A Map of the Solar System in the *Bhāgavata Purāṇa*

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Running title: Map of the Solar System

Abstract —The Sanskrit text *Bhāgavata Purāṇa* gives a detailed account of the earth as a disk, divided into a series of concentric, ring-shaped oceans and islands. This paper explores the hypothesis that the earth disk can be interpreted as a geocentric map of the solar system, showing how the planets approach and recede from the earth.

Introduction

It is widely believed that the ancients thought of the earth as a flat disk. However, there is evidence that the flat earth of classical antiquity may have been a misinterpretation of a realistic astronomical concept dating back to an earlier time. In their book *Hamlet's Mill*, Giorgio de Santillana and Hertha von Dechend (1969) studied the myths and legends of societies from around the world and found evidence for an "archaic" culture antedating the ancient civilizations we know of today. Here is what they said about how this archaic culture viewed the earth:

"It is necessary to explain again what this 'earth' is that modern interpreters like to take for a pancake. The mythical earth is, in fact, a plane, but this plane is not our 'earth' at all, neither our globe, nor a presupposed homocentrical earth. 'Earth' is the implied plane through the four points of the year, marked by the equinoxes and solstices, in other words the ecliptic" (op. cit., p. 235).

The *Bhāgavata Purāṇa* contains an account of an earth disk that may illustrate the ideas of Santillana and von Dechend. The *Bhāgavata Purāṇa* or *Bhāgavatam* is a Sanskrit text sacred to the Vaiṣṇavas or worshippers of Viṣṇu. Scholars generally date it somewhere between the 8th and the 10th centuries A.D. (Hardy, 1983, pp. 486–88), and astronomical evidence in the text itself points to a date no earlier than about A.D. 500.

The *Bhāgavatam* appears to describe the earth as a disk, called Bhū-maṇḍala or earth mandala. This disk is 500 million *yojanas* in diameter,[1] and it is divided into a series of concentric ring-shaped oceans and islands. The islands, called *dvīpas*, are further subdivided by mountains, rivers, and other geographical features. A schematic diagram of Bhū-maṇḍala is given in Figure 1. The radii of the *dvīpas*, oceans, and ring mountains are given in Table 1.

The disk of Bhū-maṇḍala is said to cut the sphere of the universe in half, and it has the same diameter as the universe. The universal sphere is called the Brahmāṇḍa, or "Brahma-egg," and it contains the sun, the moon, and the planets. There are also a few stars, as well as lower and higher worlds extending perpendicular to Bhū-maṇḍala.

[1] The length of the *yojana* is not well-defined in the existing Sanskrit literature, and a variety of lengths have been given for it, ranging mostly from 5 to 10 miles (see Cunningham, 1871).

TABLE 1

N	Radius	Thickness	Geographical type	Sanskrit name
1	50	50	Island (*dvīpa*)	Jambūdvīpa
2	150	100	Ocean	Lavaṇoda
3	350	200	Island	Plakṣadvīpa
4	550	200	Ocean	Ikṣurasoda
5	950	400	Island	Śalmalīdvīpa
6	1,350	400	Ocean	Suroda
7	2,150	800	Island	Kuśadvīpa
8	2,950	800	Ocean	Ghṛtoda
9	4,550	1,600	Island	Krauñcadvīpa
10	6,150	1,600	Ocean	Kṣīroda
11	9,350	3,200	Island	Śakadvīpa
12	12,550	3,200	Ocean	Dadhimaṇḍoda
13	15,750	3,200	1/2 Island & mtn.	Mānasottara mtn.
14	18,950	3,200	1/2 Island	Puṣkaradvīpa
15	25,350	6,400	Ocean	Svādūdaka
16	41,100	15,750	Region	Loka (Inhabited)
17	125,000	83,900	Region & mtn.	Lokāloka mtn.
18	250,000	125,000	Region	Aloka varṣa

The radii in thousands of *yojanas* of the features of Bhū-maṇḍala, as given in the *Bhāgavata Purāṇa*. The oceans, islands (*dvīpas*), and regions are all annular in shape. The radial thickness and the outer radius of each annulus are listed. There are two circular mountains. The first, called Mānasottara, cuts the island of Puṣkaradvīpa in half. The second, called Lokāloka, is the outer boundary of the annular region called Kāñcanībhūmi.

