be identified with a known lamentation-priest. In Uruk, astronomers are known to have been active in mathematics, medicine, divination, rituals, incantations, hymns, lamentations, theology, and mythology—essentially all forms of Babylonian scholarship. For instance, the astronomer Anu-aba-utēr, who is mentioned on 20 tablets with mathematical astronomy, also wrote tablets with temple-rituals, zodiacal astrology, and, very likely, mathematics and mythology. Diodorus described the wide-ranging interests of the Babylonian astronomers in the following terms:

> [The Chaldeans], being assigned to the service of the gods, spend their entire life in study, their greatest renown being in the field of astrology. But they occupy themselves largely with soothsaying as well, making predictions about future events, and in some cases by purifications, in others by sacrifices, and in others by some other charms they attempt to effect the averting of evil things and the fulfillment of the good. They are also skilled in soothsaying by the flight of birds, and they give out interpretations of both dreams and portents. They also show marked ability in making divinations from the observation of the entrails of animals, deeming that in this branch they are eminently successful.
>
> DIODORUS, *Bib.* 2.29.2–3: OLDFATHER 1933, 2.445–447

16 For Babylonian horoscopes, see Rochberg 1998.

17 For Babylonian hemerologies, see Livingstone 2013; for the related calendar-texts, which combine hemerological content with zodiacal astrology, see Weidner 1967.

Note, however, that Diodorus only mentions divination and apotropaic rituals, practices that strictly belong to the realm of the exorcist (*āšipu*); other disciplines pursued by Babylonian astronomers, such as lamentations, mathematics, and mythology are notably absent from his account.

Within the realm of the temple, additional income and status could be secured from various non-scholarly duties. A legal document from the Parthian Era mentions that the astronomer Itti-Marduk-balāṭu of the Mušēzib clan was an administrator of temple property and an overseer of temples.[18] Two specialists of mathematical astronomy from Uruk, Šamaš-ēṭir and Anu-uballiṭ, both exorcists from different branches of the Ekur-zākir clan, temporarily occupied the position of "big brother of the Rēš", high priest of the temple.[19] Some astronomers received income from prebends involving manual duties or basic services in the temple. In Seleucid Uruk, these prebends were commonly traded among the elites.

The astronomer and lamentation-priest Anu-bēlšunu, father of Anu-aba-utēr, is repeatedly attested in legal acts as a buyer of shares in the *gerseqqû* prebend, a service involving temple-offerings. A legal act from 192 BCE documents his purchase of *gerseqqû* shares pertaining to fractions of four specified days of the month.[20] The seller was a member of another elite clan. Anu-bēlšunu is unlikely to have performed the associated duties himself, since they were often subleased to an acting priest in return for a share of the income. The legal act was written by the astronomer Šamaš-ēṭir mentioned earlier. Unlike the prebends for manual duties, scholarly positions such as astronomer, lamentation-priest, and exorcist could not be traded, as far as is known.

Some astronomers acquired income outside the temple, e.g., through positions in the city administration, scribal work, farming, or business. In Uruk, the highest administrative positions were held by members of a few elite clans, some of whom occasionally pursued astral science. One example is Anu-balāssu-iqbi of the Aḫûtu clan, who was mayor of Uruk around 221 BCE. As was appropriate for a ruler, he owned a tablet of *Enūma Anu Enlil*, the ancient celestial omen-series. Šamaš-ēṭir is one of several astronomers from Uruk who wrote legal documents as a professional scribe, for which they presumably received a fee.

18 For this tablet, *BOR* 4.132, see van der Spek 1985; Boiy 2004, 211.

19 For Šamaš-ēṭir, see Ossendrijver 2011a. The Anu-uballiṭ referred to here was the son of Ina-qibīt-Anu and the grandson of Anu-aḫa-ušabši.

20 For this text, VAS 15.32 = VAT 7534 and its duplicate HSM 913.2.181, see Funck 1984, 202–207; Wallenfels 1998, 33–38. For the *gerseqqû* prebend, see Funck 1984, 126–127, 199–207.

The prolific scholar Iqīšâ owned a date grove and a temple prebend for brewing beer [Frahm 2002]. As members of the Babylonian elite, astronomers owned houses and plots of land. Two legal acts written 10 years apart document transactions involving a house and plot of land of the previously mentioned astronomer Anu-bēlšunu from Uruk [Doty and Wallenfels 2012, 9–16]. The house, which had once belonged to his father, was transferred in 224 BCE to Anu-bēlšunu and his brother; an adjacent vacant lot, to their cousin. Ten years later the same house, now in a ruined state and meant to be demolished and rebuilt, was shared with a third brother. From the documents we also learn that some neighbors belonged to prominent native clans while others bore Greek names.

7 Contacts between Babylonian Astronomers and Greek Scholars

As illustrated by the passages from Diodorus quoted earlier [also Bowen 2013b, 308–309] and by countless other references to Chaldean astrologers in Greek and Latin sources, there was a widespread awareness of Babylonian astral science in the Greco-Roman world [see ch. 4.7, p. 147]. After 331 BCE, the conditions for an exchange of knowledge between Babylonian and Greek scholars became increasingly favorable. More and more Greeks show up in cuneiform documents from Babylon, Uruk, and other cities. The Babylonian priest Berossus, who lived near 330 BCE, wrote a treatise called *Babyloniaca* in which he explains his culture to a Greek audience. Several passages deal with astronomy but their authenticity has been questioned because they have no relation to any known Babylonian concept and probably originate from a Greek scholar [De Breucker 2012].

Seleucia on the Tigris, founded in 305 BCE as a new provincial capital, was home to numerous Greeks, including the scholar Seleucus of Seleucia, who lived near 150 BCE. According to Plutarch, he defended the heliocentric hypothesis of Aristarchus of Samos [Neugebauer 1975, 610–611, 697]. Nothing is known about any contacts between him and Babylonian astronomers, and no traces of his theories have been found in cuneiform sources. However, works by other Greek astronomers, in particular, Hipparchus and Ptolemy, prove that there was a transfer of astronomical knowledge, perhaps in the form of tablets, from Babylonian to Greek astronomers [see ch. 4.7, p. 147]. Few traces of Greek concepts have thus far been identified in Babylonian astronomical texts, so that this exchange appears, for the moment, to have proceeded mainly in one direction only.

Astral Divination and Natal Astrology

CHAPTER 12.1

The Hellenistic Horoscope

Dorian Gieseler Greenbaum

1 Introduction

Divination through astrology is a practice employed around the globe. Drawing on astral religion, mythology, omens, and the reading of celestial patterns, astrology uses the "exact" science of astronomy to provide data for the interpretation of heavenly patterns. In many cases, astronomical advances are made in the service of astrology [e.g., Jones 2007, 307] and there is evidence of a "mutual dependence" between mathematical astronomical and astrological practices [Rochberg 2004b, 163]. Though theoreticians in the Hellenistic Era such as Claudius Ptolemy looked for physical causes for the effects of heavenly phenomena on earthly events, earlier practices, such as those in Babylon, relied on the heavens to give "signs"; and astronomy, which could eventually furnish predictions of future astronomical events, enhanced the astrological interpretation by such prediction. It should be noted that until the late Renaissance, the terms "astronomy" and "astrology" were interchangeable and could encompass the functions of either term.[1]

The following focuses on the interpretive tool used by astrologers known as the horoscope or astrological chart. The practices examined in conjunction with this device will be those of the ancient Near East, Egypt, Greece, and Rome, where the horoscope was widely used beginning in the late fifth century BCE.

2 The Horoscope: A Definition

The word "horoscope" is a term of multivalent meaning in both a cultural and chronological context. "Horoscope" has become the word commonly used among scholars, practitioners, and laypeople to mean, often, the chart constructed for a specific time and place using the positions of planetary bodies and the luminaries (Sun and Moon) and their placement within stylized zodi-

1 See French 1994, 33–34; Hübner 1989. See also ch. 0 §1, p. 1; ch. 8, p. 297.

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acal constellations.[2] However, the original meaning of "horoscope" in the earliest astrological texts written in Greek did not designate the entire chart as described above. In Greek, the word is a compound of «ὥρα» ("hour/time") and «cκοπός» ("mark", "aim", "object")—from «cκοπέω» ("watch", "mark", "examine").[3] Sometimes a person is meant by the term «ὡροcκόποc» ("horoscopus"), i.e., the one who marks, or watches, or examines the hour/time. Most often, though, it means "that which marks (or watches, or examines) the hour", the technical term in astrology for the zodiacal sign (at least) or the sign and degree crossing the eastern horizon at the time and place of the chart's casting. This point is equivalent to the Latin "ascendens", from which the English term "Ascendant" derives. This meaning for the term "horoscope" prevailed throughout the Medieval Period (which was dominated by the texts of writers in Arabic, whether Muslim, Jewish, or Christian) and even extended into the Renaissance and Early Modern Period.[4] The astrological Ascendant is one of the most important points for interpretation in the chart because it locates the chart in time and space, and arguably establishes a personal dimension for the "unique" moment of birth.

In modern usage, a horoscope can also be:

(1) a listing of the outcomes derived from planetary and zodiacal positions at a specific time and place;

(2) a diagram showing these positions; or

(3) merely a prediction based on the Sun's being in a particular zodiacal sign (as in the horoscopes in newspapers).[5]

In this chapter, "horoscope" primarily means the astrological diagram or list containing at least some planetary, luminary (i.e., Sun and Moon), and zodiacal positions for a specific time and place. Any deviation from this particular connotation will be noted.

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2 "Stylized" is used to denote the symmetrical 30°-segments into which the 12 zodiacal constellations were each divided regardless of the actual length of the heavenly constellation. E.g., the constellation of Aries is quite small (24°), while that of Pisces is much larger (38°). The Babylonians were the first to render the zodiacal circle into 12 equal 30°-segments: see Rochberg 2004b, 128–130.

3 See the range of meanings in LSJ, *s.v.* ὥρα, cκοπός, and cκοπέω.

4 William Lilly's 17th-century text *Christian Astrology* still equated "horoscope" with "Ascendant" [1647, 656].

5 For a detailed discussion of the various meanings of "horoscope", see Greenbaum and Ross 2010, 146–149.

3 Who Used Horoscopes?

Babylonians, Egyptians, Greeks, Romans, and people living in the greater Mediterranean region from the Hellenistic Period to Late Antiquity (and beyond) all used horoscopes in astrological practice.

The Babylonians were the earliest to develop a methodical system for interpreting astral omens in order to know and respond to divine intention [see ch. 12.2, p. 472]. Evidence of celestial omen divination in the ancient Near East appears as early as *ca* 1800 BCE in Old-Babylonian omen-texts. These and other texts influenced the later celestial omen-series *Enūma Anu Enlil* [Rochberg 1998, ix] and in turn led to the system of prognostication that became astrology, first for kings and countries, later for individuals. Though Babylonian birth notes and lists of celestial placements and phenomena do not contain an astrological Ascendant and so technically should not be called horoscopes, in spirit they are clearly documents meant to be used in the same way that horoscopes containing an Ascendant are used: for astrological descriptions and predictions about a person's life. It is splitting hairs to claim otherwise [*pace* Pingree 1997, 20; Hunger and Pingree 1999, 27].

In Egypt, astral concerns took a different route, from the Pyramid Texts, which afforded the king the same celestial divinity that gods enjoyed, to the Coffin Texts, which transferred royal prerogatives in this regard to commoners, to the system of decans. The decans may have begun as astronomical calendrical and timekeeping devices but, with their association with gods, rising, and culmination, they became important components of religious doctrine and, with later links to the zodiac, astral prediction.

Both of these cultures, along with Greek, Greco-Roman, and Greco-Egyptian practices, influenced the development of Hellenistic astrology[6] in the Ptolemaic Period and the creation of the chart we know today as the horoscope. From its origins in the fifth century BCE to its development in the second and first centuries BCE, by the second century CE the horoscope was an established feature of astrological enterprises throughout the Mediterranean world, from Rome to Egypt to Persia. Throughout its history, the horoscope played and still plays a vital role in the practice of astrology. Astrological interpretation cannot occur without the knowledge of planetary positions in zodiacal

6 This term is used as a descriptor, not of a historical period but to denote the astrological practices of the Mediterranean world from the late Hellenistic Period to Late Antiquity, whether or not they originated in Greece, but primarily using Greek as the vehicular language for these practices.

signs and the orientation of the zodiac in time and space neatly packaged in the form provided by the horoscope.

4 From Astral Divination-Texts to Horoscopes

4.1 *Mesopotamia*

Mesopotamian astral divination may in some form go back to the cylinder-inscription of Gudea (*ca* 2140 BCE), which says the best time for building a temple to Ningirsu is found by using dreams and extispicy; a "tablet 'star of the heavens' is generally cited as an indication of some of nascent form of divination by the stars" [Rochberg 2004b, 64].[7] In the Old-Babylonian Period (*ca* 1800 BCE), a tablet with omens from eclipses contains predictions for corresponding earthly events; for example, "an eclipse in the evening watch is for plagues. An eclipse in the middle watch is for diminished economy" [BM 22696, obv. 1–2: see Rochberg 2004b, 68].

The renowned celestial omen-series *Enūma Anu Enlil* contains omens of the Moon, Sun, eclipses, planets, and meteorological and atmospheric phenomena such as rainbows and cloud formations. It gives celestial signs for general weather-conditions, kings, and the state of the country using the protasis/apodosis form "*if* a celestial event happens, *then* an earthly event will occur"; for example, "If at Venus' rising the Red star enters into it: the king's son will seize the throne."[8] The omens were solely for the king and his family, not for individual citizens. However, the celestial omen-texts provided an important template for later individual astrological prediction and the basic parameters of the horoscope.

4.2 *Egypt*

Egyptian interest in the heavens and celestial phenomena begins in the Old Kingdom: both the Pyramid Texts and the Coffin Texts include some astral components [see chs 4.8, p. 160; 11.1, p. 411; 12.4, p. 509]. The importance of heavenly occurrences for earthly concerns is starkly illustrated in the connection between the heliacal rising of Sirius and the annual flooding of the

7 The phrase "tablet with the stars of the heavens" is also discussed in Koch-Westenholz 1995, 32–33.

8 Tablet 50.VI.5 [in Reiner and Pingree 1981, 49], cited in Rochberg 2004b, 75. It must be emphasized that this is but a sign of correlation between heavenly and earthly events, not a scenario of cause and effect.

Nile. The daily voyage of the Sun and its death and rebirth below and above the horizon were major features of Egyptian religion. After death, the king ascended to the heavens and became a star among other divine stars.

The stars' association with gods and goddesses is clear from the texts. Astral and earthly correspondence [Thausing 1939, 47] and the idea that the will of the gods might be read from the stars [von Lieven 1999, 99] are suggested by the implicit correlation and interaction among humans, sky, stars, and gods (seen, e.g., in the Pyramid Texts, where the king moves, like the Sun, from the netherworld to heaven and his spirit lives among the Imperishable Stars). As in Babylon, what was originally the preserve of the king became also available to commoners, as seen in the Coffin Texts.

In the system that became known as the *decans*, the sky was divided into 36 segments of 10° each: each decan rose nightly during a 10-day period and a new decan would rise heliacally every 10 days (thus the name "decan", from the term «δεκανός» used by the Greeks for this native Egyptian concept). Attested from the 9th or 10th dynasty, the decanal "star-clocks" depicted a method of timekeeping but their appearance on coffin-lids suggests funerary and religious functions as well, functions that continued into the New Kingdom and beyond [Neugebauer and Parker 1960–1969, vol. 1; von Bomhard 1999 and 2008; von Lieven 2007]. Decans eventually became part of Hellenistic astrology [Neugebauer and Parker 1960–1969, vol. 3; Greenbaum 2012]. As a method of determining time in more or less hourly components, the system of decans was instrumental in the development of the astrological Ascendant and thus the horoscope (chart) itself; the word «ὡροσκόπος» is even used to mean "decan", not "Ascendant", in early Greek astrological texts [Greenbaum and Ross 2010, 158–167].

Egypt also produced celestial omen-texts on eclipse and lunar omina, of which a Greco-Roman version is preserved [Parker 1959]. Mesopotamian antecedents for these and other omina have been established [Parker 1959, 28–34; Ross 2007b, 5–11; Williams 2008]. Alexandra von Lieven has proposed that eclipse-omens, however, had a native Egyptian tradition, citing the *Chronicle of Prince Osorkon* of the 23rd dynasty [1999, 102–103].

Mesopotamian and Egyptian practices demonstrate that astral omen-texts, reflecting the development of a relationship between humans and the sky, were seedbeds of the astrological horoscope, which connected a person's life with heavenly bodies and celestial phenomena. Babylonian horoscopic texts and their Egyptian, Greek, and Roman successors, calculated data and used content based on earlier omen-texts, focusing on specific times and specific individuals/events. Iterations of the horoscope changed through time but they were fundamentally dependent on these earlier texts.

5 Types of Astrology and the Use of Horoscopes

Different types of astrology were used for different purposes, though all relied on the same basic principles. Horoscopes could be employed in all of these types, with variations in the way different horoscopic components were interpreted depending on type.

5.1 *Natal Astrology*

Also known as genethlialogy, this is the interpretation of a client's life based on the birth-horoscope. The time and place of birth are linked to the positions of the planets, Sun, and Moon in the sky as well as how the zodiacal band was oriented at that particular time and place.

5.2 *General Astrology*

Also known as universal (καθολικά) or mundane astrology, this predicts events for countries, cities, or states, and the general population. General astrology can predict based on repeating celestial patterns, solar and lunar eclipses, and other astronomical phenomena such as the daily and yearly solar motions and the phases of the Moon. Additionally, a horoscope can be cast for the founding of a city, which can be done both before and after the fact [Heilen 2007; Boudet 2015: see ch. 12.3 §3.5, p. 506].

5.3 *Catarchic Astrology*

This kind of astrology is an umbrella used for several different but related practices—elections, events, interrogations, and decumbitures—that use similar rules and methods of interpretation. Catarchic astrology is concerned with specific events and the timing of events that occur outside of natal astrology. In a religious sense, the term «καταρχή» means the beginning of a ritual [LSJ, *s.v.* κατάρχω]. In a catarchic chart, each component takes on a specific meaning depending on the subject matter being considered. For example, depending on circumstances, the planet Mercury could represent a thief or a child, since the god Mercury is mythologically associated with thievery but is also a youth. Likewise, the planet Saturn could represent an old man or a father.

An *election* is the casting of a horoscope for the best time to begin an action. This practice takes a proactive approach, offering the best possible astrological circumstances under which the event will occur. If an unelected *event* has already happened, a horoscope can still be cast for the time it occurred and an interpretation given after the fact. Thus, electional and event charts are related, though they are not identical.

Another practice, *interrogations* (now commonly called *horary astrology*), answered questions in two ways: either by interpreting a horoscope for the time of an event like the burglary of a house (the question in this case could be Where is the thief? or Will I get my goods returned?) or by making an interpretation from a horoscope cast when the question itself was asked of the astrologer (e.g., Will my wife return to me?). Interrogations and event horoscopes are related in that the same techniques are used to interpret both types, as a passage in Hephaestio of Thebes (*flor.* 415 CE), drawing on an original text of Dorotheus, states:

> [According to] the *katarche* in which the separation has come to be, or even in which hour someone inquires of you, look at Aphrodite and the Sun.
>
> HEPHAESTIO, *Apo.* 3.11.2: PINGREE 1973–1974, 1.266.13–15[9]

The subsequent instructions for interpretation are exactly the same whether the chart is for the event or the question about the event.

Finally, *decumbiture*-horoscopes were cast for the time a patient took to his or her bed (i.e., became too ill to continue a normal daily routine). This horoscope would be used to find out both the outcome of the illness (Will the patient survive?) and crisis periods that might arise during the course of the illness. This practice is associated with medical astrology [Greenbaum 2014, 121–122: see ch. 9.3 § 4.4].

In all catarchic practices, the components of the horoscope represent different facets of the issue to be solved. For example, in a marital question or event, the Sun could represent the husband; and the Moon or Venus, the wife.

9 See Dorotheus, *Carm.* 5.17 in Pingree 1976a, 275. Hephaestio frequently quotes passages from Dorotheus in Greek. Two of the three epitomes containing this passage use similar wording (the third may merely contain a slight mistranscription or scribal error [Pingree 1973–1974, 2.17.22–24; 2.121.2–5; 2.294.23–26]). The Arabic text of Dorotheus (probably composed about 400 years later than Hephaestio's text in *ca* 800 CE [Pingree 1976a, xiv]) omits the event but retains the question:

> If you want to know, if she [a wife] returns to him [a husband], whether he will profit from her or will see joy and happiness or other than this in her, then look at the hour in which you are asked about this at the position of the Sun and of Venus. [Dorotheus, *Carm.* 5.17]

In this case, the text of Hephaestio, including both scenarios, seems more reliable as to the history of the doctrine, since it is closer in time and language to the original Dorotheus. It is common for different astrological practices to draw on each other for inspiration and method.

The zodiacal sign in which they fell and their relative strength or weakness in the horoscope were also considered. Similarly, the 12 places (τόποι or *loci*/*loca*), also known as houses (ʿ.*wy* in Demotic) of the horoscope, were assigned different functions in the καταρχή; for example, different parts of a ship if the question was a nautical one or different places in a house if a client wanted to find a lost item. All these parameters contributed to the predicted outcome.

6 The Earliest Western Horoscope

The earliest extant horoscope [see Plate 1 and translation, p. 451] was found in Babylon and dates to 410 BCE. It is not a diagram but a textual list. It does not contain an Ascendant position. It lists planetary and luminary positions, visibility and movement of planets, weather-conditions, and solstice data. The date of birth is given (24th of Tebētu, year 13 of Darius = 12/13 Jan 410 BCE) but the subsequent astronomical data do not refer to that date [Rochberg 1998, 51–53].

The contents of this horoscope clearly derive from earlier Babylonian astronomical texts [Rochberg 2004b, 63, 101]. Visibility of a planet seems to be an important consideration—this phenomenon is an important feature of astrological interpretation within all Mediterranean cultures practicing astrology, and visibility becomes a significant feature of Hellenistic astrology. While contemporary omen-texts bearing on nativity could include interpretations for an individual based on celestial phenomena [Rochberg 2004b, 9–10], there is no interpretation of the child's life or character in this earliest extant horoscopic text. In fact, very few Babylonian horoscopes contain any interpretation—the same is also true of documentary Greek and Egyptian horoscopes. One of the few examples of an interpretation is MLC 1870 [Text 5 in Rochberg 1998, 65–67], dated to 4 Apr 263 BCE, where we see, after a list of planets in zodiacal signs:

> …he will return(?) [to(?)] his place…He will be lacking property…His food will not [suffice(?)] for his hunger(?). The property which he had acquired in his youth(?) will not [last(?)]. The 36th year (or: 36 years) he will have property. (His) days will be long. His wife, whom people will seduce(?) in his presence, will….
>
> ROCHBERG 1998, 67

PLATE 1 Oldest example of an individual birth-horoscope
AO 17649: SEE ROCHBERG 1998, 52 (TEXT 1), 53 (TRANS.)

Translation of text in Plate 1

obv.

1 Tebētu the 24th, in the last part of the night of the 25th, year 13 of
2 Darius, the child was born.
3 Kislīmu, around the 15th, Mercury's first visibility in the east behind (east) of Gemini.
4 Tebētu: (Winter) solstice was on the 9th of Tebētu; <last lunar visibility (of the month)> was on the 26th.
5 Šabaṭu: Šabaṭu, dense of clouds, around the 2nd, Mercury's last visibility in the east in Capricorn.
6 The 14th of Šabaṭu, Venus's last visibility in the east in front (west) of Aquarius. (The year had) an intercalary Addaru.

rev.
1 Tašrītu the 22nd, Jupiter's (2nd) stationary point in Aquarius.
2 Around the 2nd of Addaru, (Jupiter's) last visibility in Pisces.
3 Du'ūzu the 30th, Saturn's first visibility in Cancer, (it was) high and faint;
4 around the 26th, (the ideal) first visibility. The 7th of Kislīmu, first stationary point; Tebētu the 17th, "opposition".
5 (The year had) an intercalary month Addaru.

7 Other Early Horoscopes

The languages of the extant ancient western horoscopes are Akkadian (cuneiform), Demotic, Coptic, Greek, and Latin.[10] Subsequent to the Babylonian horoscope of Jan 410 BCE and the collection of Babylonian horoscopes dated from 410 to 69 BCE, documentary horoscopes in other languages of the Mediterranean region represent dates beginning in the first century BCE. (The birthdate of the chart is unlikely to be the date when the chart was constructed.) In Greek, the earliest extant documentary horoscope (i.e., a standalone text on papyrus, carved in stone, on ostraca, papyrus, etc.) is the monument at Nimrud Dagh [see Plate 2, p. 453], dated by Neugebauer and van Hoesen to 7 Jul 62 BCE [1959, 14–16].[11]

The earliest literary horoscope (i.e., given in a "literary" source, often an astrological text) is in a treatise on determining length of life by Balbillus, the famous astrologer of Nero and Vespasian [Cumont and Boudreaux 1921, 236.24–237.10; Neugebauer and van Hoesen 1959, 76–78]. Certainly cast well after the actual birth, its date is 27 Dec 72 BCE. In Hieratic and Demotic (a late form of the Egyptian language), the earliest horoscopic ostracon has been dated to 38 BCE (ADO 633) [see Plate 3, p. 453: Neugebauer and Parker 1968, 231–234; ch. 12.4].

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10 See Spiegelberg 1910; Thompson 1912; Neugebauer 1943; Sachs 1952; Černý, Kahle, and Parker 1957; Neugebauer and van Hoesen 1959; Neugebauer and Parker 1968; Rochberg 1998; Jones 1999a; Ross 2006a, among others.

11 Controversy still reigns over the date: see Crijns 2002; Heilen 2005; Belmonte and Gonzaléz García 2010. Whatever the date may be, it is still an astrological construction. Pingree [1997, 26] claims that it is not a "birth 'horoscope'" but "rather an application of the idea of celestial omens of this form…". While it is probably not the horoscope of a birth, it represents a time depicted in astrological form: see Heilen 2005, 146, 150–152 for the argument that this is not simply the constellation of the Lion but the zodiacal sign of Leo and that there are astrological reasons for the depiction. Thus, it is a planetary configuration demonstrating astrological principles of interpretation and, therefore, conforms to the spirit of a horoscope.

PLATE 2 The Lion-Horoscope at Nimrud Dagh
HUMANN AND PUCHSTEIN 1890, VOL. 2, PL. 40

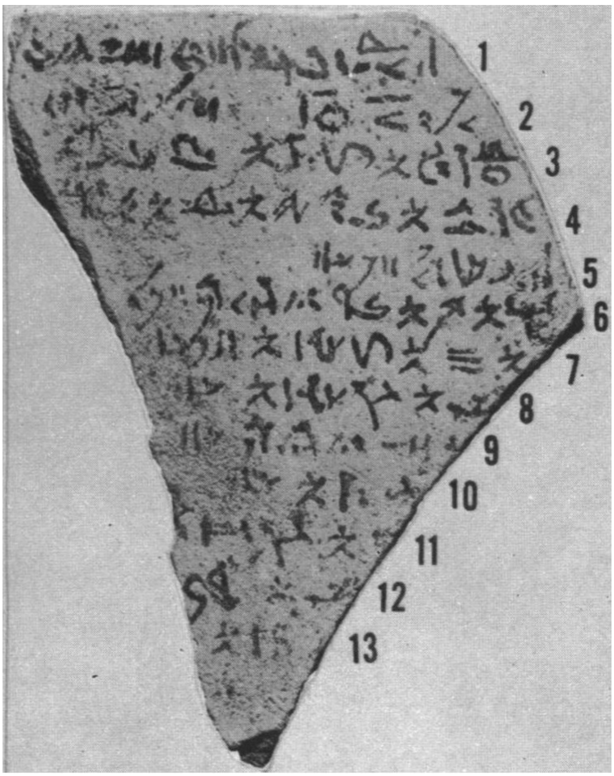

PLATE 3 Ashmolean Demotic Ostracon 633
NEUGEBAUER AND PARKER 1968, PL. 36.2

8 Horoscopes in Practice

The earliest nativity omens were for royalty and nobility [Rochberg 2004b, 61–62] and this class of people continued to be well represented among the astrologer's clientele as astrology spread through the Mediterranean region. The emperors in Rome were famous for their employment of astrologers to predict not only for them personally but for their friends and enemies (periodic bans on astrology and astrologers were also a feature of the Roman Empire) [Cramer 1954, update in Ripat 2011]. Developing from an art that was a prerogative of the highest classes, horoscopes were subsequently cast for commoners and their popularity bloomed (along with their critics).

For a practicing astrologer in this period [see chs 8, p. 297; 12.3, p. 490], personal clients provided an income. Whether the consultation was for a nativity, determining the best time to begin an action, predicting the course of an illness and whether the client would recover, answering a question about the client's life, or determining astrological compatibility in relationships—all were reasons to consult competent astrologers. In addition, general astrology concerning the fates of cities or countries was practiced by means of horoscopes cast for the creation of cities and by examining recurring celestial patterns that were considered to affect a state or country.

Astrologers may have specialized in one practice or another. Vettius Valens (second century CE) seems to be mostly interested in natal astrology, though there are some interpretations of events as they affect a nativity, e.g., the shipwreck in *Anth*. 7.6.127–160 [Pingree 1986, 274.11–275.24; Greenbaum 2009, 133–134 and 2016, 244–246]. Dorotheus (*Carmen astrologicum* or *Pentateuch*, first century CE) and Hephaestio of Thebes (*Apotelesmatica*, early fifth century CE) cover both natal and catarchic astrology in their treatises. Ptolemy (*Apotelesmatica* or *Tetrabiblos*, second century CE) deals in a theoretical manner with both general and natal astrology.

In the Greek corpus, among the documentary horoscopes, interpretations are scanty and brief, often merely a note "with good fortune" («αγαθηι τυχηι») or "good luck" («διευτυχει») [Neugebauer and van Hoesen 1959, 22–24, no. 81, Titus Pitenius, col. 7.184; col. 10.212–213]. "Literary" charts, on the other hand, are often used as illustrations of a particular technique or as teaching tools. Vettius Valens offers the best exemplar of detailed interpretations to illustrate techniques.

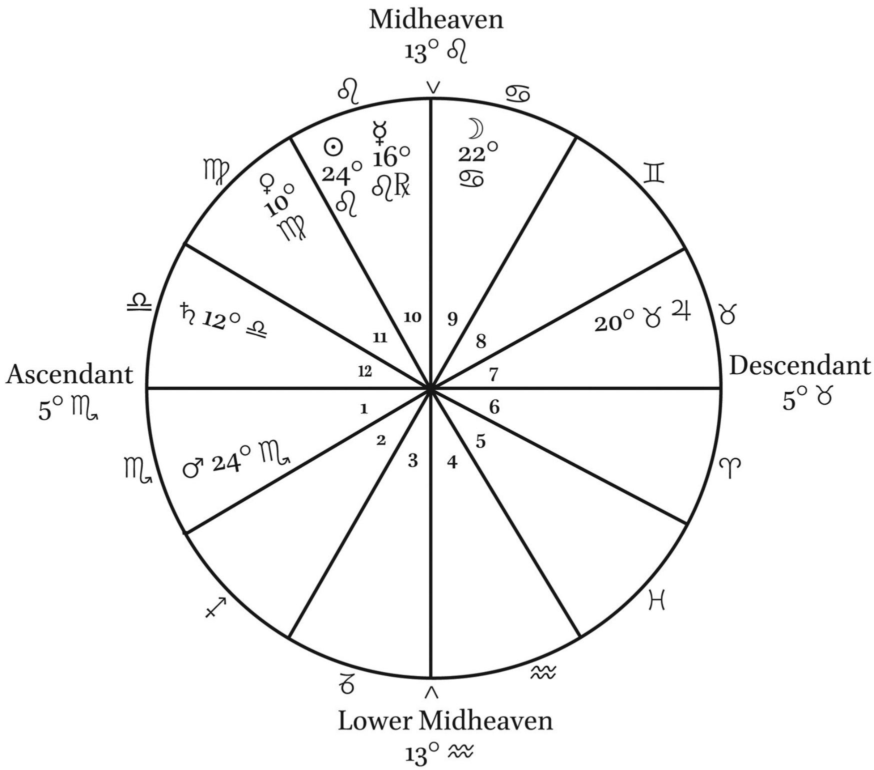

FIGURE 1 The layout of a typical modern astrological chart. This diagram shows the common modern practice of making the cardines the beginning of the 1st, 4th, 7th, and 10th houses.
♈ = Aries; ♉ = Taurus; ♊ = Gemini; ♋ = Cancer; ♌ = Leo; ♍ = Virgo; ♎ = Libra; ♏ = Scorpio; ♐ = Sagittarius; ♑ = Capricorn; ♒ = Aquarius; ♓ = Pisces;
☉ = Sun; ☽ = Moon;
☿ = Mercury; ♀ = Venus; ♂ = Mars; ♃ = Jupiter; ♄ = Saturn;
℞ = retrograde

9 The Diagram of the Horoscope

In modern horoscopy, charts containing the relevant astronomical information are usually given in a standardized round form, as in Figure 1, a simplified illustration. Here we see the 12 divisions of the chart known as places in ancient Greco-Roman astrology (now more commonly called houses, though "Ort" remains the term of choice in German), along with the orientation of the zodiacal signs (determined by the zodiacal sign in which the Ascendant falls) and the placement of planets, Sun, and Moon within both the zodiacal circle and the places.

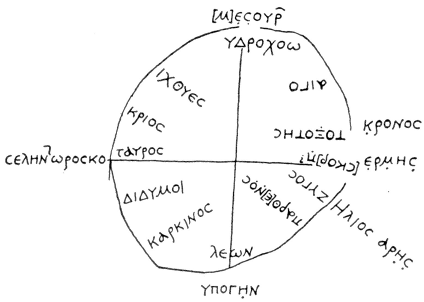

FIGURE 2A The earliest example of a horoscope in round form: *POxy*. 235 [NEUGEBAUER AND VAN HOESEN 1959, 18 FIG. 9]

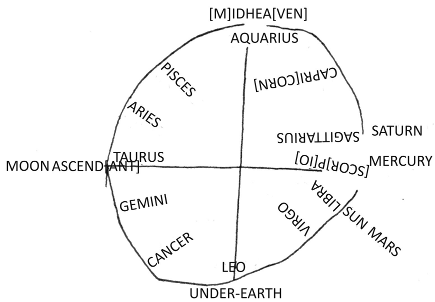

FIGURE 2B Translation

As we noted earlier, Babylonian horoscopes are given in list form, not as diagrams. In Antiquity, lists are by far the most prevalent way in which to provide the astronomical data on which the astrological interpretation will depend. The other schematic used in extant original documentary ancient horoscopes is a round diagram, not unlike the usual practice in the depiction of modern astrological charts as above.[12] However, there are only a very few ancient examples of these data in a round diagram form. Of the well over 300 extant examples of charts (both original documents and literary), only 10 appear in round form.[13] Virtually no literary texts are given in the form of a round diagram, nor are any Demotic horoscopes.[14] The earliest example of a round diagram of a chart is a papyrus in Greek from Oxyrhynchus, dated between 15 and 22 CE [Neugebauer and van Hoesen 1959, 18–19].[15]

Figure 2 shows the signs of the zodiac arranged in 12 roughly equal segments around the circle, which is bisected vertically and horizontally. Three of the points formed by bisection are labeled: «μεcουρ[ανημα]» (at the center top), «ωροcκο[ποc]» (left side), and «υπογην» (center bottom). These mean,

12 For a study of horoscopic diagrams, see Thomann 2008.

13 See Thomann 2008, 98. Thomann also mentions a circular engraving from Israel on wood, possibly astrological, discussed by Ovadiah and Mucznik 1996. (It is not at all clear that this engraving is a horoscope by the standards of the present chapter.)

14 Here should be mentioned that the Dendera "zodiac", although in a round form, is more akin to a sky map than a horoscope. Controversy continues as to whether it is an actual sky picture for a specific date or is symbolic. See, e.g., Neugebauer and Parker 1960–1969, 3.72–74, 200–202, 204; Aubourg 1995; Lull and Belmonte 2009; Park and Eccles 2012.

15 The original publication is Grenfell and Hunt 1899, 137–139.

respectively, the Midheaven (where the zodiacal circle intersects the meridian), the Ascendant (where the zodiacal circle intersects the eastern horizon), and the Lower Midheaven (Underground or Under-the-Earth), the opposite point to the Midheaven. The names of the Sun, the Moon, Mercury, Mars, and Saturn are also placed in the diagram in their zodiacal signs. Each zodiacal sign represents a 1⁄12-segment of the chart, mostly known in Antiquity as a place (τόποϲ). This diagram is accompanied by text giving other details of the horoscope.

Diagram placements: Midheaven, Aquarius; Ascendant, Taurus; Lower Midheaven, Leo; Moon, Taurus; Sun and Mars, Libra; Mercury, Scorpio; Saturn, Sagittarius.

Text preceding the diagram is as follows:

1. Thinking it proper [to ....]
2. your descendants (?), dear Tryphon [......]
3. I shall try to [set forth] for the dates [which you have given us ....]
4. These happen to be: [the .....]
5. year of Tiberius, Phaophi 1, according to
6. the old calendar Phaophi 11 to [12],
7. at the fourth hour of the night. [The Sun] happens to be
8. in Libra, male house of V[enus]
9. the Moon in Taurus, female house [of Venus]
10. Saturn (and) Jupiter in Sagittarius, male [house]
11. of Jupiter; Mars in Libra house of Venus [Mercury Ve-
12. nus] in Scorpio male [house of Mars]
13. Taurus marks the hour .... house of Venus [Midheaven]
14. Aquarius, male house [of Saturn]
15. Scorpio sets, house of Mars, Lower [Midheaven in Leo]
16. house of the Sun, housemaster Ven[us]

NEUGEBAUER and VAN HOESEN 1959, 18 (trans. slightly modified)

These diagrams in round form appear to mimic a device used by ancient astrologers to depict horoscopes for their clients [Evans 2004]. This device is called a tablet or table (πίναξ in Greek) and all extant ancient examples are round, made in various materials (stone, glass, wood, ivory).[16] Most extant *pinakes* have come from Egypt but some have been found as far north as Croatia and Grand (France) [Evans 2004; Abry 1993; Forenbaher and Jones 2011].

16 See Evans 2004; Boll 1903; Abry 1993; Neugebauer and Parker 1960–1969, vol. 3; Greenbaum and Ross 2015.

Plates 4 and 5, p. 459, show that the *pinax* is constructed of concentric circles, each circle containing different components important for interpreting the chart. One circle is divided into 12 segments, with each containing a zodiacal sign. Other circles contain 3 decan-compartments or 5 term-compartments. Planetary or Ascendant markers could be placed in the appropriate compartment. One extant *pinax*, the Tabula Bianchini, has a double zodiac wheel [see Plate 4, p. 459], so that two charts can be compared. Such comparison is called *synastry* in astrology.[17]

10 The Contents of the Horoscope

Both documentary and literary horoscopes contained items necessary for astrological interpretation. Some documentary evidence consists of mere birth-notes, in which the date and time are given but not much else [Baccani 1992; Jones 1999a; Ross 2006a]. Possibly these notes were jotted down in order for a horoscope to be calculated at a later date or for the astrologer to consult tables for calculation (direct observation was likely not a practice used in horoscope construction)[18] and insert the correct positions into a *pinax* when consulting with a client. A small number of documentary horoscopes contain detailed astronomical and astrological data but these are the exception [Greenbaum and Jones 2017]. The complete contents of a horoscope may be missing because of damage to the medium or unfinished notes.

The following descriptions of the horoscope's components include items found in both documentary and literary horoscopes from the fifth century BCE to the sixth century CE.[19] Table 4, p. 468, shows their occurrences in horoscopes as differentiated by geography/culture.

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17 Discussion of *synastry* in ancient astrological texts can be found in Ptolemy, *Tetr*. 4.5 [Hübner 1998, 309.268–311.288; Robbins 1940, 396–399]; Hephaestio, *Apo*. 3.9 and 10 and 2.23.10–11 [Pingree 1973–1974, 1.183.17–20, 184.3–5].

18 For the evidence against direct observation, see Jones 2007, 310. Ptolemy, *Tetr*. 3.3 describes a "horoscopic astrolabe" [Hübner 1998, 172.123–173.126; 3.2 in Robbins 1940, 228–229] as the only accurate way to calculate the Ascendant. However, this was probably not an astrolabe as we know it but something akin to a quadrant or a sextant [Evans 1998, 116]. In any case, this would not likely have been used by most practicing astrologers.

19 These descriptions will only include the items found in such horoscopes. They will not include every technique used in ancient astrological practice, such as, for example, aspects. This list, therefore, should not be considered as comprehensive in covering everything an astrologer might have used in interpretation. Astrological manuals are more thorough but discussing their content in full is beyond the scope of this chapter.

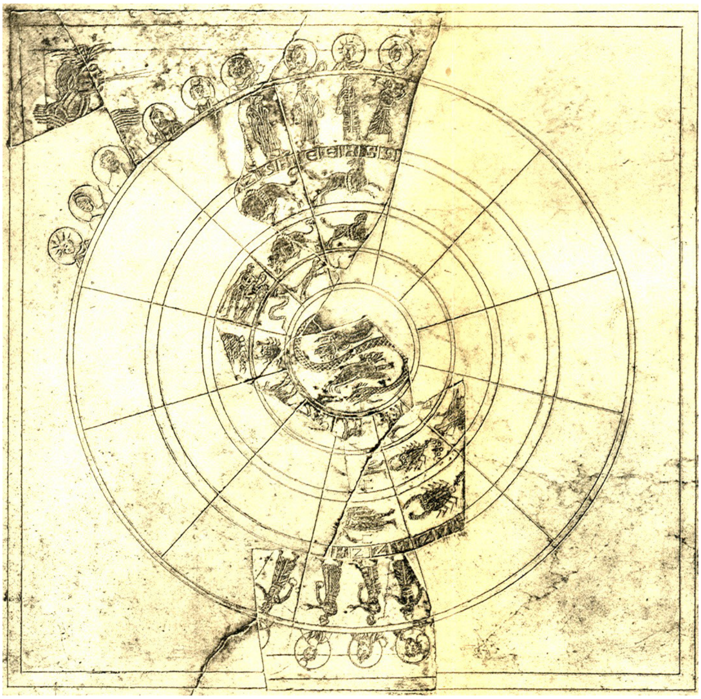

PLATE 4 The Tabula Bianchini showing two zodiac wheels
BOLL 1903, PL. 5

PLATE 5 A carved ivory *pinax* from Grand, France
ABRY 1993, PLS 2–3

(1) *Name*
Actual names are somewhat uncommon for at least two possible reasons. First, as the first item in a list, damage occurs more easily to that part of the document/ostracon/papyrus and, therefore, that piece of information is lost more readily. Second, in literary horoscopes, the name could have been deliberately omitted for privacy or other concerns.

(2) *Date of birth*
Generally this includes the year, month, and day. Often the date is given based on the regnal year of a king, using various dating systems in use when the horoscope was calculated. Modern collections of horoscopes often convert this date to a system of dating used today.

(3) *Time of birth*
This is usually given as one of the hours of the day or night or by "watch" (especially in Babylon) or by other means of dividing the day, such as the *nychthemeron*. The time (hour) of day or night allows calculation of an Ascendant, even if it does not appear in the horoscope until the time of extant examples in Demotic and Greek.

(4) *Luminary positions*
Usually both solar and lunar positions are given in (zodiacal) longitude, at least by zodiacal sign but sometimes by degree as well.

(5) *Planetary positions*
These are given by zodiacal sign and/or by degree: minutes and seconds are quite rare.

(6) *Cardines*[20]
These are the Ascendant, Midheaven, Descendant, and Lower Midheaven.

(a) *Ascendant* (ὡρόϲκοποϲ)
This is literally the hour-marker or hour-watcher. It is the point (zodiacal sign or sign and degree) where the eastern horizon in local space and time intersects the zodiacal circle. It is by far the most calculated cardine in ancient texts [Hand 2007].

(b) *Midheaven* (μεϲουράνημα)
This is also known as the culmination. It is the point where the zodiacal circle intersects the local meridian.

(c) *Descendant* (*δύϲιϲ*) *or Setting*
This is exactly opposite the Ascendant in zodiacal longitude; for example, an Ascendant of 12° Leo will produce a Descendant of 12° Aquarius.

20 κέντρα: centers or center-pins, also known as angles.

(d) *Lower Midheaven* (ὑπόγειον) *or Underground*
This is also called the *Imum Coeli* or the Anti-Culmination. It is exactly opposite the Midheaven in longitude: a Midheaven of 12° Scorpio will produce a Lower Midheaven of 12° Taurus.

(7) *Places* (τόποι)
These are the 12-part divisions of the chart in which each place represents a particular component of life experience. Places include the cardines, which are the most often given in the data for horoscopes. Interpretively, cardines were said to be the most effective or operative (χρηματιστικός) in ability to produce outcomes. See Figure 3.

(8) *Swšp/Twr*
These are Demotic Egyptian divisions of the chart as yet not definitively understood by modern scholarship [see ch. 12.4, p. 509]. The names occur only in the Demotic horoscopes from Medinet Habu.

(9) *Lots* (κλῆροι) *or parts* (partes)
Lots are specific points that have interpretive significance. They are calculated by taking the elongation between (usually) two planets and projecting that arc in one direction or another (usually) from the Ascendant point. The two lots most represented in extant horoscopes are the Lot of Fortune and the Lot of Daimon [Greenbaum 2008; 2009, 180–208] but other lots, such as the Lot of Eros, the Lot of Necessity, and Lots of the Father, Mother, or Siblings also appear in some horoscopes.

(10) *Fixed stars and constellations*
In contrast to the "wandering stars" (the planets), stars that move almost imperceptibly in a person's lifetime—about 1° in longitude during 72 years—were described as fixed. These stars seem to have greater importance interpretively in the Babylonian texts; they are rarely found in Greek horoscopic texts [Neugebauer and van Hoesen 1959, 170–171], although instructions for interpreting fixed stars and constellations appear in textbooks, for example, Teucer of Babylon's treatise on *paranatellonta* (fixed stars co-rising with zodiacal constellations).[21]

(11) *Decans*
In Hellenistic astrology, decans can have several different meanings. In the earlier use of decans (first century BCE to first century CE), decans can be both "hour-regulators" (ὡρονόμοι)—see, e.g., Anubio, *Carmen astrolog-*

21 See Hübner 1995b; Ptolemy, *Phaseis* [Heiberg 1898–1907, vol. 2; Schmidt 1993b]; and the anonymous treatise Ἀποτελέσματα τῆς τῶν ἀπλανῶν ἀστέρων ἐποχῆς (*ca* 379 CE) [Cumont and Boll 1904, 194–211; Schmidt 1993a].

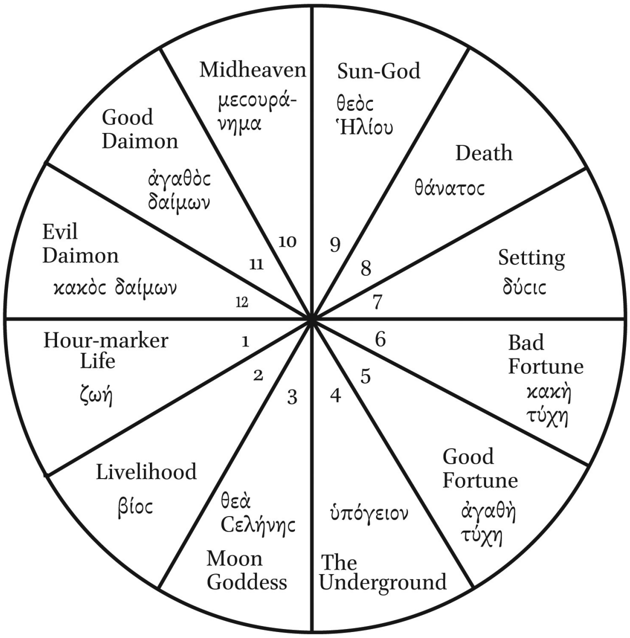

FIGURE 3 The places with their English and Greek names

icum elegiacum, fr. 2.1.8 [Obbink 2006, 24]—and threefold divisions of a zodiacal sign (and are thus 10° each). In later systems, they are associated solely with the threefold sign division. In documentary texts, decans are sometimes called horoscopes, for example, *PLond.* 98v [Neugebauer and van Hoesen 1959, 28–38]. See Table 1, p. 463.

(12) *Descriptions*

These accompany the placement of planets, luminaries, or cardines. "Description" is used as a general term for other information provided in a horoscope. The following categories cover only those used in extant examples of horoscopes.

(A) *Dignities*

These are systems for assigning "familiarities" between planets and zodiacal signs.[22] In Hellenistic astrology, the main dignities are by house, exaltation, triplicity, and term. Phase, face, and decan are also assigned to planets in zodiacal signs.

22 The term "dignity" is an anachronism in Hellenistic astrology: see Bezza 2007, 240.

TABLE 1 Exaltations and triplicity-rulers

Exaltations		Triplicity-Rulers
Sun	Aries (19°)	*Fire*
Moon	Taurus (3°)	(Day) Sun
Mercury	Virgo (15°)	(Night) Jupiter
Venus	Pisces (27°)	
Mars	Capricorn (28°)	*Earth*
Jupiter	Cancer (15°)	(Day) Venus
Saturn	Libra (21°)	(Night) Moon
		Air
		(Day) Saturn
		(Night) Mercury
		Water
		(Day) Venus
		(Night) Mars

(a) *Houses* (οἶκοι)
Each planet is assigned two zodiacal signs of "domicile". The Sun and the Moon are each assigned one. See Figure 4.

(b) *Exaltations* (ὑψώματα)
Possibly of Babylonian origin [Rochberg-Halton 1988b, 53–57] and sometimes considered to be more significant than houses, one zodiacal sign is said to be the exaltation of a planet or luminary. Exaltations are also assigned to a particular degree of the zodiacal sign, where the effect is said to be particularly powerful.

(c) *Triplicities* (τρίγωνα) *or trigons*
Also possibly originating from Babylon [Rochberg-Halton 1988b, 60–61; Ross 2007b], triplicities divide the zodiacal signs into four groups and assign them to two (or three) planets or luminaries based on day and night. By the second century CE, triplicities were explicitly assigned to the elements. Slight differences in the system are evident in different authors.[23]

23 In Dorotheus, *Carm.* 1.1 [Pingree 1976a, 161–162] a participating ruler is also given. For

(d) *Terms* (*termini*) *or boundaries or bounds* (ὅρια)
These divide each zodiacal sign into five (commonly) or more (uncommonly) ranges of degrees, each assigned to a planet. In some systems, the luminaries are also used. The most common systems are the Egyptian and the Ptolemaic. See Table 2, p. 465.

(e) *Face and decan*
The division of the zodiacal sign into three 10°-segments. Each segment is ruled by a particular planet or luminary. For Ptolemy [*Tetr.* 1.23], a planet is "in its own face" if it is in the same relationship to the Sun or Moon that its own planetary house has to the Sun's or the Moon's house. But more commonly, a face is an assignment of a planet to each 10°-segment of a zodiacal sign, starting in Aries and going in Chaldean order (i.e., Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon). See Table 3, p. 465.

(B) *Debilities*
Systems showing the weakness or ineffectiveness of planets and luminaries. The zodiacal sign opposite the house-ruler is its detriment. The zodiacal sign opposite the exaltation-ruler is its depression (ταπείνωμα), also known as fall or humiliation (Roger Beck's term [2007, 85–86, 88, 99, 116, 118]).

(C) *Housemaster* (οἰκοδεσπότης)
This can be a ruler of a particular area or an overall ruler of the chart [Greenbaum 2009, 142–151; 2016, 255–266].

(D) *Chronocrators* (*Time-Lords*)
Used in the prediction of future events in the native's life, these are planets that rule certain periods of life. There are a number of different systems for time-lords.

(E) *Interpretations*
These are descriptions of the effects determined for a native based on the particularities of his or her horoscope. (In fact, most extant horoscopes are for men.)

(13) *Visibility of planets and luminaries*
Being able to see a planet or luminary is considered an important criterion in interpretation. Though rare in Greek documentary texts, its interpretation is described and employed in texts for teaching.

Ptolemy [*Tetr.* 1.19: Hübner 1998, 66.979–982; 1.18 in Robbins 1940, 86–87], Mars is the primary ruler of water, with the Moon and Venus participating.

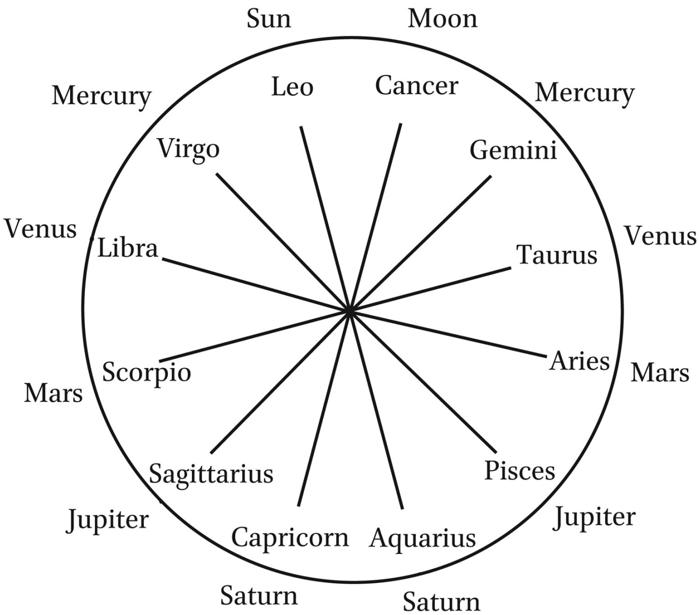

FIGURE 4 The houses of the planets

TABLE 2 Terms of the planets according to the Egyptians

Aries	Jup 6	Ven 12	Merc 20	Mars 25	Sat 30
Taurus	Ven 8	Merc 14	Jup 22	Sat 27	Mars 30
Gemini	Merc 6	Jup 12	Ven 17	Mars 24	Sat 30
Cancer	Mars 7	Ven 13	Merc 19	Jup 26	Sat 30
Leo	Jup 6	Ven 11	Sat 18	Merc 24	Mars 30
Virgo	Merc 7	Ven 17	Jup 21	Mars 28	Sat 30
Libra	Sat 6	Merc 14	Jup 21	Ven 28	Mars 30
Scorpio	Mars 7	Ven 11	Merc 19	Jup 24	Sat 30
Sagittarius	Jup 12	Ven 17	Merc 21	Sat 26	Mars 30
Capricorn	Merc 7	Jup 14	Merc 22	Sat 26	Sat 30
Aquarius	Merc 7	Ven 13	Jup 20	Mars 25	Sat 30
Pisces	Ven 12	Jup 16	Merc 19	Mars 28	Sat 30

Degrees are given as ending longitudes and are exact, e.g., 6°00′00.00″

TABLE 3 The faces of the planets

Aries	Mars 10	Sun 20	Venus 30
Taurus	Mercury 10	Moon 20	Saturn 30
Gemini	Jupiter 10	Mars 20	Sun 30
Cancer	Venus 10	Mercury 20	Moon 30
Leo	Saturn 10	Jupiter 20	Mars 30
Virgo	Sun 10	Venus 20	Mercury 30
Libra	Moon 10	Saturn 20	Jupiter 30
Scorpio	Mars 10	Sun 20	Venus 30
Sagittarius	Mercury 10	Moon 20	Saturn 30
Capricorn	Jupiter 10	Mars 20	Sun 30
Aquarius	Venus 10	Mercury 20	Moon 30
Pisces	Saturn 10	Jupiter 20	Mars 30

Degrees are given as ending longitudes and are exact, e.g., 6°00′00.00″

(14) *Movement of planets and luminaries*
These are rarely attested in extant horoscopes, though they are interpretively described in texts. Movement is basically described as forward (advancing), backward (retreating, often called retrograde in astrological texts), or stationary. The Sun and Moon never move backward.

(15) *Weather-conditions*[24]
Winds, thunder, lightning, cloud formations, rain and rainbows, and earthquakes are all meteorological phenomena that produce effects.

(16) *Eclipses*[25]
A solar eclipse occurs when the Sun's disk is partially or totally obscured by the shadow of the Moon. A lunar eclipse occurs when the Moon's disk is partially or totally obscured by the shadow of the Earth.

(17) *Lunar nodes*[26]
Lunar nodes are the points at which the orbit of the Moon intersects the zodiacal circle going north in latitude or going south. The Ascending node (ἀναβιβάζων), also known as the Dragon's Head (*Caput draconis*), is the intersection of lunar orbit and zodiacal circle as the Moon moves north. The Descending node (καταβιβάζων), also known as the Dragon's

24 Only in Babylonian horoscopes.
25 In Babylonian horoscopes; rarely in Greek.
26 Rare in extant Greek or Demotic horoscopes.

Tail (*Cauda draconis*), is the intersection of the lunar orbit and zodiacal circle as the Moon moves south.

11 Development of the Horoscope

To summarize the history of the development of the horoscope so far: we have seen that the earliest examples of horoscopes contain planetary positions but no Ascendant. As previously noted, Pingree did not consider these true horoscopes because they did not have an Ascendant or any cardine (angle) [1997, 20; Hunger and Pingree 1999, 26–27; Ross 2006a, 30] that would orient the planetary positions by direction (the Ascendant being east and the Midheaven south) and within the zodiacal circle. However, arguably, a horoscope is first and foremost a vehicle for astronomical and astrological information to be astrologically interpreted, whether or not it contains an Ascendant. As the horoscope continued to develop beyond Babylonia, practices originating in Egypt supply evidence for the Ascendant being of Egyptian origin. Evidence also indicates Egypt as the origin of the Midheaven (and Lower Midheaven) and the places of the horoscope [Greenbaum and Ross 2010, 167–175].

