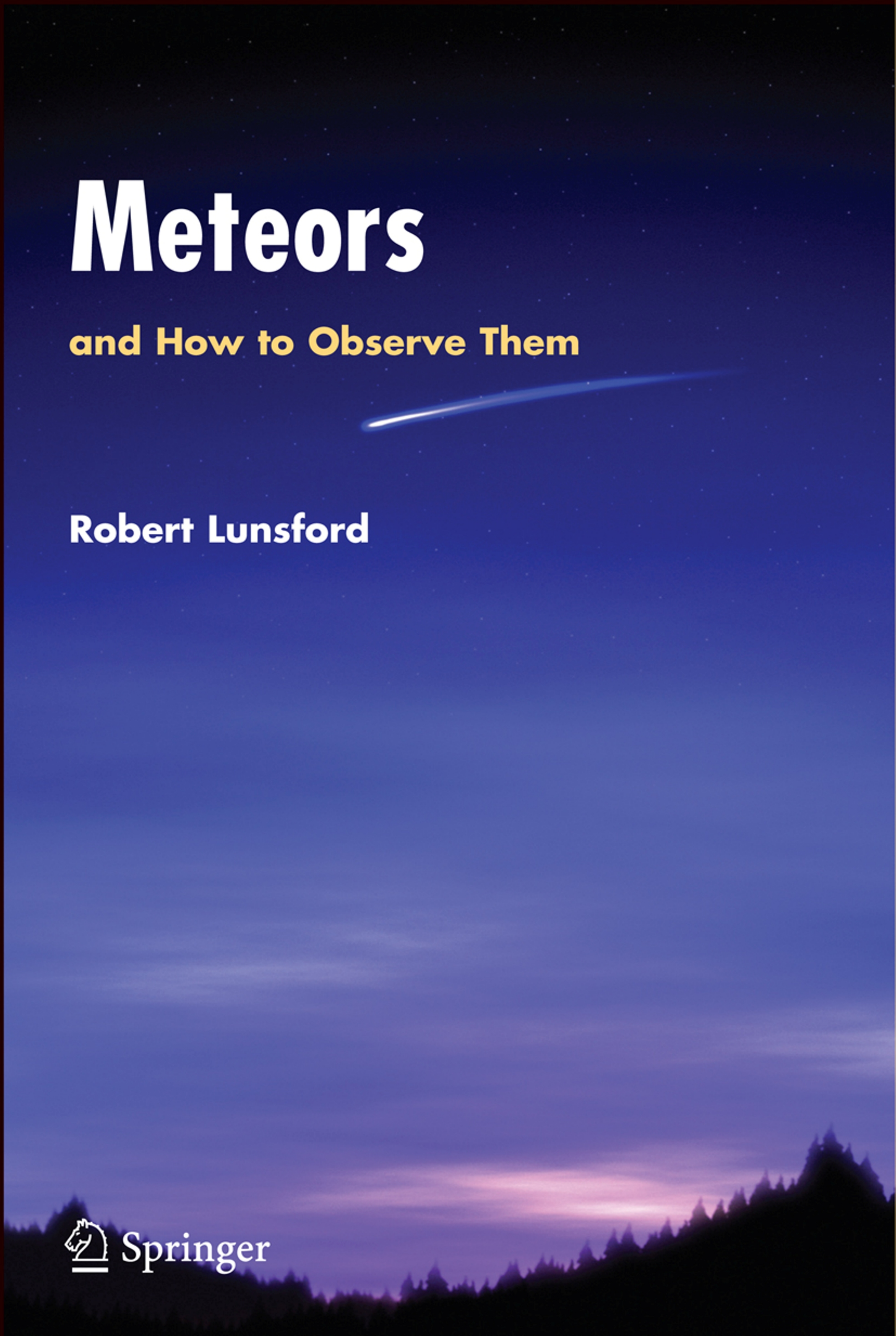
Meteors

and How to Observe Them

Robert Lunsford



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Robert Lunsford

Meteors and How to Observe Them

with 151 Illustrations

Springer

Robert Lunsford
American Meteor Society
Chula Vista, CA, USA
lunro.imo.usa@cox.net

Series Editor
Dr. Mike Inglis, BSc, MSc, Ph.D.
Fellow of the Royal Astronomical Society
Suffolk County Community College
New York, USA
inglism@sunysuffolk.edu

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I would like to dedicate this book to my wife Denise, who has endured far too many nights alone while her spouse was out under the stars with the likes of Cassiopeia and Andromeda

Preface

In this era of high-tech instruments, meteor observing is the one facet of astronomy that needs nothing more than your naked eye. Meteors can be easily seen without the aid of cameras, binoculars, or telescopes. Just find a comfortable chair and lie back and watch for the surprises that await high above you. It is a great way to involve the family in science where everyone is active at the same time, not waiting to take turns at the eyepiece. The kids especially enjoy the hunt for "shooting stars," oohing and ahing at each streak of light that crosses the sky. While gazing upwards, it is also a great way to get more familiar with the sky by learning the constellations and seeing if you can see the warrior among the stars of Orion or the scorpion among the stars of Scorpius.

Until just recently, one could simply go outside and watch for meteors from his or her yard. Unfortunately, humankind's fear of the dark and the widespread use of lighting as advertisement have lit the nighttime scene in urban areas so that only the brightest stars are visible. Serious meteor observing under such conditions is nearly impossible as the more numerous faint meteors are now lost in the glare of urban skies. Today, a serious meteor observing session entails organizing an outing to a country site where the stars can be seen in all their glory and meteors of all magnitudes can be viewed.

It is not all that complicated to observe meteors and to provide scientifically useful data. There are very few eyes scanning the skies each night for meteor activity and practically no professionals who actually observe visually. There are so few meteor observers that on a night when no major shower activity is expected, you may actually be the only observer on the Earth scanning the skies for meteor activity. It is times like these when the unexpected outburst occurs or that fireball brighter than the Moon appears. There are still discoveries to be made for those who get out during those chilly mornings and become one with the heavens above.

This book will help you to help you organize a successful meteor watch, and understand and appreciate what you observe, whether it occurs in your rural backyard or away from home.

Robert Lunsford
Chula Vista, CA

Acknowledgements

I would first wish to acknowledge the generosity of Carina Software, owners of the planetary program Sky Chart III, release 3.5.1, who allowed me to use their software to create all the charts in this book. These charts play an integral part in the book as it allows the potential observer to visualize the location of each radiant and subsequent drift against a stellar background.

I also wish to thank Dr. Peter Jenniskens for all the time and effort spent writing his book *Meteor Showers and Their Parent Comets*. This fine book was a constant source of reference material in the writing of this book. He has provided those keenly interested in meteor showers a wealth of material that any serious observer should possess.

I would also wish to thank Dr. David Meisel and the board of the American Meteor Society for the grant, which allowed assembly of the AMS video camera and system. I would also like to acknowledge Peter Gural for purchasing the components and assembling the system. This video system was the source for most of the meteor photographs in this book.

Lastly, I wish to acknowledge the help of Sirko Molau, who guided me through the software portion of the video system. His wonderful tool, *MetRec*, analyzed the meteors recorded during each night and provided data that saved me countless hours of work.

Robert Lunsford
14 February 2008

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About the Author

Robert Lunsford was star struck from an early age. His parents used to tell him that he would stand in his crib and watch the moon and stars from an adjacent window. In fact, his first words were not the normal mama or dada but rather "moontar." His passion for the sky was fueled by his parents purchasing him a small telescope. The wonder of those first views are still a fond memory for him.

Robert's first encounter with meteors occurred during the 1966 Leonid meteor storm. Although he missed the main portion of the display, the early activity was enough to ignite a passion for these fleeting streaks of light. From then on, he would observe the major shower diligently and report his observations to *Sky & Telescope* magazine. One day in the late 1970s, a newsletter devoted solely to meteors appeared in his mail. He was amazed to learn that there were so many others who shared his passion for viewing meteors! Thus began a long association with the American Meteor Society. Throughout the years, Robert has progressed from observer to author to operations manager of this group. He also has joined forces with the Association of Lunar and Planetary Observers and is the recorder for their Meteors Section. Robert also eagerly joined the International Meteor Organization as a founding member and has enjoyed the many international contacts that group has provided.

Recent highlights of Robert's meteor-related experiences include a trip to Europe to view a Leonid outburst, being part of the Leonid MAC mission which viewed two Leonid outbursts while airborne, and the observation of several unexpected meteor outbursts while out under the stars. Today Robert has branched out into video and photographic observations.

Chapter 1

An Introduction to Meteorics

Abstract

This chapter briefly discusses the process in which a meteoroid in space encounters Earth's atmosphere and becomes visible as a meteor. Should the meteor survive the plunge through the atmosphere it then encounters Earth's surface as a meteorite.

1.1 Meteoroids in Space

Contrary to most beliefs, outer space is quite empty. If it was filled with wall-to-wall dangerous space rocks, as indicated in science fiction movies, then meteors would be appearing in our skies every few seconds. Despite what you see in the movies, the chance of interplanetary spacecraft damaging debris is next to nil. The fact is that even during the strongest meteor storms, when meteors are continually appearing in the sky, the distance in space between these objects is still many miles.

The objects that appear as meteors in our skies are produced by comets and asteroids. They travel in many different orbits around the Sun and can strike Earth from any angle. The vast majority of these objects are the size of tiny pebbles. Millions of years of interplanetary collisions have reduced the number of large objects orbiting the Sun to a very small sum. Some of the parent objects have long since disintegrated. Their remains continue to orbit the Sun as meteoroids until they encounter a planet or are destroyed by the Sun's tremendous heat. There are fresh sources of meteoric material such as short-period comets that orbit the inner Solar System and long-period comets that occasionally return to the vicinity of the Sun. The large number of asteroids can also produce meteoric material. For a stream of debris to produce a meteor shower visible on Earth, it must pass close to Earth's orbit. Over the course of their lifetimes most comets and minor planets will suffer perturbations and will revolve around the Sun in many different orbits. This is especially true for those objects located near the major planets, such as Jupiter. For example, the famous Halley's Comet currently passes many millions of miles from Earth's orbit. This distance is much too far for fresh material to encounter Earth. Yet every May and October Earth encounters material from Halley's Comet that separated from the comet hundreds of years ago, when the comet was in an orbit much closer to Earth.

1.2 Meteors Entering Earth's Atmosphere

When meteoroids in space enter Earth's upper atmosphere and begin to glow they become meteors. The light and color of a meteor is produced by the meteor exciting the air molecules it encounters. Meteoroids begin to appear as "shooting stars" when they reach the outer layer of air known as the thermosphere, which is at an altitude of 75 miles above Earth's surface. These objects are visible at such a high altitude because of the tremendous velocities at which they strike the atmosphere. Meteors can strike the atmosphere are velocities ranging from 25,000 to over 150,000 miles/h. This also equals a range of 7–42 miles/s. Even the slowest entry speeds are more than five times faster than high-velocity bullets.1 The brighter meteors often appear close, but this is an optical illusion. What appears half way up in your sky and seems to land just over the hill will appear overhead for someone else a hundred miles away. People are amazed that these tiny particles can put on such a good show over a wide area.

1.3 Meteorites Reaching Earth's Surface

Due to their tremendous velocity when striking Earth's atmosphere, very few meteors survive intact and reach the ground. This is especially true for those originating from comets, as these consist mainly of ice and have the consistency of ash. Since comets produce a vast majority of the annual meteor showers it is most unlikely that anyone can claim to possess a piece of the Perseid or Leonid meteor shower. On the other hand meteors produced by asteroids consist of stone and metal and have a better chance of reaching the ground. Yet very few do survive all the way to the surface, due to their velocity when encountering the atmosphere. Those that do survive enter on the slower end of the velocity scale. They also start out larger than normal and can lose more material without completely disintegrating. Meteorites suffer the tremendous forces of ablation and appear far different that they did when out in space. Most are covered with a fusion crust. Meteorites found possessing these crusts are most likely fresh falls. Weathering tends to remove the crust and alters their appearance yet again.

Meteors decelerate rapidly as they encounter the thicker regions of the atmosphere. They will lose all of their initial velocity while still several miles up in the lower atmosphere. At this point the ablation process ceases, and the meteor becomes invisible since it no longer produces light. It then becomes subject to gravity and simply falls to the ground with an average terminal velocity of 300 miles/h. The resulting impact on the surface depends on the size of the meteorite. Most of them will simply fall into the ocean or bury themselves in the ground. Larger objects can actually displace some ground material, creating a crater.

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Chapter 2

Sporadic Meteors

Abstract

It turns out that some sporadic meteors are not so random after all. There are groups of nonshower meteors that encounter Earth on a daily basis, adding a few meteors per hour to the overall activity. Some of these are actually artificial radiants that are created by Earth's motion through space. Only one of these radiants produces enough activity to be easily seen by the visual observer. This radiant would be the Antihelion radiant, so named as the radiant's location lies opposite the Sun. Details of the position and periodic enhancements of the Antihelion shower are listed in the outbound counterpart of the Antihelions, the Helion radiant, is just as active but unfortunately lies in the direction of the Sun and is therefore unobservable by visual means.

2.1 Random Meteors

A great majority of the meteors you see in the sky above are sporadic, not belonging to any recognizable shower. The material that produces meteor showers is constantly evolving with meteoroids being spread out throughout their orbit. Not only do they spread material throughout the orbit in an organized manner, but the smaller particles are also pushed farther from the Sun by the solar wind and larger particles are pulled toward the Sun by its intense gravity. These forces tend to disperse organized meteoroids as time progresses. The dispersion process can take a few hundred years up to several thousand, depending on the interaction of the major planets. What is a random meteor today may have belonged to an organized meteor shower a thousand years ago. A thousand years from now a Geminid meteor may go unrecognized amid other new showers that have formed.

When maximum hourly rates fall below 2 per hour a meteor shower becomes difficult to recognize. The odds a sporadic meteor will line itself up with any shower radiant is at least 1 per hour. Therefore a weak shower producing one meteor per hour can suffer from sporadic contamination, artificially doubling its true activity. Meaningful meteor shower lists limit themselves to showers that produce hourly rates of at least two shower members at maximum activity. This means that the observer will actually witness an average of three meteors per hour from these showers, with one of the meteors actually being sporadic. This is meaningful, for weak showers producing ten meteors an hour or less as a large percentage of their activity can actually be associated with random activity. For stronger showers this is a smaller percentage of the observed activity and does not skew the results.

Like shower activity, sporadic rates vary throughout the year, depending on your location. From the northern hemisphere the spring season offers the lowest sporadic rates of the year. During the summer sporadic rates increase and reach a 3-month maximum during the months of autumn. The winter season offers good rates in January, but activity falls during February and March toward the spring low (Fig. 2.1). In the southern hemisphere the activity curve is not so simple. Their summer season produces a peak of sporadic activity in January, with rates then falling slowly during February and March. Sporadic rates again increase in April and May toward a secondary maximum in July. In August rates fall steeply toward the annual minimum in October. In November rates again climb toward the January maximum (Fig. 2.2).

It was once thought that the annual variation in sporadic activity was due to the angle of the ecliptic during the active morning hours. As seen from the northern hemisphere the angle of the ecliptic is steepest near the autumnal equinox in September. The angle is shallowest near the spring equinox in March. This roughly coincides with the strongest and weakest sporadic rates of the year. One would expect just the opposite as seen from the southern hemisphere with the strongest rates in March and the weakest in September.

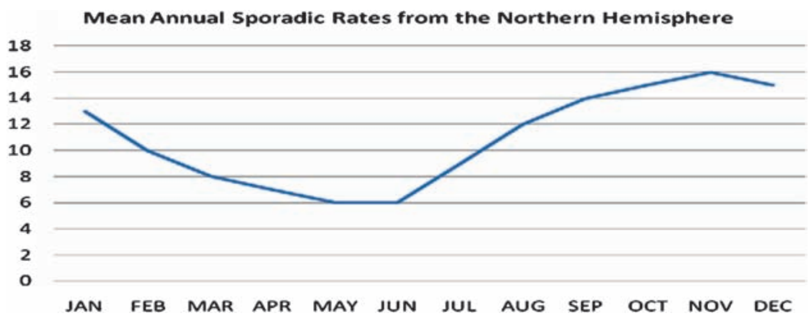

Fig. 2.1. Mean annual sporadic rates as seen from 45°N. under dark sky conditions.

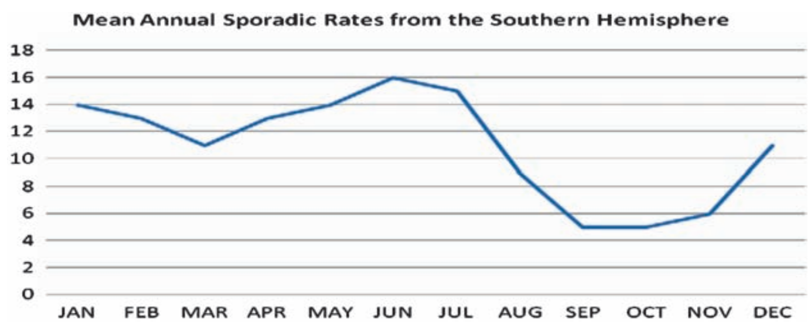

Fig. 2.2. Mean annual sporadic rates as seen from 45°S. under dark sky conditions.

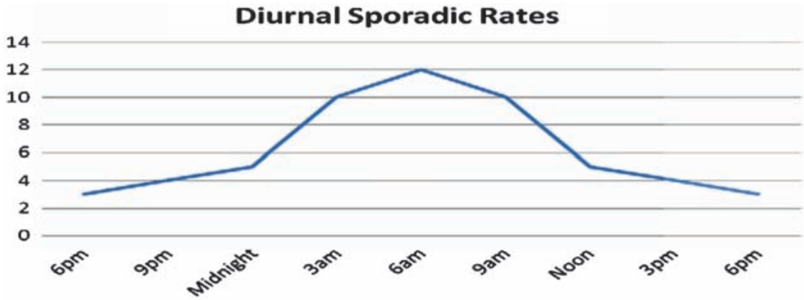

Fig. 2.3. Diurnal sporadic rates showing the peak near 6:00 a.m.

The September minimum is correct, but the peak in June/July and the secondary minimum in March do not fit at all. Therefore the ecliptic angle has little effect on the sporadic activity. The lack of data from the southern hemisphere hampers the study, but it is currently thought that the solution is simply that the lulls in sporadic activity is due to a genuine lack of material located north or south of the ecliptic plane encountering Earth at that time of year (Fig. 2.3).

No matter your location, the time of day has a great influence on the number of sporadic meteors you will see. At 6:00 p.m., when you look into the sky, you are viewing the area of space from which Earth is receding. This is much like the view out the back window of a moving vehicle in rainy weather. To be seen at this time any meteoroid must overtake Earth. Like the scarcity of raindrops on a rear window, there are very few meteoroids that catch up to Earth and can be seen at this time. The situation slowly improves as the evening progresses. Near 9:00 p.m. Earth has rotated 45° toward the east, yet the situation has scarcely improved. Any activity seen at this hour is a combined group of meteors catching up to Earth and those striking the atmosphere at a more perpendicular angle. Rates are still relatively low at midnight, with all activity striking Earth at near-perpendicular angles.

A particular group of meteors radiating from the ecliptic near the opposition (antisolar) point is often noticeable at this time. These are the Antihelion meteors, separate from sporadic meteors yet not produced by any single object. These meteors will be presented in the next chapter.

Past midnight observers will begin to see meteors that strike Earth from a head-on direction. As the graph implies, many more meteors are seen after midnight than before. The reason for this is that the observer can now see meteors from both perpendicular angles and those striking the atmosphere head on. During the early morning hours, near 3:00 a.m., an observer is now viewing the part of the sky to which Earth is approaching. There will still be some slower meteors radiating from areas in the western half of the sky, produced by meteors striking the atmosphere at a more perpendicular angle. The most notable and more numerous meteors, though, will be those radiating from the eastern half of the sky with very swift velocities. The maximum diurnal rates occur near 6:00 a.m., when nearly all meteors seen strike Earth from a head-on direction. This situation is much like viewing through the front windshield of a moving vehicle during rain. Unfortunately dawn interferes at this hour, so the best observed rates usually occur an hour or two earlier before the onset of morning twilight.

2.2 Antihelion Meteors

During the course of a year Earth intercepts particles orbiting in a prograde motion lying in low-inclination orbits centered along the ecliptic. Like most members of the Solar System these particles orbit the Sun in a direct motion and encounter Earth before their closest approach to the Sun. The source of these meteoroids is not precisely known, but it is thought that they are produced by asteroids or comets under the gravitational influence of Jupiter. These meteoroids that encounter Earth on the inbound portion of their orbit are known as Antihelion meteors. They are named for the area of the sky in which they seem to radiate, the antisolar or Antihelion portion of the sky. This part of the sky rises as the sky becomes totally dark and is best placed near 0100 local standard time (LST), when it lies highest above the horizon. During the morning hours the Antihelion radiant sinks into the western sky and lies near the western horizon at dawn. The radiant is not precisely located at the antisolar point due to the fact that slower meteors, such as the Antihelions, are affected by the apex attraction. Simply stated, the apex attraction is produced by Earth's motion through space, which causes the apparent radiant to be slightly different than the actual radiant. In this case the apparent Antihelion radiant is shifted 15° toward the direction Earth is moving (east). Therefore the apparent radiant of the Antihelion meteors lies 15°E of the exact antisolar point.

These meteors were once classified into separate showers throughout the year, with their radiant area always near the antisolar area of the sky. Among these were the delta Cancrids of January, the Virginids of February, March, and April, the alpha Scorpiids of May, the Sagittarids of June, the Capricornids of July (not to be confused with the alpha Capricornids), the iota Aquariids of August, the Southern Piscids of September, the Arietids of October, the Taurids of November (not to be confused with the Northern and Southern Taurids), and lastly the chi Orionids of December.

Observers rarely focus on viewing the Antihelion radiant, as rates seldom exceed 3 per hour. There is, though, a constant supply of slow meteors produced from this area throughout the night and during the course of a year. Rarely does an observer not see at least one Antihelion meteor during an observing session. Unlike most shower radiants, the Antihelion radiant is large and diffuse, often covering an area of 30° in right ascension (celestial longitude). The size in declination (celestial latitude) is somewhat less, making it oval shaped.

As stated before, these meteors are visible during the entire night but best seen near 1:00 a.m. LST when the radiant lies on the meridian and is situated highest in the sky. For those who observe summer or daylight saving time the culmination would occur at 2:00 a.m. Since the Antihelion radiant does not venture more than 23° from the celestial equator, shower members may be seen equally well from both hemispheres during the year. The radiant follows the ecliptic and ranges from a declination of 23°N in late November and early December to 23°S in late May and early June. Therefore it is best seen in late November and early December from the northern hemisphere and from late May to early June from the southern hemisphere.

During October and November the large Antihelion radiant overlaps that of the more active north and south Taurid radiants. During this time it is impossible to separate activity from these radiants. Therefore, at this time of year any activity from this area is classified as either northern or southern Taurid. This may artificially inflate the observed activity of the Taurids, but at this time it is the best compromise (Table 2.1)

Table 2.1. Positions of the Antihelion radiant throughout the year[1]

Date	RA	Dec	Const.	Date	RA	Dec	Const.
Jan 01	113	+21	GEM	Jul 01	292	−21	SAG
Jan 15	127	+17	CNC	Jul 15	305	−18	CAP
Feb 01	145	+13	LEO	Aug 01	321	−14	CAP
Feb 15	159	+07	LEO	Aug 15	335	−08	AQR
Mar 01	173	+02	LEO	Sep 01	351	−03	PSC
Mar 15	187	−04	VIR	Sep 15	005	+03	PSC
Apr 01	203	−09	VIR	Oct 01	–	–	PSC
Apr 15	218	−15	LIB	Oct 15	–	–	ARI
May 01	233	−19	LIB	Nov 01	–	–	TAU
May 15	247	−22	OPH	Nov 15	–	–	TAU
Jun 01	264	−23	OPH	Dec 01	081	+23	TAU
Jun 15	276	−23	SAG	Dec 15	096	+23	GEM

Table 2.2. Enhanced periods for Antihelion activity[2]

Period	Maximum	Position
Jan 02–07	Jan 04	131 (08:44) + 28
Jan 27–Feb 05	Feb 05	160 (10:40) + 09
Feb 05–12	Feb 12	152 (10:08) + 12
Feb 17–26	Feb 25	162 (10:48) + 03
Mar 18–23	Mar 22	186 (12:24) + 02
Apr 04–09	Apr 08	220 (14:40) − 08
Apr 16–23	Apr 23	223 (14:52) − 24
Apr 17–23	Apr 19	218 (14:32) − 18
Apr 27–May 06	May 05	241 (16:04) − 16
May 22–30	May 29	254 (16:56) − 16
Jun 05–14	Jun 06	260 (17:20) − 23
Jun 17–26	Jun 18	274 (18:16) − 30
Jun 23–Jul 01	Jul 01	283 (18:52) − 27
Jun 24–30	Jun 29	290 (19:20) − 21
Jul 16–22	Jul 21	315 (21:00) − 18
Jul 25–31	Jul 25	326 (21:44) − 23
Jul 30–Aug 06	Aug 02	335 (22:20) − 16
Aug 10–16	Aug 16	336 (22:24) − 04
Aug 08–26	Aug 22	354 (23:36) + 05
Aug 26–Sep 08	Sep 05	358 (23:52) + 04
Sep 01–06	Sep 05	011 (00:44) − 04
Sep 07–12	Sep 08	010 (00:40) + 01
Sep 10–18	Sep 14	357 (23:48) − 04
Sep 13–23	Sep 18	010 (00:40) + 08

There are certain times of the year when the Antihelion radiant is slightly stronger than its normal 2–3 meteors per hour. These were once thought to be the peaks of separate showers. In reality it's just areas where the concentration of particles is just a bit higher than normal. Table 2.2 lists these periods of enhanced rates for the Antihelion radiant.

Table 2.3. Helion showers[3]

Name	Period	Maximum	Position
Daytime Scutids	Dec 30–Jan 06	Jan 04	278 (18:32) − 08
Daytime chi Capricornids	Jan 17–Feb 12	Feb 01	322 (21:28) + 06
Daytime epsilon Aquariids	Jan 15–Feb 13	Feb 13	310 (20:40) − 07
Daytime chi Piscids	Mar 28–Apr 21	Apr 09	020 (01:20) + 21
Daytime omega Cetids	Apr 24–May 27	May 07	356 (23:44) + 08
Daytime epsilon Arietids	May 04–Jun 06	May 16	045 (03:00) + 21
Daytime Arietids	May 22–Jul 02	Jun 07	045 (03:00) + 26
Daytime Aurigids	Jun 09–Jul 25	Jun 27	093 (06:12) + 31
Daytime zeta Cancrids	Aug 07–22	Aug 20	120 (08:00) + 19
Daytime gamma Leonids	Aug 18–24	Aug 22	140 (09:20) + 12
Daytime psi Virginids	Sep 28–Oct 24	Oct 15	194 (12:56) − 0
Daytime iota Virginids	Nov 05–07	Nov 05	210 (14:00) − 04
Daytime delta Scorpiids	Dec 05–07	Dec 06	247 (16:28) − 25

2.3 Helion Meteors

These meteors are similar to the Antihelion meteors only in that they strike Earth on the outbound leg of their orbit. Therefore they strike the sunlit portion of Earth and are seldom seen. This radiant follows the ecliptic and is normally located only 15°E of the Sun. They are never seen in total darkness, as the Sun must be 18° below the horizon for total darkness to exist. The only opportunity of ever seeing these meteors would be from near the equator, where twilight is at its shortest. Even then the chance is remote, as the low elevation of the radiant would provide only a small fraction of the meteors seen compared to when the radiant is located highest in the sky.

Radar studies of the sky have revealed numerous showers associated with the Helion radiant. Table 2.3 lists the showers from the IAU associated with the Helion radiant.

2.4 Apex Meteors

Material that circles the Sun in a high-inclination orbit in a retrograde motion is most likely produced by Halley-like and long-period comets. This material encounters Earth after perihelion on the outbound portion of its orbit. Since they are moving in opposite directions they strike Earth at tremendous velocities often creating bright meteors with persistent trains. These particles strike Earth on the morning side of the planet and are best seen just before morning twilight, while the sky is still perfectly dark. This is not really a shower per se but an artificial radiant created by Earth's motion through space. Unlike the Antihelion radiant, which is always located on the ecliptic, the apex radiants have formed two diffuse branches located approximately 15°N and 15°S of the ecliptic, 90°W of the Sun. Therefore it rises near midnight and is highest in the sky near 6:00 a.m. LST.

One theory for the formation of the two branches is that Earth has cleared away much of the material near its orbit (zero inclination), leaving most of the material either north or south of the ecliptic. Studies of these meteors made by members of

Table 2.4. Periods of enhanced apex activity[4]

Period	Maximum	Position
Jan 1–6	Jan 03	176 (11:44) − 23
Jun 16–Jul 10	Jun 24	009 (00:36) + 21
Jul 13–21	Jul 20	021 (01:24) + 36
Jul 25–Aug 08	Aug 06	043 (02:52) + 40
Aug 12–17	Aug 15	040 (02:40) + 36
Aug 19–30	Aug 24	058 (03:52) + 41
Aug 24–30	Aug 30	074 (04:56) + 15
Aug 28–Sep 08	Sep 06	066 (06:24) − 03
Sep 16–23	Sep 21	074 (04:56) + 08
Oct 24–Nov 04	Nov 03	149 (09:56) + 28
Nov 06–11	Nov 08	146 (09:44) + 45
Dec 09–16	Dec 09	179 (11:56) + 35

the American Meteor Society (AMS) have revealed that these meteors are less numerous than those of the Antihelion radiant, and that attempts to isolate these meteors from the sporadic background are for the most part not worthwhile. There are times during the year, though, when rates from the apex source are more noticeable. Table 2.4 lists these periods along with the radiant positions.

2.5 Antiapex Meteors

Antiapex, or antapex, meteors are produced by material orbiting the Sun in a retrograde direction that encounters Earth on the inbound or preperihelion portion of its orbit. Like the sources that produce the apex meteors, these are most likely produced by long-period comets. These meteors have twin radiants located north and south of the ecliptic, 90°E of the Sun. This means they are best seen as soon as it becomes dark, after the end of evening twilight. Once again this is not a true shower but an artificial radiant created by Earth's motion through space. Unlike the apex meteors, these meteors would be among the slowest to appear in the sky. Slow meteors are affected by Earth’s gravity in such a way that the apparent radiant is actually far from the true radiant. This is called the *zenith attraction*. With the diffuse nature of the radiant, the additional offset due to the zenith attraction would make classifying these meteors very difficult. The radiant area would be so large that fully half of the few evening meteors seen could possibly be members of the antapex group. Since this is an artificial radiant it is advised that observers simply label these meteors as sporadic and save their efforts for true shower meteors.

When the antapex radiant lies highest in the sky there seems to be an increase in the fireball activity. Studies have shown that during the period from mid-February through mid-April, when the antapex radiant lies highest in the sky, fireball rates peak as seen from the northern hemisphere. If this relationship is true then the same scenario should occur during mid-August to mid-October from the southern hemisphere. Unfortunately the lack of observers located south of the equator has prevented this from being verified.

Table 2.5. Parameters of the N. Toroidal showers found in the IMO's video study[6]

Period	Maximum	Position	Expected position
Mar 30–Apr 07	Mar 31	276 (18:28) + 41	277 (18:32) + 27
Sep 29–Oct 05	Oct 04	080 (05:20) + 83	114 (07:36) + 73
Oct 06–11	Oct 07	079 (05:16) + 82	120 (08:00) + 72
Nov 23–29	Nov 29	199 (13:16) + 65	187 (12:28) + 53
Dec 06–23	Dec 20	209 (13:56) + 56	204 (13:36) + 45

2.6 Toroidal Meteors

There is a group of meteoroids in orbits inclined steeply to the ecliptic that encounter Earth on a continual basis. The source of this material in not known, but it is thought to be related to the Jupiter family of comets, the same source of the Helion and Antihelion meteors.[5] Rates from this source are less than those seen from the other sporadic groups. This diffuse radiant would be centered approximately 90°W of the Sun and 50° north and south of the ecliptic. These meteors, striking the atmosphere at near-perpendicular angles, would have an entry velocity of 22 miles/s, which would result in meteors of medium velocity.

Several showers that can be identified with the northern Toroidal source have been found in Sirko Molau's analysis of the IMO's video database, though not always in the exact position expected. This indicates a large and diffuse radiant. Reported dates and positions are listed in Table 2.5.

Of the six periods listed, the last period in December provided far and away the strongest rates. Due to the lack of data from the southern hemisphere no showers from the southern Toroidal source were found. Visual observers would have a difficult time trying to separate any possible Toroidal meteors from the sporadic background, especially when sporadic rates are high.

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Chapter 3

Major Annual Showers

Abstract

This chapter discusses the nine major annual showers that are currently active. A star chart displaying the radiant drift during the showers' entire activity is presented along with parameters of each shower, such as celestial position, radiant drift per day, and geocentric velocity. There are also wide-angle charts displaying meteor paths that the observer may see from four widely different latitudes. It becomes readily apparent why some showers are best seen from certain locations. Lastly, some photographs of actual shower members are presented.

A major annual shower is one that appears on a yearly basis without fail and produces at least a ZHR of 10 at maximum activity. Currently there are nine such showers that qualify as major annual showers. The list is fairly stable and one from 1950 would appear much like a current list. The dates of maximum activity may slightly change, but these showers reappear year after year and are the highlights of a meteor observer's year.

Beginner meteor watchers should concentrate on these showers, as they offer the best opportunity to view strong activity and to sharpen one's skills as an observer. The major annual showers are concentrated during the second half of the year. Only the Quadrantids, Lyrids, and eta Aquarids reach maximum activity during the first half of the year. Northern observers also have a distinct advantage, as most of the radiants will appear high in their skies. Only the Eta Aquarids of May and the Delta Aquarids of July are better seen by observers south of the equator.

A majority of the major meteor showers also strike Earth from a head-on position. This creates swift meteors, as seen in the observer's sky. Variations in entry velocity depend on the angle of intersection with Earth with radiants located near the apex being the fastest. The further the radiant lies from the apex, the slower the meteors will appear. Radiant position in the observer's sky will also affect the observed velocity. Those shower meteors appearing near the radiant will appear to move more slowly in short paths. These meteors are moving toward the observer and appear foreshortened. Shower meteors appearing low in the sky will also appear foreshortened, as they are traveling away from the observer. Therefore meteors striking Earth from a head-on position can still produce slow-moving meteors when these meteors are seen near the radiant or near the horizon. Meteors with a slow entry velocity, in the vicinity of 11–20 miles/s, will never produce swift meteors. The fastest meteors from each shower will appear 90° from the radiant and as high in the sky as possible for this radiant distance.

Unfortunately for working people all of these showers are best seen in the morning hours after midnight. This is the time of night that also favors random activity. Only

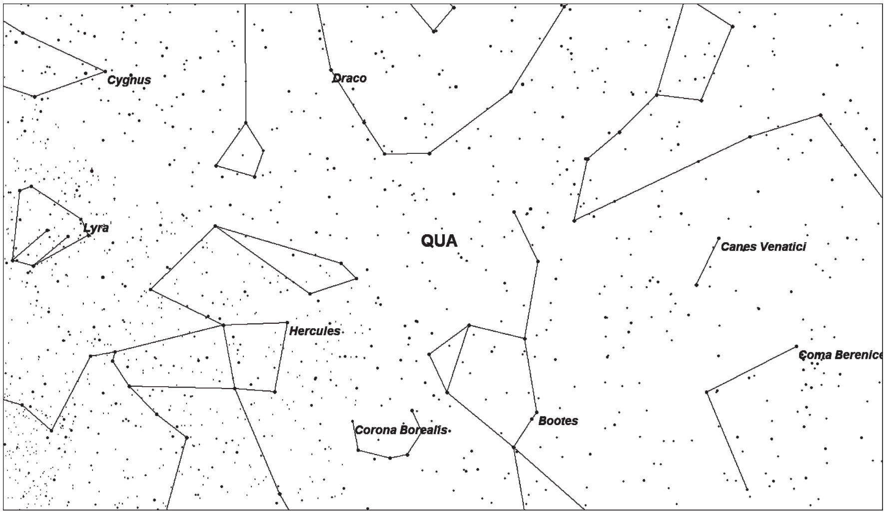

Fig. 3.1. Radiant position of the Quadrantids.

the Geminids of December appear in large numbers before midnight. Occasionally these showers will peak in intensity over the weekend and without a Moon in the sky. These are the best circumstances possible and should not be missed!

Showers are presented in this chapter in chronological order as they appear throughout the year. The name usually refers to the constellation in which the radiant is located at the time of maximum activity. The name is presented in the possessive Latin form, as has been the custom since showers were first named back in the nineteenth century. The abbreviation in parentheses is the shower code used by the International Meteor Organization (IMO). The number refers to the International Astronomical Union's (IAU) list of meteor showers.

Each shower presented here has unique characteristics. Included in the discussion are the activity period, the radiant drift during the activity period, and the observed rates seen throughout the activity. Finally, the visibility of each shower is presented from four different vantage points, ranging from 50°N latitude down to 25°S latitude. Charts showing representative shower members from each location plus photographs of actual shower meteors are also presented (Fig. 3.1).

3.1 Quadrantids (QUA) #10

Activity period: 01/01–01/05
Date of maximum activity: 01/03
Radiant position at maximum: 239 (15:20) + 49
Radiant drift per night: RA +0.8° Dec −0.2°
Geocentric velocity: 30 miles/s (49 km/s)

The Quadrantids are the first major shower of the year and appear in large numbers shortly after New Year's Day. ZHRs reach 1 on January 1 and the shower reaches maximum activity only 2 days later. By January 5 the shower is back down to a ZHR of 1. Therefore, you only have a 5-day period to see these meteors. One stretch of bad weather can ruin the entire activity period.

This shower has the potential of providing the strongest rates of the year. Average ZHRs are 120 at maximum activity. Unfortunately these rates last only a few hours, so the odds of seeing the Quadrantids at their best are remote. This display is ideally situated to be seen from high northern latitudes. Unfortunately cloudy skies and cold temperatures prevail this time of year in this region. To compound the problem a bright Moon will be present at least every third year, making the combination of clear skies and no moonlight difficult to achieve.

At maximum activity the radiant lies at 230 (15:20) + 49. This position is located in an empty portion of northeastern Bootes some 20°E of the second-magnitude star Alkaid (eta Ursae Majoris). The nearest bright star is third-magnitude beta Bootis, lying 8° to the southwest of the Quadrantid radiant. Due to the short activity period, the radiant path is short. During the 5 days of activity the radiant moves 3°E and 1°S.

As seen from 50°N latitude the radiant is circumpolar, remaining above the horizon both day and night. At the end of evening twilight the radiant lies in the northwestern sky, 15° above the horizon. If a shower is strong at this time a few meteors may be seen shooting upward from the radiant. At such a low altitude only 26% of the total Quadrantid can be seen. The remaining 74% of the meteor activity occurs in parts of the atmosphere beyond the view of the observer. The only way to relieve this situation would be to travel further northward, where the radiant would be located higher in the sky at that particular time. Further south, evening observations of the Quadrantids are much less likely, as the radiant lies below the horizon by the time it becomes sufficiently dark. The radiant lies closest to the horizon between 1800 and 1900 local standard time (LST) and then begins its slow climb into the northeastern sky. The radiant lies highest in the sky just before the start of morning twilight. This is the best time to view Quadrantid activity, and if the maximum rates occur while the radiant is high in the sky, then you are in for a special treat.

As seen from 25°N latitude the radiant lies well below the northwest horizon at dusk. It stays below the horizon until midnight so there is no chance of seeing Quadrantid activity during the evening hours. During the morning hours the radiant rises slowing into the northeastern sky and reaches an altitude of approximately 55° before the onset of morning twilight. At this altitude roughly 80% of the Quadrantid is visible, so there is no chance of seeing the full ZHR, even if your limiting magnitude is +6.5. If the ZHR is 120 the best you could hope for is seeing 100 Quadrantids per hour.

From the equator the situation is even worse. The radiant does not rise until 0200 LST. Morning twilight begins only 3 h later with the radiant lying only 30° above the northeast horizon. At that altitude only 50% of the possible Quadrantid activity is visible, so with a ZHR of 120, only 60 Quadrantids could possibly be seen from the equator.

In the southern hemisphere it is almost impossible to see much Quadrantid activity. From 25°S latitude the radiant lies just a couple of degrees above the horizon at the start of morning twilight. From this far south the best anyone could hope for is a rare Earth-grazing Quadrantid shoot upward from the northeastern horizon before it becomes too bright.

The odds of any one longitude seeing the Quadrantids at a ZHR of 120 is low. You can realistically expect to see between 25 and 50 shower members at best. Perhaps once a decade you might catch them near maximum, when the rates exceed 50 per hour. With these lower expectations observing this shower from anywhere south of the equator would be a real challenge.

Quadrantid meteors strike Earth's atmosphere at a velocity of 25 miles/s. This produces meteors of medium speed, as seen in the sky. If Quadrantid meteors are seen close to the radiant or near the horizon they will appear to move more slowly than those seen far from the radiant and high in the sky. Both of these situations decrease the path length, but the duration remains the same. This results in the meteors appearing to travel more slowly.

Until recently no parent object was known for this shower. It was first thought that the Quadrantids were produced by a fragment of comet 96 P/Machholz. Later studies by Dr. Peter Jenniskens revealed that the asteroid 2003 EH_1, a possible fragment of comet C/1490 Y_1, was the most likely producer of these meteors (Table 3.1, Figs. 3.2–3.7).[1]

Table 3.1. Radiant altitude for the Quadrantids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	15	12	10	10	12	15	19	25	33	40	48	57	68
25°N	−8	−13	−16	−16	−13	−7	−2	7	15	25	34	43	52
00	−32	−37	−40	−40	−37	−31	−22	−14	−5	6	15	23	–
25°S	–	–	−65	−65	−60	−52	−43	−33	−23	−14	−6	–	–

Fig. 3.2. A bright Quadrantid appears in Corvus.

Fig. 3.3. A long Quadrantid shoots by Gemini.

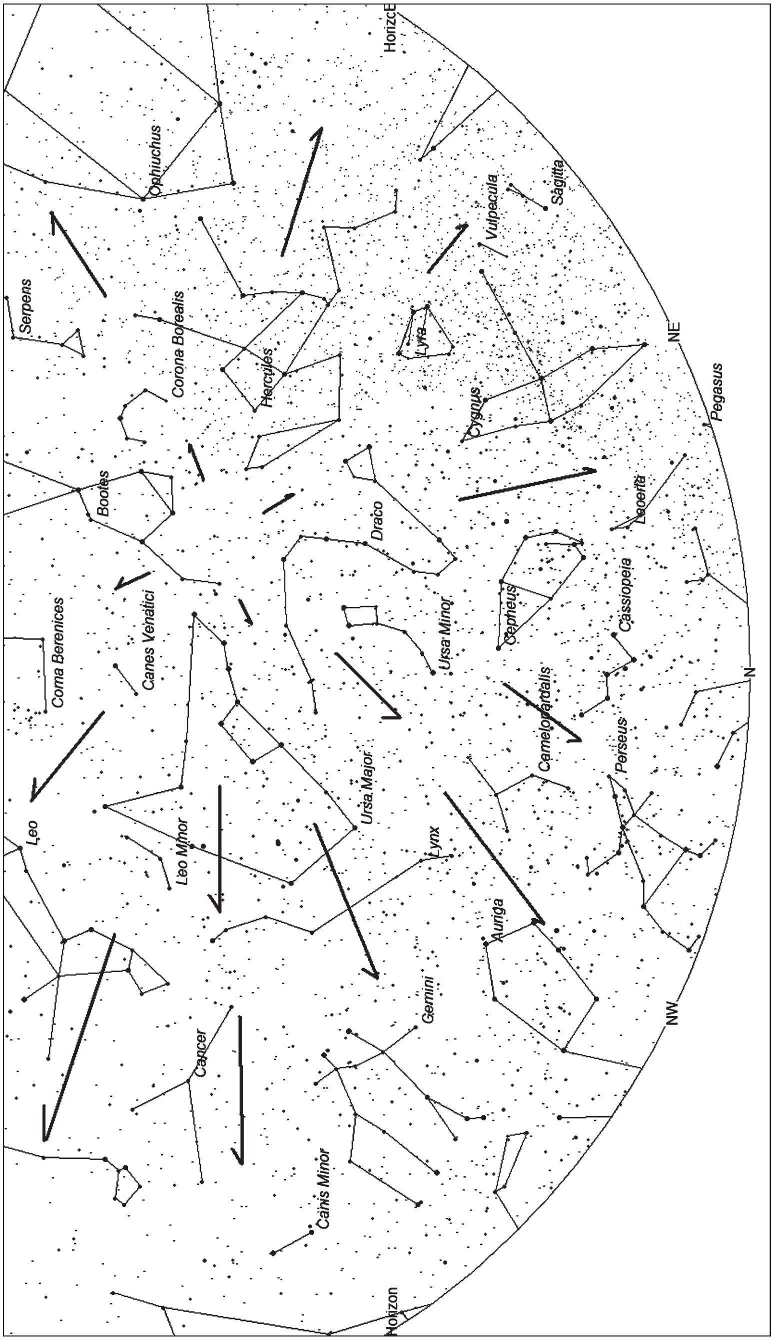

Fig. 3.4. Quadrantid activity as seen from latitude 50°N. Facing north at dawn.