The *Bhāgavatam* gives several reasons for identifying the plane of Bhū-maṇḍala not with a primitive flat earth, but with the solar system. The sun, moon, and planets are said to orbit "above" this plane (towards celestial north). Their orbits are contained within a thin, cylindrical disk of *antarikṣa* ("inner space"), which is shown in Fig. 2. This disk has Bhū-maṇḍala as its base, and its thickness is equal to the distance from Bhū-maṇḍala to the beginning of the region of heaven called Svargaloka. The thickness is 3.8×10^6 *yojanas*, much smaller than the 250×10^6 *yojana* radius of Bhū-maṇḍala itself. Thus the orbits of the planets are bounded within a narrow region between two planes that cut across the middle of the universal sphere.

In Figure 2, the disk of *antarikṣa* is shown on the right. The spacing between the two bounding planes has been multiplied by 3 for visibility. The planetary orbits in *antarikṣa* are reminiscent of the solar system, where each planet orbits the sun in a plane. The solar system is shown on the left of Fig. 2, with the same stretching of the vertical axis by a factor of 3. (Pluto was omitted in this figure due to its 17-degree orbital inclination.)

The planes of these orbits lie at small angles to one another, and thus all the orbits are close to one plane. The plane of the earth's orbit is called the ecliptic, and this is also the plane of the sun's orbit, from the point of view of an observer stationed on the earth. To an observer on the earth, the solar system is a more-or-less flat arrangement of planetary orbits that stay close to path of the sun. Thus, Bhū-maṇḍala can be interpreted as a plane parallel to the ecliptic and bounding the planetary orbits on one side (towards celestial south), while the parallel plane of Svargaloka bounds them on the other side (towards celestial north).

A notable feature of Bhū-maṇḍala is that it agrees with the solar system in scale. This is shown in Figs. 2 and 3, where Bhū-maṇḍala is plotted next to the solar system using 8 miles per *yojana*—the standard used in the *Bhāgavatam* translation that we consulted (Bhaktivedanta, 1982).

This agreement in scale becomes particularly striking if we restrict our attention to the five planets, Mercury, Venus, Mars, Jupiter, and Saturn, that are visible to the naked eye. We see that their apogees and perigees tend to line up with the circular features of Bhū-maṇḍala. Our main thesis in this paper is that these circular features of can be interpreted as a map showing apogees and perigees of the sun and these five visible planets.

Model and Results

Bhū-maṇḍala is earth-centered. In contrast, the orbits of the planets are centered on the sun. How, then, can they be compared with earth-centered features of Bhū-maṇḍala?

The solution is to express the orbits of the planets in geocentric (earth-centered) form. Although modern astronomy treats these orbits as heliocentric (sun-centered) in orbital calculations, they can be expressed in relation to any desired center of observation, including the earth.

The geocentric orbit of a planet is a product of two motions, the geocentric motion of the sun around the earth and the motion of the planet around the sun. This is shown in Fig. 4 for the planet Mercury. The looping curve of the planet's geocentric orbit lies between two boundary curves, marked A and B in the figure. If we continue plotting the orbit for a long enough time, it completely fills in the donut-shaped area between these two curves.

This is exactly what we did for the five planets, Mercury, Venus, Mars, Jupiter, and Saturn, using the planetary subroutines of Duffett-Smith (1985) for geocentric ecliptic coordinates.

To compare the resulting geocentric orbits with the features of Bhū-maṇḍala, we first compute the orbits and convert them from miles to *yojanas*. We use 1 *yojana* = y miles, where we allow y to vary from 1 to 16—an interval that covers the known historical range of possible *yojana* lengths. Then we superimpose the orbits on a map of Bhū-maṇḍala and observe the results.

For the value of y = 8 miles used in the translation of the *Bhāgavatam* that we consulted, we saw that the pattern of Bhū-maṇḍala tended to match the pattern of the solar system out to Saturn in an interesting way. In the solar system, the orbits of the outer planets Jupiter and Saturn are noticeably larger in scale than the orbits of the inner planets, Mercury through Mars. When superimposed on Bhū-maṇḍala, the orbits of the inner planets fell on the small inner cluster of seven *dvīpas* and oceans (called Saptadvīpa), and Jupiter and Saturn fell on a large outer annulus (Kāñcanībhūmi). Thus the structure of Bhū-maṇḍala seemed to mirror the structure of the solar system.