By the first and second centuries CE, extant horoscopes demonstrate the inclusion of information beyond listings of planetary and luminary positions within zodiacal signs and their orientation *via* the Ascendant and/or Midheaven. Table 4, p. 468 shows the wide variety of information that horoscopes could provide. In order to examine practices and doctrines affecting the development of the horoscope in Late Antiquity, we now turn to the text[27] of the oldest extant documentary chart to contain an Ascendant, ADO 633, dated to 38 BCE, as pictured above in Plate 3, p. 453 and translated here.

1. Year… of the Queen (Cleopatra VII), IIII *prt*,
2. day 22, day of the Moon (ϲελήνηϲ).
3. Sun: Taurus 4: Jupiter in ([*m*]-*hnw*) Cancer.
4. Moon: Capricorn 20½;…: Libra 6, Midheaven:
5. Year 14, I <*šmw*>, day 4, it being.....
6. Midheaven: Sagittarius 25. His own lot, he being dead.
7. [Saturn]: Aquarius 4. A center (*ib*), ⸢added⸣.
8. [The Ascendant]: Pisces 19. A center.....

27 Trans. Neugebauer and Parker 1968, 231–234.

TABLE 4 Ancient western horoscopes and their contents

	Babylon	**Egypt: Demotic**	**Egypt: Coptic (quite rare)**	**Greek**	**Latin (rare)**
Name	✓ (minority of texts)	✓ (rare)		✓ (rare, often missing)	
Date of birth (year, month, day)	✓	✓		✓	
Time of birth (hour of day or night; watch; division of nychthemeron/sunrise-sunset)	✓	✓		✓	
Luminary longitude (at least zodiacal sign)	✓	✓		✓	✓
Planetary longitude (at least zodiacal sign)	✓	✓		✓	✓
Visibility (planetary or luminary)	✓			✓ (extremely rare)	
Movement/phases (planetary or luminary)	✓			✓ (rare)	✓
Eclipses	✓				
Weather conditions	✓				
Places (τόποι)		✓		✓	✓
Cardines (κέντρα)		✓		✓	✓
Swšp/*Twr*		✓			
Lots		✓ (rare)		✓	
Decans		✓		✓	
Fixed stars/constellations	✓ (minority of texts)			✓ (rare)	
Lunar nodes		✓ (rare)		✓ (rare)	
Descriptions: dignities				✓	✓
Descriptions: debilities				✓ (rare)	
Additional descriptors (e.g., *oikodespotai*, Chronocrators, interpretations)		✓ (very rare)	✓	✓ (documents, less common; literary, more common)	✓

9. [Mars: Taurus] 7. His own lot.....
10. [Venus: Aries] 10. Jupiter.....
11. [The Descendant: Virgo] 19.....
12. [.............] Pisces, Scorpio.
13. [.............] A center.

Certain features in this horoscope demonstrate techniques that were becoming syncretic by this time but were still somewhat in flux. It borrows the Greek word for the Moon [see ch. 12.4, p. 509]. The *ỉbw* (cardines, κέντρα) of the horoscope are mentioned three times and the exact degree positions of the Ascendant and Midheaven are given.[28] The word «ỉb» in Egyptian means "heart"; «κέντρον» means "goad" or "the stationary compass point".[29] The word translated as "lot" is «tnỉt», which is also used in reference to houses, *ʿ.wy* (places) in the Medinet Habu horoscopes (possibly this points up a relationship between a place and a lot). Unfortunately, the horoscope's state of preservation makes definitive analysis difficult. However, its existence demonstrates the incorporation of cardines into the horoscope at least by the middle of the first century BCE, which prompts further observations about the places.

12 Whole-Sign Places

The fact that the degrees of the cardines are listed on the ostracon, rather than just the zodiacal sign, brings up another consideration: how the horoscope was divided into 12 places. We have seen each zodiacal sign being equivalent to a place. But evidence suggests that two systems were in use during the timeframe under discussion. The vast majority of extant horoscopes employ what has come to be known as the whole-sign system [Holden 1996, 13n12, called Sign-House; Hand 2000, 2007], in which each of the 12 portions of a horoscope consists of one whole zodiacal sign. The Ascendant by degree always falls within the first sign/place (in fact, it sets what sign occupies the first place). But, although the other cardines are the 10th (Midheaven), 4th (Lower Midheaven), and 7th (Setting), the Midheaven by degree "floats".[30] The cardines by degree produce a second system.

28 In fact, line 4 shows an additional Midheaven position. Possibly the text deals with two interacting dates.

29 LSJ, *s.v.* κέντρον for additional meanings.

30 See, e.g., Paul of Alexandria, *Intro*. c. 30, where he says that the Midheaven by degree could fall in the 9th, 10th, or 11th place [Boer 1958, 82.7–10; Greenbaum 2001, 63]. See also Hand 2007, 138–142.

13 Quadrant Places

The calculation of the Ascendant and Midheaven by degree (and the corresponding Descendant and Lower Midheaven) was accomplished by computing the position of the Sun and using tables of rising-times related to portions of zodiacal signs to find the Ascendant and then using that position to find the Midheaven.[31] These exact positions by zodiacal degree had another purpose. They were used in systems in which the quadrants of the horoscope were interpretively important. An example of this appears in Paul of Alexandria's (*flor*. 378 CE) *Introductio* c. 7, where the quadrants are associated with ages of life, directions, and times of day: the first quadrant, from the Ascendant to the Midheaven (going in the direction of the diurnal rotation or clockwise), represents youth and east (and sunrise); the second quadrant, from the Midheaven to the Descendant, represents Midlife and south (and noon); the third quadrant, from the Descendant to the Lower Midheaven, represents old age and west; and the fourth quadrant, from the Lower Midheaven to the Ascendant, represents extreme old age up to death and north [Boer 1958, 20–21; Greenbaum 2001, 15]. The same text designates these quadrants as either masculine or feminine.

The quadrant system could then be applied to an alternate method of dividing the places, in which the Ascendant and Midheaven, respectively, became the cusps (starting-points) of the 1st and 10th places, and the Descendant and Lower Midheaven, respectively, the cusps of the 7th and 4th places. Vettius Valens [*Anth*. 3.2] first describes this system, which evenly trisects each quadrant (a method that later became known as the Porphyry system). However, Valens's illustrations of astrological practice never employ this system.

In the *Tetr*. 1.11 [1.10 in Robbins 1940, 60–63], Ptolemy first discusses the power of the angles (γωνίαι), differentiating the "angles of the horizon" from the cardines (κέντρα). The angles and their respective places (τόποι) relate to the diurnal cycle, the winds, and the qualities hot, cold, wet, and dry. But in 3.4 [3.3 in Robbins 1940, 238–241], he speaks of the ability of the cardines to strengthen or weaken a planet. Especially in the case of the Ascendant and Midheaven, the cardine is considered to give a planet within its sign and/or near its degree the most effectiveness to act, whereas if a planet is in a sign "declining from the cardine" its power to act is weakened.

31 See discussions of calculations in Paul of Alexandria, *Intro*. cc. 28–30 [Boer 1958, 79–82; Greenbaum 2001, 60–63].

14 Development of the Horoscope after Late Antiquity

In the Early Medieval Period, the practical use of the horoscope becomes even more detailed in the explanation and use of certain techniques. For example, Abū Maʿshar (787–886 CE), in his *De revolutionibus nativitatum*, of which recensions exist in Arabic, Greek, and Latin [Pingree 1968a, xiii–xiv, xviii], delineates predictive techniques based on different methods, in which chronocrators and lots have a significant role [his example at 3.1]. The interpretation of the birth-horoscope of Constantine VII Porphyrogenitus [Pingree 1973] also places an emphasis on lots. Both of these texts are significantly dependent on earlier Hellenistic practices; their roots can be traced back to texts of the Greco-Roman Period and Late Antiquity.

The interpretation of horoscopes in all branches of astrology continued into Late Antiquity and persists today as an enduring and essential feature of the practice of astrology. It is no small measure of its importance that the meaning of "horoscope" has come to encompass, in modern times, not merely the chart itself but the entire interpretation of the contents of that chart.

CHAPTER 12.2

Hellenistic Babylonian Astral Divination and Nativities

Francesca Rochberg

1 Introduction

Astral divination and nativities in Babylonia during the Hellenistic Period reflect both the preservation of earlier practices of celestial omens from the series *Enūma Anu Enlil* and a break with that tradition in the form of new ways of thinking about prognostication from heavenly phenomena. The astral sciences in Hellenistic cuneiform sources thus exemplify the essential tension between tradition and change seen in other periods and cultures of science [Kuhn 1977]. However, it cannot be said, to quote Thomas Kuhn's statement regarding this "essential tension", that the Babylonian scribes ever represented a scientific community that "abandons one time-honored way of regarding the world and of pursuing science in favor of some, usually incompatible, approach to its discipline" [1977, 226]. In the cuneiform tradition, astral divination and/or astrology (genethlialogy) on one hand and astronomy on the other (taken to mean the consideration of the heavenly phenomena for purposes of description and prediction) have a history in which the preservation of older astral divinatory texts and their ideas continued to have value and to be compatible, even in the face of profound changes in the interests, capabilities, and functions of predictive astronomy. If the preservation of the texts of *Enūma Anu Enlil* during the Seleucid Period (312–64 BCE) is any indication, omen-divination was not abandoned in favor of horoscopy, nor was the idea of the divinity of the phenomena and their signs abandoned in favor of a mechanistic rule of the stars over humankind.

There are, nevertheless, significant unanswerable questions, such as in what context omen-divination was used during the Seleucid Period, whether there was any continuing political purpose to it or whether it was a strictly scholarly interest and, as well, how extensive the new method of constructing a "horoscope" may have been. Nor can it be shown that Babylonian theoretical astronomy reflects a new "way of regarding the world". It reflects advancement in the precision with which the periodic phenomena could be treated and in the establishment of the prodigious theoretical underpinning of the methods

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of Babylonian mathematical astronomy. This advancement, however, seemed to fit within the terms of previous understanding of the relation between phenomena, gods, and humankind embodied in the older form of prognostication from signs in heaven. It bespeaks in turn an underlying unity in epistemic values while permitting innovation and development within the bounds of the cuneiform system of astral knowledge.

Prognostication from signs in the heavens seems rooted in the idea of the starry sky as the abode of gods and of the celestial bodies as gods or manifestations of gods [Rochberg 2009]. This idea of the divinity of heavenly bodies, in one form or another, is in evidence across a wide geographical as well as chronological span of ancient Near Eastern and Mediterranean history, from third millennium Sumerian mythology and the first Akkadian celestial omens of the second millennium to the astralized iconography of deities in first millennium Syro-Palestine, the so-called visible gods of the author of the "Platonic" *Epinomis* 984d (ascription to Plato is dubious) and the divine powers of the heavenly bodies in the Greek and Greco-Egyptian magical papyri of the late Hellenistic Period. Indeed, the association of god and star seems to be as old as writing itself. The pictogram of a (usually) eight-pointed star, which later means in the cuneiform script the words "god" and "sky", as well as denoting the Sumerian/Babylonian Akkadian sky-god An (*Anu*), is attested as the divine determinative in archaic Sumerian script [see Figure 1, p. 474].

The pictographic writing for the word "star" was made up of three such star-shaped signs in a visual analog to a constellation [Figure 2, p. 474]. But, given the polyvalence of the sign read «AN» ("sky") or «DINGIR» ("god"), it is clear that the sign «MUL» (Akkadian «kakkabu»), made up of a cluster of stars in the archaic Sumerian writing system, also and simultaneously conveyed the idea that the stars were conceived of as divine in the third millennium [Rochberg 2004b, 186; 2016, 247–249].

MUL.APIN I i 1–ii 35 [Hunger and Pingree 1989, 18–79] contains a catalog of 71 stars divided into celestial pathways (*ḫarrānu*) named for the three highest cosmic gods: Enlil, Anu, and Ea. The star-catalog gives the names of the stars together with their divine names (such as the Great Twins, Lugalgirra and Meslamtaea, or the Panther, Nergal) and further descriptions as to what deities they were associated with (such as "messenger of Ninlil") or what role they played in some mythological background (such as "seeder of the plow") and where a certain star stood in relation to nearby stars. Thus, MUL.APIN I i 12–19 has

> ŠU.PA, Enlil, who decrees the fate of the land.
> The star which stands in front of it: the Abundant One, the messenger of Ninlil.

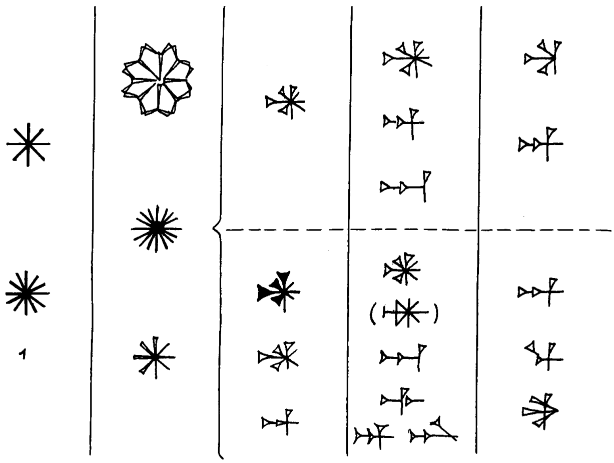

FIGURE 1 The sign for «AN» or «DINGIR» in cuneiform and its evolution
LABAT 1988, 48

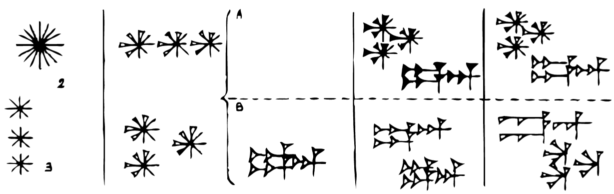

FIGURE 2 The sign for «MUL» in cuneiform and its evolution
LABAT 1988, 96

> The star which stands behind it: the Star of Dignity, the messenger of Tišpak.
> The Wagon, Ninlil.
> The star which stands in the cart-pole of the Wagon: the Fox, Erra, the strong one among the gods.
> The star which stands in front of the Wagon: the Ewe, Aya.
> The Hitched Yoke: the great Anu of heaven.
> HUNGER and PINGREE 1989, 21–24

Behind the divinized heaven also lie the agrarian origins of Mesopotamian civilization as embedded in the cuneiform star-names—from the reference to the field, the plow, the yoke, the seeder of the plow, wagon, furrow, harrow, and ear of grain to the domesticated animals, pig, ewe, horse, bull, rooster and the animals of the wild, lion, panther, stag, scorpion, eagle, raven, snake, and swallow.

The fundamental association between the heavenly bodies and gods surely underlies the practice of divination by heavenly signs, or astral divination, and, later, nativities. The poetic text of a prayer from the Old-Babylonian Period (early second millennium BCE), extant in two versions and also embedded in the opening lines of the great magical series *Maqlû* (*Burning*) [Abusch 2015], makes the notion of the celestial gods' role in divination (and magic) explicit. In the case of the two prayers, the "gods of night" («*ilū mušītim*») are called upon to stand by as a liver inspection is performed. Most of the stars enumerated in the prayer are circumpolar constellations, such as the Big Dipper (the Wagon: GIŠ.MAR.GÍD.DA = *Eriqqu*), the bright winter stars of Canis Major (the Bow: MUL.BAN = *Qaštu*), Sirius (the Arrow: MUL.KAK.SI.SÁ = *Šukūdu*), Orion (the True Shepherd of Anu: MUL.SIPA.ZI.AN.NA = *Šitadallu*), and Lyra (the She-Goat: ÙZ = *Enzu*), visible even when Shamash (Sun), Sin (Moon), Adad (a weather-god), and Ištar (Venus) have set [Cooley 2011, 75.7]. The role of the stars, constellations, and planets as celestial deities in divination and ritual continues throughout the entirety of the cuneiform astral scientific tradition.

Hellenistic Babylonian celestial divination represents the outgrowth of many centuries of forecasting events from astral phenomena and the supporting activities of observing, cataloging, and predicting lunar, planetary, and stellar appearances (synodic phases). These traditions are attested for the Old, Middle, Neo-, and Late-Babylonian (*ca* 1800 to 50 BCE) as well as from the Middle-Assyrian and Neo-Assyrian Periods (*ca* 1500 to 600 BCE). In the Seleucid Period, the archives of Babylon's Esangila Temple and Uruk's Rēš Temple contained astronomical and astrological texts, both preserving the older celestial omens and developing new text-genres, such as ephemerides, procedure-texts, and observational records as well as horoscopes and natal omens. Despite the separation into a variety of text-types and the methods that they employed, the categorization of texts as astronomical and astrological are modern conveniences useful only for parsing the various elements of the tradition. Particularly during the Seleucid Period, this late form of Babylonian astral science would circulate throughout the intellectual-cultural *oikoumene* of the Near East and Mediterranean, and be influential for other cultures, namely, the Egyptian, Greek, Roman, Judaean, Mandaean, and Indian.

2 Terminology

Throughout the cuneiform astronomical and celestial divinatory tradition, all celestial objects, i.e., stars, constellations, and planets, were classified as MUL (*kakkabu*). In addition, all celestial bodies were seen to rise from and descend below the horizon, conceived of as a round enclosure called the *tarbaṣu*, literally, pen (for cattle or sheep).

The planets were referred to collectively as MUL.UDU.IDIM (*bibbu*) or ^{d}UDU.IDIM (^{d}*bibbu*), that is, as wild sheep. In the Late Period, in addition to the use of the determinatives «DINGIR» and «MUL», the term «ÁB»/«littu» ("cow") was introduced as another determinative for the writing of star and planet names.[1] Principally, however, the construction of a planet's name with «MUL» indicates its classification as a star, while the construction with «DINGIR» indicates classification as a deity.

Various reference-terms for the location of a star or planet are attested. In chronological order of appearance in the sources, they are:

2.1 *The Paths of Enlil, Anu, and Ea*

The pathways or roads (KASKAL = *ḫarrānu*) of Enlil, Anu, and Ea describe arcs across the heavens from the eastern to the western horizon (*tarbaṣu*). They were used as a celestial reference tool beginning in the second millennium BCE and were first attested in a Middle-Babylonian copy of the prayer to the gods of night (referred to above) from Hattuša [*KB* 4.47]. The roads describe what are in effect bands of declination within which risings and settings of stars, constellations, and planets were observed. Although it is anachronistic to view the paths as declination bands in an equatorial coordinate system, the Path of Anu can best be described as the arc over the horizon where stars within approximately ±15° declination of the celestial equator are seen to rise. The Path of Enlil was to the north and actually included the circumpolar stars, and that of Ea was to the south. The text of MUL.APIN designates the Path of Enlil as the head of the cattle pen, the Path of Ea the foot.

2.2 *The Path of the Moon*

The Moon moved against the background of 18 constellations (gods) in what was imagined as the "path of the Moon (*ḫarrān* ^{d}*Sin*)":

> The gods who stand in the path of the Moon, through whose regions the Moon in the course of a month passes and whom it touches: the Stars, the Bull of Heaven, the True Shepherd of Anu, the Old Man, the Crook, the Great Twins, the Crab, the Lion, the Furrow, the Scales, the Scorpion, Pabilsag, the Goat-Fish, the Great One, the Tails, the Swallow, Anunītu,

1 For the celestial bodies as cattle and sheep, see Rochberg 2010c.

> and the Hired Man. All these are the gods who stand in the path of the Moon, through whose regions the Moon in the course of a month passes and whom it touches.
>
> MUL.APIN I iv 31–39: HUNGER and PINGREE 1989, 67–69

The Moon and the planets were understood to travel this same road [MUL. APIN II i 1–6][Hunger and Pingree 1989, 70–71; Brack-Bernsen 2003], which consisted of ecliptical constellations, many of which would lend their names to the zodiacal signs. Before *ca* 500 BCE, the path of the Moon was the preferred reference for the Moon and planets in such texts as MUL.APIN as well as the reports and letters of the Neo-Assyrian scholars. As in the paths of Enlil, Anu, and Ea, it would be anachronistic to view the path of the Moon as an early form of a coordinate system, though the stars and constellations in the Moon's path do trace a path closely related to what we think of as the zodiacal circle.

2.3 *The Counting Stars*

In the Late-Babylonian observational texts (Diaries), a group of stars near the zodiacal circle came to be used as reference-points for the positions of planets and the Moon, hence, as Normal Stars (originally coined as *Normalsterne*). The ancient term for the Normal Stars was «MUL.ŠID.MEŠ» (= «kakkabū minâti»: "counting stars"). Individually named Normal Stars are seen most often in the Diaries and Normal-Star Almanacs but also appear in horoscopes. The units of measure with respect to the Normal Stars were the cubit (KÙŠ = *ammatu*) and the finger (ŠU.SI = *ubānu*). Positions were given as so many cubits *e* (above), SIG (below), *ana* IGI (in front of), or *ár* (behind) a Normal Star. In the Late Period, the cubit was reckoned as 24 fingers or approximately (somewhat larger than) 2° of arc.[2]

2.4 *The Zodiacal Circle*

By the late fifth century BCE, the Moon and planets were positioned with respect to signs of the zodiacal circle, constructed of 12 equal 30°-parts, with the degree indicated by the term «UŠ», for which there is no known Akkadian equivalent. Zodiacal signs were called LU-MAŠ (= *lumāšu*) in the Late Period, based on an older term for "star" or even "zodiacal constellation". This convention almost certainly relates to the division of the ideal year into 12 30-day

2 Cf. the Old-Babylonian equivalence 1 KÙŠ = 30 ŠU.SI. Whether the Normal-Star units in cubits and fingers were an alternate and compatible coordinate system to that of zodiacal longitude, measured in zodiacal signs or degrees (UŠ) is discussed in Steele 2007b. The equivalent zodiacal longitudes of the Normal Stars are given in Britton 2010.

months, thereby striking a correspondence between calendar-months and zodiacal signs. The five planets and the names of the zodiacal signs were summarized in a Late-Babylonian text [Pinches and Strassmaier 1955, 1591.1–4] as follows:

MÚL.BABBAR *dele-bat* GU$_4$.UD GENNA AN	Jupiter, Venus, Mercury, Saturn, Mars
ḪUN MÚL.MÚL MAŠ.MAŠ ALLA A	Aries, Taurus, Gemini, Cancer, Leo
ABSIN RÍN GÍR.TAB PA MÁŠ	Virgo, Libra, Scorpius, Sagittarius, Capricorn
GU ZIB.ME	Aquarius, Pisces

The Babylonian zodiacal circle was normed sidereally, not at the vernal equinox [Neugebauer 1950; Steele 2007b, 310], which was set variously at Aries 8° (System B), Aries 10° (System A), and Aries 12° (System K) [Ossendrijver 2012, 115]. Observational texts giving positions of planets relative to zodiacal signs regularly employ the phrases in "the beginning" (*scil.* 0°–5°) and "the end" (*scil.* 25°–30°) of a sign [Steele and Gray 2007]. The 12 signs of the zodiacal circle constituted the preferred reference system for planetary positions given in horoscopes but these signs also show up in late nativity and other celestial omens from the Hellenistic Period [*TCL* 6.12, 6.14; BM 36746 with Rochberg-Halton 1984].

3 Sources

The category *divinatory* can serve to classify a range of texts from astral omens that concern the future of the king and the state to natal omens and horoscopes that concern an individual's personal future. During the Neo-Assyrian Period (seventh century BCE), celestial divination, together with divination from terrestrial phenomena and from the liver and exta of a sacrificed sheep, was a prestigious scholarly practice by the scribes of the royal court. Celestial omens belonged to a complete system of interpretation of phenomena "on Earth" and "in the sky", as is clear in the so-called Diviner's Manual:

> The signs on earth just as those in
> the sky give us signals. Sky and earth both
> produce portents, though appearing
> separately, they are not separate (because)
> sky and earth are related.
>
> OPPENHEIM 1974, 199.38–40

Textual evidence for systematic celestial divination spans a period of nearly 2000 years, and cuneiform omen-texts have been found over nearly the whole of the ancient Near East, at Mari, Hattuša, Emar, Alalah, Qatna, Nuzi, Susa, and Ugarit. Most of these are copies of *Enūma Anu Enlil* in Akkadian or in other cuneiform languages (Hittite, Ugaritic) [Hunger and Pingree 1999, 8–11]. Celestial omens in Akkadian appear first in the Old-Babylonian Period in a less than standardized form. The standard celestial divinatory handbook *Enūma Anu Enlil* was composed in the Kassite Period (*ca* 1500), redacted during the Neo-Assyrian Period (seventh century), and copied until the last centuries BCE.

3.1 *Enūma Anu Enlil*

From its beginnings in the Old-Babylonian Period (*ca* 1800–1600 BCE), the celestial omens of *Enūma Anu Enlil* were built around the public concerns of the king, the state, the military, and the economy. Attested Old-Babylonian celestial omens do not appear to belong to a standardized series. The six known Old-Babylonian tablets with lunar eclipse-omens contain essentially the same content, though clearly not yet in a standardized form, and the material is to a great extent paralleled in the later standard tablets 17–18 of *Enūma Anu Enlil* [Rochberg-Halton 1988a, 19–22 and 2006].[3]

Early astral divinatory texts list omens in the characteristic conditional form "*šumma P*: *Q*" ("if *P*, then *Q*") and as well "*P*: *Q*", i.e., without «šumma» ("if"). Extant texts are devoted to signs of the Moon, Sun, and weather and their consequences for kings, countries, politics, and warfare. An example without «šumma» is BM 22696.42–43:

> An eclipse on the 16th of «*Du'ūzu*»: There will be want of straw;
> there will be dead livestock; the cattle pen will be besieged.

Solar eclipse-omens are also attested [Dietrich 1996] as are solar omens that do not involve eclipses and some weather-omens. Another Old-Babylonian astral omen-tablet, with parallels in the later *Enūma Anu Enlil* tablet 37 [Horowitz 2000, 203–206] contains omens from the appearance of the sky itself:

> If the face of the sky
> until the disappearance (of the Moon) (shines like moonlight)

3 The Old-Babylonian lunar eclipse tablets are attested in four unpublished tablets from the British Museum (BM), probably from Sippar, and two from a private collection: see George 2013, nos 13, 14.

> the north wind will blow
> there will be grain.
>
> HOROWITZ 2000, 204.6–7

In addition to the omens for the Moon, Sun, and weather, planetary signs were probably of interest as implied by the alleged Old-Babylonian origins of the so-called Venus Tablet of Ammiṣaduqa or tablet 63 of *Enūma Anu Enlil* [Reiner and Pingree 1975; Walker 1984].[4] Surviving exemplars of tablet 63, all written during the Neo-Assyrian Period or later, demonstrate an awareness that 5 synodic cycles (meaning the periodic relations of the planet to the Sun) of the appearances of Venus (as evening and morning star, that is, its rising and setting in the morning and in the evening) occur every 8 years (that is, every 99 Babylonian months minus 4 days). The omens of *Enūma Anu Enlil* tablet 63 are constructed from a sequence of synodic phenomena of Venus over a period of 21 years (the length of the reign of Ammiṣaduqa) formulated as conditional statements of the form: "If Venus…, together with associated events, then…". In its extant form, as Reiner and Pingree have shown, the tablet does not preserve a list of Venus-observations from the Old-Babylonian Period but is a composite text and includes some computed values for the phenomena and the periods of invisibility that have themselves been copied and corrupted in the manuscript transmission. Its value for chronology is thus compromised.

Few celestial omen-texts from Mesopotamia proper are extant from the Middle-Babylonian and Middle-Assyrian Periods [Rochberg-Halton 1988a, 23–25] but the continuation of the tradition that would be *Enūma Anu Enlil* in its Neo-Assyrian and Neo-Babylonian recensions is well attested from areas of the periphery, such as Emar [Rutz 2013], Qatna, Alalakh, Nuzi, Susa, Ugarit, and Hattuša.

The Neo-Assyrian series *Enūma Anu Enlil* represents a comprehensive collection of celestial omens, including phenomena of the Moon, Sun, planets, fixed stars, and weather, in this way:

(a) Lunar omens comprise nearly a third of the whole, tablets 1–22. The first 13 tablets concern the IGI.DU$_8$.A.ME *ša* 30 (lunar visibilities), that is, the Moon's appearances and disappearances but mostly focused on

4 The association of this tablet with King Ammiṣaduqa of the Hammurabi dynasty is based on the appearance of part of the eighth year name of the king in place of one of consequent clauses (*apodosis*) of the omens (omen 10). Thus, the Venus Tablet played a significant role in the establishment of a chronology for the ancient Near East precisely because it was thought to preserve observations of the planet compiled in that period (the alleged Old-Babylonian text is not extant).

its first appearance (*ina tāmartišu*: at its appearance). These first tablets of *Enūma Anu Enlil* reflect the importance of the lunar syzygies, i.e., the times around conjunction (between last and first visibility or between the 27th and the first days of the month) and the day(s) of opposition (days 14 or 15).[5]

(b) *Enūma Anu Enlil* tablet 14 belongs to a group of early astronomical texts concerning lunar visibility [Al-Rawi and George 1991–1992; Hunger and Pingree 1999, 44–50]. It provides a tabulated arithmetical scheme for the length of Moon's visibility each night for the 30 days of the two equinoctial months (when day and night are of equal length as the Sun crosses the celestial equator). The interest in duration of lunar visibility is tied to the ominous nature of the Moon when visible. This table—and a second table in the same tablet that gives a supplementary tabulation of lunar visibility coefficients allowing calculation of lunar visibility in other months of the year—is underpinned by an arithmetical scheme for the variation in daylight throughout the year based on a schematic year of 360 days and a ratio of longest to shortest daylight of 2:1, also seen in the *Astrolabes* and MUL.APIN.

(c) Lunar eclipses were organized into tablets 15–22 [Rochberg-Halton 1988a]; solar omens, in tablets 23(24) to 29(30) [van Soldt 1995]; solar eclipses, in tablets 31–35(36); and weather-omens, in tablets 44–49 [Gehlken 2012]. The stellar and planetary omens begin with tablet 50(51) [Reiner and Pingree 1981] and the remainder of the planetary omens are not well preserved [Reiner and Pingree 1998, 2005]. Many tablets of *Enūma Anu Enlil* had commented texts (*mukallimtu* [Frahm 2011, 136–155]) as well as a series of excerpts called *rikis girri Enūma Anu Enlil* (guide to *Enūma Anu Enlil*) and a separate serialized commentary titled *Sin ina tāmartišu* (*If Sin* [*the Moon*] *at its appearance*) of at least seven tablets [Frahm 2011, 155–160; Gehlken 2007].

It should not go unsaid that support for the great intellectual enterprise that was celestial divination in the Neo-Assyrian Period came from the royal court and its investment in divination was an important basis of planning and decision-making.

3.2 *Late-Babylonian Natal Astrology*

While *Enūma Anu Enlil* and its complementary astronomical compendium MUL.APIN continued to be preserved into the Seleucid Period, particularly at

5 For tablets 1–8, see Verderame 2002a and 2000b.

Uruk, natal astrology was introduced sometime during the late fifth century. This development came after the invention and standardization of the 12 zodiacal signs, which provided a basis for extensive correlations and relationships to be made among the planets (including the Sun and Moon in eclipse), the 12 signs, and the 12 months. In contrast to the public omens of *Enūma Anu Enlil*, the object of the new astrology was the individual's character and fate, as illustrated, for example, by Pinches and Strassmaier 1955, 1593 [Reiner 2000], in which a child born in the region (KI = *qaqqaru*) of a zodiacal sign is assigned various characteristics (a long chin, red hair) and life experiences "he will be widowed" [Pinches and Strassmaier 1955, 1593.3′].

The correspondence between human life and the stars was not a new concept, nor was the idea of the efficacy of the stars in healing [Reiner 1995] or the idea of medical treatment in accordance with calendar days [Gurney, Finkelstein, and Hulin 1964, 300]. But a new medical astrology, well attested at Uruk, now associated diseases with planets, constellations, or signs of the zodiacal circle, and treatments were determined by astrologically propitious times.[6]

To aid in making correspondences and correlations among the elements of astral medicine were numerical and calendric schemes, such as the Babylonian *dodecatemoria* [Neugebauer and Sachs 1952–1953], which projected positions along the zodiacal circle in steps of 13°, and a calendric scheme that projected steps of 277°.[7] Each made use of the 360-day year and the 360° zodiacal circle, months and signs thereby being interchangeable, as well as days and degrees, thus making it possible to relate a date with a position in the zodiacal circle. The latter scheme is associated with the so-called *Kalendertexte* [Weidner 1967, 41–52; Hunger 1975; Brack-Bernsen and Steele 2004] found at late Uruk [Weidner 1967; Reiner 1995, 114–118]. These texts typically correlated zodiacal signs with *materia medica*—plants, wood, and stones (for amulets or beads)—temples, and place-names.

3.3 *Horoscopes*

Whether referred to as horoscopes [Strassmaier 1888; Sachs 1952; Neugebauer and van Hoesen 1959; Rochberg 1998] or "proto-horoscopes" [Hunger and Pingree 1999, 26–27], these texts provide planetary positions in the zodiacal circle and other astrological data required for forecasts about the life of an individual based on the situation of the heavens on the birth-date. The cuneiform horo-

6 See Pinches and Strassmaier 1955, 1596–1598; *BRM* 4.19–20; Heeßel 2005 and 2008; Geller 2014b. See also ch. 9.3, p. 350.

7 Note that *dodecatemoria* in Greek are 30°-segments of the zodiacal circle (μοῖραι) [Bowen and Goldstein 1991, 242, 246] and later, 2.5°-segments of a zodiacal sign.

scopes range in date from the oldest at 410 BCE to the youngest at 69 BCE. The relationship between Babylonian nativities and their Greek counterparts is a matter of discussion with implications for the question of the ultimate origins of astrology [Greenbaum and Ross 2010: see ch. 12.1 §3, p. 445].

The importance of horoscopes for understanding astral science in Late Babylonia (*ca* 500–50 BCE) is twofold. First, the celestial divinatory character of the texts is clear. Such forecasts as are preserved are formulated as omen-apodoses, such as "he will see profit." Second, the data themselves derive from several other kinds of cuneiform astronomical text-types, principally Diaries and Almanacs.[8] The several horoscopes in which planetary positions are given in degrees and fractions of degrees of zodiacal signs raise the possibility that the positions were calculated by means of methods known from the ephemerides or from interpolations from them, though that has not been securely demonstrated and remains conjectural. These parallels, however, are enough to establish a thoroughgoing interdependence among many of the cuneiform astronomical text-genres and thus a synthetic aspect to Babylonian astronomy and astrology in the Hellenistic Period, much as the descriptive astronomy of MUL.APIN had a synthetic relationship to celestial omens. The cuneiform horoscopes begin three centuries before any extant Greek exemplars; and from the time one sees Greek horoscopes, the Babylonian texts cease.[9] Consistent with the general dearth of Greek scientific literature during the last three centuries BCE, extant Greek horoscopes begin only in the first. The first extant horoscope is the famous coronation horoscope of Antiochus I of Commagene. This is, however, not a text but a monument located on the Nimrud Dagh in the Taurus Mountains, on which was carved in iconographic relief the horoscope for the date of the king's coronation in 62 BCE. The earliest preserved Greek horoscope in an original document is dated 10 BCE. In literary sources, i.e., in sources preserved in Byzantine codices, the earliest known horoscope was cast for 72 BCE but recorded not before 22 BCE in a collection of the Roman Balbillus, the astrologer of Nero and Vespasian. Greek horoscopes then continue to the beginning of the Islamic Period.[10] Greek

8 These texts are sometimes identified by the acronym GadEx, for the Goal-Year Texts, Almanacs, Diaries, and Excerpts. This terminology was coined by Abraham Sachs [1948]; the acronym was established in Neugebauer 1975, 351 and is now standard in Assyriology. These texts are also referred to as non-mathematical astronomical texts (NMATs) [see chs 5.1, p. 171 and 7.2, p. 272].

9 For the chronological distribution of Greek horoscopes, see Neugebauer and van Hoesen 1959, 161–162; Jones 1999a.

10 The documents in question consist of papyri from Egypt and Byzantine codices that contain the literary horoscopes, such as those in the *Anthologia* of Vettius Valens (second

horoscopic astrology or genethlialogy was therefore a Hellenistic development, particularly given the multiplicity of its theoretical roots in various Hellenistic philosophical trends, such as the Stoic theory of signs and Aristotelian natural science.[11] The likelihood of any pre-Hellenistic Greek horoscopy is consequently remote and the existence of the two Achaemenid-Period Babylonian horoscopes [Rochberg 1998, nos 1–2] is sufficient to establish chronological priority for Babylonian horoscopy.

The purpose of the Babylonian horoscopic document was above all to record positions of the seven planets (Moon, Sun, and five classical planets) in the zodiacal signs on the date of a birth. The astronomical data were presented following a standard formulation: "MN, (the previous month being) full/hollow, night of the *n*th, the child was born." Thereupon follow the positions of the planets in the zodiacal circle plus a number of lunar and solar data of presumed astrological interest, e.g., eclipses, equinoctial and solstitial dates, and the dated durations of lunar visibility in the middle and end of the month. The majority of horoscopes do not name the person for whom the horoscope is cast; they simply say "The child is born." In only four horoscopes is the name of the native (i.e., the individual for whom the horoscope was cast) recorded, two of which are Greek.[12] Despite the fact that two of these names are Greek, conclusions as to the nationality of those for whom horoscopes were cast need to be based on supplementary evidence, as Babylonians with Greek names are known in this period.[13] It would seem likely, at any rate, that the horoscope subjects would have been of high social standing, in which case Greek names would confirm the elite status of the native. A fourth horoscope contains a Babylonian name, well known from colophons in Uruk-texts from the Seleu-

century CE): see Neugebauer and van Hoesen 1959; Jones 1999a, 1.V.249–295 and app. C, 308–309 and 2.372–447.

11 For the Aristotelian natural science and cosmology underlying Greek horoscopy, see Solmsen 1960; Long 1982, 165–192. For relevance to Mesopotamia, see Rochberg-Halton 1988b, 51–62. For Stoic natural science and theory of signs, see Sambursky 1959, cc. 1–2, I and II; Hahm 1977; Gould 1970, 92–123.

12 Two Greek personal names, Aristocrates (written as *ᴵA-ri-is-tu-ug(?)-gi-ra-te-e* [Rochberg 1998, no. 10 obv. 2] or as "[ᴵA-r]i-is-tu-ug-ra-te-e" [Rochberg 1998, no. 11 obv. 2]) and Nikanor (written «ᴵNik-(?)-nu-ú-ru», [Rochberg 1998, no. 12 obv. 2]), are found in horoscopes from the early third century BCE.

13 Evidence of the use of Greek names by Akkadian citizens is, however, limited. A Seleucid text from Nippur, dated SE 158 (SE = Seleucid Era), which is reckoned from 311 BCE, the first regnal year of Seleucus I, shows that the son of a cult priest of Enlil, who had an Akkadian name and patronym, also had an alternate Greek name, which is designated as such in a tablet as "(so-and-so), whose other [*scil.* second] name is Eudoxus"; see UM 29–15–802 obv. 5 in van der Spek 1992, 250–252.

cid Period: Anu-bēlšunu, son of Nidintu-Anu, descendant of Sîn-lēqe-unninni [Rochberg 1998, no. 9.2]. Again, the fact that a horoscope was cast for a member of a family of scholars and priests of the Temple of Anu in Uruk suggests similarly that horoscopy was only for the upper class.

The date of birth was accompanied by the time of birth, given with respect to a part of the day, e.g., "in the last part of night" or "beginning of night". The other convention for stating the time of birth was with respect to the seasonal hours, in which a diurnal seasonal hour represents 1⁄12 of the time from sunrise to sunset and a nocturnal seasonal hour, 1⁄12 of the time from sunset to sunrise. As there were always 12 seasonal hours, the length of these hours varied throughout the year. Termed «simanu» in Akkadian, the seasonal hours were designated by ordinal numbers (i.e., 7 SI-MAN = the seventh *simanu* [Rochberg 1998, no. 21.2′]). Elsewhere, «simanu» has the basic meaning of "interval" but in the horoscopes the 12 intervals represent the divisions of the halves of the day, from sunrise to sunset or from sunset to sunrise (not the 12-*bēru* division of the day in which the 360°-circle of the sky from sunset to sunset was divided into 12 units of 30°), and denote the time of birth. The enumeration of the planetary positions usually follows the expression "in his hour (of birth)".

The body of the horoscope contains the planetary positions in the zodiacal circle. These data may follow several introductory expressions, e.g., "at that time", "in his hour (of birth)", or "that day". The first astronomical datum provided in a horoscope is the position of the Moon on the date of the birth. This appears in two forms:

(1) as a position with respect to a Normal Star in the manner of the Diaries and

(2) as a position with respect to a zodiacal sign or occasionally in degrees within a sign.

The first form is familiar from the daily observation of the Moon's position with respect to the stars made systematic in the astronomical Diaries. In a horoscope, however, the Moon's position is not, as in the Diaries, given for the purpose of an observational record but rather, presumably, for whatever influence that position was thought to have upon the life of the native. The second lunar position, with respect to a zodiacal sign, is sometimes also found in the Diaries as part of the final summary of zodiacal locations of the planets during a given month. Since the horoscope was prepared after an individual's birth, the Babylonian astrologer must have relied either on available records, such as Diaries, or on computational methods to derive the position of the Moon on the date in question, depending on whether a Normal-Star position or a zodiacal sign was desired. The method of direct computation, hypothetically at least, would have derived the zodiacal position of the Moon for a particular date by the application of numerical schemes known from the ephemerides. Another possibility would have been to deduce the corresponding zodiacal sign from the position of a Normal Star.

Use of Normal Stars as a reference-system is more characteristic of the earlier horoscopes, for which the evidence argues somewhat more forcibly for the first method, i.e., excerpting the desired lunar position with respect to a Normal Star from the appropriate Diary text. We have the following from a third century BCE horoscope [Rochberg 1998, no. 7 rev. 1–3 (dated 258 BCE)]:

> night of the 8th, beginning of night, the Moon was 1½ cubits below the bright star of the Ribbon of the Fishes, the Moon passed ½ cubit to the east.

Similarly, from another third century example [Rochberg 1998, no. 13.2–4 (dated 224 BCE)], we have:

> night of the 4th, beginning of night, the Moon was below the bright star of the Furrow by 1⅚ cubits, the Moon passed ½ cubit to the east.

This horoscope also gives the zodiacal sign of the Moon:

> In his hour (of birth), the Moon was in Libra.
>
> ROCHBERG 1998, no. 13.5

These two forms of expressing the lunar position in Babylonian horoscopes overlap chronologically until about the middle of the second century BCE, after which time the zodiacal reference system seems to become the norm. The earliest attested zodiacal position for the Moon comes in a horoscope from Uruk, dated to the middle of the third century (263 BCE). Interestingly, the texts prior to 150 BCE [Rochberg 1998, nos 9–10, 12, 19] that give the zodiacal sign for the Moon, with the exception of Rochberg 1998, no. 12 are also from Uruk. The most precise way of citing the lunar position is, of course, in degrees of longitude with respect to a zodiacal sign in the manner of Babylonian mathematical astronomy. For example, there is “[That day] the Moon was in 10° Aquarius” [Rochberg 1998, no. 5.4]. Such computed zodiacal positions are attested for the third to the first centuries BCE. Unlike the values found in the ephemeris columns, however, degree-values, when found in horoscopes, are generally integers without fractions (exceptionally to ½° [Rochberg 1998, nos 5, 9–10]).

The use of the ephemerides or their methods to generate degrees of longitude to many sexagesimal fractional places seems too detailed for use in horoscopes in which all that was needed was the zodiacal sign, a degree of a zodiacal sign, or at most a value to within ½°. The situation is similar in the context of Greek horoscopes. Computation of longitudes by means of "perpetual tables" meant that longitudes were computed to three or four sexagesimal places in order to guarantee the period-relations. The Greek horoscopes, like the Babylonian, used the integer value and dropped the fractions, as those fractional places had no practical value for horoscopy [Neugebauer and van Hoesen 1959, 24]. This argument would apply equally well in the case of the Babylonian ephemerides and horoscopes. The purpose of the sexagesimal fractions in the cuneiform astronomical tables was also to preserve the period-relations and the horoscopes would presumably not have needed more than rounded values.

Computed longitudes could also have been generated for sets of dates over the course of a number of years, such as in a tablet from Uruk discussed by Steele [2000a, 132–135]. Steele's argument in part stems from the unusual feature of that tablet, namely, that its content gives in chronological order longitudes for synodic phenomena of all the planets as well as the occurrence of eclipses. Of course, horoscopes, with the exception of the anomalous fifth-century example [Rochberg 1998, no. 1], do not make use of the longitudes of the synodic phenomena but attested methods of interpolation would have provided a means to obtain the longitudes on arbitrary dates on the basis of prepared collections of planetary longitudes such as are found in A 3405.

4 Survival of Babylonian Astral Divination and Nativities

The astral divinatory sciences of Babylonia not only held pride of place within cuneiform scribal scholarship but also produced the most profound and longest lasting legacy of any other element of Mesopotamian intellectual culture. They spread both to the east and west of Mesopotamia, where the bases for Arabic and European traditions of astrology were formed.

4.1 *In Egypt*

During the Achaemenid Period, omens in the style of *Enūma Anu Enlil* appear in a Demotic papyrus [Parker 1959]. Related to this text, although it belongs more properly to the Greek inheritance, are the celestial omens from Ptolemaic Egypt of the second century BCE that are attributed pseudepigraphically to the Egyptian priest Petosiris in the reign of the Saite ruler Nechepso (i.e., Necho II

[Rochberg 2008]). Demotic horoscopes testify to the influence of Babylonian natal astrology in the Egyptian milieu [Ross 2006b, 2007c: see ch. 12.4, p. 509].

4.2 *In Greco-Roman Culture*

The term "Chaldean" was originally a gentilic for West Semitic tribal groups located in the parts of southern and western Babylonia known as Kaldu. But, in the Hellenistic Period, in the context of Greek and Roman writers wanting to claim an authoritative source on astrology, the term came to be synonymous with "astrologer" [Rochberg-Halton 1988a, 2–5; 2010a, 1–18]. Greco-Roman attributions to the Chaldeans were sometimes spurious but in general the widespread use of this term reflects the high reputation of the Babylonian scholars in *astrologia/astronomia* [e.g., Strabo, *Geog*. 16.1.6]. Greek horoscope texts bear traces of cuneiform astrology in their use of the names of the zodiacal signs, the attribution of masculine/feminine natures to the signs, benefic/malefic natures to the planets, the Lot of Fortune, the exaltations, and the terms [Rochberg-Halton 1988b; Jones 1999a; Jones and Steele 2011].

4.3 *In India*

Because classical Indian astronomy and astrology derived from Hellenistic Greek sources, Indian texts sometimes evince a mixture of Babylonian and Greek elements. The *Paitāmahasiddhānta* (early fifth century CE) is one such work, itself foundational for the Indian mathematical astronomical tradition. Influx of Babylonian mathematical astronomy is also evident in the *Pañcasiddhāntikā* of Varāhamihira (sixth century CE). Varāhamihira's divinatory treatise, the *Bṛhatsamhitā*, was clearly influenced by Babylonian omens; and two of his works on genethlialogy, the *Bṛhajjātaka* and the *Laghujātaka*, also contain elements of Babylonian astrology,[14] Another important Sanskrit astrological text with parallels to Babylonian horoscopic astrology is the *Yavanajātaka* (*Nativity of the Greeks*) of Sphujidhvaja.

4.4 *In Judaea*

Horoscopes or nativities as such did not emerge in the Judaean context, at least not in the sense of a determination of the situation of the heavens at the moment of birth. In Hebrew, zodiacal physiognomy, in which parts of the human body are described and correlated with all or parts of a person's birth sign (the *horoscopus*) as in "the foot of Taurus" [Popović 2007, 14, 29–32], is attested at Qumran in 4Q186 [see chs 13.1, p. 529; 13.2, p. 539: Albani 2000,

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14 See Plofker and Knudson 2008; Pingree 1982, 1987, 1997, and 1998.

370–373]. Jonathan Ben-Dov points out that there are some cases in which Qumranic and other Aramaic wisdom-texts may employ terms with astrological connotations, such as "birth" with the meaning "nativity" [2014, 117 with nn21–23]. It is his view that in the culture of the Qumran-community, "astrology reflects the true preordained order of the world" [2014, 119]. He further argues for a "sapiential-deterministic" outlook in which astrology, while not explicit, should be assumed as implicit and indeed as constituting one of the ideals of science in the Judaean tradition.

4.5 *In Mandaean Astrology*

In a Sasanian context, Babylonian astrology and omens were also incorporated into Gnostic Mandaean astrology of the second century CE and preserved in the Mandaic work *Aspar maluašia* [Drower 1949], in which material clearly influenced by *Enūma Anu Enlil* and *Iqqur īpuš* is found [Rochberg 2010b, 223–235 and 1998; Bhayro 2008: see ch. 13.4, p. 572].

CHAPTER 12.3

Hellenistic Horoscopes in Greek and Latin: Contexts and Uses

Stephan Heilen

1 Introduction

This chapter is a concise survey of the contexts and uses of the numerous horoscopes in Greek and Latin that are extant from Antiquity. By "horoscopes", I mean texts that specify the usual astronomical data[1] either in full or partly, regardless of the degree of further elaboration. The survey is based on my catalog of these horoscopes [Heilen 2015, 204–333].[2] The sample to be analyzed consists of 169 so-called original documents (168 Greek, 1 Latin) and 184 so-called literary sources (177 Greek, 7 Latin), thus making a total of 353 texts (345 Greek, 8 Latin).[3]

1.1 *Preservation*

The original horoscopes are mostly extant on scraps of papyrus[4] but partly on other writing materials such as wood, ostraca, parchment, gems, or golden seal rings.[5] The geographical provenance is almost exclusively Egypt. There are, however, a few horoscopic graffiti from Dura-Europos in Mesopota-

1 I.e., the longitudes of the Sun, Moon, Saturn, Jupiter, Mars, Venus, Mercury, Ascendant, and sometimes further data such as Midheaven, certain astrological lots, and so on. For a theoretical account of Greek and Latin horoscopes, see ch. 12.1, p. 443; for information derived from literary, especially historical sources, which do not specify astronomical data, see ch. 10, p. 297.

2 This catalog is largely based on the precious, yet smaller, collections of Neugebauer and van Hoesen 1959; Baccani 1992; and Jones 1999a. Single texts will be cited using the same nomenclature that is used in the catalog. Its syntax is as follows:

Hor. [*language/culture*]. [*year*].[*month*].[*day*].

The year-count is astronomical: year 1 = year 1 CE, year 0 = year 1 BCE, year –1 = year 2 BCE, and so on.

3 This terminology was established in Neugebauer and van Hoesen 1959.

4 They are almost all edited in the three collections mentioned on p. 490n2.

5 Wood: Hor. gr. 373.V.16, 388.VI.4, 392.VII.10–11(?). Ostraca: Hor. gr. 207.II.20, 328. Parchment: Hor. gr. 326.II.8. Gems: Hor. lat. 195.IX.11, Hor. gr. 215.VI.23. Seal rings: Hor. gr. 327.VIII.17.

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mia[6] and a unique find of controversial interpretation from East Anatolia, the Lion-Horoscope of Commagene [Plate 2, p. 453].

The literary horoscopes are mostly (121 out of 184) preserved in the astrological manual of Vettius Valens of Antioch (late second century CE).[7] Only 21 literary horoscopes for dates earlier than 200 CE come from other authors (8 Greek, 4 Latin, 9 Greek in Arabic translation), namely—in chronological order of the authors—from Tarutius of Firmum (3), Dorotheus of Sidon (9), Balbillus (2), [Manetho] (1), Antigonus of Nicaea (3), Aelius Aristides (1), Firmicus Maternus (1), and an anonymous source (1).[8]

1.2 *Distribution*

The chronological distribution of the horoscopic dates runs from the early first century BCE to the early sixth century CE for original texts and from the early eighth century BCE to the early seventh century CE for literary texts.[9] By far the greatest number of literary horoscopes dates from the second century CE (due to Valens); the greatest number of original horoscopes dates from the third century CE.[10] By the date of an ancient horoscope is meant, here and in the following, that of the astronomical alignment recorded in the text, not the date of the text's composition, which is usually later but generally not known. The extant material is, of course, only a tiny part of the ancient production of horoscopes in Greek and Latin and does not reflect the development of their production faithfully since it is heavily dependent on chance circumstances such as—but not limited to—archaeological preservation (original texts) and textual transmission (literary texts).

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6 Hor. gr. 176.VII.3–5, 219.I.9, 200–300$^{(?)}$a (i.e., tentatively assigned to the third century CE, first item).

7 Two more horoscopes of the fifth century CE were later attached to Valens' manual, Hor. gr. 419.VII.2 and Hor. gr. 431.I.9 [Valens, *Anth. additamentum* 1.16–49].

8 Tarutius: see §3.5, p. 506. Dorotheus: see p. 495n24. Balbillus: Hor. gr. −71.I.21, −42.XII.27 [Rhetorius, 6.8.8–14, *CCAG* 8.4.236.8–237.10]. [Manetho]: Hor. gr. 80.V.27–28 [[Manetho], *Apo.* 6.738–750]. Antigonus: Hor. gr. 40.IV.5, 76.I.24, 113.IV.5–6 (extant as fragments in Hephaestio of Thebes, *Apo.* 2.18.21–66). Aelius Aristides: Hor. gr. 117.XI.26 [Aristides, *Or.* 50.57–58]. Firmicus: Hor. lat. −138.V.22–23 [*Math.* 6.31.1, the date of this horoscope is not certain]. Anonymous source: Hor. gr. −329.IV.16 (foundation of Alexandria, CodLBPG 78 (ninth century), f. 2v; *CCAG* 9.2.176–178).

9 Most of our texts were dated astronomically. Where this was not possible, calendrical dates (if mentioned in the texts) or paleographical features (in the case of original horoscopes) were used.

10 See the bar diagram in Heilen 2015, 524.

1.3 *The Character of the Horoscopes*

Most of the horoscopes in Greek and Latin are birth-horoscopes of individuals. Conception-horoscopes, though theoretically more important [Frommhold 2004], are very rare because of the practical problems of ascertaining the exact time of conception. The few extant examples are literary and serve special purposes: Vettius Valens and Hephaestio of Thebes illustrated the respective chapters of their astrological manuals with references to their own conception-horoscopes[11] and Tarutius computed the conception-horoscope of Romulus [see §3.5, p. 506]. In other words, we do not have evidence of any conception-horoscope in Greek or Latin cast for a non-elite individual.[12] But we do have some so-called catarchic horoscopes from Late Antiquity [see ch. 12.1 §5.3, p. 448].

1.4 *Their Context*

Deplorably, we know little about the social and institutional context of the production of horoscopes in Greek and Latin.[13] The situation is, however, better than, for example, that of ancient mathematics, for which we are faced with an "almost total lack of evidence" [Sidoli 2014, 33]. There are various reasons for our somewhat better understanding of the social context of Greek and Latin horoscopes: ancient historians provide useful information [chs 8, p. 297; 10.2, p. 398] and many astrological writers also include select biographical information on the natives or individuals for whom the horoscopes were cast. This is true, however, only for literary horoscopes.

Since the characteristics of original and literary horoscopes, and especially their source value with regard to contexts and uses of horoscopes, are different, I shall treat them separately.

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11 See Hor. gr. 119.V.13 [Valens, *Anth.* 1.21.17–26, 3.10.4], Hor. gr. 380.II.22 [Hephaestio, *Apo.* 2.1.32–34, 2.2.22–26].

12 Note, however, that there is a unique Babylonian case, the cuneiform tablet BM 33667 obv., which records the astronomical data of the conception (−257.III.17) and birth (−257.XII.15) of the same anonymous individual. See Rochberg 1998, 72–75.

13 Cumont [1937, 74] thinks that the first astrologers in Egypt were Hellenized members of the local clergy and lived in temples outside of Alexandria [134–135]. But this is uncertain, even if astrological texts in Demotic have been found in Egyptian temple libraries of the second century CE—especially at Tebtunis [Winkler 2009]—and if numerous Demotic horoscopes on ostraca cast in the same century by one or more priests of the Temple of Narmouthis are extant [Menchetti 2009, 223–224]. Note that one late ancient horoscope graffito has been found in the Temple of Sethos I in Abydos [Hor. gr. 353.IX.21–22]. Note further that the texts of some Greek horoscopes contain serious grammatical mistakes, thus indicating that they were not written by native-speakers of Greek but by poorly Hellenized indigenous Egyptians (possibly priests).

2 The Original Horoscopes

The original horoscopes in Greek and Latin are normally nothing but brief records of the minimum necessary astronomical data [p. 490n1] without biographical details and, typically, without predictions. Very few of them (5 out of 169) contain predictions.[14] For interpretations of the data and predictions, one had to consult an astrologer or a systematically arranged astrological manual. The typical brevity and limitation to indispensable technical data indicates that most of the original horoscopes were cast for people with very limited financial means.[15] The relatively few exceptions (dubbed "deluxe horoscopes" in Jones 1999a) show that a much higher degree of astronomical, astrological, and literary elaboration was possible and—in principle—desirable.