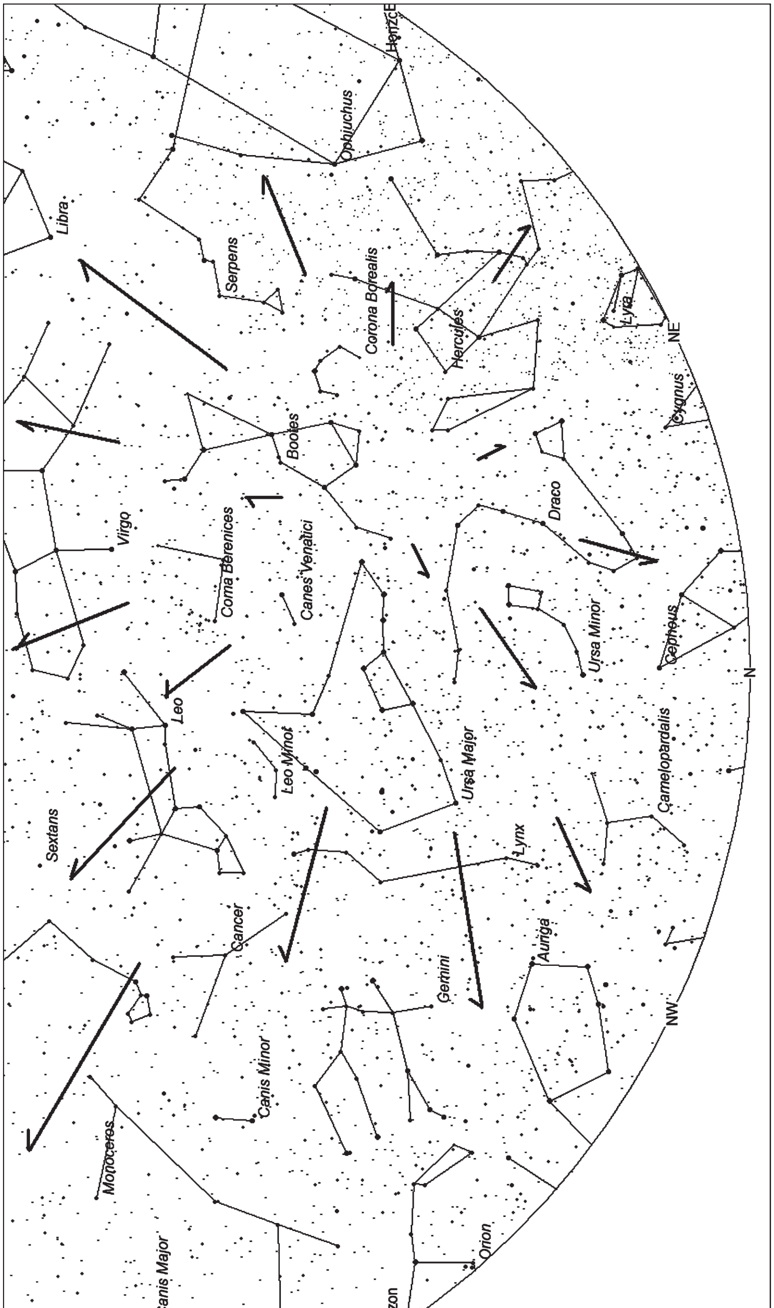

Fig. 3.5. Quadrantid activity as seen from latitude 25°N. Facing north at dawn.

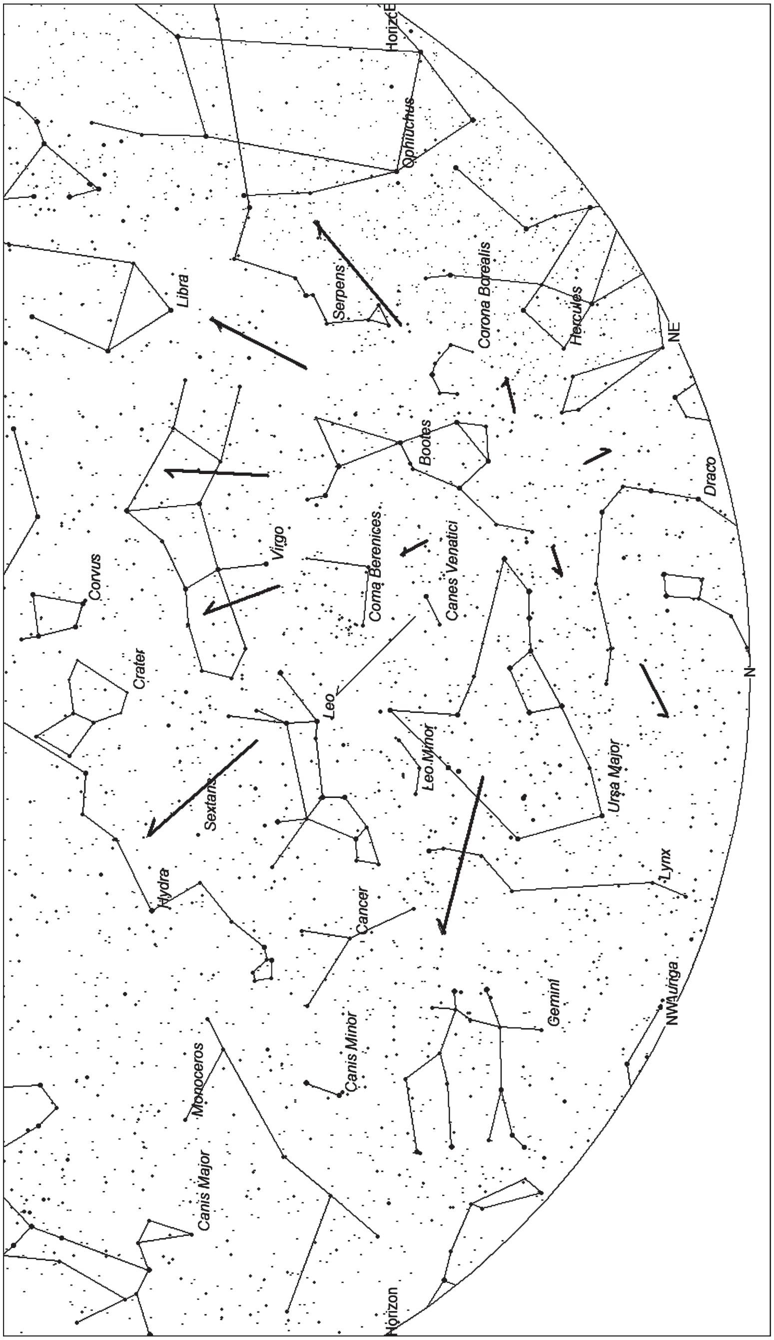

Fig. 3.6. Quadrantid activity as seen from the equator. Facing north at dawn.

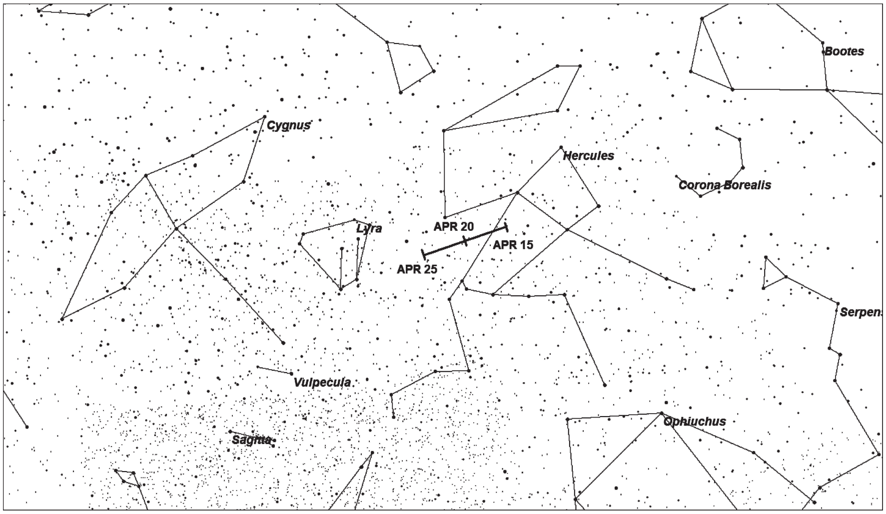

Fig. 3.7. Radiant drift for the Lyrids.

3.2 Lyrids (LYR) #6

Activity period: 04/16–04/25
Date of maximum activity: 04/22
Radiant position at maximum: 272 (18:08) + 34
Radiant drift per night: RA +1.1° Dec 0.0°
Geocentric velocity: 30 miles/s (49 km/s)

More than 3 months pass before the next major annual shower appears. This shower is named the Lyrids, but the radiant actually is located in the constellation of Hercules during its entire activity period. When this shower was first named the borders for each constellation were not uniformly defined. The radiant does lie fairly close to the bright star Vega in the constellation of Lyra. Therefore the association with Vega and Lyra was understandable given that Hercules is a dim constellation and the past borders were often ill-defined.

Lyrid meteors start appearing in central Hercules in mid-April. Rates at this time are usually no more than 1 per hour. Activity increases slightly with each passing night until the peak is reached on April 22. After, the peak rates slowly decrease until the shower passes below a ZHR of 1 on April 25.

Rates at maximum activity can vary for this shower, but they usually range from 10 to 25 shower members per hour. Rarely the Earth will pass through a dust trail created by comet Thatcher, and rates will approach or even surpass 100 Lyrids per hour for a short time. The next predicted possible outburst for this shower occurs in 2040 and 2041.[2]

The position of the radiant at maximum activity is 271 (18:04) + 34. This area of the sky is located in eastern Hercules, 8°SW of the bright star Vega. As seen from 50°N latitude the radiant lies close to the northeastern horizon at dusk. It spends the entire night climbing high into the southern sky, where it reaches a maximum altitude of 75° at dawn.

As seen from 25°N latitude the radiant does not rise above the horizon until approximately 1930 LST (2030 daylight saving time). The radiant culminates near 0400 LST when it lies nearly overhead. Dawn breaks nearly an hour later, so there are several hours available to view Lyrid activity when the radiant lies very high in the sky, and rates should be close to your ZHR as long as your skies are dark and moonless.

As one progresses further southward conditions deteriorate slightly as the Lyrid radiant is seen lower in the northern sky. As seen from the equator the radiant rises near 2200 LST and culminates at 0400 when it lies 56° above the northern horizon. At this altitude 83% of the Lyrid activity can still be seen, so observers at the equator have a good view of this shower.

As seen from 25°S latitude the Lyrid radiant does not rise until near 2300 LST. It then culminates due north at 0400 when it lies 31° above the northern horizon. At this altitude only 50% of the Lyrid activity can be seen, so hourly rates would seldom exceed 10 as seen from this latitude.

Some Lyrid activity can be seen down to latitude 56°S. Further south the radiant does not clear the horizon, and only a rare Lyrid Earth-grazer could possibly be seen. Below 60°S it would be impossible to view Lyrid activity (Table 3.2, Figs. 3.8–3.14).

3.3 η Aquariids (ETA) #31

Activity period: 04/19–05/29

Date of maximum activity: 05/05
Radiant position at maximum: 339 (22:36) − 01
Radiant drift per night: RA +0.9° Dec +0.4°
Geocentric velocity: 41 miles/s (66 km/s)

As the Lyrids reach maximum activity some long, swift meteors may be seen shooting upward from the eastern horizon at dawn. This activity belongs to the eta Aquariid meteor shower, which produces the strongest rates of any major annual shower seen from the southern hemisphere. These meteors reach a ZHR of 1 on April 19 and continue a slow climb to maximum on May 5. Rates remain low until May 2, when a long plateau of activity for the eta Aquariids begins. Unlike most meteor showers, the eta Aquariids do not possess a sharp peak where one night

Table 3.2. Radiant altitude for the Lyrids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	–	–	10	17	25	35	44	53	63	71	74	–	–
25°N	–	−17	−8	2	13	25	37	50	62	73	81	73	–
00	–	−36	−24	−13	−1	12	24	35	45	53	56	53	–
25°S	−63	−53	−38	−26	−14	−3	8	17	24	28	31	28	24

Major Annual Showers

clearly stands out as the best to view this shower. Any night centered on May 5 for a solid week has the capability of producing good activity from this shower. The best nights are usually those closer to May 5, as this is when Earth lies closest to

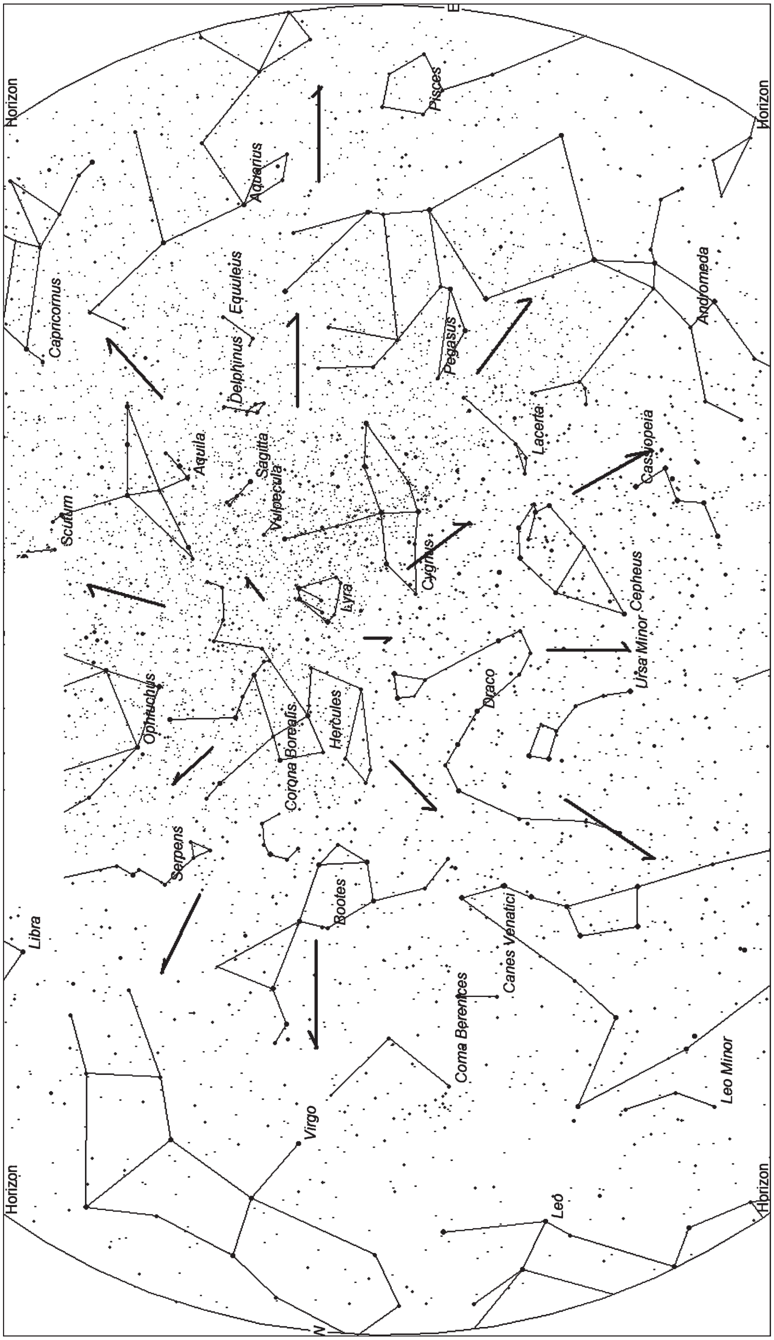

Fig. 3.8. Lyrid activity as seen from latitude 50°N. Facing north at dawn.

the orbit of Halley's Comet. At this time of year Earth just skims the outbound particles of Halley's Comet, which separated from the comet many hundreds of years ago.

Fig. 3.9. Lyrid activity as seen from latitude 25°N. Facing north at dawn.

The current orbit of Halley's Comet lies so far from Earth that no new material produces meteor showers on Earth. It is the old paths that produce the meteors known as the eta Aquariids in May and the Orionids in October. Eta Aquariids

Fig. 3.10. Lyrid activity as seen from the equator. Facing north at dawn.

activity continues throughout the month of May until the 28th, when rates have again fallen to a ZHR of 1. At maximum activity the average ZHR is 60. Actual hourly rates seen are usually much lower, as the radiant can never approach the

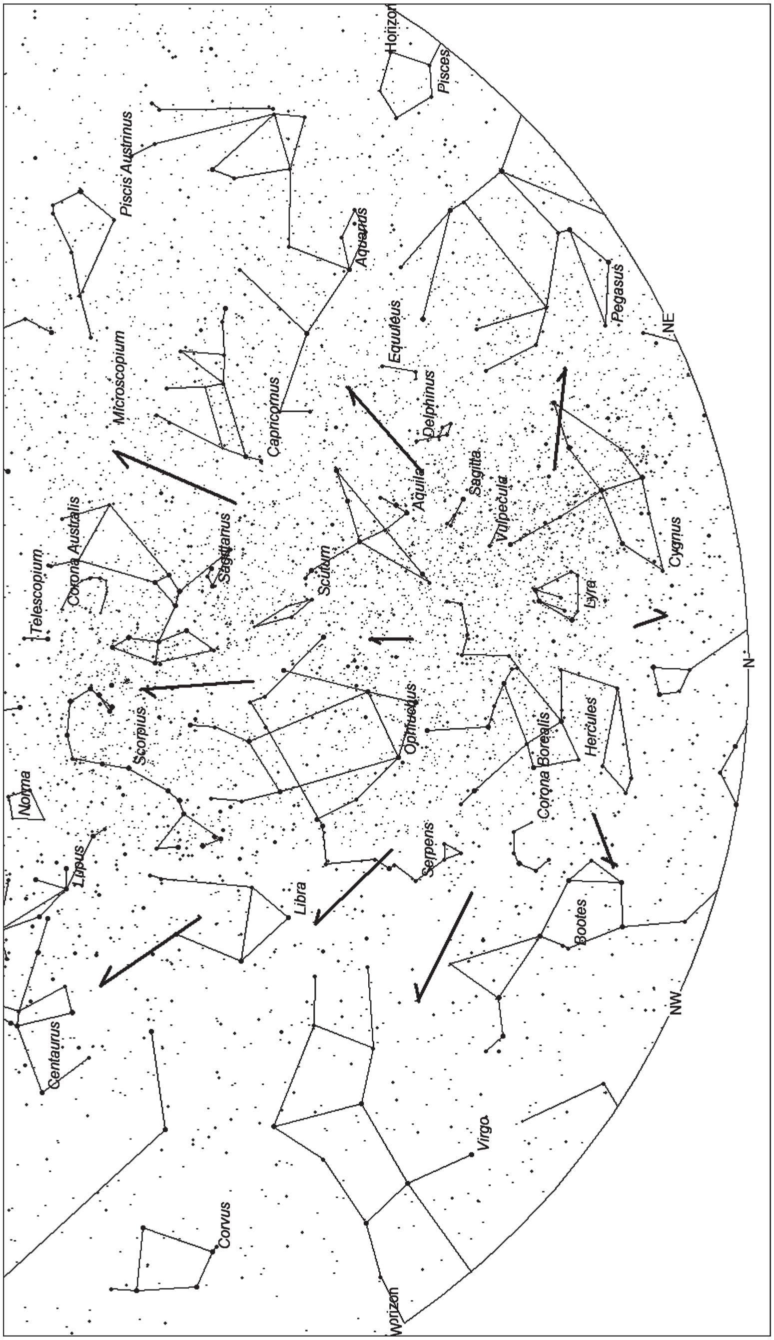

Fig. 3.11. Lyrid activity as seen from latitude 25°S. Facing north at dawn.

Fig. 3.12. A long Lyrid shoots past Arcturus (alpha Bootis).

Fig. 3.13. A Lyrid appears between the clouds.

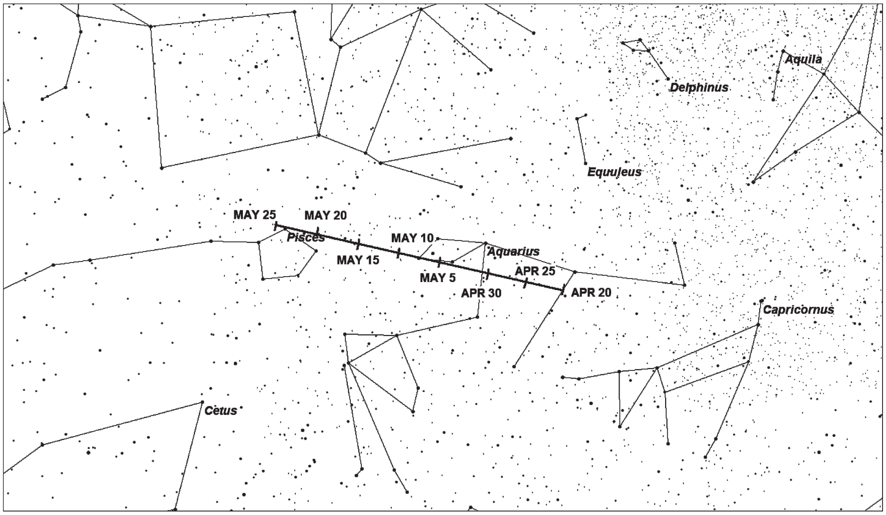

Fig. 3.14. Radiant drift for the eta Aquariids.

zenith from any location before the sky becomes too bright from morning twilight.

The radiant starts out in western Aquarius and drifts eastward through the asterism known as the "water jar" or "peace sign." This tight group of fourth-magnitude stars is an easy reference for the radiant at maximum activity. The radiant crosses into the constellation of Pisces on May 15 and spends the remaining days lying just above the "circlet" of faint stars in western Pisces.

Lying close to the celestial equator, one would think that this radiant can be seen equally well from both hemispheres. Unfortunately this is not the case, as the short nights experienced in the northern hemisphere this time of year hamper their view of this display. As seen from 50°N latitude the radiant lies only 13° above the eastern horizon at the break of dawn. At this low altitude less than 25% of the activity can be seen. Hourly counts in excess of 10 would be extremely rare from such a high latitude.

As seen from 25°N latitude the radiant rises near 0130 LST (0230 daylight saving time). By dawn (0430 LST) the altitude has increased to 39°, which allows 63% of the activity to be seen. If observing under dark skies with a ZHR of 60, this would allow an observer to see 38 eta Aquariids per hour. Of course, dawn would be the ending point of a meteor watch, so the actual radiant altitude during the preceding hour would be lower than 39° resulting in less activity being seen. The record hourly count reported for the eta Aquariids as seen from the northern hemisphere was 32 as seen from 33°N latitude. Observers located a bit further south should be able to do better if the shower is seen at maximum activity.

As seen from the equator the eta Aquariid radiant still rises at 0130 LST, but the length of night is longer, allowing an observer to view until 0515 LST. At this time the altitude of the radiant is 55°, allowing 82% of the total activity to be seen. This is an ideal vantage point for observations of this shower, but the lack of observers located near the equator and further south hinders the gathering of data for this shower.

As seen from 25°S latitude the eta Aquariid radiant still rises near 0130 LST. With the radiant being located near the celestial equator the time the radiant rises remains the same for observers along the same line of longitude no matter your latitude. At dawn (0530 LST) the radiant is situated some 55° above the southeastern horizon. These are the exact same circumstances as exist on the equator. The reason for this is that the radiant actually loses altitude the further south you go. The length of night, though, increases proportionally so that the viewing circumstances remain the same. Below 25°S, though, the loss of altitude overtakes the length of night and view circumstances become less favorable (Table 3.3, Figs. 3.15–3.22).

Table 3.3. Radiant altitude for the eta Aquariids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	–	–	–	−36	−32	−24	−15	−6	4	13	–	–	–
25°N	–	–	−66	−58	−48	−35	−21	−8	5	19	33	–	–
00	–	−81	−83	−68	−53	−38	−23	−8	7	22	37	53	–
25°S	−55	−63	−63	−56	−47	−34	−20	−7	7	20	33	47	57

Fig. 3.15. A long eta Aquariid Earth-grazer appears before the radiant has risen.

Fig. 3.16. A bright eta Aquariid targets Dephinus the Dolphin.

Fig. 3.17. A bright eta Aquariid zips through Pegasus.

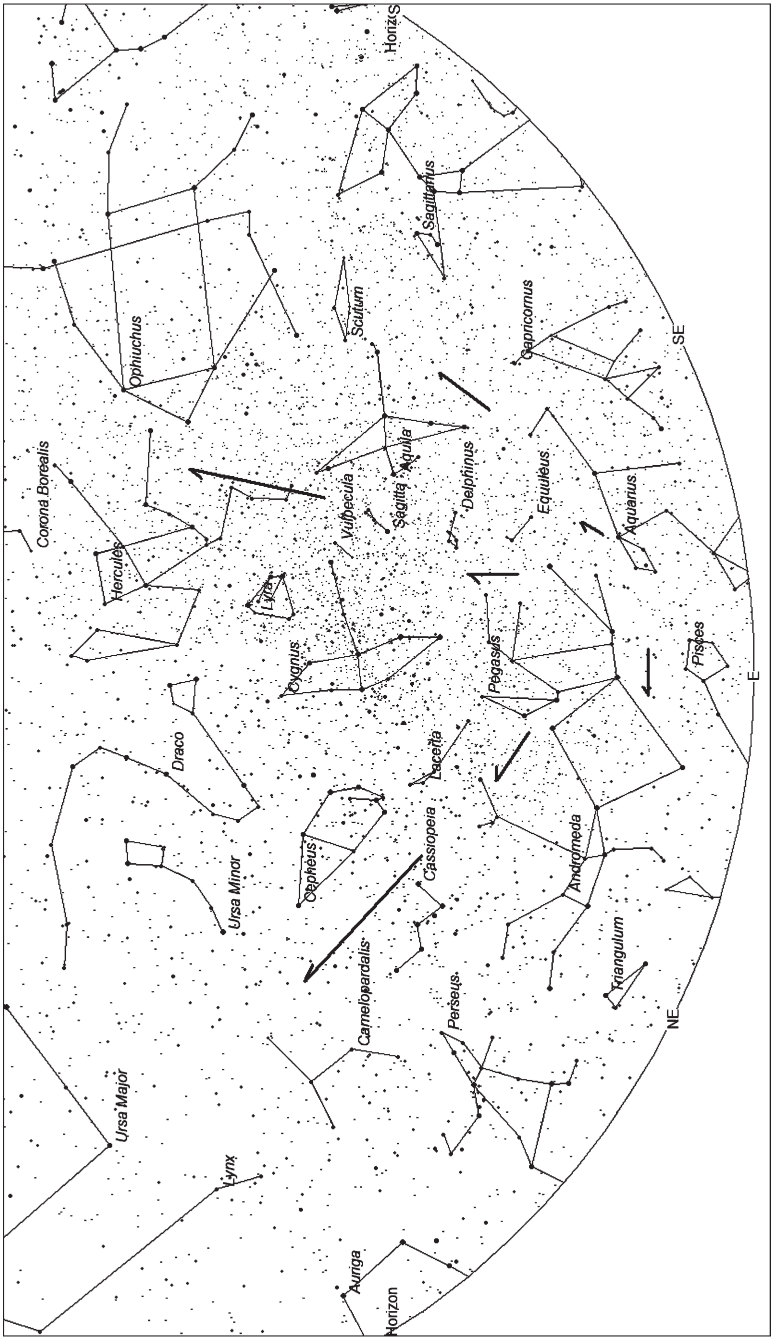

Fig. 3.18. Eta Aquariid activity as seen from latitude 50°N. Facing east at dawn.

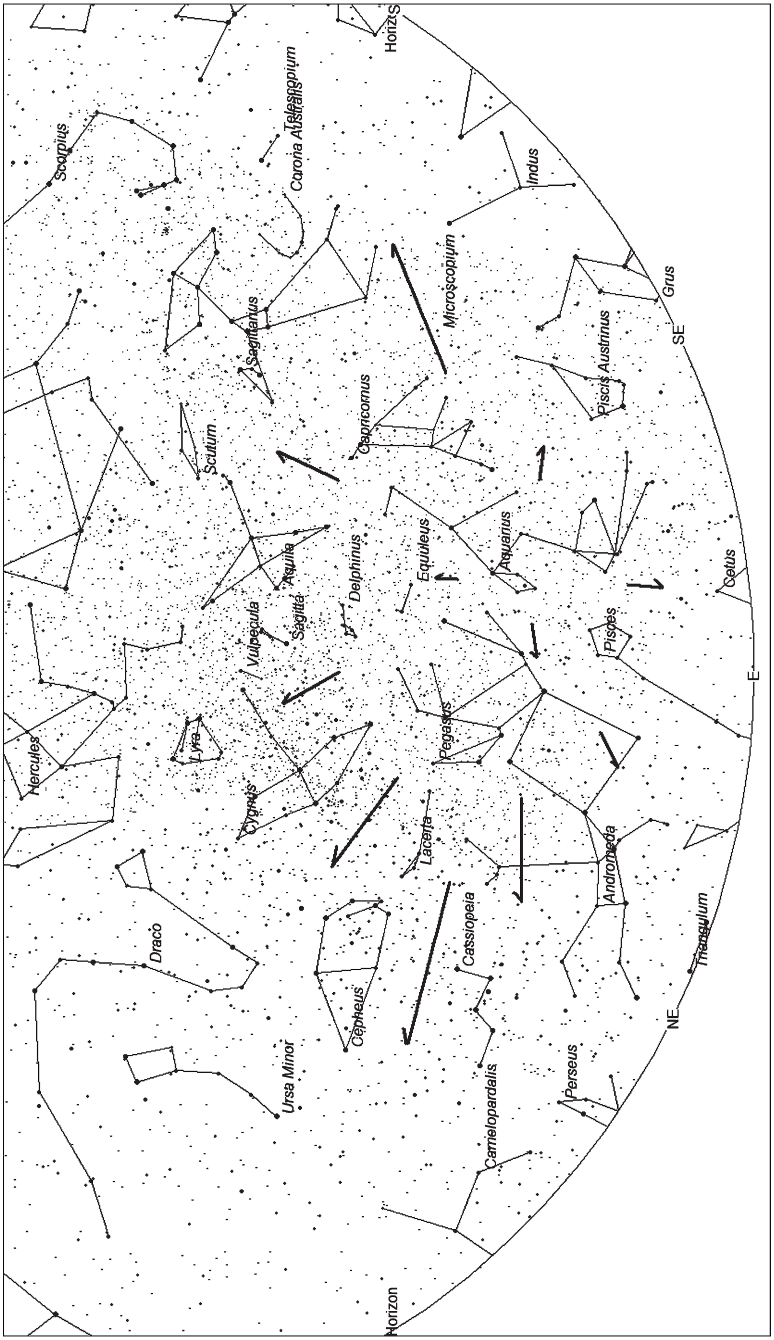

Fig. 3.19. Eta Aquariid activity as seen from latitude 25°N. Facing east at dawn.

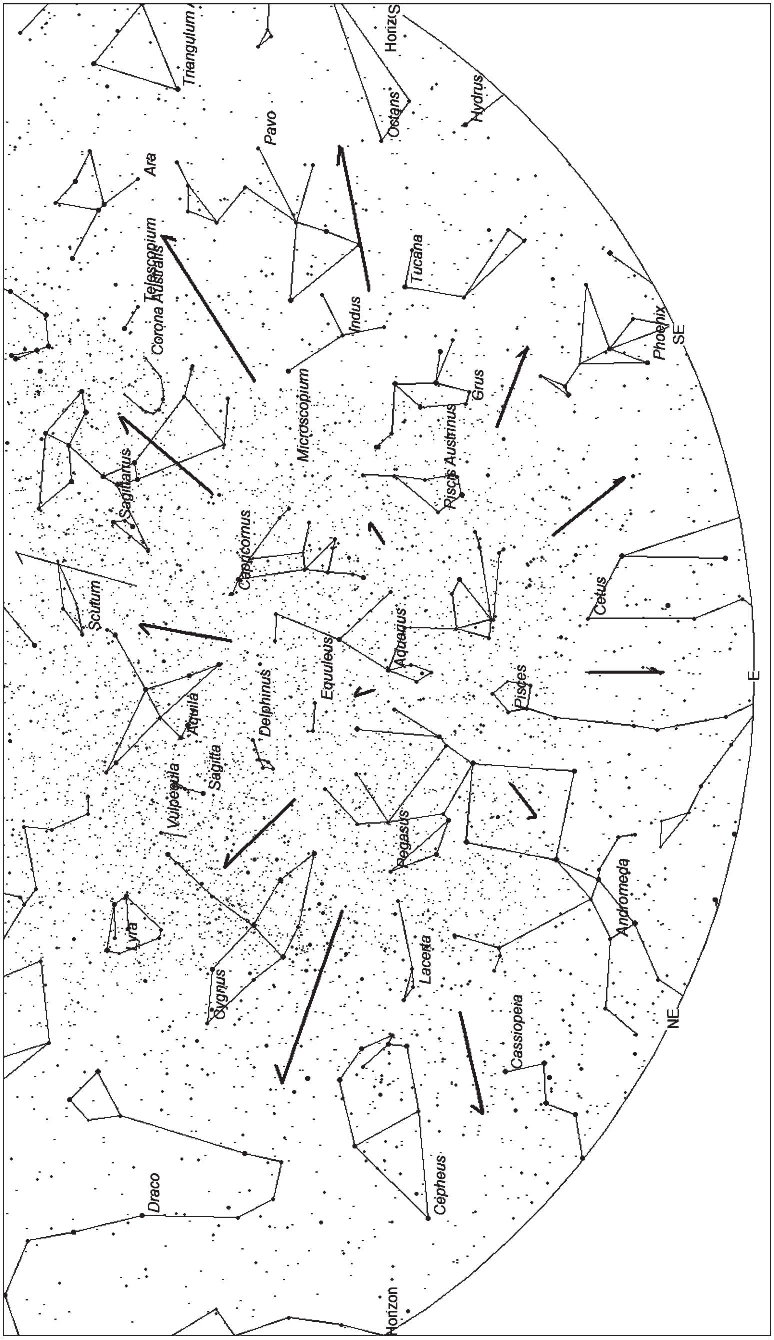

Fig. 3.20. Eta Aquariid activity as seen from the equator. Facing east at dawn.

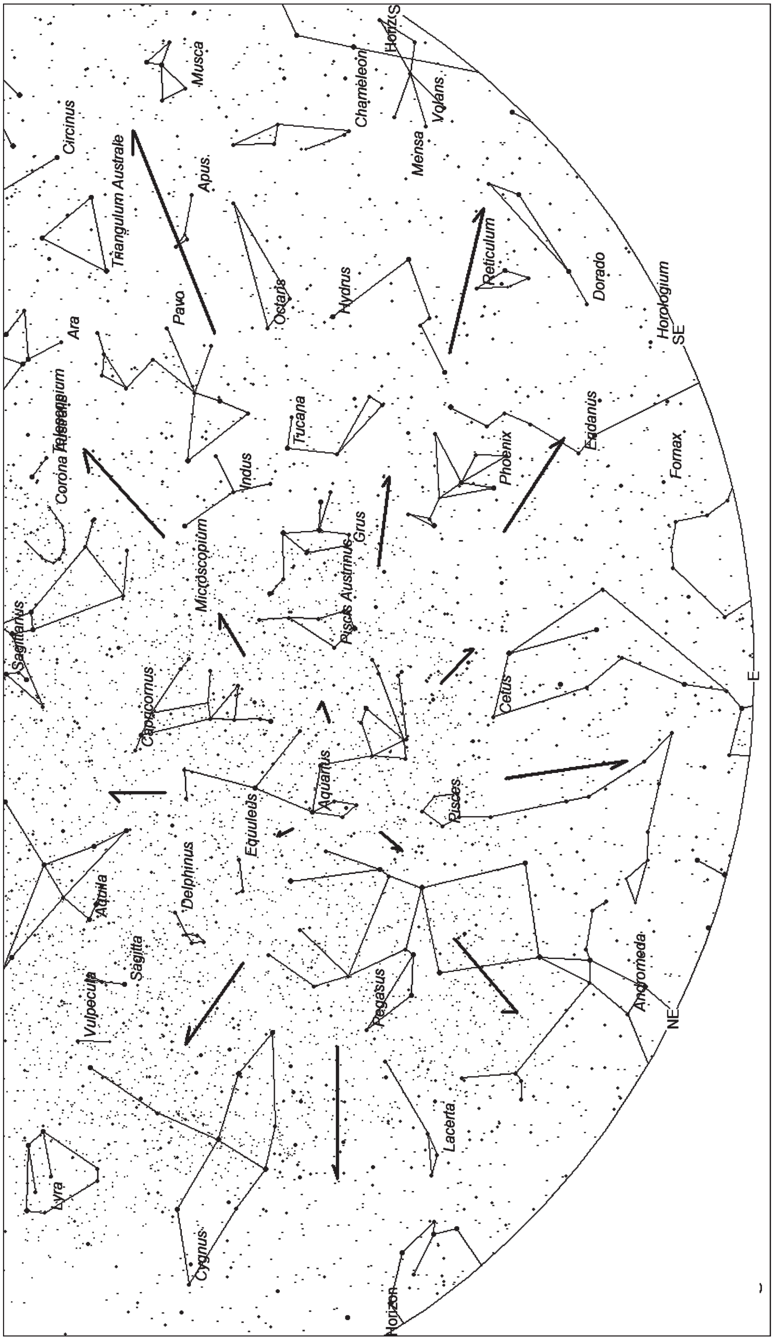

Fig. 3.21. Eta Aquariid activity as seen from latitude 25°S. Facing east at dawn.

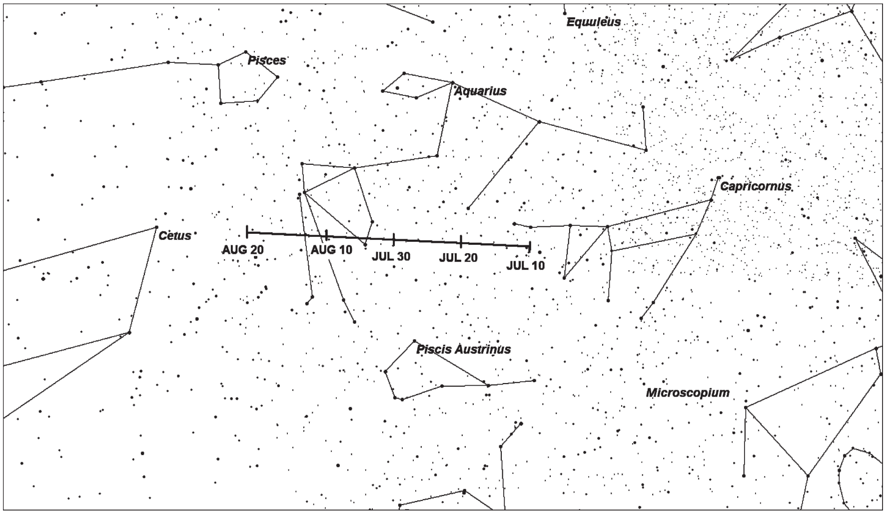

Fig. 3.22. Radiant drift for the delta Aquariids.

3.4 δ Aquariids (SDA) #5

Activity period: 07/13–08/19
Date of maximum activity: 07/27
Radiant position at maximum: 342 (22:48) − 15
Radiant drift per night: RA +1.0° Dec +0.3°
Geocentric velocity: 25 miles/s (41 km/s)

After the eta Aquariids have disappeared from view in late May another 45 days will pass until the next major annual shower occurs. The delta Aquariids (aka South delta Aquariids (SDA)) are the second most active shower visible from the southern hemisphere. Their activity begins on July 12 when the radiant reaches a ZHR of 1. At that time the radiant is located in eastern Capricornus near the faint star epsilon Capricornii. The radiant proceeds eastward approximately 1° per day into the constellation of Aquarius. At maximum activity the radiant lies at the position 339 (22:36) − 16. This position lies in southern Aquarius just west of the third-magnitude star delta Aquarii. The radiant continues through Aquarius, and by August 20 the rates have again fallen to a ZHR of 1.

The delta Aquariids can be favorably seen over most of the world. The southern hemisphere is favored by long nights this time of year and a higher radiant elevation. The average ZHRs are 20, but visual rates can range from 20–25 as seen in the southern hemisphere to 15–20 north of the equator. As seen from 50°N latitude the delta Aquariid radiant rises near 2200 LST (10:00 p.m.). It reaches the meridian near 0200 LST when it lies 24° above the southern horizon. At this altitude 41% of the available activity is seen.

As seen from 25°N latitude the radiant rises near 2100 LST (9:00 p.m.). By the time it reaches the meridian some 5 h later the radiant lies 49° above the southern horizon. With this altitude 75% of the total delta Aquariid activity can be seen.

As seen from the equator the Delta Aquariid radiant rises near 20010 LST (8:00 p.m.). It rises higher into the southeastern sky until it reaches the meridian some 6 h later. At that time the radiant lies 74° high in the southern sky. At this altitude 96% of the delta Aquarid activity can be seen.

Finally, as seen from 25°S latitude the delta Aquariid radiant rises near 1930 LST (7:30 p.m.). The radiant is observable the remainder of the night but is best seen when it lies on the meridian near 0200 LST. At this time the radiant lies 81° in altitude in the *northern* sky. In our journey from the equator south to 25°S latitude, the radiant has passed from the southern sky to the zenith and now into the northern sky. The radiant passes directly overhead for anyone located at 16°S latitude. This latitude would be the best location in which to view this display as 100% of the activity could be seen as the radiant passes directly overhead. At 81° high, as seen from 25°S latitude, the percentage falls to a mere 99%, so the loss in altitude is really insignificant (Table 3.4, Figs. 3.23–3.29).

3.5 Perseids (PER) #7

Activity period: 07/17–08/24
Date of maximum activity: 08/12
Radiant position at maximum: 047 (03:08) + 58
Radiant drift per night: RA +1.3° Dec +0.2°
Geocentric velocity: 37 miles/s (59 km/s)

The Perseids are the most popular and most observed meteor shower. The major reason for its popularity is the fact that it peaks during the northern hemisphere's summer season, when nighttime temperatures are mild and comfortable. The radiant is well placed for observers as it climbs high into the northern sky during the morning hours. For the upper two-third of the northern hemisphere the radiant is circumpolar and lies above the horizon all night long. This allows Perseid meteors to be seen at any hour of the night.

Unfortunately a great majority of those who make the effort to view the Perseids do so during the evening hours, when the radiant lies low in the north. Rates at this time are a tiny percentage of what can be seen during the early morning hours. Most of these people see a few long Perseids shooting upward from the northern horizon. These few Perseids may be enough to satisfy some youngsters, but probably not the adults, who place a bit more effort into viewing the display.

The Perseids are remnants of comet 109 P/Swift Tuttle. This comet orbits the Sun in a 130-year orbit and last visited the inner Solar System in 1992. During the years when the comet is near perihelion Perseid rates increase by a factor of three or four. During the first decade of the twenty-first century, rates are now back to a normal ZHR of 100. Enhancements of the Perseid rates can still occur when Earth passes

Table 3.4. Radiant altitude for the delta Aquariids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	–	–	–	−6	3	10	16	22	24	23	–	–	–
25°N	–	–	−12	2	15	26	37	45	49	47	40	33	–
00	–	−19	−5	10	25	40	52	65	74	70	59	46	–
25°S	—	−8	4	17	31	45	58	70	81	76	64	51	37

close to one of the old dust trails left by comet 109 P/Swift Tuttle during one of its previous passes through the inner Solar System. The next such major outburst of Perseid activity is predicted for 2028 near 0531 Universal Time on August 12.[3]

Perseid meteors are first noticed in mid-July, when the radiant is located in southwestern Cassiopeia. Many observers facing south and viewing activity from

Fig. 3.23. Delta Aquariid activity as seen from latitude 50°N. Facing south at 0200 LST.

the delta Aquariids in late July will notice swift Perseid meteors darting into their field of view from the upper left. Hourly rates can reach 5 per hour in late July and the first week of August. They really begin to take off at the start of the second week of August. Hourly rates are near 10 on August 8 and jump to near 20 on the 10th. Rates double during the next 24 h, to 40 on the morning of the 11th. Rates normally

Fig. 3.24. Delta Aquariid activity as seen from latitude 25°N. Facing south at 0200 LST.

peak on the morning of the 12th, with visual rates near 60 as seen from rural viewing sites. The average ZHR for the Perseids is 100 at maximum.

Unfortunately, no one can view the Perseids with the radiant located at the zenith, since daylight appears before the radiant can achieve such an altitude. The activity curve for the Perseids is fairly symmetrical, and postmaximum rates are

Fig. 3.25. Delta Aquariid activity as seen from the equator. Facing south at 0200 LST.

similar to those seen prior to the maximum. The shower does end only 2 weeks later, as the last Perseids are normally seen around August 24.

During the long Perseid activity period the radiant drifts from southern Cassiopeia, through the tip of northern Perseus, and on into the obscure constellation of Camelopardalis. At maximum activity the radiant lies at 049 (03:16) + 59. This

Fig. 3.26. Delta Aquariid activity as seen from latitude 25°S. Facing north at 0200 LST.

Fig. 3.27. A bright delta Aquariid shoots into Lyra the Harp.

Fig. 3.28. A bright delta Aquariid appears far from the radiant near Polaris, the Pole Star.

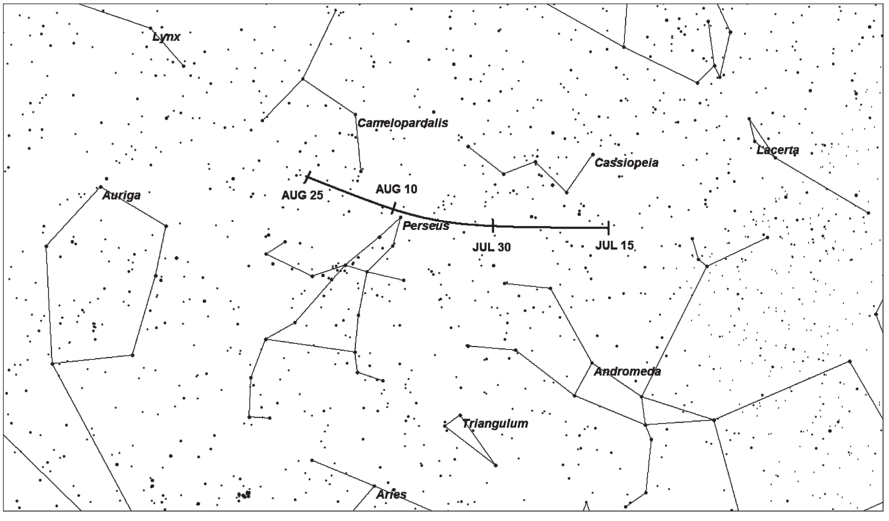

Fig. 3.29. Radiant drift for the Perseids.

position actually lies within the borders of Camelopardalis, just north of Perseus. The closest star is fourth-magnitude eta Persei, which lies 7°SW of the radiant.

As stated before, the Perseid meteors are best seen from the northern hemisphere. Although the nights are shorter this time of year north of the equator, the higher radiant altitude more than offsets the shorter nights. As seen from 50°N latitude the Perseid radiant reaches its nadir near 1800 LST (6:00 p.m.) or 1900 local daylight time (7:00 p.m.), when it lies 18° above the northern horizon. The radiant spends the remainder of the night climbing into the northern sky. At this latitude dawn begins to break near 0400 LST, and at that time the radiant has climbed to an altitude of 72°. At this altitude 95% of the Perseid activity can be seen, so it does not get much better than that!