If we examine the orbits of Mercury, Venus, and Mars, we see that each orbit seems to go from a perigee near one circular feature of Saptadvīpa to an apogee near another circular feature. The apogee of Saturn and the perigee of Jupiter also line up with the boundary circles of Kāñcanībhūmi. The agreement is rough for 8 miles/*yojana*, but it becomes quite striking if we shift to about 8.5 miles/*yojana*.

These alignments are shown graphically in Figs. 5–8, but before discussing them, we must consider whether or not a unique *yojana* length y gives a good alignment and, if so, how y is to be determined. To find an optimal y, we need to define a measure of "goodness of fit," G(y).

Each boundary curve has two extreme points, where it becomes tangent to a circle centered on the earth. These are indicated in Fig. 4. For the outer boundary curve, these are the apogee of the planet, and the point designated apogee-, where the boundary curve approaches closest to the earth. For the inner boundary curve they are the perigee of the planet and the point, perigee+, where the curve is furthest from the earth. These 4 points are called orbital turning points.

By observation, we arrived at the hypothesis that each orbit has at least one turning point that matches the radius of a circular feature of Bhū-maṇḍala. Assuming y miles per *yojana*, we can evaluate how good a match is as follows:

For each planet, Mercury through Saturn, find the smallest difference between a Bhū-maṇḍala feature radius and an orbital turning point converted into *yojanas* using y. The difference is expressed as a percentage of the width of the Bhū-maṇḍala ring in which the turning point falls. Do this over the set of all circular features of Bhū-maṇḍala (listed in Table 1) and over the set of 4 orbital turning points of the planet. Take the root mean square of these minimal percentage differences for the five planets. The reciprocal of this is called G(y). It is large if the orbits line up well with the circular features, and it is small if they do not line up well.

In Fig. 11, G(y) is plotted as a function of y, which is allowed to range from 1 to 16 miles. We can see that the curve has a pronounced peak at 8.534 miles. This length of the *yojana* is singled out as optimal, and there are no notable peaks for any other *yojana* lengths.

To check this result, we also defined another goodness of fit function, C(y), which is discussed below. This has a pronounced peak at 8.489 miles, and this differs by 0.53% from the *yojana* length obtained from G(y). C(y) is also plotted in Fig. 11.

Table 2 shows how the geocentric orbits of the five planets and the sun compare with Bhū-maṇḍala features, using an optimal *yojana* length of 8.489 miles.

In the table, we see a tendency for perigees and apogees of planets to align closely with Bhū-maṇḍala feature radii, although this correlation is not perfect. In the case of Mercury, the alignments of the perigee and apogee are about 8% and 4%, respectively. Thus the inner boundary of Mercury's orbit swings in and nearly grazes feature 10 in Table 1, and its outer boundary swings out and nearly grazes feature 13 (see Fig. 5).

For Venus, the perigee and apogee are, respectively, within about 6% of feature 8 and 1% of feature 14 (see Fig. 6). Mars does not do as well. Its perigee

TABLE 2

N	Planet	turning point	turning point radius	inner feature radius	outer feature radius	% error
10	Mercury	perigee	6019.37	4550.	6150.	8.16
10	Mercury	perigee+	7410.30	6150.	9350.	39.38
13	Mercury	apogee-	14486.08	12550.	15750.	39.50
13	Mercury	apogee	15882.92	15750.	18950.	4.15
8	Venus	perigee	2902.88	2150.	2950.	5.89
8	Venus	perigee+	3173.21	2950.	4550.	13.95
14	Venus	apogee-	18740.67	15750.	18950.	6.54
14	Venus	apogee	19014.22	18950.	25350.	1.00
11	Sun	perigee	10760.79	9350.	12550.	44.09
11	Sun	mean	10950.49	9350.	12550.	49.98
12	Sun	apogee	11139.72	9350.	12550.	44.07
9	Mars	perigee	4075.18	2950.	4550.	29.68
10	Mars	perigee+	7382.63	6150.	9350.	38.52
15	Mars	apogee-	25972.60	25350.	41100.	3.95
15	Mars	apogee	29282.39	25350.	41100.	24.97
16	Jupiter	perigee	43315.33	41100.	125000.	2.64
16	Jupiter	perigee+	48709.66	41100.	125000.	9.07
16	Jupiter	apogee-	65203.62	41100.	125000.	28.73
16	Jupiter	apogee	70599.14	41100.	125000.	35.16
17	Saturn	perigee	87237.21	41100.	125000.	45.01
17	Saturn	perigee+	99819.00	41100.	125000.	30.01
17	Saturn	apogee-	109080.82	41100.	125000.	18.97
17	Saturn	apogee	121738.82	41100.	125000.	3.89