We know the names of some of the astrologers who cast the horoscopes on papyrus and also of numerous individuals for whom they were cast. But, as expected, none of these astrologers or their clients is a historically known figure and the original texts never reveal any biographical information other than the name(s). The most detailed information that we ever get in this respect is *PLond.* 1.130 [Hor. gr. 81.III.31], which informs the reader that it was computed in Hermopolis (Lower Egypt) by a certain Titus Pitenius for a certain Hermon.

Some clients consulted more than one astrologer with regard to one and the same birth, as is clear from the case of a certain Anubio (second century CE) who had his horoscope cast by two different astrologers. The two analyses that he obtained differ in elaboration and astronomical quality.[16]

Only late and rarely in original documents do we find horoscopes in magical contexts. A total of 5 such horoscopes is extant in two papyri.[17] This is not surprising because astrology and magic had little to do with each other; and

14 Hor. gr. −3.X.2 [*POxy.* IV.804], 95.IV.13 [*PLond.* 1.98], 138–161 [*PPrinc.* 2.75], 345.VI.27 [*PSI* 4.312], 350–450a [*POAstr.* 4278].

15 Cf. Baccani 1992, 56:

> Il fattore "costo" deve rappresentare uno dei motivi per cui la stragrande maggioranza degli oroscopi che ci sono pervenuti rientra nella tipologia più semplice.

16 The first version is extant in *PPar.* 19 and *PLond.* 1.110; the second, in *PPar.* 19 *bis*. See Neugebauer and van Hoesen 1959, 39–44 (nos 137a, b, c = Hor. gr. 137.XII.4). In a similar vein, two late ancient literary horoscopes (both in political contexts and probably cast by one and the same astrologer) serve the purpose of criticizing and correcting earlier, more favorable analyses by other astrologers. These are Hor. gr. 475.I.12 (Greek text now lost: see Pingree 1976b, 135–138, with English translation of the extant Arabic translation) and Hor. gr. 484.VII.18 (Greek and Arabic versions extant: see Pingree 1976b, 135–142; this text explicitly claims to correct two earlier astrologers).

17 These are *PWarr.* 21 (containing Hor. gr. 217.V.12–13, 219.II.1, 219.II.12, 244.VII.2) and *POxy.* XLVI.3298 (containing Hor. gr. 243.I.11).

their practitioners are rightly discussed separately by James B. Rives [2011] in his brief analysis of their respective social statuses and relations.

Still later, and equally rarely, do we find horoscopes that were cast for Christians. Four such cases are extant, again exclusively on papyri.[18] Obviously, some Christians did not care about the church fathers' condemnation of astrology.

Some private individuals collected horoscopes. A certain late antique tax collector, Hermesion, created a collection of horoscopes, transcribing them from originals now lost. The horoscopes include his own (which is quite elaborate) and 7 other less elaborate ones, which probably belong to family members.[19]

One interesting, though rare, use of Hellenistic horoscopes is to assert one's identity, especially for the purpose of authenticating documents. Two are extant, one original and one literary. The original document is a golden seal ring from Syria that bears the horoscope of an anonymous owner (probably a wealthy physician) who lived in the fourth century CE [Hor. gr. 327.VIII.17].[20] Since the seal on this ring features a bust of Asclepius with his rod and the word «ΥΓΙΑ» ("health"), there is obviously a second, ornamental purpose, which we find also in the few extant horoscope gems.[21] The other comes from the astrological poem of an anonymous didactic poet writing under the pseudonym "Manetho" (early second century CE): at the end, the author presents his own horoscope in place of the traditional poetic *sphragis* [Hor. gr. 80.V.27–28: [Manetho], *Apo*. 6.738–750].[22]

18 Hor. gr. 370.I.8 [*PSI* 1.22.d] for Cyrillus, 376.X.12 [*PSI* 1.22.b, duplicate *PSI* 1.23.b] for Joannes or Joanna; 478.VI.29 [*POxy.* 16.2060] for Anup. = ?; 508.II.2 [*POAstr.* 4275] for Theodorus. See Bagnall 1993, 273–274 on the horoscopes of Christians.

19 Hor. gr. 338.XII.24, 351.I.1–3, 366.I.6, 370.I.8, 373.I.3, 376.X.12, 381.II.19, 385.IV.9 [*PSI* 1.22].

20 Richmond, Virginia Museum of Fine Arts, Inv. 67–52–11: see Heilen and Greenbaum 2016, 32, fig. 1–9, 138, 189, no. 60. Outside the Hellenistic record, one may compare the case of the Egyptian priest Heter (Thebes, second century CE), who had the lower side of his coffin lid decorated with a painting of his horoscope [Hor. dem. 93.X: see Heilen 2015, 317–318; Neugebauer and Parker 1960–1969, 3.93–95, pl. 50].

21 Hor. lat. 195.IX.11, Hor. gr. 215.VI.23. For color reproductions of the former, see Heilen 2017. A color reproduction of the latter with digital magnifying glass is available at http://medaillesetantiques.bnf.fr/ws/catalog/app/report/index.html (enter search string: Neugebauer). On a recently discovered twin of the latter gem, see Heilen and Mastrocinque 2017.

22 A *sphragis* (lit. a seal) is a self-reference by an ancient poet that is woven into the final lines of a longer poem. By mentioning his name, the poet claims the poem as his property.

3 The Literary Horoscopes

This brings us to the category of literary horoscopes, on which more can be said (except about the readers).[23] Dorotheus (first century CE) presents them in his lost poem in the same prospective manner that must have been typical of real consultations, as is clear from nine horoscopes that are preserved in Arabic translation.[24] All other extant literary horoscopes, however, are presented from a retrospective point of view (with one exception, which contains, after a discussion of past biographical events, a brief concluding prediction).[25] Their size varies considerably between a few lines of text and (rarely) several pages. Quite a number of them, even of the shorter literary horoscopes, contain potentially useful biographical information.[26] While there is no reason to doubt the historical correctness of such information, its value is, deplorably, limited by two factors. First, the literary horoscopes are by default presented anonymously, i.e., without revealing the natives' identities. This is not surprising for two reasons:

(a) Most of these horoscopes are transmitted as sample nativities in astrological manuals to which, given their empirical and (in the authors' view) scientific purpose, the identifications of the respective individuals would be irrelevant.[27] The authors, instead, care about a suitable didactic presentation, as is particularly clear in the case of Antigonus: in his long analysis of the anonymously presented horoscope of Emperor Hadrian, Antigonus anticipates possible questions and objections by his reader,

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23 Since most of the extant literary horoscopes were transmitted in astrological manuals, their readers are likely to have been primarily students and experts of this art (sometimes later astrologers refer to earlier astrologers' horoscopes) but presumably also critics and other readers. The few literary horoscopes that were transmitted in non-astrological works are likely to have been read by the broader public: see p. 491n8 on the horoscope of Aelius Aristides, §3.5, p. 506 on those of Romulus and the foundation of Rome, and §3.4, p. 505 on that of Proclus.

24 Hor. gr. −6.III.29, 12.X.31, 13.I.26, 14.XI.25, 22.III.30, 29.V.2, 36.IV.2, 43.VIII.2, 44.X.2 [Dorotheus arabus 1.21.14–20 [= Rhetorius, 5.108.1–7: Pingree 1976a, 336.21–337.10], 1.24.2–19, 3.2.19–44].

25 Hor. gr. 142.III.25 [Valens, *Anth.* 7.6.164–192]. On original horoscopes which contain predictions, see p. 493n14.

26 In the following, my quotations of relevant pieces of information from those horoscopes will follow the English translations of Neugebauer and van Hoesen 1959 with some modifications (partly corrections of mistakes). Suffice it to acknowledge my occasional debt in this summary fashion.

27 One finds the same anonymous presentation of more than 100 case studies in the dream book of Artemidorus of Daldis (second century CE). Note that some astrological authors (especially Manilius and Ptolemy) did not include sample horoscopes in their works.

which he answers as they arise, thus creating a fictitious dialogue in direct speech between himself (the teacher) and a hypothetical student.[28]

(b) Severe legal restrictions had to be observed [ch. 8.5, p. 306]. In this respect, a horoscope given by the Roman senator Firmicus [*Math.* 2.29.10–20 = Hor. lat. 303.III.14] is of particular interest. As usual, it is phrased anonymously.[29] But at the end, Firmicus gives his reader, Mavortius Lollius, to understand that they are both perfectly aware of the native's identity.[30] The biographical data contained in this text have allowed modern scholars to identify the native as Ceionius Rufius Albinus, consul in 335 CE and *praefectus urbi* in 336/337 CE [*PLRE* 1.37, *s.v.* Albinus 14]. Since Firmicus wrote his *Mathesis* in 334/337 CE, the native (born 303 CE) must have still been alive at that time [Barnes 1975, 42].

(This last is a particularly clear instance of what must have been typical of other astrological manuals too: astrological writers inserted anonymous horoscopes that would be recognized by at least some of the contemporary readers and, consequently, appreciated both for their revelations about well-known individuals and for their function as technical illustration. Altogether, only 7 of 184 literary horoscopes bear explicit identifications of the natives and only a dozen more cases, despite their anonymous presentation, have been identified by modern scholars as the horoscopes of important historical individuals.[31])

The second reason is that only rarely does the biographical information in literary horoscopes cover multiple aspects of an individual biography. Such a

28 Hor. gr. 76.I.24 [Antigonus F1 in Hephaestio, *Apo.* 2.18.21–52, esp. §§45–52]. As other scholars have seen, some late horoscopes may have been invented for educational purposes: Hor. gr. 388.VI.4 [*PKell. gr.* (unnumbered)], Hor. gr. 400–401 [Rhetorius, *Astr. epit.* 4.15: *CCAG* 8.1.232.1–234.26]; Hor. gr. 516.V.1^(?) [Rhetorius, *Astr. epit.* 4.14: *CCAG* 8.1.231.5–31]; Hor. gr. 601.II.24^(?) [Rhetorius, 5.110.1–13]. See Jones 2010, 33 esp. n63.

29 Firmicus, *Math.* 2.29.10: *is in cuius genitura Sol fuit in Piscibus….*

30 Firmicus, *Math.* 2.29.20: *cuius haec genitura sit, Lolliane decus nostrum, optime nosti.*

31 In the following list, "anon"./"expl". means "anonymously presented"/"explicitly presented". Hor. lat. –138.V.22–23 [Firmicus, *Math.* 6.31.1] anon. = Sulla?; Hor. gr. 37.XII.15 [Valens, *Anth.* 5.7.20–35] anon. = Nero; 50.X.24 [Valens, *Anth.* 2.22.1–9] anon. = Domitian?; 76.I.24 [Antigonus F1 in Hephaestio, *Apo.* 2.18.22–52] anon. = Hadrian; 80.V.27–28 [[Manetho], *Apo.* 6.738–750] expl. = [Manetho], 113.IV.5–6 [Antigonus F3 in Hephaestio, *Apo.* 2.18.62–66] anon. = Pedanius Fuscus, Hadrian's grandnephew, 117.XI.26 [Aristides, *Or.* 50.57–58] expl. = Aelius Aristides, orator; 120.II.8 [p. 497n32] anon. = Vettius Valens; 122.VI.12 [Valens, *Anth.* 7.5.6–11] anon. = C. Avidius Cassius, the usurper of 175? CE; 145.IV.11 [Cassius Dio, *Hist.* 76.11.1] anon. = Septimius Severus?; Hor. lat. 303.III.14 [Firmicus, *Math.* 2.29.10–20] anon. = Ceionius Rufius Albinus, consul 335 CE; Hor. gr. 380.XI.26 [Hephaestio, *Apo.* 2.2.23, 2.11.6–7, 2.11.9–15] expl. = Hephaestio, astrologer; 412.II.7 [Marinus, *Vita Procli* 35] expl. = Proclus, philosopher; 419.VII.2 [Valens, *Anth. additamentum* 1.38–49] expl. = Emperor Valentinian III; and six more cases from a fifth century CE court astrologer [p. 505n100].

rare case is the exceptionally complex and long horoscope of Emperor Hadrian [see p. 496n28]. In most other cases, the biographical information is instead very selective because these horoscopes were usually presented as illustrations of specific astrological tenets; in other words, they were meant to elucidate the alleged causal connection between a given birth chart and a single detail of that individual's biography. Nevertheless, Valens' *Anthologies* allow an interesting insight into how this astrologer collected and used his horoscopes.

3.1 *Valens' Use of Horoscopes*

Even if Valens does not explicitly say so, he presents quite a number of his horoscopes more than once, using the same one to illustrate now this astrological tenet, now another. The most prominent instance is Hor. gr. 120.II.8, which he adduces no fewer than 21 times in different contexts.[32] This is probably his own horoscope. Others are quoted just a few times, still others only once. All this shows that he must have owned a collection of at least 121 case studies, on which he drew selectively as his various astrological topics called for illustration. It is likely that these studies originated at least partly from personal consultations with the respective individuals (in the case of adults) or with their parents (in the case of children, especially newborn children).

An important argument in favor of this account is that 117 of Valens' 121 individuals were born within a time span of one century (61–162 CE). The remaining four exceptions are three early horoscopes (at least two of them seem to go back to earlier literary sources)[33] and one very late case of infant mortality.[34] Those of Valens' natives who were born between 60 and 100 CE all died—as far as Valens bothers to tell us—between 144 and 157 CE, i.e., well within the adult lifetime of Valens.[35] Since he also registers several infant deaths from the same years [see §3.2, p. 498], the easiest explanation is that all or most of these astronomical and biographical data come from his own intense astrological practice around the middle of the second century CE.

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32 Valens, *Anth.* 1.4.2, 1.4.5–6, 1.4.12–14, 1.8.12–18, 1.9.6–11, 1.10.1–7, 1.14.2–4, 1.15.4–9, 1.15.12–27, 1.16.5, 1.18.61–70, 1.21.17–26, 2.31.8–14, 3.4.9–11, 3.10.4, 4.11.21–26, 5.4.18–23, 5.6.25–37, 5.6.48, 5.6.70–72, 7.6.135–140.

33 Hor. gr. 37.XII.15 (Emperor Nero: see p. 496n31), 50.X.24 (Emperor Domitian [?], see p. 496n31), 54.X.29 [Valens, *Anth.* 8.7.1–11], a native who died at the age of 73 (127/128 CE).

34 Hor. gr. 173.II.3 [Valens, *Anth.* 7.4.11–15]. The child died after 13 days.

35 See Hor. gr. 67.IX.13 [Valens, *Anth.* 8.7.137–148] died age 86 (153 CE); 69.VII.16 [*Anth.* 8.7.55–63] died age 81 (150 CE); 74.IV.19 [*Anth.* 3.10.20–24] died age 81 (155 CE); 75.VII.19 [*Anth.* 3.5.6–10, 3.11.14–16, 4.8.1–23, 8.8.14–26] died 144 CE; 79.III.16 [*Anth.* 8.7.12–22] died age 73 (152 CE); 79.XI.28 [*Anth.* 8.7.194–208] died age 78 (157 CE); 85.XI.20 [*Anth.* 8.7.179–193] died age 65 (150 CE). See ch. 9.3 §4, p. 367.

Moreover, Valens seems to have updated his records occasionally, for instance, when he learned about a native's death. In dozens of cases, he specifies the age at which this or that adult person died, often in their 60s, 70s, or 80s. Such pieces of information are likely to be updates to earlier information obtained directly from the respective natives, unless one prefers the implausible assumption that in all these cases Valens obtained birth data not from the natives but from their relatives or other sources.

So, even if Valens' astrological database is lost and can be reconstructed only partly from his sample horoscopes, it must have existed and it is likely that other ancient astrologers built up similar collections of empirical data. They may well have been inspired to do so by collections of medical case histories, such as those preserved in the Hippocratic *Epidemics*. This seems especially likely if one considers the fact that in Antiquity astrology and medicine were often practiced by the same individuals.[36]

The analysis of selective biographical information contained in a few hundred horoscopes, the majority of which comes from a single author of the second century CE (Valens), will certainly not yield representative insights into the practice of astrology in the entire Roman Empire. Nevertheless, it gives us at least an idea of the social ranks for which horoscopes were cast and of the biographical details that called for astrological explanation. Hence, the reader may wish to take notice of the following data with all due caution.

3.2 *The Biographical Data in Valens,* Anthologiae

The most frequently mentioned biographical detail is premature death, especially that of an infant but also children and teenagers.[37] With regard to natives who reached adult age, we hear of numerous cases of violent death

36 See also p. 495n27 on the collection of dreams by Valens' contemporary Artemidorus of Daldis.

37 These horoscopes are (in chronological order): Hor. gr. 113.IX.10 [*Anth.* 8.7.64–70] death in the first year of life; 127.XI.23 [*Anth.* 3.7.21–26] death in the 12th year; 151.II.17 [*Anth.* 8.7.209–222] death in the sixth year; 151.XI.23 [*Anth.* 8.8.36–43] death after 12 years; 152.I.8 [*Anth.* 8.7.80–87] death in the first year; 157.XI.24 [*Anth.* 8.7.88–96] death after one year; 158.VIII.14 [*Anth.* 7.6.91–110] the native suffered from convulsions, eruptions, and eczema during his first three years and died after 33 months; 159.VII.18 [*Anth.* 7.4.16–18] death in the ninth year; 162.II.9 [*Anth.* 7.4.20–22] death after 11 years; 173.II.3 [*Anth.* 7.4.11–15] death after 13 days and 3 hours. After Valens, we have only scanty and very late evidence, Hor. gr. 482.III.21 (an infant death without precise date in Rhetorius, *Astr. epit.* 4.19, *CCAG* 8.1.240.17–28) and the special case of the birth horoscope of the son of Emperor Leo I [Hor. gr. 463.IV.25]: this child met a violent death, motivated by political reasons [*CCAG* 8.4.224.21–225.5; Pingree 1976b, 146–148].

(βιαιοθανασία), including being killed in a fight with wild beasts,[38] being poisoned,[39] being burnt alive,[40] hanging oneself,[41] drowning in bilge water,[42] drowning in a bath,[43] and fainting in a bath and dying (presumably of a heart attack).[44] The most frequently mentioned cause of violent death, however, is beheading,[45] the usual form of executing socially privileged individuals in the Roman Empire (*honestiores*, i.e., persons of senatorial, equestrian, or curial rank) [Wiedemann 1992, 78]. One of the four relevant horoscopes can be identified with certainty as that of Pedanius Fuscus, the grandnephew of Emperor Hadrian [p. 499n45 last entry]. One would wish to know the identities of the other three individuals.

We also find various horoscopes indicating (not always specifically) bodily disabilities and illnesses. Emperor Hadrian suffered from dropsy;[46] another person was "disabled in a limb";[47] another one, "disabled in a limb" and suffering from gout;[48] one had a disability of the genitals combined with a severe eye disease;[49] one had a crippled arm;[50] one was hunchbacked;[51] and another one, castrated.[52] All these ailments called for astrological explanation.

Another recurrent topic is sexuality and erotic desire (but hardly ever love, a topic that is so central to the astrological concerns of our own days). We hear of a 34-year-old soldier who served as a prison guard and got into serious trouble because he developed a sexual passion for a female prisoner;[53] of an 18-year-old man who went abroad with a distinguished woman because of friendship and esteem, who developed an erotic desire for her (to his disappointment because she died in the same year), and who returned home failed

38 Hor. gr. 91.IV.4 [*Anth.* 2.41.85–89], 115.XII.26 [*Anth.* 2.41.69–72].

39 Hor. gr. 65.V.24 [*Anth.* 2.41.73–76].

40 Hor. gr. 103.I.10 [*Anth.* 2.41.65–68].

41 Hor. gr. 89.VII.29 [*Anth.* 2.41.81–84].

42 Hor. gr. 88.V.5 [*Anth.* 2.41.77–80].

43 Hor. gr. 123.VII.2 [*Anth.* 2.41.47–50].

44 Hor. gr. 101.I.28 [*Anth.* 2.41.62–64]. In one additional case [Hor. gr. 78.IV.1: Valens, *Anth.* 2.27.5–7], the cause of the violent death is not specified.

45 Hor. gr. 86.XII.27 [*Anth.* 2.41.60–61], 87.VII.9 [*Anth.* 2.41.56–59], 97.II.23 [*Anth.* 2.41.51–55], 113.IV.5–6 [Antigonus F3 in Hephaestio, *Apo.* 2.18.62–66].

46 Hor. gr. 76.I.24 [Antigonus F1 in Hephaestio, *Apo.* 2.18.21–52, esp. §§24 and 49].

47 Hor. gr. 87.I.9 [Valens, *Anth.* 2.37.26–30]. In this and the following case, the Greek expression is «γέγονε πηρός».

48 Hor. gr. 92.XI.17–18 [*Anth.* 2.37.60–62].

49 Hor. gr. 118.XI.26 [*Anth.* 2.37.31–34, 3.3.30–41, 7.3.23–29, 7.6.141–144, 9.19.23–31].

50 Hor. gr. 104.IV.23 [*Anth.* 2.37.66–69].

51 Hor. gr. 112.VIII.17 [*Anth.* 2.37.74–75].

52 Hor. gr. 117.XI.30 [*Anth.* 2.37.56–59].

53 Hor. gr. 121.X.27 [*Anth.* 5.1.18–20, esp. 5.1.20 γυναικὸς ἠράσθη].

in his hopes;[54] of a shipwrecked man who, having been thrown on land, was loved by a woman;[55] of a powerful man who was not interested in women but only in “sordid” homosexuality;[56] of Pedanius Fuscus’ being “amorous” (i.e., fond of heterosexual affairs);[57] of a certain effeminate doer of “unspeakable acts” (i.e., a passive homosexual);[58] of Ceionius Rufius Albinus’ being an adulterer;[59] and of Pamprepius of Panapolis’ being a lewd person.[60]

When the professions of the clients are explicitly mentioned, which happens rarely, they are mostly of elevated or even the highest social rank. Among the many anonymous natives, we hear of one who was entrusted with royal office and high priesthood,[61] of other high priests,[62] of a famous priest and eunuch,[63] of two military generals,[64] of another of distinguished military rank,[65] and of someone who held an unspecified high office.[66] Since, however, these cases are rare, no reliable assertion about the social distribution of the clients is possible. All that can safely be said is that socially high-ranking individuals were among the clients and that astrological consultations were not at all limited to the lower social class, a fact that is confirmed by sources belonging to other (i.e., non-astrological) branches of ancient literature.

Three frequently recurrent biographical topics are lawsuits, trials, and banishment. Thus, we hear of a 50-year-old man’s legal action for the priesthood of a friend being won in the royal court;[67] of a 36-year-old having disputes and legal affairs on account of his wife;[68] of another 36-year old who was on trial at the royal court for supposedly having plotted the death of his wife, which had occurred two years earlier (he got away with exile);[69] of a 52-year-old man who was condemned for reasons unspecified;[70] of a 40-year-old man who was

54 Hor. gr. 142.III.25 [*Anth.* 7.6.164–192, esp. 7.6.165 ἐρωτικὴν ἐπιθυμίαν ἔσχεν].
55 Hor. gr. 474.X.1 [[Palchus], c. 57, *CCAG* 1.102, esp. l.13 παρὰ γυναικὸς ἐφιλήθη].
56 Hor. gr. 40.IV.5 [Antigonus F2 in Hephaestio, *Apo.* 2.18.54–61].
57 Hor. gr. 113.IV.5–6 [Antigonus F3 in Hephaestio, *Apo.* 2.18.62–66].
58 Hor. gr. 116.I.21 [*Anth.* 2.37.52–55].
59 Hor. lat. 303.III.14 [Firmicus, *Math.* 2.29.10–20].
60 Hor. gr. 440.IX.29 [Rhetorius, *Astr. epit.* 5.113–117: Pingree 1976b, 144–146].
61 Hor. gr. 82.VII.9 [*Anth.* 2.22.26–29, 3.13.7–9].
62 Hor. gr. 72.I.6 [*Anth.* 2.22.24–25], 102.XII.4 [*Anth.* 5.6.106–109].
63 Hor. gr. 121.I.29–30 [*Anth.* 2.22.46–47].
64 Hor. gr. 63.V.13 [*Anth.* 2.22.10–12], 122.VI.12 [*Anth.* 7.5.6–11].
65 Hor. gr. 117.VI.30 [*Anth.* 7.3.30–36].
66 Hor. gr. 111.IV.24 [*Anth.* 5.6.82–86].
67 Hor. gr. 107.V.8 [*Anth.* 5.6.87–89].
68 Hor. gr. 120.V.12 [*Anth.* 5.6.110–111].
69 Hor. gr. 122.XII.4 [*Anth.* 7.3.18–22].
70 Hor. gr. 132.II.7 [*Anth.* 6.6.11–31, 6.7.3–11].

condemned to exile because of allegations made by a woman motivated by the prospect of profit;[71] of an unsuccessful suit about inheritance made by a 53-year-old sister against her older brother;[72] of another suit about inheritance made by a 25-year-old wife against her 35-year-old husband (in the first instance, he won; but when the case was appealed two years later, she won);[73] and of two brothers who were, at the age of 33 and 39, respectively, condemned to exile.[74] Besides the three cases of exiles just mentioned, we hear of five more cases not explicitly connected to court procedures.[75]

The obvious interest of the astrologer (here Valens) is to detect and explain the astrological causes of such biographical crises and catastrophes that occurred in his social environment and sometimes under his very eyes (in the case of the 36-year-old man who had allegedly plotted the death of his wife, Valens explicitly states that he had been an eyewitness).[76] He also wishes to explain why they occurred at the precise ages of the respective natives, probably in the hope of increasing his reputation for competence at making chronologically differentiated predictions when consulting with his clients.[77]

At the same time, comparative analyses of two or more horoscopes (several examples have just been adduced) serve to demonstrate the marvelous causal connection between all human affairs. Another case of such comparison (cύγκριcιc) [see, e.g., *Anth.* 5.6.91, 7.3.17] concerns the 50-year-old man whose lawsuit for the priesthood of a friend was mentioned above. In another context, Valens presents this man's horoscope again together with that of his son to demonstrate that the father's death had been prefigured in the son's horoscope and *vice versa*.[78] The most complex extant cύγκριcιc is that of six people who almost perished together in a sea storm in 154 CE (Valens himself was one of them).[79] In this instance, our author emphasizes that he presents and com-

71 Hor. gr. 120.IX.28 [*Anth.* 7.6.195–202].

72 Sister: Hor. gr. 110.XII.15 [*Anth.* 7.6.51–57]. Brother: Hor. gr. 108.XI.6 [*Anth.* 7.6.45–50].

73 Husband: Hor. gr. 124.VII.29 [Valens, *Anth.* 7.6.27–35]. Wife: Hor. gr. 134.VI.23 [*Anth.* 7.6.36–44]. See also p. 503 and n94.

74 The elder: Hor. gr. 114.IX.24 [*Anth.* 7.3.14–17]. The younger: Hor. gr. 120.XII.8 [*Anth.* 7.3.9–13].

75 Hor. gr. 78.IV.1 [*Anth.* 2.27.5–7], 101.III.5 [*Anth.* 2.27.8–12], 105.I.1 [*Anth.* 2.22.38–39], 111.IX.30 [*Anth.* 7.6.111–116], 113.VII.1 [*Anth.* 7.6.58–65].

76 *Anth.* 7.3.22 παρέτυχον [Hor. gr. 122.XII.4]. Cf. Hor. gr. 102.XII.14 [*Anth.* 7.6.73–86, esp. 7.6.86 αὐτὸc παρέτυχον].

77 Such a differentiated prediction by an unknown author is preserved in an original horoscope, *PLond.* 1.98.82–189 [= Hor. gr. 95.IV.13]. Lines 118–189 of this papyrus are not in Greek but in Old Coptic.

78 Father: Hor. gr. 107.V.8 [*Anth.* 5.6.87–89]. Son: Hor. gr. 135.X.27 [*Anth.* 5.6.90–91].

79 *Anth.* 7.6.127–160 [Hor. gr. 114.VII.26, 118.XI.26, 120.II.8, 122.I.30, 127.VII.18, 133.IV.24].

pares the six horoscopes in order to show the admirable coherence of the natural world [*Anth.* 7.6.127 πρὸς τὸ θαυμάσαι τὴν φύσιν].[80] Such comparisons further serve the apologetic purpose of countering the so-called Cannae-argument that large-scale disasters involving many individuals' deaths are incompatible with astrology.[81] Valens would argue that when many individuals perish in battles, fires, shipwrecks, and the like, their common death is prefigured in all their individual nativities.[82]

Another important function of literary horoscopes was to provide rational explanations for profound changes of individual fortunes. By doing so, the authors implicitly denied the legitimacy of explaining such changes as chance products (and possibly advertised their own prognostic services).

Valens discusses numerous such instances: a commanding and despotic person who was exiled and died a violent death;[83] a rich and powerful man who was banished and then committed suicide;[84] a leader who encountered a hostile attitude toward his leadership and was, in his 34th year (135/136 CE), condemned to the quarry;[85] a man who was well provided for and prosperous at first but later was banished and became poor;[86] a man who was born a slave and, having entered an honorable lineage (*gens*), attained political offices and enjoyed honors before he died in 154/155 CE;[87] a rich man who lost his fortune and was banished in his 47th year (157/158 CE);[88] a man who escaped a situation in which his parents were murdered by robbers but later fell seriously ill and was banished;[89] a man who reached a distinguished military rank but fell

80 This idea complies with the Stoic concept of cosmic sympathy. Compare the protest of Favorinus of Arelate (early second century CE) against the alleged infinite nexus of human fates, reported in Gellius, *Noct.* 14.1.20.

81 See Cicero, *De div.* 2.97, which probably draws on Carneades. See also Sextus Empiricus, *Adv. math.* 5.91–92, which provocatively asks if all the Persians who had been killed at Marathon had had Sagittarius ascending at their births or if all the Greeks who drowned in the storm on their way back from Troy had Aquarius ascending at theirs.

82 A safer counterargument was chosen in Ptolemy, *Apo.* 1.3.7, which argues that universal causes take precedence over individual causes.

83 Hor. gr. 78.IV.1 [*Anth.* 2.27.5–7].

84 Hor. gr. 101.III.5 [*Anth.* 2.27.8–12].

85 Hor. gr. 102.XII.14 [*Anth.* 7.6.73–86]. The year of the condemnation that is given above in parenthesis (135/136 CE) results from the addition of 34 years to the birthdate 14 Dec 102 CE. Based on the same method of calculation, Valens' other indications of years of life in which the respective events occurred are in the main text of this paragraph converted into years CE.

86 Hor. gr. 105.I.1 [*Anth.* 2.22.38–39, 7.6.87–90].

87 Hor. gr. 109.VI.2 [*Anth.* 2.22.43–45, 8.7.149–166].

88 Hor. gr. 111.IX.30 [*Anth.* 7.6.111–116].

89 Hor. gr. 113.VII.1 [*Anth.* 5.6.126–128, 7.6.58–65].

in his 38th year (154/155 CE) because of accusations;[90] a dancer who was in his 25th year put in confinement in the course of a public riot but was defended before the governor, released through the help of friends and the entreaty of the crowd, and became more esteemed (later he became a braggart and pretender, which led to his being deprived in his 32nd year (154/155 CE) of honor, reputation, and livelihood);[91] a man who in his 20th year made an unsuccessful petition for honor to the king's court, was then ill, fell from an animal, and was dragged almost losing his eyesight, experienced fault and deception and a penalty that had to do with a woman; in his 23rd year (156/157 CE), however, he met royal favor and was made a member of a powerful assembly (the senate?);[92] a young man who went through many troubles (they are described in detail) before he eventually fared well in 164/165 CE;[93] and the changing fortune of a wife suing her husband in 160/161 CE [see p. 501 and n73].[94]

3.3 *The Horoscope of C. Avidius Cassius*(*?*)

Before we draw conclusions from this review, one last, particularly interesting case deserves attention. With respect to a man born in 122 CE, Valens [*Anth.* 7.5.9] provides the following biographical information concerning the time when the native had reached the age of 41 years and 6 months:[95]

> In this year fleeing from battle and falling from his horse as the enemy approached, and many killed and he himself wounded, he was mixed up with the rest of the fallen and, thought to be dead, escaped the danger and remained in the enemy's country until the 44th year [165/166 CE], leading the campaign.
>
> NEUGEBAUER and VAN HOESEN 1959, 119

Neugebauer and van Hoesen [1959, 120] saw that the campaign in question might have been that conducted by C. Avidius Cassius (the usurper of 175 CE) against the Parthians. In that case, the horoscope would be that of Avidius himself. In the Parthian war in question, Avidius was deputy to Lucius Verus, who entrusted him with the command of the *legio III Gallica* and auxiliary troops. Avidius' campaign began in 163 or 164 CE. He threw the Parthians out of Syria

90 Hor. gr. 117.VI.30 [*Anth.* 7.3.30–36].
91 Hor. gr. 123.I.3 [*Anth.* 5.6.119–125].
92 Hor. gr. 134.XI.4 [*Anth.* 5.6.75–81].
93 Hor. gr. 142.III.25 [*Anth.* 7.6.164–192]. This horoscope contains a prediction.
94 Husband: Hor. gr. 124.VII.29 [*Anth.* 7.6.27–35]. Wife: Hor. gr. 134.VI.23 [*Anth.* 7.6.36–44].
95 Hor. gr. 122.VI.12 [*Anth.* 7.5.6–11].

and invaded Mesopotamia. After decisive victories in 165 CE (Dura-Europos, Seleucia, Ctesiphon), he returned to Syria in late 165 or early 166 CE and became the governor of that province.[96]

These historical data match Valens' chronology: when the native was wounded in battle, he was in his 42nd year (= Jun 163 – Jun 164 CE) and he commanded the campaign until his 44th year (= Jun 165 – Jun 166 CE). Also Valens' reference to the native's invasion of the enemy's homeland [*Anth.* 7.5.9 εἰς τὴν τῶν πολεμίων χώραν] matches the historical facts given above. If our tentative identification with Avidius is correct,[97] we owe to Valens precious, otherwise unattested information about an initial setback in the Parthian war as well as—more importantly—the birthdate of the man who rose, in the following years, to be the most powerful general of the Roman Empire until he was killed as a usurper in 175 CE.

Two things are obvious with regard to all these changes of fortune: the natives are mostly males and the changes of fortune are mostly to the worse. The preserved evidence seems to allow a few new insights into Valens' activity as a practicing astrologer. It is likely that those men consulted Valens after their fortunes had changed to the worse in order to find out if their situations would turn back to the better. In order to substantiate this assumption, it is worth considering the respective years CE in which the individual changes of fortune described by Valens occurred (they have been indicated on the previous two pages after each case): with only one early exception, they belong to the 11-year period between 154/155 and 165/166 CE. This must be the timespan in which the individuals in question consulted Valens. This is also why we do not hear about their deaths, except for one who died in 154/155 CE [p. 502n87]—the others were probably still alive when Valens wrote the respective chapters of his *Anthologiae*. The very rare prediction that is attached to Hor. gr. 142.III.25 [p. 503n93] may be a unique case in which one of the predictions that Valens gave to all those men in the 150s and 160s survives. In the case of the military commander born in 122 CE, our tentative identification of the native with Avidius Cassius fits perfectly into this scenario: we know that Avidius became governor of Syria in 166 CE, and the capital of Syria was Antioch, Valens' hometown.

96 See Von Rohden 1896, 2379–2380; PIR I.A.1402, esp. 282; Aste 2011.

97 The fact that Valens computes this horoscope for the first so-called *clima* [*Anth.* 7.5.6] while Avidius was born farther north, in Cyrrhus (Syria), i.e., in the third *clima*, is not a serious argument against this identification. For a detailed explanation, see Heilen 2015, 257–259 [Hor. gr. 122.VI.12]. On the rough indication of geographical latitude by means of the so-called *climata* (belts of latitude), see Neugebauer 1975, 725–736.

It seems that Avidius, soon after his return from Mesopotamia to Antioch, consulted a local expert in astrology, maybe because his near-death experience in 163/164 CE and his later victories made him curious to understand these profound changes of his past fortune as well as his prospects for the future. Even if the native in question happened *not* to be Avidius Cassius, it would still be interesting to see that a victorious military commander entrusted his birth data and information on an earlier, inglorious episode of his life to an astrologer. The horoscopes of Vettius Valens confirm through their content what we are told more summarily by historical sources such as Suetonius, Tacitus, and the *Historia Augusta*, that at least some astrologers were socially very respectable individuals who had consultations with clients of high and the highest rank.

3.4 *Literary Horoscopes by Other Authors*

The present analysis has focused on Vettius Valens because his work allows the widest spectrum of observations on the various uses of extant literary horoscopes. As for those that are extant in other authors' works (61 of 184), they usually serve just one purpose, that of illustrating technical tenets, i.e., the most frequent among the various uses found in Valens' *Anthologiae*.[98] Rarely, however, these other authors bear witness to uses of horoscopes that have not been mentioned so far. The orator Aelius Aristides (second century CE) adduces his own horoscope in order to explain through the excellent natal positions of Mercury and Jupiter why the gods deemed him worthy of a dream in which Hermes appeared to him in the form of Plato.[99] [Manetho] (second century CE) uses his own horoscopes as a literary *sphragis* [see §3, p. 495]. In Late Antiquity, Marinus (fifth century CE) enriches his biography of Proclus with the philosopher's horoscope [Hor. gr. 412.II.7, *Vita Procli* 35]. And an anonymous astrologer who was probably at the service of Emperor Zeno cast political horoscopes of individuals that caused various sorts of problems to Zeno.[100]

98 For example, Firmicus uses the horoscope of Ceionius Rufius Albinus [Hor. lat. 303.III.14: see p. 496] to illustrate the doctrine of *antiscia*, on which see Bouché-Leclercq 1899, 161–164; Antigonus uses the horoscopes of Emperor Hadrian [Hor. gr. 76.I.24: see p. 495] and of Hadrian's grandnephew Pedanius Fuscus [Hor. gr. 113.IV.5–6: see §3.2, p. 498] to illustrate the doctrine on the fortune of dignity (τύχη ἀξιωματική); Balbillus uses his horoscopes [p. 491n8] to illustrate the calculation of an individual's lifetime.

99 Hor. gr. 117.XI.26 [Aristides, *Or*. 50.57–58]: see Heilen 2006.

100 Hor. gr. 440.IX.29 (anonymous nativity = Pamprepius of Panopolis, see p. 500n60); Hor. gr. 463.IV.25 (anonymous nativity = the infant son of Emperor Leo I, a potential rival to Tarasicodissa, the later Emperor Zeno, see p. 498n37); Hor. gr. 475.I.12 (on the coronation of Basiliscus as Emperor of the East after Zeno had fled Constantinople, see p. 493n16); Hor. gr. 483.IV.9 (Zeno's conferment of the titles "magister utriusque militiae praesentalis" and

From that late period (and probably from the same astrologer), we also have a number of retrospective discussions of so-called catarchic horoscopes that the astrologer had cast to answer the following questions:

- What is the content of a certain sealed letter?,[101]
- How can the lost linen of a slave girl be found?,[102]
- Will a certain small lion be tamed?,[103]
- Why did a man on his voyage by ship from Caesarea (Palestine) to Constantinople experience mutiny, shipwreck, and a love affair with a foreign woman?,[104] and
- What happened to two ships with precious cargo that were long overdue in, respectively, Athens and Smyrna and were therefore expected with great apprehension?[105]

These catarchic horoscopes serve the double purpose of showing, through complex correspondences between the narrative details and the astrological explanations, the admirable truth of astrology as established by revered authorities of the past (we find quotations from Dorotheus and a reference to Antigonus interspersed) and the author's own extraordinary competence in practicing this art.[106]

3.5 *The Horoscopes of Romulus and the Founding of Rome*

The most exotic use, however, at least from our modern point of view, and at the same time one that is particularly interesting for the history of astronomy, is found in the three earliest Latin horoscopes that bear witness of a unique scholarly endeavor [Hor. lat. −771.VI.24, −770.III.24, −753.X.4]. This is the only attested case in which Greek and Roman scholars in the Hellenistic Period prac-

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"consul designatus" on Theodoric, king of the Ostrogoths, the later Theodoric the Great—the Greek original is lost; for the Arabic text and translation, see Pingree 1976b, 142–143); Hor. gr. 484.VII.18 (coronation of the usurper Leontius [p. 493n16]); Hor. gr. 486.III.17 (the entry of Zeno's luckless Augustal prefect (i.e., governor of Egypt) Theodorus into Alexandria: see [Palchus] c. 31; *CCAG* 1.100–101; Pingree 1976b, 148–149). For analyses of these horoscopes, see Pingree 1976b.

101 Hor. gr. 487.IX.5 (anon., *CCAG* 1.106–107, 6.63–64).

102 Hor. gr. 478.VIII.29 (anon., *CCAG* 6.64.26–65.21).

103 Hor. gr. 483.VII.8 (anon., *CCAG* 6.65.22–66.15).

104 Hor. gr. 474.X.1 [p. 500n55].

105 Hor. gr. 475.VII.16 [[Palchus], c. 58, *CCAG* 1.103], 479.VII.14 [[Palchus], c. 59; *CCAG* 1.103–104].

106 Original hexameters from the poem of Dorotheus are quoted in Hor. gr. 484.VII.18 [p. 493n16] and also in Hor. gr. 440.IX.29 [p. 500n60]. A specific horoscope by Antigonus (probably that of Hadrian) is referenced in Hor. gr. 487.IX.5 [p. 506n101]. On causing admiration, see also p. 502 and n80.

ticed technical chronology in combination with astrological history, a branch of celestial divination that was to be developed systematically only later by Persian and Arabic scholars. Passages from Cicero, Plutarch, Solinus, and John the Lydian[107] allow us to reconstruct how Lucius Tarutius, a Roman expert in astral sciences, calculated the dates of the conception and birth of Romulus as well as that of the foundation of Rome.[108] He did so at the request of the antiquarian Marcus Terentius Varro, arguably the greatest Roman scholar of the middle of the first century BCE.

At that time, there was an increasing interest in time-reckoning and chronology among the Roman elite. While Julius Caesar had reformed the Roman calendar (45 BCE), scholars like Varro, Atticus, and others tried to establish a reliable chronology of the Roman past. This effort was at least partly motivated by the desire to have an equivalent of the impressive chronologies of older Mediterranean cultures, especially the Greek one, which reached much further back in time than the historical records of the Roman people. To put it bluntly, the Roman elite was dissatisfied with the role of cultural and historical junior partner at a time when their own political and military power had eclipsed that of all other peoples in the Mediterranean world. Since no authentic historical records of the early period of Roman history existed, Varro took a speculative approach instead.

In a first step, he adopted the calculation of Atticus, who had dated the foundation of Rome to 21 Apr 753 BCE. Since Romulus was reported to have founded Rome at the age of about 18 years, Varro, who considered Romulus a historical figure, concluded that Romulus had been born around Apr 771 BCE, plus or minus a few months. Varro's aim was to determine, within this range of uncertainty, the precise birthday of Romulus, which he probably considered to be the beginning of Roman history. To this purpose, he asked Tarutius to reconstruct, by astrological means, the planetary alignment under which Romulus had been born. The leading idea was to determine the day and hour of Romulus' birth by reversing the usual astrological procedure, whereby the astrologer starts his analysis from a given time of birth, determines the planetary alignment of that moment, and moves on to make inferences about the future life of the newly born individual.

107 Cicero, *De div.* 2.98–99; Manilius, *Astr.* 4.773; Plutarch, *Rom.* 12.3–6; Solinus, *Coll.* 1.18; John the Lydian, *Mens.* 1.14. The text of Plutarch is about all three horoscopes, the other ones only about Hor. lat. −753.X.4.

108 Two more foundation horoscopes of ancient cities are preserved: Hor. gr. −329.IV.16 (Alexandria, see p. 491n8) and 330.V.11 (Constantinople, by Demophilus: see Pingree 1977).

Varro, instead, already knew the life and deeds of Romulus, which he took to be historical fact. He wished to make inferences from these events backward to their stellar cause, that is, to the planetary alignments at the birth of Romulus. Once that alignment was found, he could determine its calendrical date. Tarutius provided Varro with three distinct horoscopes: that of the conception of Romulus (24 Jun 772 BCE, the date of a solar eclipse),[109] that of the birth of Romulus (24 Mar 771 BCE, 273⅓ days later),[110] and that of the foundation of Rome, which Tarutius dated to 4 Oct 754 BCE, thus departing for understandable reasons related to Hellenistic astrology and Roman political ideology from the premise given to him by Varro (21 Apr 753 BCE, an astrologically unfavorable alignment). Recent research has shown that Tarutius computed the astronomical data on calendrical dates more than 700 years before his own time quite accurately and that the astrological characteristics of those alignments are in compliance with the tenets of Hellenistic astrology.[111]

4 Conclusion

If these horoscopes by Tarutius had not survived, no one would dare to hypothesize that astronomy and astrology had been employed in such a way.[112] That final example may serve as a warning and remind us that much (almost all) evidence has been lost and that we are far from getting a full and representative picture of the contexts, uses, and users of horoscopes in Greek and Latin.[113]

109 According to Tarutius, it was a total eclipse but modern computation reveals that all that occurred was “a barely grazing eclipse of the Sun that could be seen, if at all, only in far northern latitudes” [Grafton and Swerdlow 1986, 149]. Tarutius must have been unable to determine the lunar parallax.

110 This is the standard length of human pregnancy in Babylonian and Hellenistic astrological theory, equivalent to 10 sidereal lunar months of 27⅓ days each [Frommhold 2004, 226–239].

111 For a detailed explanation of Varro’s and Tarutius’ method, see Grafton and Swerdlow 1985 and 1986; Heilen 2007.

112 Compare the similarly astonishing, thoroughly unique find of the Antikythera Mechanism [see ch. 9.2, p. 340].

113 A special category of the uses of ancient Greek and Latin horoscopes is that which modern scholars made of them. Some horoscopes on papyrus turned out to be helpful for the reconstruction of the chronology of late ancient Roman emperors. See Stein 1924, 33–34, 47 on Hor. gr. 258.IX.26 [*POxy.* 12.1563]; 260.IX.29 [*POxy.* 12.1476]; and 283.III.23 [*POxy.* 12.1564].

CHAPTER 12.4

Demotic Horoscopes

Micah T. Ross

1 Introduction

Even though Demotic horoscopes have yet to be collected in a single work, recent publications have increased their numbers.[1] In total, 60 horoscopes survive on 49 ostraca and in three funerary decorations. They come from Athribis, Luxor, Medinet Habu, Thebes, Karnak, and Medinet Madi [see Plate 1, p. 510]. Unlike Greek horoscopes, none of the Demotic horoscopes survive as "literary" horoscopes. All are documentary texts, appearing as graffiti or on ostraca.[2]

Derived from Babylonian personal natal astrology [see chs 12.1 §4, p. 446, 12.2 §3.2, p. 481], Demotic horoscopes largely resemble the Greek horoscopes with which they are roughly contemporary. Unlike Mesopotamian texts, both Demotic and Greek horoscopes include the Ascendant or some other indication of the astrological houses (ʿ.*wy* and τόποι, respectively) among the points

1 Heinrich Brugsch [1860] published the first Demotic horoscope from a coffin lid from Luxor. Spiegelberg [1902, 1910] published three horoscopic ostraca from Medinet Habu. Between these two publications, Flinders Petrie [1908] published a site-report including two "zodiacal tombs" of Athribis, which early discussions of horoscopy overlook. Herbert Thompson [1912] identified two more Demotic horoscopic ostraca from Medinet Habu. More than 30 years later, Otto Neugebauer [1943] joined two of the published ostraca, added a new ostracon, and presented the ostraca as the Medinet Habu archive. Later, Neugebauer and Richard Parker [1968] added two more horoscopic ostraca without provenances and counted the two ceilings of Athribis as horoscopes. Nur el-Din [1974] published a broken horoscope from Thebes and described *JdE* 51,228 [Tm 54460], which remains unpublished [el-Din 1976]. Parker [1983] published the first horoscopes of the Medinet Madi archive. Didier Devauchelle [1985] presented an undatable, partially preserved, probably horoscopic text from Karnak. Angiolo Menchetti [2005] published a horoscope from Medinet Madi but omitted analysis. Micah Ross added 10 horoscopes on 8 ostraca of Medinet Madi [2006] as well as 6 more horoscopes from Medinet Madi [Ross 2007a]. Joachim Quack [2008] identified another horoscope from Medinet Habu. In total, we have six horoscopes from Medinet Habu. Menchetti [2009] presented three more Medinet Madi ostraca. Ross 2009b also identifies a previously published horoscope from Medinet Madi and Ross 2009a presents 15 horoscopes found on 12 ostraca. Ross 2011 adds 9 horoscopes found on 7 ostraca. To date, the Medinet Madi archive has yielded 46 horoscopes found on 40 ostraca.

2 Zauzich 1971, 176, no. 319 may present the sole exception but this papyrus from the early Ptolemaic Period might be a horoscope, a sign-entry table, or some other text.

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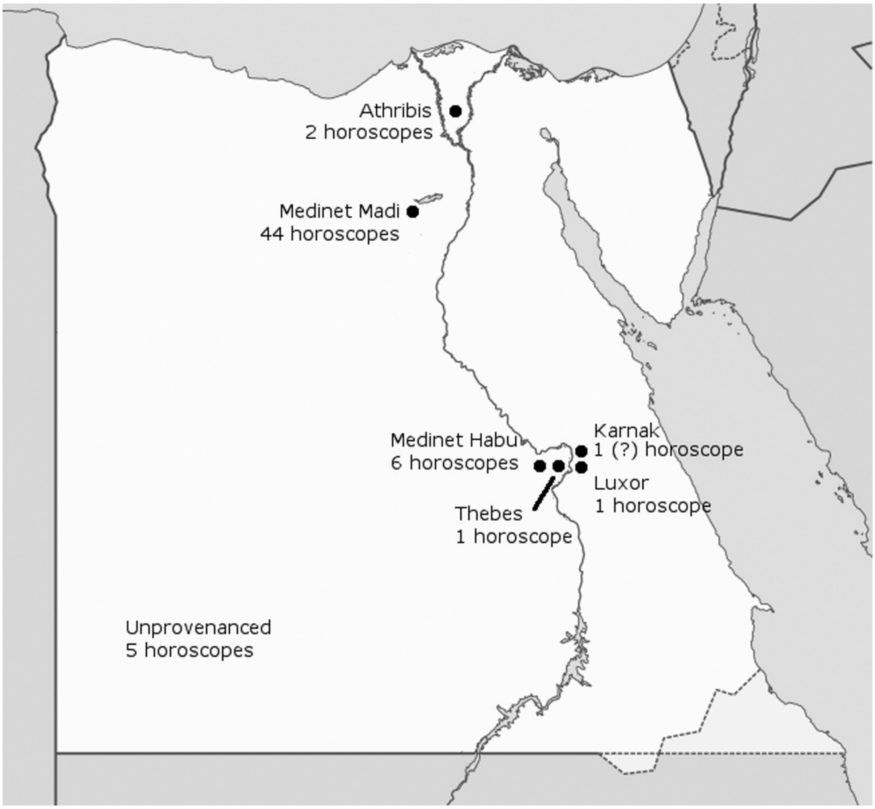

PLATE 1 Demotic horoscopes in Egypt

of interest [ch. 12.1 §10, p. 458].[3] With one possible exception, Demotic horoscopes conform to the "whole-sign house" hypothesis [Holden 1982]—that is, if a planet or astrological house is identified with a particular zodiacal sign, no further specification of the particular degree of that sign is presented. Yet, with respect to astrological doctrines, the Demotic horoscopes differ from each other as much as they differ from Greek horoscopes, which indicates a linguistic division rather than stages of astrological development. Furthermore, the two linguistic categories may only roughly correspond to the social divisions

3 The houses represent a fundamental spatial division of the cosmos that is delimited by the path of the Sun and the eastern and western horizons. Six houses always stand above the horizon and six houses are always hidden beneath the Earth.

between Egyptians and Greeks. Generally, the horoscopic texts in either language require minimal literacy: they are technical, limited to fewer than 20 words in length, and in a language that depends more on the preferences of the scribes than those of the clients. In past analyses, Demotic horoscopes have been understood in light of their Greek counterparts. In other words, since Greek has a legacy of similar content, Greek astrology has been used to analyze Demotic horoscopes. Because of this practice, an examination of historical assumptions should preface a reconsideration of the Demotic horoscopes.

2 Interpretations

Any broad declaration about the relationship of Greek astrology to Demotic horoscopes risks the elevation of cultural assumptions over textual evidence. Nevertheless, Demotic horoscopes so strongly resemble Greek horoscopes and present such limited information that reference to Greek astrology is inevitable. Modern analyses of Greek astrology often impose interpretations from Roman Greek and Byzantine literary texts on Hellenistic documentary evidence. Even for scholars who question the primacy of Hellenistic culture, the familiarity and accessibility of Greek horoscopy inclines them to interpret laconic Demotic horoscopes according to Greek literary composition. For example, David Pingree decried "Hellenophilia" but argued that

> [t]he science of astrology was developed in, most probably, the late 2nd or early 1st century BCE as a means to predict from horoscopic *themata* draw[n] up for the moment of an individual's birth (or conception), the fate of that native. This form of astrology, called genethlialogy, is rooted in Aristotelian physics and Hellenistic astronomy, but also borrowed much from Mesopotamia and some elements from Egypt....
>
> PINGREE 1997, 21

Accordingly, Pingree dismissed the earliest Hellenistic record of planetary positions as "an application of the idea of celestial omens...planets in a zodiacal sign...to a political event" [1997, 26]. This perspective conforms to the Roman and Byzantine horoscopic compendia but the same documentary evidence could equally suggest that catarchic astrology, which identifies propitious moments [see ch. 12.1 §5, p. 448], preceded genethlialogy.

If later Greek tradition could misdirect the interpretation of earlier Hellenistic evidence, over-reliance on Greek literary horoscopy may likewise distort horoscopy from non-Hellenic cultures. Most Demotic horoscopes probably relate to the moment of birth (or conception) but only two explicitly declare this relationship, that is, OGlasD 1925.96 [Tm 93274: Quack 2008] and OMM 972 [Ross 2006b].

The "fate" to which these planetary positions relate may not have been considered inescapable or even particularly important to the native. For example, the horoscopes may relate to the assignment of an individual to the organizational units of the temples called *phylae* or to some other practical use not likely to be preserved. Natal interpretations are, however, supported by Greek astrological writers who often lived a century or more later. Moreover, given that the Demotic horoscopes do not require a particular cosmology for their interpretation, modern scholars have been reluctant to ascribe a spherical cosmology to the Egyptians or, for that matter, to the Mesopotamians (who may have originated the genre).

Among the broad assumptions about the relationship of Greek astrology to Demotic horoscopes, one expectation is that Greek served as the vehicular language by which Babylonian personal astrology was introduced to Egypt. This assumption agrees with the fact that both the Seleucid and Ptolemaic dynasties relied on Greek as the administrative language. However, Egyptians had borrowed astrological techniques directly from Mesopotamia before Greek hegemony [Parker 1959]. Moreover, in Egypt, certain activities could be strongly connected with a specific language and this language was subject to change. For example, Willy Clarysse has noted that the language of Egyptian oracle-texts shifted dramatically from Demotic to Greek early in the Roman Era, even though the resulting Greek was strongly influenced by Demotic grammar [1984, 1348–1349: see Ripat 2006; Naether 2010, 370–374]. The assumption of a Greek intermediary in the case of horoscopy opens the way to the view that there was a reworking of Mesopotamian astrology in accordance with Greek science, which would entail spherical heavens, an emphasis on the order of planetary spheres, and Aristotelian elements—all of which are found in (Greek) literary astrological treatises but do not appear in the documentary texts. Although the assumption of a Greek intermediary is attractive, explanations limited to Mesopotamian and Egyptian sources can also account for the spherical heavens implied by the system of astrological houses, the ordering of planets, and the four classical elements suggested by the schemata of oppositions and trines [Greenbaum and Ross 2010; Eastwood and Graßhoff 2004, 50–52; Rochberg-Halton 1988b].

In fact, paleographical evidence suggests another hypothesis: Greek texts adopted paleographic conventions, particularly the use of logographic graphemes for the planets and the zodiacal signs, from the Demotic compositions.

TABLE 1 The relation of Greek and Demotic astronomical graphemes

Greek	⊙	☾	☿	♀	♂	♃	♄
Demotic							

This Egyptian influence on Greek paleography, however, does not seem to have occurred at the same time as the standardization of the horoscope. The consistent use of logograms for planets and zodiacal signs began with the sign-entry table *PBer.* 8279, which was composed after 42 CE, and logographic writings for Gemini and Scorpio are attested earlier. Little evidence details the earliest zodiacal symbols in Greek but one Greek papyrus, *POxy.* 4184 [Jones 1999a, 20] apparently contains the Demotic writing of Aquarius.

The earliest Greek texts which have not been altered by editors show that abbreviations of Greek words indicated Saturn and Jupiter [Jones 1999a, 62]. However, the symbols for Mars and Mercury relate to the Demotic graphemes [see Table 1]. Mars' upward pointing arrow slants in the same direction as the knife ideogram used in Demotic. Further, the grapheme for Mercury resembles the Demotic writing more strongly than a "stylized caduceus" [Jones 1999a, 62].