As seen from 25°N latitude the radiant lies below the northern horizon until 2030 LST. Between 2000 and 2100 the altitude of the Perseids is favorable for the appearance of Earth-grazers. At this particular time Earth has rotated, so that meteors can now just skim the upper atmosphere above the observer. Since the air is thin so high above Earth, Perseid meteors can last several seconds instead of the normal subsecond durations that are common when the Perseids enter the atmosphere at a steeper angle. During these several seconds of visibility these Perseid meteors can travel several tens of degrees, covering a path in excess of half the sky. Most Perseid Earth-grazers occur far from the observer; therefore, they will be seen low in the eastern or western sky. If you are fortunate, though, an Earth-grazer can shoot directly overhead and become a spectacle not to be forgotten. Most of the bright Earth-grazers, regardless of the shower, have been intensely orange in color. Unfortunately, most Earth-grazers are dim and rarely display any color but white.

The longer night observed this time of year at 25°N latitude allows the Perseid radiant to more closely approach the meridian. Still, the maximum altitude at dawn from this latitude is only 56°, far lower than that seen at 50°N. At 56° altitude the observer can count on seeing 83% of the total available Perseid activity.

As seen from the equator, Perseid activity is pretty much limited to the morning hours. The radiant rises near 2330 LST, with the period for viewing Perseid Earth-grazers existing between 2300 and 0000 LST. Dawn breaks shortly after 0500 LST, and at this time the altitude of the Perseid radiant lies at 31° above the northern horizon. With this altitude the observer located at the equator has the opportunity to view 52% of the total Perseid activity.

Observing Perseid activity becomes a challenge at 25°S latitude. From this location the Perseid radiant remains below the northern horizon until 0300 LST. Three hours later dawn begins to seriously hamper observations, with the radiant lying only 7° above the northern horizon. This low radiant altitude only allows the southern observer to view 12% of the total Perseid activity. At 32°S latitude the Perseid radiant fails to rise above the horizon. At near 35°S latitude and further southward it becomes impossible to see any Perseids at all (Table 3.5, Figs. 3.30–3.37).

Table 3.5. Radiant altitude for the Perseids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	–	–	23	26	31	37	42	50	57	66	72	–	–
25°N	–	–	−3	4	9	16	24	31	39	46	52	55	–
00	–	−30	−26	−20	−13	−6	3	10	18	23	27	32	–
25°S	−56	−54	−49	−41	−34	−26	−19	−11	−6	0	4	7	7

Fig. 3.30. A Perseid fireball shoots the length of the Little Dipper.

Fig. 3.31. A Perseid fireball appears in Cassiopeia the Queen.

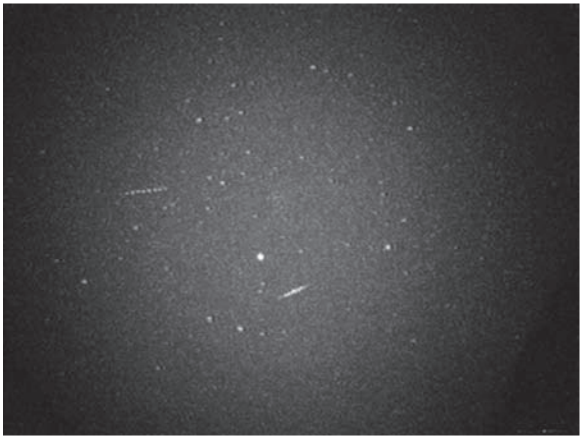

Fig. 3.32. Simultaneous Perseids head westward.

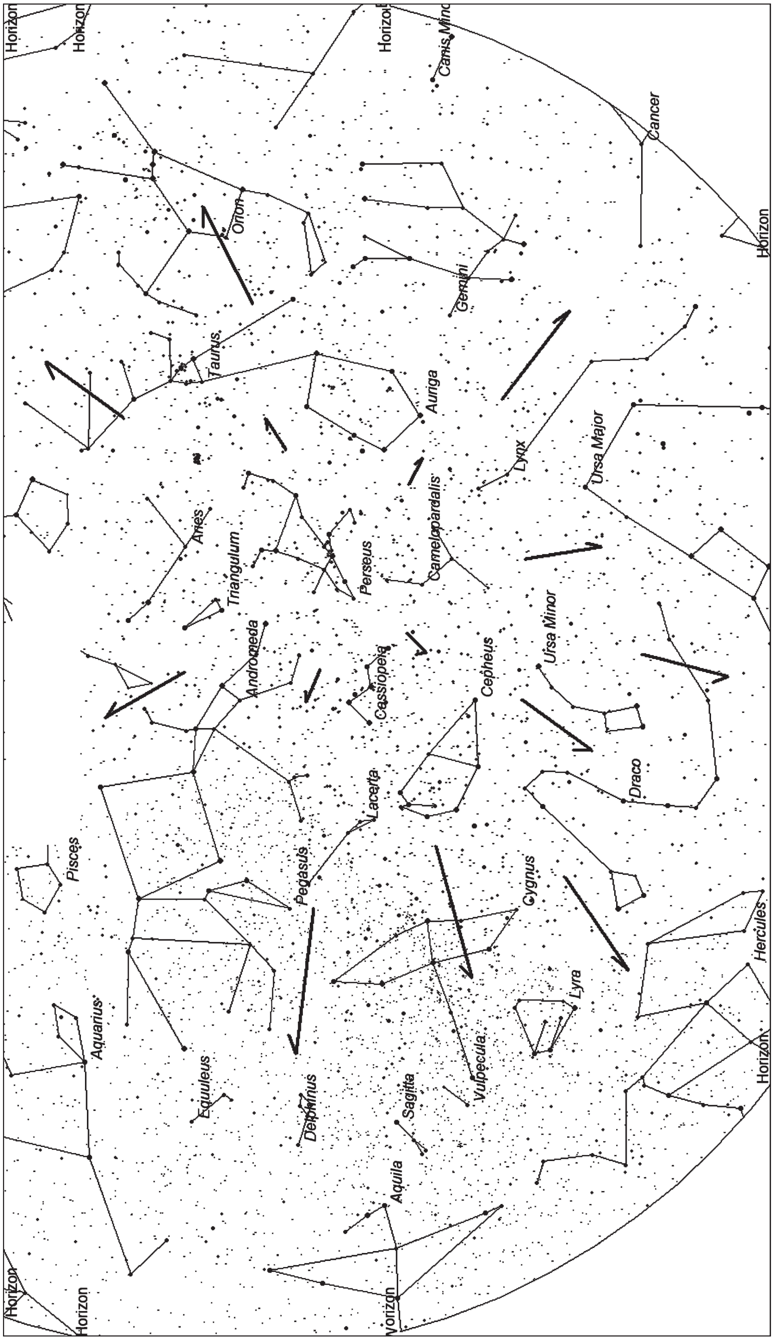

Fig. 3.33. Perseid activity as seen from latitude 50°N. Facing north at dawn.

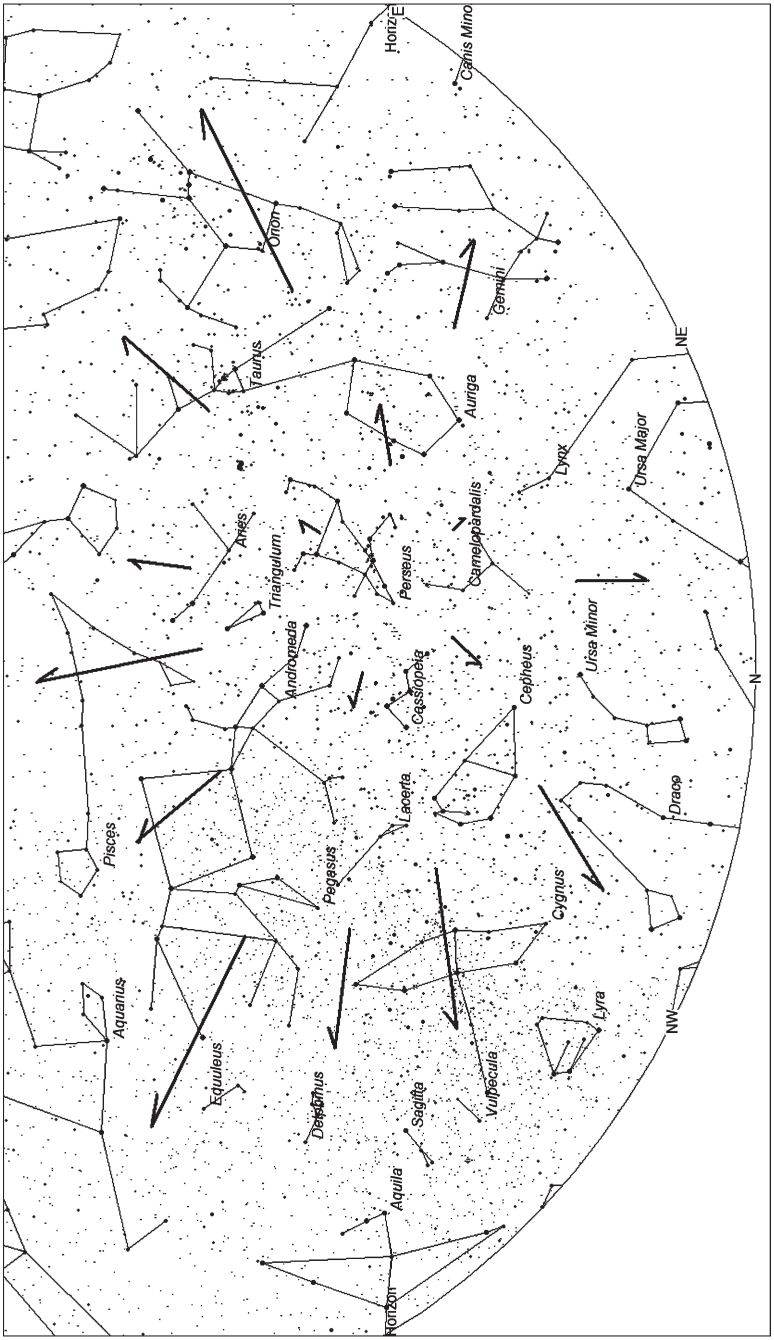

Fig. 3.34. Perseid activity as seen from latitude 25°N. Facing north at dawn.

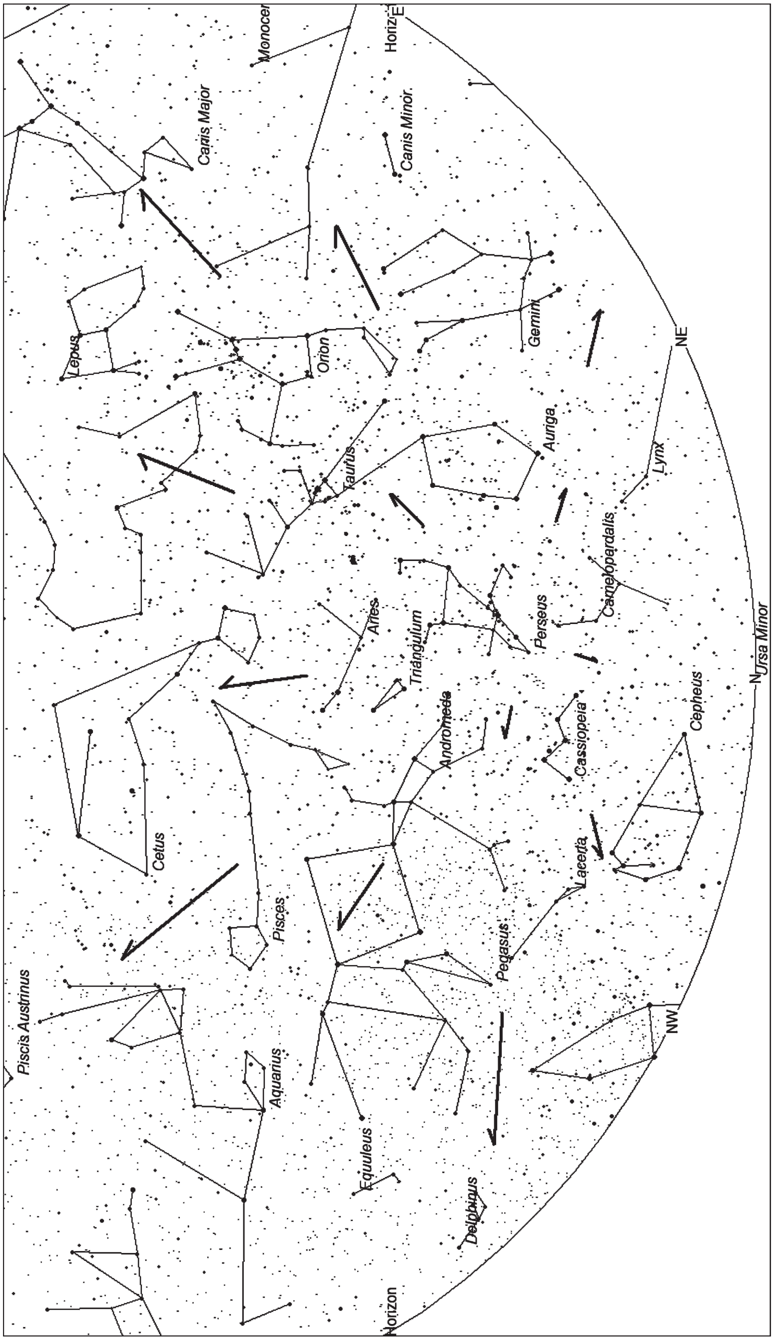

Fig. 3.35. Perseid activity as seen from the equator. Facing north at dawn.

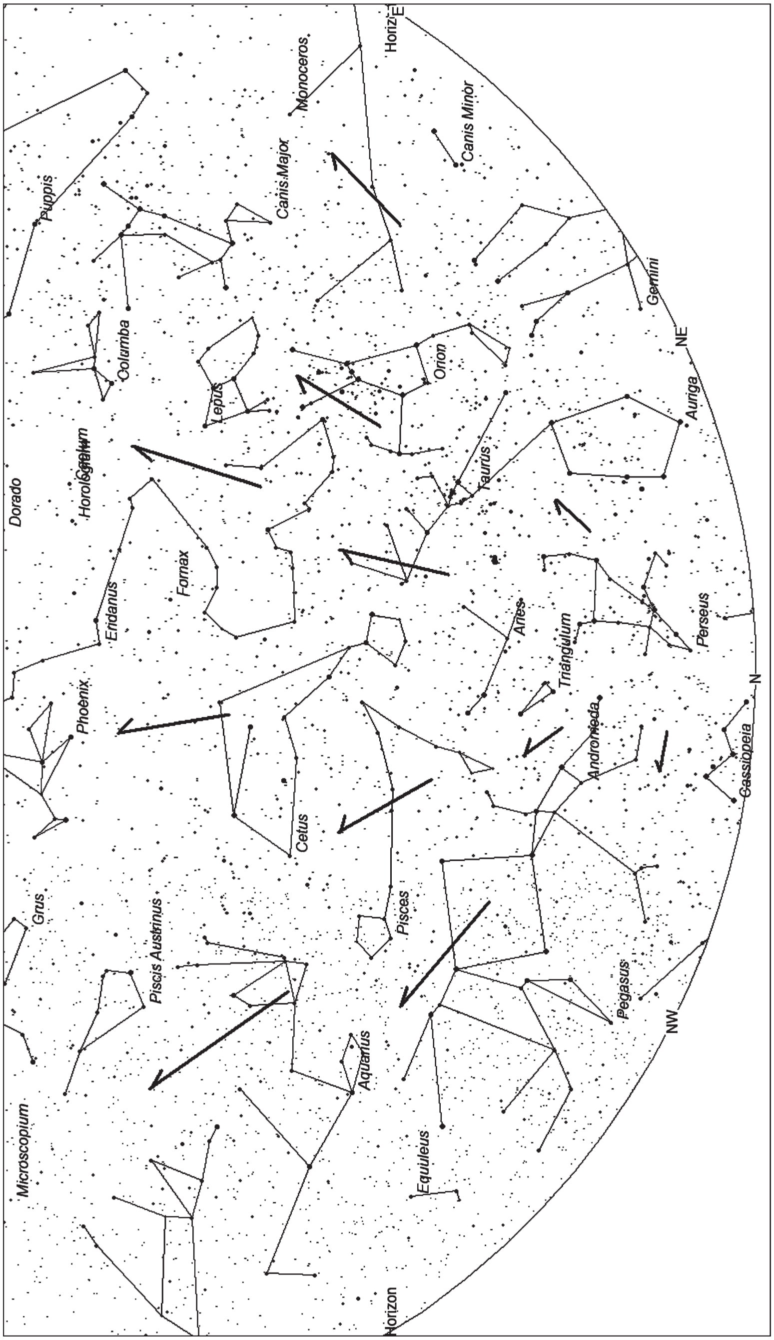

Fig. 3.36. Perseid activity as seen from latitude 25°S. Facing north at dawn.

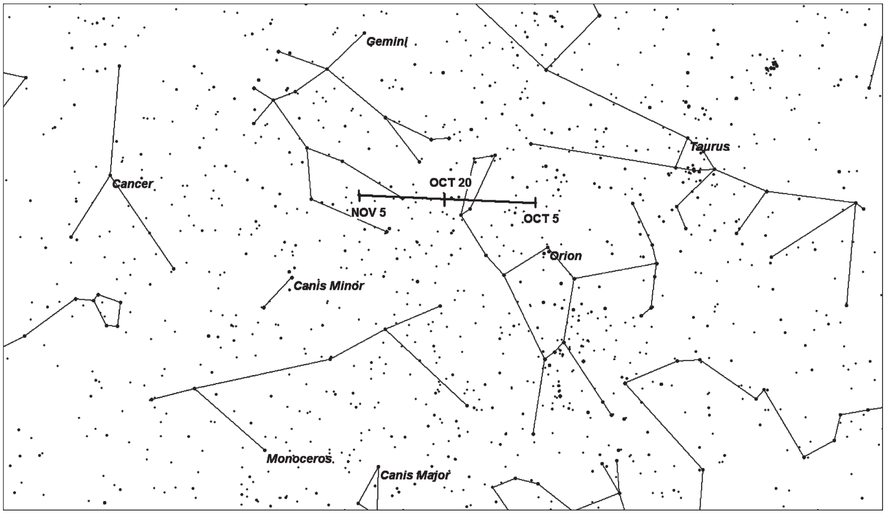

Fig. 3.37. Radiant drift for the Orionids.

3.6 Orionids (ORI) #8

Activity period: 10/02–11/07
Date of maximum activity: 10/21
Radiant position at maximum: 096 (06:24) + 16
Radiant drift per night: RA +0.7° Dec +0.1°
Geocentric velocity: 41 miles/s (66 km/s)

During October and early November Earth passes through the outer edges of old dust trails produced by Halley's Comet. These inbound particles collide with Earth creating the Orionid meteor shower. The Orionids reach a ZHR of 1 on October 2, when the radiant is located in northern Orion. Rates remain low for 2 weeks, rarely surpassing two shower members per hour. Near October 16, rates increase toward a maximum that is reached on October 21. Much like the eta Aquariids of May, which are also caused by 1 P/Halley, the Orionids remain near maximum activity for several nights. At maximum activity the radiant is located at 095 (06:20) + 16. This position actually lies in the constellation of Gemini, a few degrees west of the bright star Alhena (gamma Geminorum). After October 25, rates begin to fall again and reach back down to a ZHR of 1 on November 7.

The average ZHR for the Orionids is 25. It can be as low as 15 or as high as 60. Displays in the first decade of the twenty-first century have been better than normal, with the peak rates occurring during the 2006 return, when rates reached an average ZHR of 60. There is also increased fireball activity during years of exceptional activity. Several theories have been suggested as to the cause of these fluctuations, most of them dealing with particle resonances with Jupiter. At this particular time (2008) the exact cause is still undetermined.

With the Orionid radiant lying just north of the celestial equator, this display can be witnessed over most of Earth. The most favored latitude is 16°N, where the radiant passes directly overhead. Due to its location close to the celestial equator, the radiant rises near 2100 LST (9:00 p.m.) for any latitude. The exception to this timing occurs at north polar latitudes, where the radiant is circumpolar and far southern polar latitudes, where it never clears the horizon. Any possible Orionid Earth-grazers would occur during this time. During the late evening and early morning hours the radiant rises into the southeastern sky. It reaches its highest point above the horizon (56°) near 0400 LST, when it lies on the meridian. This is the best time to view Orionid activity, as 83% of the possible Orionid activity is available to be seen at that hour as seen from 50°N latitude.

As seen from 25°N latitude the Orionid radiant culminates at 81° above the southern horizon. From this latitude 99% of the available Orionid activity is available to be seen. The length of night during October is a bit shorter from this latitude, but the radiant still culminates in total darkness, with nearly 2 h left before dawn brings an end to observations.

As seen from the equator the Orionid radiant reaches a maximum altitude of 74° above the *northern* horizon. This situation would be a bit strange to northern observers, as Orion would be seen upside down, with meteors shooting from the lower portion of the constellation. It gets even stranger as one moves further south and the upside down Orion appears lower in the sky. From the equator 96% of the possible Orionid activity is visible, so not much difference is seen between the equator and 25°N latitude. Nights are still shorter at the equator, compared to further north, but the radiant still culminates well in advance of the beginning of dawn.

As seen from locations situated at 25°S latitude, the Orionid radiant reaches a maximum altitude of 49° above the northern horizon, still near 0400 LST. This allows the southern observer to see a maximum of 75% of the possible Orionid activity. Astronomical twilight also begins at 0400 LST, so the sky is sufficiently dark for only another 30 min before the arrival of nautical twilight, when the sky becomes too bright for practical observations (Table 3.6, Figs. 3.38–3.45).

Table 3.6. Radiant altitude for the Orionids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	−19	−14	−8	1	10	19	29	38	47	53	56	54	50
25°N	−41	−34	−22	10	3	16	29	42	56	69	81	78	62
00	−61	−47	−34	−19	−6	10	24	38	52	64	72	70	–
25°S	–	−52	−38	−25	−12	2	14	25	37	43	49	–	–

Major Annual Showers

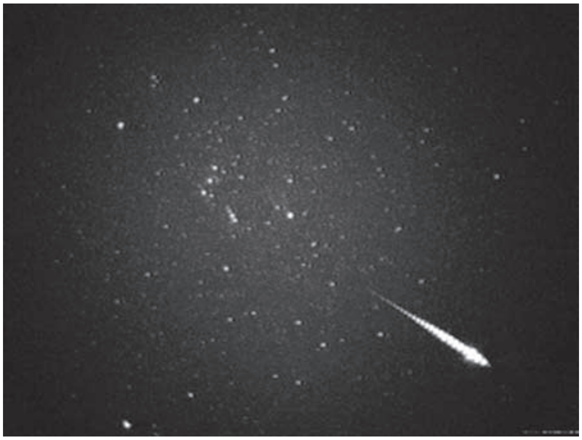

Fig. 3.38. A Orionid fireball shoots southward past Lepus the Hare.

Fig. 3.39. A bright Orionid heads toward Eridanus.

Fig. 3.40. An Orionid fireball just misses the head of Hydra.

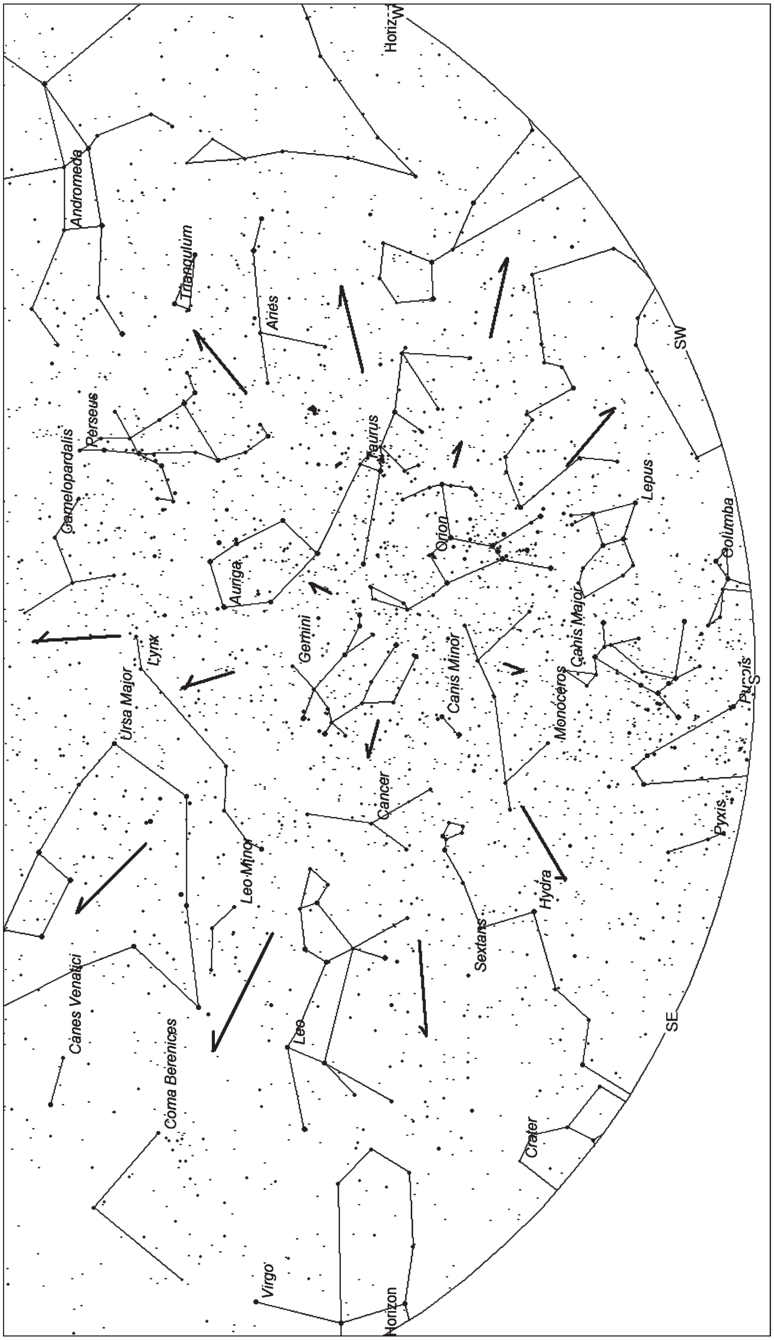

Fig. 3.41. Orionid activity as seen from latitude 50°N. Facing south at 0400 LST.

Fig. 3.42. Orionid activity as seen from latitude 25°N. Facing south at 0400 LST.

Fig. 3.43. Orionid activity as seen from the equator. Facing north at 0400 LST.

Fig. 3.44. Orionid activity as seen from latitude 25°S. Facing north at 0400 LST.

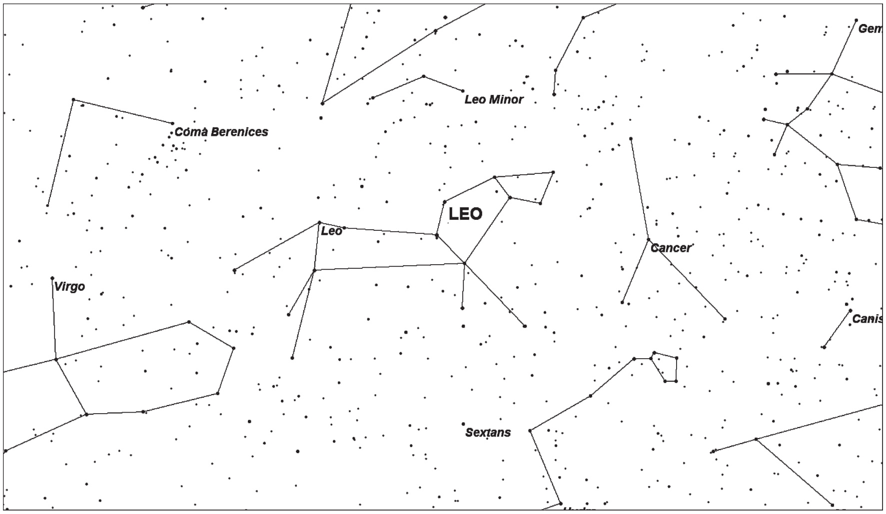

Fig. 3.45. Radiant position for the Leonids.

3.7 Leonids (LEO) #13

Activity period: 11/10–11/23
Date of maximum activity: 11/19
Radiant position at maximum: 152 (10:08) + 21
Radiant drift per night: RA +0.7° Dec −0.4°
Geocentric velocity: 44 miles/s (71 km/s)

If the Perseids are the most popular meteor shower, then the Leonids of November are the most famous. The Leonids, unlike the Perseids, can be seen over nearly the entire Earth's surface. This meteor shower has produced some of the most impressive meteor storms on record, with the period of 1998–2002 being the most recent episode of these storms. The Leonid radiant lies within the "sickle of Leo" during its entire activity period. Rates for this shower reach a ZHR of 1 on November 10. Activity remains low for the next week, with only 1 or 2 Leonids being seen each hour after midnight. Maximum activity occurs anywhere from November 17 to 19, depending on the presence of any old dust trails produced from the parent comet 55 P/Temple-Tuttle and other yearly circumstances (such as leap year). Rates seen at maximum are normally 10–15 Leonids per hour as seen from dark rural observing sites.

Exceptional displays are limited to the time when comet 55 P/Temple-Tuttle returns to the inner Solar System. The next return of this comet occurs in 2031.[4] But, unfortunately, none of the dust trails are predicted to closely encounter Earth. Instead of seeing thousands of Leonids per hour this scenario only produces several hundred Leonids per hour for the years surrounding the comet's perihelion. The situation will remain the same during the 2064 return of the comet. Not until 2097 will Earth closely approach debris from comet 55 P/Temple-Tuttle, resulting in the legendary meteor storms associated with this shower.

Although the Leonids are seen over most of Earth, the northern hemisphere has the advantage of longer nights in November and slightly higher radiant altitudes before morning twilight begins to interfere. Only from the north polar regions does the Leonid radiant reach culmination in a dark sky. As one moves south the radiant will peak in altitude in a bright morning sky. As seen from 50°N latitude the Leonid radiant rises near 2200 LST (10:00 p.m.). It spends the remainder of the night climbing high into the southeastern sky. When dawn begins to interfere just past 0600 LST, the radiant lies 62° high in the southern sky. At this altitude 88% of the total Leonid activity can be seen.

As seen from 25°N latitude the Leonid radiant rises later in the evening. The radiant clears the northeastern horizon near 2330 LST (11:30 p.m.). It also rises at a steeper angle and is situated higher in the sky at dawn. At this latitude dawn breaks near 0530 LST, and at this time the radiant lies only 12° from the zenith. This allows 98% of all the Leonid activity to be seen.

The nights become progressively shorter as you move south in November. As seen from the equator the Leonid radiant rises near 0030 LST (12:30 a.m.). Leonid activity is observable until 0500 LST, when dawn breaks, and the radiant lies 60° above the northeastern horizon. At this altitude above the horizon 87% of the Leonid activity is able to be seen. Also seen at this latitude the familiar orientation of Leo begins to rise on its back. As you progress further south the constellation of Leo will appear upside down to observers to those who normally view it from the northern hemisphere.

As seen from latitude 25°S the Leonid radiant now rises at 0100 LST. Dawn breaks shortly after 0400 LST with the Leonid radiant only 33° above the northeastern horizon. At this altitude 54% of the total Leonid activity can be seen. This reminds me of those who traveled to Australia in 2001 to view the second of two Leonid storms that night. Although a splendid sight was seen by all, those who went to Korea and Japan actually witnessed nearly twice the activity available in Australia. The skies of Korea and Japan were more prone to clouds, so the odds of clear skies and actually seeing the meteor storm were higher in Australia (Table 3.7, Figs. 3.46–3.53). Since the skies cooperated for many in Korea and Japan, we salute those who took the chance to view from further north, as you were well rewarded for the risk you took!

Table 3.7. Radiant altitude for the Leonids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	−18	−17	−14	−9	−3	6	14	23	33	42	51	58	63
25°N	−42	−42	−37	−29	−19	−7	5	18	31	44	57	71	83
00	–	−66	−57	−45	−32	−19	−5	9	22	36	49	60	–
25°S	–	−81	−68	−54	−41	−27	−14	−2	10	22	32	–	–

Fig. 3.46. A long Leonid shoots through Auriga and on into Taurus.

Fig. 3.47. A Leonid just misses Pollux in Gemini.

Fig. 3.48. A Leonids dart into Auriga the Charioteer.

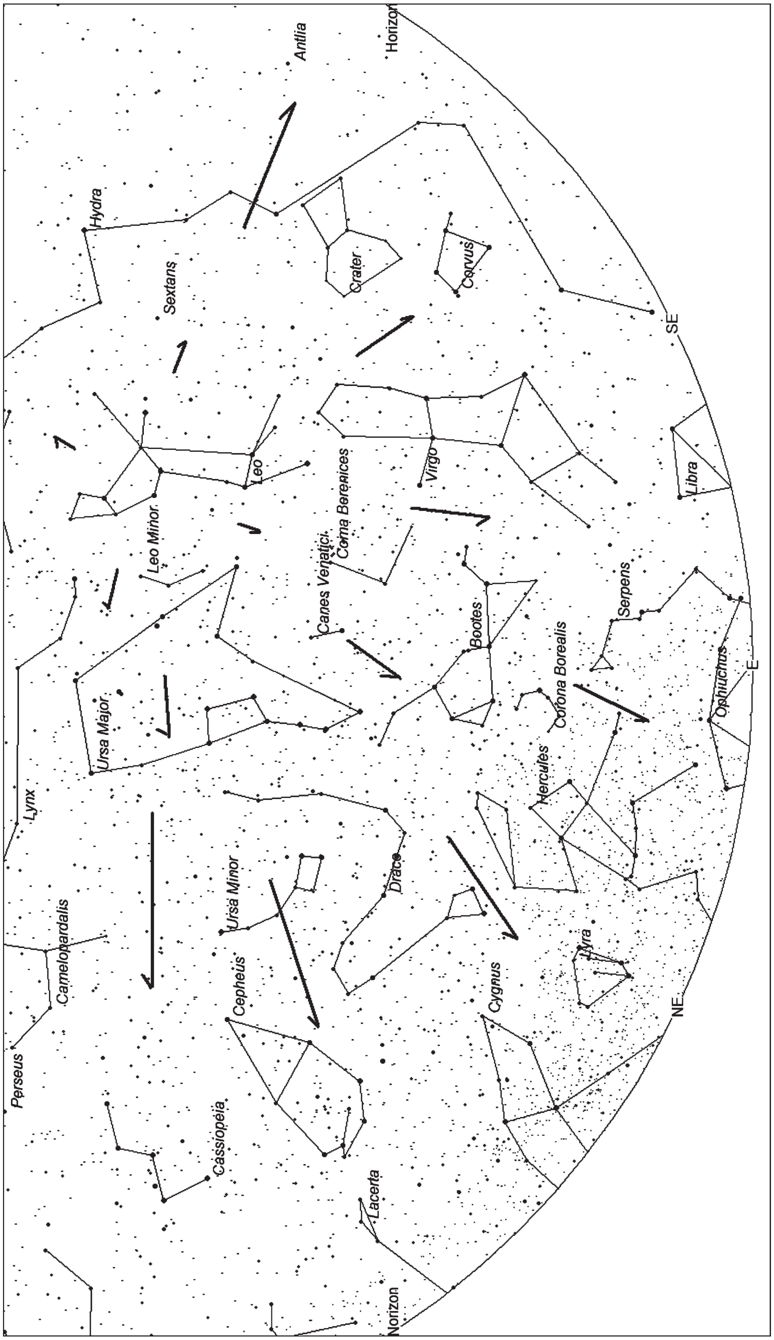

Fig. 3.49. Leonid activity as seen from latitude 50°N. Facing east at dawn.

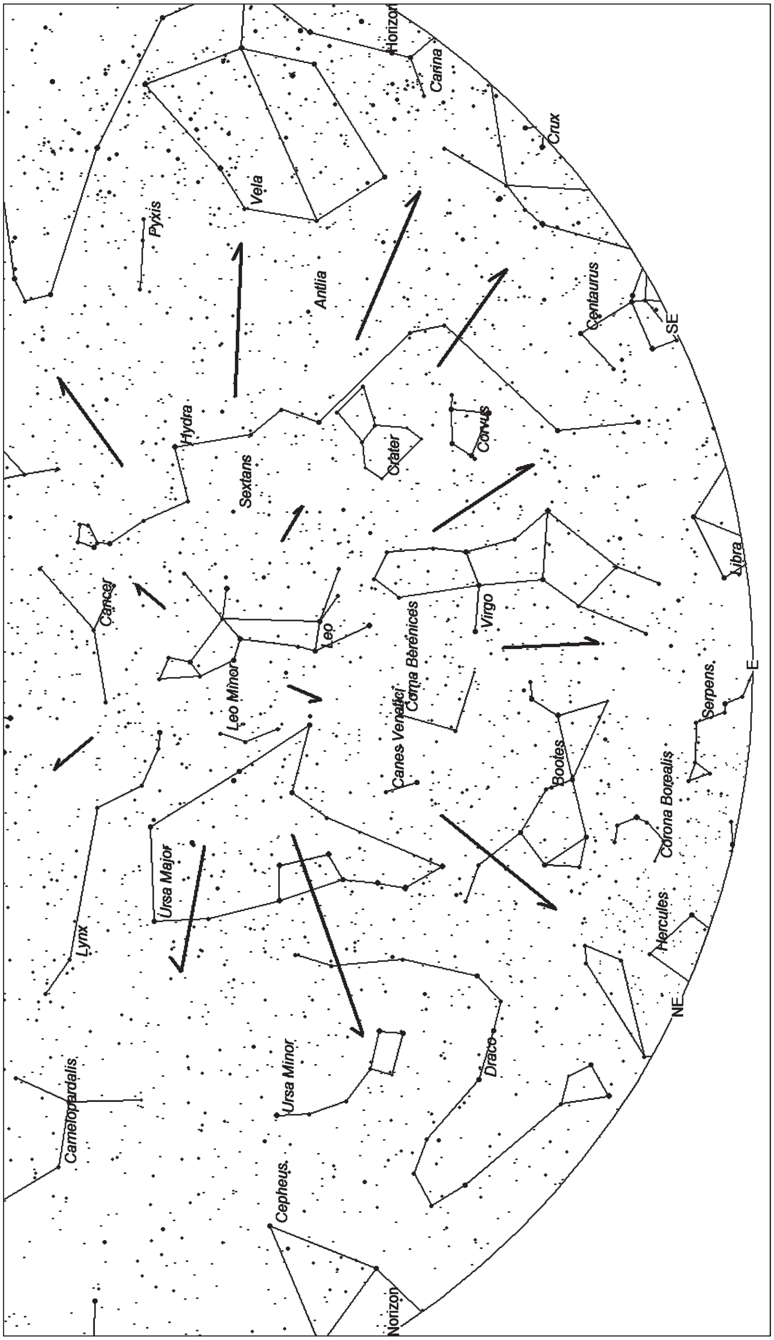

Fig. 3.50. Leonid activity as seen from latitude 25°N. Facing east at dawn.

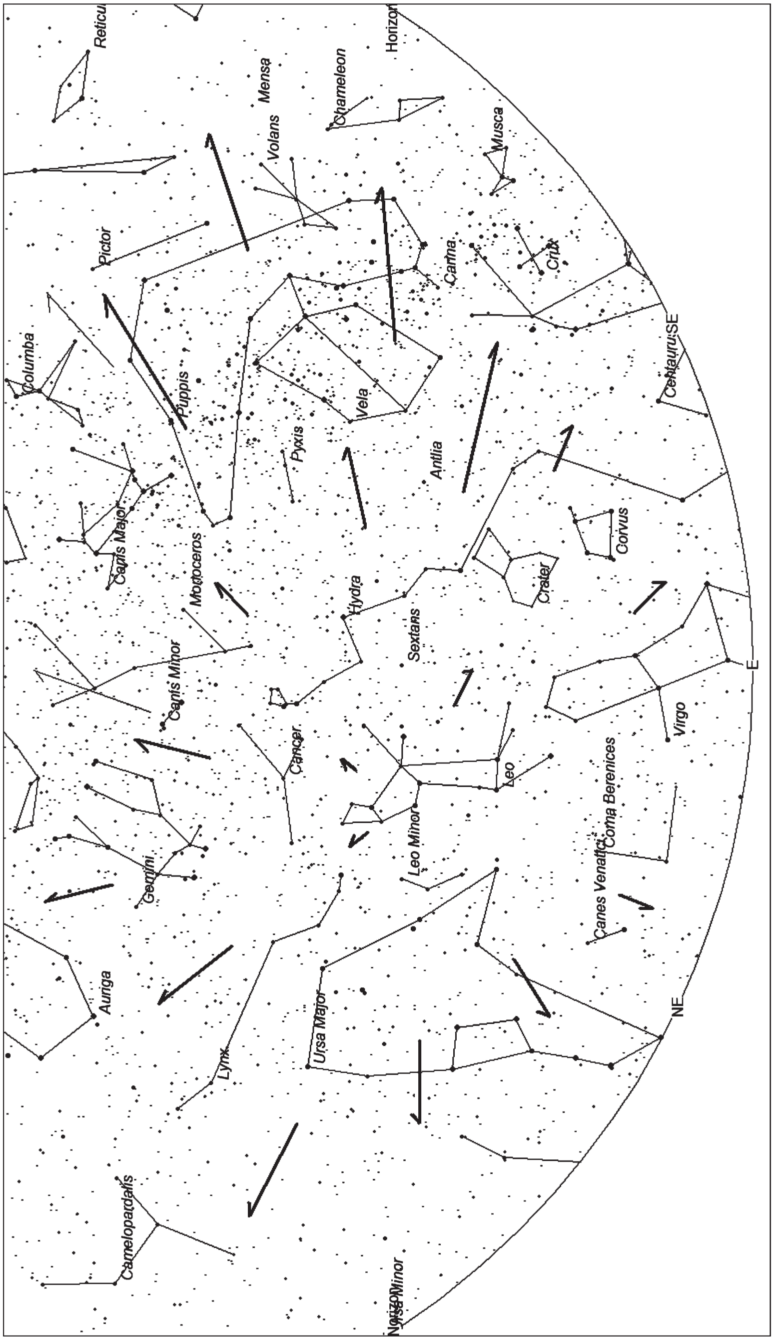

Fig. 3.51. Leonid activity as seen from the equator. Facing east at dawn.

Fig. 3.52. Leonid activity as seen from latitude 25°S. Facing east at dawn.

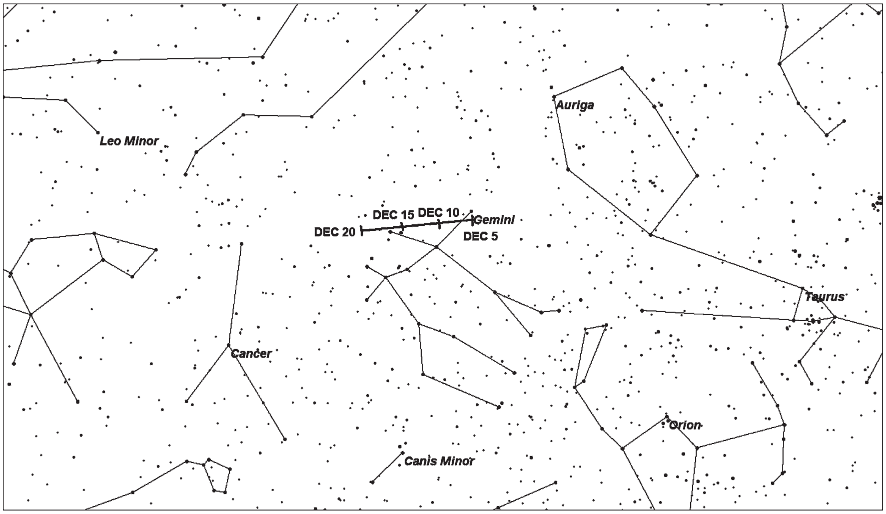

Fig. 3.53. Radiant drift for the Geminids.

3.8 Geminids (GEM) #4

Activity period: 12/07–12/17
Date of maximum activity: 12/14
Radiant position at maximum: 112 (07:28) + 33
Radiant drift per night: RA +1.0° Dec −0.1°
Geocentric velocity: 22 miles/s (35 km/s)

Although the Perseids are the most popular shower and the Leonids the most famous, if you ask a veteran meteor observer which shower is their favorite most of them would list the Geminids number one. The reason for this? It is easy, the Geminids, year end and year out, provide the most impressive meteor display of any of the annual showers. They are also visible during the evening hours, so why are not they more popular? The main reason is that they are best seen from the northern hemisphere, and the mid-December nighttime temperatures can be very cold. Folks might venture out of doors for a quick evening peek, but only diehard meteor observers are out between 1:00 and 2:00 a.m. to see the Geminids at their best.

The Geminids are different from most major annual showers in several ways. First of all they are produced by an asteroid or inactive comet known as 3200 Phaeton. Secondly, as mentioned before, they appear in large numbers during the evening hours as seen from the northern hemisphere. From up north the Geminid radiant rises or is actually above the horizon at dusk. Therefore, Geminid activity may be seen during the entire night from the northern hemisphere.

Stray Geminids first start appearing in late November. The ZHR does not reach 1 until December 7, so rates are very low during this period. After December 7 hourly rates increase, rapidly reaching 10 per hour by as early as December 10. Rates reach 25 Geminids per hour on the December 12 and can reach 40 per hour on the thirteenth. Maximum activity occurs on December 14, when the ZHR averages 120. This figure equals the rates for the Quadrantids of early January for the highest average ZHR of any major annual shower.

Unlike the Quadrantids, the Geminids have a broad maximum, and strong rates are seen from all over the world on the night of maximum activity. The Geminid radiant lies within the borders of Gemini during its entire activity period. At maximum activity on December 14 the radiant lies close to the bright second-magnitude star Castor (alpha Geminourm) and is easy to locate.

The Geminids are most active when the radiant lies on the meridian between 0100 and 0200 LST. At this time strong Geminid rates can be seen in any portion of the sky. Your best strategy would be to face toward the darkest direction, so that faint meteors can be seen. If at all possible set your field of view so that it includes the minor radiants located in western Gemini (Antihelions), Monoceros (Monocerotids), and western Hydra (sigma Hydrids). This will allow for easy classification of these showers should any activity appear. While facing in this direction the Geminid radiant will be near the top of your field of view, and Geminid meteors will shoot downward into the constellations of Orion, Monoceros, Canis Major, Canis Minor, and Hydra.