Correlation between radii of Bhū-maṇḍala features and orbital turning points. The feature radii are from Table 1, and are in thousands of *yojana*s. Each turning point falls between two feature radii and is compared with the one which is closest. The percent error is the difference between the turning point and this radius, expressed as a percentage of the difference between the two feature radii. The orbital turning points are calculated using a modern ephemeris program for the epoch of A.D. 500, using 8.489 miles/*yojana*.

and apogee come within 30% and 25% of features 9 and 15, although its third turning point (apogee- in the table) comes within 4% of feature 15 (see Fig. 7).

The turning points of Jupiter and Saturn fall, respectively, within 3% to 35% and 4% to 45% of features 16 and 17 of Table 1 (see Fig. 8).

We include the sun in the table as a special case. The sun's geocentric orbit is different from that of the planets, in that it is produced by a single heliocentric motion, rather than two. It therefore has only two turning points, the sun's perigee and apogee, which are nearly equal to one another. The perigee falls 44% higher than feature 11, and the apogee falls 44% lower than feature 12. Thus the mean of the sun's apogee and perigee lies almost exactly halfway across the "ocean" spanning features 11 and 12 (see Fig. 9).

The boundary curves of Mercury through Mars are plotted together in Fig. 10, without the overlapping curves of the orbits themselves.

In Table 2, N lists the number of the feature that comes closest to the indicated orbital turning point. We will say that this feature is "used" by that turning point. The feature numbers, N, are related to the planets as indicated in Table 3. The numbers in this table reflect the heliocentric arrangement of the solar system, and they also reflect the fact that Mercury, Venus, and Mars (but not Jupiter and Saturn) can come closer to the earth than the sun. We would expect a random series of alignments to use some features and omit others in an irregular fashion. So it is noteworthy that all of the features from 8 to 17 are used in the pattern in Table 3.

TABLE 3

	perigee	apogee
Sun	11	12
Mercury	10	13
Venus	8	14
Mars	9	15
Jupiter	16	16
Saturn	17	17

The information in Tables 2 and 3 can be evaluated using several criteria which assess the strengths and weaknesses of the orbit correlations. These are as follows:

(1) First, there are two points based on the text of the *Bhāgavatam*. Features beyond the circular Lokāloka "mountain" (radius 17) should not be used in the alignment, since it is said in the text that no luminaries (planets) pass beyond Lokāloka mountain. Also, the sun should be somewhere between the center (earth) and the circular Mānasottara mountain (feature 13).

We call these criteria 1a and 1b, respectively, and we assign them 1 or 0 for true or false. Both are satisfied by Table 2.

(2) In the ideal pattern, each perigee and apogee of a planet (or the sun) should come close to a Bhū-maṇḍala ring. To show how well this is satisfied, let n be the number of perigees or apogees within P percent of their closest feature radius. Using $P = 6\%$, the pattern in Table 2 is assigned 5, but the highest possible value would be 11 (2 for each planet and at most 1 for the sun).

(3) It would be ideal if each feature corresponded to exactly one perigee or apogee. So let r be the ratio of the number of features with this property to the total number of features used. The pattern in Table 3 is assigned r = 8/10 by this criterion, since features 8–15 each correspond to one perigee or apogee. In contrast, feature 16 serves for both the apogee and the perigee of Jupiter, since the apogee lacks a ring of its own. The situation is similar for feature 17 and Saturn.

Ideally, all circular Bhū-maṇḍala features should be used in the alignment, since unused features would be superfluous in a planetary map. Criteria 4–6 address this idea:

(4) Let n be minus the number of unused features from Jambūdvīpa up to the first feature used in the alignment. The minus sign is chosen, since the pattern gets a lower evaluation as n increases. Here the pattern in Table 2 gets a low score of -7, since the used features begin with number 8.

(5) Let m be minus the number of unused features between Lokāloka mountain and the outermost used feature. In this case, the pattern in Table 2 is assigned the highest score of 0.