While Greek astrological texts show some paleographical influence from Egypt, the earliest Demotic horoscopes betray few debts to their hypothetical Greek precursors. None of the names for the planets or zodiacal signs suggest a Greek origin, whereas the Demotic form of "Pisces", «tb.t», transliterates the Babylonian «ZIB.ME» («zibbāti», "tails"). For example, no species of fish named *tb.t* antedates the Ptolemaic Era and «tb.t» never appears outside of astral context. Moreover, the problematic astrological terms of the Medinet Habu ostraca («swšp» and «twr») do not resemble Greek loanwords but exhibit some similarity to Mesopotamian terminology.[4]

A striking contradiction to the absence of Greek influence, however, may be found in the earliest Demotic horoscope, which contains the loanword «slns» from the Greek genitive «ϲελήνηϲ» ("of the Moon") and the later horoscopes from Medinet Madi which invert this relationship. Many of the Medinet Madi

4 For a tentative equation of «twr» and «DUR», see Ross 2007b. The equation of the two terms does little to clarify the astrological doctrine. The other term, «swšp», has resisted analysis for more than a century. Although the reading «swšp» has become normative, the suggestion by Müller [1903, col. 9] that the word be read as «swš» might be profitably reconsidered, despite Spiegelberg's objections [1910, 150n1].

horoscopes relate to Greek personal names, share ostraca with Greek texts, and perform calculations in Greek numerals.[5] Inclusion of the non-horoscopic ostraca which contain procedure-texts reveals that the scribes involved in Demotic horoscopy used Greek loanwords and calques [Greenbaum and Ross 2015]. Clearly, the Mesopotamian, Demotic, and Greek sources relate to each other; but, beyond primacy of horoscopes in cuneiform, the relationships permit multiple interpretations.

3 Demotic Horoscopes

Demotic horoscopy has generated two distinct genres of text: birth-notes and horoscopes. Birth-notes list a year, month, day, and hour; horoscopes, planetary positions and a reference to the astrological houses. This implies, but does not confirm, a division of labor. At one extreme, a "notary" might generate a birth-note for a client who brought that text to an "astronomer" who prepared a horoscope for interpretation by an "astrologer". Obviously, these steps could be collapsed or modified depending on the competencies of the individuals or their requirements. At another extreme, if an individual who knew the time of his birth consulted an astrologer who used a sign-entry table and a *pinax* [Evans 2004], the inspection of his horoscope might generate no documents other than the sign-entry table which could have been prepared by an "astronomer" at another site. At another extreme, if Egyptian horoscopy included catarchic investigations, the birth-note might form the conclusion of the consultation. Although Greek horoscopy has produced "standard horoscopes" and "deluxe horoscopes", which include up to a paragraph of discussion on the position of each planet [Jones 1999a, 47], these genres do not extend to Demotic horoscopes. Only one Demotic horoscope, OGlasD 1925.96, includes any astrological interpretation and in this case both the birth-note and the planetary positions receive astrological analysis, a detail which may explain why birth-notes and horoscopes often share the same ostracon [Quack 2008].

Since only 60 Demotic horoscopes have been recovered, a statistical analysis has limited significance. Rather, the horoscopes present intermittent confirmation of horoscopy and episodic insights into the development of its doctrines. If the date proposed by Neugebauer and Parker for Ashmolean ODem. 633 [Tm 111067] is accepted, [1968, 231, 233–234], evidence of Egyptian horoscopy begins

5 Medinet Madi enjoyed a unique relationship with Greek language and the earliest(!) text listing the letters of the Greek alphabet survives from Medinet Madi [Pintaudi 2005].

in 38 BCE. The latest horoscope contains a date and planetary positions which conform to 196 CE. These texts fall into two clusters. The earlier horoscopes include the Medinet Habu archive. This archive appears to be the work of a single scribe; and because the dates of the horoscopes from it range between 13 and 35 CE, they appear to have been composed around 50 CE. The later horoscopes constitute the Medinet Madi archive and span from 129 until 196 CE. The horoscopes of the Medinet Madi archive contain the writing of several different scribes and suggest the labors of several individuals who engaged in horoscopy as a function of the temple. Because the horoscopes are irregularly distributed and the archives preserve a high degree of internal homogeneity, these archives offer the best context in which to understand Demotic horoscopes.

4 Horoscopes of Medinet Habu and the Fourth Upper Egyptian Nome

Medinet Habu occupied the hills of the ancient city of Thebes, which stood on the western bank of the Nile, opposite the modern city of Luxor, all sites within the Fourth Upper Egyptian nome which have yielded Demotic horoscopes. Only one of the five horoscopic ostraca of the Medinet Habu archive was retrieved from the campaign by the University of Chicago in 1929–1930 which cleared the area north of the Mortuary Temple of Rameses III. The others were purchased on the antiquities market. Spiegelberg purchased one horoscopic ostracon in Gurna and two more ostraca were purchased 10 years later by Wreszinski in Luxor [Spiegelberg 1910]. Because of the methods by which they were acquired, these ostraca preserve almost no archeological context and not even the proximity of their discoveries to one another can be established.

Although the Medinet Habu archive preserves limited archaeological information, its style of composition illuminates Egyptian astrological doctrine and possibly the development of the horoscope. Marked by a homogeneity which suggests a single author, the horoscopes exhibit a highly standardized format. They first report a birth-note and then list the position of the Sun and Moon. Next, the horoscopes present the signs which contain a subset of the astrological houses called cardines (*ỉb*, κέντρα) [see p. 460].[6] These are presented in opposed pairs: the first and seventh, then the 10th and fourth astrological houses. After the cardines, the horoscopes include three mysterious occurrences of «swšp», two obscure occurrences of «twr», and the zodiacal signs

6 Isidore of Seville, *Etymologiae* 3.38 attempts to derive the Latin terminology from "cor" ("heart").

which occupy them. The ostraca end by listing all of the astrological houses in order, beginning with the second house. This list of astrological houses repeats the positions associated with the cardines (except the horoscope), the *swšp*, and the *twr*. Planetary positions appear only as additions to the list of astrological houses. Through the standardization of format, the doctrine of 12 astrological houses is emphasized and the first house has a key role.

In his edition of these horoscopes, Neugebauer [1943] altered the text to reflect a proposed uniformity. Neugebauer understood these horoscopes in light of Greek astrology and argued that the *swšp* correspond to the ἀποκλίματα (cadent houses). The cadent houses include the third, sixth, ninth, and 12th astrological houses; but none of the four well-preserved ostraca count the first of these houses as a *swšp*. In addition to equating the *swšp* with an inapt Greek analogue, Neugebauer redacted three of the four legible ostraca to fit this scheme:

> Ostraca 2 and 3 interchange "right" and "left" in indicating the *swšp*'s [*sic*]...Ostraca 1 turns all the *swšp*'s [*sic*]... 90 degrees toward the east, obviously by erroneously calling the left-hand *swšp* the "middle" one and then modifying all the rest accordingly.
>
> NEUGEBAUER 1943, 119

Thus, Neugebauer manipulated the majority of the *swšp* to establish an incomplete analogy. Quite possibly, the *swšp* do not relate to the cadent houses at all [see Figure 1, p. 517].

Neugebauer also exchanged the left and right «twr» in one ostracon to produce the correspondence of the left and right «twr» with the third and seventh astrological houses. However, because this change is limited to only one ostracon, Neugebauer may have better discerned the method of calculating the *twr*. Despite this relatively neat fit of the *twr* with specific astrological houses, Neugebauer found no Greek analogue which applies to both of these astrological houses. Perhaps the astrological doctrines relative to these positions derived not from a hypothetical Greek intermediary but from a Babylonian source, since neither «swšp» nor «twr» appears in other Demotic texts and the terms confound analysis as Greek loanwords.

Outside the Medinet Habu archive, another ostracon from Thebes, now conserved in Leiden, may conform to the standard format [el-Din 1974]. The beginning of the ostracon has broken away but the text begins with the last of the astrological houses, "the house of the Evil Daemon" («pꜣ ꜥ.wy n wrỉ.t»). The termination of a section with the 12th astrological house suggests a compositional structure similar to the Medinet Habu archive. After this solitary reference

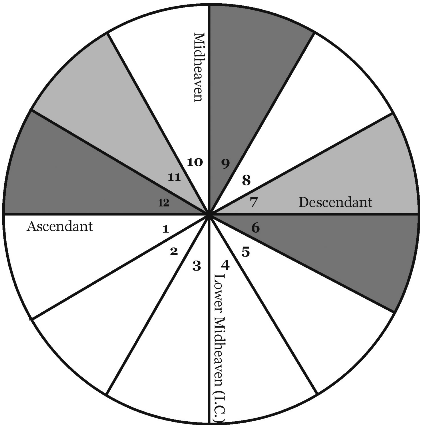

FIGURE 1 A reconstruction of *Swšp* and *twr*

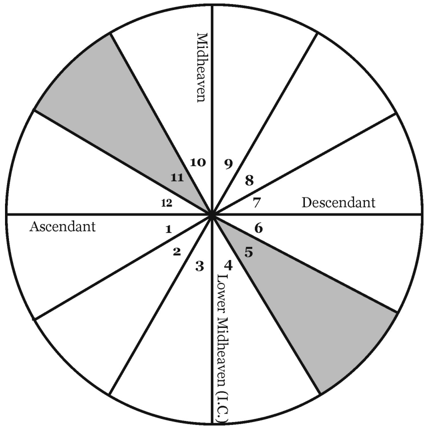

FIGURE 2 A reconstruction of *Špšy.t* and *šy*

to the astrological houses, the horoscope presents two lots (*tnỉ.t*, κλῆροι) [see p. 461]. The final lines seem to discuss the purpose for the horoscope. Although the end of the text is unclear, el-Din has related the text to marital difficulties. Better photographs have recently invited new readings but the missing contents may preclude complete understanding.

Two other Demotic ostraca also from the Fourth Upper Egyptian nome employ a different compositional model. Rather than focus on the horoscope and emphasize the astrological houses, these Demotic horoscopes accentuate the fifth and 11th astrological houses [see Figure 2]. The first horoscope begins with the positions of the Sun and Moon [Neugebauer 1943, 120], then reports the four cardines in the same order as the ostraca from the Medinet Habu archive: first, seventh, 10th and fourth.The horoscope ends by naming the signs in the House of Fate (*pr pꜣ šy*) and the House of Fortune ([*pr tꜣ*] *špšy.t*). The former may be identified as the 11th astrological house but the latter has been effaced. The second horoscope of this format begins with a date, presumably that on which the note was written, a name and patronymic, then another date with a specific hour. After these elements, the horoscope considers the astrological interpretation of both the hour and lunar conditions of the birth.[7] Next, the horoscope reports the outermost planets first but exchanges the posi-

7 A strict interpretation of the date as that of the Full Moon runs counter to the astronomical details. The broader view that the note indicates the last half of the lunar month may be more easily coordinated with Greek and Indian astrology. See, e.g., Vettius Valens, *Anth.* 2.23, 3.6; Hephaestio, *Apo.* 2; Paulus, *Intro.* 16; Olympiodorus, *In Paul. Alex.* 15; Sphujidhvaja, *Yavanājataka* 1.89; Kalyāṇavarman, *Sārāvalī* 5.15–16.

tions of Venus and Mars. Among these planets, the horoscope contains phrases which suggest that Sun, Moon, and Ascendant were added after the planetary positions had been investigated. Likewise, the horoscope repeats planets which share a sign in separate lines. This second horoscope also ends with the fifth and 11th astrological houses, "his fortune" (*tꜣy=f špšy.t*) and "his fate" (*pꜣy=f šy*), respectively. The fact that these two houses stand opposite to each other recalls the left and right *swšp*, but the approximate fit of the houses renders the parallel inexact.

The Fourth Upper Egyptian nome preserves the Medinet Habu archive and three horoscopes with seemingly related doctrines. Specifically, these horoscopes select sets of the astrological houses. One group selects five houses in two sets; the other examines only two houses. The proposed rule by which the first group determines the two sets of astrological houses does not fit well with the evidence and lies open to review. Likewise, the terminology cannot be easily connected with other Egyptian or Greek ideas. The rule by which the second group determined the two astrological houses under consideration is clearer. However, the selection of these two astrological houses suggests a precursor to the doctrine of Tyche and Daemon in Greek astrology [Greenbaum 2016]. The two groups may even have some relationship to each other, possibly obscured by the approximate fit generated by the "whole-sign house" hypothesis. Although alluring, the possibility that the doctrine of Tyche and Daemon began in Mesopotamia, passed through Hellenistic Egypt and reorganized Roman religion demands more evidence.

5 The Medinet Madi Archive

The Medinet Madi and Medinet Habu archives form complementary collections. Whereas the Medinet Habu archive was purchased on the antiquity market and represents the work of a single scribe, the Medinet Madi archive was recovered by excavations of the University of Pisa. Photographs from the excavation show how some of the 1,555 ostraca recovered were sorted into stacks but no record preserves exactly which ostraca these were. Unlike the Medinet Habu archive which was recovered from a site central to Upper Egypt, Medinet Madi constituted a relatively small and secluded settlement in the Fayyum, which enjoyed economic development under Ptolemy Soter but was not its largest settlement. Finally, in contrast to the Medinet Habu archive which occurs early in Demotic horoscopy, the Medinet Madi archive contains late Demotic horoscopes. Because of its location and date, the Medinet Madi archive exhibits not only the idiosyncrasies of Fayyumic dialects but extensive bilingualism.

While horoscopic ostraca constitute a mere 2–3% of the Medinet Madi archive, the broader category of astronomical ostraca includes birth-notes, calculations, procedure-texts, and other miscellaneous astronomical reckonings and accounts for 10–12% of the archive. Thus, horoscopy comprises a considerable portion of the archive. Even though the non-horoscopic ostraca of the Medinet Madi archive contain many irregular terms and unusual words, the horoscopes of Medinet Madi contain fewer difficult readings than the horoscopes of Medinet Habu because they conform to astrological doctrines known from Greek texts. Most include a birth-note but about a quarter of them omit any explicit date. Only slightly more than half of the dated horoscopes indicate the time for which the horoscope was calculated. About half of the horoscopic ostraca from Medinet Madi explicitly connect planetary names with zodiacal signs but the other half of this archive contain horoscopes involving only eight zodiacal signs. The composition of these minimalist horoscopes depends on a rigorous ordering of the horoscopic elements—Saturn, Jupiter, Mars, Venus, Mercury, Sun, Moon, and Ascendant—known from Greek sources and which may be confirmed by the fact that the inferior planets must appear within a limited distance from the Sun and occasionally (on comparison with modern computations) by the positions indicated in the associated birth-notes.

The horoscopes of Medinet Madi thus restrict their contents more than those from Medinet Habu. With only two exceptions, the Medinet Madi horoscopes do not exceed the eight minimal horoscopic elements. First, OMM 374 includes the descending node (indicated by a grapheme) among the horoscopic elements [Ross 2009a, 86–88]. This symbol bears a resemblance to another grapheme on the earliest Demotic horoscope which marks the bending (κάμπειος) or the position of the Moon farthest from the zodiacal circle [Ptolemy, *Tetra.* 150]. Second, OMM 134 includes «rʿ.t šy», meaning either the Lot of Fortune or the astrological house of the Good Daemon. A literal reading of «rʿ.t šy» favors "Lot of Fortune" by identifying «rʿ.t» as "Lot" («κλῆρος») and «šy» as "Fortune". However, Demotic terminology for the astrological houses varies. Both «ʿ.wy» and «tni͗.t» indicate astrological houses. Thus, «rʿ.t» might indicate an astrological house, while «šy» names the 11th astrological house in the Medinet-Habu tradition. Unfortunately, in this sole instance of «rʿ.t šy», the Lot of Fortune falls near enough to the 11th astrological house that the question is not easily decided [Ross 2011, 56–62; Greenbaum 2016].

Finally, OMM 842 computes the time of conception from the positions of the Sun, Moon, and Ascendant at birth. This ostracon closes with legal terminology («Iw.f r mt ll r…»: "He will make a complaint against…"), which clarifies the purpose of the horoscope: the calculation was evidence in a paternity dispute [Ross 2011, 59–61]. The variations in OMM 374 and 134 stand open to interpretation.

They may suggest that the horoscopes were computed for different purposes. The computation of the time of conception on OMM 842 supports the interpretation that the astrologers computed horoscopes for a range of purposes. On the other hand, the Medinet Madi archive contains the work of several scribes, who may represent divergent traditions in astrological education. The fact that OMM 374 and 134 relate to the Medinet-Habu tradition supports the interpretation that local astrological traditions could vary.

In those cases in which the purpose of the horoscope may be discerned, the reason for casting the horoscope challenges assumptions about the role of horoscopy. Only the horoscope that computes the time of conception decisively communicates the purpose of its computation as evidence in a legal complaint. In four other legal texts from Medinet Madi, the horoscopes encrypt dates [Menchetti 2009]. The ostraca with these horoscopes also contain Greek names and legal terminology rendered by Demotic numerals corresponding to the numeric uses of the Greek alphabet. These horoscopes include years and counts of days but these dates do not agree with the planetary positions. Rather, the number of years decreases as the date represented by the planetary positions becomes later, as if the years were counting down to the date of composition or a known epoch [Menchetti 2009, 225].[8] Although astrology and encryption inspire fantasies of occult doctrines and secret teachings, the context for these encryptions is prosaic. The plain text contains only personal names, titles, and terms relevant to a lengthy legal complaint which forms a large portion of the Medinet Madi archive.

Some horoscopes from Medinet Madi are explicitly didactic. In OMM 1187, the horoscope shares an ostracon with a procedure-text which derives the position of the Sun from a count of days, some calculations, and another more challenging procedure-text [Ross 2007a, 166–169]. The orthography of OMM 1187 resembles both OMM 251, which includes a table of fractions and an exhortation to do the calculations by "your own hand". These texts also resemble ODN 27 which discusses astronomical calculations and the goal-year period of Mercury [Bresciani, Pernigotti, and Betrò 1983, 35–39]. One interpretation of the Medinet Madi archive holds that role of the temple was educational. In that case, the curriculum may have extended to the astronomy needed to cast horoscopes.

8 In two cases, 1545 and 1198, the addition of these years to the time of the horoscope results in 204. In one of the remaining cases, some serious error seems to have confused the planetary positions, which ought to be either 86 or 46 years before 204 CE. In the other case, a date contained within the ostracon yields the proper epoch when added to the year count but the planetary positions are incomplete and possibly confused.

The remaining horoscopes of Medinet Madi preserve little context and no astrological interpretation. Their purpose remains conjectural. The absence of astrological interpretations may imply that such information was consigned to perishable papyrus, given to the client, limited to verbal communication, considered transitory or relative to a highly specific situation unlikely to be repeated, or deemed intuitively obvious from the horoscope. The unexpected uses for some horoscopes from Medinet Madi suggest the possibility of unanticipated uses for the remaining horoscopes. Two horoscopes which share the same ostracon, such as OMM 134 or 1066, might imply that the compatibility of two individuals was under investigation. Alternatively, the proximity of the horoscopes might indicate merely that the astrologer intended to meet with two clients in succession. A horoscope and an unrelated birth-note might reflect the working notes of the scribe or record the determination of a propitious time for a wedding or ceremonial installation for the native of the horoscope. Only OMM 972 explicitly declares the horoscope to be genethlialogical. While the planetary positions conform to a birth-note identified as "the birth of Serenus" (written «ϲερενου εντκατου»: *scil.* «Σερήνου ἐντίκτου»), the purpose for the horoscope is not recorded.

Many Medinet Madi horoscopes probably reflect the uses of horoscopes recorded in Greek astrological handbooks. To be sure, the archive includes many Greek texts and Greek enters Demotic as transliterations into Demotic characters, as Greek words in Demotic compositions, and as a source of translation. These strategies even appear in the same compositions. For example, ODN 27 transliterates the name "Antoninus" as the loanword «Antnn» in the first line, includes foreign words like «μοιρολογοϲ» and «χρονοκρατωρ» (without diacritical marks), and translates «νυχθήμερον» as «grḥ-mtr». At Medinet Madi, Greek and Demotic language overlap. Presumably, their astrology did too.

6 Horoscopic Outliers

The overlap of the Egyptian and Greek languages resulted in the development of Coptic. According to Quaegebeur [1982], the Old Coptic script began as an attempt to clarify the pronunciation of divine names in magical texts. The likely origin of this writing system and the fact that two texts composed in Old Coptic relate to astrology clarifies the intellectual context of horoscopy in Egypt.[9]

9 The two astrological texts are the Old Coptic horoscope [Černý, Kahle, and Parker 1957; Neuge-

One text, the so-called "Old Coptic horoscope", *PLond.* 98, probably purchased at Thebes, demonstrates the socio-linguistic position of Old Coptic as a vehicular language for religious wisdom. This text uses Greek in its first three columns and Old Coptic peppered with Demotic signs in the last three columns. The Greek portion renders the names of the decans in Greek with occasional Demotic characters. It echoes the horoscopes of the Medinet Habu archive [see Table 2, p. 523]. First, the planetary positions appear in the order of Sun, Moon, Saturn, Jupiter, Mars, Venus, and Mercury. Then, the Greek text reports the four cardines but breaks with the format of the Medinet Habu archive in their ordering. Whereas the Medinet Habu archive set pairs of cardines in opposition, the Old Coptic horoscope lists the 1st, 4th, 10th, then the 7th astrological houses. Next, the Greek portion of the Old Coptic horoscope reports the lots. Although these lots are specifically named lots, they do not conform to the lots known from Greek astrological treatises. Neither do they conform to the "whole-sign house" hypothesis. Rather, their distribution resembles the middle and left *swšp* and the left *twr* of the Medinet Habu archive.

Not only is the language different but a different style of handwriting indicates a second author who composed the Old Coptic of the fourth, fifth and sixth columns, which present interpretations of the planetary positions. Because these interpretations preserve conditional statements, they probably repeat extracts from an astrological compendium. In general, the Greek portion of the Old Coptic horoscope resembles the compositional structure of the Medinet Habu archive and the Coptic portion resembles Greek astrological treatises of the fifth century—perhaps even more strongly than the nearly contemporary treatises by Vettius Valens or Ptolemy [Neugebauer and van Hoesen 1959, 35]. In content, the Coptic passages refer to the astral influences during certain portions of the life of the native. Because of these references, they recall the «χρονοκρατωρ» of the Medinet Madi material. These passages indicate conditional clauses with Demotic characters and thus invite speculation about the language of the original composition and the astrological doctrines contained in it. The division between Greek astronomy, albeit supplemented with the Egyptian decans, and Coptic astrology also suggests a division between either the sources from which the data was derived or a division between the labors of scribes with different linguistic competencies who prepared the sections. The final interpreter must have been bilingual but may have had difficulty reading Demotic script.

bauer and van Hoesen 1959; Kasser 1963] and *PMich.* 6131 [1941]. Satzinger [1994] summarizes the corpus of Old Coptic texts but further examples may be added from Medinet Madi.

TABLE 2 Comparison of compositional structures

Medinet Habu			Medinet	Old
I	**II**	**III**	**Madi**	**Coptic**
Date		Date	<Date>	
☉☽	☉☽	Hour and Lunar Phase	☉☽	☉☽
Cardines (I, VII, X, IV)	Cardines (I, VII, X, IV)			Planets ♄♃♂♀☿
Swšp and *Twr*		Planets (♃♄♂♀☿) ☉,☽, and Ascendant added to planetary entries	Planets ♃♄♀♂☿	Cardines (I, IV, X, VII,)
Houses (II–XII)	*Šy* (XI) and *Špšy.t* (V)	*Šy* (XI) and *Špšy.t* (V)	Ascendant (I)	Lot of Fortune (XI) and Two Unnamed Lots (X, VIII)

Each column corresponds to a variety of Egyptian horoscope. From top to bottom, each column reports the compositional structure of the information of a type of horoscopic text. Angle brackets indicate optional information; parentheses indicate ordering, either of planets or information associated with the astrological houses.

The second horoscopic text in Old Coptic is poorly preserved but the topic has been determined by «ϩⲱⲗ», either in reference to Horus or one of the superior planets, and the discussion of «ⲁϩⲉϥ» ("his life") in connection with numbers. Presumably these numbers reflect years of the life of the native and the text preserves a tradition similar to that of the «χρονοκρατωρ» of the Medinet Madi archive and the periods of the Old Coptic horoscope. Despite the attempt by Worrell [1941], the poor state of preservation has prevented the extraction of a coherent tradition from the remaining fragments and classification may be premature.

Whereas the Old Coptic horoscopy fits with the genethlialogical traditions of Greek astrology, three other late Egyptian horoscopes suggest uses for horoscopes not connected with divination or the legal obfuscations of Medinet Madi. Like the Old Coptic material, these horoscopes do not contain Demotic text but originated in Egypt when Demotic was used. The first of these horoscopes appears on the coffin of Ḥtr. Greco-Roman coffins of Egypt frequently depict the sky-goddess Nwt. A subset of these coffins surrounds this depiction of Nwt with images representative of the zodiacal signs. In the coffin of Ḥtr, the names of the planets and the position of the Ascendant have been incised as hieratic additions to the zodiacal signs. In this case, the lifespan of Ḥtr is known and the date of death confirms that the planetary positions of correspond to the natal horoscope.

Funerary horoscopy, however, is not limited to the coffin of Ḥtr. Just as coffins frequently depicted Nwt (Nut) and occasionally included zodiacal iconography, so did tomb-decorations. The two "zodiacal tombs" at Athribis include iconographic representations of the planets among the depictions of the zodiacal signs. Likewise, the composition and ordering of the images of the zodiacal signs may be taken to indicate the location of the Ascendant.

Furthermore, astral elements constitute a standard element of Egyptian religious art. The earliest record of the decans appears on coffin lids and the trope migrated to tomb walls. Thus, the appearance of a complete set of zodiacal signs among funerary art conforms to the trend of adopting this fundamental celestial division in to cosmological compositions. Similar appropriations of the Mesopotamian zodiacal circle appear on the ceilings of temples at Dendera and Esna. Such inclusion of horoscopic information befits funerary inscriptions which record the details of the life of the tomb owner: his titles, his children, and his accomplishments. However, according to Greek astrological manuals, a natal horoscope retains little value after the death of the native, aside from the anecdotal confirmation or contradiction of astrological doctrines by literary horoscopes in Greek astrological manuals. A private tomb, however, operates in a different rhetorical mode from a scientific text. Perhaps the preparers of these funerary decorations assumed that these horoscopes would have some value in the afterlife. Perhaps the horoscopes, like personal names, embodied the individual connection that the tomb owner had with the cosmos. Perhaps the information in the horoscopes would have been useful in protective spells. At any rate, their divinatory use presumably ended with the death of the native.

7 Conclusions

Taken individually, Demotic horoscopes largely share the format and content of Greek horoscopes. The two traditions cannot be easily disentangled. The Old Coptic horoscope preserves an example of this entanglement: the Greek portion of a horoscope resembles the earliest Demotic horoscopes and the Coptic portion resembles Greek compositions from Late Antiquity. Within this context, some individual Demotic horoscopes preserve Egyptian astrological doctrines not preserved in the Greek astrological tradition and introduce one key innovation to the Mesopotamian horoscopes.

First, the *swšp* and *twr* of Demotic horoscopes cannot be found in Greek. Because of the flexibility of Demotic technical terms and the tendency toward indicating cardines, planets, and houses with whole signs, the *swšp* and *twr* of Demotic astrological compositions may be called *tnỉ.t* (lots). Some Greek lots (κλῆροι) may represent the same calculations but the *swšp* and *twr* have not been identified outside the corpus of Demotic horoscopes. In the search for their explanation, comparison with Mesopotamian traditions may yet prove fruitful.

In addition to the *swšp* and *twr*, some Demotic horoscopes emphasize the Houses of *špšy.t* (Fortune) and *šy* (Fate). The *špšy.t* and *šy* may merely indicate a special interest in the 5th and 11th astrological houses. However, these terms may also reflect the Greco-Egyptian theology related to the Agathos Daemon and Agathe Tyche. Whether the religious doctrine proceeded from astrology or the astrological terms reflected other Egyptian interest remains under investigation. Because Demotic horoscopes conform to the "whole-sign house" hypothesis which equates an entire astrological house with an entire zodiacal sign, the houses of *špšy.t* and *šy* may result from the same calculation which produced the left and right *swšp* or they may derive from the Ascendant, with particular astrological houses marked as relevant to the purposes of the horoscope.

The key innovation over the Mesopotamian tradition, the astrological houses, seems to be an Egyptian creation. Mesopotamian horoscopes make no reference to the Ascendant or any other cardine. In contrast, Egyptian sources which precede both the Demotic horoscopes and the introduction of the zodiacal signs suggest an indigenous fascination with the cardines [Greenbaum and Ross 2010]. In general, Egyptian observers noted heliacal risings and decans, and had long marked nocturnal hours in the Ascendant. Despite the difficulty of such observations, one Egyptian tradition of marking the nocturnal hours at the Midheaven even survived into Arabic. Likewise, a position analogous to the Lower Midheaven marked the "Judgment of Osiris" at the climax of the *Book of Gates*, which describes physically a celestial position which astrological houses describe temporally.

As stated above, any broad declaration about the relationship of Demotic horoscopes to the surrounding, contemporary astronomical cultures, risks interpreting the evidence on the basis of broader assumptions about those cultures. Because they contain more elements than their cuneiform forebears, Demotic horoscopes seem to have developed Mesopotamian personal astrology but the details remain obscure. The mysterious elements of Demotic astrological doctrine may have cuneiform precursors which have not yet been published or fully understood. Other elements of Demotic horoscopes reflect Egyptian cultural preoccupations but these religious and astronomical elements were not unique to Egypt. In other instances, postulated Greek intermediaries could explain the differences with the Mesopotamian corpus as the insertion of

Greek ideas. But this interpretation invites circular reasoning because it limits the function of Egyptian horoscopes to only those roles which had parallels in Hellenistic society—that is, to precisely those functions likely to be preserved in the later Greek traditions which directed the reconstruction of Demotic horoscopy.

Theological Contexts

CHAPTER 13.1

Hellenistic Astronomy in Early Judaic Writings

James C. VanderKam

1 Introduction

From the period of the Hebrew Bible, there is no surviving work that can be classified as an astronomical composition. Only in the age of Early Judaism do we find texts that could pass under this rubric. The point is worth making because the diverse writings of the Hebrew Bible[1] are in so many respects the sources from which later writers drew and which they employed in diverse ways. These writings did serve as sources for later writers who were more concerned with astronomical data but they must also have had access to information from elsewhere.

This chapter begins with comments on a few statements of astronomical relevance in the Hebrew Bible, followed by sections on the Astronomical Book of Enoch, the Book of Jubilees, and the texts found in caves near Khirbet Qumran (the Dead Sea Scrolls).

2 The Hebrew Bible

Though the writers of the works in the Hebrew Bible show little interest in scientific topics, they did write lines and sections touching upon astronomical phenomena. A prime example is the creation story in Genesis 1:1–2:4a, particularly 1:14–19 where on the fourth day God created the Sun, Moon, and stars. Their purpose was to "separate the day from the night" and to "be for signs and for seasons and for days and years" [1:14].[2] The section establishes the deity's absolute control over the celestial luminaries and explains the functions that he assigned to them, though not all the terms in 1.14 are clear in meaning (especially the ones translated "signs" and "seasons").

1 The phrase "Hebrew Bible" refers to the books in the Jewish scriptures. They are the same as the books in the Protestant Old Testament, while the Catholic Old Testament consists of the books in the Hebrew Bible and those of the Apocrypha.
2 Citations of biblical books come from the New Revised Standard Version.

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Other material pertinent to astronomy appears elsewhere. The schedule of sacred festivals anchors the celebrations in a fixed annual calendar. No passage in the Hebrew Bible explains the full nature of that calendar—e.g., how many days constitute a year and thus whether the year was lunar, solar, or a combination—or the calculations involved in defining it; but the festivals are usually dated throughout a year beginning in Spring with months identified by number (first, second, and so on).

Another point deserving emphasis is that numerous passages in the Bible take a negative stance toward divination and at times refer more specifically to those who observe the stars. One is Isaiah 47:12–13, which underscores the futility of astrology:

> Stand fast in your enchantments
> and your many sorceries,
> with which you have labored from your youth;
> perhaps you may be able to succeed,
> perhaps you may inspire terror.
> You are wearied with your many consultations;
> let those who study[3] the heavens
> stand up and save you,
> those who gaze at the stars,
> at each New Moon predict
> what shall befall you.

Passages in the Hebrew Bible, then, articulate a view of God as the one in total control of the Sun, Moon, stars, and their movements, through which he does not send messages; and, while there are passages presupposing some sorts of astronomical calculations in establishing the calendar of festivals, overall the Hebrew Bible presents a negative view of use of the luminaries for predictive purposes.

3 The Astronomical Book of Enoch

When the text of 1 Enoch re-emerged in the West in the late 18th century, it was known only in a Geʿez translation in which chapters 72–82 are an astronom-

3 The strange form «הברו » and «הברי» of the Masoretic text is widely interpreted as a corrupt form of the Akkadian «baru». The poetic parallel “those who gaze at the stars” supports the hypothesis.

ical treatise containing revelations by the angel Uriel to Enoch, the seventh patriarch from Adam. Enoch's unusual age at death—365 [Gen 5:24]—may have suggested calendrical associations. At any rate, Enoch became the Jewish figure associated with knowledge about the heavenly lights and the calendar. Fragmentary remains of four manuscripts, copied in the Aramaic language and containing text related to the composition in 1 Enoch 72–82, were found among the Dead Sea Scrolls [4Q208–11]. These limited remains provide a fuller insight into the astronomical system of the author. The Astronomical Book may have been written in the late third century BCE [see ch. 13.2 §2.2, p. 542].[4]

The Astronomical Book attested in the Geʿez manuscripts begins with a long chapter [72] in which the angel details the contours of a 364-day year with no reference to intercalation. The Sun rises through 6 adjacent gates (*scil.* arcs) on the eastern horizon and sets through their counterparts on the western; it remains in each of the 6 gates for 1 month of 30 days. At four places there is an extra day, twice said to be "because of its sign" [vv. 13, 25 in some manuscripts]: the final day of months 3, 6, 9, and 12. The author protests the views of opponents who fail to include the 4 extra days and who, therefore, must have employed an annual calendar of 360 days. He makes evident his use of Genesis 1 in his presentation of the luminaries (e.g., he calls the Sun the greater and the Moon the smaller light in 72:35, 73:1) and of Isaiah 30:26 (the light of the Sun is 7 times that of the Moon in 72:37). He also describes the stars as organized under four heads (corresponding to the seasons), 12 subordinate leaders (corresponding to the months), and 364 lower-ranking chiefs (for the days) [82:9–20].

The Aramaic copies make clear that the short lunar sections which have survived in the Ethiopic tradition [73:1–74:9, 78:6–17] preserve only a small portion of the material devoted to the Moon and its movements in the original text. These sections trace day-by-day and month-by-month the period of visibility and the fractions of the lunar surface illuminated in a strictly schematic fashion. That is, the system is a numerical pattern and not based solely on observation. From the myriad and seemingly confusing details in the fragmentary texts, H. Drawnel has managed to compile tables of two schemes in the lunar sections that are distinguished by whether the Full Moon falls on day 14 or day 15 of the month. He summarizes the evidence as follows:

> The foremost example of a conscious literary activity is the monthly pattern of lunar visibility in which each *nychthemeron* is described in exactly

4 The texts have been published in Milik 1976 and in Tigchelaar and García Martínez 2000.

> the same manner with the same short formulaic sentences [4Q208; 4Q209 frr. 1–22, 29–34, 36–41]. The principle of arithmetical progression is consistently used with the fraction of ½⁄7 (= 1⁄14) as its factor. The pattern breaks up at the beginning and end of the calculation when not periods of lunar visibility but the amount of lunar light is discussed (col. F, day 30 or day 1; day 28 or 29); however, the same fraction ½⁄7 is applied. The pattern of lunar visibility is used to account for probably twelve months of the lunar year.
>
> DRAWNEL 2011, 31 (modified)

Each of the schemes has sections for the Moon during nighttime and during daytime. Both contain the daily data for the following categories:

The Moon during the night

A	B	C	D
Night	Sunset to Moonset	Moonset	Moonset to Sunrise

The Moon during the day

E	F	G	H
Sunrise to Moonrise	Equation	Moonrise	Moonrise to Sunset

In the waxing phase, the formulas express the following:
A: the number of the night in the month
B: the fraction of the time the Moon shines
C: a notice that the Moon sets and enters a gate (the number may be given)
D: the fraction for which the Moon is dark the remainder of the night
E: the fraction of the period of the Moon's invisibility
F: the fraction of the amount of light added on the lunar surface
G: a notice that the Moon rises from a particular gate
H: the period in fractions when the Moon is present in the sky.[5]
During the waning phase, the order of the elements changes to reflect the movements of the Moon and there is a reversal in the data listed in F, E, and H (in parentheses): A, D, F (subtracted), G, B, E (fraction of the time that it is present in the sky), C, H (when the Moon is absent).

5 The verb "rule" from Gen 1:16 figures in this part of the scheme: cf. Drawnel 2011, 421–424, 246–259, and in various other places.

Drawnel [2011, 301–311, 425], following a series of earlier scholars, has shown how the lunar evidence and schemes in the Astronomical Book were influenced by Mesopotamian sources such as *Enūma Anu Enlil* tablet 14 and the astronomical Diaries from the first millennium (for some units of measure).[6]

4 The Book of Jubilees

A retelling of the stories from Genesis 1 to Exodus 24, Jubilees was written in Hebrew at some point in the mid-second century BCE. Jubilees too was at first available in modern times only in the complete Geʿez translation. Later, large parts of a Latin rendering became available and between 1947 and 1956 fragmentary remains of 14 manuscripts—all written in Hebrew—were identified among the Dead Sea Scrolls. The Geʿez translation has proved to be a faithful rendering of the Hebrew original (*via* an intermediate Greek version). The writer knew the Enoch literature, including the Astronomical Book, to which he makes reference [Jub 4:17, 21].

The book is certainly not an astronomical work but several sections in it convey information about calendars and calculations of times. The first is in the rewriting of Genesis 1 in which the writer assigns the role of determining the calendar not to the Moon but to the Sun alone [2:9]. A second is in the section about Enoch himself, in which the author says that he, the first to learn to write, recorded

> in a book the signs of the sky in accord with the fixed pattern of their months so that mankind would know the seasons of the years according to the fixed patterns of each of their months.[7]
>
> Jub 4:17

Also, during his sojourn with the angels—a more widespread understanding of the phrase he “walked with האלהים [*scil.* angels]” [Gen 5:22, 24]—they told him about “the dominion of the Sun” [Jub 4:21].

The most important section occurs in chapter 6 where the author sets forth the contours of the year. It is significant that he does so in dealing with the yearlong flood—a passage in the Hebrew Bible that is filled with precise dates [Gen 7:6–8:14]. The angel who reveals the Book of Jubilees to Moses says that the first

6 See also Albani 1994 and Ben-Dov 2008.

7 Translations of Jubilees are from VanderKam 1989, vol. 2.

days of the 1st, 4th, 7th, and 10th months are "memorial days and days of the seasons" located at "the four divisions of the year" [Jub 6:23]. These four dates commemorate specific events during the flood [vv. 24–27]. Each of the seasons so demarcated consists of

> 13 weeks; their memorial extends from one to the other: from the first to the second, from the second to the third, and from the third to the fourth. All the days of the commandments will be 52 weeks of days; (they will make) the entire year complete.
>
> Jub 6:29–30

The angel predicts, however, that the Israelites will stray from this arrangement and, in the process, celebrate festivals on improper dates just as the nations do.

> There will be people who carefully observe the Moon with lunar observation because it is corrupt (with respect to) the seasons and is early from year to year by ten days.
>
> Jub 6:36

The writer insists that a year lasts 364 days. It is a truly sabbatarian arrangement with 52 weeks exactly and it never changes—there is no provision for intercalation. If one follows another system, e.g., one dependent on trying to identify each New Moon visually, all the festivals will fall at the wrong times [vv. 37–38]. Banishing the Moon from any calendrical role is unique to Jubilees among Jewish texts. No observation is needed for the solar calendar of 364 days.

The book also reflects some of the scriptural distrust of astrology. It tells a story about a certain Kainan who found an inscription on which early peoples had recorded

> the Watchers'[8] teaching by which they used to observe the omens of the Sun, Moon, and stars and every heavenly sign.
>
> Jub 8:3

Kainan sinned through use of their recorded instructions.

8 The Watchers were angels who left heaven to marry women and have children with them; they taught their wives illicit arts: see, e.g., 1 Enoch 6–11.

5 The Qumran Texts[9]

The community of the Dead Sea Scrolls knew and used the books of the Hebrew Bible, the Astronomical Book of Enoch, and the Book of Jubilees. However, the information in some of the so-called calendar-texts most closely resembles the elaborate lunar sections in the Astronomical Book of Enoch.

(A) Two texts are explicit that the year lasts 364 days. In 4Q252 col. 2.2–3, Noah left the ark at the end of a complete year of 364 days; and in 11Q5 col. 27.5–6, David wrote songs for the daily burnt offerings, for each day of the 364-day year. Other texts such as the Temple Scroll presuppose a year of the same length. It is known that the calendar began on a Wednesday (the luminaries were created on the fourth day of the week) and that each quarter consists of months having 30, 30, and 31 days. On these bases, one can easily fill in the gaps in the strictly schematic but fragmentary calendar-exts.

(B) The calendar-texts among the scrolls [3Q319–330, 3Q337, 3Q394.1–2, and 6Q17][10] fall into several categories. To provide an overview of them, it is convenient to use a modified version of the division suggested in the official publication by Talmon, Ben-Dov, and Glessmer [2001, 7–14]. Their translations of the texts are used for the examples below, with page numbers in parentheses after the citations.

5.1 *Calendrical Documents*

(a) Enumerations of months and the numbers of days in each [6Q17].

(b) Schedules of the Sabbaths and festivals. An example from 4Q394 frr. 1–2 illustrates the type. Column 5.1–12 reads:

> first] in it Sabbath, on the twenty-second in it the Festival of the (New) Oil, (on the day) aft[er the Sa]bbath, aft[er it the Wood] Offeri[ng on the twenty-eighth in it Sabbath.]

The month in question is the sixth.

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9 Almost all of the 900+ texts found in 11 caves around Khirbet Qumran were copied or written in the first century BCE or the first century CE [see ch. 13.2 §1, p. 539].

10 Editors have subdivided several of these numbers into more than one document, and some of the documents contain sundry kinds of calendar-texts.

5.2 *Mishmarot Registers*

To understand these lists, it is crucial to know about the use made of the *mishmarot* or priestly watches/shifts. According to 1 Chronicles 24:7–18, the large priestly class was divided into 24 such groups (sometimes called courses); each of these served at the temple for one week before the next one on the list replaced it on Sunday. In many calendar-texts among the scrolls, the names of these priestly groups became a way to designate the 7-day span in which they served at the temple. For example, a text may refer to day 5 in Jeshua (the name of the ninth priestly group); the day is Thursday in this group's week of service. Since there were 24 courses and a 364-day year consists of exactly 52 weeks, each group served twice in a year (totaling 48 weeks), with 4 serving 3 times. This would mean that in a 6-year cycle, one would rotate through the 24 groups exactly 13 times, with the new 6-year cycle beginning exactly where the previous one did. A number of the texts attest such a cycle. In works of this category, the units for dating events are months, weeks (designated by *mishmarot* names), and days. Some of the texts do no more than list the 24 names [4Q329 fr. 1], while others record information such as the name of the course serving at the beginning of the years, the seasons, and months in a 6-year cycle [4Q328–329 fr. 2].

More complex types of *mishmarot* list the courses (and the days of entry into service) with the dates for the Sabbaths and the beginnings of the months [4Q322–324, 4Q324a, 4Q324c], while others detail the names of the priestly groups in whose weeks of duty the festivals fall in a 6-year span. A good example is 4Q320 fr. 4 cols 3–6, part of which reads [Talmon, Ben-Dov, and Glessmer 2001, 54]:

> The first year its festivals
> On the 3rd (day) in the week of the sons of Ma'oziah (falls) the Passah
> On the 1st (day) [in] Jeda['iah] falls the Waving of the[Omer]
> On the 5th (day) in Se'orim (falls) the [Second] Passah
> On the 1st (day) in Jeshu'a (falls) the Festival of Weeks.
>
> fr. 4 col. 3.1–5

It continues the enumeration to the last festival in the first year and proceeds through the next five years in the same way.

5.3 *Mixed-Type Rosters*

Some texts combine some or all of the above units with lunar phenomena, e.g., 4Q320 fr. 1 col. 2.1–4 which reads:

on the 5th (day) <in (the week of) Immer>[11] at the 30th (day of the lunar month) on the 23rd (day) in the 10th (solar month)
on the 6th (day) in Jeḥezqel at the 29th on the 22nd in the 11th (solar month)
on the 1st (day) in Joiarib at the 30th on the 22nd in the 12th (solar) month
The second year *vacat*

Talmon, Ben-Dov, and Glessmer 2001, 48

A few other texts add two moments in the movements of the Moon during a month to the units listed above. One of these is simply dated, not named; the other is termed *duq* (the form varies).[12] An example is 4Q321 where parts of col. 2.3–4 read:

On the four[th (day) in (the week of) Mijamin (which falls) on the fifteenth] in the seventh (month); and *duqah* (is) on the fi[fth (day) in (the week of) Se'orim, (which falls) on the second]
in it (the seventh month). On the sixth (day) in (the week of) Shekaniah (which falls) on the fif[teenth in the eighth (month); and *du*]*qah* (is on the) Sabbath in (the week of) Abiah (which falls) on the second in it (the eighth month).

Talmon, Ben-Dov, and Glessmer 2001, 71

The meaning of "duq" (and thus of the unnamed or X date) has been debated. One appealing suggestion is that the Qumran lunar texts that record the date in the month, the X date, and *duq* correspond with the Lunar Three in cuneiform texts: the number of days in the previous lunar month, NA (the interval in mid-month between sunrise and moonset on the day of the first moonset after sunrise), and KUR (the interval between moonrise and sunrise on the day of the last visibility of the Moon). The X date would correspond with KUR, that is, the "last morning visibility of the Moon at the end of the lunation" and *duq* would be the equivalent of NA and refer to the "first moonset after sunrise, on the day following the Full Moon".[13]

There is no explicit statement in any of the scrolls regarding intercalation of the 364-day calendar to bring it into harmony with the true solar year that is

11 The symbols "< >" indicate that the words are supralinear.
12 4Q317 combines these two points with information like that in the Enoch lunar tables.
13 Ben-Dov 2008, 208–244. The quotations are from p. 237.

about 1.25 days longer. It seems there should have been some means for supplementing the year because several of the festivals with fixed dates are also tied to certain harvest seasons and, thus, could not wander throughout the solar year. One text mentioned as a possible source of information about intercalating is 4Q319 [4QOtot]. The section that deals with the "signs" («'otot») indicates that one occurs every three years. As the editors describe the system,

> the calculations of this section are based on a unique correlation of three discrete time-reckoning devices: the standard Qumran six-year *mishmarot* cycle, the seven-year *šemitah* cycle, and the forty-nine-year jubilee cycle. In order to achieve a full integration of these cycles, a time span of six jubilees is required (49 × 6 = 294), after which the initial situation is restored, i.e. the priestly course Gamul serves at the beginning of year 1 of the first jubilee, as it did in the beginning of the first cycle.
>
> TALMON, BEN-DOV, AND GLESSMER 2001, 201

Does each sign mark the point at which intercalation took place? Every three years one could add 30 days to the 354 in the fixed lunar calendar of 1 Enoch and Qumran to bring it into harmony with the 364-day year. While that is true, this would still not effect agreement between the 364-day system and the true solar year. As a result, if there was a system for intercalating the 364-day year, its details remain unknown.

In addition, among the Qumran finds were several astrological texts, namely, 4Q186 [see ch. 13.2 §3.1, p. 548] (and 4Q561), a physiognomic work containing astrological data, and 4Q318 [see ch. 13.2 §2.1, p. 540] that includes the names of the zodiacal signs and offers predictions. And finally, what is possibly a sundial was found in the ruins of Khirbet Qumran, evidence that such an instrument was known and presumably used by the community of the scrolls.

CHAPTER 13.2

Astral Divination in the Dead Sea Scrolls

Helen R. Jacobus

1 Introduction

The Dead Sea Scrolls comprise some 900 manuscripts that were written in Hebrew and Aramaic (the majority of the scrolls are in Hebrew with about 15–16% in Aramaic) that were collected and preserved in caves, possibly by a Jewish sect, in and around the environs of Qumran from the first century BCE to the first century CE. The first-century Jewish historian Josephus described a Jewish sect, the Essenes, as being skilled in preserving the names of angels[1] and in foretelling the future.[2] According to Josephus, the Essenes also believed in predestination.[3] It is interesting to consider whether the scrolls that are, or

1 See Josephus, *De bello Jud.* 2.142. The specific names of angels are not mentioned by Josephus. In several parabiblical texts, some fragments or related fragments of which have been found in the Dead Sea Scrolls in Hebrew or Aramaic, there are parallel stories in which angels teach the secret knowledge of the calendar, astronomy, astrology, and divination in authorized and unauthorized situations. In an expansion of Gen 5:23–24 (in which all the days of Enoch were 365 years—65 until after the birth of Methuselah and 300 "walking" with the "Elohim"—the length of the solar year), the secrets of astronomy and the cosmos are revealed as authorized knowledge to Enoch by the archangel Uriel during his afterlife in heaven. The narrative is retold in the Hebrew fragments of the Book of Jubilees [Jub 4:17], in the Aramaic fragments of 1 Enoch (Uriel's name is not extant), and in the hitherto unknown Aramaic literary work The Genesis Apocryphon, sources collected and preserved in caves in and around Qumran.

In the same scrolls in an expansion of Gen 6:4–7, named angels descend to Earth before the Flood, marry the daughters of men, and teach them secret skills, including healing arts, astronomy, and divination; and their offspring, giants, fill the Earth with wickedness [Nickelsburg 2001, 165–201; Stuckenbruck 2014, 12–14, 27–33]. Of relevance to 4Q318, to be described, angels in the Book of Jubilees include the angels of thunder and lightning [Jub 2:2]; and an angel of Thunder, Ram'el (Thunder of God), is named among the list of angels who descend to Earth to teach their skills, unauthorized, to the daughters of men in the *Book of Watchers* in 1 En 6:7: see VanderKam 1989, 87–88; Nickelsburg and VanderKam 2004, 23–26; García Martínez and Tigchelaar 1997–1998, 28–33; Milik 1976, 139–189; Day 2016; Langlois 2008; Reed 2005, 5–51; Bhayro 2005; Fröhlich 2011; Stuckenbruck 2014. Corresponding fragments exist in the Dead Sea Scrolls. I have proposed that 4Q318 and 4Q208–4Q209 are zodiacal calendars that can function as lunar ephemerides and reflect angelic knowledge in these parabiblical narratives [Jacobus 2014, 44–176, 221–228, 260–343, 451–452].

2 See Josephus, *De bello Jud.* 2.158: cf. Taylor 2012, 57, 60–61, 92.

3 See Josephus, *Ant.* 13.171–173 [VanderKam 1994, 76–78]. Josephus illustrates his statement that

 | DOI:10.1163/9789004400566_044

may be, concerned with astral divination reflect such a belief. The texts here arguably reflect variously on Josephus' historical report about the Essenes and may provide evidence for a keen interest in a connection between the heavenly bodies and the destiny of individual human beings as part of a belief system in late Second Temple Judaism.

The first group of scrolls to be discussed in this chapter is concerned with the practical aspects of astronomy, including prognostications that are based on an ominous meteorological event, here, thunder, and contains calendars that can function as solar and lunar handy tables giving the zodiacal sign of the Sun and Moon on the days of the month [§§2.1–2]. The second group of texts are possibly more exclusively astrological but do not deal with technical astronomy [§§3.1–2].

2 Aramaic Astronomical Texts

2.1 *4Q318: 4QZodiacal Calendar and Brontologion*[4]

This fragmentary zodiacal calendar details the zodiacal sign in which the Moon is located for each day of a 360-day calendar composed of 12 30-day months. Just over two months of this calendar have survived. The calendar-text is followed by four lines of a fragmentary divination-text, the *Brontologion*. Such texts foretell the fate of the people in specific parts of the country and of the king's court from the date that a clap of thunder occurs (probably the first thunder of the year), according to the Moon's zodiacal sign for that day of the year. It takes the form of an archaic Mesopotamian-style prediction that can be used with the Moon's position in the schematic zodiacal calendar, which precedes it in the manuscript, on the day that thunder occurs; hence, the thunder omen-text is based on the Moon's zodiacal sign. The Qumran *Brontologion* is the only

the Essenes believed in Fate with stories relating to three Essenes who made successful royal predictions: see *Ant*. 13.310–313, 17.345–348, 15.368–371 [Taylor 2012, 91–95; Jacobus 2014, 15–18].

4 This text is registered as *4QZodiology and Brontology ar*. The code "4Q" means that the numbered manuscript came from Qumran Cave 4 (similarly, "1Q" means Cave 1). The abbreviation "ar" means that the text was written in Aramaic. The entire text of 4Q318 is referred to as *4QBrontologion* in some places such as the Shrine of the Book, in Jerusalem, where it is housed. However, it is more accurate to use that title for the omen-text portion of 4Q318 only. (The title "4QZodiacal Calendar" is preferred to clarify that the 12 signs are divisions of the zodiacal circle and that the text is related to a group of similar late Babylonian texts such as those described as employing the scheme of *dodecatemoria* [Brack-Bernsen and Steele 2004; Jacobus 2014, 91–99].)

known text of this kind in Aramaic [Greenfield, Sokoloff, Pingree, and Yardeni 2000, 270–273; Albani 1993; Wise 1994; Jacobus 2010 and 2014, 177–220, 258–259].

The calendar-text can be mathematically reconstructed for the year given its existing schematic content. Every 30 days the Moon traverses all 12 zodiacal signs in addition to the sign in which it was positioned at the outset. As the Moon travels at a rate of approximately 13° per day, it requires somewhat less than 2½ days to travel through each of the signs. However, in *4QZodiacal Calendar*, the Moon passes through each zodiacal sign in a schematic 30-day month in an recurrent pattern of 2 days, 2 days, and 3 days. The scheme is identical in each month, moving forward by one sign parallel to the same day in the previous month.

Although there is no information about intercalation in the text, there are parallels between the zodiacal sign that the Moon occupies in *4QZodiacal Calendar* and the lunar data in the Babylonian horoscopes, particularly for intercalary years. Even more surprisingly, there are also parallels between the lunar data in *4QZodiacal Calendar* and the positions of the Moon on the zodiacal circle for dates in the Jewish calendar, according to western astrological ephemerides.[5]

In a 360-day calendar, one could intercalate a 30-day lunar month every 6 years instead of going by the Mesopotamian 19-year calendrical cycle. However, from the empirical findings, it would appear that it may not have been necessary to intercalate the 360-day calendar separately.[6] The 360-day calendar is attested in late Babylonian texts in which the zodiacal signs are substituted for numbers that have an arrangement similar to that of 4Q318. *4QZodiacal Calendar* could indirectly have descended from such schemes [Brack-Bernsen and Steele 2004; Pearce 1988; Geller 2014b: cf. Wee 2016]. The 360-day calendar (prior to the invention of the zodiacal band) [Britton 2010; Rochberg 2004b, 126–131] is known from the third millennium in Mesopotamian administrative documents [Brack-Bernsen 2007; Englund 1988] and is evidenced in divinatory calendar-texts [Brown 2000b, 113–122; Heeßel 2010]. *4QZodiacal*

5 See Jacobus 2014, 99–132. The Babylonian horoscope data are collected and published in Rochberg 1998. 4Q318 may have worked with the Babylonian system of intercalation in the 19-year cycle whereby an additional 30-day lunar month is added seven times to the lunar year every two or three lunar years. On intercalation, see Rochberg 1995; Britton 2002; Rochberg 2004b.

6 For a comparison of 4Q318 and the rabbinical calendar showing an agreement particularly in the years when an intercalary month had been added, see Jacobus 2014, 122–132. For bibliographic references and discussion of how a 360-day year may have worked in practice, see Jacobus 2014, 83–91.

Calendar begins with the Moon in Taurus in the first month, whereas in the related late Babylonian texts the 360-day calendar commences with the Moon in Aries.

The *Brontologion* is written in the style of Mesopotamian omen-texts but incorporates specific elements known from Latin and later Hellenistic astrological geography.[7] Like its zodiacal calendar, the *Brontologion* also begins with the Moon in Taurus. Similar dual texts with a formulaic style identical to that of 4Q318—which comprises a 360-day zodiacal calendar with an accompanying omen-text with sign-by-sign predictions in their zodiacal sequence—are found in late Byzantine astrological treatises, indicating that there was probably a common source, of which the mode and routes of transmission are not known.[8] David Pingree thought that the origin of the Aramaic and Byzantine versions of 4Q318 would lead back to Tablet 44 of the omen-series *Enūma Anu Enlil* in the predictions dealing with weather [Greenfield, Sokoloff, Pingree, and Yardeni 2000, 272] but this has proved not to be the case [Gehlken 2012].

Some names of the zodiacal signs in the text seem to be Judaized: "The Kid" for Capricorn, a goat-fish, may be at once a theological interpretation and an avoidance of the biblical prohibition on the mixing of species in Lev 19:19 extended to include chimera.[9] The same names are found in the zodiacs on Byzantine synagogue floors in ancient Palestine in Hebrew; they are also in use in Hebrew today, with the exception of Aries, the Ram, which became the Lamb [Greenfield 1995; Jacobus 2014, 148–157].

The month names in *4QZodiacal Calendar* are Aramaic translations of the Babylonian months. These are also used in some late books in the Hebrew Bible and have remained in use in the Jewish calendar. See Table 1, p. 543 for a reconstruction of *4QZodiacal Calendar*.