The Geminids also produce the largest number of Earth-grazing meteors. This is especially true for locations where the radiant lies on the horizon at dusk or rises during the night. Most Geminid Earth-grazers are seen low in the north or southern skies. They are easily identified by their long paths, lasting many seconds. Occasionally a Geminid Earth-grazer will pass higher in the sky and will often be the highlight of the night.

Many of the Geminid meteors seen are bright and colorful. Several each night can fall into the fireball category, which is magnitude –5 or brighter. Due to the shallow angle at which they strike the atmosphere, Geminid meteors are of medium-to-slow speeds, depending on where they appear in the sky. The combination of bright meteors and slower velocities creates an ideal situation for photographing meteor activity. The best time to photograph Geminid activity is again when the radiant lies highest in the sky. Earlier in the night Geminid Earth-grazers may be a tempting target, but most of them are faint, low in the sky, and difficult to photograph.

As seen from 50°N latitude the Geminid radiant rises near 1700 LST (5:00 p.m.). This is near the time of nautical twilight, so Geminid Earth-grazers may be seen as soon as it becomes dark. The radiant culminates near 0200 LST, as it does for all locations, with the radiant lying 17°S of the zenith (73° altitude). At this altitude 96% of all the Geminid activity can be seen. At dawn the radiant still lies 33° above the western horizon, so activity can be seen until daylight interferes.

The best location for viewing Geminid activity lies along 33°N latitude, where the radiant lies directly overhead near 0200 LST. A bit further south, at 25°N latitude, the radiant reaches within 8° of the zenith. At this altitude 99% of all the Geminid activity can still be seen. The radiant rises near 1900 LST (7:00 p.m.) when the sky is totally dark, allowing Geminid Earth-grazers to be better seen than from locations further north.

From the equator viewing conditions become slightly less optimal. From this location the Geminid radiant rises near 2000 LST (8:00 p.m.). It culminates near 0200, when it lies 57° high in the northern sky. At this altitude still 84% of all Geminid activity can be seen. At dawn the radiant still lies 35° high in the western sky.

As seen from 25°S latitude the Geminid radiant does not rise until 2100 LST (9:00 p.m.). When it reaches the meridian some 5 h later it has risen to 32° above the northern horizon. At this altitude only 53% of all the Geminid activity can be seen. Dawn arrives 2 h later, and the radiant still lies 25° above the northwestern horizon.

The Geminid radiant clears the horizon down to 57°S latitude, but south of 50° twilight interferes at this time of night; therefore, this would be the southern limit of seeing Geminid activity (Table 3.8, Figs. 3.54–3.60).

Table 3.8. Radiant altitude for the Geminids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	8	17	26	35	44	54	63	71	73	69	62	52	43
25°N	−7	3	14	26	38	51	63	75	82	73	62	48	37
00	–	−12	0	13	25	36	46	54	57	53	45	35	–
25°S	–	–	−13	−2	8	18	25	29	32	29	25	–	–

Fig. 3.54. Geminid activity as seen from latitude 50°N. Facing south at near 0200 LST.

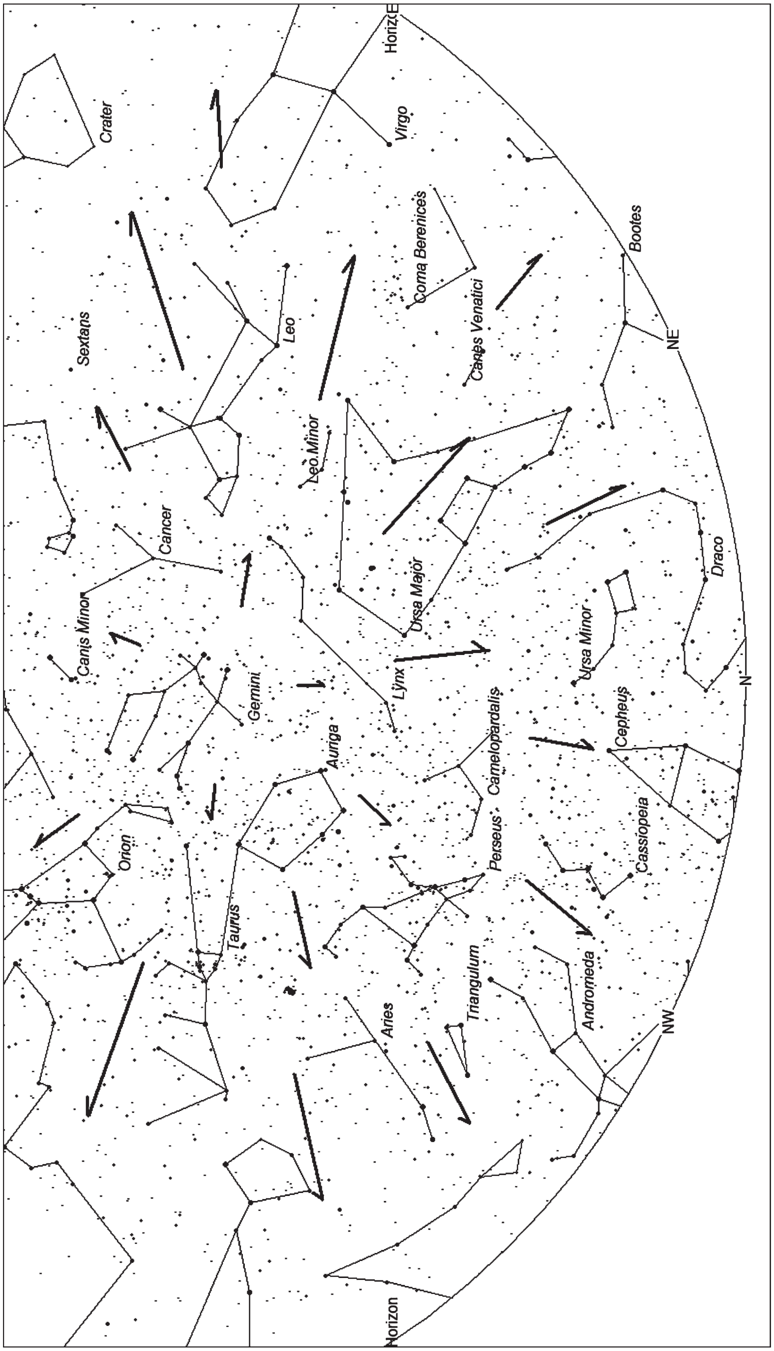

Fig. 3.55. Geminid activity as seen from latitude 25°N. Facing north near 0200 LST.

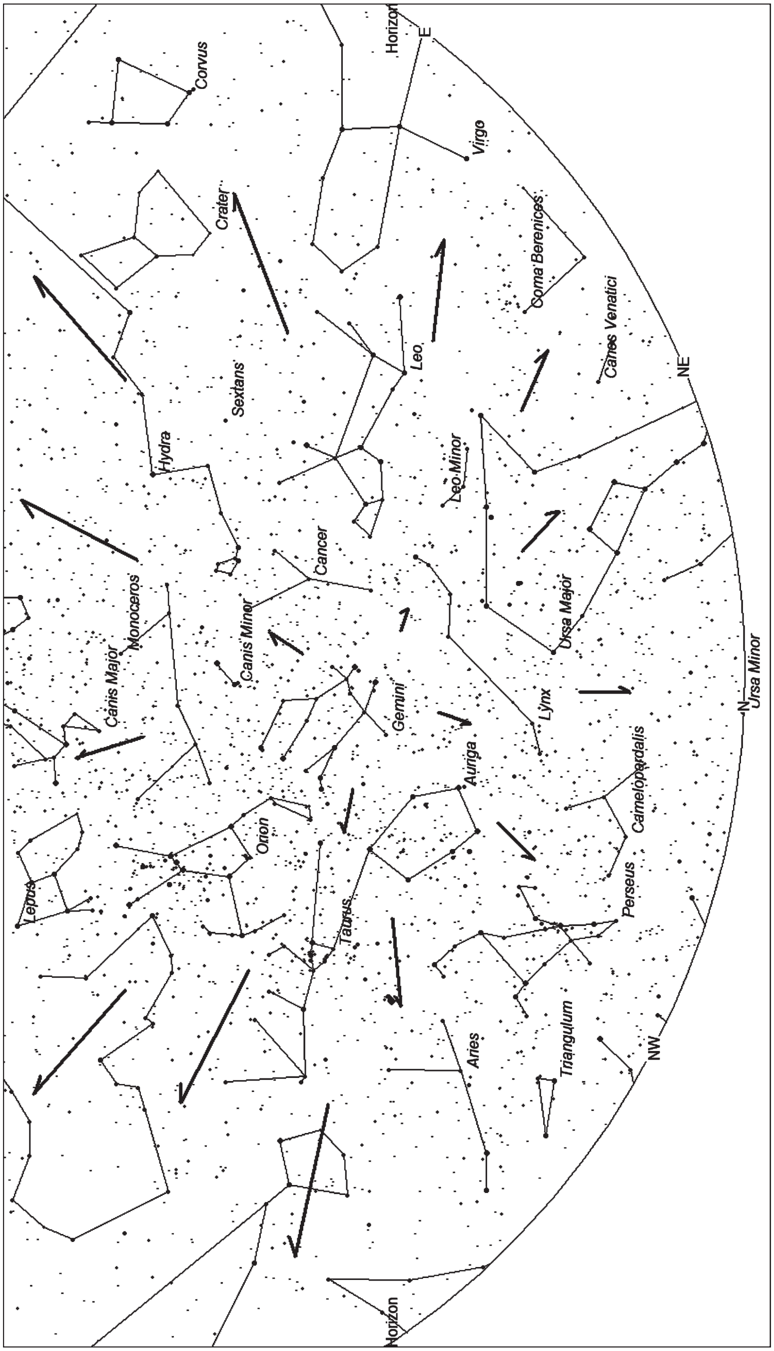

Fig. 3.56. Geminid activity as seen from the equator. Facing north near 0200 LST.

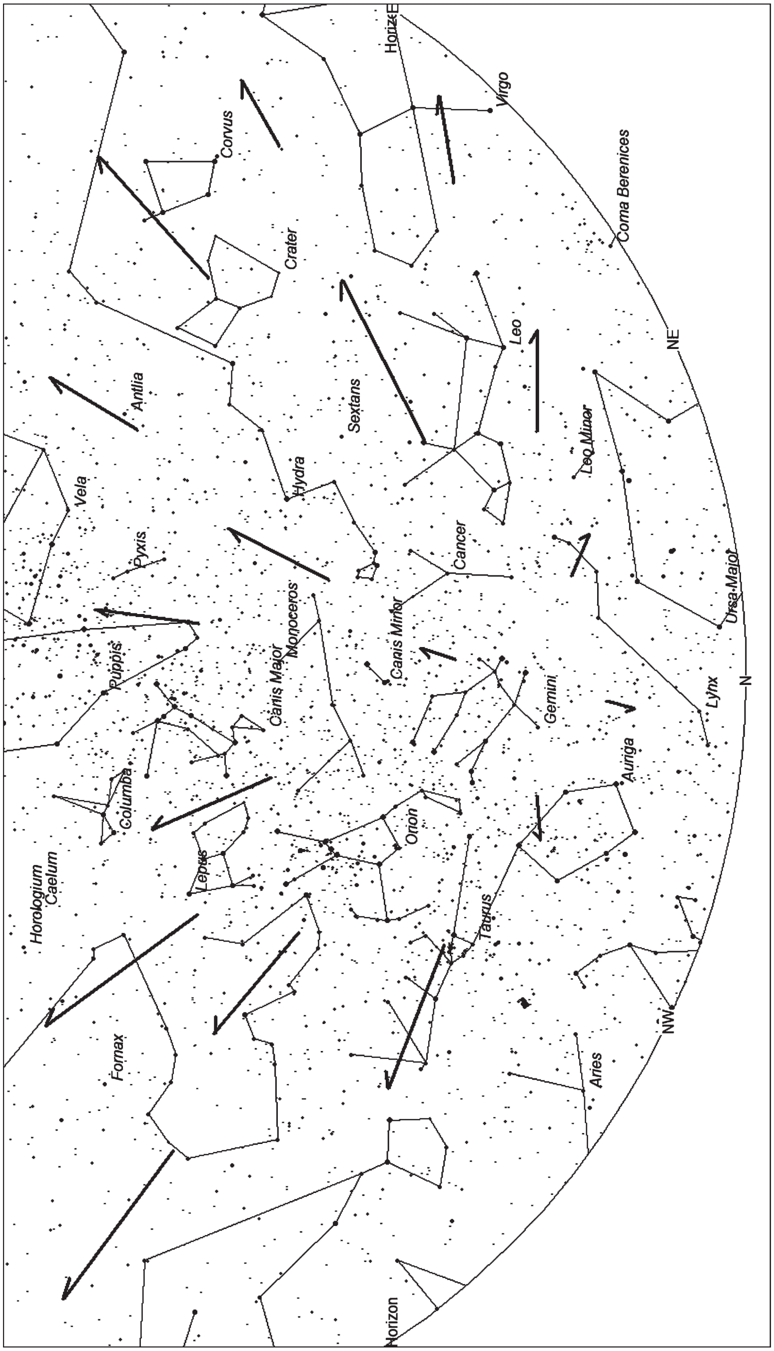

Fig. 3.57. Geminid activity as seen from latitude 25°S. Facing north near 0200 LST.

Fig. 3.58. A Geminid clashes with the Sword of Orion.

Fig. 3.59. A bright Geminid streaks past the Dog Star Sirius (alpha Canis Majoris).

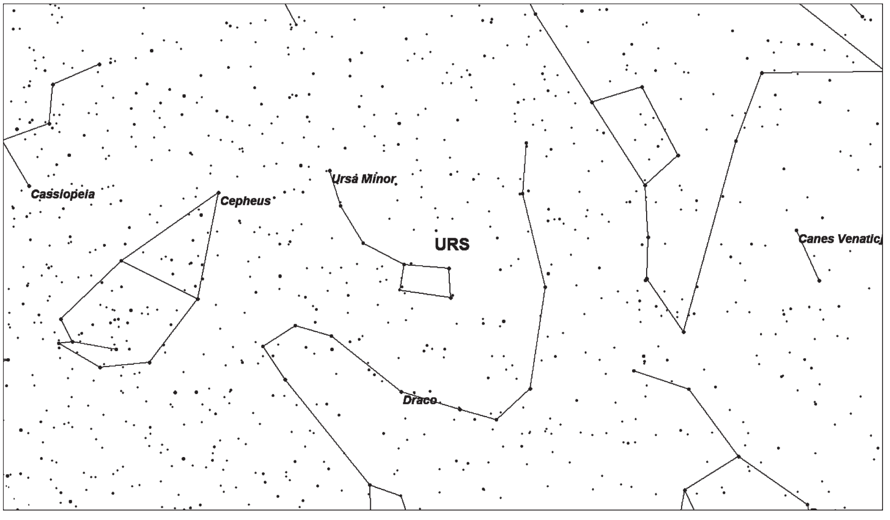

Fig. 3.60. Radiant position for the Ursids.

3.9 Ursids (URS) #15

Activity period: 12/17–12/26
Date of maximum activity: 12/22
Radiant position at maximum: 275 (18:20) + 75
Radiant drift per night: RA +0.0° Dec +0.4°
Geocentric velocity: 21 miles/s (33 km/s)

The Ursids, or Ursid Minorids, are a difficult shower to observe, as they possess a short peak of activity and are rarely seen from the southern hemisphere. Also, reaching peak activity just before Christmas, at a time when cloudy skies prevail over large areas of the northern hemisphere, prevents widespread observations of this activity. Needless to say it is also cold this time of year, as experienced by the upper two-third of the northern hemisphere. It is amazing we have any data at all on this shower!

The Ursids are active between December 17 and 26, with maximum activity occurring on December 22. Rates are low away from the night of maximum activity. Although the average ZHR for this shower is 10, rates are sometimes dreadfully low on the night of maximum activity. This author has seen rates at maximum activity with no Moon range from zero to 26 shower members per hour. That is quite a spread, so one does not know what they will see beforehand with this shower.

The Ursid radiant is located in southern Ursa Minor, near the bowl of the "Little Dipper." The position on December 22 lies at 217 (14:28) + 76. This position is close to the second-magnitude orange star known as Kochab (beta Ursae Minoris). The radiant is circumpolar for all observers north of 13°N latitude. The radiant lies lowest in the sky between 2000 and 2100 LST and highest between 0800 and 0900 LST. Unfortunately for most observers, it is too light to view any activity when the radiant lies highest in the sky. From high northern latitudes Ursid activity may be seen at any time of night. Activity may technically be seen all night long north of latitude 13°N, but realistically the radiant does not achieve a usable altitude from the lower half of the northern hemisphere until the morning hours arrive.

Occasionally the Ursids may see a sudden outburst of activity when Earth crosses one of the dust trails created by comet 8 P/Tuttle. The table lists the strongest of possible upcoming outbursts, all on December 22 of the listed year (Table 3.9).[5]

As seen from 50°N latitude the Ursid radiant lies 40° high in the northern sky at dusk. At this altitude 64% of all the Ursid activity may be seen. The radiant reaches its nadir between 2000 and 2100 LST, when it lies 36° in altitude. The radiant spends the remainder of the night rising to the right (or east) of Polaris reaching an altitude of 63° at dawn (0700 LST). At this altitude 89% of all the Ursid activity may be seen.

Table 3.9. Universal times and lunar conditions of possible strong Ursid outbursts

Year	Universal time	Moon (%)
2016	12:40	−36
2017	17:17	+17
2018	19:29	100
2030	21:11	−05
2034	14:15	+88

As one proceeds southward the viewing conditions for the Ursids worsen. As seen from 25°N latitude the Ursid radiant lies 13° above the northern horizon at dusk. Two hours later the radiant reaches a minimum altitude of 11°. At dawn the radiant has risen to an altitude of 37°, which allows 60% of the total Ursid activity to be seen. During a normal year when the peak ZHR is 10, observers would see only six Ursids per hour at best, even if their sky is very dark with a limiting magnitude of +6.5.

Conditions become very poor for viewing the Ursids as we reach the equator. At dusk (1900 LST) the Ursid radiant actually lies 13° below the northern horizon. The radiant does not rise until 0200 and only reaches a peak altitude of 9° at dawn (0500 LST). This low altitude only allows 16% of the total Ursid activity to be seen.

The Ursid radiant fails to clear the horizon south of 14°S latitude. Activity may be seen a few degrees further south, but due to the normal low rates, Ursid Earth-grazers would be extremely rare (Table 3.10, Figs. 3.61–3.66).

Table 3.10. Radiant altitude for the Ursids as seen from various latitudes

LST	18	19	20	21	22	23	00	01	02	03	04	05	06
50°N	38	36	36	36	37	38	40	43	47	50	54	58	61
25°N	13	12	11	11	12	13	16	19	23	27	30	33	37
00	–	−13	−14	−14	−13	−11	−8	−5	−2	2	6	9	–
25°S	–	–	−39	−39	−38	−36	−33	−29	−26	−22	−18	–	–

Fig. 3.61. A bright Ursid appears far from the radiant in Virgo.

Fig. 3.62. A bright Ursid appears in Leo the Lion.

Fig. 3.63. An evening Ursid darts past Aries the Ram.

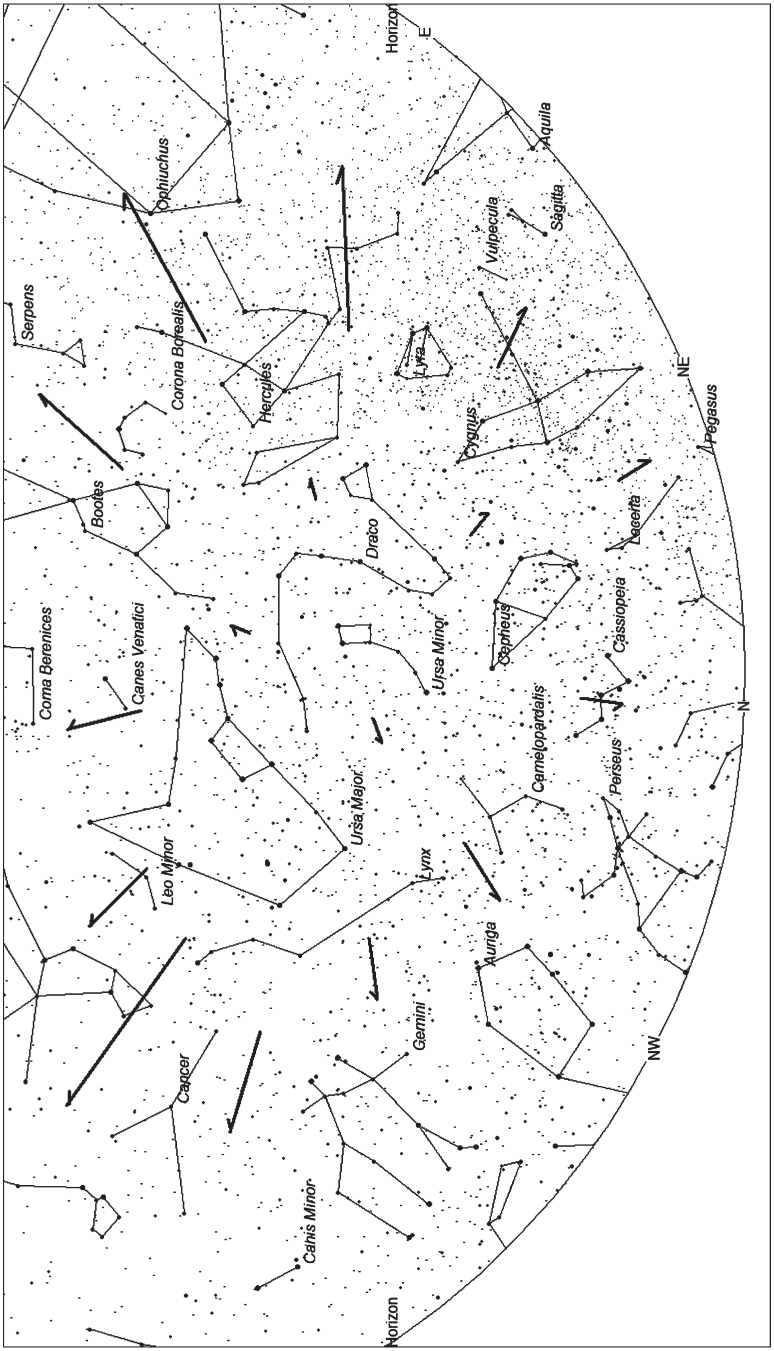

Fig. 3.64. Ursid activity as seen from latitude 50°N. Facing north at dawn.

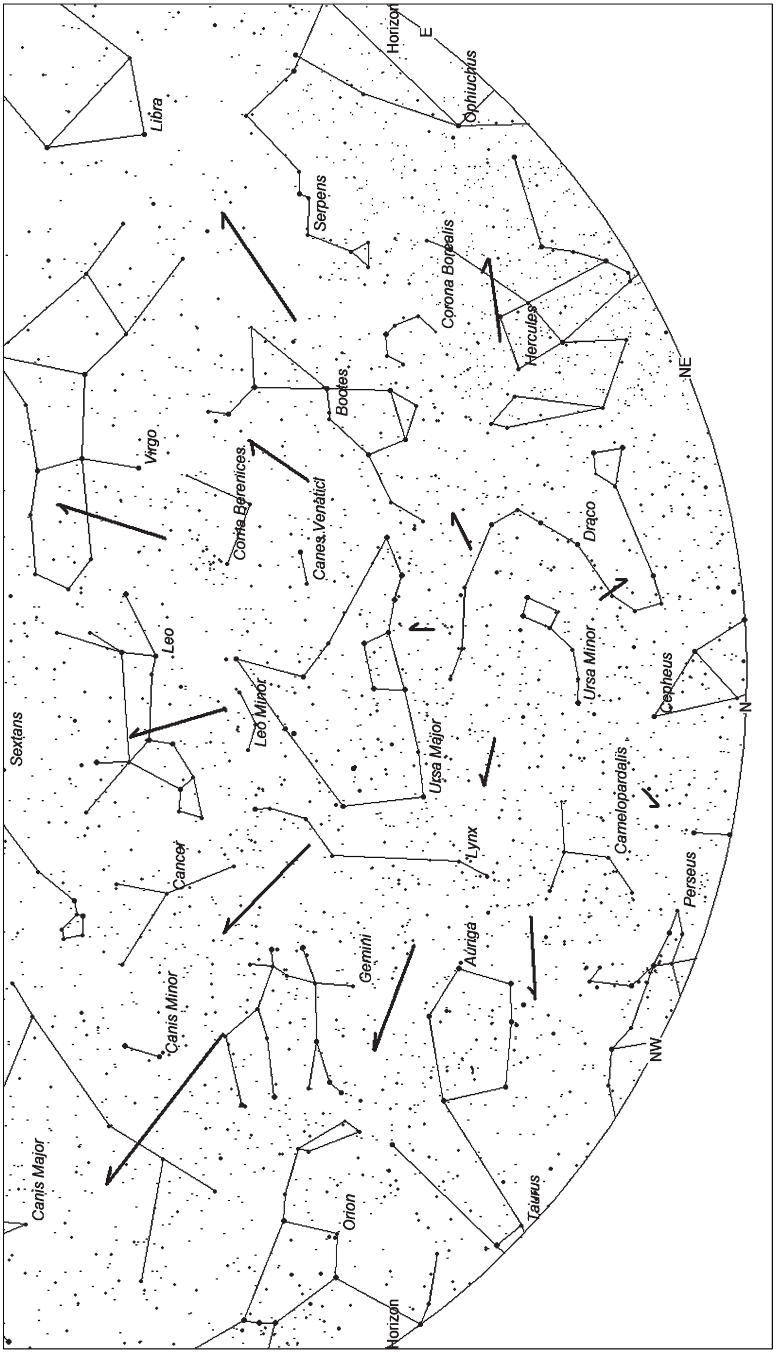

Fig. 3.65. Ursid activity as seen from latitude 25°N. Facing north at dawn.

Fig. 3.66. Ursid activity as seen from the equator. Facing north at dawn.

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Chapter 4

Minor Annual Showers

Abstract

This chapter discusses the 17 minor annual showers that are currently active throughout the year. These are showers that produce a ZHR of more than 1 but less than 10 shower members per hour at maximum activity. A star chart displaying the radiant position or drift during the showers entire activity is presented along with parameters of each shower such as celestial position, radiant drift per day, and geocentric velocity. Potential observers of these weaker showers are advised on how to best increase their chances of viewing this activity. Photographs of actual shower members are presented when available.

A minor annual shower is one that produces a peak ZHR greater than 1 but less than 10 and appears unfailingly on an annual basis. There are currently 17 such showers that qualify for this list. This list is not nearly as steady as the major annual shower list. Weak showers are often demoted, and new ones, recently recognized, are added. These showers are rarely known to the public, as they lack the activity of the Perseids and the rich history of the Leonids. Yet they are just as important as these more notable showers. They all have unique characteristics and deserve study.

Most of these showers are produced by unknown bodies that may or may not still exist. Since the Solar System is always evolving the parameters for these showers change over time, too. What may be a minor shower today may someday rival the mighty Geminids, due to perturbations by Jupiter. On the other hand they could also disappear altogether. Year-to-year observations by amateurs help scientists increase their knowledge of these obscure showers. Although rates can be low, observers are encouraged to monitor them.

These showers are spread more evenly throughout the year and often occur concurrently with each other and major annual showers. Observers can keep their observing skills sharp by plotting activity from these showers, especially when no major showers are occurring. These showers sometimes hold surprises and can produce brief spikes in activity caused by unknown dust trails. Perhaps more than half of these are missed due to the lack of monitoring such showers. The list below is presented in chronological order, with tips on how to best view any possible activity (Fig. 4.1).

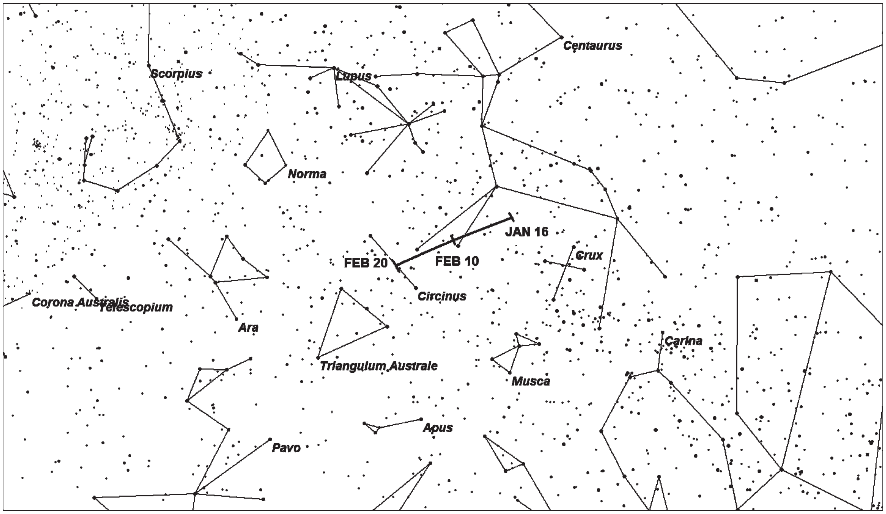

Fig. 4.1. Radiant drift of the alpha Centaurids.

4.1 α Centaurids (ACE) #102

Activity period: 01/28–02/21
Date of maximum activity: 02/08
Radiant position at maximum: 211 (14:04) − 59
Radiant drift per night: RA +1.1° Dec −0.3°
Geocentric velocity: 35 miles/s (56 km/s)

The first minor shower of the year is also one of the strongest, especially as seen from deep southern latitudes. The alpha Centaurids possess an average ZHR of 5. They are active from January 28 through February 21. Maximum activity occurs on February 8, when the radiant is located at 211 (14:04) − 59. This area of the sky is located in southeastern Centaurus, very close to the brilliant blue-white star Hadar (beta Centauri).

These meteors are best seen from around 45°S latitude, where the balance of early sunrise and radiant altitude is optimum. At this time of year from that latitude the sky does not become dark until near 2100 LST, or 9:00 p.m. At that time the radiant lies low in the southeast. It spends the remainder of the short summer night rising high into the southern sky. Morning twilight interferes before the radiant can culminate. The best rates would occur during the last hour before dawn, when skies are still perfectly dark. This radiant is visible up to 31°N latitude, and perhaps a rare alpha Centaurid Earth-grazer can be spotted from a few degrees further north. This shower can produce rare outbursts of strong activity, such as were witnessed in 1980 from Australia. There may have been other outbursts, but the lack of southern observers hampers our knowledge of this shower. The alpha Centaurids have an entry velocity of 35 miles/s, and most shower members will appear to move swiftly across the sky (Fig. 4.2).

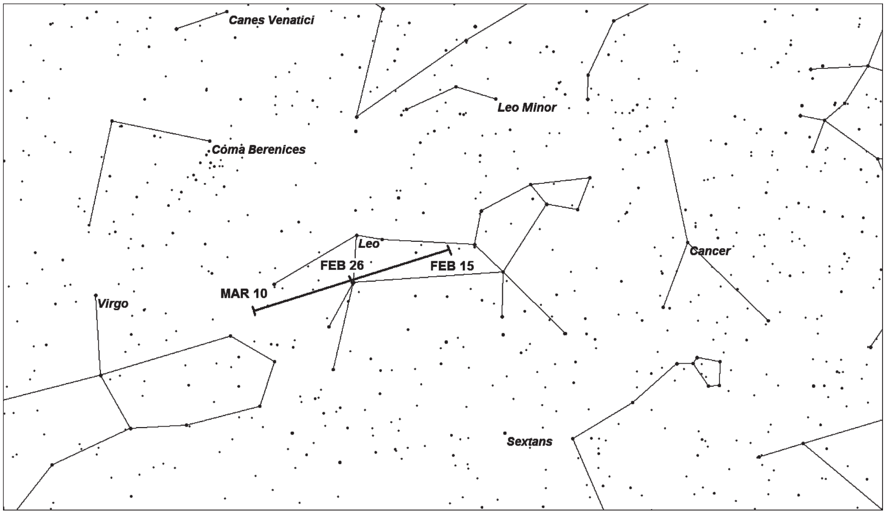

Fig. 4.2. Radiant drift of the delta Leonids.

4.2 δ Leonids (DLE) #29

Activity period: 02/15–03/10
Date of maximum activity: 02/25
Radiant position at maximum: 168 (11:12) + 16
Radiant drift per night: RA +0.8° Dec −0.3°
Geocentric velocity: 14 miles/s (23 km/s)

The delta Leonids barely survived the purge of ecliptical radiants into the antihelion group. The main reason was its distance from the center of the antihelion radiant, a full 13° to the north. Many still believe that this very weak shower is just the northern branch of the antihelion radiant in February. Sirko Molau's study of radiants obtained by video data fails to show any activity from this radiant.[1] With strong evidence such as this it will most likely not survive the next update of the IMO's working list of visual meteor showers.

The delta Leonid radiant becomes active in mid-February and peaks near February 25, with a ZHR of 2. Shower activity ends near March 10, as the radiant approaches the Virgo border. On the night of maximum activity the radiant lies at 168 (11:12) + 16, very close to the third-magnitude star theta Leonis. As seen from 25°N latitude, the radiant rises between 1800 and 1900 LST (6:00 and 7:00 p.m.) and lies highest in the sky near 0100 LST. Near this time would be the best opportunity to witness any delta Leonid activity. The delta Leonids have an entry velocity of 14 miles/s, and most shower members will appear to move slowly across the sky (Figs. 4.3 and 4.4).

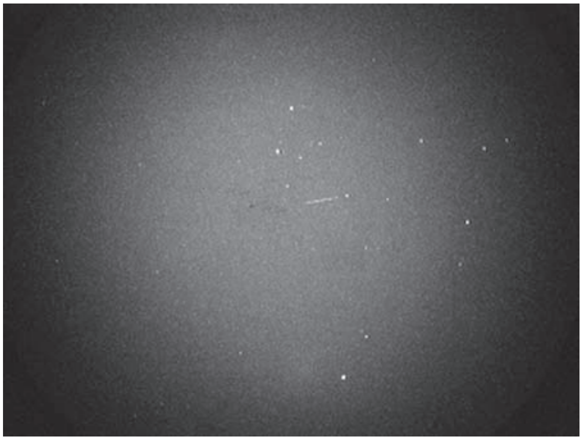

Fig. 4.3. A delta Leonid shoots into Gemini.

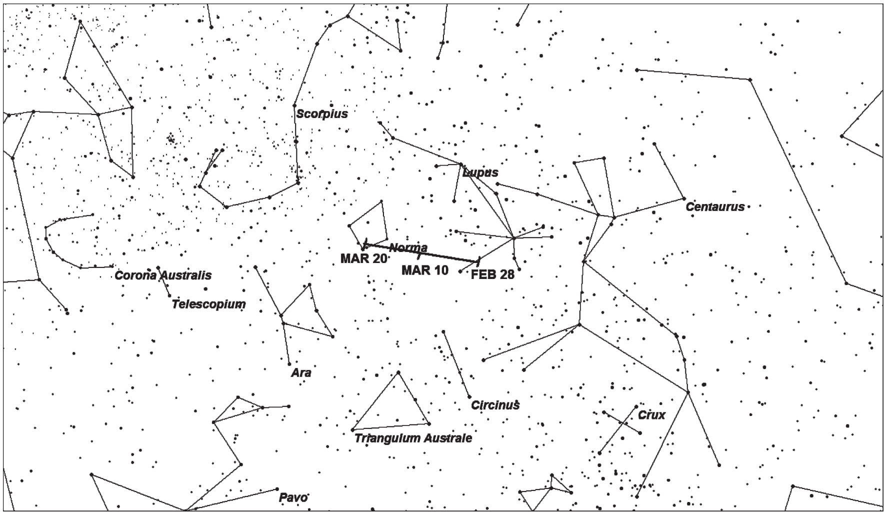

Fig. 4.4. Radiant drift of the gamma Normids.

4.3 γ Normids (GNO) #118

Activity period: 02/25–03/22
Date of maximum activity: 03/13
Radiant position at maximum: 239 (15:56) – 50
Radiant drift per night: RA +1.2° Dec +0.2°
Geocentric velocity: 35 miles/s (56 km/s)

The gamma Normids are an obscure shower with very little available data. The radiant position is not well known, nor is the exact activity period. The best estimate is that this shower is active from February 25 through March 22, with maximum activity near March 13. On this date the radiant is thought to be located near 239 (15:56) − 50. This position lies in central Norma, near the faint star Eta Normae. The average ZHR at maximum is 4. Southern observers often state this shower does not appear or produces ZHRs in excess of 10.

Much like the Ursids of December, you do not know exactly what you will get when trying to view this shower. With such a deep southern declination this shower is best observed from the southern hemisphere. As seen from 25°S latitude the radiant rises near 2000 LST (8:00 p.m.) in the southeastern sky. It reaches its maximum altitude above the southern horizon at the start of morning twilight. The radiant clears the horizon as far north as 40°N latitude. Due to the low rates it would nearly be impossible to see any activity from this far north. A further 10°S is necessary before one could expect to see more than one meteor per night at maximum. The Gamma Normids have an entry velocity of 35 miles/s, and most shower members will appear to move swiftly across the sky (Figs. 4.5–4.7).

Fig. 4.5. A gamma Normid streaks past the constellation of Corvus.

Fig. 4.6. A bright gamma Normid ends near Arcturus in southern Bootes.

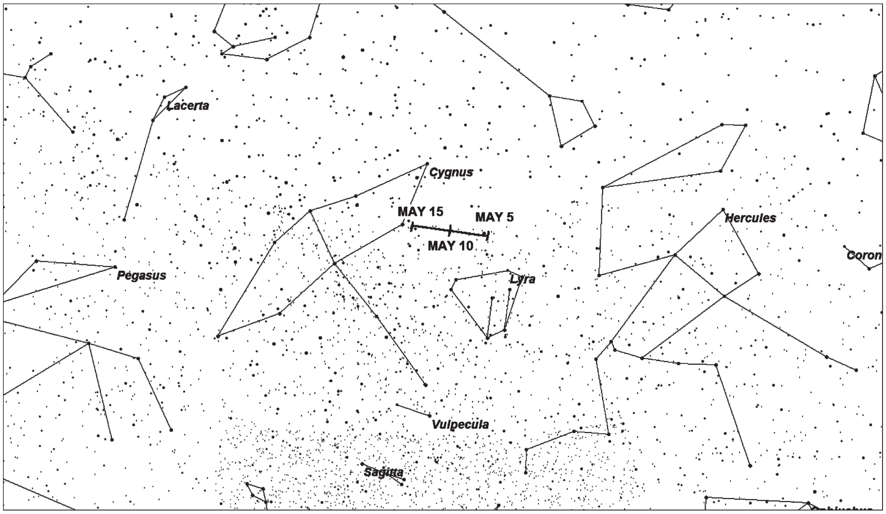

Fig. 4.7. Radiant drift of the eta Lyrids.

4.4 η Lyrids (ELY) #145

Activity period: 05/03–05/12
Date of maximum activity: 05/08
Radiant position at maximum: 287 (19:08) + 44
Radiant drift per night: RA +1.0° Dec +0.0°
Geocentric velocity: 27 miles/s (44 km/s)

The eta Lyrids are a relatively new shower, first noticed after the passage of comet C 1983 H_1, IRAS-Araki-Alcock, back in 1983. It has just been recently added to observing lists as an annual shower. The activity period is only 10 days long, ranging from May 3 through 12. Maximum activity occurs on May 8, when the ZHR reaches 3. The radiant begins in northern Lyra and is located at 287 (19:08) + 44. This position lies 6°NE of the brilliant white star Vega (alpha Lyrae). The radiant drifts eastward and ends in northwestern Cygnus, near the third-magnitude star delta Cygni. The eta Lyrids have an entry velocity of 27 miles/s, and most shower members appear medium-swift in the sky. Many observers notice these meteors when observing the eta Aquarids.

Even though nights are short in the northern hemisphere during May, the area between 40 and 50°N latitude still offers the best view of this display. The radiant reaches maximum altitude an hour before the start of morning twilight, allowing a great view of any activity as the radiant lies near the zenith (Fig. 4.8).

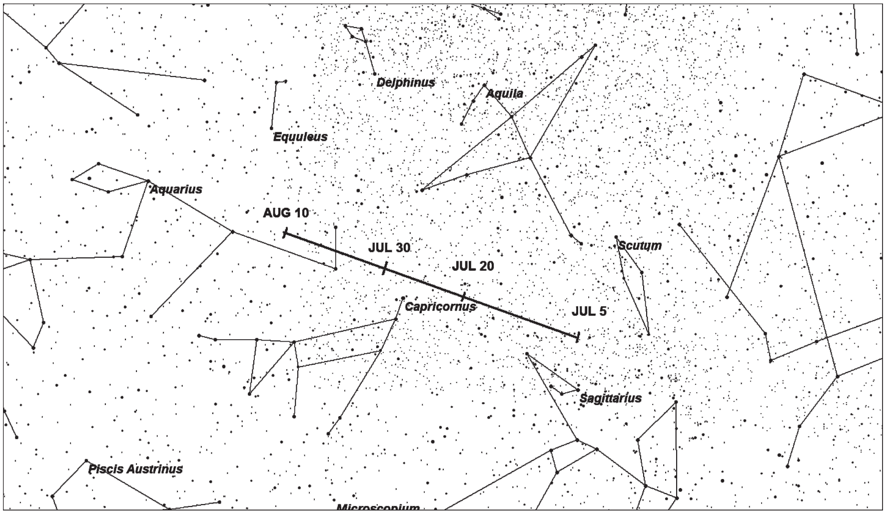

Fig. 4.8. Radiant drift of the alpha Capricornids.

4.5 α Capricornids (CAP) #1

Activity period: 07/03–08/15
Date of maximum activity: 07/29
Radiant position at maximum: 307 (20:28) − 10
Radiant drift per night: RA +1.0° Dec +0.3°
Geocentric velocity: 14 miles/s (23 km/s)

Nearly 2 months pass until the next annual minor shower becomes active. July ushers in the alpha Capricornids, with a wide radiant located in northeastern Sagittarius. The radiant slowly shifts toward the northeast with each passing night. At maximum activity (July 27) the radiant lies just northeast of the wide naked-eye double star alpha Capricorni. Soon after maximum the radiant moves into the boundaries of Aquarius, where it remains until activity ceases. Maximum ZHRs for this shower average 4, but rates usually remain above 1 during most of the time the radiant is active.

The alpha Capricornids encounter Earth from the side; therefore, they are slow meteors, with an entry velocity of 14 miles/s. These meteors appear to move slowly, especially when compared to the Perseids. The difference in velocity is also noticeable when compared to the slightly swifter delta Aquariids. Being slow, they are easy to identify and usually last at least 1 s, if not longer. The alpha Capricornids are a fairly bright shower, and slow, bright meteors can be spectacular. They often fragment, with the separated pieces appearing as tiny meteors of their own.

This shower is easily observed over most of Earth. The radiant passes directly overhead, as seen from 10°S latitude. It culminates at midnight LST and is best seen near this hour. This is the third of 4, the Antihelion and delta Aquariid being the first two radiants active in July in the same general area of the sky. Care must be taken when trying to determine shower association between these radiants. The alpha Capricornids are the easiest to recognize, due to their slow velocity. But any of the other three showers can produce slow meteors if they appear close to the radiant or close to the horizon. Unless you can see the area of the sky containing these radiants, it would be difficult to differentiate between them (Figs. 4.9 and 4.10).

Fig. 4.9. An alpha Capricornid fireball streaks through Cygnus.

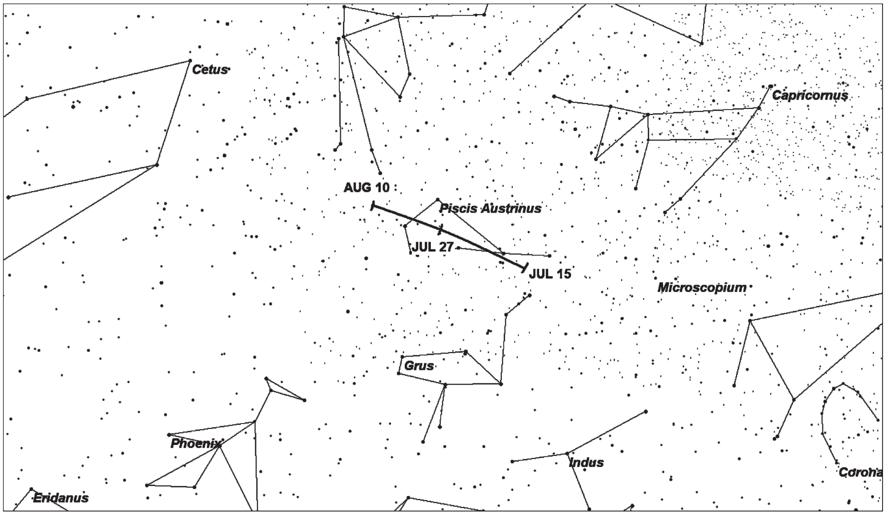

Fig. 4.10. Radiant drift of the Piscis Austrinids.

4.6 Piscis Austrinids (PAU) #183

Activity period: 07/15–08/10
Date of maximum activity: 07/27
Radiant position at maximum: 341 (22:44) − 30
Radiant drift per night: RA +0.9° Dec +0.4°
Geocentric velocity: 22 miles/s (35 km/s)

The Piscis Austrinids are the last of the four radiants to become active during July in this portion of the sky. They reach a ZHR of 1 on July 15. Rates slowly climb until maximum activity is reached on July 27, when the ZHR reaches 5. After, maximum rates slowly decline until the shower falls below a ZHR of 1 on August 10. The radiant starts out in southwestern Piscis Austrinus and is located only a few degrees west of the bright star Fomalhaut (alpha Piscis Austrinus) on July 27. It continues eastern into the constellation of Sculptor before activity ends.

This shower is best seen at 30°S latitude, where it passes overhead near 0200 LST. It clears the horizon all the way up to 60°N latitude, but activity from this shower is rarely seen that far north. It should be noted that this shower peaks in activity the same night as the much stronger delta Aquariids. The few Piscis Austrinids that do appear tend to be swamped by the more numerous delta Aquariids. Care should be taken to correctly associate each meteor with the proper radiant, or the delta Aquariids may be under-represented or the Piscis Austrinids over-represented. The best way to do this is to face in the general direction of the radiant so that shower members may be easily traced back to their source. The Piscis Austrinids have an entry velocity of 22 miles/s, and most shower members will have a medium velocity (Fig. 4.11).