(6) Finally, let k be minus the number of blocks of contiguous unused features in the whole pattern. This measures how much the pattern is broken up by unused circles. By this measure, the pattern in Table 2 is assigned -1.

Criteria 2–6 are intended to express what we would expect to find in a solar system map in which perigees and apogees of geocentric planetary orbits are represented by a series of concentric circles, and they also express criticisms that can be lodged against the map given in Table 2 and in Figs. 5–10. To sum up, in such a map, each perigee or apogee should correspond to a circle, and each circle should correspond to a perigee or apogee. Criteria 1a and 1b express the special roles of Lokāloka mountain and Mānasottara mountain.

Our first observation is that the 6 criteria can be used to define the optimal *yojana* length, without making any reference to the goodness of fit function, G(y). Consider the range of possible *yojana* lengths from 1 to 16 miles. For a given *yojana* length, add criteria 1a, 1b, and 2–6 together, using weights designed so that each criterion varies over the same range on the interval of possible *yojana* lengths. This is done to give the criteria equal weight. The resulting curve C(y) is plotted in Figure 11, along with G(y). (We added 10 to the curve to make it positive.) As we pointed out above, this curve has a pronounced maximum at 8.489 miles, close to the maximum of G(y).

Critical Analysis of the Results

It is clear that Bhū-maṇḍala, as described in the *Bhāgavatam*, can be *interpreted* as a geocentric map of the solar system out to Saturn. But an obvious and important question is: Did some real knowledge of planetary distances enter into the construction of the Bhū-maṇḍala system, or are the correlations between Bhū-maṇḍala features and planetary orbits simply coincidental?

One problem with interpretations in general is that they pick out certain features from a body of material, while neglecting others. This choice may be dictated by the pattern that is being seen, and thus this pattern may be imposed by the viewer on the evidence, rather than being inherent in the evidence itself.

In this case, the decision to give an astronomical interpretation to an ostensibly geographical description is supported by substantial material in the text of the *Bhāgavatam* connecting Bhū-maṇḍala and the adjoining region of *antarikṣa* with the ecliptic (sun's orbit) and the planetary orbits. The circular features of Bhū-maṇḍala stand out as the most likely candidates for an astronomical interpretation, due to their shape and to the fact that they have roughly the right size for planetary orbits. Also, since they are given dimensions in the text, they can be examined quantitatively.

Given this starting point, we can carry out a statistical analysis by defining a null hypothesis as follows: The medieval author of the *Bhāgavatam* had no access to correct knowledge of planetary distances, and therefore all correlations between Bhū-maṇḍala features and planetary distances are due to chance.

If such a null hypothesis involves a known statistical distribution, such as a normal distribution, then there are standard statistical methods for evaluating whether or not the observed data satisfy this hypothesis. The basic method would be to ask how probable the correlations in question are, given a statistical distribution of possible Bhū-maṇḍala features. The problem is that we do not know this statistical distribution.

Nonetheless, by looking at the *Bhāgavatam's* discussion of distances in Bhū-maṇḍala, we can make some general observations about how these distances were expressed numerically. For example, from Table 1, we see that large powers of 10 were used. Throughout Purāṇic literature, numbers such as *sahasra* (1,000), *lakṣa* (100,000), and *koṭi* (10,000,000) are common. Fractions of these numbers, such as 1/2, 1/4, and 1/8 are also common, and we see such fractions in the table. The table also shows procedures such as doubling a previous distance. In other parts of the *Bhāgavatam*, we encounter multiples of a previous distance by 10 (i.e. the shells of the Brahmāṇḍa).

Table 1 thus presents a combination of regular rules and seemingly arbitrary decisions, such as the decision to set thickness 16 equal to radius 13 instead of doubling thickness 15. We took the null hypothesis to mean that such decisions were made by complex cultural causes that would be effectively random relative to the unknown dimensions of the solar system. Thus, we interpret Table 1 as a combination of regularity and effectively random choice.

Based on such observations, we wrote an algorithm to generate sets of artificial Bhū-maṇḍala feature radii. This algorithm applies rules generalized from

Table 1, and it applies these rules in a random fashion. We are prepared to make the C code for this algorithm available for examination. Although the algorithm is in many ways arbitrary, it does generate sets of radii similar to those in Table 1, and one particular set of random choices generates Table 1 itself. (In line with the table, the algorithm also designates one ring as "Mānasottara mountain" and another as "Lokāloka mountain.")