2.2 *4Q208–4Q209*

The detailed calendrical component of 4Q208–4Q209 [4QAstronomical Enoch[a–b]] is contained in two separate Aramaic manuscripts from Qumran.

7 Yardeni has dated 4Q318 to the Herodian Period: see also Pingree's contribution in Greenfield, Sokoloff, Pingree, and Yardeni 2000; Jacobus 2014, 80–82. In particular, the fragmentary text states, "If it thunders [when the Moon is] in Taurus, the Arabs will suffer famine." Cf. Manilius, *Astr*. 4.754, in which the Arabs are governed by the sign of Taurus.

8 For a summary of these texts and bibliographic references, see Jacobus 2014, 191–207.

9 None of the Dead Sea Scrolls contravenes the ban on creating any images of the heavens in Deut 5:8; there are no diagrams or illustrations at all in any of the texts. The prohibition on divination in Deut 18:10 appears to have been interpreted less literally. On the zodiacal sign names in 4Q318, see Greenfield 1995; Jacobus 2014, 133–145.

TABLE 1 *4QZodiacal Calendar* [4Q318] reconstructed

	Nisan	Iyyar	Sivan	Tammuz	Av	Elul	Tishri	Heshvan	Kislev	Tevet	Shevat	Adar
1	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈
2	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈
3	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉
4	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉
5	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊
6	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊
7	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊
8	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋
9	♌	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋
10	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌
11	♍	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌
12	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍
13	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍
14	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍
15	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎
16	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎
17	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏
18	♐	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏
19	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐
20	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐
21	♑	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐
22	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑
23	♒	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑
24	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒
25	♓	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒
26	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓
27	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓
28	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓
29	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈
30	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓	♈

Shaded dates are in extant fragments. The 360-day calendar begins on Nisan 1 (Moon in Taurus).
Aries = ♈; Taurus = ♉; Gemini = ♊; Cancer = ♋; Leo = ♌; Virgo = ♍; Libra = ♎; Scorpio = ♏; Sagittarius = ♐; Capricorn = ♑; Aquarius = ♒; Pisces = ♓

Radiocarbon dating indicates that the older manuscript, 4Q208, is from the second century BCE [Jull, Donahue, Broshi, and Tov 1995]. J. T. Milik described these texts as comprising one year of a "synchronistic calendar" whose components formed a lunisolar calendar consisting of a triennial cycle of alternating full (30-day) and hollow (29-day) months in which the 354-day lunar year was intercalated by a 30-day lunar month every three years, equating to a 364-day solar year ($354\times3 + 30/3 = 364$). He argued that the second and third years were abbreviated and summarized in a part of the literary sections of the *Book of Luminaries* in 1 Enoch which survived in 4Q209. [1976, 274–275].[10]

The calendrical and non-calendrical literary fragments of 4Q209 (4QAstronomical Enoch[b]) are part of the corpus of the so-called Aramaic Astronomical Book of Enoch in the Dead Sea Scrolls, 4Q208–4Q211 (4QAstronomical Enoch[a–d]).

Some fragments correspond to parts of the *Book of Luminaries*, one of the five books of the Book of Enoch [1 En 72–82] preserved by the Orthodox Ethiopic Church in the classical Ethiopic language, Ge'ez [Neugebauer 1981; VanderKam 2012]. The part of 4Q209 comprising the lunar calendrical data very barely overlaps with 1 En 73:1–74:9 [Nickelsburg and VanderKam 2004, 99–103; Drawnel 2011, 29–46; VanderKam 2012, 359–368]. The Ethiopic text has been rewritten in a highly abbreviated form in the first person as a narrative by Enoch describing the teaching of astronomy and the calendar by the archangel Uriel. Most of the text of the 4Q208–4Q209 fragments was not included in the Ethiopic *Book of Luminaries*, as discussed by Milik; however, the synchronistic calendar of 4Q209 is also part of the same Aramaic manuscript containing Enoch's cosmological experiences in the literary narrative that was included in the *Book of Luminaries*, although clearly in terms of genre and style it is, arguably, a separate document.[11]

Some parts of the *Book of Luminaries* were later additions to the Aramaic manuscripts: 1 En 74:10 is a Hellenistic gloss [Neugebauer 1981, 18–19] and 1 En 72, the first chapter of the *Book of Luminaries*, was not found in the Dead Sea Scrolls. This chapter may not have survived or it may not have existed in its received form: one can only speculate. There is a section of 4Q211 [4QAstronomical Enoch[d] ar] containing unit fractions in decreasing denominations of 360 that is also entirely absent from the *Book of Luminaries*.[12]

The surviving textual elements of 4Q208–4Q209 consist of alternate 29-day and 30-day lunar months in a 354-day lunar year. Very little data for the solar

10 Milik has proposed that the solar-year element of the synchronistic calendar-text was 364 days. Subsequently, some scholars have argued for 360 days [see Albani 1994, 82–83; Drawnel 2011, 46; Jacobus 2014, 323, 334–340]. For the complex reception history of these fragments, see Knibb 1978, 1–46; VanderKam 2012, 335–352. (That the lunar calendar is of 354 days is not disputed.) For a development of Milik's hypothesis that the fragments of 4Q209 contain three years of a triennial cycle, see Ratzon 2015, 2017, and 2019; Jacobus 2020b, contra Ratzon.

11 4Q209 fragments 23, 25, 26, and 28 approximately correspond with literary material in 1 En 76, 78, 79, and 82: see Nickelsburg and VanderKam 2004, 104–116; Drawnel 2011; VanderKam 2012.

12 See Milik 1976, 296–297; Nickelsburg and VanderKam 2004, 116; Drawnel 2011, 232–234; Jacobus 2014, 337–340.

year are present in the fragments. (My detailed hypothesis for the proposal that the synchronized solar year is 360 days is to be published elsewhere.) In addition to numbered "gates" through which the Moon rises and sets (the Sun rises in a numbered gate in the largest fragment of 4Q209 only).[13] 4Q208–4Q209 contain the day of the lunar month and proportions in fractions of sevenths and half-sevenths of the Moon's "shining" and "concealment" and other synonyms to describe the Moon's phases. There are also different verbs pertaining to its waxing and waning [Tigchelaar and García Martínez 2000; Drawnel 2011, 237–301; Jacobus 2014, 293–300, 316–318].

According to Henryk Drawnel, the fractions of sevenths and half-sevenths and the technical terminology concern different time periods of lunar visibility using the variables of moonrise, moonset, sunrise, and sunset. He argues that 4Q208–4Q209 is not a calendar, rather, that it is based on the Mesopotamian lunar tables in Tablet 14 of *Enūma Anu Enlil*.[14] Drawnel does not include the gates and the solar data in 4Q208–4Q209 in his theoretical model. However, his textual reconstruction of all the fragments and his placing them in the context of the full and hollow lunar months has provided an invaluable tool for scholars.

One can combine the data found in the fragments of the synchronistic calendar of 4Q208–4Q209 and the proposed cognate zodiacal signs represented by the gate numbers in 1 En 72 [Jacobus 2014, 268–283 *contra* Neugebauer 1981, 156–161][15] with a similar schematic arrangement as that in 4Q318 for the Moon's stay in each zodiacal sign. It is then possible to produce a model of the full lunar year in these texts incorporating the surviving data in the fragments. According to this reconstruction, the Moon would begin the year in Aries. See Table 2, p. 547, for the proposed reconstruction of the 4Q209–4Q208 lunar year.

The shaded areas in Table 2 represent the preserved text fragments with the extant gate numbers—from which the waning Moon rises for the first time after sunset (the beginning of the new day of the month) or, if waxing, sets

13 4Q209 fragment 7, column 3, which is renumbered as Fragment 1 on the Leon Levy Dead Sea Scrolls Digital Library website.

14 Drawnel 2011, 302–307; Al-Rawi and George 1991–1992. See also ch. 12.2 §3.1, p. 479.

15 Neugebauer dismisses the idea that the gate numbers in the *Book of Luminaries* represent zodiacal signs, arguing that the gates are zones on the horizon where the Sun and Moon rise and set. Jacobus 2014, 263–274 argues that there is no contradiction in ancient astronomy between these arcs and the Sun's apparent journey through the zodiacal signs, and that Neugebauer does not take into account the wealth of zodiacal astronomical instruments, designs, and literature from Antiquity concerned with using the zodiacal signs and related zodiacal calendars. This type of science is found in many different kinds of zodiacal sundials and solar zodiacal *horologia* as well as in theology [Jacobus 2014, 344–325].

for the first time after sunset—given in boldface red in their calendrical order. (Note: each gate number represents two zodiacal signs; these are equidistant to the solstices running sequentially from Gate 1 (Sagittarius–Capricorn) to Gate 6 (Gemini–Cancer)). These are fragments containing lunar data (and in one column, also solar data) that can be identified as belonging to dates in Months I, III, VII, IX, X, and XII [Jacobus 2015, 2018, and 2020b]. It may be seen that no two days are alike regarding the day of the month, a 29- or 30-day month, gate number, or the lunar fractions. The data for the fragments signified by the shaded areas are as follows:[16]

Month I — 4Q209 fr. 16

Night 25: the waning Moon is hidden for 5/7ths; it shines for 2/7ths. (The Moon sets in Gate 3 [It would have risen in Gate 2, Aquarius].)

Night 26: the waning Moon is hidden for 5½/7ths and shines for 1½/7ths (based on the fractions and restored days of the month, it is a 30-day month).

The Moon rises from Gate 3 (Pisces) on Night 26.[17]

Month III — 4Q208 fr. 33

Night 27 the waning moon shines for 1/7th and sets in Gate 6 (having risen in Gate 5).

Night 28 it rises in Gate 6 (Gemini) shines for ½/7th. (A 30-day month).

Month VII — 4Q208 fr. 16

Night 25: the waning moon sets in Gate 4 (contra Drawnel, who reconstructs that it rises from this gate) and shines for 2/7ths.

Night 26 it rises from Gate 4 (Virgo) and shines for 1½/7ths (a 30-day month).[18]

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16 See Drawnel 2011 for the fragment numbering, text, and restoration [in square brackets]. Note that the fragment numbering in the plates in Milik 1976; Tigchelaar and García Martínez 2000; Drawnel 2011, and the Leon Levy Dead Sea Scrolls Digital Library online differ in many instances from those in the editions, as is the case with many fragments in other manuscripts as well.

17 There is a possible overlap with 4Q208 fr. 15 (Nights 26–27).

18 In addition, 4Q208 fr. 33 accords with Month III, days 27–28 (30-day month). The waning Moon shines for 1/7th on day 27 and on day 28 it it shining for ½/7ths, rising from Gate 6.

The data in another early fragment, 4Q208 fr. 16 agrees with the data for Month VII, days 25–26 (30-day month). Of interest, the scribe corrected his error for Night 25, which stated that the Moon shines for 2½/7ths, instead of the correct fraction of 2/7ths.

TABLE 2 A reconstruction of 4Q208–4Q209

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	29	30
1	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	.5	
2	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	1	.5
3	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	**4** ♈	1.5	1
4	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	2	1.5
5	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	**3** ♓	4 ♈	5 ♉	2.5	2
6	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	3	2.5
7	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	3.5	3
8	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	4	3.5
9	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	4.5	4
10	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	**5** ♉	6 ♊	6 ♋	5	4.5
11	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5.5	5
12	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	6	5.5
13	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	6.5	6
14	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	(7)	6.5
15	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	6.5	(7)
16	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	6	6.5
17	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	5.5	6
18	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	5	5.5
19	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	4.5	5
20	1 ♐	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	4	4.5
21	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	3.5	4
22	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	3	3.5
23	1 ♑	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	2.5	3
24	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2	2.5
25	2 ♒	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	1.5	2
26	**3** ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	**4** ♍	3 ♎	**2** ♏	1 ♐	1 ♑	2 ♒	1	1.5
27	3 ♓	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	.5	1
28	4 ♈	5 ♉	**6** ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓		.5
29	4 ♈	5 ♉	6 ♊	6 ♋	5 ♌	4 ♍	3 ♎	2 ♏	1 ♐	1 ♑	2 ♒	3 ♓		
30	4 ♈		6 ♊		5 ♌		3 ♎		1 ♐		2 ♒			

Shaded areas indicate fragments with extant "gate" numbers (in bold red). The top row gives the months and the first column, the days of the month. The two far right columns show fractions of the visible Moon in sevenths and half-sevenths for 29- and 30-day months [after Drawnel 2011]. The 354-day lunar calendar begins on Day 1 Month I (Moon in Aries).

Aries ♈: gate 4; Taurus ♉: gate 5; Gemini ♊: gate 6; Cancer ♋: gate 6; Leo ♌: gate 5; Virgo ♍: gate 4; Libra ♎: gate 3; Scorpio ♏: gate 2; Sagittarius ♐: gate 1; Capricorn ♑: gate 1; Aquarius ♒: gate 2; Pisces ♓: gate 3

Month IX 4Q209 fr. 7, col. 2
Nights 23: (the waning Moon sets in Gate 3 [it rose in Gate 4, Virgo]) to Night 27: the Moon rises from Gate 2 (Scorpio) on Night 26, shining for 1½⁄7th (a 30-day month).

Month X 4Q209 fr. 3
Night 4: the waxing Moon is 2⁄7ths light and 5⁄7 ths dark and shines for 2⁄7ths in Gate 2 (Aquarius). It sets in Gate 3 (Pisces) from whence it rises before sunset.
Night 5: The waxing Moon has already risen from Gate 3 (Pisces) and shines after sunset and sets in that gate; it is light for 2½⁄7ths (a 29-day month).

Month X 4Q209 fr. 7, col. 3
Nights 8 to Day 10: the Sun rises in Gate 1 (Sagittarius to Capricorn); the waxing Moon rises in Gate 5 (Taurus; a 29-day month) on Day 9 and shines after sunset in that gate for the first time, in which it sets on Night 10 [broken].

Month XII 4Q208 fr. 24, col. 1
Night 2 to Night 4. On Night 3: the waxing Moon is 1½⁄7ths shining (and dark for 5½⁄7ths). The Moon rises from Gate 4 (Aries, a 29-day month) on Day 2 and shines in that gate during Nights 3 and 4.

3 Astrological Texts

3.1 *4Q186: 4QZodiacal Physiognomy*[19]

Astral divination is most likely also attested in the Hebrew scroll 4Q186, which is registered as *4QHoroscope*, formerly as *4QCryptic*, and written mainly back to front in mirror writing. This technique is probably intended to be magical but is nonetheless easy to decipher. It also contains occasional letters in Greek, paleo-Hebrew, and a cryptic script that is found in a number of other Dead Sea Scrolls. The text appears to assign a zodiacal sign to a checklist of physical attributes and temperament. The native's physical and spiritual qualities are determined by the *molad* (literally, birth, origin, or source [Clines 2009, 208]) "under which he was born", possibly meaning a birth-time or a birth-chart [Morgenstern 2000; Popović 2007, 48–51]. It is not known whether the *molad* is the rising sign or Ascendant (attested in first-century Greek birth-charts), the solar zodiacal sign, the Moon's sign, or the Moon's zodiacal sign at conception,

19 This is the title preferred by Popović [2007].

or whether it has another meaning [Albani 1999, 282–289, 292–296, 294–296, 301–315; Schmidt 1998].

4Q186 quantifies the type of "spirit (*ruaḥ*)" that correlates with the individual's body-type in a ratio of nine parts of light to one part of darkness. It offers a prediction or a character assessment based on the bodily and spiritual qualities: "He will be humble/poor" is attested.[20] It has been argued that the text contains sectarian elements [Popović 2007, 172–194; Alexander 1996].

There is an intriguing parallel linking the genre associated with 4Q186 and later Greco-Roman physiognomic texts. For example, the person's coloring, hirsuteness, height, stature, hair type, eye type given in Ptolemy's *Tetr.* 3.11—and humoral temperament, rather than spirit—again probably indicates a common source.[21]

The physical lists in 4Q186 are strikingly similar to the Aramaic physiognomic text 4Q561, which is registered now as *4QHoroscope ar*, formerly as *4QPhysiognomic/Horoscope* [Puech 2009, 303–321]. The editor, Puech, argues that *4QHoroscope ar* is a nonsectarian, "plus ancienne" Aramaic version of 4Q186 [2009, 303–305]. He states that it contains technical astrological terms, including "the house of the spirit" [part reconstructed; 4Q561, fr. 3.9] and predictions. Puech and Popović disagree on the astrological status of 4Q561: Popović [2007, 66–67; 2011, 222n1] states that 4Q561 is a list of physiognomic types only and that the new title, *4QHoroscope ar*, is "regrettable". Puech [2009, 303–305] rejects Popović's suggested title of "4QPhysiognomy ar" for the text.

3.2 *Wisdom- and Mystery-Texts*

The Hebrew, non-astronomical Wisdom (also known as Sapiential) and Mystery literature from Qumran—the latter is classified as Wisdom but can also be treated separately—include possible witnesses to the suggestion that some form of horoscopes for individuals were created around the turn of the era in Second Temple Judaism. The term "molad" also appears in some of these texts in possible astrological contexts. Scholars have understood the term to signify a birth-chart [Goff 2013, 199; Schmidt 2006], the astrological sign under which one was born [Strugnell and Harrington 1999a, 117],[22] or the plan of the horo-

20 4Q186 fr. 1.2.9b: the same word «עני» can mean "humble" or "poor".

21 Ptolemy states that one's physiognomy is due to the influences of the planets, whether rising or setting, whether stationary or not, and where they stand in the quadrant of the birth-chart.

22 Critical editions: *4QInstruction*^{b} (4Q416) fr. 2.3.9 (= 4Q418 fr. 9.8) in Strugnell and Harrington 1999a, 110–113; *4QInstruction*^{c} (4Q417) fr. 2.1.10–11 in Strugnell and Harrington 1999a, 172–177, 182.

scopes [Morgenstern 2000, 143]. Commenting on the term's usage in 4Q299 (*4QMysteries^{a}*), Schiffman states, "Here the reader encounters the familiar concept of predestination found in the Qumran sectarian corpus" [1979, 42].[23] While 4Q186 and 4Q561 contain physiognomic prognostications and have a practical function, some Wisdom- and Mystery-texts containing possible astrological terms (as well as those that do not) are intended for spiritual instruction.

Although the Dead Sea Scrolls are rich in references in different contexts to foreseeing the future in a very wide variety of texts, manuals on how to practice the art of prophecy are less common. Nonetheless, the existence of zodiacal astronomical tables and physiognomies arguably reflect some of the different types of mystical genres in the scrolls themselves. This observation supports the historicity of some of the classical literary sources, without wishing to ascribe the writing, copying, and preservation of the scrolls to a single, identifiable community or sect. The collection as a whole comprises documents from different time-periods and Qumran-scholars today acknowledge that the social history and the cultural origins of the group, or groups, who assembled this remarkable archive is highly complex.

23 *4QMysteries^{a}* (4Q299) fr. 3a.2.b13; Schiffman 1997, 41–42. *1QMysteries* (1Q27) contains text overlapping with 4Q299 and *4QMysteries^{b}* (4Q300).

CHAPTER 13.3

Hellenistic Astronomy in Early Christianities

Nicola Denzey Lewis

1 Introduction

Christianity and astrology have long been held to be fundamentally antithetical. The monotheism of Christianity appears to contradict the very principle of ancient astrology, which assigns agency and divinity to astral bodies. What has been seen as the inherent passivism of astrology—that humans are not in control of their actions and that all is "fated"—seems to some to be inimical to Christian notions of free will.[1] In a classic example, the Christian self-styled philosopher Justin Martyr (100–165 CE) challenged Stoic determinism in proposing Christian free choice (προαίρεσις):

> But neither do we affirm that it is by fate (καθ' εἱμαρμένην) that people do what they do, or suffer what they suffer, but that each person by free choice (κατὰ τὴν προαίρεσιν) acts rightly or sins.
>
> *Apol. sec.* 7: BARNARD 1997, 270

In fact, the widely held perception that early Christians actively and consistently opposed astrology (that is, the science of astronomy in its use for prognostication) is largely misinformed and oversimplified. Christians, like Jews and other non-Christians in the Roman Empire, engaged both sides of a lively and impassioned debate concerning the validity—not to mention the true significance—of astrology and astrological prognostication.[2] In the first four centuries, Christians had not yet consolidated any orthodox perspective on the limits and scope of human will, nor on the power of the cosmos to control, direct, or presage human activity. It took time for Christians to develop alternative models of cosmology and agency; indeed, the Ptolemaic model of the cosmos [see ch. 4.4 §5, p. 121] persisted well into the Early Modern Period. Christians, therefore, adopted most of the principles of Ptolemaic astronomy

1 For the traditional view, see Riedinger 1956; Amand de Mendieta 1973.

2 For good overviews that treat a wider variety of sources, see Hegedus 2007; Denzey Lewis 2013; von Stuckrad 2000a. For Jewish astrology, see Sukenik 1934; Charlesworth 1977; von Stuckrad 2000a and 2000b; Stählin 1974.

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into their scientific thinking about the nature of the world and about the role of human and divine agency in it. In this chapter, I cannot include every example of astrological discourse, imagery, or practice among Christians in the early Roman Era; instead, I will focus on key texts, figures, and particular attitudes which become apparent in a broad survey of our extant sources.

Astrology is a broad category. It can range from a generalized doctrine such as the correspondence of macrocosm and microcosm, and cosmic sympathy, to genethlialogy (the construction of individual, native horoscopes), to astrology as a skill (τέχνη) with practical applications.[3] Astrological principles can form the scientific basis for sciences from meteorology to ethnography, from medicine to botany. Technologies such as agriculture depended on astronomical principles, as ancient farmers determined when to plant according to configurations of the stars, Moon, and planets in the night sky. Because of astrology and astronomy's fundamental standing in various aspects of science and technology, it would be unreasonable for Christians to have rejected these sciences wholesale. Often enough, astronomy as a scientific discipline (τέχνη) did not impinge on Christian theology. However, Christian apologists of the second to fourth century who rejected Greek science as part of a complete repudiation of Greek culture literally demonized astrology, seeing the science as a technology brought and controlled by fallen angels or demons. On the whole, Christian objections to astrology correlated with the degree of dissonance that Christians felt with Greco-Roman culture as a whole. Although the best known Christian position against prevailing cultural mores and modes was one of rejection, those Christians who embraced or retained Greco-Roman culture more actively within their worldviews were more likely to incorporate astronomy and astrology.

Christians inherited from Greek philosophy established modes for considering cosmic administration. From Stoicism primarily emerged the notion of Fate (εἱμαρμένη), a generalized principle of cosmic causality that came in the first and second centuries to be understood as something directed by the stars and planets [see ch. 14.1, p. 607]. Necessity (ἀνάγκη), another Greek principle of cosmic causality, appears frequently in Christian magical spells, although it is less often associated with astral bodies. Moira (μοῖρα) or one's lot is occasionally abstract but sometimes still tethered to the Greek Moirai (Μοῖραι), the goddesses associated with the administration of individual fates. Christians rarely engaged Roman ideas of fortune, especially as anthropomorphized into the

3 On generalized astrological principles permeating even Christian literature, see von Stuckrad 2000b.

goddess *Fortuna*. Astrology appears overtly in some Christian sources, named as such; but astrological determinism could also feature more subtly as a set of assumptions about the way in which cosmic forces directed events and people, assumptions tied loosely to Stoic concepts, particularly that of Providence (πρόνοια).[4]

This chapter will survey some key shifts in the articulations of astrology and astronomy featured in Christian writings from the first to the fourth century. A chronological sweep is the best way to assess change over time; however, certain issues (such as whether Jesus of Nazareth's birth was presaged by the Star of Bethlehem) proved perennially problematic without any new ways appearing to address the problem over the course of centuries. Christian rejections of Greek science became less strident as the Roman Empire Christianized, at which point, ironically, older Greek arguments against astrology such as those formulated by Carneades (214–129 BCE) were once more taken up by Christian thinkers.[5]

2 Christian Astrology of the First Century

As Christians began the slow process of forming their collective identity, it is difficult to tease out elements of their astrological knowledge and beliefs. This is due in part to the paucity of first-century Christian sources but also to the fact that our extant Christian writings often allude to astrological ideas only elliptically. Three sources from this era—the writings of the apostle Paul, the infancy narrative of the Gospel of Matthew, and a letter from the bishop Ignatius at the close of the century—provide three very different "snapshots" of Christians drawing upon latent astronomical ideas in their articulation of the cosmos and its operation. All three writers agree that the arrival of Jesus Christ into the cosmos had fundamentally altered it in some measurable way. They differ, however, in the degree to which they deliberately engage that conviction. In so doing, they established a baseline for subsequent Christian accounts of the nature of the "Christ-event" as "a cosmologically significant event". Let us begin with Paul, whose astronomical and astrological ideas have long been ignored by modern interpreters.

4 For Providence in Christian "Gnostic" sources: Williams 1992; Perkins 1980; Williams 1996, 202–207.

5 The best summary of Carneades' legacy remains Amand de Mendieta 1973.

2.1 *Paul*

The apostle Paul, our earliest Christian writer, frequently alludes to incipient Hellenistic Jewish astrological ideas. The central event in Paul's Christianity was not Jesus' crucifixion at the hands of Roman authorities; instead, Paul transposed the crucifixion onto a new scale of cosmic significance. Celestial beings whom he describes darkly as "archons of this age" and the "enemies of Christ" had "crucified the Lord of glory" in their ignorance [1 Cor 2:6–8, 15:25]. Christ, however, had emerged victorious from his confrontation with these powers. Paul transformed the shame of Jesus' crucifixion as a despised criminal into an act which subverted the cosmic order. This "Christ-event" in Paul's understanding, initiated no less than a "reconciliation of the cosmos" [Rom 11:15, 2 Cor 5:19]. This idea that the cosmos was anything other than a reflection of order and beauty was, arguably, a major Christian innovation: it paved the way for later negative assessments of the cosmos as demonic—a Christian view that has been, historically, wrongly attributed to Gnosticism.[6]

Paul's language in his letters is characteristically elusive and allusive rather than systematic and explanatory; thus, determining the degree to which he drew upon ideas from Greco-Roman astronomy is difficult.[7] A key problem for modern Pauline interpreters has been Paul's assessment of "the law", since this term can have the sense of either Torah or some sort of natural or cosmic law. Curiously, Paul associates Torah with angels [Gal 4:5; 3:19, 23], thus suggesting that, on some level, the law is cosmic and cosmically administrated. Drawing on what appear to be Platonist ideas, Paul notes in his letter to the Romans that the human body is always acted upon by cosmic laws. The allusion here, albeit vague, is to an astrological theory of the passions (παθή or παθήματα) that are associated with cosmic bodies and encrust the soul on its descent into the body. In Rom 7:23, he notes two different laws that govern him, the law of God and the law of sin. This law of sin compels him to behave in ways contrary to the law of God. There are principles of causality here that Paul appears to share with astrology, which posits that planetary and stellar influences govern the body until the soul's release from the flesh.

On a number of different occasions, Paul discusses the malevolent influence of the elements (στοιχεῖα), a problematic but technical notion most likely from Stoicism that modern translators of the New Testament render variously as "elements of the cosmos" or "elemental spirits".[8] According to Paul, before

6 For this outdated perspective, see Dodds 1965; Cumont 1912a; Jonas 1993; and Reitzenstein 1904.

7 For a modest beginning, see Reitzenstein 1904; Stählin 1974, 319–340.

8 LSJ, 1648. For mainly philological analyses of «στοχεῖον», see Adam 1963, 229–232; Burkert 1959,

their salvation, people were enslaved to these cosmic forces [Gal 4:3]. Some in his community had evidently fallen back into what Paul considered to be cosmic enslavement, as was apparent from their observance of "days and months and seasons and years" [Gal 4:8]. Though the Stoics originally used «cτοιχεῖον» to designate each of the four fundamental elements (earth, air, fire, water), the term made its way into a wide variety of later non-Christian sources, from Cicero [*Tusc. disp*. 18–19] to the Corpus Hermeticum.[9] Philo, Paul's nearest Jewish contemporary, accuses non-Christians of worshiping the elements [*De Abr*. 68–88]. Like Paul, he notes that non-Christians mistakenly worship the elements as gods. Some people, he says, "revere the elements, earth, water, air, fire, which have received different names from different peoples", simple bodies associated with Demeter, Poseidon, Hera, and Hephaestus, respectively [*De vita cont*. 3.3: Colson 1941, 115]. But Philo is quick to note that the elements themselves are merely "lifeless matter incapable of movement by itself" [*De vita cont*. 3.4: Colson 1941, 115]. Philo's cautious words reveal to us that, at least for some, worship of the heavenly bodies may have had a place within certain first-century Jewish circles. The Galatians may have been participating in Jewish rituals which somehow involved some combination of the observance of "days, months, seasons and years", a reverence for the Sun and Moon, and astrological piety.

An "astrological" or cosmical reading of Paul is generally overlooked due to a tendency in Christian theological scholarship to isolate Paul from his own cultural context. It is clear that he alludes to cosmological concepts with which his audience is familiar since he does not take the time to articulate them fully. At the same time, the cosmic, astrological elements of Paul's undisputed epistles are emphasized in the overtly cosmic orientation of the Deutero-Pauline Ephesians, and Colossians. In Eph 6:12, "Paul" asserts that our battle is not on Earth but against the elemental forces or spirits in the cosmos. This cosmical reading of Pauline theology will re-emerge forcefully in some Christian writings of the second century, as we shall see.

2.2 *The Gospel of Matthew and the Star of Bethlehem*

In the Gospel of Matthew's infancy narrative [Mt 2:1–12], Persian astrologers (Magi) follow the Star of Bethlehem. Some have interpreted Luke's remark that the Magi seek "the newborn king of the Jews" whose star they observed "at its rising" («ἐν τῇ ἀνατολῇ») [2:9] as technical language drawn from astrology

167–197. See too Reicke 1951, 264: "Paul's speech on the observation of days, months and years makes us think of the astrological fatalism of antiquity."

9 See *Kore Kosmou* and the *Stobaei Hermetica* [Nock and Festugière 1972], 3.409, 486.23, 25.

[Hegedus 2003a, 83]. The heliacal rising of a star was a sign or omen, the validity of which is never questioned in the narrative itself. At the same time, it is unclear if the author of this passage meant that the star was Jesus' natal star. Given Matthew's predilection for reading Old Testament passages as pointing forward prophetically to Jesus' status as the Messiah, the phenomenon of the star may have been merely an allusion to Num 24:17: "a star shall come forth out of Jacob and a scepter shall rise out of Israel" [Brown 1993, 373–374; Stendahl 1968, 136].

Some modern scholars, from astronomers to historians, have used the phenomenon of the Star of Bethlehem to pinpoint a precise date for Jesus' birth by determining the astral event that may have been interpreted in Antiquity as a positive omen. Michael Molnar [1999], for example, notes that the Moon's occultation of Jupiter on 17 Apr in 6 BCE would have been a divine omen according to Roman astrology. The astronomer Mark Kidger [1999] offers a variety of possible celestial matches, including a triple conjunction of Mars, Jupiter, and Saturn that took place that same year [Sachs and Walker 1983]. It is highly unlikely, however, that Jesus' birth coincided with a significant astral event: the Gospel of Luke's nativity account mentions nothing of it despite the author's penchant for inserting relative dating and historical detail [Luke 1–2]. Matthew, however, may be thinking of Jesus as a cosmically ordained ruler in the style of Near Eastern and Roman sovereigns who broadcast their horoscopes or astral signs to justify their claim to power.[10] It remains unclear, ultimately, how deliberately Matthew engaged astrological ideas. Nevertheless, the insertion of the Star of Bethlehem into the story of Jesus' birth served as an exegetical problem for centuries of Christian thinkers who sought to sever Jesus' agency from the suggestion that the Star of Bethlehem served as his natal star [Denzey 2003; Hegedus 2003a].

2.3 *Ignatius of Antioch*

The letters of Ignatius of Antioch (*ca* 35–*ca* 98 CE) constitute some of our earliest Christian writings. In his *Epist. ad Ephes*. 19.2–3, Ignatius likens Jesus to a powerful star in a hymnic passage with remarkable imagery:

> How then was he manifested to the aeons?
> A star shone in heaven, beyond all the stars,
> and its light was unutterable,

10 Cf., e.g., the Greek coronation horoscope of Antiochus I of Commagene (7 Jul 62 BCE) with an image (Plate 6) or the astrological imagery on Augustan coins (Plate 5) in Barton 1994a (unpaginated).

> and its newness caused astonishment,
> and all the other stars, with the Sun and Moon,
> gathered in chorus round this star,
> and it far exceeded them all in its light.
> And there was perplexity, whence came this new thing, so unlike them.
> By this all magic was dissolved and every body of wickedness vanished away,
> ignorance was removed and the old kingdom was destroyed.[11]

Although it is likely that Ignatius was drawing on themes also present in the Gospel of Matthew—namely, that Jesus' birth was heralded by a portent—in this passage, he appears to give a cosmical interpretation of Christ using language that is reminiscent of the Deutero-Pauline writings but nowhere directly paralleled in that corpus. The themes which Ignatius presents—that Jesus constituted a new star which caused astral confusion and, ultimately, the disruption of astral fatalism and magic—were taken up, as we shall see, by later Christian writers, particularly those often characterized as "Gnostic".

3 Christian Astronomy of the Second Century

As Christians continued to form their identity in the second century by drawing boundary lines between themselves and non-Christians, the category of astronomy came to be deployed as one feature that distinguished non-Christian Greeks from Christians [Denzey Lewis 2013]. In Christian apologetic writings, astrology is a Greek craft (τέχνη) that was objectionable because of its association with a multiplicity of gods and an ineluctable fatalism, or because such systems of knowledge transcended the boundaries of licit knowledge. The Syrian Christian apologist Tatian (120–180 CE) rails against astrological fate as an "exceedingly unjust" system introduced by demons who laid out the zodiacal circle [*Or. ad graec.* 8–9: Whittaker 1982, 15–19]. Similarly, the North African Christian Tertullian claims that astrology was introduced by fallen angels [*De idol.* 9.8, 9.1], a theme present even as early as the Jewish pseudepigraphical 1 Enoch. In 1 Enoch 8:2–3, the Watcher angels teach various technologies (astrology, but also skills such as metallurgy and cosmetics) that constitute "inappropriate" knowledge. Tatian and Tertullian adopt this condemnation of technologies as part of their wholesale rejection of Greek and Roman culture

11 Lake 1985, 193 (with modifications).

and knowledge. But Christian apologists also considered astrology demonic because fallen angels used it to trick humans into impious systems of worship and to convince people that there was no such power as free choice. Tatian's language of freedom at the close of his condemnation of astrology is striking:

> But we are above fate, and instead of planetary (i.e., erring) [πλανητῶν] demons, we have come to know one Lord who does not err; we are not led by fate and have rejected its lawgivers.
>
> *Or. ad graec.* 9.2: WHITTAKER 1982, 19

As astrology came to be associated with Greek culture and subsequently devalued, Christian heresiologists often identified astronomical practices with so-called heretical Christians. In other words, the active use of astrology/astronomy came to be perceived as part of the "toolbox" that heretics used to deceive their followers. Astrology was associated with both wrong belief and wrong praxis. Thus, around 160 CE, Irenaeus of Lyons reports that Marcionites practiced numerology in assigning numbers to the planets, stars, and constellations [*Adv. haer*. 1.13.4]. The author of *Refutatio omnium haeresium*, once attributed to Hippolytus of Rome, gives a technical and detailed account of Christian astrologers. He tells us of a group called the Peretae in Syria who were convinced that the stars were powers of destruction [*Ref*. 5.11]. He notes, too, that a Jewish-Christian group, the Elchasites, called on the witness of the 7 planets to seal or consecrate their baptisms [*Ref*. 9.10]. All these uses of astrology are actively refuted as untenable in a series of formal arguments that he draws from non-Christian philosophy [*Ref*. 4]. In the fourth century, Epiphanius of Salamis discusses the Phibionites, who treated as divinities the *monomoiriai*, the single degrees of the zodiacal circle [*Panarion* 26.9].

Since original writings from these so-called Gnostic and Jewish-Christian sources no longer remain, it is difficult to ascertain the degree to which groups such as the Peratae practiced astronomy or whether the charge of using astrology/astronomy was part of a standard polemical devaluation.[12] Certainly the heresiologists successfully associated astrology with one particular set of clearly defined heresies, Gnosticism. The term "Gnosticism" has engendered significant debate in recent decades, with a significant movement toward abandoning the term as an early modern invention which quickly falls apart under

12 For a strong argument that the Peratae, at least, did have a strong astrological foundation to their ideas, see DeConick 2012: see also p. 567.

scrutiny [King 2005; Williams 1996]. The classic studies of Gnosticism from last century worked with a very limited set of partisan heresiological texts and only a few "Gnostic" treatises, and they often declared Gnosticism as espousing a pessimistic cosmology in which individuals were perceived as trapped by hostile celestial forces.[13] Astrology, with its connotations of astral fatalism, quickly became designated the theoretical and practical underpinnings of a pessimistic cosmology.

By and large, however, our extant Gnostic writings do not embrace astrology but adopt a variety of nuanced positions in relation to it. Many of the Nag Hammadi documents discovered in 1945 retain astrological ideas, often polemically. In the *Testimony of Truth*, for example, the law (probably a reference to Torah) is attributed to the "errant power of the stars" [NHC 9.29.15–18: Giversen and Pearson 1977], that is to say, the text plays on the verb "to err" or "to wander" («πλανάω») and suggests that the "errant/wandering" stars are a direct reference to the malevolent forces of the planets. In the *Paraphrase of Shem*, Nature gives each celestial demon its own star by which it controls life on Earth [NHC 7.27.25]. In other documents from the Nag Hammadi collection—notably the Apocryphon of John, *On the Origin of the World*, and the Gospel of the Egyptians—astrology undergirds their demonology. The evil cosmic rulers who threaten humankind are present in standard groups of either 7 or 12.[14] In 1978, the British scholar A. J. Welburn demonstrated convincingly that the 12 authorities correspond to the zodiacal signs as well as to specific planets in the astrological systems correlating planets and signs that were standard in Antiquity [DeConick 2009a, 248–249]. Significantly, the division of this list by its ancient redactors into 7 who rule the firmaments and 5 who rule the abyss reflects a traditional division in astrology in which 7 "day"-signs lie above the intersection of the zodiacal circle and equator and the remaining "night"-signs below [Welburn 1978, 253]. Still, it is difficult to know to what extent these 12 zodiacal archons actually govern human existence according to those who composed these texts, since their authors never directly associate them with either the planets or the zodiacal signs. The archons, in a more-or-less traditional order, appear to have been recognized as a set in Antiquity. A monument

13 See, in particular, the seminal work of Jonas 1993. On "cosmic pessimism" more generally in the Roman Empire and Late Antiquity, see Cumont 1912b and Dodds 1965.

14 On systems of 7 and 12, see Culianu 1983; the 7 (referred to in these sources as the Hebdomad) also relate to the days of the week, which are of course themselves associated with the planets. On the archons and their astrological connections, see DeConick 2009a, 247–249.

preserved in the British Museum bears the image of the goddess Selene surrounded by the zodiacal arch. Beneath the monument are engraved the names of 7 of these archons.[15]

Certain "Gnostic" texts also evince the principle of *melothesia* in which body parts are assigned to the care of celestial powers in astrological medicine [see ch. 9.3 §4.3, p. 372]. We find this teaching explicit in the long recension of the Apocryphon of John, which lists parts of Adam's body and the demons who control them.[16] The Valentinian teacher Basilides[17] also incorporated *melothesia* into his teachings [Epiphanius, *Panarion* 26.9–10: DeConick 2009a, 249].

In particular, two second-century "Gnostic" texts, the excerpts of the Valentinian teacher Theodotus preserved by Clement of Alexandria in his *Stromateis* and the Gospel of Judas from the recently discovered Codex Tchacos, are worthy of individual attention. Both present extensive discussions of astrology, yet in very different ways. A final crucial source of information on late second-century Christian astrology are the writings of Bardaisan of Edessa, a Christian, whose *Book of the Laws of Countries* (actually written by one of his students) reveals yet another sophisticated Christian involvement with astrology and astronomy. We will turn to a more detailed discussion of each of these three important texts.

3.1 *The Excerpts of Theodotus*

The remarkable excerpts of the Valentinian teacher Theodotus constitute one of the longest theological pieces from a second-century "Gnostic" embedded into later Christian writings. The astrological language of the excerpts builds upon Ignatius' *Epistula ad Ephesios*:

> Therefore the Lord came down bringing the peace which is from heaven to those on earth…a strange and new star arose destroying the old astral decree, shining with a new unearthly light, which revolved on a new path of salvation, as the Lord himself, men's guide, who came down to earth to transfer from fate to his providence those who believed in Christ.
>
> CLEMENT, *Exc. ex Theod.* 74: CASEY 1934, 87

15 BM 1818,0214.1. See reproduction in Barton 1994a, pl. 10 (unpaginated). The inscription bearing the names of the archons appears to have been added later.

16 See NHC 2.1.11.23–12.25, 1.15.14–24; *CodBGn* 8502 2.48.11–50.5; Welburn 1978, 241–254.

17 The Valentinians were Christian philosophers, exegetes, and teachers who based their understanding of the cosmos on the views of their teacher Valentinus of Alexandria, a prominent theologian of the second century CE.

Theodotus defines Fate (εἱμαρμένη) as "a concourse of many opposing powers" [*Exc. ex Theod.* 69.1, 72.1]. From this "revolt and warfare" between celestial beings, the Lord descends to transfer believers from the influence of Fate to his own beneficial Providence (Πρόνοια). Theodotus also makes it clear that the means of salvation from astral enslavement is baptism:

> Until baptism, they say, fate [εἱμαρμένη] is real, but after it, the astrologists are no longer right. For it is not only the washing that is liberating, but the knowledge of who we were, what we have become, whither we hasten and from what we are redeemed; what is birth, and what, rebirth.
>
> CLEMENT, *Exc. ex Theod.* 78: CASEY 1934, 89

The power of baptism, for this Valentinian Christian, overwrites one's nativity, providing a "clean slate" astrologically. This moment of spiritual or cognitive transformation in which an individual recognized that he or she stood in an elevated position in relation to the lower cosmic powers formed part of the conceptual associations in the Late Empire with the term "rebirth" («ἀναγένεσις» or, less frequently, «παλιγγενεσία») [Grese 1988].

3.2 *The Gospel of Judas*

The Gospel of Judas in the recently discovered Codex Tchacos draws from a different strand of Christian tradition than the Valentinian Theodotus, one often identified as Sethianism or Sethian Gnosticism. This text reveals an extensive and unprecedented astral theology.[18] The word "star" appears 15 times in the extant manuscript—more often than in any other Christian text from this period of Antiquity. Stars apparently exert negative force: they lead Judas and the other disciples "to err" [45:13]. There is an obvious play here on the Greek word for planets («πλανώμενοι ἀστέρες» or «πλανήτοι») since their name derives from the verb «πλανάω» meaning "to wander" or "to err". Thus, the stars appear at face value to be connected to sidereal determinism. Each of the 12 disciples has his own star [42:7–8], including Judas, whose star, Jesus says, leads Judas "astray" [45:13–14, 55:10–11, 56:21–24, 57:16–20].

The text of the Gospel of Judas is unfortunately lacunose, making its astral language even more challenging to decipher. Although it is possible here that the document draws on Greco-Roman astrology, it evinces closer parallels with certain Jewish apocalyptic writings, particularly those that liken the priests of

18 For a detailed discussion of astral language in this gospel, see Denzey Lewis 2009; DeConick 2009a, 254–268; Adamson 2009; Förster 2009.

the Temple in Jerusalem to angels and, by extension, to errant stars. Stars work in concert with angels or spirits [37:4–5, 40:16–17, 41:4–5]. This idea is very common in Antiquity, appearing in both Jewish and other non-Christian sources. The 12 disciples are indirectly but clearly identified with the 12 zodiacal signs, as in Rev 21:10–14.[19] In fact, the Gospel of Judas' closest conceptual parallel within the Christian canon is the Book of Revelation, with its heavily astrologically tinged language that does not necessarily mean that John espoused astrological ideas. Rather than arguing that the author of the Gospel of Judas knew and drew upon Greco-Roman astrology, therefore, we should consider instead that he likely used astrology as a sort of veneer or intellectual overlay to give his essential ideas concerning the depravity of second-century Christianity particular authority or potency.

3.3 *Bardaisan of Edessa*

The learned Christian Bardaisan (154–222 CE) remains largely unknown to us but what we do know presents a glimpse into the worldview of an early, non-Roman elite Christian. Although his writings no longer survive, a Syriac treatise penned by one of his students, Philip, the *Book of the Laws of Countries* constitutes the earliest and best of the numerous Christian anti-astrological treatises composed in the first six centuries CE.[20] From it we learn that reverence for the astral and planetary bodies constituted a potent and respected component of eastern Roman and non-Roman religiosity. A learned man such as Bardaisan would have been schooled in the philosophical underpinnings of astrology and have written and discoursed on this science to enhance his reputation as a man of knowledge. But was Bardaisan already a Christian when the *Book of the Laws* was written? There is no reason to suppose otherwise.

On the assumption that Bardaisan knew and accepted some basic principles of astrology, scholars have debated the extent to which he himself was a practicing astrologer. The *Book of the Laws* contains numerous technical terms drawn from astrology—the (wandering) stars[21] sometimes stand in "opposition"; there are "right-handed" benefic and "left-handed" malefic stars; at Mid-

19 See also [Clement], *Hom.* 2.23; Denzey Lewis 2009; DeConick 2009a, 250–253. On the zodiacal signs in Judaism, see Sukenik 1934, 33–35; Charlesworth 1977, 183–200. On the apostles and the zodiacal signs, see Hübner 1983b and 1975, 120–137.

20 Bardaisan had written other astrological treatises, including his *On Fate* addressed to an Antoninus and others to which Ephrem Syrem refers. Nau [1899] published a fragment of yet another brief astrological treatise by Bardaisan. For a more detailed assessment of Bardaisan's astrology, see Denzey 2005; Hegedus 2003a.

21 There does not seem to be a distinction between wandering or planetary stars and fixed stars in the treatise: the word used simply means star.

heaven they act against nature [*Book of the Laws* 576]. Clearly, Bardaisan had a solid grasp of the fundamentals of ancient astrological theory. Because this book is also, in part, an ethnographic work, Bardaisan also employs a series of arguments known as the "the laws of foreigners" which outline the customs of various foreign peoples and uses these as proof that human culture and customs are powerful enough to override astral and planetary influence.

On careful reading, however, one may wonder if Bardaisan was really as learned in practical and theoretical astrology as his later critics maintain. Many of the technical terms which he employs would have been known to any educated person of the second century. He appears not to have any direct knowledge of "Chaldean" astrology, which he confuses with Egyptian astrology [*Book of the Laws* 582]. Nor should we overestimate Bardaisan's originality in his monologue on astrology in this book: large chunks of it appear to have been lifted directly from the Peripatetic philosopher Alexander of Aphrodisias' *De fato* [*ca* 200 CE]. The *Book of the Laws* also bears a strong relationship to Philo's *De providentia*, particularly to Philo's passages on human law overriding Providence. Predictably, perhaps, even in the part actually dealing with the laws of countries, Bardaisan draws on Carneades.[22]

Still, Bardaisan acquired notoriety in Late Antiquity, not because he was known to have been a learned astrologer, but because, unlike later dogmatic Christian anti-fate treatises, the *Book of the Laws* never refutes the idea that the planets have an influence on humans. Bardaisan informs his interlocutor Awida that "there exists something which the Chaldaeans call Fate. And not everything happens according to our will" [*Book of the Laws* 570: Drijvers 1996, 31]. The point of the book, however, is not to expound the power of the stars and planets to rule over human existence, nor to provide practical directions for prognostication or genethlialogy. Rather, the treatise emphasizes repeatedly that God provides all people with free will, which they can exercise to help them to rise above Fate's constraints [Hegedus 2003b].

4 Christian Engagement with Astrology in the Third Century

The division of Christian sources into second century and third century is, in many ways, arbitrary and unhelpful, particularly when we are considering undated texts such as those from Nag Hammadi. However, insofar as we can locate conceptual developments in one century or another, certain documents

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22 For a concise summary of Bardaisan's sources, see Kelley 2008, 614.

ascribed to the third century appear to reveal a new engagement with the notion that the pre-existent Christ was powerful enough to alter the course of the planets and stars and, thus, to abrogate Fate [Denzey Lewis 2013]. Already evident in Ignatius of Antioch's *Epistula ad Ephesios*, the idea features prominently in a few so-called Gnostic writings of this era. Christ, in this sense, took his place as a sort of Ruler of the Cosmos (κοσμοκράτωρ) who could literally turn the cosmic axis and throw the prognostications of the astrologers off. The *Refutatio* reports that a group which the author calls the Naassenes termed Jesus the "Aipolis (ἀ‹ε›ιπόλος)…who both revolves and carries around the entire cosmical system by his revolutionary motion" [*Ref*. 5.8.34: Roberts and Donaldson 1986–1997, 5.55]. Even Clement of Alexandria adopted the idea. Likening Christ to a new Orpheus, he writes of the re-tuning of the cosmos:

> Behold the might of the new song! It has made men out of stones, men out of beasts. Those, moreover, who were as dead, not being partakers in the true life, have come to life again, simply by listening to this song. It also composed the universe into melodious order, and tuned the discord of the στοιχεῖα [elements] to harmonious arrangement, so that the whole κόσμος [cosmos] might become ἁρμονία [an attunement].
>
> *Protrept*. 1: ROBERTS and DONALDSON 1986–1997, 4.1.20

The witness of these texts proves that certain forms of Christianity adapted within Rome's rich religious marketplace by peddling salvation on a cosmic scale, in line with other religious groups like Mithraism or some cults of Isis that apparently offered much the same although dressed up in different forms.

It is not always Christ who alters the cosmos, even in Christian texts. In the *Trimorphic Protennoia* from Nag Hammadi, the lots (Copt. ⲕⲗⲏⲣⲟⲥ, Gr. κλῆροι) of Fate and the planetary domiciles (Copt. ⲟⲓⲕⲟⲓ, Gr. οἶκοι) tremble and are overturned at the cosmic descent of the divine hypostasis Protennoia: the "entire circuit" of the planets and stars ceases to be established [NHC 13.1.43.13–26]. The next discourse in the treatise *On Fate* describes more fully this process of cosmic disruption and rectification: On Protennoia's descent as Voice, all together the elements [Copt. ⲥⲧⲟⲓⲭⲉⲓⲁ, Gr. στοιχεῖα] trembled, and the foundations of the underworld and the ceilings of chaos shook [13.1.43.7–11: Turner 1990, 419]. For the author of this text, the entire astrological mechanism of Fate—its astrological lots and domiciles as well as the very circuit of the stars—was shaken out of its foundations by the beneficent power of Protennoia.

In another untitled cosmogonic text from Nag Hammadi known as *On the Origin of the World*, beings termed the "perfect ones", by their presence in the cosmos, subvert Fate and cancel the circuits of the stars that bound humans into their astrological destiny [NHC 2.5.126.13]. This text is an "inverse apocalypse": rather than moving from a state of order to disorder, the author of *On the Origin of the World* believes that the cosmos was re-ordered from a state of chaos.

In the Apocryphon of John, the forces of astrological chaos are also routed, this time by Pronoia: in the long recension of this treatise, Pronoia twice descends "into the midst of darkness and the inside of Amente" causing Chaos to shake [NHC 2.30.25–26], thus annulling sidereal determinism. In all these texts, a higher celestial power appears not merely to liberate individuals but to liberate the entire cosmos, to set right a cosmic order which had become subverted through the actions of legions of celestial daemons or archons. Salvation was, at least in part, a cognitive act by which the individual perceived the profundity of that cosmic redemption: it was the realization that he or she was no longer held in thrall within a universe that was only apparently ordered, that is, within a cosmos of chaos. On this point, the Apocryphon shares a fundamental conviction with the Valentinian Theodotus, although they disagree on both the agent of salvation and the means.

Although a number of so-called Gnostic texts express the conviction that the cosmos had been altered such that Fate no longer controlled human births and destiny, one often overlooked treatise dating from the third century, the *Pistis Sophia*, develops the idea extensively. It also contains perhaps the most in-depth knowledge of astrology of all our extant Christian "Gnostic" writings.

4.1 *The* Pistis Sophia

The *Pistis Sophia* is the sole text from the Coptic Askew Codex, now in the British Museum. At 346 folio pages, it is our longest complete "Gnostic" document. It contains a revelatory dialogue between the Savior and his disciples, particularly his favored disciple Maria (Magdalene). Astrological ideas permeate all four books of the manuscript, particularly the final book's discussion of the different kinds of human souls and their destinies, which are controlled by various powers including Fate, Necessity, the Moirai, and the Erinyes [Denzey Lewis 2013, 127–144].

In the opening dialogue, Maria expresses concern about those who have been taught "the magic of the archons of Fate" by the fallen angels, wondering if they still have the ability to foresee the future [*Pistis* 1.20]. The Savior explains that he has taken away "a third of their power" by turning the cosmic pole "for the salvation of all souls". The action threw into misalignment the spatial relationships between the constellations and planets and, by extension, the influences (Copt. ⲁⲡⲟⲥⲧⲉⲗⲏⲥⲙⲁⲧⲁ, Gr. ἀποτελήϲματα) of the stars [1.20]:

> When the astrologers find the *heimarmenē* [Fate] and the sphere turned to the left, according to the first distribution, then their words will concur and they will say what is due to happen. But when they meet the *heimarmenē* or the sphere turned to the right, they do not speak anything of the truth, because I have turned their (periods of) influence and their quadrangles and trines and eightfold figures, since their periods of influence remained turned to the left from the beginning.
>
> *Pistis* 1.21: SCHMIDT and MACDERMOT 1978, 30

As a consequence, the author of the *Pistis Sophia* explains, the calculations of astrologers were in vain: horoscopes have become effectively invalidated. There appears to be some incipient knowledge here of the theory of aspects and of Hipparchus' precession of the equinoxes [see Glossary, p. 648], which has been transformed into an esoteric teaching: the cosmos no longer has the same form as astrologers believe it does because the advent of a powerful Ruler of the Cosmos with the power to shift the cosmic axis has inexorably changed the game of destiny. This truth, however, is only perceptible to certain individuals possessing special knowledge.[23] However, Jacques van der Vliet has noted that in the *Pistis Sophia* Jesus does not entirely invalidate astrology: the truth can be determined by an astrologer who is clever enough.

> He, however, who can find their computation from the moment that I reversed them [i.e., the circuits of the celestial spheres] and made them spend six months looking to the "parts" [Copt. ⲙⲉⲣⲟⲥ, Gr. μέρη] on their left and six months to the orbits on their right—he, then, who can observe them in that way, he will discover their influences [Copt. ⲁⲡⲟⲥⲧⲉⲗⲏⲥⲙⲁⲧⲁ, Gr. ἀποτελήςματα] precisely and can predict everything that they will bring about.
>
> 1.30.19–25: VAN DER VLIET 2005, 525

What these "Gnostic" texts have in common is not an inexorable or ineluctable fatalism but the conviction that astrological powers had been routed by the arrival of the Savior.[24] The celestial power of astrology, therefore, has either been annulled [*Pistis Sophia*], replaced by a higher power [*Exc. ex Theod.*], or

23 On this treatise's disclosing (a) a theory of aspects, see Barton 1994b, 74; (b) the precession of the equinoxes, see Hodges 1997.

24 As van der Vliet aptly puts it [2005, 530], texts such as the *Pistis Sophia* represent "an ancient Christian tradition that considers the breaking of astral Fate as a major achievement of the Incarnation".

re-ordered into harmony [*Trim. Proten.*]. In systems where the Savior annuls astrology, the cosmos may be physically altered [*Pistis Sophia*] or a sacrament such as baptism can confer freedom from one's natal destiny and allow an individual to be "born again", now higher than the contingent astrological powers [*Exc. ex Theod.*, Apoc. of John]. At the same time, this particular Christian tradition does not consider astrology to be based upon fallacy: for it, malevolent cosmic administration is real and the power of Fate is real—but only for a time and only for those who have not found salvation.

One final sense of astrology to emerge in these third-century texts is the conviction that the planets (and occasionally the zodiacal signs) bring negative passions that encrust the human soul on its way to incarnation into the flesh. After death, the ascending soul gives up these vices. In the Gospel of Mary from the third- or fourth-century Berlin Codex, for example, the soul addresses the powers of Desire (Venus), Ignorance (Mercury), and Wrath (Saturn) [1.16.5–12].[25] In the *Pistis Sophia*, the soul addresses five "archons of the Midst" (Jupiter, Mars, Mercury, Venus, and Saturn) and gives back their "allotted fate". The *Refutatio* reports that the Naassenes held to a similar doctrine [*Ref.* 5.2], and April DeConick [2012] intriguingly reconstructs the esoteric doctrine of astrological ascent held by the Peretae, literally, the Wanderers. This doctrine of planetary vice percolates through Antiquity, most prominently in the Corpus Hermeticum but also throughout Christian "Gnostic" sources [Culianu 1983; DeConick 2009a; Grese 1979; Denzey Lewis 2013].