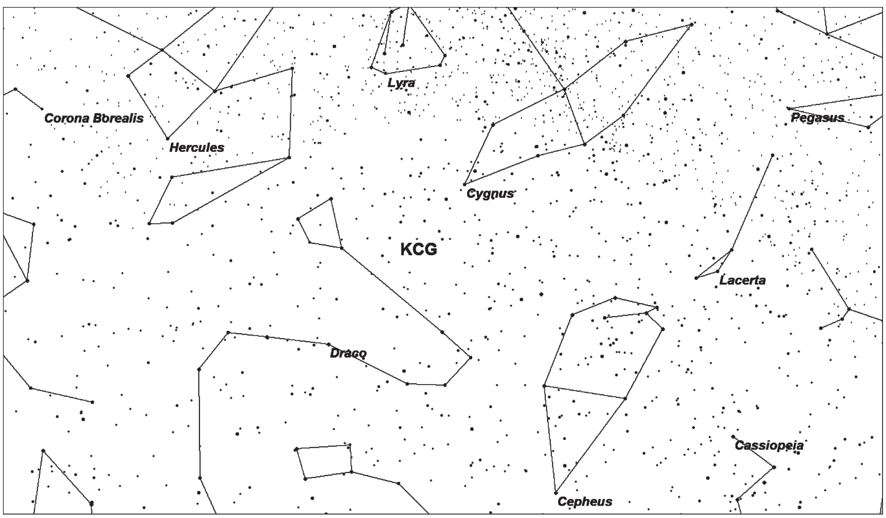

Fig. 4.11. Radiant position of the kappa Cygnids.

4.7 κ Cygnids (KCG) #12

Activity period: 08/03–08/25
Date of maximum activity: 08/17
Radiant position at maximum: 286 (19:04) + 59
Radiant drift per night: RA +0.3° Dec +0.1°
Geocentric velocity: 16 miles/s (25 km/s)

The kappa Cygnids are the northern skies' version of the alpha Capricornids. This shower also produces slow, often bright, fragmenting meteors that grace the northern summer sky. This shower is active most of August and reaches maximum on August 18, when the average ZHR reaches 3. This shower is a rarity, as it is best seen as soon as it becomes dark during the evening hours. There are probably many novice observers who try to view Perseid activity early in the evening only to see kappa Cygnids, probably thinking they were Perseids.

This shower is best seen from high northern latitudes, where the radiant lies near the zenith at dusk. The radiant is circumpolar from areas north of 30°N latitude. Viewing this activity becomes difficult in the low southern latitudes and impossible south of 30°S latitude. On August 18 the radiant lies at 286 (19:04) + 59. This position lies 5°N of the faint star kappa Cygni. Interestingly enough, the radiant never actually enters the boundary of Cygnus as it lies just over the border in southern Draco during the entire activity period. Due to the high declination the radiant drift appears short when compared to those that lie close to the celestial equator (Figs. 4.12–4.14).

Fig. 4.12. A kappa Cygnid passes by Polaris.

Fig. 4.13. A bright kappa Cygnid appears in Cepheus.

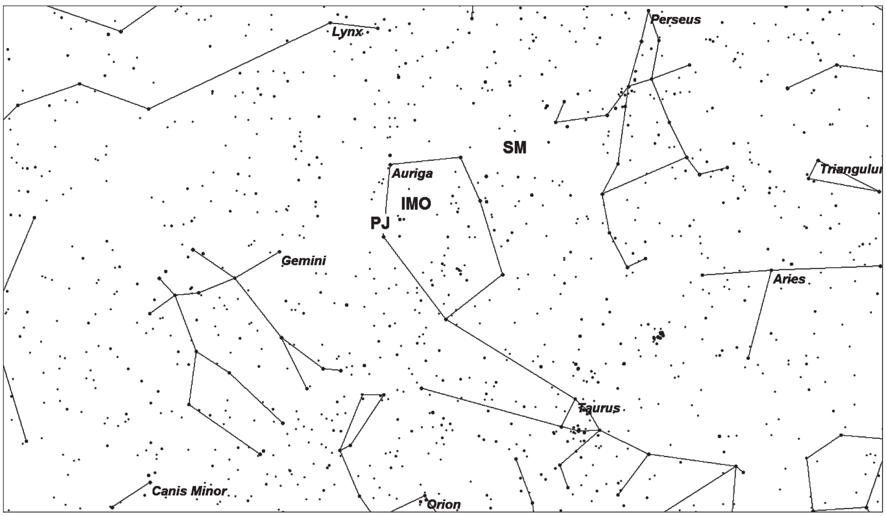

Fig. 4.14. Radiant positions of the Aurigids.

4.8 Aurigids (AUR) #206

Activity period: 08/25–09/08
Date of maximum activity: 09/01
Radiant position at maximum: 084 (05:36) + 42
Radiant drift per night: RA +1.1° Dec 0.0°
Geocentric velocity: 41 miles/s (66 km/s)

In late August and early September swift meteors appear from the constellation of Auriga. These meteors are known as the Aurigids, or alpha Aurigids. In normal years the ZHR of this shower peaks near 7 on the morning of September 1.

Occasionally this shower produces a short outburst of bright meteors, with ZHRs approaching 100. This last occurred in 2007, but unfortunately, no more are expected during the first half of the twenty-first century.[2]

The chart lists three different radiants for this shower, as seen on September 1. The normal annual activity seems to occur from the IMO radiant. The 2007 outburst coincided with Peter Jenniskens' position. Video data from Sirko Molau support a radiant on the Auriga/Perseus border.[3] My plots show that the 1994 Aurigid outburst coincided with Molau's position. Regardless of the radiant, these meteors are easy to identify, as they appear similar to Perseids but trace back to the large constellation of Auriga.

Activity is very low away from maximum. These meteors are first seen near August 25, and activity ceases near September 8. The radiant is best placed for viewing from high northern latitudes. It is circumpolar from the upper half of the northern hemisphere. It is best placed during the last hour before morning twilight.

Activity is visible south of the equator, but the radiant does not rise until after midnight and culminates lower in the northern sky. Aurigid activity is not seen south of 50°S latitude (Figs. 4.15–4.18).

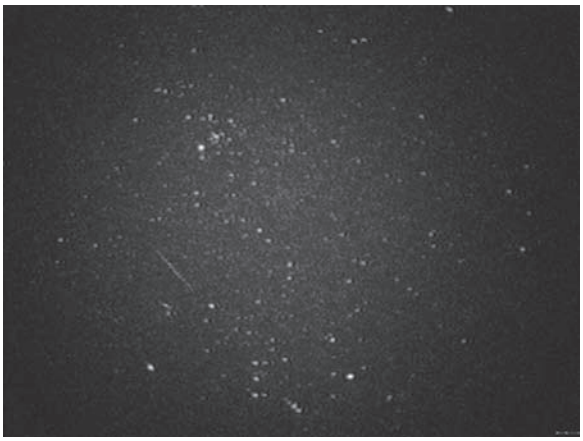

Fig. 4.15. An Aurigid from Molau's radiant enters Orion.

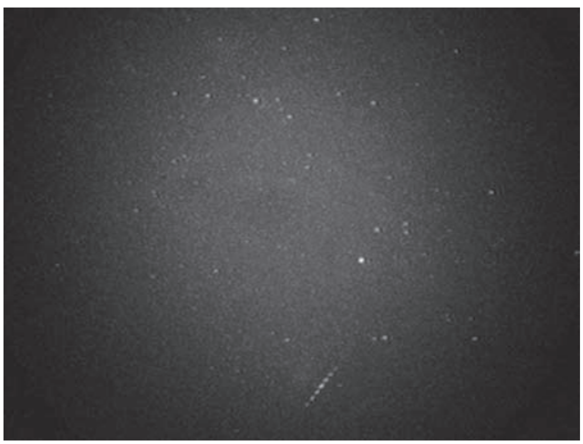

Fig. 4.16. An Aurigid from the IMO's radiant travels northward.

Fig. 4.17. A bright Aurigid from Jenniskens' radiant appears in Lynx.

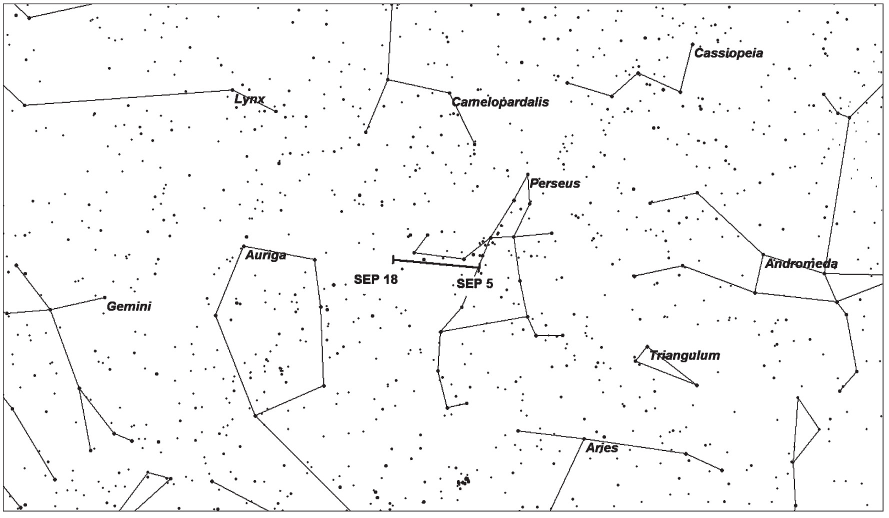

Fig. 4.18. Radiant drift of the September Perseids.

4.9 September Perseids (SPE) #208

Activity period: 09/05–09/17
Date of maximum activity: 09/09
Radiant position at maximum: 060 (04:00) + 47
Radiant drift per night: RA +1.1° Dec +0.1°
Geocentric velocity: 40 miles/s (64 km/s)

This shower was once part of the delta Aurigids. When data revealed that there were two separate maximums the early portion of the delta was separated into the September Perseids.

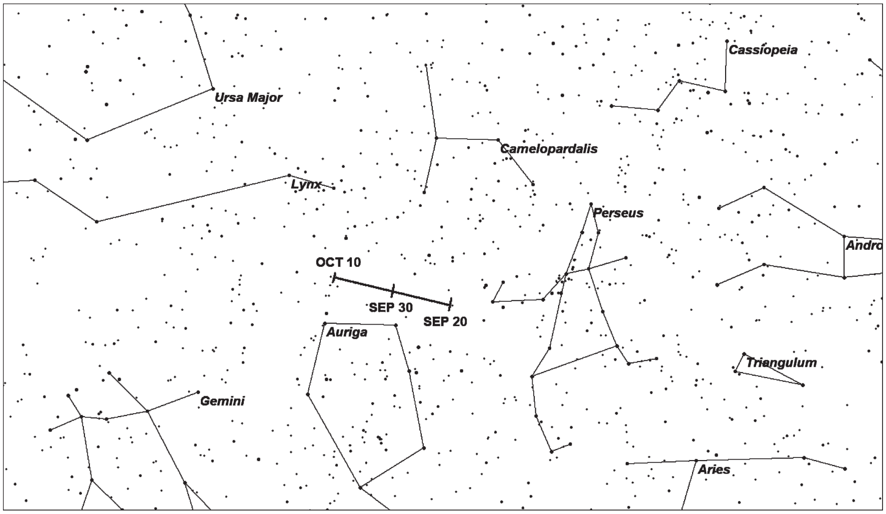

Fig. 4.19. Radiant drift of the delta Aurigids.

Do not confuse this shower with the much stronger Perseids of August. These meteors are swift, like the August Perseids, yet their peak ZHR is only 5. Activity from this shower is usually first noticed near September 5. Maximum activity is reached only four nights later, on September 9. Rates slowly dwindle as September progresses. As activity begins the radiant is located in east-central Perseus near the third magnitude star delta Persei. On the ninth its position is 060 (04:00) + 47. This position lies 3°SE of delta Persei. By the end of its activity the radiant has drifted close to the Auriga border.

This shower is best seen from near 50°N latitude, where the radiant passes directly overhead near 0200 LST. It may also be seen down to 43°S latitude, where it just skims the horizon. Activity is not seen further south, as the radiant fails to clear the horizon (Fig. 4.19).

4.10 δ Aurigids (DAU) #224

Activity period: 09/18–10/10
Date of maximum activity: 10/03
Radiant position at maximum: 088 (05:52) + 49
Radiant drift per night: RA +1.1° Dec +0.1°
Geocentric velocity: 40 miles/s (64 km/s)

This shower is active from September 18 through October 10. During that time the radiant drifts eastward from the Perseus–Auriga border to extreme northern Auriga. Maximum activity occurs near October 3, when the ZHR reaches 3. Like the September Perseids, this shower is best suited to be seen from high northern latitudes where the radiant passes overhead during the dark morning hours. The position of the radiant at maximum is 088 (05:52) + 49. This position lies 5°NW of the brilliant

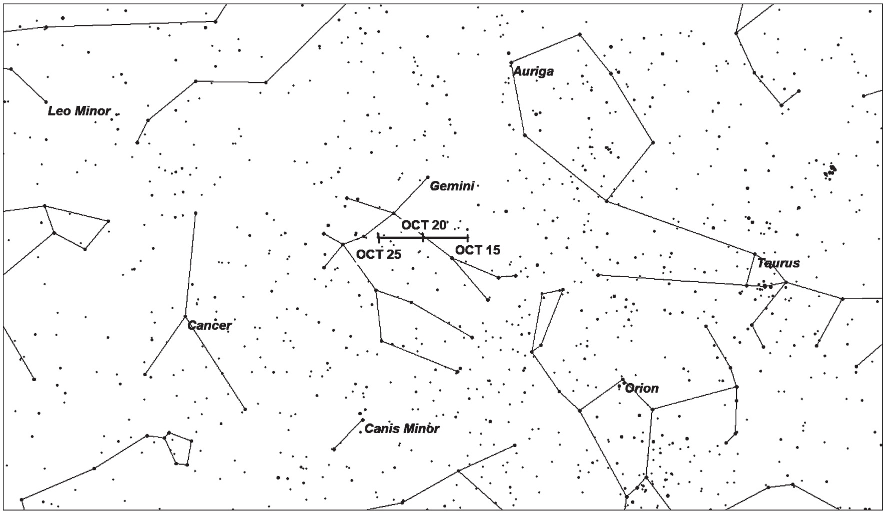

Fig. 4.20. Radiant drift of the epsilon Geminids.

zero magnitude yellow star Capella (alpha Aurigae). With an entry velocity of 40 miles/s a majority of delta Aurigid activity would appear to travel swiftly through the sky (Fig. 4.20).

4.11 ε Geminids (EGE) #23

Activity period: 10/14–10/27
Date of maximum activity: 10/18
Radiant position at maximum: 102 (06:48) + 27
Radiant drift per night: RA +1.0° Dec 0.0°
Geocentric velocity: 43 miles/s (70 km/s)

The epsilon Geminids are active between October 14 and 27. Maximum activity occurs on October 18, when the average ZHR reaches 2. This shower may be slightly stronger, but it is possible that shower members from this shower are included in the much more numerous Orionid count. These meteors are similar in appearance to the Orionids, and the radiants are roughly 10° apart, so confusion in shower association is possible. This radiant lies near the apex of Earth's motion; therefore, these meteors are among the fastest possible of those bound to the Sun. They strike Earth's atmosphere at 43 miles/s, which is even a bit faster than those of the nearby Orionid shower. The epsilon Geminids are well seen over most of Earth but are best seen near 27°N latitude, where the radiant passes directly overhead near 0500 LST.

When activity begins in mid-October the radiant lies near the Gemini–Auriga border. The radiant moves roughly 1°E each night and is located at 102 (06:48) + 27 on October 18. This position lies just 2°NE of the third magnitude star epsilon Geminorum. By the time the shower ceases activity the radiant lies in central Gemini, 5°W of the bright first magnitude star Pollux (beta Geminorum) (Figs. 4.21–4.23).

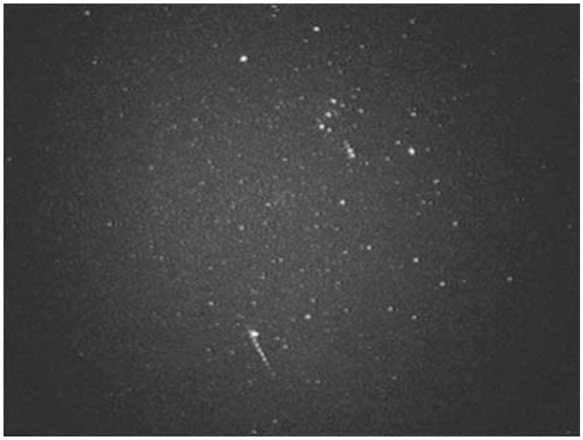

Fig. 4.21. An epsilon Geminid strikes the Dog Star.

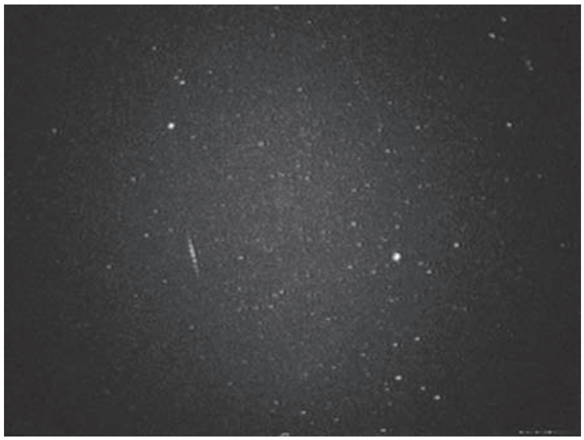

Fig. 4.22. An epsilon Geminid appears in eastern Monoceros.

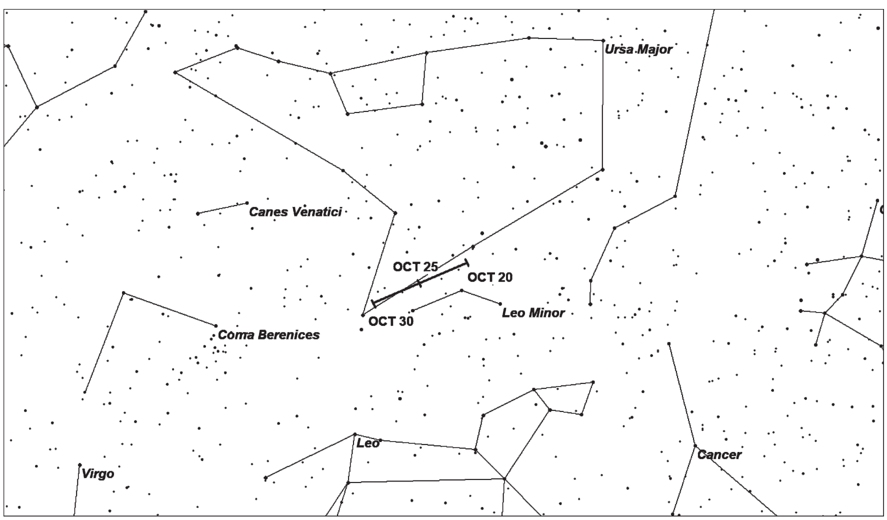

Fig. 4.23. Radiant drift of the Leo Minorids.

4.12 Leo Minorids (LMI) #22

Activity period: 10/19–10/27
Date of maximum activity: 10/24
Radiant position at maximum: 162 (10:48) + 37
Radiant drift per night: RA +1.0° Dec −0.4°
Geocentric velocity: 39 miles/s (62 km/s)

The Leo Minorids is a shower new to many observers. While viewing the Orionids many observers have noticed weak activity from Leo Minor. For the past 20 years only the Dutch Meteor Society has listed this radiant among their annual showers.[10] Sirko Molau's study of video radiant has confirmed this activity, and it is now listed among the annual showers of the International Meteor Organization (IMO).[11] Activity from this shower begins near October 19 and reaches maximum ZHR of 2 on October 24. By the 27th rates have fallen below a ZHR of 1. This radiant is first located in northeastern Leo Minor and finishes up in southern Ursa Major. On the night of maximum activity it is located at 162 (10:48) + 37. This position lies on the Leo Minor/Ursa Major border, 5°E of the fourth magnitude star beta Leo Minoris (Figs. 4.24–4.26).

Fig. 4.24. A Leo Minorid shoots past Orion.

Fig. 4.25. A Leo Minorid fireball appears in Hydra.

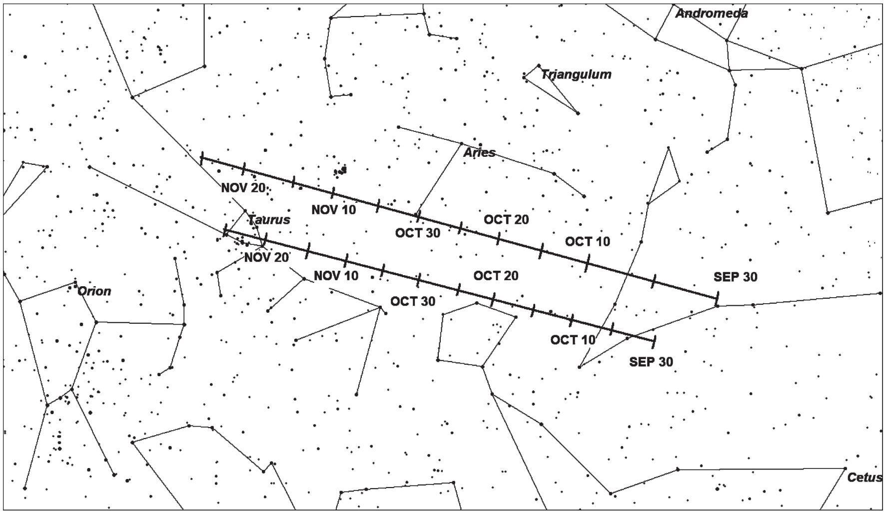

Fig. 4.26. Radiant drift of the Northern and Southern Taurids.

4.13 Northern and Southern Taurids

4.13.1 Southern Taurids (STA) #2

Activity period: 09/25–11/25
Date of maximum activity: 11/05
Radiant position at maximum: 052 (03:28) + 15
Radiant drift per night: RA +0.9° Dec +0.1°
Geocentric velocity: 17 miles/s (27 km/s)

4.13.2 Northern Taurids (NTA) #17

Activity period: 09/25–11/25
Date of maximum activity: 11/12
Radiant position at maximum: 058 (03:52) + 22
Radiant drift per night: RA +0.8° Dec +0.3°
Geocentric velocity: 18 miles/s (29 km/s)

During the last week of September Earth begins encountering the inbound particles of comet P 1/Encke. These particles appear in our skies as Taurid meteors in two distinct branches north and south of the ecliptic. Both of these radiants are diffuse, and the positions mentioned are for the central cores of each radiant. These diffuse radiants overlap the equally diffuse Antihelion radiant during October and November. Therefore, the Antihelion meteors are impossible to separate from the two Taurid radiants. During this time it is advised that one just list activity from the two Taurid radiants since they are the stronger sources.

The orbit of comet P 1/Encke encounters Earth for 2 months, producing the longest stretch of activity for any meteor shower. These showers may be called the Taurids but actually produce activity in eastern Pisces in late September, in Aries during October, and finally Taurus in November. The reason they are called Taurids is that they reach maximum activity in November, when the radiants are centered in the constellation of Taurus.

Like the Antihelion meteors, these meteors strike Earth at nearly a 90° angle; therefore, they appear to move slowly across the sky. The fastest angular velocity for these meteors would be near 14° per second. This velocity could only occur with the radiant at the horizon and the meteor appearing at the zenith. Most Taurid meteors would possess angular velocities closer to 5° per second, which is slower than most other meteors.

The Taurids often produce colorful fireballs, especially when near maximum activity. Activity can also vary year to year, and studies by David Asher of Armagh Observatory and Kiyoshi Izumi have determined a periodic cycle of 3.39 years.[4] If this is the case then the years of 2008, 2012, 2015, 2022, 2025, 2032, 2039, 2042, 2049, and 2052 may produce stronger than normal rates, with notable fireball activity.

Since the Taurid radiants lie near the opposition point they are visible in the sky most of the night, especially as seen from areas north of the equator. The fact that they lie high in the sky during the evening hours accounts for many of the Taurid fireball sightings. The radiant is best placed near midnight LST, when it lies highest in the sky. Only the south polar regions of Earth cannot view Taurid activity due to the fact the radiant remains below the horizon and the area is bathed in 24-h sunlight/twilight this time of year.

The Taurids are active during both the Orionid and Leonid meteor showers. When facing toward the radiants of these showers, especially during the Orionids (due to close proximity), it is interesting to watch the "battle" between the two areas, with Taurid meteors being flung slowly eastward and Orionid and Leonids shooting swiftly westward.

The Southern Taurids reach maximum activity on November 5, which is a week earlier than the northern branch. On this date the center of the radiant is located at 052 (03:28) + 15. This position lies in extreme western Taurus, 15°W of the bright orange first magnitude star Aldebaran (Alpha Tauri).

The Northern Taurids reach maximum activity on November 12, with the radiant center located at 058 (03:52) + 22. This position lies in western Taurus just 3°SE of the naked-eye open star cluster known as the Pleiades, or the Seven Sisters (Figs. 4.27–4.29).

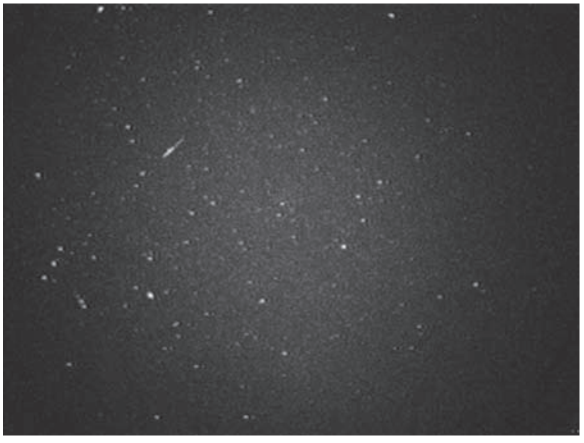

Fig. 4.27. Orion's shield stops this southern Taurid.

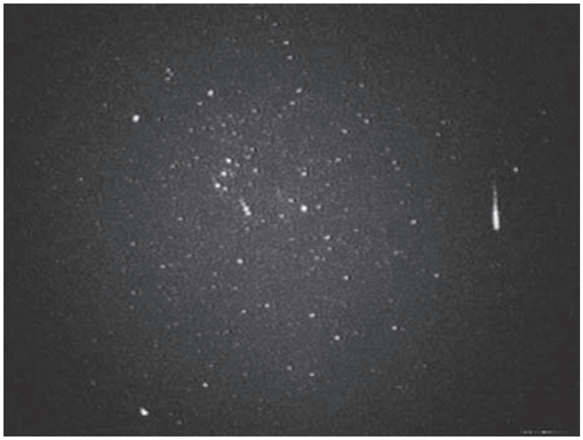

Fig. 4.28. This bright northern Taurid drops into Eridanus.

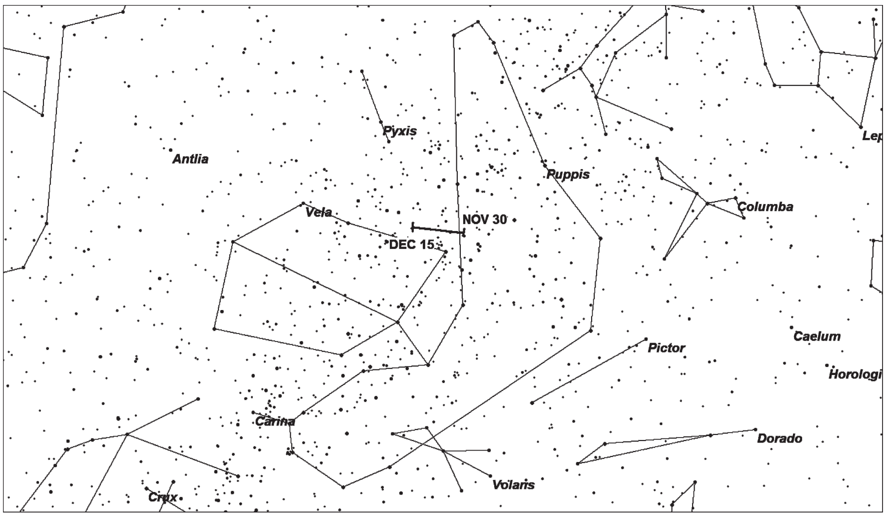

Fig. 4.29. Radiant drift of the Puppid-Velids.

4.14 Puppid-Velids (PUP) #255

Activity period: 12/01–12/15
Date of maximum activity: 12/06
Radiant position at maximum: 123 (08:12) − 45
Radiant drift per night: RA +0.5° Dec 0.0°
Geocentric velocity: 25 miles/s (40 km/s)

The Puppids-Velids are the core of a vast complex of weak showers active from December through March. Maximum activity seems to occur during the first 2 weeks of December, when the combined ZHR of these radiants averages 10. During the remainder of the activity period rates are too low to be properly studied by visual means. With such low rates and high sporadic rates visible from the southern hemisphere during the same period, the chance of sporadic pollution falsely inflating shower ZHRs is great.

Members of the Puppids-Velids are obvious when seen from sites in the northern hemisphere, where the radiant lies close to the horizon. Shower members will be visible as long, graceful meteors shooting upward from the south. These meteors are often seen in conjunction with the much stronger Geminids, especially when the observer is facing southward. This shower is rarely seen north of 45°N latitude, as the core of the radiant lies on the horizon from this location.

During the 2 weeks of maximum activity the core drifts from eastern Puppis into western Vela. Near the center of this activity period the core lies a few degrees north of the second magnitude star Naos (zeta Puppis). To southern observers, where the radiant lies high in the sky, this area of the sky is a wonderful treat to behold, as it is centered on the Milky Way and encompasses many bright stars and constellations (Figs. 4.30–4.32).

Fig. 4.30. A Puppid-Velid streaks above Corvus.

Fig. 4.31. A faint Puppid-Velid slices through Sirius and Canis Major.

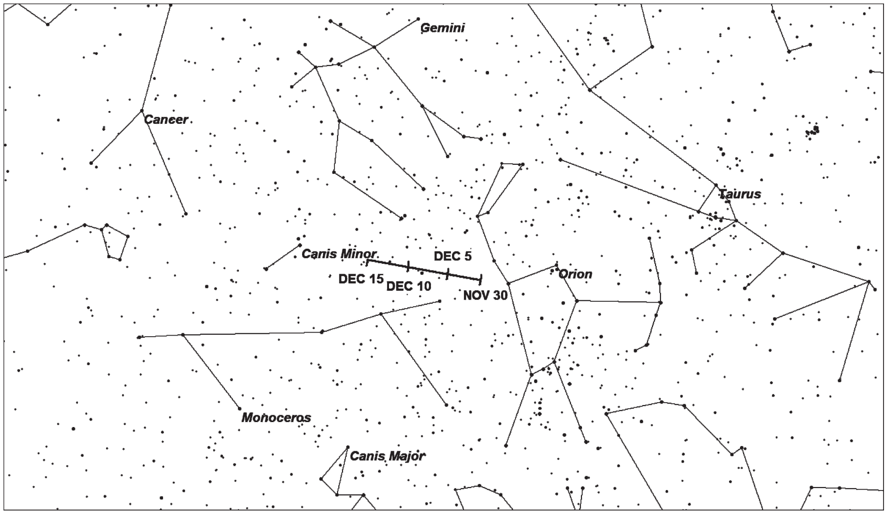

Fig. 4.32. Radiant drift of the Monocerotids.

4.15 Monocerotids (MON) #19

Activity period: 11/27–12/17
Date of maximum activity: 12/08
Radiant position at maximum: 100 (06:40) + 08
Radiant drift per night: RA +0.9° Dec 0.0°
Geocentric velocity: 26 miles/s (42 km/s)

The Monocerotids are among the many radiants active during the first half of December. Most of these meteors are seen in conjunction with observers concentrating on the much stronger Geminids. Due to the low rates from this shower and the fact observers are concentrating on the Geminids, details on this shower are not well known. The activity period most often seen is November 27 through December 17, with maximum activity occurring on December 8. Sirko Molau's study of video radiants gives an activity period of December 6–19, with a maximum activity occurring on the sixth. Molau notes that data from the ascending branch are missing; therefore, we may assume the shower starts in late November.[5] Jenniskens has an activity period of November 27 through December 17 with maximum activity occurring on December 13.[6]

This shower is visible over most of Earth and is best placed on the meridian near 0100 LST. Only the south polar regions would miss this shower, due to constant sunlight/twilight this time of year. In late November the radiant lies in eastern Orion, just a few degrees east of the bright orange variable star Betelgeuse (Alpha Orionis). At maximum activity, regardless of which date you prefer, the radiant lies in extreme northern Monoceros. The radiant drift ends near the Monoceros–Canis Minor border. With an entry velocity of 26 miles/s, most Monocerotid meteors would be of average speed (Figs. 4.33 and 4.34).

Fig. 4.33. A bright Monocerotid appears in southern Orion.

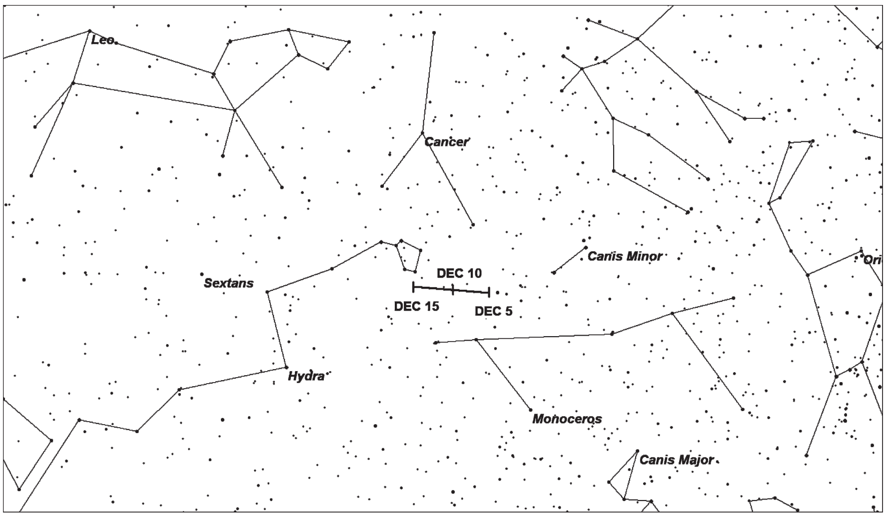

Fig. 4.34. Radiant drift of the sigma Hydrids.

4.16 σ Hydrids (HYD) #16

Activity period: 12/03–12/15
Date of maximum activity: 12/11
Radiant position at maximum: 127 (08:28) + 02
Radiant drift per night: RA +0.8° Dec −0.2°
Geocentric velocity: 36 miles/s (58 km/s)

This is a recently discovered shower found during radar studies during the 1960s. Data are fairly scarce due to the low rates. The shower parameters most often seen are an activity period of December 3–15, with maximum activity occurring on the

11th. Sirko Molau's video data show a wider activity period lasting from November 30 to December 24. He mentions that the shower may end a bit earlier, around December 18.[7] Jenniskens lists an activity period of December 3 through the 18, with a late maximum occurring on December 17.[8]

On December 5 the radiant lies near the Hydra–Canis Minor border. It travels 1°E per day and is located at 127 (08:28) + 02. This position lies 3°SW of the dim star sigma Hydrae. At the end of the activity period the radiant ends up located just below sigma Hydrae.

Being located virtually on the celestial equator, this shower is visible over the entire Earth except where 24-h daylight/twilight interferes. The radiant rises during the late evening hours and is best placed highest in the sky near 0300 LST. These meteors strike the atmosphere at speeds of 36 miles/s, which would produce mostly swift meteors (Figs. 4.35 and 4.36).

Fig. 4.35. A sigma Hydrid shoots into Crater the Cup.

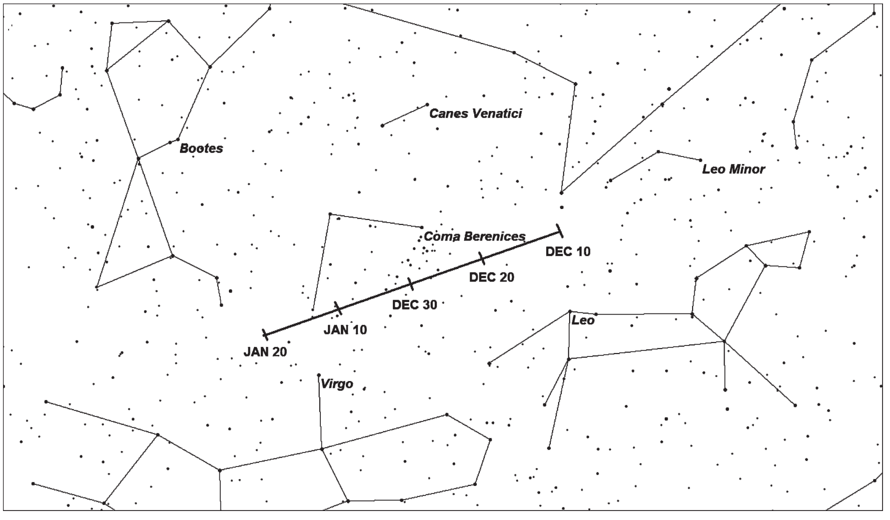

Fig. 4.36. Radiant drift of the Coma Berenicids.

4.17 Coma Berenicids (COM) #20

Activity period: 12/12–01/23
Date of maximum activity: 12/20
Radiant position at maximum: 177 (11:48) + 25
Radiant drift per night: RA +0.8° Dec −0.3°
Geocentric velocity: 40 miles/s (65 km/s)

The Coma Berenicids are a shower of long duration lasting from December 10 through January 20. The maximum is thought to occur near December 20, but both this and the activity period are not precise.

December and January in the northern hemisphere is a difficult time and place to gather data, especially over such a long period. The radiant first starts out in extreme northern Leo. At maximum activity it lies at 177 (11:48) + 25. This position resides in an empty area of northeastern Leo. The nearest bright star is Denebola (beta Leonis), which lies 10° to the south. The radiant soon crosses into the constellation of Coma Berenices, where it remains for most of the remainder of the activity period. It crosses the border into northern Virgo only a day before falling below a ZHR of 1 (Jan 19).

The Coma Berenicid radiant rises near midnight and is best seen during the last hour before dawn near 25°N latitude but well placed for the entire northern hemisphere. Extreme southern latitude observers with the short nights this time of year would have a difficult time viewing this activity.

Peak ZHR for the Coma Berenicids is 5, but during most of the activity period it only averages 1–2 per hour. This activity is noticed during the Geminids, when viewing during the last few hours before dawn. These meteors will be shooting out of eastern Leo, often toward the constellation of Gemini. With an entry velocity of 40 miles/s this shower produces mostly swift meteors, with the brighter member exhibiting persistent trains (Figs. 4.37 and 4.38).

Fig. 4.37. A Coma Berenicid darts by Alphard (alpha Hydrae).

Fig. 4.38. A Coma Berenicid appears in Crater.

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8. Jenniskens, Peter (2006) *Meteor Showers and their Parent Comets*. 738, Cambridge, New York

Chapter 5

Variable Showers

Abstract

There are some meteor showers whose strength varies considerably from 1 year to the next. They may provide strong activity one year and none the next. Eleven of these showers are presented along with radiant charts for easy locating. Parameters such as activity period, date of expected maximum activity, and geocentric velocity are listed. A discussion of possible future displays is offered along with photographs of actual shower members obtained by the author.

There are meteor showers that only appear during years when circumstances are favorable. Most of these circumstances involve Earth crossing one of the dust paths created by the parent object. The showers listed here have the potential of producing meteor storms or no activity at all. For most of them the annual activity is closer to nothing at all. In several instances activity has appeared only once, and we await a possible reoccurrence sometime in the future.

Most of these showers are thought to be produced by debris produced by long-period comets during their previous return to the inner Solar System. Only rarely have the parent objects been discovered. These are the showers that normally only produce activity when Earth lies close to the dust trail. The other showers are produced by the Jupiter family of comets. These are comets with short orbits that lie wholly within the inner solar system and are influenced by passages close to the giant planet Jupiter. All of the showers on this list associated with the Jupiter family of comets have had their sources identified.

An interesting fact about the following list is that a vast majority of the showers are best seen during the evening hours. This is a completely opposite situation when compared to the showers on the major annual shower list. It allows the meteor observer the opportunity to observe during the evening hours and possibly witness some activity other that the normal slow sporadic activity that usually occurs during this time of night.

Despite the normal low activity of these showers, some of them appear on the annual list of meteor showers in the hope that it will encourage observers to watch for them. The average returns of these showers are below the criteria set for minor showers, so identification would normally be difficult for the visual observer. When observing during the evening hours, though, the sporadic rates are much lower than that seen during the morning hours; therefore, the chance of sporadic pollution of a dataset is much less. An observer can be confident that a meteor is a true shower member as long as the angular velocity and the path length are within the range given for each shower.

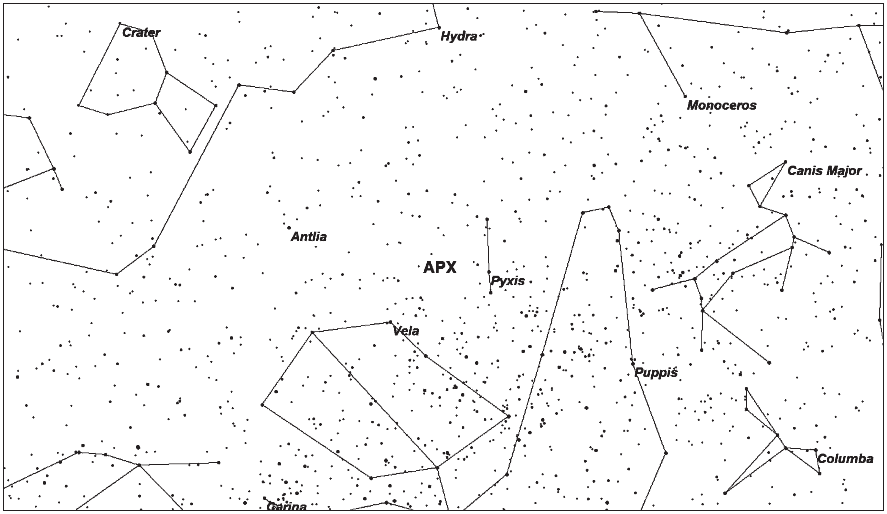

Fig. 5.1. Radiant position of the alpha Pyxidids.

The variable showers are presented in chronological order, with a brief history, current status, and future prospects. Also included are the observing parameters listed – where are the best locations and when are the best times to view any possible activity. Although numerous outbursts have occurred in the past, those included here are predicted to be active in the twenty-first century (Fig. 5.1).

5.1 α Pyxidids (APX) #122

Activity period: 03/06–03/06
Date of maximum activity: 03/06
Radiant position at maximum: 135 (09:00) − 35
Radiant drift per night: –
Geocentric velocity: 16 miles/s (26 km/s)

Veteran South African meteor observer Tim Cooper discovered this shower on the night of March 6, 1979. Visual rates only averaged 5 per hour, but in the normally slow March evening skies these meteors were obvious. A slightly weaker display was seen the following year. and not much else has been seen since. Studies of this display by Dr. Peter Jenniskens have led to possible future repeats of this shower in 2038 and 2039.[1] Of the two years 2039 appears to be more favorable, with the dust trail lying closer to Earth.

The radiant is located at 135 (09:00) − 35. This area of the sky is located in southern Pyxis, 4°E of the fourth-magnitude star alpha Pyxis. The radiant is visible everywhere south of 55°N latitude. It is best seen near 35°S latitude, where the radiant passes though the zenith near 2200 (10:00 p.m.) LST. This time of night would be the best time to view any possible activity, as this is when the radiant is located highest above the horizon, no matter your location. Shower members would possess a medium-slow speed (Fig. 5.2).

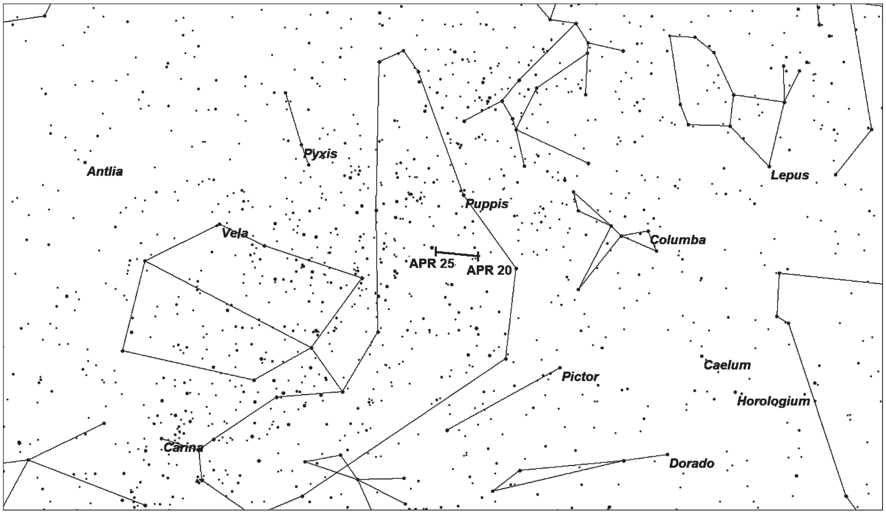

Fig. 5.2. Radiant drift of the pi Puppids.

5.2 π Puppids (PPU) #137

Activity period: 04/15–04/28
Date of maximum activity: 04/23
Radiant position at maximum: 110 (07:20) − 45
Radiant drift per night: RA +0.4° Dec −0.1°
Geocentric velocity: 11 miles/s (18 km/s)

The pi Puppids are produced by the debris of Jupiter family comet 26 P/Grigg-Skjellerup. Earth approaches the orbit of this comet each April 23 of each year. Normal activity at this time consists of only a few meteors per night. At times when Earth passes close to dust trails of comet 26 P/Grigg-Skjellerup, then enhanced activity can be observed. Unfortunately, during the first quarter of the twenty-first century, we will see very little activity from this shower. 2003 and 2006 produced the last encounters. But the display was not notable in either year. Not until 2029 does Earth begin to again approach the dust trails close enough to produce enhanced activity.[16] Further encounters in 2034 appear far more promising than those in 2029.

The pi Puppid radiant is active from only April 15 through 28. Maximum activity occurs on the 23rd, with the radiant located at 110 (07:20) – 45. This position lies in southwestern Puppis near the third-magnitude star sigma Puppis. Due to the low southern declination activity this shower cannot be seen north of 35°N latitude. The radiant may actually clear the horizon up to 45°N latitude, but at this time of year twilight will interfere will all attempts to view this shower north of 35°N latitude.