We used this algorithm to determine how common are patterns which satisfy the criteria we have discussed above. The specific method is as follows: We say that a randomly generated set of radii and a particular *yojana* length *satisfies* a criterion if it does as well or better by this criterion than the actual set of radii defined in Table 2, using 8.489 miles/*yojana*. Let x and y be two sets of rings and *yojana* lengths. If C(x) represents a criterion for x, then x does as well or better than y on C if $C(x)>=C(y)$.

The purpose of the "as well or better" rule is to avoid the following problem: If we observe that one thing matches another, we may be misled by adopting loose criteria for a match, so that a match by our criteria may be quite probable by chance. But if the formal analysis considers matches that are as loose as those we observe, then it should reveal whether such loose matches are probable or not.

We combined criteria 1a and 1b into a single criterion, (namely 1a and 1b), and we included the "goodness of fit" function G(y) as a 7th criterion.

For each subset of these 7 criteria, we calculated the probability that a randomly generated set of radii satisfied all the criteria in the subset for some *yojana* length between 1 and 16 miles. This was done by using a computer to generate 20,000 random sets of rings, and checking each set for the full range of *yojana* lengths. (We used an increment of .00375 miles in *yojana* length).

The probability that criterion k is satisfied is fairly large for each k=1,...,7, considered separately. These percentages are listed in columns 1 and 2 of Table 4, below. But if we combine several criteria, the percentage goes down rapidly. This is illustrated in columns 3 and 4. For example, 0.785% of the trials satisfied all of the criteria from 1–5, and none of the trials satisfied criteria 1–6 or 1–7.

Note that the addition of criterion 4 reduced the percentage only slightly, from 6.39% to 6.035%. This is due to the fact that the original pattern in Table 2 does not score very well on criterion 4, and therefore many randomly generated patterns do as well or better on this criterion. However, the addition of criterion 6 reduces the percentage from 0.785% to 0%. This is because the original pattern is not broken up by unused circles, even though this is likely to happen by chance.

TABLE 4

Individual Criteria	Percentage	Combined Criteria	Percentage
1:	45.695	1:	45.695
2:	43.405	12:	29.680
3:	24.705	123:	6.390
4:	59.780	1–4:	6.035
5:	64.300	1–5:	0.785
6:	74.410	1–6:	0.000
7:	27.135	1–7:	0.000

If we combine 6 with 1, 2, and 3 directly, we find that the 4 criteria 1236 are satisfied by only 0.04% of the trials. Leaving aside 1, we find that 0.105% of the trials satisfy the 3 criteria 236. These are among the strongest criteria, in the sense that no more than about 1 set of artificial radii in 1000 do better than Table 2 on these 3 criteria combined, for some *yojana* length between 1 and 16 miles.

Criterion 7, the goodness of fit function G(y), also has a strong effect, especially in combination with 6. Thus the combination 267 is satisfied for 0.23%

of the trials and 367 is satisfied for 0.03%. The combination 2367 was satisfied for only 1 of the 20,000 trials (0.005%).

Criteria 2–6 are general in nature, and they are designed to penalize irregularities in the correlation between Bhū-maṇḍala features and perigees and apogees of planets. Ring patterns satisfying criteria 2, 3, and 6 for some *yojana* length have a probability of about 0.1%, and this probability goes down sharply as more criteria are added. It can be concluded that patterns of rings satisfying such combinations of criteria are quite rare in the output of our pattern-generation algorithm, which was intended to create sets of rings similar to those of Bhū-maṇḍala in the *Bhāgavatam*. This seems to go against the null hypothesis, which says that any correlation between Bhū-maṇḍala features and planetary orbits must be coincidental. The alternative to the null hypothesis is that some real knowledge of planetary distances may have entered into the construction of the Bhū-maṇḍala system in the *Bhāgavatam*.