4.2 *Anti-astrological Polemic in the Third Century*

While religious treatises such as the *Pistis Sophia* and the *Trimorphic Protennoia* engage astrological ideas if only to reject sidereal or planetary influences, other Christian sources refused to engage them at all. Beginning in the third century, we find Christian anti-astrological polemic coming into its own as a distinctive, if tediously repetitive, discourse. In his *Convivium decem virginum* (*Banquet of the Ten Virgins*)—a Christianized version of Plato's *Symposium*—Methodius of Olympus (260–312 CE) addressed the "problem of Fate" raised by astrology (μαθηματική):

> For of all evils, the greatest one that is implanted in the minds of many is that which refers the causes of sins to the motions of the stars, and which

25 See Welburn 1978, 247. The association between these vices and the planets is not made explicit in the text but appears to draw on traditional teachings. They are, however, explicit in the Corpus Hermeticum: see Grese 1979.

> says that our life is guided by the necessities of fate, as those say who study the stars, with much insolence.
>
> *Conv. decem virg.* 8.13: CLARK 1993–1997

Methodius develops a systematic attack on the principles of astral fatalism, devoting the next three chapters of his eighth discourse to detailed refutations of Fate. He ends each argument with the triumphant litany: "Therefore, there is no fate." There is nothing original about Methodius' approach: all his refutations are cribbed from the work of Carneades which had passed through ancient collections of sayings or opinions (*florilegia*). What is remarkable, however, was how different Methodius' approach to Fate was from Christian authors a century earlier. There was a sea-change in the way that Christians thought about Fate. Methodius clearly felt free to reject, even ridicule, the entire notion as merely academic nonsense. The belief in Fate was yet another nefarious invention of the Greeks. At the same time, Methodius himself draws his standard arguments from Greek sources.

Methodius' approach was the standard for third-century Christianity and would remain so until the modern era. For example, Methodius' contemporary Arnobius (*ca* 297–303 CE) makes a similar vague charge against imaginary non-Christian interlocutors:

> For the whole company of the learned will straightway swoop upon us, who, asserting and proving that whatever happens, happens according to the decrees of Fate, snatch out of our hands that opinion, and assert that we are putting our trust in vain beliefs.
>
> *Adv. nationes* 7.10: CLARK 1993–1997, 521

Arnobius then proceeds to employ the same arguments as Methodius: if Fate existed, one would have to deny both the omnipotence and goodness of God; the individual would not act out of free will and the entire cosmic economy of salvation would fail to make sense. The very regularity and conformity of these third-century arguments about Fate signals the end of serious debate. The refutation of Fate became part of a repertoire of arguments against a non-Christian philosophy which no one appears to have embraced with any earnestness.

5 Christian Astrological Debates *ca* 300 CE

Two different late third-century sources provide interesting insights into emergent late antique attitudes toward astrology. The first is the Clementine literature, a set of Syrian Christian texts which incorporate these standard philosophical arguments against astrology into a novelistic form by way of Bardaisan's *Book of the Laws of Countries*. The second is the extraordinary Christian intellectual Origen of Alexandria, who forged a somewhat different path through the standard refutations of astrology.

5.1 *The Clementine Literature*

The writings which have come down in Greek, Latin, and partially in Syriac under the collective name "Clementine" often contain particular astrological data.[26] They may date to the mid-fourth century or perhaps earlier. The Clementine *Recognitiones* and the *Homiliae* share a complicated relationship which scholars have not yet successful discerned. Sometimes the two sets of literature parallel one another closely; at other times, they differ. Nicole Kelley [2008, 615] and F. S. Jones [2001, 63] have noted that the author of the *Recognitiones* chooses his Bardaisanite material carefully, moving away from any assertion of astrological Fate's inexorability; whereas, in the *Homiliae*, baptism can erase astral destiny by washing an individual clean [Rehm and Irmscher 1953, 19.23.5]. There is no passage parallel to this in the *Recognitiones*. This is not to say that the latter has no theory of Fate: its last three books are all on astrology with long excerpts apparently borrowed from Bardaisan's *Book of the Laws* particularly its sections on the foreign laws [Kelley 2008, 614, 616]. Moreover, in the *Recognitiones* [Rehm and Strecker 1994, 1.32.2–4], the patriarch Abraham is described as an astrologer and horoscopes come true as predicted [9.32.5].

In a significant scene in the *Recognitiones*, the interlocutor Faustinianus offers his view of astrology:

> There is neither God, nor is there any worship here at all, nor [is there] providence in the world, but fortuitous chance and astral fate drive all things [*sed fortuitus casus et genesis agunt omnia*].... Therefore, make no mistake, for whether you pray or you do not pray, whatever your horoscope contains, this will happen to you.
>
> REHM and STRECKER 1994, 8.2.2–3: cf. KELLEY 2008, 616

Clement, and his companions, Aquila and Nicetas, refute the old man with a series of arguments that quickly became traditional and standard in Christian literature of the third and fourth centuries [Rehm and Strecker 1994, 9–10: cf. 14.1–5, 8.5–9.33, 15.1–4]. Demons, not Fate, are the source of evil in the world

26 For studies, see Kelley 2008; Schoeps 1951; and Jones 2001.

but their power can be resisted through the strength of human free will. As Kelley [2008, 617] demonstrates, the Christians organize their arguments into five points:

(1) Astral fatalism and the theory of horoscopes would render God's righteousness absurd, along with any prayers or practice of virtue [Rehm and Strecker 1994, 8.12.2–3].
(2) The Sun, Moon and stars, properly interpreted, are signs which point to God's providential care for the world [Rehm and Strecker 1994, 5.29.2, 8.20.8].
(3) Demons create the illusory impression that Fate is real [Rehm and Strecker 1994, 9.12.3].
(4) Faustinianus believes that he has experienced the true validity of one's natal horoscope but this is merely a subjective interpretation of events [Rehm and Strecker 1994, 9.32.2–3].
(5) The differing laws and customs of various peoples disproves the supposedly universal scope of astrological Fate [Rehm and Strecker 1994, 9.19.1–29.2].

These arguments parallel the order and nature of those in the *Book of the Laws*.

Kelley notes a crucial difference between the treatment of this last point in the *Recognitiones* and the *Book of the Laws*. Bardaisan proceeds to affirm the existence of Fate, while the passage from the *Recognitiones* omits this entirely. It is, therefore, clear that by this time in a Syrian Christian environment, the Christian authors or redactors of this material wished to distance themselves from any true statement of astrology's validity, while still finding Bardaisan's authority (and the arguments of Carneades) rhetorically persuasive and powerful.

5.2 *Origen of Alexandria (184–253 CE)*

Origen had a positive view of the cosmos, which for him exhibited a divine order and vitality [Scott 1991, 117]. Like other Christians of his generation, Origen drew upon Carneades' arguments against astrology. In his *In Iesu nave homiliae*, he also anathematizes those who use astrology [Baehrens 1921, 331.12–15] because they bring about the defeat of the people of God. But there are places in his writings that indicate that Origen was a sophisticated and original thinker capable of moving beyond stock arguments. In book 23 of his *Philocalia*, Origen addresses the subject of astrological Fate. The stars, he argues, are signs, properly understood—not agents of human activity. At the same time, he allows that constellations and planets do in fact have limited abilities to presage events [23.6]. The problem is that their messages are meant for the higher powers, not for humans. Origen returns to the classic argument that fallen angels had brought with them knowledge of astrology, which they had improperly given to humankind [23.6]. In essence this argument does not mean that the stars had no potency; in fact, for Origen, the stars possessed intelligence, even souls [Barton 1994a, 74–75; Scott 1991].

6 Conclusions

The preceding survey can offer only a cursory examination of a vast and complex subject. Although a wholesale rejection might be an expected Christian response to astrology, we find this response primarily in apologetic literature that repudiates Greek culture and knowledge. We find inklings of other responses to astrology, however, as Christianity attempted to define itself against the tremendous weight of an inherited imaginative universe. Christians were unwilling (and unable) to reject every aspect of astrology's long reach: the doctrine of cosmic sympathies, for example, lived on long after the art of casting nativities. Second-century Christians were more likely than those of the fourth century to admit that astrology was either powerful or correct. Thus, Tatian and Tertullian consider it demonic knowledge rather than sheer nonsense, as did Methodius or Arnobius. For those who considered astrology to have a modicum of power, Christians (as others in the Roman Empire) found ways to escape it. Baptism stands out as the most significant technique for escaping one's natal fate, since it brought a "new birth" and, therefore, a "fresh start" for those who had received the sacrament.

At the same time, astrological elements or ideas in a Christian text do not necessarily imply a full knowledge of astrology or that an author was a practicing astrologer. At least in the case of a text such as the Gospel of Judas, the astrological elements appear to give the treatise a certain *cachet*, a sort of "dressing up" of the text by using a discourse with which an ancient audience would already be familiar and perhaps associate with esoteric knowledge. Whatever the genre, most discourses involving astrology in Christian texts remain superficial in their engagement with this science. This is not to say that Christians never practiced astrology: the very survival of astrological arts beyond Antiquity attests to what we cannot observe—certain groups and individuals passed along arts and knowledge which Christian authorities could only see as demonic.

CHAPTER 13.4

Cosmology in Mandaean Texts

Siam Bhayro

1 Introduction

The Mandaeans are a Gnostic sect which, from at least the third century CE but perhaps even from the second century CE, was native to Mesopotamia and southwest Iran, having migrated there from the Jordan Valley [Buckley 2002, 3]. Their language, Mandaic, is one of the three great eastern Aramaic literary dialects of the first millennium CE (along with Syriac and Jewish Babylonian Aramaic). It preserves a corpus of literature, much of which was probably composed prior to the advent of Islam and possesses a very distinctive orthography and southern Mesopotamian script [Lipiński 2001, 70].

The study of Mandaean beliefs and customs, particularly regarding the Mandaean conceptions of the heavens and the role of astronomy, reached its fullest development in the middle of the last century in German with Rudolph 1965, in Italian with Furlani 1948, and in English with Drower 1962. Since then, comparatively little has been accomplished and the production of up-to-date editions and translations of the Mandaic sources remains a desideratum.

2 Nomenclature

When listed together, the Mandaic names for the seven planets are clearly derived from Akkadian [Furlani 1948, 125–138] and were probably adopted by the Mandaeans within a Babylonian context following their migration from the Jordan Valley [see Table 1, p. 573]. Similarly, the term for constellation or zodiacal sign «maluaša» is perhaps derived from Akkadian «lumāšu» combined with the determinative «MUL» for "star" («MUL.lumāšu»).[1]

1 Kaufman 1974, 67; contra Müller-Kessler 2005, 182, who prefers Akkadian «*mulmāšu» taken to derive from Sumerian «MUL.MAŠ». See ch. 12.2 §1, p. 472.

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TABLE 1 Mandaic and Akkadian names of the planets

	Mandaic	***Akkadian***
Sun	*Šamiš*[a]	*Šamaš*
Moon	*Sin*[b]	*Sīnu*
Mars	*Nirig*[c]	*Nergallu*
Mercury	*Nbu*[d]	*Nabû*
Jupiter	*Bil*[e]	*Bēlu*
Venus	*Libat*[f]	*Delebat*
Saturn	*Kiuan*[g]	*Kajamānu*

a The word «Adunai» (i.e., Hebrew "Lord") is also used to refer to the Sun and derives from the accusation that Jews worship the Sun.
b Other names for the Moon include «Agzʿil», «Ṭaṭmʿil», «Ṣaurʿil», and «Sira» (which is probably the main form outside the planetary lists).
c Pallis [1926, 36] conjectured that the final syllable of Akkadian «Nergallu» was discarded because its correspondence to the theophoric ending «–el» made it unsuitable for a consistently negative character. Mars is also called Marik.
d Or «ʿnbu»: other names for Mercury include «Maqurpiil», «Mšiha» (i.e., "Messiah" or "Christ", in a derogatory way), and the Arabic loanword «ʿaṭarid».
e Jupiter is also given the name «Angʿil».
f Pallis [1926, 36] conjectured that the initial syllable of Akkadian «Delebat» was misunderstood as the Mandaic relative pronoun.
Other names for Venus include «Amamit» (the underworld goddess), «Argiuat», «Daitia», «Kukbat» (the diminutive of "star"), «Spindar», «ʿstira» (i.e., "Ishtar" or "Astarte"), and «Ruha» or «Ruha ḏ-qudša» (i.e., "Spirit" or "Holy Spirit", in a derogatory way).
g Saturn is also referred to as *br šamiš* (The Son of the Sun).

On the other hand, the names of the constellations themselves are not derived from Akkadian [Furlani 1948, 142; Drower 1949, 69–70] and, with most having cognates in Syriac and Jewish Babylonian Aramaic,[2] appear to be common Aramaic (even West Semitic) terms [see Table 2, p. 574]. The mixed origins of the nomenclature accord with what we can observe of Mandaean cosmological traditions, which seem to reflect a variety of backgrounds.

2 The exceptions being «Sarṭana» ("Cancer"), which has Syriac and Mishnaic Hebrew cognates, and «Hiṭia» ("Sagittarius"), which appears to be Common Semitic—the above point, however, still stands.

TABLE 2 Mandaic names of the zodiacal constellations

Aries	*ʿmbra*
Taurus	*Taura*
Gemini	*Ṣilmia*
Cancer	*Sarṭana*
Leo	*Aria*
Virgo	*Šumbulta*
Libra	*Qaina*
Scorpio	*Arqba*
Sagittarius	*Hiṭia*
Capricorn	*Gadia*
Aquarius	*Daula*
Pisces	*Nuna*

3 Sources[3]

The main Mandaic astronomical source is the *Aspar maluašia* (*Book of the Signs of the Zodiac*), which was published in facsimile with an English translation by Drower in 1949. Originating probably in the Sasanian Period, *Asp. mal.* is a compilation of texts dealing with astrology and omens, which preserves Mesopotamian, Greco-Roman, and some Iranian material [Rochberg 1999–2000, 245–246].

The *Ginza Rba* (*Great Treasure*), the chief Mandaean collection of sacred texts, probably reached its final form toward the end of the Sasanian Period (222–651 CE). It is divided into two halves, called the *Ginza iamina* (*Right Ginza*) and the *Ginza smala* (*Left Ginza*) [Buckley 2002, 10–11], and was published with a Latin translation by Petermann in 1867. Lidzbarski's German translation [1925] and analysis remains the standard reference-work to this day. The canonical prayers for baptism, daily ablutions, festivals, and other occasions were published by Drower in *The Canonical Prayerbook of the Mandaeans* [1959].

Magical texts can be an important source for Mandaean customs and traditions regarding the cosmos. Among these is the corpus of Mandaic incantation

3 Only sources used in this chapter are mentioned. For a brief overview of Mandaic literature, see Buckley 2002, 10–16.

bowls [e.g., Yamauchi 1967; Segal 2000], each of which represents the application of magical lore in an individual case, as well as several scrolls containing scribal handbooks that list series of incantations. A selection of texts from such scribal handbooks was published by Drower in 1943 under the unfortunate title "A Mandaean Book of Black Magic".

In terms of practice, Drower [1949, 1] observed that the Mandaean new-year rite, in which the priests consult *Asp. mal.* in order to determine what the year ahead holds for the community, reflects the ancient Babylonian new-year festival which was associated with the Temple of Nabû and in which the fates were determined. Similarly, Widengren [1968, 552–553] draws parallels between the Mandaean marriage ceremony, in which the seven planets present gifts to the couple (with *Libat* giving her gifts to the bride and the others giving their gifts to the groom), and the ancient Mesopotamian coronation ritual in which each of the seven planetary deities presents a gift to the new king. This is an exception to the usually negative portrayal of the planets in Mandaean thought and custom.

In terms of literature, Rochberg[4] has drawn striking parallels between *Asp. mal.* and the ancient Mesopotamian texts *Enūma Anu Enlil*, *Šumma ālu*, and *Iqqur īpuš*. For example:

> *Iqqur īpuš* §77.1
> If in Nisan the moon is surrounded by a halo (lit. a "drawing" *uṣurtu*): There will be an eclipse; [one] king will conquer [another] king.
>
> *Asp. mal.* 210
> If in Nisan the moon sits within an enclosing line (*ṣurta*), war, or else a king will kill the king of kings.
>
> ROCHBERG 2010b, 231

The coincidence of both content and terminology is remarkable, with Akkadian «uṣurtu» (written «giš.ḫur» in this case) being cognate with Mandaic «ṣurta». The term probably refers to the appearance of a circular line surrounding the Moon. This suggests that the Mandaeans possessed at least partial translations of the earlier cuneiform material [Rochberg 1999–2000, 243–245]. According to Müller-Kessler [2004, 53–54], the likely period for the Mandaean reception of Babylonian astronomical traditions was the second century CE,

4 See Rochberg 1999–2000, 239–240 and 2010b, 223–235.

when the Mandaeans would have come into contact with functioning Babylonian temples (the repositories of the Mesopotamian sciences) in cities such as Babylon, Borsippa, and Kutha.

4 The Reception of Greco-Roman Traditions

Some parts of *Asp. mal.* show a clear Greco-Roman influence [Rochberg 1999–2000, 241–242]. For example, one section, “Characteristics of the Seven Stars” [*Asp. mal.* 286: cf. 108], gives the order of the seven planets from lowest to highest orbit—from Saturn (seventh), to Jupiter, Mars, Sun, Venus, Mercury and Moon (first)—thus reflecting the Ptolemaic system.

For example:

> *Asp. mal.* 286
> The characteristics of Jupiter: It is hot and moist. It is good. It is male. It is a day-star. It governs the loins and the four humors of the body. It governs the blood. Its exaltation is in Cancer. Its depression is in Capricorn. Its apogee is in Libra. Its perigee is in Aries. It occupies 12 years and is the sixth orbit.

In describing Jupiter in terms of its hot and moist qualities, and stating that it governs the humors controlling human health, this section of *Asp. mal.* reflects the dominant Greco-Roman scientific system. The Mandaic term for “humors” in this passage is «aklaṭ», which derives from Arabic «aḵlāṭ». Furthermore, in the following description of Venus, the writer uses the term «balga» (“phlegm”), which derives from Arabic «balḡam».

The passage cited above bears comparison with the following excerpt from another Mesopotamian scientific compilation, the *Syriac Book of Medicines*, which arranges the planets according to the same system but from highest to lowest orbit:

> *Syriac Book of Medicines* f. 230a
> The star of *Bel*, which is called Zeus, is placed in a region of water and in the second circle of the sphere, and it fulfills its course in 12 years.

It is clear, therefore, that a systematic analysis of the reception of Greco-Roman traditions in Mandaic sources should also include comparable materials in both Syriac and Arabic.

5 Mandaean Conceptions of the Cosmos

Accordingly, we should not speak of *the* Mandaean conception of the cosmos. Not only do Mandaic sources reflect a variety of received traditions, their contents also vary according to context and genre. Still, the following are among the more common notions.

(a) The planets and constellations are usually considered to be evil. For example,

Ginza iam. 27

The seven *dēvs*,[5] the seducers, seduce all the children of Adam. The first is *Šamiš* by name. The second is the Holy Spirit, *ʿstira*, also *Libat*, *Amamit* by name. The third is *Nbu*, the false Messiah.... The fourth is *Sin*, *Ṣaurʿil* by name. The fifth is *Kiuan*, the sixth is *Bil*, the seventh is *Nirig*.

Drower 1959, no. 94

Hail to you, hail to you, O soul! You have departed from the world! You are leaving behind corruption and the stinking body in which you have been.... For during the years that you spent therein, every day the seven were your enemies—the seven were your enemies and the 12 beset you with persecution.

Similarly, *Ginza iam.* 97 refers to the constellations as *trisar maštuṣia baṭlia* (the 12 good-for-nothing monsters), and incantation bowl SD63 lists a number of maleficent agents, including *šuba razia* (the seven mysteries) and *trisar šurbatun* (their 12 families) [Morgenstern 2011, 76–77]. Drower notes, however, that some magical texts treat the heavenly bodies positively [1962, 26]. Drower 1943, no. 25, for example, invokes them to guarantee a successful courtship:

šuba kukbia utrisar maluašia ḏ-nitia Plan abatar Planita kḏ puma ptia uriria daib.

[I have adjured] the seven planets and the 12 signs of the zodiac, so that Mr X shall come after Miss Y, with mouth open and saliva dribbling.

(b) Each planet is said to be carried in a ship[6] as it makes its way through the various constellations. The constellations are referred to as *batia* (houses), each of which has its own characteristics and directly influences the nature and fortunes of humans [e.g., *Asp. mal.* 148–158].[7]

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5 Mandaic *daiuia*—derived from Middle Persian «dēw» (“demon”, “devil”).

6 See Drower 1962, 75–79, which includes illustrations of the Sun-Ship and Moon-Ship.

7 Drower [1949, 94] demonstrates that this text depends upon Arabic astrological tradi-

(c) The Sun is generally viewed positively. The Mandaeans use a solar calendar, and the Sun is associated with the most frequently invoked light and life-powers *Yawar-Ziwa* (Dazzling Light) and *Simat-Hiia* (Treasure of Life) [Drower 1962, 27, 75–76].

(d) The two female planets, Venus and the Moon, are strongly linked with female affairs and are in opposition to one another. The Moon is associated with miscarriages and abnormal births; thus, for example, «baṣran sira» ("Moon-deficient") may refer to those born with abnormalities [Drower 1962, 329–330]. Venus is associated with success in love and reproduction; thus again,

> *bšumẖ ḏ-Libat marat alahia uanašia kbiš unurẖ šbiq*
>
> in the name of Venus, mistress of gods and men, he is brought into subjection and his fire is kindled.
>
> DROWER 1943, no. 21

(e) Three of the planets are associated with the three Abrahamic faiths. In *Ginza iam.* 112, we read « l-Nirig plaglẖ zaina lmibad qraba» ("to Mars they allotted arms to wage war"). Mars, the son of Jupiter, is thus quarrelsome and violent in nature; hence, his association with Islam, as in:

> *Nʿrig ḏ-mitqria abdala arbaia*
>
> Mars, who is called Abdallah the Arab [*scil.* Muhammad].
>
> *Ginza iam.* 231

Saturn, because of his connection with Saturday, is associated with the Jews, as in:

> *Kiuan ḏ-mitiqria iahu rba adunai ṣbabut*
>
> Saturn, who is called the great Yahu, the Lord of Hosts.
>
> DC 44.1182

Mercury is associated with learning and is often referred to as *Nbu sipra hakima* (Mercury the wise scribe). On the other hand, perhaps on account of his status as the messenger of the gods, there is also an association of Mercury with Christ, as in «Nbu mšiha» ("Mercury, the Christ") [*Ginza iam.* 27] and, hence, Christianity.

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tions. For how the planets and constellations were thought to combine to influence human affairs, see, e.g., *Asp. mal.* 1–85.

6 Concluding Remarks

The Mandaeans survive today in Iraq and Iran as well as in diasporas in Europe, North America, and Australia [Buckley 2002, 6]. They preserve a rich culture, both textually and orally, that reflects various influences in its development over the best part of two millennia. At present, there are two projects that aim to preserve this culture: Matthew Morgenstern's "Mandaic Dictionary Project" at Tel Aviv University, which focuses on the textual sources, and Christine Allison's "Worlds of Mandaean Priests" project at the University of Exeter, which focusses on Mandaean rituals and oral traditions. It is hoped that these projects will facilitate further research into an endangered tradition.

CHAPTER 13.5

Astral Discourse in the Philosophical Hermetica (Corpus Hermeticum)

Christian Wildberg

1 Introduction

This chapter gives an interpretative summary of the scope and content of the astrological passages in the philosophical Hermetica. The phrase "philosophical Hermetica" refers mainly to the 18 extant tractates in Greek and Latin associated with the mythical figure of Hermes Trismegistus; but to these we must add the surviving Hermetic fragments found in the *Anthologia* compiled by Ioannes Stobaeus in the fifth century CE. In view of the modern association of Hermetism and astrology, one might suppose that the Hermetica must be replete with astrological discourse but such an expectation is going to be disappointed. What we would call astrology proper plays only a marginal role in these Hermetic writings and the considerably older, more technical and observational discipline of astronomy, none whatsoever.

However, one may say that, in this type of literature, the viability and practice of astrology receive something like a metaphysical foundation or framework. This framework is erected over two fundamental tenets of Hermetism which, in and of themselves, have nothing to do with astrology: first is the doctrine of the preeminent importance of the Sun and second, the thesis of the essential divinity of mankind. The Sun, the most radiant celestial body by far, is identified, in ways that are not always clear and conspicuous, with the supreme deity of the universe and its life-giving creativity. It, or more precisely its light, is also connected to human consciousness. Human beings, in turn, are the descendants of a primordial androgynous human who, as direct offspring of the supreme deity, ranks among the highest beings within god's creation. Together, these two doctrines establish the essential connection between the heavens and humanity.

The Hermetic texts declare themselves to be ancient Egyptian lore, a claim that modern scholarship, ever since Isaac Casaubon in the 16th century, has often vigorously disputed.[1] To be sure, there is much terminology in the Her-

1 On the modern debate about the date and provenance of the Hermetica since the publication of Ficino's Latin translation in 1463, see Ebeling 2007, chs 3–6; Scarpi 2017.

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metica that is reminiscent of Hellenistic philosophy; but the way in which philosophical terms and concepts are employed is often enough entirely un-Greek.

At the heart of the metaphysics emerging from these pages lies, as has been said, the importance given to the Sun but not so much as to the celestial body *per se* as to its effect, the solar light radiating from it and pervading the entire cosmos. It is light or, as the formula often reads, "life and light",[2] that acts directly in beneficial ways from a distance on all beings in the universe. It enlivens all of nature and brings it to fruition. Yet solar light is the physical manifestation of its principle, divine light, which first created the world; and even more important than the daily experience of sunlight is the manifestation of divine light in the miracle of human consciousness or awareness. In fact, mankind is created with consciousness (νοῦϲ) for the explicit purpose of appreciating creation's goodness, of practicing cosmic awareness, and of bearing witness to the divinity of both nature and humanity.

In many ways, the core doctrines of the Hermetica are uncannily reminiscent of the suppressed monotheistic religion of solar light preached and practiced during the reign of Amenophis IV, the pharaoh who changed his name to Akhenaten (meaning roughly "Servant of Sunlight"). Akhenaten ruled over Egypt for a mere 17 years in the mid-14th century BCE. Yet, during this brief period, he succeeded in revolutionizing Egyptian religion by literally abolishing its traditional veneration of the myriad of anthropomorphic and theriomorphic deities in favor of the exclusive worship of solar light. If the ideas contained in the Hermetic writings originated in Egypt (which is now emerging as the new *opinio communis*), they likewise betray a remarkable disinterest in the traditional iconography and myths that one would normally associate with Egyptian religion. With one notable exception, there is no religious significance given to Isis and Osiris, to Seth or Horus, or to any of the other gods that played a role in the Nile valley.[3]

For the topic in hand, it is worth pointing out that the central concern for the veneration of the Sun is in some passages extended to a veneration of the planets and the sphere of the fixed stars, each of which is likewise believed to operate at a distance on the world and on the affairs of mankind in particular. Without a doubt, these passages have a distinctly astrological flavor, though it is also true to say that they are often beset with textual problems bordering on

2 On the life-and-light-formula, see CH 1.9, 1.12, 1.17, 1.21, 1.32; 13.9, 13.12, 13.8, 13.19; Stobaeus, *Anth.* [Wachsmuth and Hense 1884–1923, fr. 23.9].

3 The exceptions are in Stobaeus, *Anth.* [Wachsmuth and Hense 1884–1923, frr. 23–26]. But here Isis and Horus are reduced euhemeristically to imagined interlocutors.

PLATE 1 Hermes Trismegistus with Moses. Marble intarsia by Giovanni di Stefano, Siena Cathedral (1482–1483)

Hermes, dressed as an astrologer in star-studded hat and garments, hands down a book on which is written "SVSCIPITE O LICTERAS ET LEGES EGIPTII." The text is ambiguous, as it can either mean "O, do accept the literature and laws of the Egyptian" or "O Egyptians, accept literature and the laws." This ambiguity in the cultural significance of Hermes is replicated in the iconography of the figures on the left. The man in the foreground wears a turban and may well depict an Egyptian, whereas the man in the background, who bears a not too distant resemblance to Marsilio Ficino, the first Latin translator of the Hermetica (1471), dons western garb. The inscription on the right carries an entirely Christian message.

the verge of unintelligibility. One can show on purely philological grounds, and in a few cases quite clearly, that these passages owe their existence to a process of Hellenistic or late antique redaction.[4] In consequence, astrology, especially that of the horoscopic kind, seems to be a concern that accrued to Hermetism at a later stage in its historical and intellectual development.

Since astrological passages in general are scattered throughout the Corpus and do not connect easily to form a single coherent discourse about the nature and influence of the celestial bodies, it is perhaps best to present the evidence in the form of a survey that goes through the Hermetica in the order of their now standard arrangement. I shall first discuss the evidence in the 17 extant Greek Hermetic tractates, then take a look at the Latin *Asclepius,* and conclude with a summary of astrological passages in the excerpts of Stobaeus.

2 CH 1 The *Poimandres*

The first and most famous Hermetic tractate of the entire collection is the so-called *Poimandres*.[5] In this bold and sweeping narrative, the author, Hermes, recounts how he received, while in a state of elevated awareness, revelatory knowledge about the universe, its nature, and divine origin. The agent of this revelation is, apparently, nothing other than the narrator's own mind or consciousness (νοῦϲ). Hermes' bears witness to an internal discourse (λόγοϲ) that speaks in the voice of divine consciousness, describing in vivid images the creation of the world and of mankind. The Hermetic revelation culminates in the proclamation of human immortality.

One characteristic and quite unusual feature of this narrative, which also distinguishes it sharply from the biblical Genesis, is the fact that Light/Consciousness itself seems to be the highest creative force, not an instrument or product thereof. In fact, according to this account, cosmic light is nothing but the visible manifestation of divine consciousness. Since divine consciousness is also the narrator, the treatise is, in a sense, the Word or Gospel of Light.

Now, in §7, where this Light is said to be the creator of a "boundless cosmos", Hermes requests further instruction about the elements of nature [§8]; and it is here that we get a somewhat garbled and compressed account of the generation of planets on the one hand and animals, including man, on the other [§§8–12]. The stretch of text is a good example of the general interpretative dif-

4 On the phenomenon of mechanical interpolation in the Hermetica, see Wildberg 2013.
5 On the title, see Kingsley 1993.

ficulties one encounters in this body of literature. The passage of interest [see below] appears to be a composite of an original text and a later redaction. In the present case, there are four indications that the lines beginning in §9 until "just as consciousness wanted" in §11 may have been part of such a revision:

(a) The last clause of §11 lacks a subject; upon inspection, it seems likely that that clause is simply the continuation of the last sentence of §8.

(b) §9 narrates the creation of the planets (or rather their administrators) by a second god, the demiurge, who himself is a creation of the *logos* of the first god. The cosmos then splits up, in §10, into a divine region filled with *logos* and a lower, material region devoid of *logos*. But the material stratification of the universe had already happened and in a different way, in §5.

(c) In §8, the supreme deity brings about the beautiful diversity of the cosmos directly by the power of his own will, a motif that reoccurs in the creation of mankind in §12 (quoted partially). But in the astrological passage cited below, the creative role is given to a second god, a demiurgic god of fire and spirit (πνεῦμα). This stands in marked contrast to the predominant monotheistic doctrine of the *Poimandres*[6] and the rest of the Hermetica: there is only one god, whom human beings must recognize and venerate [e.g., CH 1, 3, 4, 5, 11, 13, 14].

(d) The astrological passage obscures rather than clarifies the role of the *logos* in this account. Earlier in the narrative, the *logos* was said to issue from divine consciousness [§6]: it is that which Poimandres utters and which Hermes is listening to. In §8, too, God's will is informed by the divine *logos* and thus becomes creative. But in §10, strangely, the *logos* is said to abandon the *descending* material elements, leaving the entire lower region devoid of *logos*. Perhaps the two conceptions of *logos* fit together in some way; but they do not do so obviously or easily.

Let us now turn to the passage in question [CH 1.8–12]:

8 Since I was in a state of bewilderment, he [*scil.* Poimandres] addresses me once more: "You saw in your consciousness the archetypal form (ἀρχέτυππον εἶδοϲ), the cause prior to the ceaseless first cause (ἀρχή)." Just so Poimandres (spoke) to me.—I reply: "The elements of Nature, then, where did they come from?"—To which he responds: "By the will (βουλή) of God, which understood the reason-principle (λόγοϲ), beheld the beautiful cosmos, and imitated it as it made it into a cosmos by its own elements and begotten souls, *…"[7]

6 Cf., for example, the final hymn in CH 1.31.

7 The sentence breaks off here and to all appearances continues at the end of §11: see p. 585n9.

9 "But Consciousness, the God who is male-and-female, who is in full existence (ὑπάρχων) as life and light, begot by its reason-principle (λόγος) a further Consciousness, a craftsman (δημιουργός) who, as God over fire and spirit (πνεῦμα), crafted seven administrators (διοικηταί) who encompass the perceptible world with their orbits. And their administration is called Fate (εἱμαρμένη).

10 "Straightaway God's reason-principle (λόγος) leapt up from God's descending elements into the pure creation of nature and was united with the Creator-Consciousness, for it was of the same substance.[8] And what was devoid of reason (τὰ ἄλογα), i.e., the descending elements of nature, were left behind so as to be matter only.

11 "The Creator-Consciousness, united with the reason-principle (λόγος) that encompasses the circuits and rotates (them) in a rush, turned its creations around and let them turn from an indefinite beginning to a limitless end: they begin where they end. And their revolution brought forth from the descending elements, just as Consciousness wanted, non-rational animals, for they did not contain the reason-principle; and air brought forth winged (animals); and water (brought forth) creatures of the sea. And earth and water were separated from one another, just as Consciousness wanted.

*…and it [*scil. the* will][9] brought forth from itself what animals it could, quadruped beasts, wild and domestic animals.

12 "But Consciousness, the Father of all things who is life and light, gave birth to Man (ἄνθρωπος), equal to him, whom he loved as his own child. He was indeed of exquisite beauty, since he bore his father's image. For indeed, God really loved his own form; he gave him all of his own creation.

Reading this cosmological conglomerate in isolation, the metaphysical picture that emerges is that of a highest deity bringing forth a second deity, a master over fire and *pneuma*, who in turn creates seven administrators who encircle the perceptible world. It is not immediately clear whether these administrators

8 The word used is «ὁμοούσιος», which is of course a catchword of later Christian controversy but could also be used in an entirely unmarked way: cf., e.g., Plotinus, *Enn.* 4.4 [Henry and Schwyzer 1964–1982, 4.4.28.55].

9 Nock felt compelled to insert "the earth" as subject at this point because the verb «ἐξήνεγκεν» ("brought forth") lacks one. It has to be a feminine noun and so cannot simply be supplied from the previous sentence. It, therefore, seems likely that the sentence in fact continues the relative clause from the end of §8, which is interrupted by the long cosmological insertion. Once this is recognized, the inference suggests itself that the subject of «ἐξήνεγκεν» is god's will.

are celestial bodies themselves or rather deities that govern the movements of the planets. Presumably the latter. In any case, the combination of the resulting revolutions determines everything that happens here below in the terrestrial world. The text employs at this point the Stoic term for Fate, «εἱμαρμένη». Importantly, the creation of the animal kingdom too is the work of the planetary administrators, whereas mankind is the direct creation of the supreme deity [§12].

This complicated metaphysical framework prompts the question of the relationship between the two major creations of the highest deity, the celestial hierarchy on the one hand and humans on the other. The first point to note is that the first man—a male-female human from an androgynous father [CH 1.15]—is the brother of the first celestial administrator. In this way, the Hermetica elevate humanity as such far above the rest of the animal kingdom [see §9, p. 593: cf. CH 10.24–25]. It is only after the original man decides to become a creator himself and falls from heaven to live and procreate on Earth that he becomes subject to influence of the planetary forces: "[A]lthough he was above the harmonious edifice, he has become a slave within it." [CH 1.15].

However, before Man descends, each of the celestial administrators gives him a share of their "order" («τάξις») [1.13]. We are not told at this point precisely what this entails; only near the end of the treatise [CH 1.25–26] do we learn that human beings who manage to escape from the cycle of rebirth and rejoin the deity will return "energies" («ἐνέργειαι») to the spheres: first, the increase and decrease of their bodies; then, the contriving of evil, treacherous desire, excessive use of power, recklessness, the desire for wealth; and, finally, falsehood. Stripped of these seven actions [CH 1.26 ἐνεργήματα], the now purified humans enter the eighth sphere, the sphere of the fixed stars, from where they hope to ascend to the presence of god in a region even further out (the Ninth).[10] The implicit anthropology is that a pure and divine human core personality is subjected to a (largely corrupting) character formation (ἠθοποιία) due to the planets.[11] The *Poimandres* does not specify how and when such character formation takes place, only when and how it is reversed.

10 On the celestial ascent, see also the Coptic Hermetic text *Discourse on the Eighth and Ninth*, preserved in NHC 6.6.

11 This seems true, even if, in the case of the first man, these influences were presumably benign:

> And after the man had observed what the craftsman had created with the father's help, he also wished to make some craftwork, and the father agreed to this. Entering the craftsman's sphere, where he was to have all authority, the man observed his brother's craftworks; the governors loved the man, and each gave a share of his own order. [CH 1.13: Copenhaver 1992, 3]

It also remains unclear how exactly the negative energies line up with the seven planets or how they relate to the seven-fold empowerment that the original Human received from the administrators in an act of benign generosity. We have to assume that the "natures" («φύϲειϲ») of the seven administrators somehow pass on into mankind as a whole because the original Human begets sevenfold androgynous offspring whose natures resemble those of the administrators [§16]. Assuming, furthermore, that «ταξίϲ», «ἐνέργεια», and «φύϲιϲ» are more or less interchangeable terms and pick out a sort of bestowed ability or character trait, this must mean not that each of the seven humans resembled any one of the seven administrators but rather that they resembled them collectively. Otherwise it would be inexplicable how any one ascending human being could, after death, return the respective energies to each of the planetary spheres.

This kind of perplexing story in which pieces from different narratives partially overlap but never seamlessly fit together is quite representative of the Hermetica. What we get is a cryptic and piecemeal sort of astrological metaphysics. The important point to note, however, is the fact that the heavens tend not to be discussed in isolation and for their own sake but always in their relation to and significance for mankind.

3 CH 2

One apparent exception to this rule is the thoroughly enigmatic second tractate that purports to record a conversation between Hermes and his disciple Asclepius. The treatise lacks a title because, in the manuscript tradition, the beginning of the tractate has gone missing, although an excerpt of an early stretch is extant in Stobaeus. The Greek is at times exceedingly corrupt and, if one compares the text handed down in the codices with Stobaeus' rendering, one can see quite clearly how Stobaeus himself was struggling to smooth over the difficulties.[12] In any case, the doctrine of celestial mechanics espoused here, to the extent that it can be discerned at all,[13] is far more techni-

12 There is plenty of evidence that Stobaeus himself was reading a corrupted text and it is, therefore, questionable editorial practice, generally adopted by Nock and Festugière and other editors and translators, to prefer the (intelligible) readings in Stobaeus to the more difficult readings in the codices. Not unlike Walter Scott centuries later, Stobaeus felt free to alter the grammar and contents so as to turn the words into a text that made sense to him.

13 Scott 1924–1936, 2.75–110 repeatedly complains about the tractate's incoherence.

cal and "scientific" than what we have gleaned so far from the *Poimandres*. The main ideas are the following five points:

(1) Motion can only take place in the context of rest;
(2) the universe moves within a space that is much larger than it and that space is at rest;
(3) the planets are not simply moved by the rotating sphere of the fixed stars but possess their own (counter-)motion;
(4) all motion is due to soul;
(5) the encompassing immobile cosmic space (τόποϲ) is god, or more precisely divine consciousness, from which all goodness emanates.

The idea that there is spiritually significant space beyond the sphere of the fixed stars tallies with the ascent narrative of CH 1. Further parallels can be found in the Latin *Asclepius* [27, 33] as well as, outside the Hermetica, in Philo, *De somniis* 1.63 and *De fuga et inventione* 75 as well as in Plotinus, *Enn.* 2.5 [25], [Henry and Schwyzer 1964–1982, 2.5.3.39].[14]

Up to this point, we have learned that the universe is the creation of divine consciousness, that consciousness contains and suffuses heaven and Earth in a manifestation of immobile space, that the planets move on their own accord (like a swimmer swimming against the current),[15] that they are governed by divine administrators and impart their powers on human beings (which manifest themselves in mostly nefarious character traits), and, finally, that they influence by their movements the course of the history below.

4 CH 3 *Sacred Discourse*

The third tractate might be used further to flesh out this picture because it explicitly speaks about the function and importance of astrology for human life. Unfortunately, careful philological analysis of this short genesis titled "Sacred Discourse" («Ἱερὸϲ Λόγοϲ») reveals that the text has been heavily contaminated. The most likely explanation for this fact is that marginal notes were at some point mechanically copied into the late antique archetype. As it stands,

14 The order of dependency and influence is a matter that awaits renewed discussion. *Prima facie*, it seems much more likely to me that polymath scholars such as Philo and Plotinus had read Hermetic treatises than that the author(s) of the Hermetica had studied Philo and Plotinus. In fact, the latter hypothesis is incredible.

15 This is the terrestrial analogy given by Hermes in CH 2.8.

the text is nearly incomprehensible unless the original narrative and the intrusions are carefully separated.[16]

To give the reader an impression of the extent of the problem, I will here present the tractate in full:

	Sacred discourse	**Marginalia**
1	God is the splendor of everything; he is something divine, and nature too is divine. God is the first cause of what exists; he is consciousness, nature, matter, and the wisdom to show forth all things. The divine is first cause and nature, activity and necessity, completion and renewal. A boundless darkness was in the abyss, and by divine power water and subtle, intelligent *pneuma* were present in Chaos. Then arose a holy light, and beneath the sediment solidified out of the watery substance elements [a][…] of a fertile nature.	[a] And all the gods are looking down (on it),…
2	While everything was undetermined and unwrought, light things separated off upward and heavy things were laid as foundation upon the wet sediment, after the wholes were separated by fire and elevated by *pneuma* to be carried by it. And heaven became visible in seven circles [b][…] along with all their signs, and heaven was entirely completed with the gods in it. And the circumference wound itself around the air, carried along on a circular path by divine *pneuma*.	[b]…since gods are in fact visible in the formations of stars.
3	Each god, by his peculiar power, brought forth what was ordained to him: [c][…]	[c] And there came to be four-footed animals, reptiles, animals in water, and feathered animals as well as every fertile seed, herbs and the green of every flower. The seeds of rebirth (the gods) gathered in themselves.
	the generations of man so that the works of the gods be known and there be an active testimony to (the works of) nature; and the multitude of men [d][…] so that they increase in their growth and multiply in multiplicity;	[d] Also the mastery over everything under the sky and the exact knowledge of what is good.

16 For a detailed philological discussion and interpretation of this tractate, see Wildberg 2013. On the Egyptian background of the ideas expressed, see Podemann Sørensen 1993.

(*cont.*)

	Sacred discourse	Marginalia
	and every embodied soul [e][…] so that it recognize the signs of good things [f][…] and discover [g][…] every workmanship of good things.	[e] By portent-sowings of the course of the circular gods for the observation of heaven and the course of the heavenly gods, and the activities of divine works and of nature… [f]…for the knowledge of the divine power of Fate (when it is?) disturbed. [g] of good and bad things
4	[h][…]	[h] It is the beginning of their living and scheming against <the> Fate of <the> course of <the> circular gods, and dissolving it. For this there will be great monuments of craftsmanship on Earth, after, in the name of times (?), they have left behind darkness…
	And all generation of ensouled flesh and of fruitful seed [i][…] will be renewed by Necessity, by the gods' renewal and by the course of nature's numbered circle. The entire cosmic blend, which is renewed by nature, is the divine, since nature indeed rests firmly in the divine.	[i]…and the inferior kinds of each craft.

What emerges is the following picture. The original Hermetic text began with a formulaic preamble affirming the divine origin and goodness of the universe. Next, light is said to emerge from darkness and to separate out the elements from chaos. The spheres of the fixed stars as well as the seven planets become visible; gods reside in them and initiate circular motion [CH 3.1–2]. This much is more or less in line with the cosmogony of the *Poimandres* [CH 1]. But then CH 3 departs from the first treatise in two respects: for one thing, the astral gods, not the first god, are creating human beings [§3]; and second, the human race is formed for the explicit (and perhaps sole) purpose of being conscious spectators bearing witness to the goodness of God's creation [§3]. There is nothing that is particularly astrological in this story, except that mankind is intimately tied up with the astral deities who gave existence and meaning to human life. Stargazing was much like peering at harbor lights to guide one home.

A later scholar of Hermetism studied this particular text but had ideas of his own about such matters, ideas that look as if they have been influenced by the biblical account in Genesis and a great deal of admiration for astrology. First, he fleshed out the original creation-story because it proceeded, in typical Hermetic fashion, too quickly from the creation of the universe to the creation of mankind [marginal comment c]. In gloss d, human beings are given mastery over everything under the sky, along with the knowledge of what is good (and evil?). Then, he turns distinctly astrological: the celestial gods sow portents and in that way convey the foreknowledge of what is Fated, in both a good and a bad sense. In stilted language that differs stylistically from the original narrative—note some big and late words of the Greek language such as «τεχνουργήματα» ("products of craftsmanship") and «ἀμαύρωσις» ("darkening")—the Hermeticist avers that astrology is the foundation of technological and cultural progress [comments h, i].

At this point, the general impression arises that the Hermetica may contain two different star narratives that are curiously intertwined. In one narrative, the celestial order as a whole is symbolic of the world's goodness and the divine origin of mankind. Humanity's main purpose is to behold the world in the spirit of *contemplatio caeli,* not to change it. Humans exist because without them, the cosmos would lack the kind of consciousness that is capable of recognizing and appreciating the work of the gods. More than that, in the discernment of the heavens, humankind comes to the realization of its own nature. In the other narrative, which inscribed itself into the margins and was eventually copied into the text itself, the spheres, and in particular the planets, are messengers of Fate that reveal to those in the know the code of human destiny. The redactor turned an enchanted-world discourse into a manifesto of the cultural role of astrology as the motor of progress. Whatever the precise details, it seems that we can discern two quite different voices, the one being the voice of a philosophical creationist who proclaims the world's perfection and goodness, the other being the voice of a praxis-oriented astrologer who proclaims the necessity of astrology for human flourishing in a potentially hostile world.

5 CH 4 *The Mixing Bowl*

The short fourth tractate, which bears the perplexing title *The Mixing Bowl or The Monad*, is written very much in the spirit of an enchanted world narrative. God's goodness induced him to create man as an adornment of the divine cosmos, and "man became a spectator of god's work. He looked at it in astonishment and recognized its maker" [CH 14.2: Copenhaver 1992, 15]. In §8, we encounter again the motif, already familiar from the *Poimandres*, that a sufficiently reverent soul may, after the death of the body, ascend through the spheres and be reunited with god.

6 CH 5

The fifth tractate, *That the Invisible God Is Most Visible*, offers instruction in natural theology and fosters the appropriate veneration of the cosmos and its maker [esp. §§3–4]. The distinction between creator and creation seems to be deliberately fluid. Although there is a theoretical difference, god is pantheistically present in every part of the universe [§§9–10]. In this way god is, paradoxically, both entirely visible and invisible [§10].

7 CH 6–8

The following two tractates (on god's goodness and on evil, respectively), do not contain any passages dealing with celestial matters. Tractate 8, which defends the thesis that death is really only a matter of increase and diminution (and otherwise an illusion), draws at one point [§4] a clear distinction between the relative disorder of the world here below on Earth and the stability and order of the heavens. But this is minimally significant for the purpose of our present discussion. The overarching concern is to establish, once again, the typically Hermetic hierarchical ontology of god, universe, and humanity.

8 CH 9

As a matter of general doctrine of the Hermetica, the celestial cosmos is seen not so much as the product of god's work but itself as an important agent in the life of the universe. So again in tractate 9, where the universe is much more than an arrangement of matter in space, it is itself productive and has understanding. The author calls it an instrument of god's will [§6] and likens it to a good farmer of life (ἀγαθὸς ζωῆς γεωργός). The point of such language is not so much to articulate an absolutely coherent natural philosophy but to change the consciousness and perception of the reader. A Hermetist lives in a world that is quite different from the world construed by the ordinary mind, a universe that is as perfect as it is divine and does not require any human effort and ingenuity to improve it. It is precisely this awed awareness of the universe that deflates the temptation to become a *homo faber* and instead leads one back to its maker.

9 CH 10

That, at any rate, is the theory. The very long and substantive tractate CH 10, which bears the enigmatic title "Key", rehearses some of the by now familiar themes. But it also features some other pronouncements that are new and surprising. On the one hand, the genealogy of god-cosmos-humanity, is firmly in place[17] and so is the optimistic doctrine that human souls may attain immortality when and if they change into δαίμωνες and end up dancing on "into the chorus of the gods" [§7]. The context of this sort of assertion seems to be provided by euhemerism because earlier, in §5, we read that Uranus and Cronus are Hermes' ancestors.[18] Syntax disturbances in the text at that point suggest again that this remark may be part of a later redaction: nowhere do we receive any additional information that would help us understand further details of this doctrine. There are some other brief remarks, possibly later redactions, insisting (twice) on the importance of the role of the Sun in the process of creation [§§2–3]. But the most surprising declaration comes right at the end of the treatise, §§24–25:

> For a human being is a living being that is divine and not to be associated with the other living beings on Earth but rather with the gods that are said to be in heaven. Or rather, if one should dare to speak the truth, the real human being is actually superior to them or at any rate equal to them in power. None of the celestial gods will descend to Earth, leaving the boundary of heaven behind; but man does ascend to heaven and measures it, and knows which kind of things are above and which kind of things are below, and accurately learns everything. And the greatest thing of all: he ascends without even leaving the Earth! Such is the greatness of his reach. This is why one should venture to say that man on Earth is a mortal god and god in heaven an immortal man.

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17 See CH 10.14: "So there are these three: god the father and good, the cosmos, and man. And god encompasses the cosmos but the cosmos encompasses man." Cf. also CH 10.22:

> The cosmos is subordinate to god but man is subordinate to the cosmos and the non-rational animals are subordinate to men. God is beyond all things and among all things. The energies belong to god-like rays, the natures are the rays of the cosmos, the technical skills and sciences belong to humans.

18 Lactantius, *Epit.* 14 reports in the context of discussing euhemerism:

> That Uranus was the father of Saturnus, both Hermes affirms and sacred history teaches. When Trismegistus said that there were very few men of perfect learning, he enumerated among them his relatives, Uranus, Saturnus, and Mercurius.

(Saturnus is the Latin version of Cronus.)

The characteristically Hermetic doctrine of mankind's divinity is most pointedly articulated here and it is presumably this that is meant by "the key". But it is not the only place where it can be found. The thesis is of a piece with the anthropology of the *Poimandres* [CH 1] and somewhat less exalted claims can be found in CH 4.5 and 11.19–20. Two points are worth noting. First, it would be a mistake to dismiss such pronouncements as little more than astro-Hermetical conceit. The conviction of the divinity of the physical world, including mankind, is the natural consequence of the refusal to carve the world up dualistically into mortal and immortal, perishable and eternal, perfect and imperfect. Second, the Hermetists did not make this claim on the basis of a fully worked out system of knowledge, esoteric or not.[19] Instead, what motivated and convinced them was the (to them) maximally impressive and astonishing phenomenon of awareness or consciousness as such.[20]

10 CH 12

This treatise, titled in the most authoritative manuscripts "About What Is Common, for Tat",[21] is one of those that celebrate just this consciousness, emphasizing the essential unity of human and divine mind. Without losing the connection to its divine source, consciousness is again likened to the light emitted by the Sun [CH 12.1]. The text is conspicuous, however, for the omission of any mention of astrology. Near the end of the treatise [§19] we read:

> Through consciousness, then, every living thing is immortal but above all man, who can both receive god and keep his company. With this form of life alone does god communicate, at night through dreams, by day through omens, and through all of them he foretells (man) the future, through birds, through entrails, through inspiration, through the oak tree,....

19 In fact, such specialized knowledge would be more of a hindrance than anything else to the required shift, and full use, of one's consciousness: cf. *Asclepius* 13 and §14, p. 598.

20 There is another peculiarity in CH 11: the word «κόϲμοϲ», which the authors of the Corpus Hermeticum quite regularly use in reference to the universe as a whole, is employed here in the plural to denote the seven planets, with the Sun being declared their leader [CH 11.7]. There does not seem to be any parallel for this usage of «κόϲμοϲ» elsewhere.

21 This is the reading in codices A and B. The other manuscripts have "About the Common Consciousness (or Mind, νοῦϲ), for Tat". In any case, it is clear that by "what is common" the title of the treatise, if genuine, refers to consciousness.

If astrology, and not the much more fundamental cultivation of consciousness, had been central to the educational project of Hermetists, this would have been the place to say something about it. But in fact, all we get is the standard Hermetic exhortation to venerate the heavens as a whole: "If you wish to contemplate god, look at the order of the universe (κόϲμοϲ), how well arranged this order is" [CH 12.21].

11 CH 13–15

The next tractate contains an extremely garbled and incomprehensible astrological passage that is, again, quite clearly an intrusion of a marginal note into the main text and presumably at the entirely wrong place.[22] For the purposes of this survey, it is only necessary to point out that there is talk of the zodiacal circle (ζωόφοροϲ κύκλοϲ) and the number 12, which evidently refers to the standard division of the zodiacal band and circle. This is remarkable, since the Egyptians typically divided the sky into 36 decans, not 12 signs, which is part of the Babylonian tradition and does not appear in Egyptian art and literature before Hellenistic times.[23] CH 13 does not contain anything further of interest for our topic, nor does CH 14.

What used to be CH 15 is no longer recognized as an independent treatise. Adrien Turnèbe, in his *editio princeps* of the Hermetica in 1554, had combined two Stobaeus excerpts (I and II A) with a Greek version of a passage from the Latin *Asclepius* [§27] and printed that conglomerate as tractate 15 [Holzhausen 1997, 1.198.] The texts are now typically presented among the excerpts from Stobaeus [see §15, p. 600].

22 For what it is worth, Copenhaver 1992, 52 presents the passage at 13.12 as follows:

> This tent—from which we also have passed, my child—was constituted from the zodiacal circle, which was in turn constituted of [ ] entities that are twelve in number, one in nature, omniform in appearance. To mankind's confusion, there are disjunctions among the twelve, my child, though they are unified when they act.

23 The Egyptian system of 36 decans was in place by the mid-third millennium BCE.

> Each of these decans, probably beginning with Sirius, was invisible for 70 days, and was given a 10-day period of special significance (a decade) following its period of invisibility and rebirth from the *duat*. [Campion 2008, 1.99]

On Egyptian timekeeping, see Parker 1970.

12 CH 16

The *Signposts*[24] *of Asclepius, for King Ammon* [CH 16], on the contrary, are again brimming with star discourse and quasi-astrological material. This tractate is a letter sent, in the world of this particular literary fiction, from Asclepius, the pupil of Hermes, to a King by the name of Ammon (= Amun).[25] The text is of interest also for the fact that it explicitly articulates the Egyptian tradition of Hermetic doctrine. This looks like a deliberate bit of "Egyptianizing" on the part of some Hellenistic or late antique author, especially since this Greek text self-referentially warns against the highly significant and symbolic Egyptian words being translated into the "pompous, loose, and florid language of the Greeks" [§2]. But then again, what precisely would be the reason to doubt that the Egyptian claim contains a genuine core?

CH 16 can be conveniently divided into five parts. After the introductory address to the king, in which the author curiously warns right at the beginning that the views expressed here may not agree with other Hermetic teachings [Part 1: §§1–2], the text turns into a long exposition of the function and importance of the Sun and its light [Part 2: §§3–9]. The Sun is said to be positioned in the middle (N.B. not the center) of the cosmos, between the Earth and the sphere of the fixed stars, binding them together. It sends out the energy of its free and ungrudging light both above, to the immortals, and below, to Earth. In a language that is reminiscent of Akhenaten's great hymn, the Sun is praised as the force that enlivens and awakens all creatures; it is in fact the creative energy that brought them forth in the first place and subjects them to change.

But then, in §§10–15 (Part 3), the author segues into an elaborate demonology that has no parallel in other Hermetic writings. The author claims that the Sun is surrounded by enormous troops of demons that oversee all human activity and cause natural catastrophes such as earthquakes, floods, and famine. These demons (who are deployed by the Sun) are somehow connected to the stars [§13] and may have either good or evil intentions, although the predominant sentiment seems to be that these demons spell trouble for mankind.

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24 Something like this must be the sense of the Greek «ὅροι». The more common translation would be "definitions" but the text does not contain any definitions in the familiar sense at all.

25 King Ammon does not seem to be any historical figure and it makes little sense to identify him with Amun, the King of the Egyptian pantheon, who presumably would not stand in need of any instruction by a human, however much enlightened by Hermetic wisdom. Scott may be right in that the god-king is here euhemerized [1924–1936, 2.435].

> They reshape our souls to their own ends, and they rouse them, lying in ambush in our muscle and marrow, in veins and arteries, in the brain itself, reaching to the very guts.
>
> CH 16.14; COPENHAVER 1992, 60

More importantly, the text draws a direct connection to horoscopic astrology:

> The demons on duty at the exact moment of birth, arrayed under each of the stars, take possession of each of us as we come into being and receive a soul.
>
> CH 16.15; COPENHAVER 1992, 60

The next three paragraphs [§§16–18: Part 4] return to the theme of the Sun, claiming that if anyone received a ray of the Sun to shine upon the rational part of the soul (ἐν τῷ λογικῷ), such an enlightened person would be protected from the maleficent influence of demons. With its astral demonology and firm belief in action at a distance, beneficent in the case of the Sun, mostly maleficent in the case of the planets and stars, this treatise offers a metaphysical blueprint for the practicing astrologer. The text ends (Part 5) with a reaffirmation of the divinity of the universe (all individual beings and things are parts of god) and, in an almost Hegelian fashion, asserts that god ceaselessly makes himself in the making of all things [§19].