At 25°N latitude the radiant lies 17° high in the southwestern sky, at the end of nautical twilight, with the Sun's altitude at 12° below the horizon. At this altitude only 29% of the total pi Puppid activity can be seen. Circumstances improve

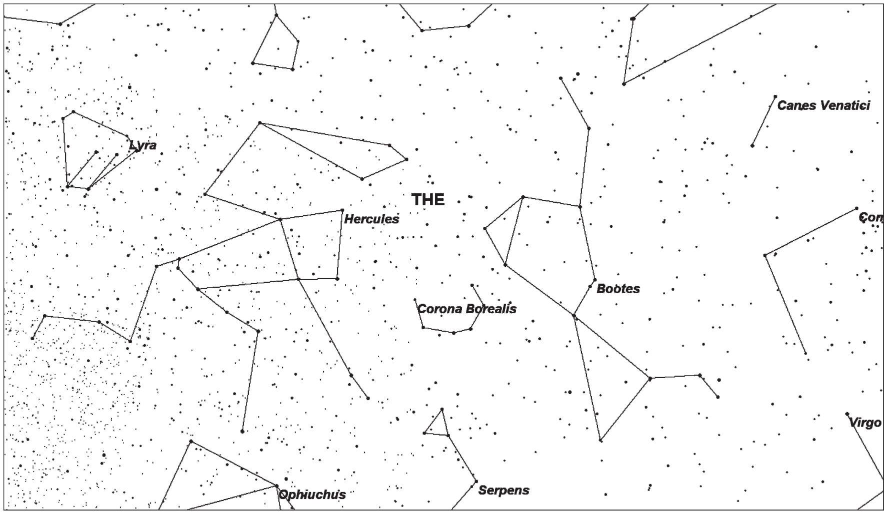

Fig. 5.3. Radiant position of the tau Herculids.

greatly as one moves southward. As seen from 25°S latitude the radiant is situated 67° high, with the Sun lying 12° below the horizon. These circumstances allow the observer to see 92% of the total pi Puppis activity. That is quite an improvement compared to 25° north latitude!

This radiant is best seen as soon as it becomes dark during the evening hours. The setting of the radiant ranges from 2130 LST at 25°N latitude to 0100 LST at 25°S latitude. Below 45°S latitude the radiant is circumpolar and remains in the sky 24 h. With an entry velocity of 11 miles/s, these meteors would appear to travel slowly (Fig. 5.3).

5.3 Tau Herculids (THE) #61

Activity period: 05/19–06/14
Date of maximum activity: 06/02
Radiant position at maximum: 236 (15:44) + 41
Radiant drift per night: RA −0.1° Dec +0.9°
Geocentric velocity: 9 miles/s (15 km/s)

The tau Herculids are a rarely seen shower these days. These meteors are produced by the debris of comet 73 P/Schwassmann-Wachmann 3. This comet endured a tremendous breakup in 1995, and these fragments had a close encounter with Earth in May 2006. Many observers were able to record low activity from the Tau Herculids that month and into early June. This author was fortunate enough to record a few tau Herculids on video during this time.

A more favorable encounter is predicted for June 2, 2011, near 05:45 Universal Time. This timing favors all of North America plus the Moon is new at this time, creating favorable circumstances. High rates are not expected, but this shower should dominate the otherwise slow June evening. Other encounters are predicted for the following dates: May 31, 2017; May 29–31, 2022; May 6, 2033; April 29–May 8, 2049; April 30–May 9, 2065; June 25, 2086; and July 18–20, 2098. The multinight return of 2022 appears especially favorable, as high rates are expected from a close approach to the 1995 debris. The return of 2049 also appears to offer good rates.[2]

The tau Herculid radiant has not been precisely located. Old lists that included this shower as an annual occurrence listed the radiant at 228 (15:12) + 39. This position actually lies well with the boundaries of Bootes. More recent lists give scattered data, with a position near 236 (15:44) + 41. This position lies where the boundaries of Bootes, Corona Borealis, and Hercules meet. The nearest easily seen star is mu Bootis, which lies in northern Bootes. The radiant lies high in the east as soon as it becomes dark. It reaches its maximum altitude near 2300 (11:00 p.m.) LST. Observers near 40°N latitude will see the radiant near the zenith at this time. Those situated north of 55°N latitude will find night-long twilight to be a problem in trying to view this shower. Down south activity can be seen anywhere north of 50°S latitude. The radiant will fail to rise if you venture any further south than that (Figs. 5.4–5.6).

Fig. 5.4. A rare tau Herculid heads for Serpens Cauda.

Fig. 5.5. Another rare tau Herculid appears in Scutum.

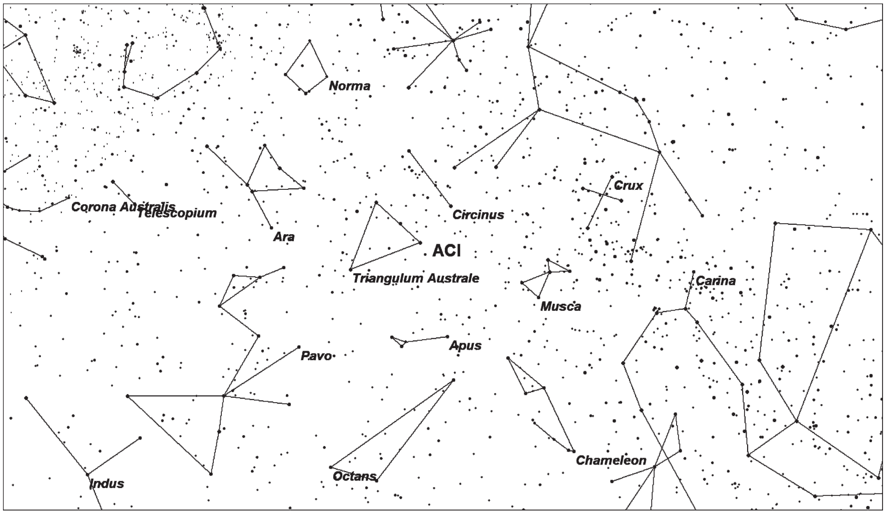

Fig. 5.6. Radiant position of the alpha Circinids.

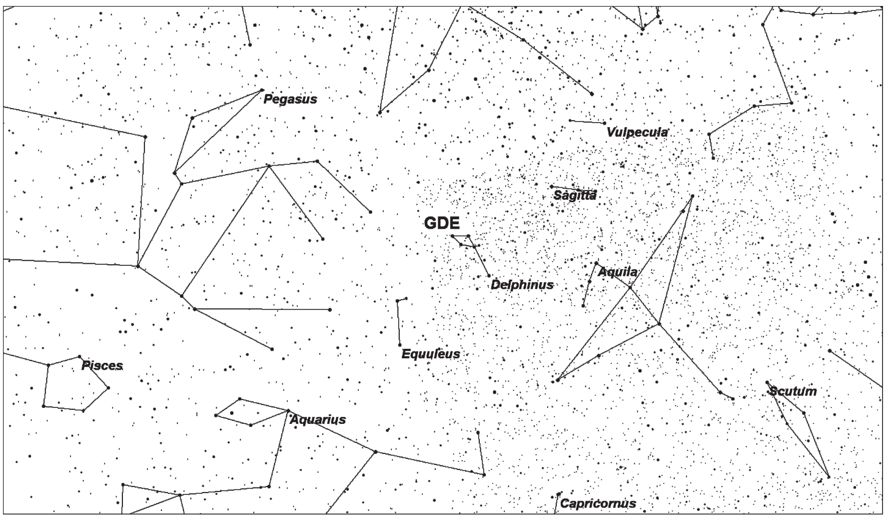

Fig. 5.7. Radiant position of the gamma Delphinids.

5.4 α Circinids (ACI) #162

Activity period: 06/04–06/04
Date of maximum activity: 06/04
Radiant position at maximum: 218 (14:32) − 70
Radiant drift per night: none
Geocentric velocity: 17 miles/s (27 km/s)

Evidence for the alpha Circinids comes from a single observation made from Queensland, Australia, back in 1977. Even with this scant evidence studies by

Dr. Peter Jenniskens have shown that future displays of this shower are possible in 2011 and 2033.[3]

The radiant for the alpha Circinids is located at 218 (14:32) – 70. This area of the sky is located in southern Circinus. The nearest bright star is zero-magnitude Rigel Kentaurus (Alpha Centauri), 10° to the north. Due to the far southern declination of this radiant these meteors cannot be seen north of 20°N latitude. Far southern observers are favored for this shower, as the radiant passes high in the southern sky, reaching maximum altitude near 2200 (10:00 p.m.) LST. South of 20°S latitude this radiant is circumpolar and in the sky 24 h a day. The radiant lies highest in the sky near 2200 (10:00 p.m.) LST on early June evenings (Fig. 5.7).

5.5 γ Delphinids (GDE) #65

Activity period: 06/01–06/20
Date of maximum activity: 06/11
Radiant position at maximum: 312 (20:48) + 17
Radiant drift per night: RA +0.8° Dec +0.2°
Geocentric velocity: 35 miles/s (57 km/s)

The gamma Delphinids are known for a single outburst that occurred in 1930. Despite the lack of activity since then Dr. Peter Jenniskens is predicting that this shower may reappear on June 11 in the years 2013 and 2027.[4] ZHRs during the 1930 outburst were well in excess of 100, but those in future years are totally uncertain. Any activity from this radiant would be noteworthy.

The gamma Delphinid radiant is located at 312 (20:48) + 17. This area of the sky is located in northeastern Delphinus near the well-known double star gamma Delphini. Delphinus is above the horizon most of the night and is most easily located highest in the sky between 0300 and 0400 LST. Observers located in the northern tropics are best situated to view this activity as the radiant passes overhead during the time mentioned earlier. This is one of the rare variable showers that produce swift meteors (Fig. 5.8).

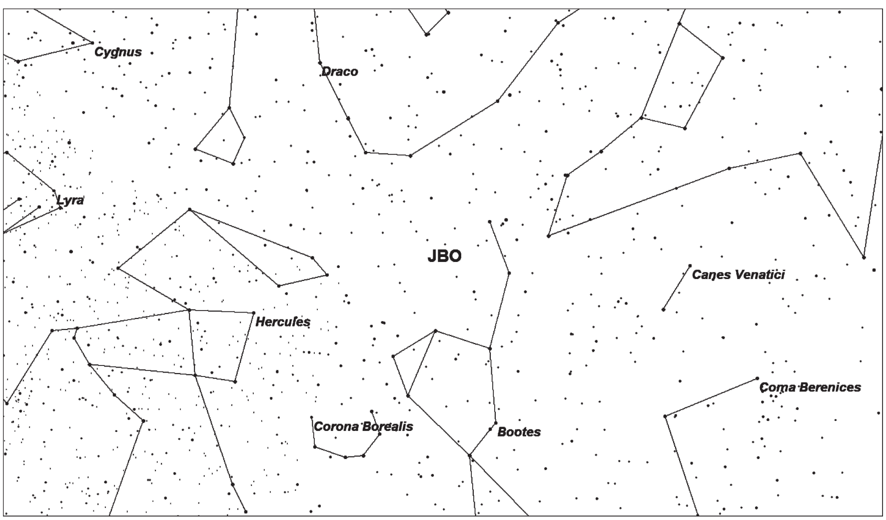

Fig. 5.8. Radiant position of the June Bootids.

5.6 June Bootids (JBO) #170

Activity period: 06/22–07/02
Date of maximum activity: 06/27
Radiant position at maximum: 224 (14:56) + 48
Radiant drift per night: RA +0.6° Dec −0.4°
Geocentric velocity: 11 miles/s (18 km/s)

A few June Bootids usually appear each night during late June and early July. These meteors are debris from Comet 7 P/Pons-Winnecke. This shower had been silent for nearly 75 years when suddenly on June 27, 1998, the skies were filled with these meteors. On that night Earth encountered an unknown swarm of debris left behind by the comet during the first half of the nineteenth century. Rates peaked with a ZHR exceeding 500. For the next 5 years the shower was quiet with only a few meteors per night at maximum. In 2004, a very modest outburst again occurred when ZHRs approached 20.[5] Similar weak returns are also predicted for the years 2010 and 2028.

At maximum activity the June Bootid radiant lies at 224 (14:56) + 48. This position lies in northern Bootes some 15°E of the second-magnitude star Alkaid (eta Ursae Majoris). The radiant is best placed near the time evening twilight ends. The most favorable latitude to view this shower is 48°N latitude, where the radiant lies near the zenith at dusk. Further north the sky remains light later into the evening until you reach 55°N latitude, where the sky does not darken sufficiently to allow observing. Nights are longer in the southern hemisphere, but the radiant altitude begins to suffer significantly as you pass south of the equator. June Bootid activity may be seen down to 42°S latitude. Any further south and the radiant does not clear the horizon at all.

The June Bootids meteors strike Earth from the trailing side; therefore, they are catching up to Earth and are among the slowest meteors. The entry velocity is only 11 miles/s compared to 43 miles/s for Leonid meteors (Fig. 5.9).

Fig. 5.9. A June Bootid darts into Aquila the Eagle.

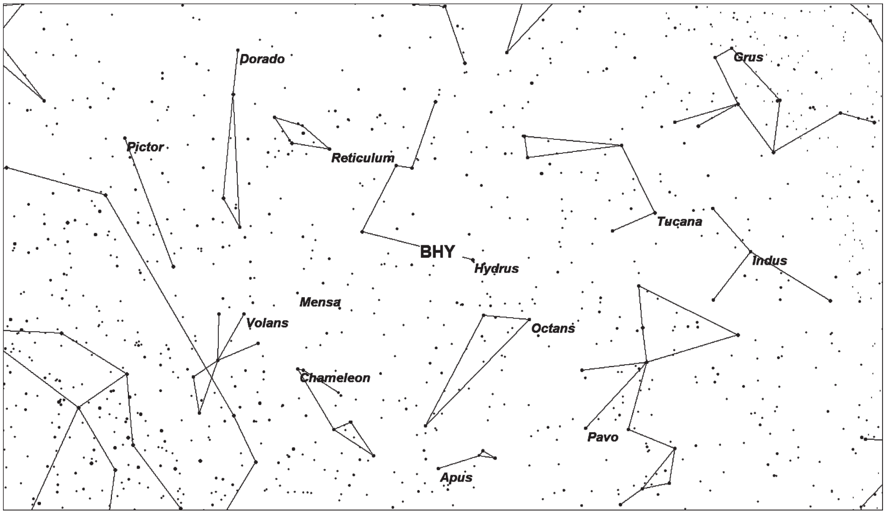

Fig. 5.10. Radiant position of the beta Hydrusids.

5.7 β Hydrusids (BHY) #198

Activity period: 08/17–08/17
Date of maximum activity: 08/17
Radiant position at maximum: 023 (01:32) − 76
Radiant drift per night: –
Geocentric velocity: 16 miles/s (25 km/s)

The beta Hydrusids have been seen only once (Fig. 5.10). On August 16, 1985, a group of observers in western Australia witnessed a short but strong display of bright, slow meteors from an area located just south of the Small Magellanic Cloud. At the peak, ZHRs were estimated in excess of 100. Studies of this outburst by Dr. Peter Jenniskens have led him to believe that possible occurrences of this display may again repeat in 2020.[6]

The radiant for this display was estimated at 023 (01:32) – 76. This area of the sky is located in southern Hydrus, 4°S of the Small Magellanic Cloud. The nearest bright star is third-magnitude beta Hydri, located 15° to the west.

Due to the extreme southern declination the radiant is not visible north of 14°N latitude. This basically limits the area of visibility of this shower to the equatorial regions and the entire southern hemisphere. The further south one is located, the more favorable the radiant altitude will be. As seen from 25°S latitude, this area of the sky is located low in the south at dusk and spends the night rising higher into the southern sky. It is best placed just before dawn, when it lies high in the south (Fig. 5.11).

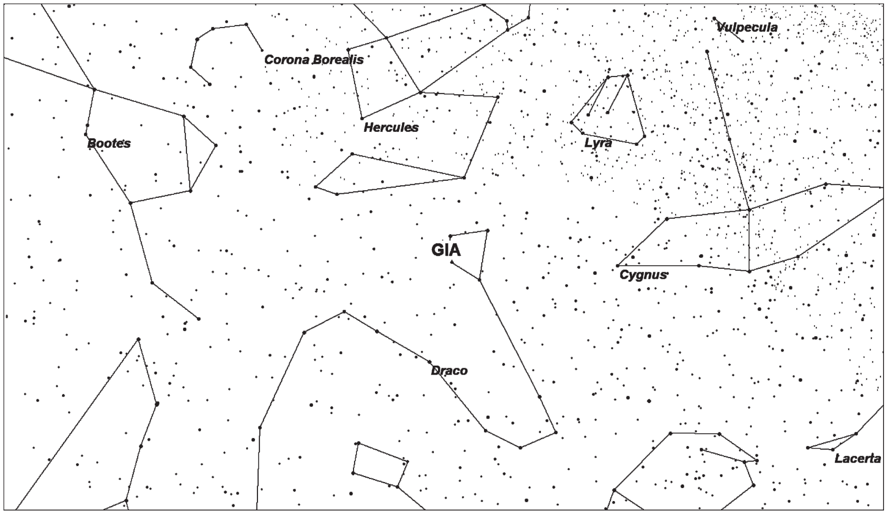

Fig. 5.11. Radiant position of the Draconids.

5.8 Draconids or Giacobinids (GIA) #9

Activity period: 10/06–10/10
Date of maximum activity: 10/08
Radiant position at maximum: 262 (17:28) + 54
Radiant drift per night: RA +0.4° Dec 0.0°
Geocentric velocity: 12 miles/s (20 km/s)

The Draconids provided two of the more memorable meteor storms of the twentieth century. Each October Earth approaches the orbit of 21 P/Giacobini-Zinner. On the evening of October 8 usually one or two of these meteors can be seen among the random meteors that normally grace the sky. In certain years Earth closely approaches one of the dust trails left behind by 21 P/Giacobini-Zinner, and more activity can be seen.

The storms that occurred in the last century were produced by extremely close encounters to these dust trails. Unfortunately no such close encounters are predicted for the near future. There should, though, be enhanced activity in the years 2011, 2012, 2020, 2024, 2025, 2030, 2035, 2037, 2042, and 2044. Of these encounters the one in 2011 appears to be the most favorable, especially for the eastern hemisphere. Rates are still forecast to be modest that year, with ZHRs near 20.[7]

This shower is only active for four nights centered around October 8. At that time the radiant is located at 262 (17:28) + 54. This area of the sky is located in southern Draco, in the west side of the asterism know as the Lozenge, or the head of the dragon. The high northern latitudes are best suited to view this shower as the radiant lies very high in the sky as soon as it becomes dark during the evening hours.

Radiant altitude is reduced as one proceeds southward. It becomes a serious issue south of the equator. At the equator the Draconid radiant lies near 30° in altitude at dusk. Further south, at 25°S latitude, the radiant lies less than 5° in altitude at dusk. Observations of this shower from locations further south would be nearly impossible.

Like all evening showers the Draconids produce slow meteors, with the entry velocity being 12 miles/s. These meteors are usually faint, and observations from urban areas or in the presence of moonlight would be difficult (Figs. 5.12 and 5.13).

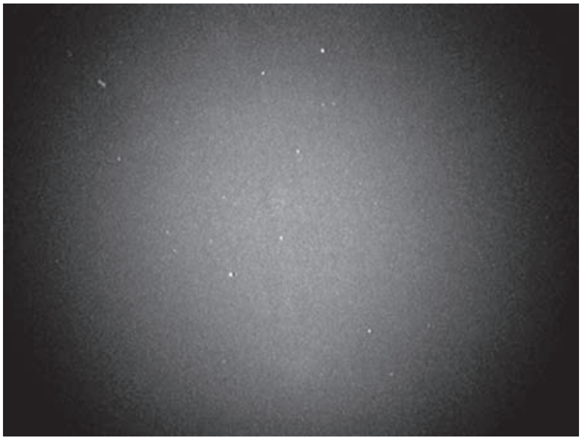

Fig. 5.12. A short Draconid appears in Vulpecula.

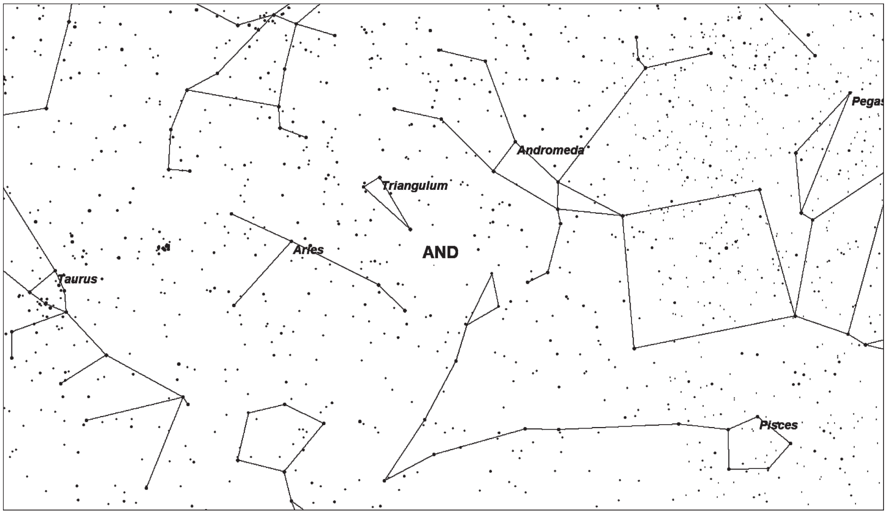

Fig. 5.13. Radiant position of the Andromedids.

5.9 Andromedids (AND) #18

Activity period: 11/08–11/15
Date of maximum activity: 11/09
Radiant position at maximum: 025 (01:40) + 27
Radiant drift per night: RA +0.2° Dec +1.0°
Geocentric velocity: 12 miles/s (20 km/s)

The Andromedids are best known for two meteor storms produced during the nineteenth century. Since then rates have basically amounted to a trickle each year. The main orbit of comet 3 D/Biela no longer intersects Earth, so all we witness each year is the few bits of debris that populate the outer regions of the comet's orbit. Unfortunately it appears that no storms will reappear in the near future. The two nineteenth-century meteor storms radiated from northern Andromeda near the star Almach (Gamma Andromedae). Today, meteors associated with 3 D/Biela have a radiant in northern Pisces, some 15°S of the original radiant. The nearest bright star to the current radiant is Hamal (Alpha Arietis), which is located 6° to the southeast.

The nineteenth-century meteor storms occurred in late November. Today the maximum occurs earlier, on November 9. On November evenings the radiant lies low in the north at dusk. It reaches its maximum altitude between 2200 and 2300 (10:00 and 11:00 p.m.) LST. This activity is best seen from the lower northern latitudes where the radiant passes overhead. Further north sees the radiant sink toward the south, but the nights are longer, which is a slight advantage. Further south the radiant sinks toward the northern horizon, and the nights become shorter, a distinct disadvantage. At 12 miles/s these meteors would appear to move slowly (Fig. 5.14).

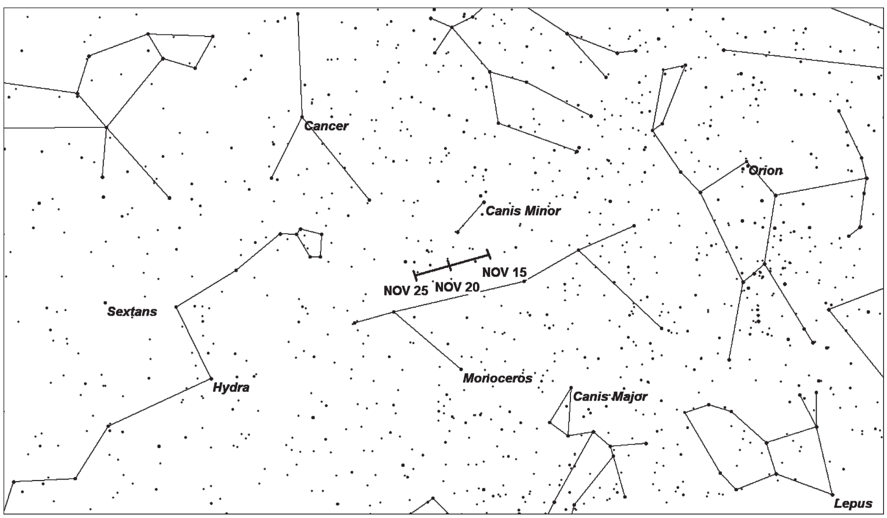

Fig. 5.14. Radiant drift of the alpha Monocerotids.

5.10 α Monocerotids (AMO) #246

Activity period: 11/15–11/25
Date of maximum activity: 11/21
Radiant position at maximum: 117 (07:48) + 01
Radiant drift per night: RA +0.8° Dec −0.2°
Geocentric velocity: 40 miles/s (65 km/s)

Shortly after the Leonids reach maximum activity in November observers concentrate on a short-lived display called the alpha Monocerotids that peaks on November 21 or 22. This shower is known for producing short but strong outbursts that had been seen four times in the last century. Interestingly enough, the years of these outbursts all ended in "5." The first three outbursts were totally unexpected and observed by accident. It was thought that other outbursts of this shower had been missed due to the short duration (30 min) of the main shower.

Thanks to meteor journal articles, the Internet, and e-mail, the 1995 event was well publicized and ultimately well observed and recorded. As knowledge of dust trails increased during the late 1990s it was found that the 10-year period for the alpha Monocerotids was just a coincidence and that no outburst would again occur in 2005. Unfortunately this forecast was true, and these outbursts proved to be rarer than once thought. The next possible outburst of the alpha Monocerotids is predicted to occur near 10:58 Universal Time on November 22, 2043.[8]

The first signs of this shower appear near November 15, when one or two shower members appear each night. These low rates remain steady right up to the time of maximum activity. During a normal year, when no outburst is expected, they may increase to 1 or 2 per hour near maximum but certainly no more. In fact, Sirko Molau's study of activity obtained by video methods fails to distinguish this shower at all.[9] The low rates seen prior to maximum continue after maximum until November 25. After that the shower falls below the level of detection by observers.

Early publications placed the alpha Monocerotid radiant in central Monoceros. After the well-documented outburst of 1995, the radiant was repositioned to the Monoceros–Canis Minor border, 5°SE of the brilliant star Procyon (alpha Canis

Fig. 5.15. A long alpha Monocerotid darts through Aries.

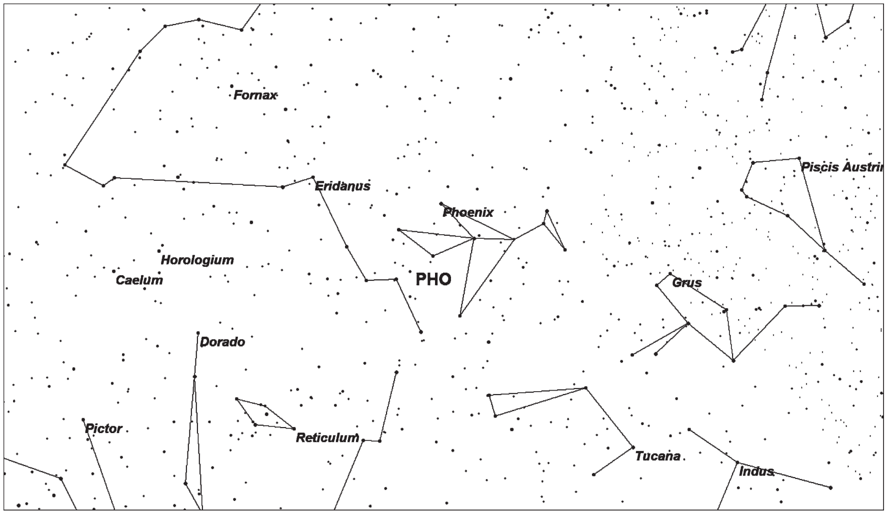

Fig. 5.16. Radiant position of the Phoenicids.

Minoris). This area of the sky rises between 2100 and 2200 LST no matter your location. The radiant is best placed between 0300 and 0400 LST, when it lies highest in the sky. Activity from the alpha Monocerotids is visible everywhere except the far southern latitudes, where daylight and twilight persists for 24 h a day.

Alpha Monocerotid meteors strike Earth at 40 miles/s, which normally produces fast meteors. This is one of the few variable-strength showers that produce swift meteors (Fig. 5.15 and 5.16).

5.11 Phoenicids (PHO) #254

Activity period: 11/28–12/09
Date of maximum activity: 12/06
Radiant position at maximum: 018 (01:12) − 53
Radiant drift per night: RA +0.6° Dec −0.2°
Geocentric velocity: 11 miles/s (18 km/s)

Phoenicid meteors are rarely seen and are most noted for past outbursts during the nineteenth and twentieth centuries. In fact, shower members have been so scarce that some groups have considered dropping this shower from their annual lists. Unfortunately no outbursts are predicted in the near future for the Phoenicids.[10]

The Phoenicid activity period spans November 28 through December 9. If we take the timing of the last outburst in 1956, then maximum activity today would fall on December 6.

The Phoenicid radiant lies in southeastern Phoenix, in an area some 7°N of the first-magnitude star Achernar (alpha Eridani). Due to the far southern declination this area of the sky is invisible north of 37°N latitude. For those in the low northern latitudes the radiant rises shortly after dusk and lies highest in the sky near 2000 (8:00 p.m.) LST. Further south the radiant has already risen by the time it becomes dark. Although the radiant passes through the zenith as seen from 53°S latitude, unfortunately the Sun is still above the horizon at 2000 LST as seen from the far southern latitudes. Conditions are more favorable near 25°S latitude where evening twilight has ended at 2000 LST, yet the radiant still lies near 60° altitude in the southern sky.

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Chapter 6

Daytime Showers

Abstract

Most people do not realize that there are active radiants situated in the vicinity of the Sun. These meteors cannot be seen at night, but through radio observations their activity can be followed throughout the day. This chapter lists twelve such showers with activity periods, date of maximum activity, radiant position at maximum activity, radiant drift per day, and geocentric velocity. A few of these radiants are situated far enough from the Sun so that there is a small chance of viewing before dawn. In these cases, viewing circumstances are discussed.

During the course of the year there are active radiants located in the same portion of the sky as the Sun. These radiants are normally referred to as daytime showers. Only in a few instances are any of the showers visible just before dusk or dawn. Even then only a minute fraction of the total activity is seen.

These showers are best monitored by radio or radar methods that can operate both day and night. Two of the stronger showers of the year occur simultaneously in broad daylight. The daytime Arietids peak on June 7, with an equivalent ZHR of 60, and the zeta Perseids peak on June 9 with an equivalent ZHR of 40. The period June 7–9 is certainly the highlight of the year for radio observers!

There are many suspected daytime showers. The showers listed below are all well known and recur on an annual basis. These are also the best available targets for radio observers. The daytime showers are discussed in chronological order, with the available data listed under each shower.

Unlike the annual showers, both major and minor, the daytime showers cluster during the first half of the year. Some of the activity during this period may be explained by the fact that a few of these showers are the twins of nighttime showers visible during the second half of the year. The inbound particles are visible at night late in the year, while the outbound particles have a radiant close to the Sun and are active approximately 6 months earlier.

A majority of the information for these daytime showers was obtained from the International Meteor Organization's Meteor Shower Calendar.[1]

6.1 Capricornids/Sagittariids (DCS) #115

Activity period: 01/15–02/04
Date of maximum activity: 02/02
Radiant position at maximum: 299 (19:56) − 15

Radiant drift per day: RA +0.9° Dec +0.2°
Geocentric velocity: 18 miles/s (29 km/s)

The Capricornids/Sagittariid radiant is located 18°NW of the Sun in northern Sagittarius. This daytime radiant culminates near 1100 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 1100 and 1400 (11:00 a.m.–2:00 p.m.) LST and from 25°S latitude between the hours of 0900 and 1400 (9:00 a.m.–2:00 p.m.) LST. Expected radio rates are of medium intensity.

6.2 χ Capricornids (DXC) #114

Activity period: 01/29–02/28
Date of maximum activity: 02/14
Radiant position at maximum: 315 (21:00) − 24
Radiant drift per day: RA +0.9° Dec +0.2°
Geocentric velocity: 11 miles/s (18 km/s)

The chi Capricornid radiant is located 17°SW of the Sun in southern Capricornus. This daytime radiant culminates near 1100 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 1000 and 1300 (10:00 a.m.–1:00 p.m.) LST and from 25°S latitude between the hours of 0800 and 1500 (8:00 a.m.–3:00 p.m.) LST. This shower is also a member of the helion group of radiants. Expected radio rates are low.

6.3 April Piscids (APS) #144

Activity period: 04/08–04/29
Date of maximum activity: 04/20
Radiant position at maximum: 007 (00:28) + 07
Radiant drift per day: RA +0.8° Dec +0.3°
Geocentric velocity: 17 miles/s (27 km/s)

The April Piscid radiant is located 23°SW of the Sun in central Pisces. This daytime radiant culminates near 1000 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0700 and 1400 (7:00 a.m.–2:00 p.m.) LST and from 25°S latitude between the hours of 0800 and 1300 (8:00 a.m.–1:00 p.m.) LST. Expected radio rates are low.

6.4 δ Piscids

Activity period: 04/24–04/24
Date of maximum activity: 04/24
Radiant position at maximum: 011 (00:44) + 12
Geocentric velocity: unknown

The delta Piscid radiant is located 21°W of the Sun in central Pisces. This daytime radiant culminates near 1000 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0700 and 1400 (7:00 a.m.–2:00 p.m.) LST and from 25°S latitude between the hours of 0800 and 1300 (8:00 a.m.–1:00 p.m.) LST. Expected radio rates are low.

6.5 ε Arietids (DEA) #154

Activity period: 04/24–05/27
Date of maximum activity: 05/09
Radiant position at maximum: 044 (02:56) + 21
Radiant drift per day: RA +0.8° Dec +0.2°
Geocentric velocity: 13 miles/s (21 km/s)

The epsilon Arietid radiant is located only 5°NW of the sun in central Aries. This daytime radiant culminates near noon LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0800 and 1500 (8:00 a.m.–3:00 p.m.) LST and from 25°S latitude between the hours of 1000 and 1400 (10:00 a.m.–2:00 p.m.) LST. Expected radio rates are low.

6.6 May Arietids (DMA) #294

Activity period: 05/04–06/06
Date of maximum activity: 05/16
Radiant position at maximum: 037 (02:28) + 17
Radiant drift per day: RA +0.8° Dec +0.2°
Geocentric velocity: 16 miles/s (25 km/s)

The May Arietid radiant is located 18°W of the Sun in central Aries. This daytime radiant culminates near 1100 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0800 and 1500 (8:00 a.m.–3:00 p.m.) LST and from 25°S latitude between the hours of 0900 and 1300 (9:00 a.m.–1:00 p.m.) LST. Expected radio rates are low.

6.7 o Cetids

Activity period: 05/05–06/02
Date of maximum activity: 05/20
Radiant position at maximum: 028 (01:52) − 04
Geocentric velocity: unknown

The omicron Cetid radiant is located nearly 40°SW of the Sun in extreme southeastern Pisces. This daytime radiant culminates near 1000 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0700 and 1300 (7:00 a.m.–1:00 p.m.) LST and from 25°S latitude between the hours of 0700 and 1300 (7:00 a.m.–1:00 p.m.) LST. It is too bad the expected rates are low, since there would be an opportunity to view some of this activity from the southern hemisphere.

6.8 Arietids (DAR) #171

Activity period: 05/22–07/02
Date of maximum activity: 06/07
Radiant position at maximum: 044 (02:56) + 24
Radiant drift per day: RA +0.7° Dec +0.6°
Geocentric velocity: 22 miles/s (37 km/s)

The Arietid radiant is located 32°W of the Sun in northeastern Aries. This daytime radiant culminates near 1000 LST regardless of your location. This shower is best observed by radio from 50°N latitude between the hours of 0600 and 1400 (6:00 a.m.–2:00 p.m.) LST and from 25°S latitude between the hours of 0800 and 1200 (8:00 a.m.–12:00 p.m.) LST. Expected radio rates are high.

This is one of the few daytime showers that can be observed directly. Just before dawn near maximum activity a few members of the Arietids may be seen shooting upward from the northeastern horizon. These meteors would appear as Earthgrazers, meteors with long durations. As seen from 25°N latitude the Arietid radiant lies 15° above the northeastern horizon at dawn. At this altitude 26% of the total Arietid activity can be seen.

Observing conditions worsen as you move northward. At 50°N latitude the radiant stands only 3° above the horizon at dawn. At this altitude only 5% to the total Arietid activity can be seen. Observing conditions improve slightly seen from the equator. On the equator the radiant stands 18° above the horizon at dawn. At this altitude 31% to the total Arietid activity can be seen. By proceeding further into the southern hemisphere the observing conditions begin to deteriorate again. At 25°S latitude the radiant falls back to 15° above the northeastern horizon.

This shower is also a member of the helion group of radiants.

6.9 ζ Perseids (ZPE) #172

Activity period: 05/20–07/05
Date of maximum activity: 06/09
Radiant position at maximum: 062 (04:08) + 23
Radiant drift per day: RA +1.1° Dec +0.4°
Geocentric velocity: 17 miles/s (27 km/s)

The zeta Perseid radiant is located 17°W of the Sun in western Taurus. This daytime radiant culminates near 1100 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0700 and 1500 (7:00 a.m.–3:00 p.m.) LST and from 25°S latitude between the hours of 0900 and 1300 (9:00 a.m.–1:00 p.m.) LST. Expected radio rates are high.

This strong radiant does clear the horizon shortly before dawn from most locations. Unfortunately, with the equally active Arietids nearby it would be impossible to distinguish between the two radiants. This is part of the Taurid complex produced by comet 1P/Encke, the outbound particles in the same orbit that produces the Southern Taurids in October and November.

6.10 β Taurids (BTA) #173

Activity period: 06/05–07/17
Date of maximum activity: 06/28
Radiant position at maximum: 086 (05:44) + 19
Radiant drift per day: RA +0.8° Dec +0.4°
Geocentric velocity: 19 miles/s (30 km/s)

The beta Taurid radiant is located only 8°W of the Sun in eastern Taurus. This daytime radiant culminates near 1100 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0800 and 1500 (8:00 a.m.–3:00 p.m.) LST and from 25°S latitude between the hours of 0900 and 1300 (9:00 a.m.–1:00 p.m.) LST. Expected radio rates are of medium activity.

The beta Taurids are the third strongest daytime shower but unfortunately located much too close to the Sun for any possibility of visual observations. This is also part of the Taurid complex produced by comet 1P/Encke. These are the outbound particles in the same orbit that produces the northern Taurids in October and November.

6.11 γ Leonids (GLE) #203

Activity period: 08/14–09/12
Date of maximum activity: 08/25
Radiant position at maximum: 155 (10:20) + 20
Radiant drift per day: RA +0.8° Dec −0.3°
Geocentric velocity: 14 miles/s (22 km/s)

The gamma Leonid radiant is located 10°N of the Sun in western Leo. This daytime radiant culminates near noon LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0800 and 1600 (8:00 a.m.–4:00 p.m.) LST and from 25°S latitude between the hours of 1000 and 1400 (10:00 a.m.–2:00 p.m.) LST. Expected radio rates are low.

6.12 Sextantids (DSX) #221

Activity period: 09/09–10/09
Date of maximum activity: 09/27
Radiant position at maximum: 152 (10:08) 00
Radiant drift per day: RA +0.8° Dec −0.3°
Geocentric velocity: 14 miles/s (22 km/s)

The Sextantid radiant is located 33°W of the Sun in central Sextans. This daytime radiant stands between 15° and 20° in altitude at the start of morning twilight. This distance is far enough from the Sun that some activity from this radiant could be seen if caught near maximum activity. Jenniskens lists a ZHR for this shower as 20.[2] The radiant culminates near 1000 LST regardless of your location. This shower is best observed from 50°N latitude between the hours of 0600 and 1200 (6:00 a.m.–12:00 p.m.) LST and from 25°S latitude between the hours of 0600 and 1300 (6:00 a.m.–1:00 p.m.) LST. Expected radio rates are of medium intensity.

References

1. McBeath, Alastair (2006) 2008 IMO Meteor Shower Calendar, 28
2. Jenniskens, Peter (2006) *Meteor Showers and Their Parent Comets*. 727, Cambridge, New York

Chapter 7

New Showers?

Abstract

In analyzing the video database of the IMO, Sirko Molau has discovered 19 new showers that do not currently appear on the IMO's list. These showers are not "one-shot wonders," but rather they have reappeared for at least four consecutive years to make this list. These new showers should be recognized by observers out in the field. Due to their low rates they have not been recognized from the sporadic activity. The author encourages observers to use the information provided in order to verify activity from these sources.

Often when out under the stars observers will notice activity in a constellation or a particular part of the sky. Most of the times these are simply chance alignments of sporadic meteors. Short outbursts do occur, but they are usually one-time events never to be repeated.

Video techniques have taken a lot of the guesswork out of comparing activity year after year. Before the advent of video technology in meteor observing the observer would plot meteors and then check the results for intersections after the watch. When suspected radiants were found the activity had to be checked on the same date the following year to see if the activity repeated itself. Needless to say for a single observer this was a daunting challenge. The Moon will spoil a single calendar date every third year plus the chance of cloudy skies is ever present.

When a large database consisting of many observers and thousands of meteors is available one can study the annual activity in detail to verify if showers repeat year after year. Sirko Molau in Germany has accumulated such a database of video data. This database has more than 10 years' worth of unbiased data that have been reduced and analyzed using the same software. Sirko had at his disposal over 188,000 meteors obtained from the period 1993 through 2006. From the analysis of these meteors, 54 total showers were found to repeat themselves for at least four consecutive years.

Along with the well-known annual meteor showers and sporadic sources, 19 possible new showers were identified. These new showers all possess low rates but would be visible to visual observers as the unaided eye is more sensitive to fainter meteors than most video camera systems. The eye also has an advantage in that it possesses a much wider field of view compared to camera lenses designed for meteor work. Of course, the camera has the advantage in that it never experiences fatigue or gets cold being outside during winter nights. Video cameras also record data on nights when the Moon shines brightly, a time when the visual observer rarely makes the effort to observe. Unfortunately, all of the data were recorded

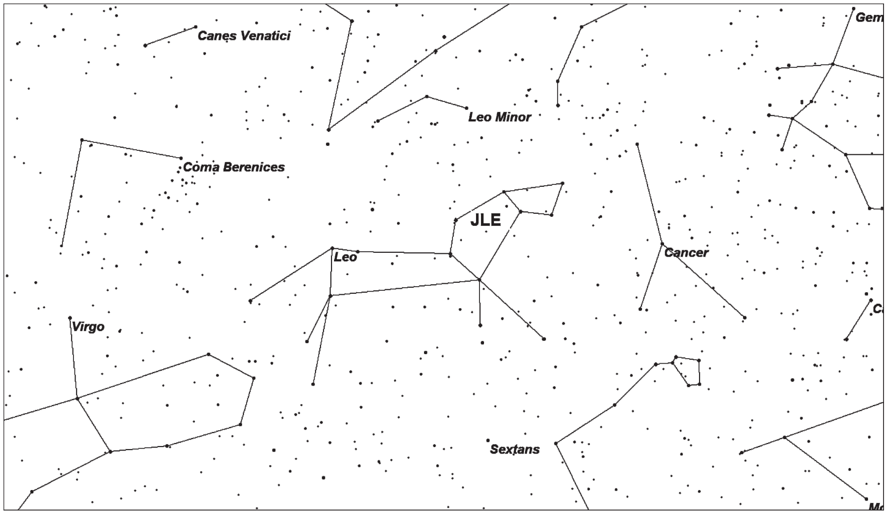

Fig. 7.1. Radiant position of the January Leonids.

from Europe, where the view of southern activity is hampered. Therefore, there is an under-representation of southern radiants, which hampers our complete knowledge of annual meteor activity.

Following is the list of new showers in order of their occurrence throughout the year. Information on these showers was obtained from Sirko Molau's analysis of the IMO's video meteor database.[1] Some of these new showers are identified in the International Astronomical Union's (IAU) list of radiants. The corresponding IAU's numbers were obtained from their website (Fig. 7.1).[2] Please note that as more data is collected the parameters of these showers are updated. It may be possible that some of the data presented may become quickly outdated. It is advised that you seek the latest information on these showers when making preparations to observe them.

7.1 January Leonids (JLE) #319

Activity period: 01/01–01/06
Date of maximum activity: 01/03
Radiant position at maximum: 146 (09:00) + 25
Radiant drift per night: RA +1.2° Dec –0.5°
Geocentric velocity: 34 miles/s (55 km/s)

The January Leonid radiant lies within the "sickle" of Leo, very close to the same position occupied by the November Leonids. In early January the January Leonid radiant rises near 2000 (8:00 p.m.) LST. The radiant reaches its highest altitude above the horizon near 0300 LST. This would be the best time to try and verify any activity from this radiant.

There are two slightly more active radiants located nearby, the Antihelion radiant to the west in Cancer and the Coma Berenicids to the northeast in northeastern Leo. The weak alpha Hydrid radiant also lies to the southwest. Besides these three

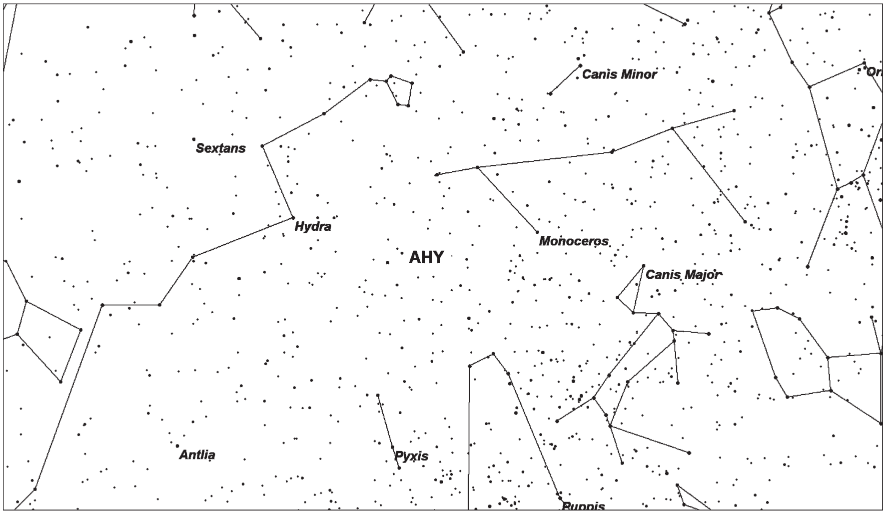

Fig. 7.2. Radiant position of the alpha Hydrids.

radiants the much stronger Quadrantid radiant is active during the morning hours. With an entry velocity of 34 miles/s most members of the January Leonids would appear to move swiftly, with very similar characteristics to the Coma Berenicids. The lower northern latitudes are most favored to view this activity. There were 118 members of this shower found in the video radiant study (Fig. 7.2).