Historical Considerations

One natural question is: If the *Bhāgavatam* incorporates knowledge of planetary distances, then when did this knowledge originate and how did it come to be incorporated into the text? Unfortunately, it is difficult to give a definite answer to this question, since we know very little about the origin of the *Bhāgavatam*. Hardy (1983) attributes the *Bhāgavatam* to 9th-century South India on linguistic and literary grounds, but it is hard to say where or when specific information in the text may have originated. Thus O'Flaherty (1975, p. 16) remarks that, "since the Epics and Puranas represent an oral tradition that was constantly revised over a period of several thousand years, a passage actually composed in the twelfth century A.D. may represent a surprisingly accurate preservation of a myth handed down since the twelfth century B.C.—or a completely original retelling of that myth."

References in the text to the zodiac, with the vernal equinox in the beginning of Aries (Meṣa), suggest input from the *jyotiṣa saṣtras*— Indian astronomical texts that are generally traced to Hellenistic Greek sources (Pingree, 1976). However, the *Bhāgavatam* presents astronomical information in a way that is quite different from the *jyotiṣa saṣtras*, and thus it appears to be connected with a different astronomical tradition. Of course, the j*yotiṣa saṣtras*, in line with Greek astronomy, make the distances to the planets much smaller than they really are.

Cosmological presentations similar to that of the *Bhāgavatam* are found in other Purāṇas, in the *Mahābharata*, and in Jain and Buddhist texts (Harley and Woodward, 1987). The Jain and Buddhist cosmologies are particularly complex, and they seem to be imaginative elaborations of themes originating in earlier Hindu cosmology. Harley and Woodward (op. cit., p. 372) point out that paintings portraying these cosmologies generally pay little attention to quantitative dimensions, even though these may be mentioned in written texts.

Purāṇic cosmology is generally similar to that of the *Bhāgavatam*, with some variations in nomenclature and in quantitative dimensions. From a survey of Purāṇas, we concluded that many Purāṇic presentations of Bhū-maṇḍala appear to be garbled and incomplete. Of the texts we examined, only the *Bhāgavatam* gives a complete and consistent account of the dimensions of the different features.

If the dimensions given in the *Bhāgavatam* do, in fact, represent realistic planetary distances based on human observation, then we must postulate that *Bhāgavata* astronomy preserves material from an earlier, and presently unknown, period of scientific development. Other texts represent elaborations of material from this earlier period, with varying degrees of divergence from the original.

This hypothesis should be pursued by seeking other evidence of an earlier astronomical school. However, we should also mention another hypothesis based on the traditions surrounding the *Bhāgavatam* itself. This is that the text is a product of divine inspiration, and therefore it may encode levels of meaning not understood even by the author himself. According to this hypothesis, the *Bhāgavatam* may contain information that was unknown in the period of its composition, but which can be discerned in the text now on the basis of our more advanced scientific knowledge. In this case, a simple model of the ecliptic, which could have been based on Greek astronomy, is supplemented by information reflecting advanced knowledge of planetary distances.

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Figure Captions

Figure 1. The circular features of Bhū-maṇḍala, drawn to scale. The rings on the left are collectively called Saptadvīpa, and they are a subset of Bhū-maṇḍala, which is shown on the right.

Figure 2. The solar system out to Neptune, compared with the region of planetary orbits, as described in the *Bhāgavatam*. The planets are said to orbit between the two disks of Bhū-maṇḍala and Svargaloka. The scale assumes 8 miles per *yojana*, and the angle of view is 75 degrees from the vertical. Vertical relief (perpendicular to the ecliptic) is multiplied by 3 so that it can be seen in the figure.

Figure 3. The solar system, compared with Bhū-maṇḍala. The scale assumes 8 miles per *yojana*.

Figure 4. The structure of a geocentric orbit (of Mercury, in this case). The geocentric orbit of a planet is bounded by boundary curves A and B, each of which has two extreme points relative to the center. These are marked as perigee, perigee+, apogee-, and apogee.

Figure 5. The geocentric orbit of Mercury, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 6. The geocentric orbit of Venus, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 7. The geocentric orbit of Mars, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 8. The geocentric orbits of Jupiter and Saturn, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 9. The geocentric orbit of the sun, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 10. The boundary curves of the sun and Mercury through Mars, compared with Bhū-maṇḍala using 8.489 miles/*yojana*.

Figure 11. Plot of the two functions, G(y) and C(y), measuring how well Bhū-maṇḍala lines up with planetary orbits at y miles/*yojana*. The *yojana* length y ranges over 1 to 16 miles, an interval that encompasses nearly all known variants of the *yojana*.