13 CH 17–18

The last two treatises of the extant Greek Corpus Hermeticum have very little that is of interest for our topic. The brief excerpt CH 17 (without title) affirms the efficacy of corporeal statues of deities, arguing that they are reflections of the incorporeal. CH 18 (*On the Soul Hindered by the Body's Affections*)[26] is a panegyric of kings and of the Sun, here apparently equated with the highest deity. This tractate contains no demonology and much of the theology of the Sun is familiar enough (its goodness, creative energy, emitting its rays above and below, and so on). But there is one startling image that is reminiscent, once again, of the solar iconography of the Amarna Period: in §11 the author says:

26 As in several other cases, the title bears no relation to the actual content of the tractate.

> The sun, nourisher of all that grows, harvests the first pick of the crops as it first rises, *using its rays like great hands* to gather in the crops, and *the rays that are its hands* gather in the most ambrosial "effluences" of the plants.
>
> COPENHAVER 1992, 65

There is no good reason to dismiss the image of the hand-like rays of the Sun as "la rhétorique la plus banale" [Festugière 1949–1953, 1.91]. For the question might at least be asked how the Hellenistic or late antique author of this text knew of this unusual iconography, given that the reliefs of the Armana Period had been either wholly obliterated or firmly buried under ground.

14 The Latin *Asclepius*

We can now turn to the one surviving Latin Hermetic tractate, the so-called *Asclepius*, a text that also circulated in Greek and Coptic.[27] The treatise contains a lengthy albeit unsystematic, and at times apparently "unorthodox"—if there is such a thing as orthodox Hermetism—overview of Hermetic doctrines. Judging from the fact that the treatise was extant in three languages and even quoted by the Fathers of the church such as Cyril, Lactantius, and Augustine, among others, we can presume that it had a wide distribution and substantial readership in Late Antiquity.

The imagined situation is an instruction of Hermes to his pupil Asclepius. In the beginning, the ideas presented look familiar enough: monotheism, creationism, the divinity of consciousness, the centrality of the Sun, the fundamental interconnectedness of all things in the universe, and the admiration of god's creation as man's purpose:

> 3 [...] The heavens, a perceptible god, administer all bodies whose growth and decline have been charged to the sun and moon. But god, who is their maker, is himself governor of heaven and of soul itself and of all things that are in the world. From all these, all governed by the same god, a continuous influence carries through the world and through the soul of all kinds and all forms throughout nature. God…causes all things to reach as far as heaven so that they will be pleasing in the sight of god.
>
> COPENHAVER 1992, 68

27 Remains of the Greek version are extant in the Papyrus Mimaut, in Lactantius, [Anthimus], Cyril of Alexandria, Stobaeus, and John Lydus. A Coptic translation of parts of the Greek is extant in NHC 6.7 (*The Prayer of Thanksgiving*) and 6.8 (*Asclepius 21–29*).

To confirm the impression of the centrality of this sort of astral mysticism for the Hermetic philosopher, Asclepius is told in §13 that the various and often demanding branches of learning are less important than "pure philosophy, which depends only on reverence for god", i.e., Hermetism. Importantly, the text goes on, pure philosophy should use the other disciplines of learning "only to wonder at the recurrence of the stars".

This looks very much like the kind of general astral mysticism that prevailed in the Greek Hermetica. But once again, in this text we also encounter another voice that seems more serious about the business of astrology, going well beyond a mere *contemplatio caeli*. In §19, Hermes announces that he is about to disclose the greatest of divine mysteries. The first such disclosure is an assertion of a serious form of polytheism (*deorum genera multa sunt*), a view that stands in sharp contrast to the unequivocal monotheism of the main body of the Hermetica. The passage goes on to distinguish between two major kinds of gods, sensible and intelligible ones, and then propounds a complicated doctrine according to which each class of gods has a leader or head (*princeps*) whom they follow or, as the text puts it in a mixture of Latin and Greek, whom they possess as the principle of their being (*princeps* οὐσίας). The author uses also a peculiar Greek neologism to denote this princeps or leader, «οὐσιαρχής».[28] There follows an at first sight surprising statement that Jupiter is the οὐσιαρχής of heaven because he is the principle of life for all things (*per caelum enim Iuppiter omnibus praebet vitam*). This makes sense only if "Iuppiter" is the Latin term for Zeus, by which the original Greek must have meant not the planet Jupiter but god the father and creator of everything, i.e., the familiar first Hermetic principle. If god is associated with life, light is associated in good Hermetic fashion with the Sun (cf. the life-and-light theology of the *Poimandres*). In fact, light is said to be the οὐσιαρχής of the Sun (*solis* οὐσιαρχής *lumen est*). Moving on, the hypostasis of omniformity[29] is the οὐσιαρχής of the 36 divisions of the fixed sphere; and the seven planetary spheres have *Fortuna* (or εἱμαρμένη, as the author goes on to explain) as *their* principle of being. One might have thought that the planets are the principles and causes of Fate. But here the order of aetiological priority is reversed: Fate governs the movement of the planets. But this is, of course, precisely the reason why the planets' constellations can be read and interpreted astrologically.

The text goes on to speak about the element air but then breaks off before we can discern any further concrete doctrine.

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28 This Greek word only here in the Latin *Asclepius*. [Dionysius the Areopagite] uses the feminine genitive «οὐσιαρχίας» once [*De div. nom.* 180.12].

29 For the association of omniformity with the cosmos as a whole, see also CH 11.16 and 13.12.

For long stretches the *Asclepius* goes through an array of different doctrines, discussing the exalted nature of humanity, an apocalypse of Egypt, death, the universe, space and time, before it turns distinctly astrological again near the end [§§39–40], when Asclepius inquires about the role of Fate (εἱμαρμένη). Hermes replies, strangely, with a complex disjunction: εἱμαρμένη "is the maker of everything, or else the supreme god, or the second god made by the supreme god, or the ordering of all things in heaven and earth made steadfast by divine laws" [Copenhaver 1992, 91]. Moreover, εἱμαρμένη is virtually equated with iron Necessity. These confused identifications are quite bizarre but they may well be of a piece with the earlier astrological metaphysics of §19. One must keep in mind that the doctrine of fatalism is a philosophical crutch that serves to reconcile the disillusioned soul with the hardships of life. However much such discourse may smack of Hermetism, fatalistic determinism has nothing to do with the Hermetic proclamation, so often articulated in these texts, of the radiant goodness of god and splendor of the universe.

15 John of Stobi

When John Stobaeus composed his famous collection of excerpts in the fifth century (the so-called *Four Books of Extracts, Sayings and Precepts,* often simply *Anthology*), he had access to a different and presumably much larger body of philosophical Hermetica than the one that the manuscript tradition has handed down to us. Stobaeus also seems to have had a keen interest in astrology, since a good proportion of his excerpts pronounce themselves on this topic.[30] The most important text in this regard is perhaps fr. 6 [Wachsmuth and Hense 1884–1923, 1.21.9]. It deals with the topic of the 36 decans and might well represent a complete tractate rather than a mere excerpt from a longer work. It is too extensive to cite in full but may be paraphrased as follows.

Hermes instructs Tat about the 36 decans. These powerful rulers reside between the sphere of the fixed stars and the spheres of the planets, slowing down the outer sphere and accelerating the planets [§§1–4]. They are the

30 I am not dealing in this context with the most extensive Stobaean fragment, Wachsmuth and Hense 1884–1923, fr. 23 also known as the *Kore Kosmou*. The text strikes me as syncretistic and derivative: in it Hermetic and Platonic elements are further "Egyptianized" by folding them into a fictitious dialogue between Isis and Horus. The astrology in this text operates with zodiacal signs [fr. 23.20] and is consonant with what I believe is a secondary layer in the Hermetica, one of astrological conceit that includes an optimistic confidence in the benefits of human science and philosophy [68].

guardians of celestial order, not illuminated by the Sun like the other celestial bodies nor influenced in any way: they are free [§§5–6]. They not only determine all celestial movements, including the changes of day and night but have also the greatest influence on us as they determine such things as the downfall of kings, revolts, food shortages, floods, and earthquakes [§§7–9]. The decans are a particular class of demons, with neither body nor soul, commanding a host of celestial servants and soldiers that determine the point of death of everything that lives [§§10–14]. Below the spheres of the planets, there are other meteorological phenomena as well as comets, which function as heralds of unusual events [§§15–16]. Finally, the text asserts that it is impossible to be happy without astrology; moreover, astrology allows the soul to find its way once it returns to the heavens [§§17–19]. The general tenor of these doctrines reminds one of the astrological layer in the Latin *Asclepius* and the elaborate demonology of CH 16.

Stobaeus, Fr. 12 [Wachsmuth and Hense 1884–1923, 1.5.20] emphasizes the importance of Fate (εἱμαρμένη), Providence (πρόνοια), and Necessity (ἀνάγκη). Just as in the *Asclepius*, the stars have powerful influences on us and are themselves servants of cosmic Necessity. Fr. 14 [Wachsmuth and Hense 1884–1923, 1.5.16] says essentially the same thing in other words: Providence, Necessity, and Fate govern the circular movements of the stars and planets. The excerpt from a Hermetic tractate on Fate, also preserved by Stobaeus [fr. 29 = Wachsmuth and Hense 1884–1923, 1.5.14], affirms the influence of the seven planets on us. The text, 13 lines in all, is written in hexameters, which is unusual for Hermetic writings; and the *Anthologia Palatina* [9.491] attributes one of the verses to the mathematician Theon of Smyrna (second century CE), who ostensibly wrote commentaries on the Hermetica [John Malalas, *Chronographia* 13.343]. It is perhaps worthwhile to cite the poem in full.[31]

> Seven much-wandering stars circle along the threshold to Olympus,
> And with them eternity runs along always.
> Night-illuminating Moon, terrible Cronus, the sweet Sun,
> Aphrodite, builder of bridal chambers, wild Ares, winged Hermes,
> And Zeus, the oldest, from whom all of Nature came to light.
> But they selected the human race; there is in us
> Moon, Zeus, Ares, Aphrodite, Kronos, Helios, and Hermes.
> For this reason, we are bound to draw from the ethereal vapor
> Tears and laughter, anger and procreation, reason, sleep, and desire.

31 The Greek text is found in Nock and Festugière 1972, 4.99.

> The tears are Cronus, Zeus is procreation, reason Hermes,
> anger Ares, but the Moon is sleep, and Aphrodite desire,
> And Helios is laughter. For through him every mortal mind
> Rightly rejoices and so does the boundless universe.

This anthropology, however puzzling in its metaphysics, is clear enough in its phenomenological contention: the life of each individual human being as well as the human race as a whole is intimately connected with the planets. They direct us in every detail of our lives and manifest themselves in the sum-total of our cognitive and emotional experience.

In a way, this text represents something like the poetic pinnacle of astrological speculation in the extant philosophical Hermetica. In character, it is clearly of a piece with the kind of later and derivative Hermetism that sees its culminating achievement in astrology. From here one can draw a direct line to the tradition of so-called technical Hermetica, the bread and butter of working horoscopists and magicians.[32] In the light of this, one might say that the pervasive association of Hermetism with astrology has a certain amount of justification but that it is at the same time too simple. "Star-gazing" can have many different motivations and serve different purposes: the heavens, and in particular the dazzling spectacle of a starry night, can be taken as a sign of the benevolence of a deified cosmos (cosmotheism), beckoning the beholder to aspire to a higher form of existence, a celestial home whereto the soul might return and be saved (astral mysticism). But the stars can of course just as well be imbedded in a narrative of divine hierarchy and power, in which case the very survival and flourishing of man would depend on the foreknowledge of the rulers' will (astrology proper). It is not clear to me that these two points of view are easily compatible.

16 Conclusion

I have tried to show that astrology does not play as central a part in the extant philosophical Hermetica as one might have expected. What one *can* say, however, is that the peculiar metaphysics and anthropology espoused in these texts must have been, historically speaking, conducive to the rise of horoscopic astrology.[33] The main and most authentic Hermetic idea seems to be one that

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32 On this tradition, see van Bladel 2009.

33 As opposed to the so-called judicial astrology mainly practiced by the Babylonians. On the distinction, see Neugebauer 1946.

concerns human consciousness, proclaiming the discovery that each individual human being is part of the absolute consciousness of god, which in turn is the ultimate creative principle of the universe. God is visible and manifest in the world's entirety and his principal physical manifestation and counterpart is the light of the Sun. Hermetism urges the reader to come to the realization of just this "fact" and to practice *contemplatio caeli* as part of a natural theology that hopes to facilitate man's return to the deity. The heavens are symbolic of divinity as such and give, as cosmic adornment, powerful testimony to divine goodness. Man's privilege and purpose is to gaze at the stars in admiration and recognize the divine presence in them. Exact observation, calculation, and the prediction of astral positions do not belong to this kind of mindset; and action at a distance seems to have been restricted mostly to the Sun.

However, one can see how Hermetism so understood could serve as the metaphysical groundwork for astrology proper. If we can trust the evidence, the texts also speak of a quite different version of celestial symbolism. In this version of Hermetism, the heavens are described as symbols of power and influence; they endow mankind with the ability to rule over nature. Man needs these powers because the world is not entirely hospitable and benevolent; the stars and planets are seen as portent bearers of Providence, Necessity, and Fate, and the observation and interpretation of the stars as symbols of the quality of time is elevated to the level of the master science of astrology.

It is not unreasonable to believe that the former kind of solar religion stands rather close to an older and perhaps original form of Hermetism, an astral philosophy that bears conscious witness to the divine creation and venerates the invisible creator through his visible representative, the Sun. In contrast, in the other type of approach to the cosmos, now conceived as considerably less benign, even evil, a premium is put on astrology as the art that protects against the potentially harmful influences of Fate ordained by the celestial rulers. It is perhaps not too far fetched to suggest that one kind of discourse is reminiscent of the Amarna-style religion of solar light, whereas the other looks more like Hellenistic astral discourse influenced by both Babylonian astrology and Greek natural philosophy. It seems indisputable that the Hermetica emerge from an Egyptian background. Nevertheless, it is remarkable that neither variety of astral discourse on display taps into the traditional Egyptian concern for the necessity of upholding, through priestly ritual, the cosmic order or the continuation of the balance between earth and sky. There is no talk, for example, of Egyptian deities, of Ma'at, or of the risings and settings of Sirius.[34] It seems

34 Cf. Campion 2012, 82–93. Which is why Hermetism does not feature much, if at all, in the

that there may well be a good historical explanation for this. If the core ideas of Hermetism reach back (*pace* Casaubon) to the religious reforms of Akhenaten, the absence of traditional religious iconographies would only be too natural; and it may have been partly thanks to this absence that the somehow surviving remnants of Hermetic metaphysics appealed to the cultural elites of the Greco-Roman overlords—and thus experienced their first renaissance at the dawn of Late Antiquity.

available discussions of Egyptian astronomical writings: see, e.g., Cumont 1937; Neugebauer 1942a; Neugebauer and Parker 1960–1969; Parker 1974; Slosman and Bellecour 1983; Maravelia 2006.

Hellenistic Astronomy in the Philosophical Schools

CHAPTER 14.1

Astronomy and Divination in Stoic Philosophy

Giuseppe Cambiano

1 Posidonius on Astronomy and Physical Theory

Posidonius, as reported on the authority of Alexander of Aphrodisias (whose source is Geminus) by Simplicius in his commentary on Aristotle's *Physics*, distinguished between natural philosophy and astronomy in saying, "It is the task of natural philosophy (φυσική) to examine in the case of heaven and stars their substance, power, quality, generation and destruction." Natural philosophy can prove "questions related to their size, shape and order", whereas astronomy does not address anything of that kind but rather "proves the order or arrangement of the heavenly bodies" and "talks about the shapes, sizes and distances of Earth, Sun and Moon, about eclipses and conjunctions of the stars, and about the quality and extent of their movements" by means of arithmetic and geometry. Often both the natural philosopher and the astronomer "will propose proving the same point, e.g., that the Sun is large, the Earth is spherical; but for all that, they will not go by the same procedures". The natural philosopher produces his explanations starting from the substance or power of the heavenly bodies, or from the processes of coming into existence and change, or because "it is better that it be thus." The astronomer, on the other hand, assumes his hypotheses from the natural philosopher and does not explain why the Earth or the stars are spherical. Nor is his task to know what is at rest by nature or what sorts of things are capable of motion. Therefore, natural philosophy has a higher cognitive value for the Greeks while astronomy depends on natural philosophy, from which it must take its first principles, that is, "that the movements of the stars are simple, uniform, and orderly".

Simplicius says that this is how Geminus (or rather Posidonius cited in Geminus) "expounds the difference between natural philosophy and astronomy, taking his starting-points from Aristotle". In fact, Posidonius' description of the astronomical method fits into Aristotle's general view of demonstrative science and finds some parallels in the deductive structure of both Euclid's *Elementa* and Aristarchus' *De magnitudinibus et distantiis solis et lunae*.[1]

1 See Diels 1882–1895, 291.21–292.31 = Kidd 1988–1999, 1.F18 [trans. Kidd, lightly revised]. For

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Posidonius was a Stoic philosopher of the first half of the first century BCE who defended the deductive structure of Euclid's *Elements* against the charge of the incompleteness of its principles that was made by the Epicurean Zeno of Sidon [Friedlein 1873, 199.3–200.6, 214.15–218.11]. We have evidence of Posidonius' interest in questions of mathematical geography but only scanty evidence of his inquiries into mathematical astronomy. Cleomedes [Todd 1990, 53.269–286] says that he calculated the size of the Sun on the basis of the hypothesis that the orbit of the Sun is 10,000 times greater than the circumference of the Earth. His interest in astronomy is further confirmed by his construction of a celestial globe [Cicero, *De nat. deor.* 2.88].

2 The Early Stoics and the Study of the Heavens

We do not know if the Stoics who were active in the three centuries after the foundation by Zeno of Citium of their school in Athens during the late fourth century BCE were engaged in mathematical astronomy or even if they distinguished between natural philosophy and astronomy. Unfortunately, no text of early Stoicism has been preserved. We have only scattered references and decontextualized quotations in late authors that are constructed in the form of doxographical schemes organized by questions, partially deriving from Aristotle [Mansfeld 1992]. They list the tenets advanced by individual philosophers or schools in response to each question and show that the early Stoics, with the exception of Ariston of Chios, who neglected physics, also included the study of the heavens in the task of natural philosophy. Many questions recorded by the doxographical traditions fit with the agenda that Posidonius assigns to the natural philosopher, for example, to determine what the substance of the heavenly bodies, their shape, size, power, quality, and order are.

To Zeno and Cleanthes, Zeno's immediate successor as scholarch, are attributed the tenet that Sun, Moon, and stars and the whole of the heavens are fiery but made of craftsmanlike, not destructive, fire out of which things grow and are preserved. Chrysippus, however, distinguished the Sun composed of pure fire from the Moon composed of two elements, fire and air; and Posidonius agreed with him. As for the shape of the heavenly bodies, the prevailing thesis in the school was that they were spherical.

similar distinctions, see Seneca, *Epist.* 88.26–28 and Diogenes, *Vitae* 7.132–133. See also Kidd 1978 and 1988–1999, 1.129–136, 362–365; Lloyd 1991, 265–268; and, above all, Bowen and Todd 2004, 193–204 and Bowen 2013a, 38–50.

An exception is Cleanthes, who defined the shape of the stars as conical in consequence perhaps of his attribution of a conical shape to fire [Diels 1965, 312b, 344b]. Our sources are silent on why Cleanthes adopted this view. Was it because the stars emit cones of light or because of a polemic against Plato's attribution to fire of a pyramidal shape [*Tim.* 56b]? Certainly, the Epicureans in particular were the target of Cleanthes' criticism of others' notions of the shape of the stars. In Cicero's *De nat. deor.* 1.24, 2.47, the Epicurean Velleius finds more beauty in the shape of a cylinder or a cone or a pyramid; whereas the Stoic Balbus finds that the sphere, "in which all parts are similar one to another and the center is at an equal distance from every point on the circumference", is the most beautiful shape. Polemics arose also on the question of size. Whereas, according to Epicurus, the Sun is as great as it appears [*Epist. ad Pyth.* 91] and the various worlds have various shapes [*Ep. ad Herod.* 74], the Stoics held that the Sun is much greater than the Earth [Diogenes, *Vitae* 7.144] but avoided assigning to them figures or numerical ratios, unlike the astronomer Aristarchus in his *De magnitudinibus* [Barnes 1989].

The heavenly bodies are parts, according to the Stoics, of one great body, the cosmos, whose shape is spherical and whose structure has a certain order depending on its having at its center the Earth, which is also spherical. The outer circle of the cosmos contains the fixed stars and, between these and the Earth, the planets. The purest part of fire, called aether, is located in the outer periphery of the cosmos and of it the heavens are made. Aether is weightless and to the Stoics it is not a fifth element, as in Aristotle's *De caelo*, by which the heavenly world was thus distinguished from the sublunary one.

In Plutarch's account, the Stoics said,

> The luminous and tenuous part of the aether by reason of its thinness became sky, the part which was condensed or compressed became stars, and that of these the most slow and turbid is the Moon.
>
> PLUTARCH, *De fac.* 928c–d

In Chrysippus' distinction, a part of the cosmos, that is, the aether, rotates around the center, while another, that is, the Earth, is fixed. The number of the fixed stars cannot be grasped, while the planets are seven in number and smaller in size than the fixed stars. These were theses that answered Posidonius' question, which had first been raised by Aristotle, about which bodies have power of motion and which of rest.[2]

2 On Stoic cosmology, see Lapidge 1978; Hahm 1977; Furley 1999, 432–451; White 2003.

The astronomical themes would have been a constant object of disagreement and polemic among the philosophical schools. Cleomedes, author of the *Caelestia*, which was composed probably in the first imperial age,[3] seems to follow the general principles and methodology of Posidonian Stoicism, sharing the view of a hierarchical relation between natural philosophy and astronomy.[4] He employs numerical ratios, for example, for the size of the circumference of the Earth, preferring Posidonius' solution to that of Eratosthenes [*Cael.* 1.7; Bowen 2003]. However, he also uses typical concepts of Stoic tradition, like the sympathy (συμπάθεια) that is held to connect all parts of the cosmos, the exhalations arising from the Earth by which the heavens and the stars are nourished, and the doctrine of conflagration.

Cleomedes claims to answer typical *topoi* of doxographical traditions, such as the shape, size, and power of the Earth and the heavenly bodies, employing what dialecticians, the Stoics, called the fifth undemonstrated argument, that is, the form of argument constructed through multiple disjuncts: for example, if *x* is either *A* or *B* or *C*; but *x* is neither *A* nor *B* (which is for the most part proved by *reductio ad absurdum*); then, *x* is *C*. By it Cleomedes proves that the Earth is spherical [*Cael.* 1.5] and is located in the center of the cosmos [*Cael.* 1.6]. Cleomedes went on disproving the theses of other philosophers, refuting in *Cael.* 2.1 the opinion that the size of the Sun is as great as it appears, that is, as great as a foot, as it was commonly ascribed to Epicurus. He took this erroneous view as a consequence of the negative features of the Epicurean ethics, typical of men who searched only for pleasure [Todd 1990, 2.1.358, 410]. The plain fact is that, by reducing the size of the Sun, the Epicureans aimed to deny the beneficial power of the Sun over the Earth and, therefore, divine Providence [Todd 1990, 2.1.357–375, 2.1.421]. To Cleomedes, it was essential to show the excellence of the Earth and the heavenly bodies. Not by chance did he call both the Sun and the Moon god [Todd 1990, 2.4.128–132, 2.5, 2.5.99–100]. He then confirms the centrality of theology in the Stoic account of the heavenly bodies.

3 Theology and the Philosophy of Nature

To the Stoics, theology was an integral part of the philosophy of nature. Chrysippus saw theology as the final stage of philosophical studies, describing it as a kind of initiation [Plutarch, *De stoic. rep.* 1035a–b]. It was Cleanthes,

3 See Jones 2003, 333–337; Bowen and Todd 2004, 2–4: for a later date, see Neugebauer 1975, 2.959–965.

4 On Cleomedes and Posidonius, see Bowen and Todd 2004, 5–17.

author of *On Gods* [Diogenes, *Vitae* 7.174], who emphasized this theological dimension. He listed four reasons men had formed the notion of god: the most important, which also proves the existence of god, was the beauty of the cosmos and of the heavenly bodies along with the regularity of their motions [Cicero, *De nat. deor.* 2.15, 3.16]. Cicero relates Chrysippus' reasoning as follows:

> If there is anything in nature that the human mind and human intelligence, strength and power cannot create, then the craftsman of such things is superior to man. But the heavenly bodies in their everlasting regularity cannot be created by man. They must, therefore, be created by what is better than man. But what other name is there for this than god?
>
> CICERO, *De nat. deor.* 2.16

Chrysippus then further argued *a fortiori* that

> if the works of nature are more perfect than the works of art, as art achieves nothing by chance, even more reasonably the works of nature are not due to chance.
>
> CICERO, *De nat. deor*. 2.87–88

So, if someone were to bring to Britain or Scythia the celestial globe made by Posidonius,

> which in its revolution shows the movements of the Sun and stars and planets, by day and night, just as they appear in the sky,...who of these barbarians would doubt that it has been produced by reason?[5]

The reason that pervades the whole of nature is endowed with a divine power and the whole cosmos can be said to be the substance of god who is, above all, embodied in the heaven and the stars. And as the substance of the heavenly bodies is the aether, Zeno, followed by all the Stoics, claimed that god is aether. However, as the possession of intelligence calls for a soul, an analogy can be drawn with living beings, by which the cosmos itself is a living organism. Reason in the human soul is the ruling principle; hence, the cosmos too has its ruling principle in the aether.[6]

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5 See Pease 1941. On Stoic theology, see Mansfeld 1999; Algra 2003. On the argument from design, see Sedley 2008, ch. 7.

6 See Cicero, *De nat. deor.* 1.36–37, 2.39, 2.54; Diogenes, *Vitae* 7.138–139, 142–143. On Stoic cosmobiology, see Hahm 1977, 136–184.

Cleanthes also took a peculiar position on this point. He wrote a *Hymn to Zeus*, the master whom the entire cosmos obeys as it moves around the Earth. Is it possible to identify Zeus with a heavenly body? Persuaded as they were that the ancients were closer to the truth, the Stoics practiced both allegorical interpretation of myths and poets' tales about gods and etymological research on the names of gods for theological aims. Evidence of this state of affairs is the *Theologiae graecae compendium* (*Summary of Greek Theology*) written by the Stoic Annaeus Cornutus (first century CE).[7]

Cornutus identifies the Sun with Apollo and the Moon with Artemis, while qualifying Zeus as the cosmic soul that dwells in the most important part of the cosmos, that is, the sky [Lang 1881, 3.3–9]. In the Stoic tradition, then, Zeus represents the supreme god that rules over the cosmic order as a whole, more than a specific star. Such was probably the Zeus to whom Cleanthes' hymn was addressed. Nonetheless, it remains difficult to define the relationship, if any, between Zeus and the ruling principle, which Cleanthes identified with the Sun, that is, the highest star, which contributes most to the ordering of the whole.

Cleanthes compared the Sun to a plectrum, because in its rising the Sun, "by the percussion of its rays, leads the cosmos into its harmonious course" [Clement, *Strom.* 5.8]. It does not seem necessary to link this simile to a Pythagorean influence, for the notion of a cosmic harmony can also be found in Heraclitus and certainly in Plato. As a matter of fact, the musical activity that Cornutus ascribed to Apollo and the Sun is termed «μουςικός» and «κιθαρίςτης» [Lang 1881, 67.16–21]. Still puzzling is why Cleanthes, although identifying the Sun with the ruling principle, reacted very critically to the heliocentric hypothesis in his *Against Aristarchus*, claiming

> that the Greeks ought to bring an action for impiety against Aristarchus the Samian on the moving the Earth of the cosmos, because he sought to save the phenomena by assuming that the heaven is at rest while the Earth is revolving along the ecliptic and at the same time is rotating about its own axis.
>
> PLUTARCH, *De facie* 923a

Aristarchus' *De magnitudinibus* does not hint at a heliocentric hypothesis but this hypothesis is attributed to him by Archimedes in his *Arenarius* 1.1.4–7, where it is said that for Aristarchus the fixed stars as well as the Sun remain

7 See Most 1989. On Cleanthes' *Hymn*, see Thom 2006.

unmoved in space.[8] In Plutarch's account, Cleanthes criticized Aristarchus above all because he made the Earth rotate, instead of making it stay at rest, not because he made the Sun remain at rest. This was incompatible with the traditional view of the Earth as the hearth of the universe. The context and language of Cleanthes' charge are religious, confirmed by his reference to impiety. Also, his calling the Earth ἑστία (hearth) when «ἑστία» is also the name of Hestia, a goddess of the Greek pantheon, suggests a religious emphasis. Plutarch [*De comm. not.* 1075.a–b, *De stoic. rep.* 1051f–1052a] says that Cleanthes and Chrysippus distinguished Zeus as the supreme, that is eternal, god from the multiplicity of gods that are perishable.

4 The Cosmic Conflagration

This connects to a central theme of Stoic cosmology, that is, conflagration. The cosmos, although organized by divine Providence, is not eternal but subject to birth and death, like any other living being. In the late account of Nemesius [*De nat. hom.* 38], conflagration would take place at the accomplishment of the so-called Great Year, when the planets will return to the same relative position they had at the beginning. On the question of the length of this period, there was great debate [Cicero, *De nat. deor.* 2.51].

In the process of conflagration, everything—the Sun and Moon and the rest of the gods—turns into flame according to Cleanthes or into rays of light according to Chrysippus, whereas Zeus alone is everlasting. At the moment of the conflagration, the fire is in its purest state, pure aether, hence complete realization of the divine unity. But Zeus is at the same time craftsmanlike fire, which proceeds to construct the cosmos once again giving rise to a new cycle in which the other elements derive from the fire by transformation and the stars assume once again the positions and the motions that they had in the preceding cycle [Hahm 1977, 57–90; Mansfeld 1979].

Not all Stoics accepted this idea of perpetual cosmic conflagration. In the second century BCE, Diogenes of Babylon perhaps abandoned the theory after having endorsed it in his youth, while Panaetius of Rhodes doubted it, preferring the Aristotelian theory of the eternity of the world [Alesse 1994, T130–134]. It was Posidonius who came back to the original doctrine of the school [Diogenes, *Vitae* 7.142].

8 See also Plutarch, *Plat. quaest.* 1006c; Diels 1965, 355b. See Heath 1913, 303–310; Bowen 2013a, 251–259. On attempts to connect Cleanthes' view to Pythagorean suggestions, see Isnardi Parente 1991, 197–210; Bénatouïl 2005.

5 The Extra-Cosmic Void

The Stoics admitted there was a void outside the cosmos which extended outward from the periphery in order to justify the possibility of the increased volume of the fiery mass expanding at the moment of conflagration. They excluded, however, a void inside the cosmos, once again in opposition to the Epicureans. This is consistent with their view of the cosmos as wholly coherent in its inner organization because its parts are connected by a tension produced by the movement of the *pneuma*, a mixture of air and fire that pervades the universe. The result is a reciprocal sympathy between these parts, as in the relation between heaven and Earth. That the account of earth and water as elements occupying the lower part of the cosmos is the basis for the doctrine may be derived from the Heraclitean suggestion that humid exhalations come up from the sea and the rivers.

6 The Nourishment of Celestial Bodies

Any fire needs fuel to be nourished and, since the heavenly bodies were made of fire, they were presumed to take their nourishment from the vapors rising up from the Earth and the waters, which were heated by the Sun itself, until in the end the fuel was exhausted and only the fire survived. To Cleanthes, it was this necessity for the Sun to be nourished that explained its course through the heavens and the solstices as well [Cicero, *De nat. deor*. 3.37]. On the other hand, the changes of the seasons, which depend on the position of the Sun in relation in its course among the stars, had to be taken as an obvious confirmation that the Sun and the heavenly bodies that occupy the upper place influence in turn what occupies the lower place. The same held in the case of the tides, which depended on the movements of the Moon, a phenomenon carefully observed and studied particularly by Posidonius.

7 Divination and Astrology in Stoicism

From the existence of a sympathetic connection between the heavens and the Earth, the Stoics also inferred the existence of various forms of divination. From the beginning, they paid careful attention to those practices which included the observation of the flights of birds side by side with dreams and the viscera of sacrificed animals. In Cleanthes' view, the foreknowledge of future events was one reason the notion of god had formed [Cicero, *De nat. deor.* 2.13]. Chrysippus wrote on Fate, Providence, divination, oracles, and dreams, and after him the custom of writing on divination was followed by Diogenes of Babylon, Antipater, and Posidonius [Cicero, *De div.* 1.6]. Divination was defined as the science of understanding and interpreting the signs that gods give men. The existence of divination could indeed be taken as real proof of the existence of the gods: if gods do not exist, neither divination nor astrology exists; but it is absurd to abolish such a multitude of things already believed by all men; therefore, gods exist [Sextus Empiricus, *Adv. math.* 9.132].

An analogous argument was used to prove the existence of Fate as the connection of all causes: if it is not the case that all things are engendered by Fate, the seers' predictions were not true. Fate, then, is a necessary condition for the possibility of divination in that divination is true if the predicted event is dependent on a network of causes [Bobzien 1998, 87–96, 173–174]. Yet, no man is able to know the whole series of causes and, on that basis, foretell the future. It must, then, be foretold by means of signs that, however, do not necessarily belong to the network of causes on which the event depends. Hence, prediction is not the cause for the event to take place. What ensures that they are signs of hidden events, as the future ones, is precisely the existence of the gods; for, if they exist and take care of human things, it is then necessary that they give men notice about the future [Cicero, *De div.* 1.117].

Yet, at the same time, being provident, the gods also give men the capacity to interpret the signs that they send. But a basic distinction must be made between *natural* divination, in which signs are dreams or prophecies, and *artificial* divination, for which indeed the art of interpreting the signs is required. In the latter, astrology is also included, for it too proceeds on the basis of repeated observations, personal or transmitted by the ancients, of what ensues from each sign. This allows one to interpret what each sign means in order to foretell the future by means of reasonings and conjectures [*De div*. 1.34, 1.109, 1.118]. Thus its procedure exhibits features that are also peculiar to an empirical science like medicine [Long and Sedley 1987, 1.263–266; Hankinson 1988; Repici 1995].

Among the divinatory practices, the Stoics also included the observation of the behavior of the stars. The problem of assigning a date to these practices is connected to the problem of establishing the date of the introduction of astrological practices to the Greek world. The interconnection between star-risings and meteorological phenomena as well as the organization of calendars had long since been established. But astrology as a predictor of future events concerning an individual, on the basis of the astrologer's capacity to identify phenomena occurring in the heavens at the moment of the individual's birth exactly and interpret them, became a common practice only later in Greece.

There are no references to horoscopic astrology in any Greek or Latin text dating from before the latter parts of the first century BCE [see ch. 12.3 §1, p. 490]. The formulation of horoscopes, different from celestial omens, requires mathematical astronomy to calculate planetary positions and ascendants and, hence, planetary angles and the degrees of the zodiac, a science whose diffusion in the Hellenistic world is not attested before the second century BCE.[9] It is, therefore, difficult to assume that astrology was included in the early Stoics' philosophical elaborations on divination. It has, however, been claimed that a case of horoscopic astrology can be detected in the following example, a polemical retort to Chrysippus during a debate on the conditional statements referring to the future: "If someone was born at the rising of the Dog-Star, he will not die at sea" [Cicero, *De fato* 11–14]. If this conditional is true, the following conditional will also be true: "If Fabius was born at the rising of the Dog-Star, Fabius will not die at sea." Assuming that this proposition was formulated by Chrysippus (*ca* 279 – *ca* 206 BCE), astrology would appear to be a theme for the Stoics in the third century BCE. But Cicero presents this proposition *verbi gratia*, as an *exemplum fictum*. Moreover, the example exhibits peculiar features, for it is the prediction not of an event but of a nonevent, and that leaves the type of death by which Fabius, and everyone born at the rising of the Dog Star, will die in a completely indeterminate state. If it was an astrologers' theorem, it was a very weak theorem. It seems, therefore, preferable to think that only in the second century BCE did the Stoics begin to consider the question of astrology [Long 1982; Bobzien 1998, 144–179]. Nor was it fully accepted by them from the beginning.

Diogenes of Babylon, pupil of Chrysippus and author of the book *On Divination*, accepted Chaldean astrology for the characters and dispositions of individuals but not for the particular events of their lives; and he used as a counterexample the case of twins who had lived different lives, which was also used polemically by his contemporary Carneades. This can be taken as confirmation that the status of astrology, and of divination in general, was for the most part a subject of competition among the philosophical schools. Yet more radically, Panaetius of Rhodes did not venture to deny the existence of a divinatory capacity but seems to have been doubtful about it [Alesse 1997, T136–140: cf. Alesse 1994, 230–254].

It was once again Posidonius who restored the validity of divination, connecting himself to the ancient Stoic tradition of Zeno and Chrysippus

9 For a general account, see Bouché-Leclercq 1899. On Babylonian influence on Hellenistic astronomy, see Neugebauer 1975; Barton 1994a, 18–19. On the late origin of predictive astronomy, see Bowen 2002. See also Jones 2003, 339–340 and ch. 4.7, p. 147.

[Diogenes, *Vitae* 7.149]. Posidonius' worry about astronomical hypotheses was directed to the fact that astronomers used seemingly contradictory mathematical devices for determining where the heavenly bodies would be located at a given time; thus, he also addressed a problem that astrology raised for philosophy [see chs 4.2, p. 71; 4.3, p. 95]. In Cicero [*De div*. 1.130], we read that Posidonius considered the meteorological predictions as valid predictions. But a great interest in astrology is attributed to him only by late sources, Augustine [*De civ. Dei* 5.2, 5.5] and Boethius [Kidd 1988–1999, F112]. The former mentions Posidonius in the context of a discussion on natal astrology.

Hippocrates the physician had suspected that two brothers, who had fallen ill in the same day and had had the same treatment until recovery, were twins. Posidonius inferred that they had been conceived and born under the same constellation, relating their medical history to the influence and arrangements of the stars when they had been conceived and born. He actually put side by side the hour of birth and the hour of conception in order to prevent the objection that, if the hour of the birth was the same, then all twins would share the same destiny. Both Augustine and Boethius presented Posidonius as representative of a hard astrology, in which the stars are assumed to be not only signs but also causes of events. Yet, it is not certain that this was Posidonius' actual position. But we cannot assume that for Posidonius the astronomers did not practice astrology, though the distinction was made at the time between astronomers for whom astrology was the point of their work and those for whom it had no part at all [Bowen 2013a].

Not all the Stoics agreed with Posidonius that astronomy was worth pursuing and, thus, they regarded his distinction between natural philosophy and astronomy as grounds for ignoring one of the disjuncts.[10] The Stoics living in the Roman Empire, such as Epictetus, Marcus Aurelius, and even Cleomedes, did not express a great appreciation of astrology. On his part, Seneca recognized the possibility of making meteorological predictions from the observation of lightning [*Nat. quaest*. 2.11] but, when discussing Chaldean astrology grounded on the influence of the five planets, he argued:

> Then thousands of stars do shine in vain? The greatest error of those skilled in horoscopes do not depend on the fact that they assign us to only a few stars? One star influences one person, another influences another,...but it is more difficult to know what power they have than to doubt whether they have power.
>
> SENECA, *Nat. quaest*. 2.32.7–8

10 See Strabo, *Geog*. 2.3.8; Seneca, *Epist*. 88.21–28: cf. Bowen 2009.

This implies an acceptance of the influence of the stars but a denial of any ascription to astrologers of the capacity to formulate valid predictions on the grounds of the observation of a number of stars that is too restricted. Nor can Geminus' *Intro. ast*. be invoked as evidence for Stoic support of astrology in the second half of the first century BCE. The fact that he composed *Epitome of Posidonius' Meteorology* does not prove by itself that he shared all the tenets of the Stoic philosophy of nature, not even those concerning the heavenly bodies. So, on the measure of the terrestrial circumference, Geminus makes reference to Eratosthenes' figures, while Posidonius' solution is not even mentioned [16.6]. Geminus' attitude toward astrology does not seem to be entirely clear.

His astrology includes horoscopic divination but "extended little beyond the Babylonian-style birth omens" [Jones 2003, 341: cf. Aujac 2002, lxxxii]. In one passage, the Chaldean assumption of a "sympathetic" connection among those born under opposed signs is introduced by a *seems* and followed by critical remarks on the existence of similar connections [2.5–14], while chapter 17 is entirely devoted to an argument against astrometeorology. But Geminus does not see horoscopic astrology as a critical part above all because what he values is the causal explanation, that is, the ways in which it depends on philosophy, as emphasized by Posidonius [Bowen 2013a].

In a context relating to astrology, Tacitus [*Ann.* 6.22] reports a philosophical controversy about Fate and contrasts the Epicureans with those who think that events happen according to the nexus of natural causes, not according to astral movements. If the latter are Stoics, it appears that in the second century CE they repudiated astrological determinism. No doubt the conceptual framework of Stoic philosophy, with its notion of a unitary and coherent cosmos in which all parts are interrelated and connected by "sympathetic" links, gave significant support to cultivated classes' acceptance of astrology. But the Stoic ideas of a universal "sympathy" and Fate were only a very general background to Manilius' poetic handbook of astrology for a court audience.

It will suffice to point out the probable inclination toward Pythagoreanism of Nigidius Figulus, a contemporary of Cicero who practiced divination and astrology, or the significant weight accorded by Ptolemy to Aristotelian doctrines. More likely, the reasons why astrology spread should be searched for, not so much in philosophical debates, but in the changing of political and social contexts, which grew more and more uncertain, giving birth to a deeper desire for reassurance about the benevolence of the gods through divinatory interpretation of the signs they sent to men [Barton 1994a, 35–62].

CHAPTER 14.2

Plotinus on the Motion of the Stars

James Wilberding

1 Introduction

Plotinus (204/5–270 CE) is traditionally credited with being the founder of a very influential school of thought known as Neoplatonism. In the past, the Neoplatonists were often neglected by historians of science because they were seen to be thinkers who concerned themselves solely with speculations about metaphysical principles such as the Platonic Forms, gods, intellects, and souls, and who were dismissive of the natural sciences and more generally of the sensible world as being a mere image of the real, intelligible world. More recent scholarship has succeeded in correcting this misperception by establishing a more balanced picture of the Neoplatonists' engagement with the sensible world. While it must be conceded that the Neoplatonists were not engaged in the kind of empirical or mathematical research that has become synonymous with science, they devoted much time and energy to reflecting on the metaphysical underpinnings of a wide range of the sensible phenomena studied by such natural sciences as biology, physics, and astronomy.[1]

Plotinus' engagement with the study of the stars is a case in point. As Porphyry, his student and biographer, reports, Plotinus did devote himself to the study of treatises on the stars including astronomical tables; but he hastens to add that Plotinus did not approach these works "in the manner of an astronomer".[2] This fits with what we find in the *Enneads*. Plato's famous challenge to his students to develop a mathematical model consisting of regular, circular and ordered motions that accounts for the *prima facie* irregular motions of the heavenly bodies, even assuming that this challenge is not apocryphal,[3] appears not to have made much of an impression on Plotinus.

1 For some examples of recent studies on these aspects of Neoplatonic thought, see Chiaradonna and Trabattoni 2009; Wilberding and Horn 2012.

2 See Porphyry, *Vita Plotini* 15.21–26. On the sense of «μαθηματικῶς», see the comments *ad loc*. by A.-P. Segonds in Brisson, Cherlonneix, Goulet-Cazé, Goulet, Grmek, Flamand, Matton, Pépin, Saffrey, Segonds, Tardieu, and Thillet 1992. In *Enn*. 3.1.5–6, Plotinus also appears to be discussing the work of a particular astrological writer and this might be Ptolemy.

3 See Simplicius, *In de caelo* 2.12 [Heiberg 1894, 422.14–24, 488.14–24, 492.31–493.5]. Serious doubt has been cast on the historical value of Simplicius' report in Bowen 2013a.

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We find no discussion of retrograde motions, epicycles, the number of celestial spheres, or the virtues of concentric *versus* eccentric spheres. Yet the stars are the subject of much discussion in the *Enneads*. There are three treatises devoted entirely to the stars:

Enn. 2.1 [40] "On the Heavens",
Enn. 2.2 [14] "On the Motion of the Heavens", and
Enn. 2.3 [52] "On Whether the Stars Are Causes".

Other treatises also contain sustained discussions of the stars.[4] Moreover, as indicated by the chronological order of these three treatises (indicated in the square brackets), Plotinus' interest in the stars stretched over his entire career. This material reveals that there were roughly three central themes in Plotinus' examination of the stars: showing the stars to be eternal, establishing the limits of astrology's validity, and explaining the cause of celestial movement. Given the constraints of space, the examination that follows will focus on the last of these.[5]

2 The Plotinian Study of Celestial Motion

Celestial motion is a topic to which Plotinus devotes an entire treatise, albeit a very short one, early in his writing career [*Enn.* 2.2] and he returns again and again to this topic throughout his career, leaving us with a handful of passages in the *Enneads* that offer some further information about his views.[6] Yet this material is not without its difficulties, as the dialectical approach of the treatise on celestial motion and the extreme concision of the other passages make definitive conclusions elusive. Nevertheless, it is possible to make out the main lines of Plotinus' position.[7]

Once again, it must be emphasized that Plotinus' interest in celestial motion was limited to its metaphysical underpinnings. All of his discussions are aimed

4 See esp. *Enn.* 3.1; 3.2–3; 4.4.6–8, 24–42.

5 For some recent discussion of the first and second themes, see Wilberding 2006, 41–70 and Adamson 2008, respectively.

6 See in particular *Enn.* 2.1.3.13–30; 3.2.3.28–31; 3.7.4.29–33; 6.4.2.34–49; and 4.4.16.20–31.

7 Richard Harder has suggested that these passages offer incompatible explanations of celestial motion and that Plotinus' views on the issue evolved over time [Theiler, Beutler, and Harder 1956–1971, 1b.534–35]. For an attempt at reconciling these passages, see Wilberding 2006, 66–68.

at a general explanation of the simple circular motion of the heavens, with no attention paid to specific or anomalous motions. In this respect, Plotinus' approach is comparable to that of Aristotle. For even if Aristotle does appropriate Eudoxus' system of concentric spheres in order to determine the number of unmoved movers, which is certainly more than can be said of Plotinus, he is content to leave all of the details of this system, including the exact number of planetary motions required, to mathematical astronomers and to focus his attention more narrowly on explaining the causes of simple circular motion [*De caelo* 2.10.291b8–10; *Meta*. 12.8.1073b10–13 and 1074a16–17].

3 Circular Motion and the Intellect

Right at the beginning of his treatise "On the Motion of the Heavens", Plotinus manages to put his explanation in a particularly pithy form:

> Why does it move in a circle? Because it is imitating Intellect.
>
> Διὰ τί κύκλῳ κινεῖται; ὅτι νοῦν μιμεῖται.
>
> *Enn*. 2.2.1.1: cf. 3.2.3.28–31

This succinct formulation left a massive impression on generations of subsequent philosophers, many of whom explicitly acknowledge it as Plotinus' legacy to philosophical astronomy.[8] As Plotinus would be the first to emphasize, this thesis of imitation has roots in Platonic texts; yet it is important that we appreciate the originality of Plotinus' contribution here. In the *Timaeus*, Plato establishes only a general association between circular motion and intellect but he neither explains this association nor characterizes the former as an

8 This account is explicitly attributed to Plotinus by Damascius, *De princ*. [Westerink and Combès 1986–1991, 3.75.8–12]; Proclus, *In rem pub*. [Kroll 1899–1901, 2.212.12–13]—cf. *In Eucl.* [Friedlein 1873, 147.20, where the subject of «φηςὶν» is left implicit, assuming that the text is correct as stands—and Philoponus, *In meteor*. [Hayduck 1901, 12.24–25]; *In de an*. [Hayduck 1897, 56.21–26, 138.33–139.1]; *De aet. mundi* [Rabe 1899, 486.17–18]. Simplicius credits "that divine man" at Heiberg 1894, 382.18–19. Many others appropriate Plotinus' formulation without attributing it to him. Some of these attribute it rather to Plato, e.g., Asclepius, *In meta*. [Hayduck 1888, 151.7–14: cf. 448.2–3, 450.27–28]. Others simply appropriate it, e.g., Eustratius, *In an. post*. [Hayduck 1907, 152.6–9], Sallustius, *De deis et mundo* [Rochefort 1960, 7.3.1–2], and often in Proclus *In Tim*. [Diehl 1903–1906, 1.203.1, 2.72.16–19, 2.77.16–17, 2.94.20–23].

imitation of the latter.[9] This is then expanded upon in *Leg.* 10.897e1, e5, and 898b3, where Plato characterizes circular motion as an image (εἰκών) of intellect and he now supports this characterization by pointing out that uniformity and sameness are key shared features of each [*Leg.* 10.898a8–b4].

3.1 *Imitation in Ubiquity*

For Plotinus, by contrast, the key shared features appear to be rather different and I should like to underline two of these here. In a brief report on Plotinus' cosmology in his commentary on Aristotle's *De anima*, Philoponus rightly draws attention to both of them, one of which is this:

> [The heavens] also imitate the Intellect, which is partlessly present everywhere, in another way. For just as that [viz. the Intellect] *is* everywhere, so too does the heaven *come to be* everywhere. By coming to be everywhere, then, it imitates that which is everywhere.[10]
>
> HAYDUCK 1897, 56.30–33

To be sure, Philoponus manages to articulate this explanation in a much clearer and more straightforward manner than we find in Plotinus. But what he is offering here is a very reasonable interpretation of one line of thought in *Enn.* 2.2. [esp. 2.2.1.39–51, 2.2.2.22–23, 2.2.3.17–22]. The Intellect is, for Plotinus, everywhere in the sense that it is identical to the Forms in which all things participate and the heavens are coming to be everywhere in the sense that over the course of a celestial revolution each of their parts comes to occupy the entire circuit. Nevertheless, one might be forgiven for thinking that the relation of imitation that holds between the heavens and the Intellect on this account is a bit thin. Ubiquity, after all, is only one of the Intellect's many superlative features and it is hardly its most central one, so why should the heavens' imitation of Intellect be limited to ubiquity?

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9 See *Tim.* 34a2–3, where circular motion is described simply as «περὶ νοῦν καὶ φρόνησιν μάλιστα». Plato does describe the generated gods, among whom the celestial bodies may be counted, as imitating the demiurgic intellect at 42e8; but no connection is made to circular motion here.

10 Philoponus returns to this explanation in slightly different formulations at Hayduck 1901, 12.28–31 and 1897, 138.33–139.2—both with explicit reference to Plotinus—cf. Hayduck 1897, 102.4–7.

3.2 *Imitation in Progression and Reversion*

The other shared feature, which is anchored in Plotinus' theory of procession and reversion, arguably leads to a more robust account of imitation. According to this theory, there is a single, ultimate principle, the One, from which all things derive, with Intellect being the first principle to be derived from it.[11] Plotinus frequently uses the image of the circle to represent the Intellect's relation to the One.[12] Here the One is likened to the center-point of the circle and the Intellect to the circle itself or, rather, the disk consisting of all possible radii of a given length proceeding from the center point.[13]

This is meant to illustrate a number of different features:

(1) procession: just as the center-point remains at rest while the radii proceed from it, so too does the One remain at rest while the Intellect proceeds from it [see, e.g., 4.2.1.28–29, 6.8.18.12–13];

(2) reversion: just as the circle turns back to itself and its center, so too does the Intellect turn back to itself, its contents (the Forms), and its source, the One [see, e.g., 1.7.1.23–24, 6.8.18.12–13: cf. 5.1.8.20–22];[14]

(3) continuity of principle and product: the One is the source of the Intellect just as the center is the starting-point in the construction of a circle; and just as each of the radii, while proceeding from the center, remains in contact with the center, so too does the Intellect continue to partake in the One even as it proceeds from it [4.2.1.23–27, 6.5.5.12–13, 6.8.18.24–25]; and

(4) compatibility of unity and plurality: just as the many radii partake of the single center-point, which *qua* point remains partlessly one, so too do the contents of the Intellect, the Forms, all participate in the One without their plurality compromising the One's unity [see, e.g., 4.2.1.27–28, 5.1.11.7–13, 6.5.5.16–23].

Given these parallels between the Intellect and circles, we may expect that the full explanation of what it means for celestial circular motion to be an imitation of the Intellect will go well beyond ubiquity as well as the uniformity and

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11 For a more detailed examination of the generation of the Intellect from the One, see Emilsson 2007.

12 See *Enn.* 1.7.1.23–28, 4.2.1.23–29, 4.4.16.23–27, 5.1.11.7–13, 6.5.5 *passim*, 6.8.18.8–24, 6.9.8 *passim*.

13 The Greek term «κύκλος» can mean "circle" or "disk" and even "sphere".

14 The circle reverts upon itself in that its construction may be seen as beginning at a point on the periphery, *A*, and moving along the periphery until it returns to *A*. Insofar as this motion itself is continuously reined in by the center-point (rather than going off in a straight line tangent to the periphery), we may say that the circle is reverting upon its center.

sameness highlighted by Plato. Indeed, according to Plotinus' ancient readers, it was above all circular motion's reversion toward itself and/or its center that explained its association with the Intellect [(2), p. 623].

Thus, when Philoponus, for example, reports verbatim that according to Plotinus the heavens move in a circle "because they are imitating Intellect", he immediately explains this in terms of self-reversion:

> For just as the divine and demiurgic Intellect, by reverting back upon itself, contemplates all things and Himself in those things, so too, he [viz. Plotinus] says, do the celestials, imitating this Intellect, effect a reversion to themselves.[15]
>
> HAYDUCK 1901, 12.24–27

Elsewhere, also with explicit reference to Plotinus, he explains it rather in terms of reversion to one's source:

> Since the inferior things revert upon their superiors, so too does the heaven, by moving in a circle, imitate the activity of Intellect.
>
> HAYDUCK 1897, 138.33–139.3

In fact, this equivalence between reverting upon one's source and reverting upon oneself is simply another feature that the Intellect shares with circles and circular motion, since the Intellect's reversion toward the One is for Plotinus tantamount to its apprehension of itself [see, e.g., 5.6.5.16–17, 6.9.2.33–43: cf. Emilsson 2007, ch. 2].

4 Plotinus on Celestial Motion

There is, however, another, deeper connection between imitation and reverting to one's source that plays an important role in Plotinus' understanding of celestial motion. According to Plotinus' general theory of emanation, each thing becomes, as it were, an (inferior) imitation of its principle by reverting

15 Philoponus also attributes this explanation to Plotinus: see Hayduck 1897, 56.21–30. Elsewhere one can find this same explanation of the association between circular motion and intellect given without reference to Plotinus, e.g., Hayduck 1897, 117.34–118.3, 124.33–125.11; Heiberg 1894, 4.1–5, 41.27–29; Hayduck 1888, 151.7–14; Sophonias, *In de an.* [Hayduck 1883, 9.21–22]; Hermeias, *In Plat. Phaed.* [Lucarini and Moreschini 2012, 22.8–13]. Cf. also Plotinus, *Enn.* 3.2.3.28–31.

back to that principle. Thus, not only is a star's circular motion an imitation of the Intellect's activity of reversion, it is also itself the result of the star's own activity of reversion back to Intellect, which is in a sense its principle. In other words, whereas Plato appears to be *describing* circular motion as bearing certain similarities to Intellect, for Plotinus "imitating Intellect" serves as a *causal explanation* of celestial motion [2.2.1.1 ὅτι νοῦν μιμεῖται] and his treatise "On the Motion of the Heavens" is devoted in large part to delivering this explanation in terms of the stars' bodies and souls. In doing so, Plotinus revises Plato's theory of celestial motion, partly in response to certain criticisms raised by Aristotle.

4.1 *Plato's Account*

For reasons of space, let us simplify things by limiting ourselves to three particular aspects of Plato's explanation of the motion of the stars. First, Plato does not think that the matter or body of the heavens or the stars plays any role in the explanation of celestial motion. Rather, second, he makes the soul alone responsible for the motion. That is to say, the soul is itself an extended circle moving in a circular motion and the celestial bodies are simply embedded in and carried around by this motion [*Tim.* 34b3–36d7].[16] Third, for Plato, there appears to be no final cause of the soul's circular motion: we are simply told that the Demiurge created it and set it in motion [*Tim.* 34b3–8, 36d4–7].[17] Aristotle subsequently criticized Plato on all three points[18] and in responding to these criticisms Plotinus appears to be pushing Plato's theory in a more Aristotelian direction.

4.2 *Aristotle's Criticism*

To begin with Aristotle's criticism of the celestial body, in the *Timaeus* Plato reasoned that the heavenly bodies are made up of the same four elements that constitute the sublunary bodies—earth, water, air, and fire—with fire predom-

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16 Whether these statements about the extension and circularity of the soul are to be taken literally is a matter of scholarly debate: see Johansen 2004, 139–142.