7.2 α Hydrids (AHY) #331

Activity period: 12/31–01/11
Date of maximum activity: 01/07
Radiant position at maximum: 129 (08:36) − 09
Radiant drift per night: RA +0.6° Dec −0.1°
Geocentric velocity: 24 miles/s (39 km/s)

The alpha Hydrid radiant lies on the Hydra/Monoceros border, southwest of the bright star Alphard (alpha Hydrae). In early January the alpha Hydrid radiant rises near 2000 (8:00 p.m.) LST. Like the January Leonids, this radiant reaches its highest altitude above the horizon near 0300 LST. This would be the best time to try a view activity from these showers.

There are three other active radiants to the north of the alpha Hydrids. These include the weak January Leonids, the stronger Antihelion radiant, and the slightly stronger Coma Berenicids. In addition to these three radiants the much stronger Quadrantids are present in the morning sky. With an entry velocity of 24 miles/s

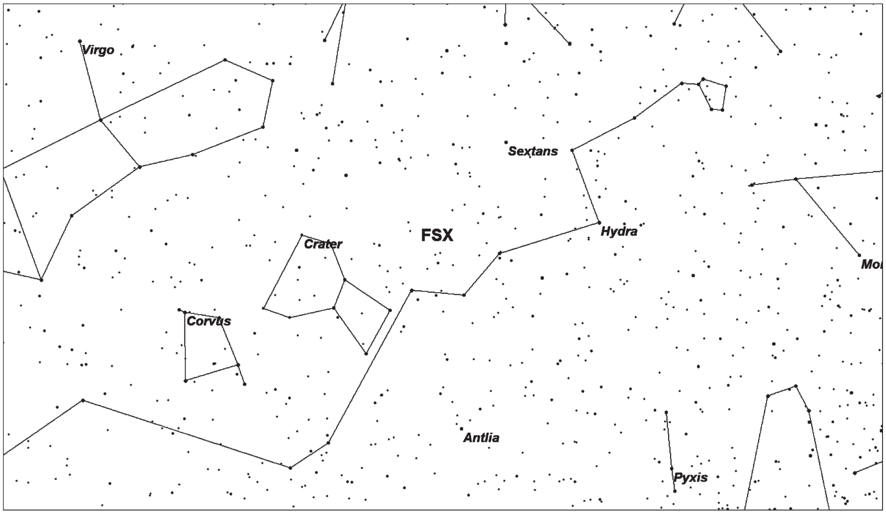

Fig. 7.3. Radiant position of the February Sextantids.

most members of the alpha Hydrids would possess a medium velocity. There were 128 members of this shower found in the video radiant study (Fig. 7.3).

7.3 February Sextantids (FSX)

Activity period: 01/31–02/06
Date of maximum activity: 02/02
Radiant position at maximum: 158 (10:32) − 11
Radiant drift per night: RA +0.7° Dec −0.7°
Geocentric velocity: 26 miles/s (42 km/s)

The February Sextantids are active from a radiant located on the Sextans/Hydra border. The nearest bright star is Alphard (alpha Hydrae), located 15° to the west. In early February this radiant rises near 2100 (9:00 p.m.) LST and reaches its highest altitude above the horizon near 0400 LST. There is only one other active radiant in this vicinity of the sky. The Antihelion radiant lies to the northwest in western Leo some 20° away. With an entry velocity of 26 miles/s most members of the alpha Hydrids would possess a medium velocity, faster than the average Antihelion meteor. There were 101 members of this shower found in the video radiant study (Fig. 7.4).

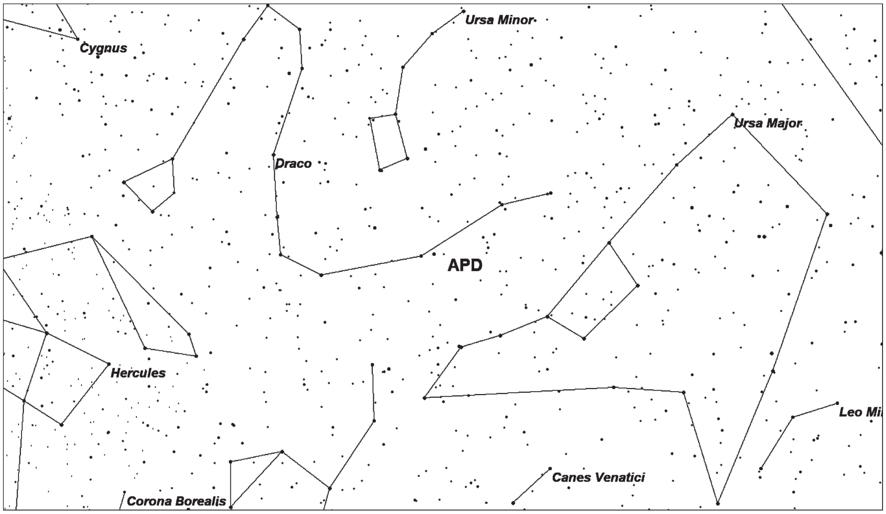

Fig. 7.4. Radiant position of the April Draconids.

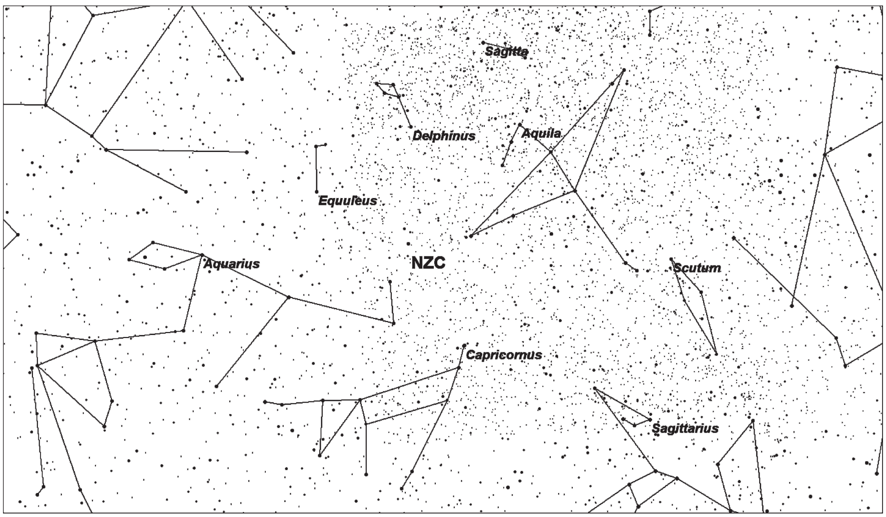

Fig. 7.5. Radiant position of the North June Aquilids.

7.4 April Draconids (APD)

Activity period: 03/31–04/06
Date of maximum activity: 04/06
Radiant position at maximum: 202 (13:28) + 64
Radiant drift per night: RA −1.8° Dec +0.3°
Geocentric velocity: 11 miles/s (18 km/s)

The April Draconid radiant is located just north of the well-known "Big Dipper." It also lies very close to the Thuban (alpha Draconis), the pole star of ancient civilizations. This radiant is circumpolar as seen from areas north of 26°N latitude. It reaches its highest altitude above the horizon near 0200 LST and is best viewed near this time. There is only one other active radiant in this vicinity of the sky. The Antihelion radiant lies to the northwest in western Leo some 20° away. With an entry velocity of 11 miles/s most members of the April Draconids would appear to move slowly across the sky. There were 101 members of this shower found in the video radiant study (Fig. 7.5).

7.5 North June Aquilids (NZC) #164

Activity period: 06/23–06/30
Date of maximum activity: 06/25
Radiant position at maximum: 304 (20:16) – 07
Radiant drift per night: RA 0.9° Dec +0.3°
Geocentric velocity: 25 miles/s (40 km/s)

The North June Aquilid radiant lies on the border of Aquarius and Aquila. The nearest bright star is Altair (alpha Aquilae), located 10° to the northwest. This radiant rises near 2000 (8:00 p.m.) LST and reaches its highest altitude above the horizon near 0200 LST. This would be the best time to try and observe this activity. There is only one other active radiant in this vicinity of the sky. The Antihelion radiant lies to the southwest in eastern Sagittarius some 20° away. With an entry velocity of 25 miles/s most members of the North June Aquilids would possess a medium velocity. With 288 members of this shower found in the video radiant

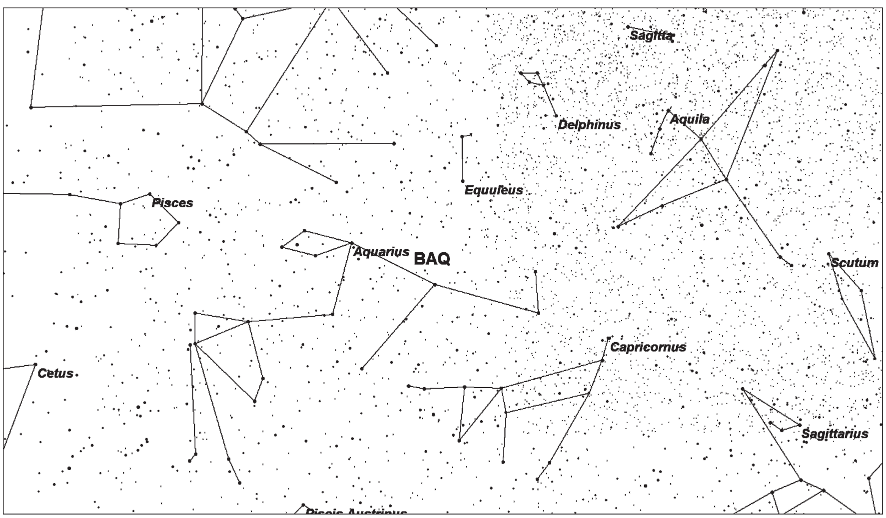

Fig. 7.6. Radiant position of the beta Aquariids.

study, these meteors should stand out in the normally placid late June skies. The difference in velocity between the North June Aquilids and the Antihelions should be readily apparent, especially when facing in the general direction of the radiant (Fig. 7.6).

7.6 β Aquariids (BAQ)

Activity period: 07/17–07/22
Date of maximum activity: 07/19
Radiant position at maximum: 323 (21:32) – 02
Radiant drift per night: RA 0.1° Dec +0.4°
Geocentric velocity: 24 miles/s (39 km/s)

The beta Aquariid radiant lies in western Aquarius just north of the third magnitude star Sadalsuud (beta Aquarii). This radiant rises near 2000 (8:00 p.m.) LST and reaches its highest altitude above the horizon near 0200 LST. This would be the best time to try and observe this activity. There is only one other active radiant in this vicinity of the sky. The Antihelion radiant lies to the southwest in western Capricornus. The only possible way to separate the two radiants would be to face directly at them so that the paths can be traced back with some accuracy. With an entry velocity of 24 miles/s most members of the beta Aquariids would possess a medium velocity. The beta Aquariids would be slightly faster on average than the Antihelions. There were 159 members of this shower found in the video radiant study (Fig. 7.7).

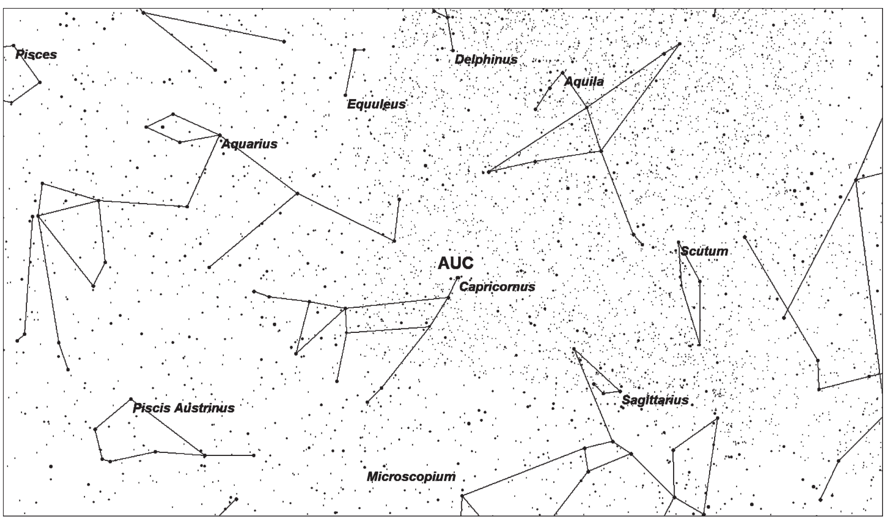

Fig. 7.7. Radiant position of the August Capricornids.

New Showers?

7.7 August Capricornids (AUC)

Activity period: 08/13–08/24
Date of maximum activity: 08/22
Radiant position at maximum: 306 (20:24) − 11
Radiant drift per night: RA −1.0° Dec −0.8°
Geocentric velocity: 12 miles/s (19 km/s)

The August Capricornid radiant lies in western Capricornus, close to the naked-eye double star alpha Capricornii. Do not confuse this radiant with the more active alpha Capricornids. That shower peaks on July 30, and all activity ends by August 22. In mid-August this radiant has already risen by the time it becomes dark. It reaches its highest altitude above the horizon near 2300 (11:00 p.m.) LST. This would be the best time to try and observe this activity. By this date in August all of the activity in Capricornus and Aquarius that peaked in intensity in late July has ended. The Antihelion radiant is currently located in northeastern Aquarius, far enough away to allow shower association to be easy should the observer be facing this portion of the sky. With an entry velocity of 12 miles/s, members of the August Capricornids would travel slowly across the sky. This slow speed should make them easy to identify. There were 376 members of this shower found in the video radiant study (Fig. 7.8).

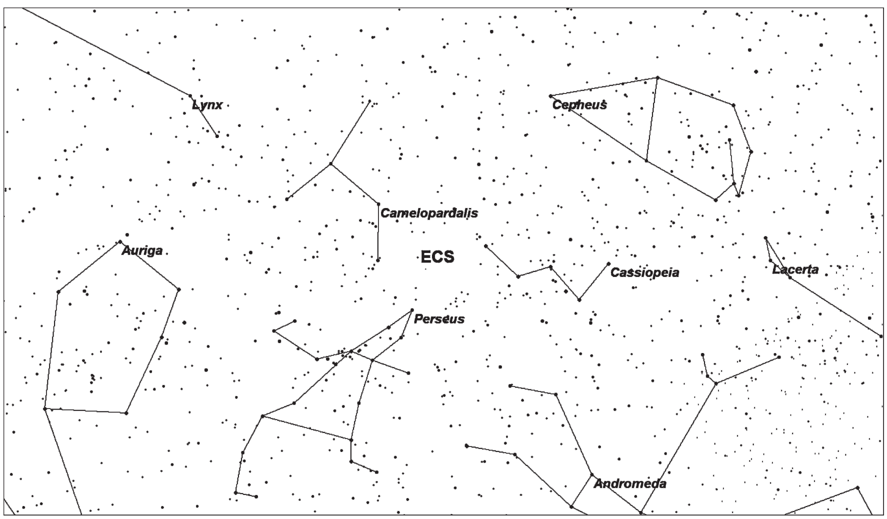

Fig. 7.8. Radiant position of the epsilon Cassiopeiids.

7.8 ε Cassiopeiids (ECS)

Activity period: 08/20–08/26
Date of maximum activity: 08/26
Radiant position at maximum: 035 (02:20) + 62
Radiant drift per night: RA −1.1° Dec −1.2°
Geocentric velocity: 31 miles/s (50 km/s)

The epsilon Cassiopeiid radiant lies in eastern Cassiopeia, 3°SE of the third magnitude star epsilon Cassiopeiae. This radiant is circumpolar for locations north of 28°N latitude. It reaches its highest altitude above the horizon near 0430 LST. This would be the best time to try and observe this activity. By this late date in August the Perseids have died down to less than 1 shower member per hour. The Aurigids are just beginning to appear, but their rates would be similar to the Perseids. The high sporadic rates seen this time of year in the northern hemisphere would make the likelihood of sporadic pollution high. The observer of this activity would have to be careful in associating any meteors with this shower. The ever-present Antihelion radiant lies far enough away and will not present any difficulties with classifying these meteors. With an entry velocity of 31 miles/s most members of the epsilon Cassiopeiids would possess a medium-fast velocity. There were 196 members of this shower found in the video radiant study (Fig. 7.9).

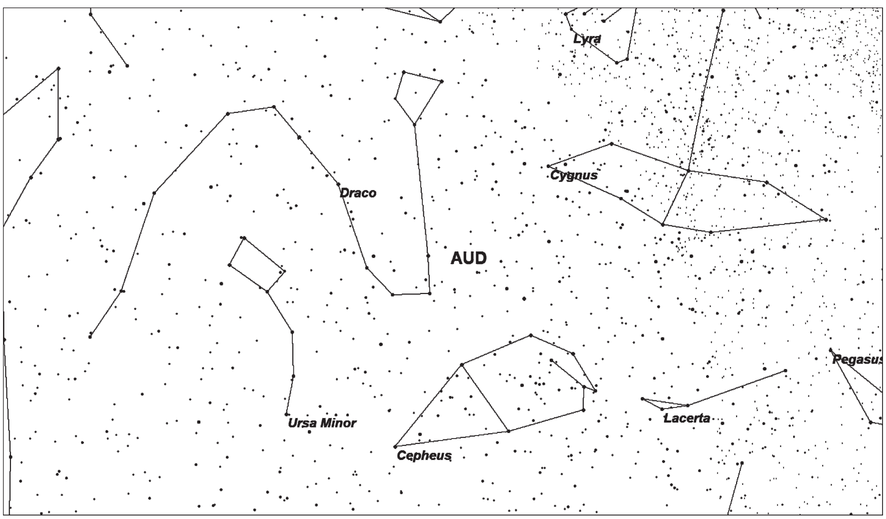

Fig. 7.9. Radiant position of the August Draconids.

7.9 August Draconids (AUD) #197

Activity period: 08/26–09/01
Date of maximum activity: 08/27
Radiant position at maximum: 292 (19:28) + 65
Radiant drift per night: RA −1.8° Dec −1.2°
Geocentric velocity: 19 miles/s (30 km/s)

The August Draconid radiant lies in Draco near the Cepheus border. An easier way to find this area would be look half-way between the bright stars Kochab (beta Ursae Minoris) and Deneb (alpha Cygni). The August Draconid radiant lies close to the Kappa Cygnid radiant, but by this time in late August the Kappa Cynnids have fallen to a ZHR of less than 1.This radiant is circumpolar for areas north of 25°N latitude. It reaches its highest altitude above the horizon near 2100 (9:00 p.m.) LST. This would be the best time to try and observe this activity. The Antihelion radiant is currently located on the Aquarius/Pisces border, far enough away not to confuse the observer. With an entry velocity of 19 miles/s, members of the August Draconids would have an average velocity, similar to the Antihelions. There were 172 members of this shower found in the video radiant study (Fig. 7.10).

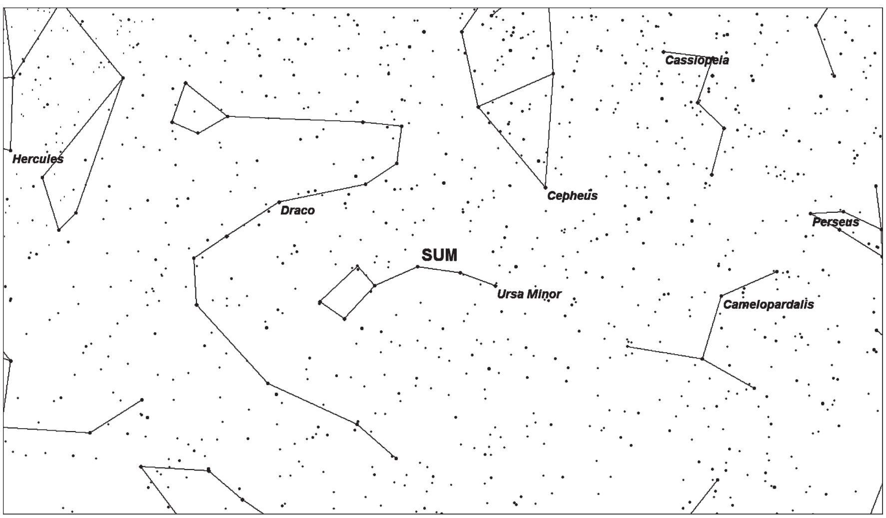

Fig. 7.10. Radiant position of the September Ursa Minorids.

7.10 September Ursa Minorids (SUM)

Activity period: 08/28–09/03
Date of maximum activity: 09/01
Radiant position at maximum: 261 (17:24) + 83
Radiant drift per night: RA −1.7° Dec +1.4°
Geocentric velocity: 24 miles/s (38 km/s)

The September Ursa Minorid radiant lies in central Ursa Minor not far from Polaris, the North Star. This radiant is circumpolar for areas north of 7°N latitude. Interestingly enough, just 14° further south at 7°S latitude, it cannot be seen at all! It reaches its highest altitude above the horizon near 1800 (6:00 p.m.) LST. Most locations in the northern hemisphere are not dark until an hour or two later, so the period just as dusk settles in would be the best time to try and observe this activity. The much stronger Aurigids are active the same night, but their activity is mostly limited to the morning hours. The southern September Lyncid radiant also peaks on this night but is weak and lies far from Ursa Minor. With an entry velocity of 24 miles/s, members of the September Ursa Minorids would have an average velocity. Only 80 members of this shower were found in the video radiant study, so activity is bound to be low (Fig. 7.11).

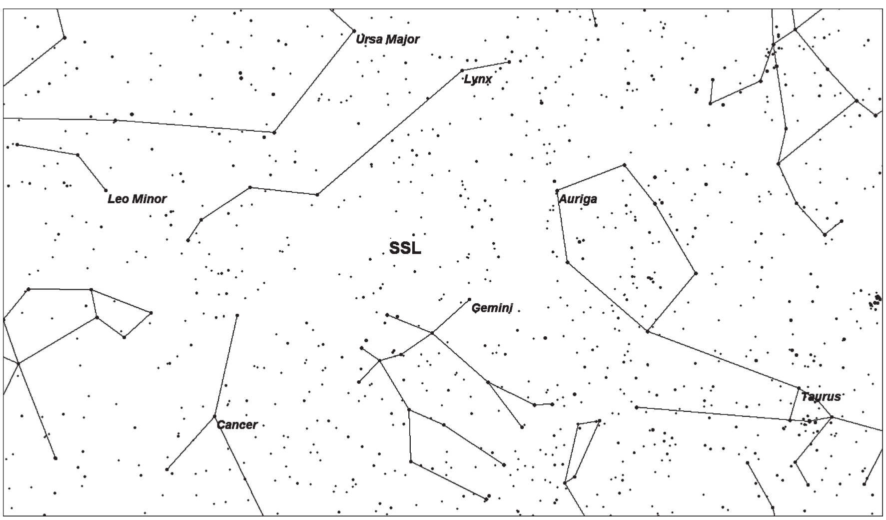

Fig. 7.11. Radiant position of the Southern September Lyncids.

7.11 Southern September Lyncids (SSL)

Activity period: 08/28–09/05
Date of maximum activity: 09/01
Radiant position at maximum: 111 (07:24) + 39
Radiant drift per night: RA +1.4° Dec −1.5°
Geocentric velocity: 32 miles/s (52 km/s)

The Southern September Lyncid radiant actually lies in extreme eastern Auriga, just over the border from Lynx. This position also lies 6°N of the famous double star Castor (alpha Geminorum). The radiant rises near midnight LST and reaches its highest altitude above the horizon near 0800 LST. Since this is during daylight hours the best time to view activity from the southern September Lyncids would be during the last dark hour before dawn. The much stronger Aurigids are active the same night, and care must be taken to avoid confusing the two showers. Both showers produce swift meteors, but the Aurigids would be far more numerous. If any observer is serious about seeing any of this activity he or she should include both radiants within their field of view. Viewing toward the north would also allow the monitoring of the epsilon Ursa Minorids. With an entry velocity of 32 miles/s most members of the Southern September Lyncids would move swiftly. A respectable 220 members of this shower were found in the video radiant study (Fig. 7.12).

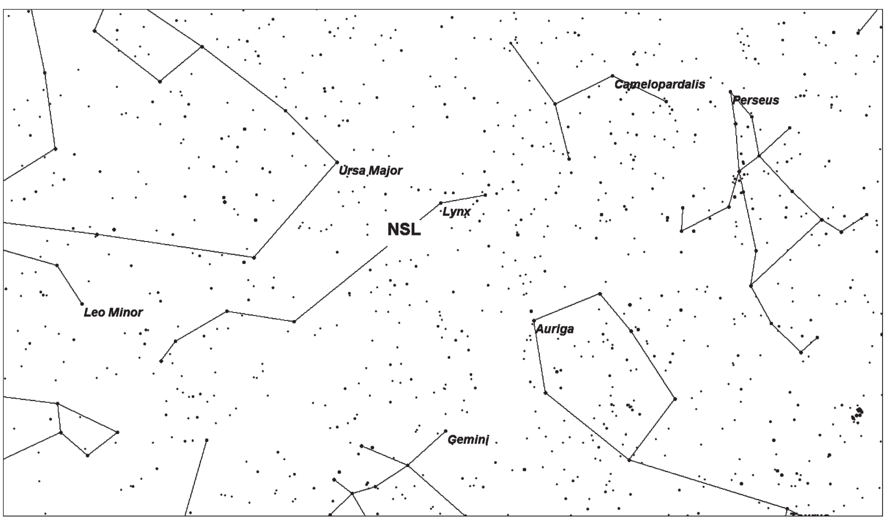

Fig. 7.12. Radiant position of the Northern September Lyncids.

7.12 Northern September Lyncids (NSL)

Activity period: 09/09–09/16
Date of maximum activity: 09/13
Radiant position at maximum: 114 (07:36) + 56
Radiant drift per night: RA +2.6° Dec −0.1°
Geocentric velocity: 33 miles/s (53 km/s)

The Northern September Lyncid radiant lies in a remote area of northern Lynx. The nearest bright star is Capella (alpha Aurigae), located some 20° to the southwest. The radiant is circumpolar north of 34°N latitude. It lies highest above the horizon near 0700 LST. Since this is during daylight hours the best time to view activity from the Northern September Lyncids would be during the last dark hour before dawn. The stronger September epsilon Perseids are active during this period, and care must be taken to avoid confusing the two showers. Both showers produce swift meteors, but the September epsilon Perseids would be more numerous. If any observer is serious about seeing any of this activity they should include both radiants within their field of view. With an entry velocity of 32 miles/s most members of the Northern September Lyncids would move swiftly. There were113 members of this shower found in the video radiant study (Fig. 7.13).

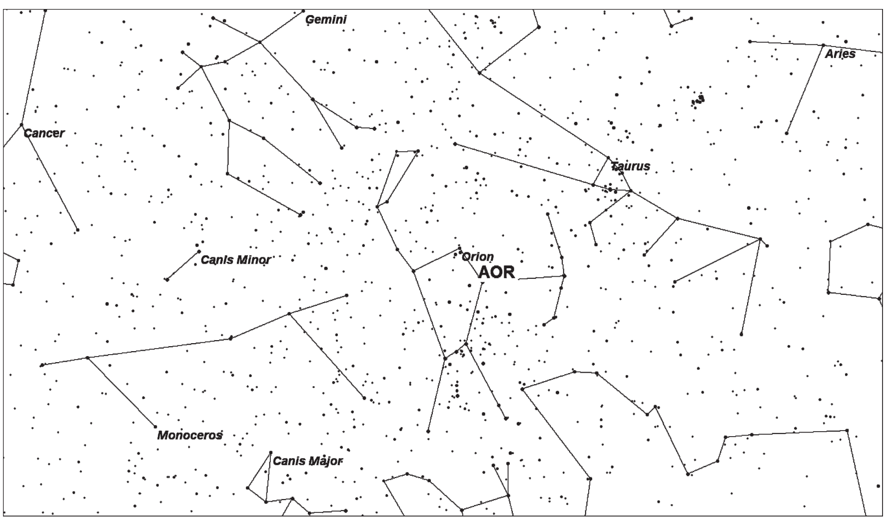

Fig. 7.13. Radiant position of the September alpha Orionids.

7.13 September α Orionids (AOR) #211

Activity period: 09/24–09/30
Date of maximum activity: 09/27
Radiant position at maximum: 081 (05:24) + 07
Radiant drift per night: RA +1.4° Dec −0.1°
Geocentric velocity: 37 miles/s (59 km/s)

The September alpha Orionid radiant lies in northwestern Orion near the bright star Bellatrix (gamma Orionis). Do not confuse this shower with the much stronger Orionids, which become active the first week of October. This radiant rises near midnight LST and lies highest above the horizon near 0500 LST. The other showers active during this time of year include the weak delta Aurigids to the north and the two Taurid radiants to the west.

The strong sporadic rates seen this time of year allow the possibility of sporadic pollution, where sporadic meteors imitate shower meteors. Observers should be careful to make sure the radiant distance and velocity equal to what is expected before listing any meteors as September alpha Orionids. With an entry velocity of 37 miles/s most members of the September alpha Orionids would move swiftly. There should be some activity available to visual observers, as 432 members of this shower were found in the video radiant study (Fig. 7.14).

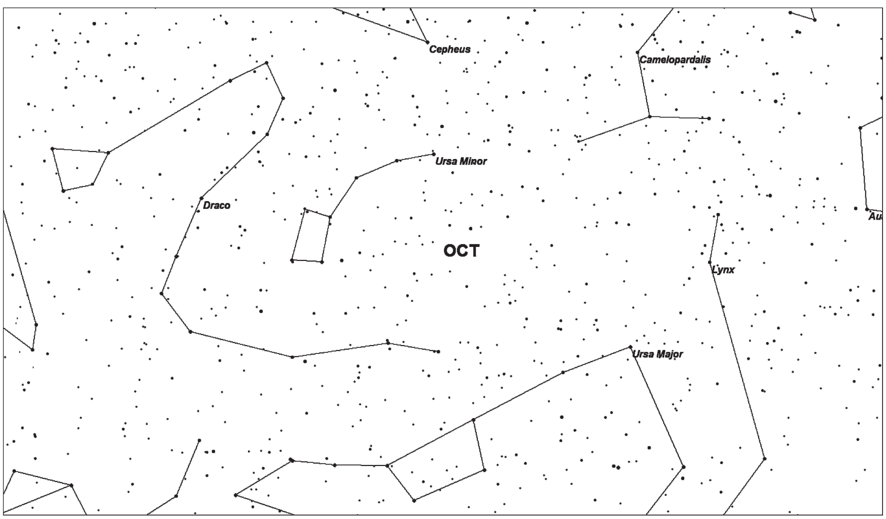

Fig. 7.14. Radiant position of the October Camelopardalids.

7.14 October Camelopardalids (OCT)

Activity period: 10/01–10/10
Date of maximum activity: 10/05
Radiant position at maximum: 162 (10:48) + 79
Radiant drift per night: unknown
Geocentric velocity: 29 miles/s (47 km/s)

This possible shower is a recent discovery. Shower members may appear between October 1 and 10, but the main maximum lasts only 2 h long on the night of the fifth. This shower is known for producing bright meteors. The radiant lies near the Draco/Camelopardalis border. The nearest easy star to identify the radiant is fourth magnitude SAO1551. Polaris (alpha Ursae Minoris) lies 12° to the north. This area of the sky is circumpolar from nearly the entire northern hemisphere. The radiant lies highest above the horizon at both dusk and at dawn. Due to this unusual situation this shower would be totally invisible from the southern hemisphere. With an entry velocity of 29 miles/s most members of the October Camelopardalids would be of medium-swift velocity. This shower should be easily detected by visual observers, and all are encouraged to monitor the northern skies around this time to try and verify this activity (Fig. 7.15).

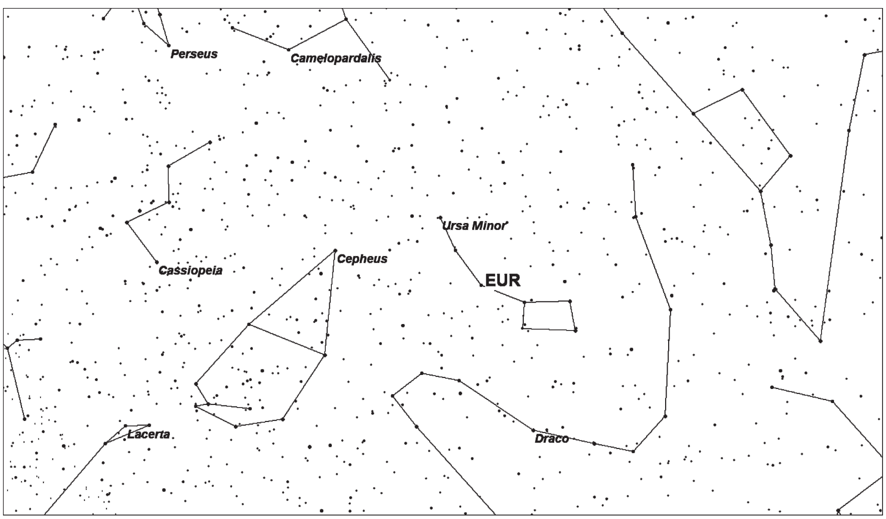

Fig. 7.15. Radiant position of the epsilon Ursa Minorids.

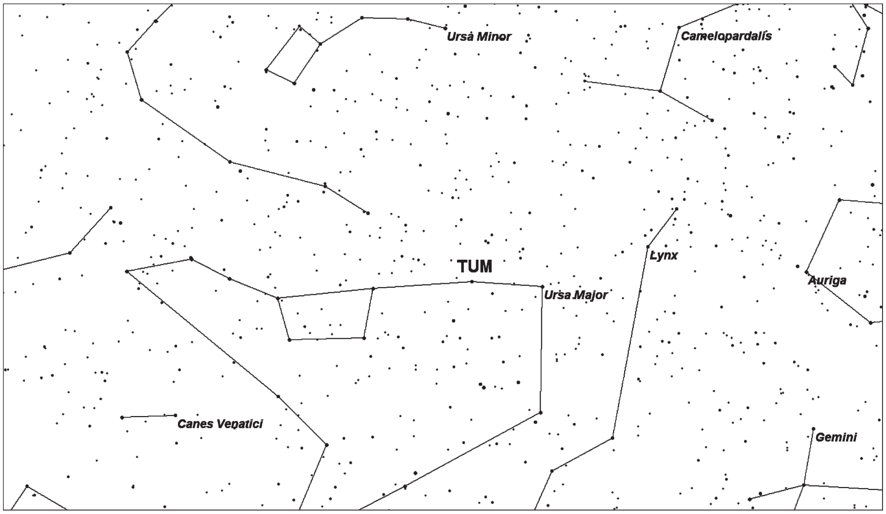

Fig. 7.16. Radiant position of the tau Ursa Majorids.

7.15 ε Ursa Minorids (EUR)

Activity period: 10/10–10/16
Date of maximum activity: 10/12
Radiant position at maximum: 248 (16:32) + 82
Radiant drift per night: RA −3.6° Dec +0.9°
Geocentric velocity: 22 miles/s (35 km/s)

The epsilon Ursa Minorid radiant lies in central Ursa Minor very close to the fourth magnitude star epsilon Ursa Minoris. This radiant is circumpolar for areas north of 8°N latitude. It reaches its highest altitude above the horizon near 1600 (4:00 p.m.) LST. Most locations in the northern hemisphere are not dark at that hour, so the best time to try and observe this activity would be shortly after dusk. The quiet evening skies would also allow the observer to better sort these meteors from the sporadic. The stronger Orionids and Taurids are active during this same period, but their radiants are located far from the celestial pole. With an entry velocity of 22 miles/s, members of the epsilon Ursa Minorids would have an average velocity. There were 141 members of this shower found in the video radiant study (Fig. 7.16).

7.16 τ Ursa Majorids (TUM)

Activity period: 10/12–10/18
Date of maximum activity: 10/15
Radiant position at maximum: 146 (09:48) + 65
Radiant drift per night: unknown
Geocentric velocity: 33 miles/s (53 km/s)

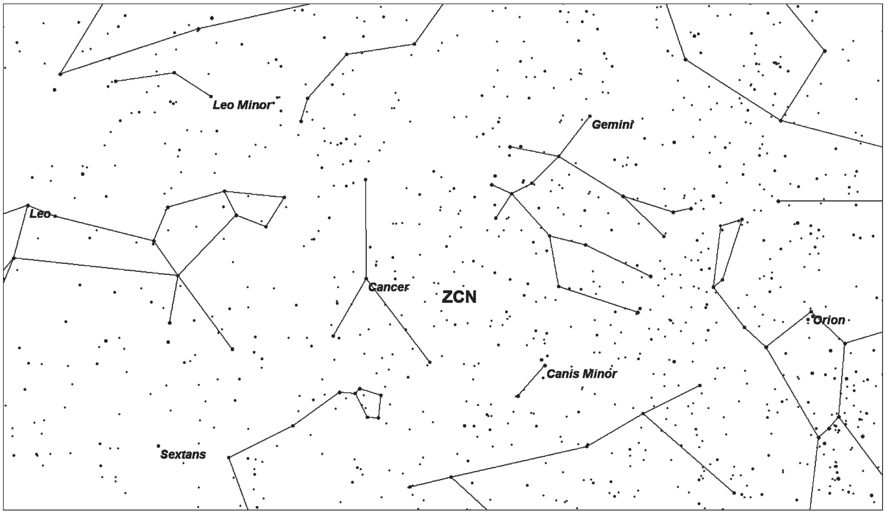

Fig. 7.17. Radiant position of the zeta Cancrids.

The tau Ursa Majorids is another recent discovery using video techniques. The radiant is poorly placed during the evening hours for all but the highest northern latitudes. It is best seen during the late morning hours when it lies the highest in a dark sky. At this time it is well placed for observers in the northern hemisphere. Activity may be seen from the southern tropics, but shower members would be sparse. It actually culminates after sunrise for all but the highest northern latitudes. These meteors have been verified by two different sources, so confidence in the shower as being a real annual event is high. With an entry velocity of 33 miles/s most of these meteors would be medium-swift. Observers are encouraged to make efforts to view this activity and to report it to a national or international meteor group (Fig. 7.17).

7.17 Zeta Cancrids (ZCN) #243

Activity period: 10/27–11/04
Date of maximum activity: 10/31
Radiant position at maximum: 121 (08:04) + 16
Radiant drift per night: RA −0.7° Dec +0.3°
Geocentric velocity: 37 miles/s (60 km/s)

The zeta Cancrid radiant lies in eastern Cancer. The nearest bright star is Pollux (beta Geminorum), which lies 10° to the northwest. On late October evenings this radiant rises near 2300 (11:00 p.m.) LST and reaches its highest altitude above the horizon near 0600 LST. The fully dark hour before dawn would provide the best opportunity to view this shower. The stronger Orionid radiant lies 15° to the west, so care must be taken not to classify any Orionids as zeta Cancrids. The Taurid radiants are also active during this period but lie further to the west. With an entry velocity of 37 miles/s, members of the zeta Cancrids would appear to move swiftly

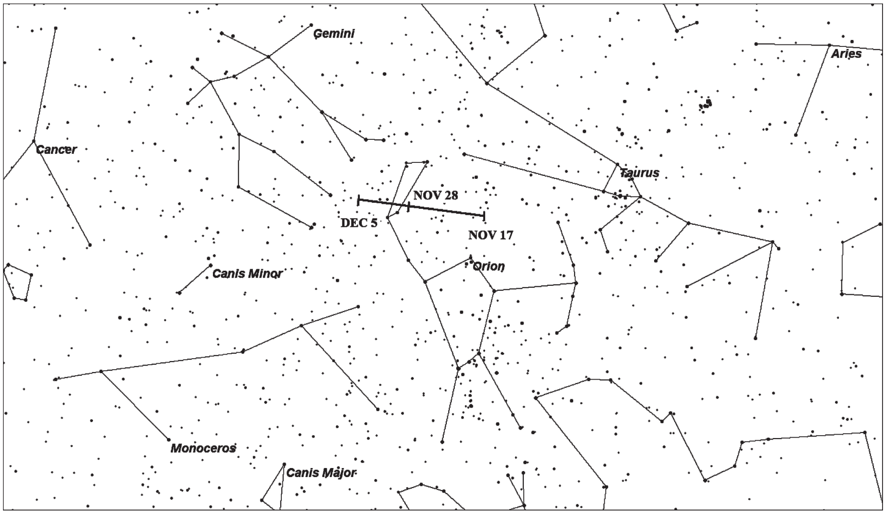

Fig. 7.18. Radiant drift of the November Orionids.

across the sky. The Orionids also have a similar velocity. With 324 members in the video radiant study, this shower was well represented (Fig. 7.18).

7.18 November Orionids (NOO) #250

Activity period: 11/18–12/09
Date of maximum activity: 11/28
Radiant position at maximum: 091 (06:04) + 16
Radiant drift per night: RA +0.8° Dec +0.1°
Geocentric velocity: 27 miles/s (44 km/s)

The November Orionid radiant starts out in northern Orion and ends up in western Gemini. On the night of maximum activity the radiant is located 8°N of the bright orange variable star Betelgeuse (alpha Orionis). On late November evenings this radiant rises near 1900 (7:00 p.m.) LST and reaches its highest altitude above the horizon between 0100 and 0200 LST. Two active radiants lie in the same region of the sky. The core of the Antihelion radiant is located 15° to the west. Antihelion rates should be slight higher. The Monocerotid radiant lies 9° to the southwest near Betelgeuse. On November 28 the Monocerotids should be weaker than the November Orionids. With an entry velocity of 27 miles/s, members of the November Orionids would appear to move medium-fast across the sky. The Monocerotids also have a similar velocity, while the Antihelions would be slower. With 915 members in the video radiant study, this shower was well represented and should be a distinct center of activity in the late November sky (Fig. 7.19).

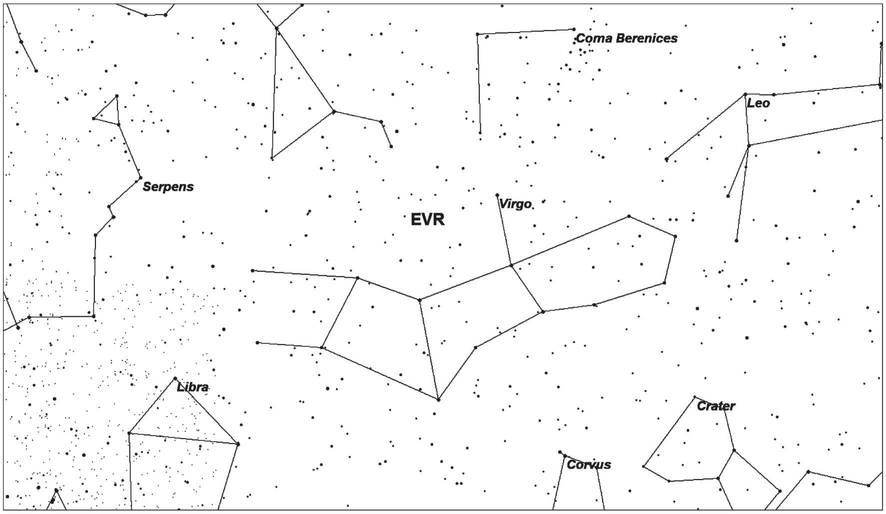

Fig. 7.19. Radiant position of the epsilon Virginids.

7.19 ε Virginids (EVR)

Activity period: 12/19–12/24
Date of maximum activity: 12/20
Radiant position at maximum: 202 (06:04) + 09
Radiant drift per night: RA +1.3° Dec 0.0°
Geocentric velocity: 39 miles/s (62 km/s)

The epsilon Virginid radiant is located in northern Virgo 5°SE of the third magnitude star epsilon Virginis. On mid-December mornings this radiant rises near 0100 LST and reaches its highest altitude above the horizon near 0700 LST. For the southern portion of the northern hemisphere and the southern hemisphere this occurs after sunrise. If this is true in your location then it is best to watch during the last dark hour before dawn. The more active Coma Berenicid complex lies close by to the north, and care must be taken to properly separate this activity. The Antihelion radiant in Gemini and the Ursid Minorids lie far from this radiant and should not interfere. With an entry velocity of 39 miles/s, members of the epsilon Virginids would appear to move swiftly across the sky. This is a similar velocity to the Coma Berenicids. There are 131 members of this shower represented in the video radiant study.

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Chapter 8

Observing Meteor Showers

Abstract

There are many ways to observe meteor showers, ranging from simple naked-eye counts to videotaping the activity through intensified cameras. The author discusses all levels of visual observing and the parameters that are necessary to provide useful data. The author provides advice on when and where to best view shower activity. Also included are lists of equipment to aid in observing and to eliminate wasted time while out under the stars. Finally, observing methods other than visual, such as telescopic, photographic, video, radio, and fireball observing are discussed.

Now that we have examined the many sources and showers that are available to be viewed, it is time to discuss how to observe these showers. Unlike other observing pursuits in astronomy, meteor observers do not need any expensive equipment in order to be successful. Your eyes are all that is really needed! Human vision is a wonderful tool for this viewing activity, as it has a wide field and can detect faint meteors that are beyond the reach of cameras. Extra wide-angle cameras can view larger portions of the sky, but meteors must be bright in order to be captured.

The eye also has its drawbacks, as fatigue can set in and ruin the ability to be alert. This is the largest drawback, especially considering most of the showers peak after midnight, a time when most people are sound asleep. A camera has no such problems with fatigue yet can still be blinded by bright lights or dew.

A meteor shower is often one's first contact with astronomy. As a child you may have been fortunate to have parents who took you outside at night to see the "shooting stars." Perhaps they also showed you the Big Dipper or the brilliant constellation of Orion the Hunter. To children and some enthusiastic adults, meteor showers are like having the 4th of July several times a year. The only difference is that this is nature's display of fireworks and can be just as colorful as the artificial displays. It is the surprise of each event that drew the author to this field. They could be dim or they could be bright, but no two meteors are exactly alike. The bright ones can produce every color of the rainbow. They can be so short that they appear like a star waxing and waning in brightness with no perceptible motion. They can also stretch from horizon to horizon and last several seconds.