17 Particularly striking is Plato's description of the World-Soul's self-sufficiency:

> It is able to keep its own company and does not require anything else; as acquaintance and friend, it is sufficient to itself.
> αὐτὸν αὑτῷ δυνάμενον συγγίγνεσθαι καὶ οὐδενὸς ἑτέρου προσδεόμενον, γνώριμον δὲ καὶ φίλον ἱκανῶς αὐτὸν αὑτῷ. [*Tim.* 34b6–8]

18 On Aristotle's criticism of the body, see §4.3, p. 626. Regarding the soul's being extended and having spatial motions, see *De an.* 406b25–407b5; and regarding the final cause of celestial motion, see *De an.* 407b5–11. Some scholars have defended Plato by pointing out that the Demiurge's desire for the good provides the final cause. But Aristotle's point is that the celestial soul is the sort of thing that should itself be aiming at some goal when it acts.

inating in order to account for their luminosity. His reasoning is that earth is required to provide the body's solidity and tangibility, and fire for its visibility, with the other two being required for somewhat arcane mathematical reasons that we may skip over here.[19] Aristotle vehemently opposed Plato's view with arguments that left a lasting impression on subsequent thinkers, including Plotinus.

Briefly, Aristotle argued that since there must be one simple body corresponding to each simple motion, there must be another element unique to the heavenly bodies that corresponds to, and accounts for, their circular motion; and he added that unlike the sublunary elements, this fifth element must contain no contrary qualities if it is to be compatible with everlasting existence [*De caelo* 2.1–4 with Hankinson 2009]. This puts Plotinus in a difficult situation. Although he agrees with Aristotle that serious problems beset Plato's view that the four sublunary elements themselves constitute the heavens, he unambiguously rejects Aristotle's "assumption of the fifth body" and seeks to remain true to Plato [2.1.2.12–13]. His solution is to "listen more carefully to Plato" in order to develop an interpretation of Plato's view that steers clear of what he sees to be the major problems [2.1.7.1–2].

4.3 *Plotinus' Resolution*

What results, however, is a theory of celestial matter that appears to harmonize certain aspects of the Platonic and Aristotelian theories. Plotinus nominally reaffirms his Platonic commitment to all four elements being present in the heavens but he carefully distinguishes the celestial versions of the elements from their sublunary counterparts. He identifies celestial fire with a corporeal light that is distinct from both the incorporeal light and the flame that we may encounter here on Earth [2.1.7.20–31]. By contrast, the other three elements are present to the celestial fire simply as qualities: earth as solidity, water as cohesiveness, and air as lightness or softness [2.1.7.2–19].

The combination of these elements results in a special kind of celestial body that features in Plotinus' explanation of celestial motion in two ways. First, insofar as it is a fiery body, it has a natural desire to move in a straight line toward the periphery of the universe, where it must stop going in a straight line because there is no more space beyond the universe [2.1.3.13–18: cf. 2.2.1.21–22, 29; 4.4.16.29; 6.4.2.35]. Then, because its special constitution makes it uniquely amenable to the soul's needs and commands, this body is led around in a circle by soul [2.1.3.18–20: cf. 2.2.1.37–48].

19 *Tim*. 31b4–32c4, 39e10–40b8 (with *Epin*. 981d5–982a3): cf. Plotinus, *Enn*. 2.1.6.2–6.

As for the two criticisms directed at Plato's understanding of the soul, Plotinus is clearly interested in responding to these, too, although some of the details remain murky. One clear point that deserves much emphasis is that Plotinus sees the souls in the heavens as contemplating Intellect and being primarily directed to it. This teleological orientation toward Intellect that Plotinus often describes using the language of desire and love [see, e.g., 2.2.2.12–14, 22–23; 4.4.16.27–29: cf. 3.7.11.27–29] bears a much stronger resemblance to Aristotle's account of celestial spheres moving out of a desire for the Prime Mover, which is also an Intellect, than to Plato's celestial soul. The real difficulty that remains is explaining how the soul's desire for Intellect translates into circular motion without turning the soul into an extended magnitude that is itself moving spatially, as Plato appears to have done.

That Plotinus wants to distance himself from the literal reading of the *Timaeus*' claims about the soul being extended and moving in space is clear enough. Throughout the *Enneads*, Plotinus affirms that the soul is not something extended and that no soul has a spatial location, every soul being ubiquitous instead.[20] In *Enn.* 2.2, he then reinterprets the soul's circular motion as a spiritual motion. It is "a movement of self-concentrated awareness and intellect and of life, and at no point outside or elsewhere" [2.2.1.9–11: Armstrong 1966–1988, 2.41], and the center around which the soul is moving is not a center in any spatial sense but its source, Intellect [2.2.2.6–15]. While all of this might allow Plotinus to sidestep the criticisms that Aristotle directed at Plato's extended soul, this would seem to come at a high price since it is hardly clear why a *spiritual* circular motion of the soul should result in *spatial* circular motion of the celestial bodies.

Plotinus' most considered solution to this problem is to be found in the final chapter of *Enn.* 2.2. One part of his strategy here is to remind us that non-spatial motions of the soul giving rise to spatial motions in the body is a common phenomenon and he draws our attention to the motions the human body undergoes in response to joy or desire, which are also motions of the soul [2.2.3.12–15]. Yet Plotinus is fully aware that this analogy alone does not explain the genesis of circular motion and that he needs to say more about the psychology of the heavens, which he begins to do by distinguishing between two powers of the World-Soul. First, there is a higher power that is naturally capable of perception and opinionative reasoning and that keeps itself in the heavens; then, there is a lower power—indeed, Plotinus calls it the "lowest" power of soul—that is distributed across the entire universe [2.2.3.1–6].

20 See, e.g., 2.4.11.13–17, 4.2.1.62–76, 4.3.2.41–46, 4.3.22.14–15, 4.7.5.24–51, 5.8.2.35–38, 6.4.1, 6.4.4–5, 6.4.13, 6.9.5.40–46.

Some of Plotinus' remarks elsewhere might encourage us to posit a third part or power of the World-Soul, above both of these, one that is not in the sensible universe at all and whose thinking is not merely opinionative [see, e.g., *Enn.* 2.3.9.31–34: cf. Karfik 2007, 368]. Yet no such higher power is invoked here and the way in which Plotinus transitions directly from the perceptive and opinionative power to Intellect suggests that he might be conceiving of this power as encompassing not just perception and opinion but also its intellective powers [2.2.3.17–22]. We may leave this issue aside, however, since what interests us most in the present context is how Plotinus sees these two powers as working together to solve the problem outlined above.

This distinction is introduced apparently to provide a certain division of labor. Only the lower power of soul is said to be "interwoven" with body[21] and this interwovenness is the key to explaining the translation of psychological motions into spatial motions. Soul is bound up with body in such a way that its activities are no longer separable from body and this allows Plotinus to maintain that this soul (or power of soul) is in this limited sense extended and engaged in a spatial motion, while avoiding the objectionable thesis that soul *per se* is extended. Thus, the lower power is the one directly responsible for the circular motion of the heavens: "It leads round the body with which it is interwoven (περιάγει τὸ cῶμα, ἐν ᾧ ἐμπέπλεκται)" [2.2.3.10].

As we saw above, for Plotinus all souls and intellects are essentially determined by a spiritual motion of reversion to their respective source and this is also the case for this lower power of soul: it reverts back to the higher power, which serves as the final cause of the lower power's motion [2.2.8–10]. Yet the interwovenness of the lower power appears to have two important consequences for its reversion. First, it does not revert in its entirety; rather, only that part of it that is closest to its source—the part in the heavens—reverts [2.2.3.7–8]. This further division of the lower power into sublunary and celestial parts might seem redundant but it is necessary to confine the circular motion to the celestial region. Second, this reversion is at once spiritual and spatial: its circular motion *is* a motion of reversion to the higher power [2.2.3.8–10, 15–17].

Determining the sense in which the higher power of soul may also be said to be extended and engaged in spatial motion is more difficult. One might have expected that, since the spatial motion of the heavens has now been accounted for by the lower power, the higher power would be free to be wholly non-spatial and spiritual; but the account of the lower power's motion examined above would seem to demand that the higher power is itself circular in some spatial

21 See «διαπλεκεῖcα» at 2.2.3.2 (with reference to *Tim.* 36e2) and «ἐμπέπλεκται» at 2.2.3.10.

sense and this is partially corroborated by Plotinus' repeated use of spatial language to describe it. He says the higher power keeps itself "among the spheres (ἐν ταῖϲ ϲφαίραιϲ)" [2.2.3.4] and he twice describes it as "containing [the lower power] within a circle (κύκλῳ περιεχούϲηϲ)" [2.2.3.7].[22] There is even some suggestion that it, too, is undergoing some spatial motion.[23]

Nevertheless, it cannot be spatial in quite the same way as the lower power. For, whereas the lower power is "interwoven" with body, the higher power is said to be "borne upon (ἐποχουμένη)" the spheres, a term that Plotinus elsewhere uses to describe the relation of the highest soul, which remains in the intelligible region, to the descended soul and its body [2.2.3.4–5: cf. 4.3.7.17, 6.7.5.23–30]. Thus, even if this power is undergoing a spatial circular motion—and there is some reason for doubt here—this motion cannot be responsible for the circular motion *of bodies*.[24] It would seem that the most that can be said on this front is that the higher power must be spatially circular in some minimal sense that allows it to function as the final cause of the lower soul's circular motion but that neither it nor its own brand of "circular" motion is really spatial, as Plotinus urged us to see at the start of the treatise [2.2.1.9–11].[25]

5 Conclusion

This gap in Plotinus' explanation is particularly disappointing in light of the great potential that the stars have for Plotinus' theory of agency. For the stars emerge from Plotinus' account as viable candidates for being perfect moral agents. They are free of affections [see, e.g., 2.9.5.4–5, 4.4.42.23–30] and always

22 The contrast between the higher soul's "containing" function and the lower power's "having run upward (ἀνέδραμε)" echoes an explanation of celestial motion described at 2.2.1.14–19.

23 At 2.2.3.19–20, Plotinus characterizes this power as «πρὸϲ τὸ πανταχοῦ ϲυμφέρεται», which has been understood by some scholars, e.g., Kalligas 2014, 276, as an ascription of spatial motion.

24 «ϲυμφέρεται» ("is carried along") is a verb of passive motion (note the contrast in 2.2.1.3–5) and would be an infelicitous choice to refer to any motion, be it spatial or spiritual, for which the soul power itself is supposed to be responsible. Perhaps Plotinus only means that the higher power is accidentally subject to the motion of the spheres insofar as it is "borne upon" them as they are moved by the lower power, as he himself suggested at the start of the treatise: Ἢ ἴϲωϲ οὐδὲ τοπικὴ ἡ κύκλῳ, ἀλλ' εἰ ἄρα, κατὰ ϲυμβεβηκόϲ [2.2.1.8–9]: cf. Aristotle, *De an*. 406a16–20.

25 For one attempt at a more detailed account of this manner of spatiality, see Wilberding 2005.

contemplating, devoting their entire attention to the intelligible principles.[26] And yet they are hardly entirely divorced from the goings-on in the sublunary world. On the contrary, their movements are in tune with sublunary events, signaling what is to come; and they even influence sublunary agents to some degree, while being absolved of any responsibility for evil.[27] Thus, even if Plotinus is largely content to leave this implicit, the stars appear to offer a model solution to the age-old dilemma between the contemplative life and the practical life, with their actions simply flowing, as it were, from their contemplative activity [Wilberding 2008].

26 See, e.g., 2.3.3.22–25, 2.3.9.34–42, 4.4.7.1–2, 4.4.8.34–61, 4.4.35.37–44.

27 See Adamson 2008 for specific passages and analysis.

Historical Glossary of Important Terms in Hellenistic Astronomy

This Glossary collects terms found in the texts and contexts of Hellenistic astronomy. In keeping with the conception of Hellenistic astronomy developed in the present volume, it aims not so much to understand these terms and their related concepts as they are understood today but, so far as possible, to decipher their sense as they were understood by those engaged in the various Hellenistic astronomies. Accordingly, this Glossary is historical, indeed philological, in nature and it assumes a geocentric cosmology.[1]

It is also incomplete in two senses: first, it does not collect all the terms used in Hellenistic astronomy and its diverse contexts but focuses mainly on those that figure in this particular volume; and second, most of the entries concern terms as they were used in only some of the relevant languages. There is, then, much work to be done before we have a proper historical Glossary of Hellenistic astronomy. The present offering is but a first step.

Anomaly (ἀνωμαλία, *anomalia*)
If a motion (κίνηϲιϲ) varies, that is, if it is not always the same (ὁμαλή: cf. ὁμή) and so is uneven, unsmooth, or irregular (ἀνωμάλη), it has anomaly. The angular motion of all the planetary bodies is anomalous because it is faster at perigee and slower at apogee.

a. Moon
   1. first lunar
      The periodic variation in the Moon's velocity or daily progress in longitude, i.e., its variable angular velocity. The period of this anomaly is the anomalistic month [see Month, lunar: a].
   2. second lunar
      This is the periodic variation in the Moon's motion as its elongation from the Sun increases and decreases. This second lunar anomaly is also called evection.

b. Sun
   The periodic variation in the Sun's angular velocity or daily progress in longitude as it revolves around Earth. The period of this anomaly is the tropical year [see Year: b].

1 Terms given in italics are defined elsewhere in the Glossary. In lists of terms in more languages than Greek and Latin, the terms are preceded by letters as follows:

A	for Akkadian	Ar	for Aramaic	E	for Egyptian
G	for Greek	L	for Latin		

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c. Planets
  1. first or solar
     To an observer on Earth, each of the five planets appears in the course of its direct motion eastward to vary in the amount and direction of its daily progress as it makes stations and retrogradations. Such periodic variation in eastward motion is an anomaly with respect to the Sun because it is a matter of the planet's elongation from the Sun.
  2. second or zodiacal
     Again, to an observer on Earth, the five planets make a periodic variation that correlates to the variation in the longitude where their stations and retrogradations are observed to occur as well as to a variation in the distance between their first and second stations. This variation is an anomaly with respect to the ecliptic or zodiacal circle [see Circle: k] because it relates to the planet's longitude.

Ascendant. See Horoscopus

Aspect (*aspectus*, *facies*)
There are two ways of defining aspects. In the first, the aspects are defined in terms of how the seven *planets*—that is, the five planets (Saturn, Jupiter, Mars, Venus, Mercury) and the two luminaries (the Sun and Moon)—stand in relation to one another and thus look (*aspicere*) to one another. Thus,

a. opposition (κατὰ διάμετρον)
   Two such planets standing at the ends of the same diameter of the zodiacal circle [see Circle: k], that is, 180° from one anther, are in opposition.
b. quartile (κατὰ τετράγωνον)
   Two planets that are 90° from one another are in a quartile aspect and form a side or sides of tetragon (τετράγωνον, *quadratum*).
c. sextile (κατὰ ἑξάγωνον)
   Planets that are 60° from one another are in a sextile aspect and form a side or sides of a hexagon (ἑξάγωνον, *hexagonum*).
d. syzygy (κατὰ συζυγίαν) or *antiskian* (κατ' ἀντισκίαν)
   Two planets that are contained by the same parallel circles (defined by the rotation of the celestial sphere [see Circle: b]) and thus rise from the same place and set at the same place are in syzygy. Such planets "cast shadows" in opposite directions. They are also equidistant from *Midheaven* or *Lower Midheaven*.
e. trine (κατὰ τρίγωνα)
   Planets that are 120° from one another are in a trine aspect and form a side or sides of a trigon (τρίγωνον, *trigonum*, *trigon*).

In the second, the aspects are relations between zodiacal signs [see Sign, zodiacal: b]. The definition of the particular aspects in this second sense are analogous to those above.

Astrology, Hellenistic: types

a. catarchic

The determination of the astrological circumstances for or at the occurrence of some undertaking or event.

1. election

The determination of the best time to begin some undertaking.

2. event

The interpretation of an event that has occurred based on the time of its occurrence.

3. decumbiture (κατάκλιϲιϲ)

The determination of the course and outcome of an illness based on the time when the invalid took to his or her bed.

4. interrogation

The determination of the outcome of an event such as a burglary or of a horoscope cast at the time when the question about the event was asked of the astrologer.

b. general (universal, mundane)

The prediction of events for countries, cities, states, and their populations based on periodic celestial phenomena. It may include the determination of the best time for founding a city or the interpretation of the horoscope cast at the time the city was founded.

c. natal (genethlialogical)

The interpretation of the native's life based on the birth horoscope, which connects the time and place of birth to the positions of the Sun, Moon, and five planets as well as to the orientation of the zodiacal circle [see: Circle: k].

d. hororary. See Astrology, Hellenistic: types a.4

Astronomy, Hellenistic: names

a. Babylonian

There was no Akkadian term for either astronomy or astrology. Astronomy was subsumed under the scribal art (*ṭupšarrūtu*) and also classified with wisdom (*nēmequ*). Neither «ṭupšarrūtu» nor «nēmequ» should be translated by "astronomy".

Although there was no term for astronomy/astrology, the term for astronomer/astrologer was "ṭupšar *Enūma Anu Enlil*" ("scribe of [the celestial omen series] *Enūma Anu Enlil*"). This title has traditional roots going back centuries, at least to the seventh century BCE in the celestial-divination advisers to the Neo-Assyrian royal court. However, the title itself, "ṭupšar *Enūma Anu Enlil*", is much more frequently attested in the colophons of Seleucid astronomical texts that identify the scribal owner or copyists of astronomical tables (*tērsītu*).

b. Early Christian

For early Christians, astronomy and astrology were analogous terms, almost invariably considered negatively. Following Jewish apocryphal tradition, knowledge of the stars was taught to humans by fallen angels. Christians continued, in the main, to consider astronomy to be demonic. The Christian idea that astrology was demonic knowledge derives from two influential texts: 1 Enoch and the interpretation of Gen. 6:1–4 by Philo Judaeus (Alexandrinus). On the development of this claim by Christian writers to persuade one another and to separate themselves from non-believers, see Greenbaum 2009, app. 3A.

c. Egyptian

The Egyptian language did not have a general term for either astronomy or astrology, though there is evidence that both subjects were known to them under some description and practiced.

First is the documentary evidence of lunar omens and horoscopes in Demotic and belonging to that period from the sixth century BCE onward in which Egyptian astronomy, while continuing a traditional interest in matters of timekeeping (divisions of the day or hours, lengths of daytime and nighttime, the risings and settings of fixed stars and planets, the lunar and solar calendars), acquired new practices and knowledge due to the influence of Babylonian astronomy.

Next is the evidence of the titles of those who had knowledge of the heavens. In a linguistic tradition over four millennia, Egyptian vocabulary shifted considerably. Old Egypt records the words for "teach" and "star" as homophones («sbꜣ») but no astronomical texts have survived from this early era. In Middle Egyptian and Demotic, the phrase «imy-wnw.t» ("who is in the hour") described a class of priests charged with a body of astronomical knowledge that was extended under the influence of Babylonian astronomy. An autobiographical inscription on the funerary statue of the *imy-wnw.t* priest Harkhebi lists his competencies. Although this list details a wide range of observations, calculations, and predictions, it does not record a lexical category analogous to astronomy. A similar list of astronomical skills appears in the Temple of Edfu. In some cases, the *imy-wnw.t* priest is expected to know (*rḫ*) astronomical topics that included astrological prognostication. The verb «rḫ» may be connected with calculations, especially those computed by tables; but the word has a wide semantic range. In Coptic, the most recent phase of the Egyptian language, two terms referred to practitioners of astral sciences. The first term, «ρεϥωπ μνcιου» ("man who calculates the stars"), may be a calque for the Greek «μαθηματικός». The second term, «ρεϥκα ουνου» ("man who calls the hours"), represents an indigenous tradition with a long history.

d. Greco-Roman

The three terms for astronomy—«ἀcτρονομία», «ἀcτρολογία», and «μαθηματική»—were established in classical times, well before the question of horoscopic astrology arose in the Greco-Roman world. For Plato, the term of choice was «ἀϲτρονομία», a term which indicates by its formation the study of the grouping of fixed stars into constellations («ἄϲτρον + νέμω») or, more generally, the study of the temporal and spatial order governing the behavior displayed by the heavens («ἄϲτρον + νόμοϲ»).

For Aristotle, however, the preferred term for astronomy is «ἀϲτρολογία», presumably because of its emphasis on theory or reasoning (λόγοϲ). (There is no occurrence of «ἀϲτρονομία» in the corpus of his writings.) As Aristotle uses it, «ἀϲτρολογία» should be rendered as "astronomy" and never by "astrology". To emphasize that such theorizing may draw on mathematical argument, Aristotle often writes of astronomy as μαθηματική and astronomers as μαθηματικοί. In these contexts, it is an egregious mistake to render these terms by "mathematics" and "mathematicians", since, for him, the mathematical science of astronomy is neither mathematics *simpliciter* nor a branch of mathematics like arithmetic and geometry nor applied mathematics. Depending on context, what Aristotle means by the former is either mathematical science or the particular science mathematical astronomy (ἀϲτρολογία); and by the latter, either mathematical scientists or the subset of mathematical astronomers (ἀϲτρολόγοι).

In Hellenistic times, the term chosen for astronomy, that is, for the science that concerns timekeeping and the determination of the positions of the celestial bodies at any given moment, is significant insofar as it indicates an allegiance or bias and so affords a key to understanding an author. Thus, for Hipparchus, «μαθηματικόϲ» signifies technical expertise in astronomy and so does not apply to the likes of Aratus, whom he regards as a mere ἀϲτρολόγοϲ at best. Again, although Philo uses «μαθηματική» for astronomy, it is apparently not his own term: he more commonly calls it ἀϲτρονομία and thereby brings out a Platonic emphasis on celestial order. But whether it is ἀϲτρονομία or μαθηματική, for Philo, astronomy includes the Chaldaean science (ἐπιϲτήμη) of astral divination. Thus, he puts predictive and prognosticatory astronomy under the same rubric and, by emphasizing the order disclosed by this science, he suggests a way to the abandonment of many of its key tenets, especially its astrology, in favor of an understanding of the cosmos that is in accord with Scripture as he interprets it.

In the main, however, in Greek and Latin texts of the Hellenistic Period, the term for astronomy used by writers such as Strabo, Geminus, Vitruvius, and Pliny, who typically took a stand in favor of or against the inclusion of astrology in the traditional science, was «ἀϲτρολογία»/"astrologia".

Ptolemy's usage merits special notice because, to judge from what has survived and is currently known, he redefined astronomy by synthesizing the projects of Babylonian mathematical astronomy with Greek descriptive astronomy to establish a unified predictive science that included horoscopic astrology. In positing a single science called ἀϲτρονομία in which predictions about Sun, Moon, and ἀϲτέρεϲ serve as the basis for prognostications about the impact of their motions and configurations on the sublunary realm, he did not assign a special term either to predictive astronomy or to prognosticatory astronomy. Indeed, in his works, the former is variously called ἀστρολογία and ἀστρονομία; and its practitioners are often called μαθηματικοί—their discipline, though never identified simply as μαθηματική, falls under τὸ μαθηματικόν, i.e., that part of theoretical philosophy concerned with the heavens. The practitioners of the second, whom Ptolemy usually calls ἀστρολόγοι—their science being ἀστρονομία and, implicitly, ἀστρολογία as well as μαθηματική—are often said by others to be Chaldaeans and μαθηματικοί/*mathematici*.

e. Judaic, Late Second Temple

There is no overall terminology for astronomical or astrological concepts in either the Hebrew or the Aramaic Jewish texts. Astronomically-related nouns appear across several genres of different origins in various forms related to the heavenly bodies. One Aramaic narrative refers collectively to "all the constellations of the heaven, the Sun, the Moon, and the stars" [The Genesis Apocryphon ar]. A Persian loan-word, «raz », understood as "mystery", appears as an unknown quality in a number of Hebrew Wisdom-texts; some scholars relate it to the horoscope, depending on its context. It is also used poetically, for example, in The Thanksgiving Psalms: "…luminaries according to their mysteries, stars according to [their] paths…". Some detailed Hebrew and Aramaic astronomical calendrical texts use vernacular language to describe lunisolar phenomena technically on certain days in the month. Thus, it is said that the Moon's light is "completed" at the Full Moon (mid-month) and that the Moon's disk is "obscured" [*4QcryptA Lunisolar Calendar*] or "empty of all light" [4QAstronomical Enoch^{b} ar] at conjunction (end of the month).

f. Mandaean

In Mandaic, the term for astrologer is "kaldaia" (i.e., "Chaldean"), often used in a pejorative sense. The term "madna" is used for horoscope. The Mandaeans did not, so far as one can tell, have a general term for either astronomy or astrology. Yet, a Mandaean compendium of celestial knowledge is attested in the *Book of the Zodiac* (*Aspar maluašia*).

Band, zodiacal (ὁ τῶν ζῳδίων κύκλος, ὁ ζῳδιακὸς κύκλος; *circulus zodiacus*)

A band, otherwise known as the zodiac, that is equidistant above and below the zodiacal circle [see Circle: k]. Its width is set variously. The earliest specification comes from Geminus, who sets it at 12° without explanation. Pliny, like many others later, accepts this value; but, while he recognizes that this is just wide enough to accommodate the latitudinal motion of the Moon, he allows that it is not wide enough for Venus, which, as he says, can extend 2° on either side. Olympiodorus later gives the width of the zodiacal band as 20°, perhaps in aiming to buttress the theory that comets arise when planets approach fixed stars by accommodating the value of $\pm 8;56^\circ$ for Venus' latitudinal motion given in Ptolemy's *Handy Tables* and thus accounting for a comet observed in 565 CE. In *PMich.* 149, the width is given as 48° but this is perhaps a slip in which the zodiac is confused with the band about the celestial equator that is defined by the Sun's oblique course.

The band is "zodiacal" because of its division into *dodecatemoria* [see *Dodecatemorion*: a] named after the zodiacal constellations [see Constellation: b].

It is clear in some Babylonian astronomical contexts that the *lumāšū* (written LU.MAŠ.MEŠ) represent the 12 zodiacal signs [see Sign, zodiacal: b] that the Sun traverses in its path. There is a phrase attested for the Sun's "forward motion (progress) in longitude", namely, «zi ᵈšamaš ina LU.MAŠ.MEŠ» ("forward motion of the Sun through the zodiacal signs").

Calendar

These instruments for regulating the activities of a community typically required identifying a lunisolar cycle in which some number of lunar months is identified with a number of years, and, sometimes, a number of days or a solar cycle in which one year is identified with a number of days. Thus, for example, the Metonic Cycle is a lunisolar cycle with $19^y = 235^m = 6940^d$, whereas the Babylonian 19-year cycle, from which it derives, has only $19^y = 235^m$. To understand an ancient calendar, it is important to know the epochs of the temporal units in the cycle [see Epoch]. In lunar-stellar and lunisolar calendars, it is also important to determine how the sequence of 29- and 30-day months—hollow and full months, respectively—was established in practice. If it was not by direct observation but by some scheme or calculation, one should determine whether it included intercalation. For example, in the Babylonian 19-year calendar of the Seleucid Era, there are 7 intercalary months inserted in years 1, 4, 7 9, 12, 15 (where the intercalary month is a second month XII or intercalary Addaru) and in year 18 (where the intercalary month is a second month VI or intercalary Ulūlu). In this way, the first month, Nisannu, is kept near the vernal equinox [see Table 1, p. 638].

Cardinal points

a. equinoctial

One of two points (σημεῖα, *puncta*) in the Sun's path or zodiacal circle [see Circle: k] defined by its intersection with the equinoctial circle [see Circle: c]. The point on the Sun's course northward is the vernal equinoctial point; the point on its southward course, the autumnal equinoctial point.

b. solstitial

One of two points on the Sun's path or zodiacal circle where the Sun reaches its greatest distance from the equinoctial circle. The point where the Sun turns southward is the summer solstitial point; the point where it turns northward, the winter solstitial point.

TABLE 1 The epochs in select Hellenistic calendars

	Babylonian	Greek	Egyptian		Roman	Judaean	Mandaean
calendar	lunisolar[a]	lunisolar	luni-stellar[b]	fixed [c]	Julian[d]	lunisolar-zodiacal[e]	solar[f]
day	sunset	sunset	morning twilight	morning twilight	midnight	sunset	morning twilight

a Based on the cycle $19^y = 235^{syn.\,m}$ established in 475 BCE.

b Based on the cycle of $25^y = 309^m = 9125^d$ with intercalations intended to keep its months in accord with those of the wandering calendar.

c Based on the cycle $1^y = 12^m \times 30^d + 5^d$ with a sixth day added in every fourth year. The Egyptian wandering year, which is older—it was in use in the Old Kingdom (2664–2115 BCE)—is the same but without the addition of the sixth day in the fourth year. This wandering year returns to synchrony with the Sun in 1,461 of its years = 1460 fixed years (the Sothic Period). Both calendars were used in civic life.

d Based on the cycle $1^y = 12^m = 365^d$ with 1 day intercalated every 4 years. The names and lengths of the months varied throughout the Roman Empire.

e As reconstructed, the schematic Aramaic calendars 4Q318 and 4Q208–4Q209 are based on a cycle in which $19^y = 235^{syn.\,m}$. In 4Q208–4Q209, the zodiacal signs are represented by numbered "gates". This 19-year cycle is determined mathematically: in 4Q318, and in 4Q209 fr. 7.col. 3, the same astronomical configuration of (a) solar and lunar positions in a zodiacal sign and (b) the lunar phase is repeated every 19 years on the same dates as they appear in the texts [Jacobus 2020a].

4Q318 lists day-by-day of each lunar month the Moon's zodiacal sign in a cycle of $1^{sol.\,y} = 360^d = 12^{lun.\,m} \times 30^d$. The zodiacal signs and Aramaic lunar month-names are explicit.

4Q208–4Q209, in a cycle in which $1^{lun.\,y} = 6 \times 29^d + 6 \times 30^d$ (alternating) $= 354^d$, detailing the phases of the Moon, when it rises and sets, and its zodiacal sign by means of a "gate" number. This cycle is harmonized with a solar year of 360^d. This solar year is inferred from the entrance of the Sun into a gate, based on the Sun's passage through the 360° of the zodiacal circle and the solar year-length of 4Q318.

There is no historical data on how the Aramaic or Hebrew calendars from Qumran were intercalated. See Jacobus 2020a.

f Based on the cycle, $1^y = 12^m \times 30^d + 5^d$ with 5 epagomenal days after month VIII.

TABLE 1 The epochs in select Hellenistic calendars (*cont.*)

	Babylonian	Greek	Egyptian		Roman	Judaean	Mandaean
month	day of Moon's first visibility after conjunction	day of Moon's first visibility after conjunction	first day of Moon's invisibility before conjunction	morning twilight at the end of day 30 of a month or epagomenal day 5	midnight at the end of the last day of a month	*lunar*—day of Moon's first visibility after conjunction in the zodiacal sign following the Sun's sign [4Q318] or in the same sign [4Q208–209] *solar*—the Sun's entry into a zodiacal sign	morning twilight at the end of day 30 or epagomenal day 5
year	first lunar visibility at/after vernal equinox	— [a]	heliacal rising of Sothis (Sirius)	heliacal rising of Sothis (Sirius)	various[b]	first lunar visibility at/after vernal equinox; the Sun is at Aries 0°	the first day of the first month (M *awwal sitwa*, Ar *šabaṭ*) of the winter season (months I–III)

a The Athenian calendar is best known of the Greek calendars. Its record shows wildly variable month- and year-lengths.

b E.g., the Julian year in Egypt (the Alexandrian year) began with Thoth 1 on Aug 29 of the Julian year in Rome; and in Asia, with Dystros 1 on Augustus' birthday (Sep 23).

Cardine (*cardo*). For Ascendant, see Horoscopus. See Midheaven, Descendant, Lower Midheaven.
Note that, the arcs from the Ascendant and Descendant to Midheaven and Lower Midheaven vary during the course of the year because of the different orientations of the zodiacal circle [see Circle: k].

The cardines are today often called angles.

Celestial sphere. See Sphere of fixed stars

Chronocrator or Time-Lord (χρονοκράτωρ)
A planet that rules a certain period of life.

Circle (κύκλος; *circulus*, *orbis*)

a. colure (ὁ κόλουρος [κύκλος]; *colurus*)
   There are two colures: the equinoctial colure goes through the poles of the zodiacal circle and the two equinoctial points [see Cardinal points: a]; the solstitial colure, through these same poles and the two solstitial points [see Cardinal points: b].
b. day-circle
   The parallel circle that any celestial body describes from east to west as a result of the daily rotation of the celestial sphere.
c. deferent
   A circle that has the center of another circle, an *epicycle*, on its circumference.
d. *dodecatropos* (δωδεκάτροπος)
   The circle through the four *cardines*. Though this circle is thought to rotate, it is the zodiacal circle [see Circle: k] which rotates as its degrees coincide in succession with the *cardines*.
e. eccentric (ὁ ἔκκεντρος [κύκλος])
   A circle that does not have the Earth at its center. Martianus Capella does not write of the planet's orbit being eccentric; instead, he prefers to say that the Earth is eccentric (*telluris eccentros*) to the orbit.
f. epicyclic (ὁ ἐπίκυκλος [κύκλος]; *epicyclus*)
   A circle that has its center on the circumference of another circle, the *deferent*.
g. equinoctial (ὁ ἰσημερινὸς [κύκλος], *circulus aequinoctalis*)
   The parallel circle that the Sun describes from east to west on the day of equinox as a result of the daily rotation of the celestial sphere.
h. horizon circle (ὁ ὁρίζων [κύκλος])
   The observer's horizon construed as a circle projected onto the *celestial sphere*.
i. hour
   One of 24 meridians of longitude that divide the equinoctial circle into hours, viz. equal arcs of 15°.

j. meridian (ὁ κατὰ κορυφὴν [κύκλος], *meridianus*)
The great circle though the poles of the sphere of the fixed stars and the observer's zenith. This circle divides *daytime* and *nighttime* into two equal intervals.

k. zodiacal (ὁ ζῳδιακὸς [κύκλος], *circulus/orbis zodiacus*)
The projection onto the celestial sphere of the path described by the Sun in its annual eastward motion. In Greek, it is sometimes designated as the circle through the middle of the zodiacal signs (ὁ διὰ μέσων τῶν ζῳδίων) [see Sign, zodiacal: b], where the signs in question are the divisions of the zodiacal band, i.e., the *dodecatemoria* [see *Dodecatemorion*: a].

Colure. See Circle: a

Constellation ([κατηστερισμένα] ζῴδιον, ἄστρον; *signum*, *stella*, *sidus*, *astrum*)

a. A grouping of *fixed stars* in a shape typically of a living creature and from the very beginning associated with myth. Note: though «ζῴδιον» originally designated the representation of a living creature or animal, it soon included the representation of any object.

b. zodiacal
A constellation through which the Sun passes on its annual course eastward.
The Babylonian word for a zodiacal constellation was «lumāšu» and in Seleucid astronomical texts occasionally a zodiacal sign could be designated with the pseudo-logogram «LU.MAŠ».
Though Greeks and Romans recognized 13 constellations on or near this path, it was from early on the custom to speak of 12. For their names, see Table 1, p. 12, Table 2, p. 47. The zodiacal constellations neither divide the path of Sun into equal arcs nor do they reach to the same distance above and below this path either severally or collectively.

Day (A *ūmu*, *me*; G ἡμέρα, νυχθήμερον; L *dies*)
The interval from one epoch (e.g., the setting of the Sun) to the next. The length of the day actually varies throughout the course of the year. This variation, which is not the same as the annual variation in *daytime*, has a trigonometric component due to the inclination of the Sun's path or zodiacal circle [see Circle: k] to the equinoctial circle [see Circle: c] and a physical component due to the variation in its speed along this path [see Equation of time].

Daylight
The interval from the start of morning twilight to the end of evening twilight.

Daytime (A *me*; G ἡμέρα; L *dies*)
The interval from one sunrise to the next sunset. This interval, i.e., daytime, increases and decreases throughout the year; it is longest on the day of summer *solstice* and shortest on the day of winter *solstice*.

Decan (E *bꜣk.tjw, bꜣk.ti͗.w*; G δεκανός)
a. One of 36 small groups of stars that rise consecutively every 10 days. They were used to mark divisions of *nighttime* into decanal hours [see Hour: c].
b. A 2½°-arc of a zodiacal sign [see Sign, zodiacal: b].
c. A 10° arc of a zodiacal sign [see Sign, zodiacal: b].
d. The divinity presiding over a decan [see Hour: c].
These assignments of divinities were made by taking the planets in their Chaldaean order [see Planets, order: b.1], beginning with Aries.

Depression (ταπείνωμα; *deiectio*)
The point in the zodiacal circle where a planet has its weakest influence. It is located 180° from the planet's *exaltation*.

Descendant (δύσις)
The part of the zodiacal circle [see Circle: k] (specified either by zodiacal sign [see Sign, zodiacal: b] or by the degree of a zodiacal sign) that intersects the client's horizon [see Circle: h] in the west at the occurrence of some event in question.

Dodecatemorion (δωδεκατεμόριον; *dodecatemorium*)
a. One of the segments of the zodiacal band [see Band, zodiacal] when divided crosswise equally into 12. The *dodecatemoria* were given the names of the zodiacal constellations [see Constellation: b]. They were also called zodiacal signs [see Sign, zodiacal: a].
b. One of the arcs of a zodiacal sign [see Sign, zodiacal: b] when divided equally into 12.

Dodecatropos. See Circle: d

Ecliptic. See Circle: k

Epoch (ἐποχή; *epocha*)
a. In ancient astronomy, the position of a celestial body at a characteristic moment, e.g., a first appearance. Tables of the dates when the body has these positions are called epoch-tables.
b. The fixed moment in time when some calendrical interval begins.

Equation of time
The difference between the local mean time (the time of *day* measured in equinoctial hours [see Hour: b]) and the local apparent time (as indicated by the Sun, say, on a sundial or by its position on its day-circle [see Circle: b]). This difference varies throughout the year. As Ptolemy realized, the key to its numerical quantification is to define the epoch of the day as the Sun's crossing the observer's meridian [see Circle: j]. (He chose the *daytime* crossing.) When plotted over the course of a solar year, this difference describes a closed figure-8 known as an analemma.

Equator, celestial. See Circle: g

Equinox (spring, fall: ἰσημερία; *aequinoctium*)
One of two days of the solar year in which nighttime and daytime are equal in length. When the Sun is at the vernal equinoctial point, it produces the vernal or spring equinox; when it is at the autumnal equinoctial point, the autumnal or fall equinox [see Cardinal points].

Evection. See Anomaly, Moon: a.2

Exaltation (A *bīt niṣirti*; G ὕψωμα)
The zodiacal signs [see Sign, zodiacal: b] in which a planet has its most potent influence. The following are the Greek exaltations (ὑψώματα):

Sun	at	Aries 19°
Moon		Taurus 3°
Mercury		Virgo 15°
Venus		Pisces 27°
Mars		Capricorn 28°
Jupiter		Cancer 15°
Saturn		Libra 21°

The Babylonians (already prior to the invention of the *zodiac*) located a similar place in the heavens, a region called *bīt niṣirti* (house of the secret), where a planet had a particularly propitious significance. Obviously, these *bīt niṣirti* were not given as degrees within a zodiacal sign but simply as one or another region of the zodiacal constellations [see Constellation: b]. The locations of the Greek *exaltations* agree with the Babylonian assignments of the *bīt niṣirti* in all cases except that of Venus, which in the omen literature is in the constellation Leo and in the horoscopic literature, in the zodiacal sign Pisces.

Exeligmos (ἐξελιγμός).
According to Ptolemy [*Alm.* 4.2], the *exeligmos* is an eclipse-cycle equal to three Saros-Cycles [see Saros: b] in which:

19,756 days = 669 synodic months
= 717 anomalistic months
= 726 draconitic months
= 723 revolutions in longitude + 32°
≈ 54 years

This cycle was known earlier to Geminus [*Intro. ast.* c. 18], who does not mention the Saros-Cycle or the equation with 726 draconitic months.

Face (πρόσωπον). See decan: c, d
For the faces, see Table 3, p. 465.

Horoscopus (ὡρόσκοπος: *horoscopus*)
The part of the zodiacal circle [see Circle: k], specified either as a zodiacal sign [see Sign, zodiacal: b] or as a specific degree of a zodiacal sign, that intersects the client's *horizon circle* in the east at the occurrence of birth or the event in question.

Babylonian horoscopes do not employ this concept.

Hour (G ὥρα; L *hora*)

a. seasonal (A *simanu*)
   1⁄12 of *daytime* or of *nighttime* on any *day* but a day of *equinox*. On all such days, the lengths of daytime and nighttime are unequal for any observer who is not at the terrestrial equator. This means that seasonal hours of daytime are not equal to seasonal hours of nighttime either in the same day or in different days.
b. equinoctial
   1⁄12 of daytime or of nighttime on the day of equinox. On these days, the length of daytime and nighttime are the same for any observer on Earth where the Sun rises and sets. Thus, equinoctial hours are equal throughout the day of equinox.
c. decanal
   The interval of nighttime delimited by the rising of two consecutive decans [see decan: a].

House (οἶκος; *domus*)
The astrological houses constitute a system of rulership by which planets are assigned as rulers of zodiacal signs. According to Ptolemy [*Tetr.* 1.17], the houses divide the zodiacal circle [see Circle: k] into two halves, with six signs [see Sign, zodiacal: b]

in each. One half spans the signs from Leo to Capricorn; the other, from Cancer to Aquarius. The Sun was assigned to Leo and the Moon to Cancer—the two signs associated with summer and heat. The remaining five signs in each semicircle became the houses of the five planets in order of their distance from Earth, i.e., Mercury, Venus, Mars, Jupiter, and Saturn. Thus, Saturn, for example, the farthest from the Sun and Moon, was assigned the two signs Capricorn and Aquarius as houses, both of which are associated with winter and cold. Each of the five planets had two houses assigned to it.

Hypsoma. See Exaltation

Lot (κλῆρος) or Part (*pars*)
A point on the zodiacal circle determined by adding the elongation of two planetary bodies, often the Sun and the Moon, to the *Ascendant* in one or the other direction. There are seven lots, though they need not all appear in a given horoscope.

Lower Midheaven or Underground (ὑπόγειον; *imum coeli*)
The point below the client's horizon circle [see Circle: h] and 180° away from *Midheaven*, where the zodiacal circle [see Circle: k] intersects the client's meridian circle [see Circle: j].

Mean Sun
In Antiquity, the mean Sun was an ideal body moving in the zodiacal circle with mean velocity [see Motion, mean]. It coincides with the true Sun at apogee and perigee.

Today, the mean Sun is said to move in the celestial equator and coincides with the true Sun at longitude 0° (the vernal equinox).

Meridian. See Circle: j

Midheaven or Culmination (μεσουράνημα)
The intersection above the horizon at a given location of the meridian circle and the zodiacal circle [see Circle: j, k].

The point where the zodiacal circle intersects the client's meridian circle [see Circle: j, k].

Month, lunar (A *arhu*; G μείς, μήν; L *mensis*)

a. anomalistic

   The interval of the Moon's return to the same velocity or daily motion, e.g., of its return to its greatest velocity, which occurs at perigee, a point that completes a circuit of the zodiacal circle in the direction of increasing longitude in about 9 years.

b. draconitic
   The interval of the Moon's return to the same node. Knowledge of the draconitic month is essential to the theory of eclipses.
c. sidereal
   The interval of the Moon's return (in longitude) to a fixed star.
d. synodic
   The interval of the Moon's return (in longitude) to the Sun.

Month, solar (Egyptian)
The fixed interval of 30 days. Twelve of these months along with 5 additional or epagomenal days comprised the year-length of 365 days that is characteristic of the Egyptian wandering year. See Table 1, p. 638.

Motion, mean
A celestial body's mean motion during some interval is its average daily angular displacement.

Given, a cycle of

$$p \text{ days} = q \text{ months} = r \text{ years},$$

the mean daily motion m of the Sun is:

$$m_S^{\circ/d} = \frac{r \times 360}{p}.$$

For the Moon, one needs a cycle that includes the number of times that the Moon goes around the zodiacal circle, that is, its revolutions [see Saros: b]. Thus, given

$$p \text{ days} = q \text{ months} = r \text{ years} = k \text{ revolutions},$$

the Moon's mean motion is:

$$m_M^{\circ/d} = \frac{k \times 360}{p}.$$

The fact that such cycles are known does not mean by itself that the mean motions were computed and known.

Night, Nighttime (νύξ; *nox*)

The interval from one sunset to the next sunrise. Nighttime is longest on the day of winter solstice and shortest on the day of summer solstice [see Solstice].

Node (σύνδεσμος, *nodus*), lunar

One of two points where the lunar orbit intersects the plane of the zodiacal circle. The node where the Moon rises north of the zodiacal circle is the Ascending Node; the node where it goes south, the Descending Node.

Normal Star. See Star: c

Oblique ascension. See Rising-time

Parallax

The shift in a celestial object's position when it is observed from the Earth's surface instead of from its center [Figure 1, p. 113]. The effect of this shift is to make the apparent position of the object lower than its true position (which is computed). Hellenistic astronomers were aware of parallax in the cases of the Moon and Sun only. It is important to allow for parallax in computing tables for solar eclipses, since the observer's location on Earth affects or contributes to what is actually seen. (This is not so for lunar eclipses.)

Parapegma (παράπηγμα: *parapegma, kalendarium*)

A *parapegma* was a calendrical table based on the solar year. It was originally inscribed on stone with a hole for a peg that was moved from entry to entry as the year progressed but later written as a document. The tables themselves correlated dates in the year of phases of the fixed stars (usually first and last appearances) with seasonal changes in the weather. As Geminus notes, it was commonly supposed that *parapegmata* recorded causal connections between astronomical phenomena (including solar phenomena, such as solstices) and these changes in the weather. In any case, whether the astronomical phenomena are taken as causes or as signs (as Geminus insists), the *parapegma* belongs to the general practice of celestial prognostication (astrology).

Place (τόπος; *locus*)

In Hellenistic astrology, there are 12 places, each being an equal division of the chart [see p. 403] or *dodecatropos* [see Circle: d], that is made by starting at the *Ascendant* or from a point that is 5° or 15° ahead of it. The places are numbered in the direction opposite to the daily rotation. Since, at any given time, these places are of equal length, any given place will actually vary in length over the course of a day as *Midheaven* moves to and fro [see Beck 2007, 42–43] along the meridian [see Circle: i]. Nevertheless, in practice, the places are treated as though equal in length. Each place concerns a particular aspect of a person's life. The first place, for example, is Life (ζωή). See Figure 3, p. 462.

Planet. See Star: d

Planets, order

Not every list of the planets implies a theory about their arrangement in space. Moreover, planetary lists are numerous and may vary when they share the same name. In fact, the assignment of a list to some person or culture may sometimes tell more about the source making the assignment than it does about the person or culture to which the list is assigned.

a. non-spatial lists
   1. Babylonian
      The order Jupiter, Venus, Mercury, Mars, Saturn is the standard enumeration of the five planets in cuneiform documents of the Seleucid Era. It is based on whether the planets are benefic, malefic, or ambiguous. In Babylonian horoscopes, the five planets are preceded in order by the Moon and Sun.
   2. Demotic
      The sequence of the five planets in the Medinet Madi horoscopes is Saturn, Jupiter, Mars, Venus, Mercury, Sun, Moon.

b. Greco-Roman lists with spatial commitments
   1. Chaldaean
      The order Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn attributed to the Chaldaeans is a Greco-Roman fiction.
   2. Greek (Platonic)
      The Greek order Moon, Sun, Venus, Mercury, Mars, Jupiter, Saturn is attributed to Plato. There were variants, however; thus, for some, the order was Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn (Venus and Mercury interchanged); whereas for still others it was Moon, Venus, Sun, Mercury, Mars, Jupiter, Saturn (Venus and Mercury re-positioned about the Sun).
   3. Pythagorean
      The order ascribed to the Pythagoreans is Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn. This is the order adopted by Ptolemy.

Precession

a. of the stars
   The slow motion of the fixed stars eastward about the axis of the zodiacal circle [see Circle: k]. This is how Ptolemy understood precession. See Figure 5, p. 292.

b. of the *equinoxes*
   The slow motion of the equinoxes westward due to the revolution of the celestial

poles about the poles of the zodiacal circle. This is, apparently, how Hipparchus, who discovered precession, understood it. See Figure 5, p. 292.

Today, this motion is attributed to decay in the Earth's rotation, that is, to a wobble consisting in the revolution of the axis of the Earth's daily rotation from west to east, that maintains the Earth's obliquity to the plane of its orbit about the Sun.

For Ptolemy, the rate of precession was 1° in 100 years, which implies a period of 36,000 years. The period is, in fact, roughly 25,800 years, which implies a rate of 1° in 71⅔ years.

Rising-time

The time that it takes for an arc of the zodiacal circle [see Circle: k] to rise above the observer's horizon circle [see Circle: h].

Saros (cάροc/cαρόc)

a. the interval

The term « cάροc» (or «/cαρόc») derives from the Babylonian word for 3,600, «šār». Its use to indicate an interval of 3,600 years is attested as early as the work of Berossus (*flor.* early third century BCE), a scholar (possibly Babylonian) writing in Greek (or originally Aramaic), and is common in subsequent Greek historical literature.

This interval is defined explicitly by Hesychius, the lexicographer (fifth century CE), in a report about Abydenus (second century CE?).

b. the cycle

Use of the term "Saros" for the eclipse-cycle of 223 lunar months was established by Edmond Halley in 1691, though even after then some continued to call it the Chaldean Period or Cycle. This eclipse-cycle, first evident in Babylonian texts where it is simply called "18 years", roughly marks the return of a solar (or lunar) eclipse in type, time of year, location of the body eclipsed, magnitude, and direction. In this cycle, which sets

6585⅓ = 223 synodic months
= 239 anomalistic months
= 242 draconitic months
= 241 revolutions in longitude + 10°
≈ 18 years, 11 days, and 8 hours,

the return in location and time, for example, is plainly approximate, not exact.

The use of the term "Saros" in this sense is rare in Antiquity: for Ptolemy, e.g., this cycle is the Periodic Interval (περιοδικὸc χρόνοc). It is only in an entry found *sub voce* in the *Suda* (late tenth century CE) that this cycle is called a Saros. This entry is, however, incomplete, makes no mention of the use of the cycle for predicting eclipses, and is flawed by setting its length at 222 "lunar" months. Why the cycle was called a Saros is also unclear.

Science, celestial. See Astronomy, Hellenistic

Sign, zodiacal (A LU.MAŠ; G ζῴδιον; L *signum*)

a. A *dodecatemorion* [a].
b. A 30°-arc of the zodiacal circle [see Circle: k]. Each such sign got its name from the *dodecatemorion* [a] that delimited the arc in the zodiacal circle.

Solstice (summer, winter: A *šamaš* GUB; G τροπαί; L *solstitium*)

One of two days of the solar year in which either daytime or nighttime reaches its greatest or maximum length (for those not at the equator). When the Sun is at the *summer solstitial point*, it produces the summer solstice and the length of daytime is greatest; when it is at the *winter solstitial point*, the winter solstice and the length of nighttime is greatest [see Cardinal points]. The Latin "solstitium" derives from the observation that the Sun appears to stand still in the month or so preceding and following its arrival at the solstitial point itself.

Sphere of fixed stars

There is no evidence in cuneiform for the conception of a celestial sphere. It is found first in Greek literature.

It was generally assumed in Greco-Latin texts that the fixed stars [see Star: a] were equidistant from the center of the celestial sphere, i.e., the center of the Earth; but there were some who entertained the idea that this was not true.

Prior to Copernicus, this sphere was held to rotate, thus causing all those celestial bodies that rise and set for observers on Earth to rise in the east and set in the west and all other bodies to revolve in the same direction about the poles of this sphere. For observers north of the terrestrial equator, this was the original clockwise motion. After Copernicus, the rising and settings of the celestial bodies was attributed to the (counterclockwise) rotation of the Earth from west to east, a motion in the same direction as its annual revolution about the Sun.

Star (A MUL or MÚL, *kakkabu*; E *sb3*; G ἀστήρ, ἄστρον; L *stella*, *sidus*, *aster*, *astrum*)

a. fixed (ἀπλανής -ές, *inerrans*)
   A star that remains in position relative to the other stars. Within the class of fixed stars, Aratus, for example, uses «ἀστήρ» for an individual star and «ἄστρον» for a *constellation*.
b. counting [stars] (always in plural: MUL.ŠID.MEŠ, *kakkabū minâti*)
   The Babylonian term for the set of reference-stars near the zodiacal circle that serve in the *Diaries* to specify the positions of the Sun, Moon, and five planets.
c. Normal. See Star: b
   A modern term for a star that was used by the Babylonians to specify the positions of the Sun, Moon, and five planets.

d. wandering (πλανώμενος -ον, πλανήτης -ες, *erratica -um*, *planeta* [*stella*])
A star that observably changes position in relation to the other stars. The Babylonians termed these *bibbu* (wild sheep), connoting the fact that they did not keep to their courses as did the fixed stars. There are seven wandering stars or planets: the Moon, Sun, Mercury Venus, Mars, Jupiter, and Saturn. Later, once it was recognized that the Sun and Moon do not make retrograde motions, there was a distinction between the seven and the five wandering stars.
Some authors, such as Geminus, tend to use «ἀστήρ» for individual stars whether fixed or planetary and «ἄστρον» for the constellations as well as for celestial bodies in general; others are freer in their terminology. In Latin, "astrum" has all these meanings.

Systems A and B

Babylonian mathematical astronomy consists in the main of planetary and lunar tables—designated *tērsītu* (computed tables) in colophons—and a group of procedural texts stating the arithmetical rules (algorithms) used to calculate the various columns of the tables. Such tabular and procedural texts date to the period from the mid-fifth to the mid-first centuries BCE, with the bulk of preserved tablets dating to the Hellenistic or Seleucid Period in the second century BCE.

Characteristic of the table texts are parallel columns of numbers that represent dates or positions of the lunar and planetary appearances or other data relevant to calculating the synodic arc ($\Delta\lambda$) of a planet or the Moon. These methods were based on recognition of period-relations (expressed in units of time such as the year, month, day, or degree) as well as two types of recursive mathematical steps (algorithms) now called Systems A and B. (There are variants and other, less well-attested systems too.) Their distinguishing signature was in the application of the step-function in System A and the zigzag-function in System B to the calculation of longitudes. The final construction of both systems took place early in the Seleucid Era.

Each scheme entailed an understanding of an intimate connection found between synodic arc ($\Delta\lambda$), or progress in sidereal longitude made by the planet or Moon from one synodic phenomenon to the next of the same kind (e.g., first visibility to the next first visibility), and synodic time ($\Delta\tau$), or the time required for the body to complete a synodic cycle between successive phenomena of the same kind. Using step-functions, System A calculated progress in longitude as a function of longitude, that is, differences in longitude $\Delta\lambda$ were treated as dependent on longitude itself. Thus, $\Delta\lambda = f(\lambda)$. System B derived longitudes of synodic arcs as a function of the serial number n of $\Delta\lambda$ in the table. Thus, $\Delta\lambda = f(n)$.

Zigzag- and step-functions, so called from modern graphical representations of the calculations in the columns of the Babylonian tables, were therefore used to account for the difference between a position or date y_n and the next in sequence y_{n+1}, reckoned as longitude in degrees or as time in *tithis*. Thus, $y_n = y_{n-1} \pm d$. In System A, this difference d was variable in accordance with subdivisions of the zodiacal circle into zones of longitudinal progress, the simplest version consisting of two such zones of progress, one fast and the other slow, and more complicated versions consisting of four and six zones. In this way, System A described (mathematically) the synodic arc directly with a step-function of longitude, i.e., $\lambda = f(\lambda)$. In System B, on the other hand, the difference was constant and was applied not to phenomena (or synodic events) in the zodiacal circle but rather to the event-number in the table.

Tables of data organized in accordance with Systems A and B are also found in Greek and Latin during the Hellenistic Period.

Term (ὅριον; *terminus*)
The astrological doctrine of terms subdivided the zodiacal signs [see Sign, zodiacal: b] by certain numbers of degrees, the precise number of which was assigned differently in different systems (the so-called Egyptian system, which was originally Babylonian, and the so-called Chaldean system). The term or subdivision was assigned one of the five planets (or in some systems, additionally the Sun or both the Sun and Moon) as Lord, which therefore had particular influence in that segment (term) of the zodiac. For the cuneiform evidence of the terms, see Jones and Steele 2011.

Tithi
A Sanskrit term for ¹⁄₃₀ of a mean synodic month. Otto Neugebauer applied it to the same concept as it serves in Babylonian ephemerides, where the numbers of *tithis* are given without any accompanying term. This is now established usage in the study of Babylonian mathematical astronomy.

Triplicity. See Aspect: e

Year (A *šattu*; G ἐνιαυτός; L *annus*)

a. sidereal
The time that it takes for the Sun to return to a fixed star.

b. tropical
The time that it takes for the Sun to return to an equinox or solstice (τροπαί).
This difference in the sidereal and tropical year-lengths is due to *precession*. The Babylonians did not recognize the tropical year.

c. Great Year (*annus magnus*)
A period or cycle in which there is a whole number of days, lunar months, and solar years. (The Babylonians did not include days in such cycles.)

Zodiac. See Band, zodiacal

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1 Citations are by the section numbers in Lidzbarski 1925.

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2 [Palchus] has been identified as Abū Maʿshar. See Pingree 1968b, 279 and 1971, esp. 203f.

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Index of Passages

See the Bibliography for editions used in the indices.

Akkadian

Aramaic

Coptic

Egyptian

Ethiopian (Geʿez): see also 4Q208–211 in the Qumran passages below

Greek

Hebrew

Latin

Mandaean

Qumran

Syriac

Index of Names

Premodern

Modern

Index of Subjects

Akkadian

Coptic

Demotic

Egyptian

Greek

Mandaean

General