Observing meteor showers is an adventure, as you never know exactly what you are going to see. Scientists are getting better in forecasting the exact time and strength of each shower, but you never know for sure unless you venture out under the stars. There are ways to increase your odds of seeing more activity, which will be discussed in the next section.

8.1 Basic Visual Observations

Visual observing is the simplest form of meteor watching. You need nothing but well-rested eyes. The basic session should be at least 1 h long. This period of time is long enough to give a good representation of the meteor activity. During major showers it will be noted that activity seems to occur in bursts. There will be periods of no activity and periods when activity is strong. This is completely normal and the result of random sorting of the meteoric material in space. If you view for periods of less than 1 h you may observe a period of inactivity or a burst, both of which will skew your results.

The basic meteor observation involves counting the number of meteors you see during your observing session. In order to produce scientific useful results, you must also provide some details of your session so that your observations may be compared to others. First of all you need to accurately document your beginning and ending times. You must also record any breaks that were taken during this session. Logging these breaks is important, as it provides the exact amount of time you were actually observing. Not recording breaks skews your results, so that it will appear that your activity was actually less than it really was. This is important when scientists examine activity all over the world.

Your observing conditions are also important to record. First of all you must note any obstacles in your field of view, such as hills or trees. It is highly advisable to have a clear field of view, but sometimes that will not be possible. If a tree is blocking the edge of your field note this is obscuration to the nearest 10%. About 10 or 20% is acceptable, but if it surpasses 20% it would be best to find a new spot from which to view. You would be missing too much activity to make your session worthwhile. Observing with obstructions also introduces another correction when your data are analyzed, so it should be avoided if at all possible.

There is one obstruction that is often difficult to avoid and equally difficult to estimate. These are clouds that happen to drift through your field of view during the observing session. Thin cirrus clouds are usually not a major problem; it is the thick cirrus or other opaque clouds that totally obscure meteors and the sky while you are trying to observe. Thin cirrus can be dealt with using a limiting magnitude correction (to be discussed later). It is extremely difficult to judge the obscuration when it is constantly changing. Again, as was the case with hills and trees, if the constant obscuration exceeds 20% it is time to take a break or end the observing session. It is often possible to keep changing your field of view to avoid clouds. However, this can also be annoying if it lasts too long.

One last important factor that must be included in a basic meteor session report is the limiting magnitude of your sky. The reason for such an estimate is to provide a correction so that all observations examined will have the same sky conditions. These estimates should be taken each hour during your session, as sky conditions can change throughout the night. This may sound intimidating, but it is actually quite easy to estimate. All you need to do is to estimate the magnitude of the faintest star you can see in your field of view. There are two methods you can use to accomplish this. This first involves obtaining a star chart with the magnitudes listed directly on

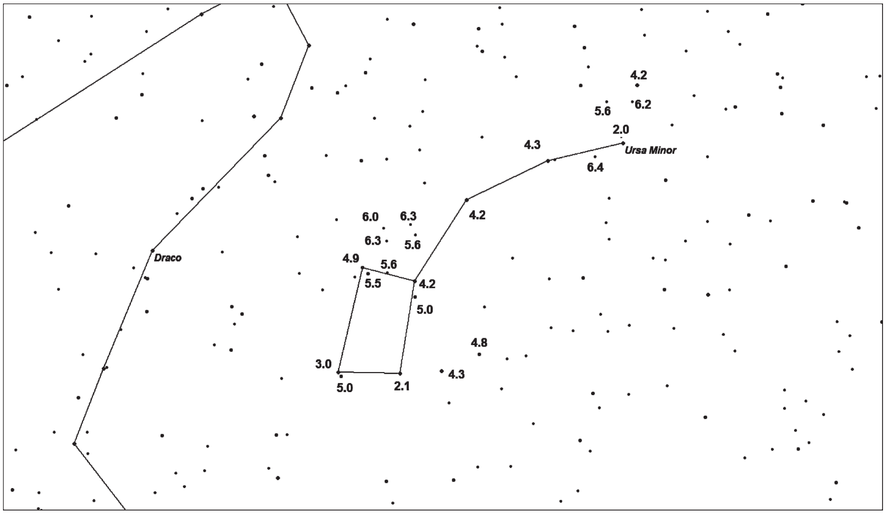

Fig. 8.1. A limiting magnitude chart for the Little Dipper.

the map. See Fig. 8.1 for an example of such a chart. Looking at the chart *first* you find a star on the chart you can easily recognize in the sky. Find successive fainter stars until you cannot find one. The last star you were able to see will be your limiting magnitude.

The drawback to this method is that it is time consuming and requires you to constantly use a light to see the chart. If you have a red-filtered flashlight that will have the least impact on your night vision. These drawbacks can be overcome if you use the same chart and begin to memorize the magnitudes of each star. This will overcome the need to constantly look back and forth between the sky and your chart and having to use a flashlight. This is one reason the Little Dipper (Ursa Minor) is a favorite area to use, as it is always in the sky for observers in the northern hemisphere.

The other method of estimating your limiting magnitude is called the star count method. The star count method involves counting the number of stars in a predetermined area of the sky. These areas are usually small squares or triangles located throughout the heavens. See Fig. 8.2 for an example of two star count areas. This method requires some preplanning before the session to determine just what areas are located in your field of view during the observing session. There are usually two to three areas available no matter where you look. Once your star count area has been identified in the sky, then start with the corner stars and sweep across the area in one motion, starting at one of the corners or sides. Do not strain your eyes, trying to see the faintest stars possible. Just gently sweep over the area, counting the number of stars you see. Be sure to include the corner stars, or your estimate will be too low. Proceed to the next area and repeat. Log your star counts at the beginning and end of each hour using at least two, preferably three, star count areas, if they are available near or within your field of view. There is no need to calculate your limiting magnitudes until after the session is over.

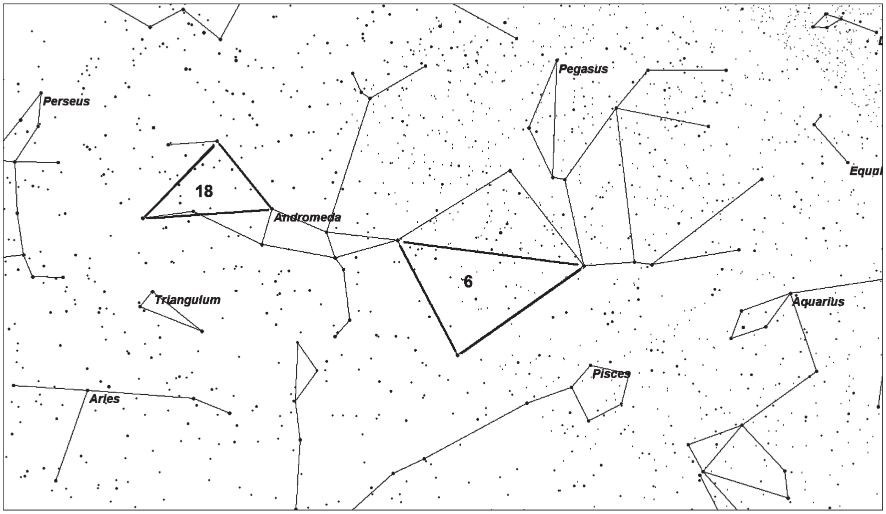

Fig. 8.2. Star count areas in Andromeda and Pegasus.

To find your resulting limiting magnitude use the table associated with this method. This table and other star count areas are available online at http://www.imo.net/visual/major/observation/lm. The equivalent limiting magnitudes in the table are given to two decimal places.

Do not round to the nearest tenth. It may seem ridiculous to expect accuracy to one-hundredth of a magnitude, and, of course, this is impossible with the naked eye. But when calculating zenith hourly rates this small difference does change the rate slightly, so it is suggested that the observer go ahead and list their estimates to two decimal places. The average of the two or three areas will give you your resulting estimate.

Like obstructions, there are limits when observing in poor conditions. It is advisable not to observe when your limiting magnitude is brighter than +5.0, unless a major shower is occurring. The corrections to your data under such poor conditions will be very large. Besides, under such conditions you will only be seeing a small fraction of the activity that is actually occurring.

In review, a basic meteor-observing session involves counting the number of meteors seen during a specified time and under specific conditions. The estimate of your limiting magnitude will take a few sessions to master, but soon it will become second nature.

To be honest, basic meteor counts are not very useful to scientists. What is necessary for your session to be of value to others is to associate each meteor you see with a shower or label it as random (sporadic) and to estimate its brightness. No one expects scientifically useful data the first few times out under the stars, but after a few sessions of obtaining basic data it is advised that the observer try to provide more data so that their observations can prove even more useful. Assigning shower associations and meteor magnitudes is the next step in becoming a proficient meteor observer providing scientifically useful data.

8.2 Intermediate Visual Observations

After a few sessions it will become apparent that meteors come in all lengths, velocities, and magnitudes. No two are alike no matter how many you see. Most of them will be short and faint, especially if you watch from rural areas. How does the observer tell one from another? Shower association is the next important step in providing a scientifically useful observation.

To provide accurate observations you must be able to discriminate between shower and sporadic meteors. Although shower meteors can appear in any portion of the sky they all trace back to one area called the *radiant*. This is the area of the sky where the meteors seem to originate. Since particles of the same meteor shower travel in a similar orbit around the Sun, when they encounter Earth they pierce the atmosphere in parallel paths. The observer located directly below these meteors will see them fan out from a radiant located directly overhead. Others will have the radiant lower in the sky, depending on their angle to these parallel meteors. If the angle is 90°, then the radiant will lie on the horizon.

It is often difficult to understand why the radiant moves across the sky each night. The rotation of Earth causes the Sun, Moon, planets, and stars to rise and set each day. Since the radiant is projected upon the sky as seen from Earth it, too, will rise and set. In addition to this motion the radiant will also shift its position approximately 1°E each night. This is due to Earth revolving around the Sun. Since the radiant moves against the stellar background it will be important to know its position in the sky beforehand so that you can judge whether a meteor traces back to the radiant.

It is important to note that shower meteors will very seldom appear at the radiant. Only those meteors heading directly toward you will appear at the radiant. These will not look like meteors but rather stars that suddenly appear and disappear. These "point meteors" seem to occur approximately once every 10,000 meteors.

Shower meteors are visible as long as their radiant is above your horizon. Since meteors do not occur at sea level, but rather many miles above Earth, the possibility exists that shower meteors can occur when the radiant is located slightly below the horizon. Under this circumstance the meteors just skim the upper portion of the atmosphere, creating the phenomena known as "Earth-grazers." These meteors are only normally seen during the strongest showers.

Shower rates are normally low until the radiant has attained a sufficient altitude above your horizon. It is suggested that you wait until the radiant has risen to at least 30° above your horizon before commencing observations. At this point you will be able to see at least 50% of the shower activity. As the radiant rises further into your sky that portion of the activity blocked by Earth will decrease until the radiant has reached its highest point above the horizon.

When out under the stars it is best not to look directly at the radiant but at a point 30–60° away. At this location meteors will be sufficiently long to be easily seen, even when faint. At this distance the radiant still lies at the corner of your field of view, and easy shower association is still possible.

During major showers it is suggested that you stand up at least once an hour to help ward off fatigue. At this time shift your chair so that you continue to view the same portion of the sky. If this shift points you toward a tree or any other source of interference, then you can always move 45° to the other side of the radiant.

It is also important to view approximately half way up in the sky, 45° in altitude. This point in the sky is high enough to avoid including the horizon in your field of view. It is also low enough to view the denser portion of the atmosphere, where most of the activity will be seen. Some observers think erroneously that it is best to view straight up at the zenith. This is great if using a telescope, since the column of air directly above is thinnest in this direction. But for meteors you want to view through a thicker column of air. The strip of sky just above the horizon would be best for this were it not for the fact that the ground would block a large portion of your field of view. The best compromise would be an altitude where the bottom of your field of view lies just above the horizon. So a "45 degree rule" comes into play – 45° high and 45° from the radiant is the best bet to see the most activity.

Shower meteors will appear shortest at the radiant and longest 90° distant from the radiant. This is important to remember, as no long meteors can occur near the radiant. Short meteors can appear at any distance from the radiant. Shower meteors that appear beyond 90° distance from the radiant will again begin to shorten. Figure 8.3 gives an example of a meteor appearing directly out of the Perseid radiant. The meteor is too long to be a Perseid, so it is most likely sporadic. A good rule to recall is that shower meteors must be twice their length distant from the radiant to actually be a member of that shower. Therefore, a meteor 5° long must start no closer than 10° from the radiant to be associated with that shower.

It is often difficult to "eyeball" a meteor back to its radiant. Some observers have used rulers or strings to trace the path of a meteor. You can try using a black cord or thick shoestring to accomplish this. You would think that a white cord would be easier to see in the dark, but since the night sky is actually gray the dark cord is more easily visible. Once a meteor is seen stretch the cord over its path as precisely as possible. Now trace that path backward and see if it passes within 10° of the radiant. If it does then the meteor most likely belongs to that shower. This may seem like an excessively large radiant area (20° across), but for an event lasting less than half a second on average, it is difficult to achieve precision. The large radiant area allows for such errors.

Shower meteors will also appear slower near the radiant than further out. Near the radiant meteors are moving toward you. They will have the same duration, but

Fig. 8.3. A sporadic meteor appears near the Perseid radiant.

the path length is short. Therefore, the angular velocity will be small, only a few degrees per second. Meteors reach their maximum angular velocity at a radiant distance of 90° and an altitude of 90°. It is important to remember that meteors with slow entry velocities (less than 20 miles/s) will always appear to travel slowly across the sky no matter their radiant distance. The maximum angular velocity for a meteor entering the atmosphere at 15 miles/s is 13° per second. But this is very rare, as few meteors appear at 90° from the radiant with the radiant on the horizon. Most of these meteors will travel less than 10° per second, relatively slow.

Another confusing point is that meteors entering the atmosphere with velocities in excess of 20 miles/s can either appear to move fast or slow, depending on their radiant distance and altitude. A meteor with an entry velocity of 35 miles/s can have an angular velocity ranging from 0 to 28° per second. A majority of these meteors, though, will appear swift, with angular velocities in excess of 10° per second.

Shower association sounds like a daunting task, but with experience it can become second nature, taking only a second or two to decide. If you watch the same area of the sky during a major meteor shower the shower meteors will all come from the same direction and have similar velocities. A sporadic interloper with a different path and velocity should be easy to spot.

In addition to shower association a second parameter to provide useful data is the magnitude of each meteor. This data provides us with the population index of a shower; the ratio of one meteor magnitude class versus another. This is an important factor when determining the zenith hour rate (ZHR) of a shower.

Estimating meteor magnitudes seems easy, but even experienced observers spend more time determining this than shower association. An observer needs to pick out stars of whole magnitudes that lie within your field of view. The easiest method is to use charts with stellar magnitudes included directly on the chart. Find stars with magnitudes ranging from +1.0 to +5.0. Memorize these stars and compare the meteors you see to these stars. Although some experienced observers record magnitudes down to half-magnitude intervals, it is suggested that you stick to whole magnitudes. The reason for this is a bias toward whole magnitudes. No matter how unbiased you try to be, one records more meteors of whole magnitudes than half magnitudes. To avoid this bias simply record all meteors to the whole magnitude. This itsel will be a challenge, as you usually have less than one half second in which to judge the brightness. Some meteors flare or have a terminal burst. Be sure to record the brightest portion of the meteor as its magnitude (Fig. 8.4).

There are many more faint meteors than bright ones. The ratio between each magnitude class is usually 2.5–3.0. This is called the "*r*" value. This means that there are 2.5–3.0 times more meteors of magnitude +3.0 than that of +2.0. You can plug in any values you wish in this ratio. Unfortunately, the eye has difficulty perceiving fainter meteors, so the observer will usually peak between magnitude +3.0 and +4.0 for sporadic meteors, depending on the observing conditions. If your average for sporadic meteors is brighter then you may be overestimating your magnitudes. Shower meteors tend to be brighter, so a peak between +2.0 and +3.0 is acceptable for shower meteors.

Seeing meteors of magnitudes +5 and +6 is difficult, as they must occur near the center of your field of view. Observers who view under pristine skies with limiting magnitudes of +7.0 have the best chance to observe these faint meteors. Those who report meteor magnitudes near their limiting magnitude arouse some skepticism, as it is difficult to detect motion in such faint objects. I have found that my faintest meteor magnitudes are one whole magnitude brighter than my limiting stellar

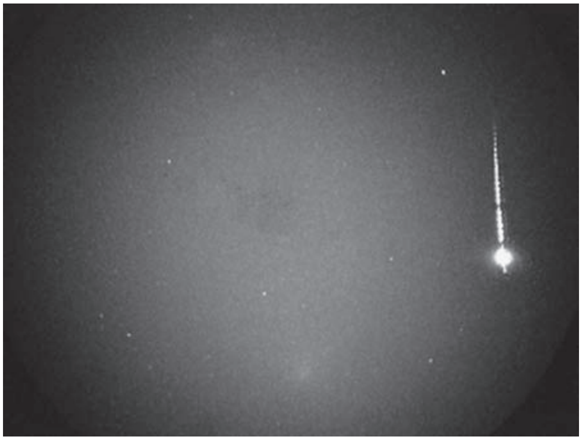

Fig. 8.4. An example of a meteor with a terminal burst.

magnitude. This magnitude class makes up only a few percentage of the entire night's total.

Before ending the discussion on meteor magnitude, the bright end of the magnitude scale must be discussed. Occasionally there are meteors that are brighter than any of the stars or planets. These are called fireballs and are most frequently seen during the major annual showers. It is difficult to estimate their brightness, as there are no suitable references. Venus reaches a magnitude −5 when brightest. This is the low range of the fireball magnitudes. Iridium flares can reach as bright as magnitude −8. The Moon can vary from −5 at thin crescent to −9 when half illuminated to −13 at its full phase.

The Moon is an extended object and difficult to compare to a meteor. What you can do, though, is use the moonlight on the ground to help estimate the brightness of fireballs. Hopefully no one is staring at the ground when a fireball occurs, but often one can see the landscape being illuminated at the edge of his or her vision. If you are familiar with the illumination produced by the different phases of the Moon then this will help you estimate the magnitude of your fireball. If your fireball exceeds the light of the full Moon it is time to use your best judgment as the next reference, the Sun, which is magnitude −27. A fireball that turns the sky blue is in the vicinity of magnitude −20. Just remember, like in all magnitude estimates, observers (especially newcomers) tend to overestimate the brightness of meteors.

If you can master the parameters listed under basic and intermediate categories then you can provide scientifically useful data. Perhaps 90% of meteor observers are in this category. There are some, though, that go beyond this and submit data that are not easily obtained but can be very helpful in analyzing meteor activity.

8.3 Advanced Visual Observations

There are several parameters not mentioned previously that are not absolutely necessary to list when observing meteors and meteor showers. These include meteor color, length, duration, angular velocity, radiant distance, meteor altitude, distance from the center of your vision, and the recording of persistent trains. The more information you can provide about a meteor, the better. Although it is difficult to record more than a few details during high activity, while rates are low try adding some, if not all, of these parameters.

Meteor color would seem to be a basic parameter, but the reason it is listed under advanced is because it is not a necessary parameter. Meteor colors are highly subjective to each individual observer. Even experienced observers witnessing the same meteors often see different colors. It is interesting to record colors and to see the diversity and where your color threshold lies. Other than white, most observers see yellow, orange, and blue. Swift meteors tend to be blue, green, or yellow, while slower ones are orange and yellow. When seeing color in swift meteors you are actually witnessing the reaction of the upper atmosphere to the passage of the meteor. Color in slower meteors is produced by the meteor itself and can hint at the principal composition of the meteor. A red meteor indicates a presence of silicon, orange indicates sodium, yellow indicates iron, green indicates nickel, blue indicates magnesium, and violet indicates calcium.

The length of each meteor is an interesting parameter to record. This is helpful in recording the meteor's angular velocity if you choose to do it mathematically. Most observers grossly overestimate the length of each meteor. If you view 45° from any radiant the average length will be near 5°. That sounds short, but it is the distance of the "pointers" located in the Big Dipper. For observers in the southern hemisphere this is roughly the length between the brilliant stars alpha and beta Centauri. A short meteor is one that is 2° of less. A long meteor would be one in excess of 10° in length.

The duration of each meteor is difficult to record. Like meteor lengths the duration of meteors is usually overestimated. The average meteor lasts only 0.4 of a second. Recording duration to 0.1 of a second is improbable. A more realistic goal would be to achieve a 0.2 s accuracy. This can be done using the appearance of the meteor. A meteor streak or flash indicates a duration of 0.2 s. The head of the meteor becomes visible at 0.4 s but is still difficult to see. The head is easy to see at 0.6 s. At 0.8 s and slower the meteor is easy to follow and to trace its path. Fireballs can last several seconds. Meteors in excess of 5 s are rare and should be viewed with suspicion. Re-entering satellites and booster rockets can imitate fireballs but usually last much longer.

The estimate of angular velocity is a useful tool in shower association. Shower meteors are expected to exhibit a certain angular velocity (expressed in degrees per second) at different radiant distances and altitudes. If your estimate of the angular velocity does not fall within the expected range for the area of the sky you are viewing then most likely your meteor does not belong to that particular shower. The International Meteor Organization (I.M.O.) suggests that you estimate the length of a meteor and then mentally prolong its duration to 1 s.[1] This will instantly give you its angular velocity. It is important that you know the length of a second accurately. If you are mathematically inclined you can also calculate the angular velocity by dividing the length of a meteor by its duration. It should be noted that the IMO does not endorse using the mathematic procedure.

Recording the radiant distance for each shower meteor is another interesting project. Since the radiant is an area rather than a point in the sky, there is no need to be precise with this estimate. An estimate to the nearest 10° is sufficient. At each increment from the radiant each meteor is expected to exhibit a certain length.

If you also record the altitude of each meteor in conjunction with the radiant distance then you can also calculate the expected angular velocity.

Meteor altitude should also be recorded in increments of 10°. The altitude can not only help determine the angular velocity, but it can also give the absolute magnitude of each meteor. The absolute magnitude is the brightness of a meteor negating the effect of the atmosphere. There is little difference between a meteor's actual magnitude and the absolute magnitude in altitudes above 45°. Below 45° altitude, the thickening atmosphere blocks more of the light from both stars and meteors. At an altitude of 10° this magnitude extinction can reach a full 5 magnitudes at sea level. Therefore a brilliant fireball of magnitude −5 will only appear as a bright zero magnitude. For long meteors the altitude should be estimated for the midpoint of the path. Finally, at higher elevations, where the air is thinner, the magnitude is far less than that experienced at sea level. It is for this reason that it is suggested that the elevation of your observing site be listed on your report form.

Recording the distance from the center of your vision (DCV) was an experiment initiated by the American Meteor Society. Theory has it that with increasing brightness the average DCV should also increase. The results of one study agreed with the theory – with some interesting results. About 99% of the sixth-magnitude meteors reported occurred within 10° of your DCV. This helps you understand why less than 1% of the available sixth-magnitude meteors are actually seen. You have virtually no chance of seeing such a faint meteor unless it passes near the center of your field of view. Even then most of them are missed, especially the swift meteors.

On the bright side of the magnitude scale, over 90% of the negative magnitude meteors occurred outside the 10° range. The means a large portion of these bright meteors occurs at the edge of your field of view and are not well seen. If you choose to include DCVs, estimate these distances to the nearest 10°. This measurement can also describe the accuracy of your observation. A lower DCV would indicate that the meteor was well seen and that the data are more accurate than those seen at the edge of your field of view.

The last item you can include is the appearance of persistent trains. Persistent trains are smoke-like streaks left behind in the meteor's path after the meteor itself is extinguished. This phenomenon is usually only seen in swift meteors. The cause of these trains is not precisely known, but it is thought to be caused by emissions from the meteor itself or a chemical reaction with the atmosphere as the meteor passes though the volume of air. It could also be a combination of the two. If you witness a persistent train you should note its duration in seconds. Quite often they only last one-half second. Extremely bright fireballs can produce trains lasting several minutes. Do not confuse persistent trains with meteor trails. These trails are the streaks often seen in swift meteors, but they do not persist once the meteor has vanished.

8.4 Plotting Meteors

Some advanced meteor observers have the desire to record the meteor paths they see on star charts. This adds another dimension to their observations, as they not only have raw data but also plots of the meteors they see. Meteor radiants become readily apparent when several meteors line up from the same source.

Plotting is an art that takes a while to master. The first few hundred are bound to be inaccurate. It takes at least one thousand plots before anyone becomes proficient. Constant plotting is also necessary in order to keep your skill sharp. Since it takes more time to plot than to record data, meteor plotting is especially advantageous when activity is low. Do not plot when rates exceed 20 meteors per hour. You will be missing too many meteors while focused on the chart. Plotting shower members during major annual showers is not necessary, as these radiants are already well known.

To accurately plot meteors you need to obtain gnomic star charts. These charts are specially designed to allow you to draw meteors as straight lines. Meteors plotted on any other form of chart would need to be curved to be accurate. These charts are inexpensive and available from the IMO. See the contact details for the IMO in the list of meteor groups in Chap. 10 of this book.

To plot meteors you will also need a large clipboard and a clear ruler. The clear ruler will allow you see stars that may be helpful in order to achieve an accurate plot. A small red flashlight is also a must. With one hand on the ruler and the other drawing the plot, you will need a come up with an idea of how you wish to light your clipboard. Some observers attach it directly to their clipboard. Others secure it to their hat. Most of us secure it to a string around our neck and use our mouth to hold it while plotting. Sanitary, probably not, but simple, and the string prevents any accidents plus keeps it from being lost.

Another must-have item for plotting is the black cord mentioned before. Immediately after seeing a meteor, extend the cord over the meteor's path. Stretch it out until you encounter a bright and easily identifiable star on each end. Now go to your plot and line your ruler up with these stars. Once they are lined up then draw the path of the meteor. Be careful not to overestimate the length of the path, which is a common error. Also be sure to number the plot with a reference number or the time in which you saw it so that you can easily match it up with the data you recorded for that particular meteor.

8.5 Using a Cassette Recorder

After several sessions of writing data on forms out in the field you will notice that quite a bit of time is spent looking at the form and not the sky. This time should actually be subtracted from your observing time. For the experienced observer this usually amounts to 15 seconds per meteor if just recording data and 30 s if recording data and plotting. Newer observers usually take much longer. If you average 30 seconds per meteor and see ten during the hour, then you should record your effective observing time, or "TeFF," as 55 min, or 0.92 of an hour. You cannot get around losing this time when plotting, but if you are just recording data you can use a cassette recorder to record your data on tape. You do not want to keep recording during the entire session, as it will take an equally long time to listen and record your data on paper. We suggest buying a microphone with an off–on switch. This will allow you to tape only when recording data and allow you to record many more meteors per tape. It also will allow you to keep the recorder under covers in case it is cold. These items have been known to fail in subfreezing temperatures, so it is important to keep them from freezing. There is also the possibility of using voice-activated recorders, but these seem to either start too late or stop prematurely and cut off a portion of the data.

Record the data in the same order as they appears on your observing form, or you will be jumping around on the page when listening to the tape. Another tip is to pause a second or two before stopping your tape in order to give you enough time to write. If you have to hurry while recording your data it may become illegible.

One last item that we cannot stress enough is to constantly, at least once an hour, make sure the device is working. Rewind it and replay recent recordings so that you can verify this. Check it every time you make a limiting magnitude estimate. During important sessions keep it close enough to your ears so that you can hear it running when it is recording.

8.6 Visual Observing Forms

There are numerous visual observing forms you can take out into the field or fill in after the watch. Each meteor group has its preference as to which data to include. With the advent of personal computers and spreadsheet programs it is now simple for you to create your own visual observing form. As long as your forms contain the basic information necessary there should be no reason why any meteor group would not accept your data.

Forms should be laid out in a logical sequence, such as time, magnitude, type, and then any other parameters you wish to include. This is most important if you record your data on tape to be played back after the session. If you record your data in the same sequence you list it on the tape, then transferring the data to paper will be easier.

In addition to listing the facts about each meteor the form should be set up to also include your name, observing location, and the time of the observing session. Separate areas for listing the limiting magnitude throughout your session are also helpful. You might also like to include the temperature and humidity (an indicator or transparency) in the beginning and at the end of the session. A comments line is also useful to indicate moonrise/moonset or other important factors that occur during your watch. See examples of visual observing forms in Figs. 8.5–8.8.

8.7 When to Observe

Many more meteors (both shower and sporadic) are visible during the early morning hours than during the evening hours. Therefore, it is advisable to limit your watch to the morning hours unless the radiant of a major shower is well positioned above the horizon during the evening. If you only have an hour to watch then do so during the last fully dark hour before dawn. The stop time, no matter the length of your session, should be at the onset of nautical twilight. At the start of astronomical twilight, when the Sun lies 18° below the horizon, the sky is still sufficiently dark to continue observing, especially if facing the western half of the sky.

Although the sky may still seem dark at this point of nautical twilight, the limiting magnitude rapidly worsens, introducing large corrections to your data. The Moon also plays a large role in meteor observing, as bright moonlight can spoil the show. The maximums of the Geminids and Perseids can still be impressive despite the light of a full Moon. All other showers can be severely compromised by moonlight. It all

DATE: ____ (year) ____ (month)____ (day) Begin ____ h____ m

End _____ h_____ m (____)

LOCATION: Long.=_________________ W.

Lat.=__________________N. Elevation =___________m

OBSERVER:______________________________PLACE:_______

____

LIMITING MAGNITUDE: _____@____:____

_____@____:____ _____@____:____ ______@_____:____

_______@____:____ _______@____:____

_______@____:____ _______@___:___ ______@____:___

PERCENT CLOUDY: ____% @ ____:____ ____% @ ____:___

____% @ ____:___ ____% @ ____:____

DIRECTION FACING & ALTITUDE: _______@____:____

_______@____:___ _______@____:____

BREAKS:____

____

COMMENTS:____

____

N	TIM	M	COL	TY	SP	TRA	ACCU	REMARKS

Fig. 8.5. A sample of a basic visual meteor form.

depends on the phase of the Moon and its position in the sky. The most favorable period is when the Moon is a slender waning crescent to the time it reaches a waxing gibbous phase. This encompasses the period when the Moon is 25–10 days old.

ADVANCED VISUAL METEOR OBSERVING FORM

DATE: ____ (year) ____ (month)____ (day) Begin ____ h____ m

End _____ h_____ m (____)

LOCATION: Long.=_________________ W.

Lat.=__________________N. Elevation =___________m

OBSERVER:______________________________PLACE:_______

____

LIMITING MAGNITUDE: _____@____:____ _____@____:____

_____@____:____ ______@_____:____

_______@____:____ _______@____:____

_______@____:____ _______@___:___ ______@____:___

PERCENT CLOUDY: ____% @ ____:____ ____% @ ____:___

____% @ ____:___ ____% @ ____:____

DIRECTION FACING & ALTITUDE: _______@____:____

_______@____:___ _______@____:____

BREAKS:____

____

COMMENTS:____

____

TIME	M	TY	DURA	LEN	V	DC	R.	AL	PL	REM

Fig. 8.6. A sample of an advanced visual meteor form.

Between 10 and 25 days old the Moon is either too bright or in the sky most of the night. If your sky is transparent then successful meteor observations can be undertaken when the Moon is near its last quarter or third-quarter phase. Although bright and in the

BASIC VISUAL METEOR OBSERVING FORM

DATE: 08 (year) 12 (month)14 (day) Begin 10h 00 m End 12 h 00 m (PST)

LOCATION: Long.=117°42' 31" W. Lat.=37°03' 55" N. Elevation =100m

OBSERVER: Meteor Man PLACE: Coldsville, CA USA

LIMITING MAGNITUDE: +5.0@10:00 +5.1@11:00 +5.2@12:00 ______@_____:____ _______@____:____ _______@____:____ _______@____:____ _______@___:___ ______@____:___

PERCENT CLOUDY: 0% @ 10:00 0% @ 11:00 10% @12:00 ____% @ ____:____

DIRECTION FACING & ALTITUDE: N45° @10:00 N45°@12: 00 _______@____:____

BREAKS: None____

____

COMMENTS: Full Moon near radiant. Speed = Slow, Medium, Fast Accuracy = Poor, Fair, Good

N	TIM	M	COL	TY	SP	TRA	ACCU	REMARKS
1	100	2		GE	M		G	
2	100	4		GE	M		G	
3	101	3		GE	M		G	
4	101	4		GE	M		G	
5	102	3			S		F	
6	102	2		GE	M		G	
7	103	1		GE	M		P	
8	103	0			S		G	Fragmented
9	103	3			F	1.0	G	
	104			GE	M		G	
	104	2		GE	M		F	
	105	4		GE	M		G	
	105	3			M		F	
	105	1		GE	M		F	
	105	0	YEL	GE	M		G	
	110	3			S		G	
	111		YEL	GE	M		G	Geminid
	111	2		GE	M		F	
	112	3		GE	M		F	
	113	1		GE	M		P	

Fig. 8.7. A sample of a completed basic visual meteor form.

sky during the entire morning, at this phase the moonlight is much less intense than at times when the phase is closer to full. A table is provided in the back of this book giving lunar circumstances for the major annual showers up to the year 2040.

ADVANCED METEOR OBSERVING FORM

DATE: 08 (year) 02 (month)14 (day) Begin 10h 00 m End 13 h 00 m (UT)

LOCATION: Long.=117°42' 31" W. Lat.=37°03' 55" N. Elevation =100m

OBSERVER: Meteor Man PLACE: Coldsville, CA USA

LIMITING MAGNITUDE: +6.0@10:00 +6.1@11:00 +6.2@12:00 +6.1@13:00

_______@____:____ _______@____:____

_______@____:____ _______@___:___ ______@____:___

PERCENT CLOUDY: 0% @ 10:00 0% @ 11:00 10% @12:00 10% @13:00

DIRECTION FACING & ALTITUDE: S45°@10:00 S45°@13: 00

_______@____:____

BREAKS:

None____

____

COMMENTS: Temp 34° Humidity 55% - Temp 30° H umidity 65%

TIME	M	TY	DURA	LEN	V	DC	R.	AL	PL	REM
1011	3		.4	2°	5					
1019	5	AN	.6	3°	5		60			
1027	4		.6	4°	7	0				
1033	3		.8	5°	6					
1038	4		1.0	5°	5					
1043	3	AN	.6	4°	7		40			
1048	2		.6	5°	8					
1059	1		1.0	3°	3					
1111	2		.4	6°						1 sec
1118		AN	.6	5°	8		60			
1125	3		.8	6°	5					
1133	5		.6	5°	8	0				
1150	4		.6	5°	8					
1200	2		.4	3°	8					
1213	1		.6	4°	7					
1219	4		1.0	7°	7					
1229			.6	5°	8					
1235	1		.4	2°	5					
1245	4		.6	4°	7	10				
1255	2		.6	4°	7	20				

Fig. 8.8. A sample of a completed advanced visual meteor form.

8.8 Where to Observe

The main requirement for a suitable observing site is a dark sky, free of obstacles such as trees or buildings. The suggested minimum limiting magnitude is +5.0. If you cannot see stars of at least magnitude +5.0 then it is suggested you find a darker observing site. Unfortunately, this rules our most urban locations with all the lights present that obscure the fainter stars. Remember, though, that your eyes take time to adapt to the darkness. If you cannot see these faint stars after going outside, wait 30 min and let your eyes adapt to the darkness. Your sky may be suitable after all! It is astounding to see the increase in meteor activity seen from rural sites verses urban ones. Unfortunately, it is just a waste of your time to try to observe meteor showers under poor conditions. We all envy those people who can simply step into their backyard and have dark skies.

If you are forced to seek darker skies in rural areas we highly suggest that you not go alone. A companion helps keep you alert while both observing and driving. It is also not a good idea to do observing from any roadside pull out. Look up the nearest astronomical group, as they usually offer secure areas under dark skies in which you and others can carry out your astronomical aspirations. During periods of major showers there are also many other people out watching the display. This offers an opportunity to share your passion for meteor showers with others and perhaps the chance to find another observing partner.

If observing with a partner or in a group everyone *must* keep their own data. Meteor analysis all over the world is based on the single observer. Data from more than one person must never be combined. Do not let others influence your data, either. Record your estimates for each meteor, not someone else's. This does not mean you cannot communicate among observers, but always record your data first before discussing any particular meteor. For example record your estimate for a bright fireball and then you can discuss it with others. Do not first shout "Wow, that must have been a magnitude −15!" Record your estimate first, then discuss it. Do not go back and change your estimate after discussions, no matter how far off you feel it is. Even though you are in a group you must act as if you are observing alone. We cannot stress this point enough!

8.9 Equipment

You do not need much equipment when observing meteor showers, but there are a few items that can make the session much more comfortable. A good lawn chair is an important investment. Those cheap metal tube models fold up nicely, but after a few sessions they usually end up ripping or the tilt adjustment fails and you end up needing something to prop them up. Heavy-duty plastic lounge chairs are nice, and there are fancy ones available if you are so inclined. Do not forget a pillow to keep your head comfortable.

Experienced observers usually have a method of tracking the time without having to check a wristwatch every time they see a meteor. One method that is becoming more popular is the use of talking clocks. These are clocks that announce the time at the touch of a button. These clocks can be found in stores for the visually impaired and at some electronic stores such as Radio Shack. Another method is to have a shortwave receiver and listen to the time signals provided by the National Institute of Standards and Technology on the shortwave frequencies of 2.5, 5.0, 10.0, 15.0, and 20.0 MHz. To the first-time user these time signals can be somewhat annoying, and you certainly do not want to use this method if viewing from your backyard, where the neighbors can be bothered. But out in rural areas, especially if viewing alone, these signals and the constant information provided can be a companion.

Even during the summer months you can become chilled just lying there motionless. Bring a blanket to protect against the cold. You can always lie on it if you do not need it. You might bring a light sleeping bag and end up crawling inside it halfway through the session. A heavy sleeping bag is necessary during the cooler months, when most of the meteor activity occurs. A hat or stocking cap is also advisable, as a lot of heat escapes from your head during the course of a night. Long underwear is also recommended for warmth. Some ingenious observers in Canada have built "coffins" to use during their severe winter nights. Some of these coffins even have heaters attached to blow warm air inside. No sense being miserable if you are going to outside at night!

Other items not to forget if viewing away from home are extra pencils, forms, and charts. It is also a good idea to have a second red flashlight plus extra batteries for both the flashlight and the cassette recorder. If viewing away from home also remember to bring plenty of water and some snacks should you become hungry during the watch. A cell phone is also a good idea, in case those staying home need to contact you or vice versa. Be sure your remote observing site has phone coverage, as there are dead zones outside city areas where cell phones will not work.

8.10 Telescopic Observations

This name is a bit misleading, as very few observers actually use telescopes to view meteoric activity. The field of view through a telescope is much too small to allow a chance to see many meteors. Nearly all observers in this field use binoculars, which offer a wider field and allow observers to see faint meteors that would otherwise be missed by an observer using their unaided eyes. Typical telescopic observers use 8 × 50 or 10 × 60 binoculars, where the first number indicates the magnification and the second the aperture of the objective lenses in millimeters. The apparent field of view should range between 45 and 70°.[2] An observer using binoculars can typically see meteors as faint as eighth magnitude. This allows the observer to see an average of 6 and 8 meteors an hour during early morning sessions.

The typical telescopic observer plots the activity he or she sees. Plotting charts are available free of charge from the IMO at http://www.imo.net/files/data/telescopic_charts/. With the small field of view, telescopic plots are usually far more accurate than those produced by visual observers.

Major annual meteor showers usually do not add a substantial number to the telescopic rate. These showers are usually weaker in the fainter magnitudes. Only one telescopic shower has been discovered and verified. These are the alpha Lyrids of mid-July. Telescopic rates during this period average three times the normal rates. There must be others, but the lack of telescopic observers has prevented them from being discovered.

Comfort is a prime obstacle to telescopic observers. Normal binocular tripods necessitate that you sit and look upward. This can be strenuous after only a short period of time. Small, lightweight binoculars can be hand-held but do not offer the limiting magnitude that larger sizes can produce. These smaller binoculars are also often not as well built as the larger ones. Serious telescopic observers should invest in a side mount, which allows you to lie back comfortably in a lounge chair while observing. The mount lies to one side and holds the binoculars over the eyes of the observer. This is basically a hands-free operation, which allows the observer to easily plot the activity seen and also keep warm while observing. These mounts are expensive but can also be used for casual deep-sky viewing during the nonproductive evening hours.

This is a neglected field, where any amateur can contribute valuable information. The only group that currently has a section devoted to telescopic observing is the IMO. Details on the Telescopic Section are available online at http://www.imo.net/tele. The section commissioner may be contacted at tele@imo.net.

8.11 Photographic Observations

There is always a yearning to capture on film or disk some of the meteor activity one sees. In order to accomplish this you need a camera that is capable of taking time exposures in the range of 5–15 min, depending on the sky conditions and your particular setup. Most of us, myself included, still use the trusty old mechanical single lens reflex (SLR) film camera for this purpose. The setup is simple, as all you need besides the camera is a tripod and a cable release to keep the shutter open for the desired length of time. Just aim the camera at the sky, focus, and hope a bright meteor passes through the camera's field of view. A meteor will appear as a streak passing perpendicular to the parallel star trails on the exposure. This presents an accurate positional accuracy, much better than plotting, that can be used in scientific research.

There are some strategies one can employ to increase your odds of capturing a meteor. The first is to make sure plenty of bright meteors are available so you would want to photograph during the night of maximum activity of a major annual shower. The Geminids are the best, followed by the Perseids and the Orionids. Geminid meteors are especially photogenic, as their slower velocities allow them to cross the field of view for a longer period, allowing the camera to capture more light.

You can also use special lenses and fast film to enhance your quest of capturing meteors on film. The standard 50 mm f1.8 lens is actually a good lens for this purpose. It has a decent field of view and is fairly fast. A wide-angle lens such as the 24- or 28-mm varieties is also good. These lenses have a larger field of view but at f2.8 are slower than the standard lens. You can somewhat make up for this deficiency by using a faster film. Film speed should be at least ISO (International Organization for Standardization) 400 and films as fast as ISO 3200 are also available.

No matter your sky conditions you want to take exposures of at least 5 min. Taking shorter exposures uses too much film, plus you spend too much time at the camera. You will want to use this interval if your sky conditions are poor with light pollution, a bright Moon, or hazy conditions. For these times be sure to use a film with an ISO of 400, so it will not fog. Also, at this interval, the star trails on your photograph will be short, allowing you to still easily recognize the constellations.

If your conditions are better you can stretch the interval to 10 min using a film rated at ISO 400–1600. At this rate you only need to advance the film six times per hour. Finally, if you photograph under excellent conditions you can experiment with exposures up to 15 min long and films as fast as ISO 3200. By trying a number of combinations of exposure times versus film speed you will find the right combination for you.

Although star colors and pink and green meteors are nice, there is no reason to use color film. It is more expensive than black-and-white film and offers no advantages other than decorative. This is especially true with faster films and longer exposures, which often produce unappealing green or brown sky backgrounds.

You will also want to aim your camera where the meteors are most numerous. The lower 45° of the sky produces more meteor activity, so you will want to aim your camera as low as possible but still avoiding the horizon and haze. Most of us, unless you are photographing in the dry air from the desert or a mountaintop, will end up pointing the camera roughly half way up in the sky. You will also want to avoid pointing the camera directly at the radiant, as shower meteors that appear near the radiant are short and not good candidates for photography. The area of sky 45–90° distant from the radiant produces longer meteors, which are much easier to see on film.

Memorize the field of view of the camera. If you see a bright meteor pass through this area then immediately end the exposure and advance to the next. This will limit the stars trailing and produce a more pleasing picture. You can avoid star trails altogether by mounting the camera on a tracking device that follows the star's path through the sky. This must be accurately aligned with the north or south celestial pole in order to work. Some observers simply use their telescope mount, with or without the scope, for this purpose.

What kind of success can you expect photographing meteors? During the strongest annual showers you can only expect to capture an average of 1 meteor per hour. The odds of a bright meteor passing through the camera's field of view are remote. Meteors must be at least of first magnitude to show up on film. Even at this brightness they only show up as a faint streak. Unfortunately a great majority of the meteor activity is second magnitude and fainter. For this reason many serious photographers use two or three cameras aimed at different areas of the sky in order to increase their chance of capturing meteors on film.

Unless you process your own film you should ask that your pictures of the night sky be developed but not printed. This will save you a lot of money. Once they are developed take a magnifying glass and examine each frame, looking for that streak of light that indicates a meteor. Have these frames printed and verify that indeed it is in fact a meteor and not a plane or satellite.

You may wonder how your digital camera would fare in capturing meteors. Unfortunately, the normal digital camera has an exposure limit of only 15 s. This interval is much too short, and you will end up taking hundreds of exposures before capturing a meteor. Digital SLRs are another story. These expensive cameras take wonderful pictures of the night sky without the need for film. All the adjustments you need are on the camera, including ISO settings and exposure length.

Digital SLRs also seem more sensitive, as many photographers using these devices have captured two to three times more meteors per hour than those taken

Fig. 8.9. An example of an unguided time exposure.

Fig. 8.10. An example of a guided time exposure.

with film cameras. If you can afford a digital SLR by all means make the purchase. Not only do they produce outstanding photos of the night sky, they also produce fine results through the telescope (Figs. 8.9 and 8.10).

8.12 Video Observations

Video observation is the newest technique in recording meteor activity. This method uses either an intensified camera or a low-light camera to capture the meteors that pass within its field of view. The video feed can be attached to either a camcorder to save the observation on tape or fed directly into a computer for instant analysis and archiving.

A video system has many distinct advantages and few drawbacks when compared to other forms of monitoring meteor showers. The most advantageous feature is that it can act as another set of eyes and gather data whether you are present or not. I myself set up a video system because my work schedule changed and I need to be on the job at 2:00 a.m. This is during the prime meteor-observing hours, so instead of missing the opportunity to observe on the clear nights I work, I use the video system to record, and then I analyze the activity that I otherwise would have missed. I also find it useful to use when the Moon is bright and the resulting meteor activity is low. I also take my system to rural observing locations when I am doing telescopic work. While I am at the eyepiece a camcorder is attached to the video camera and is recording the night's meteor activity. During major annual showers I also record the activity from remote observing sites using a camcorder while doing simultaneous visual observations.

The accuracy of video data is much better than visual or telescopic plotting. However, due to the normally larger field of view, the accuracy is less than that achieved by photographic means. An offset to this disadvantage is the fact that a video system can capture many times more meteors than an ordinary camera.

An intensified video system consists of three parts, a lens, the image intensifier, and the video camera. A fast lens projects the sky onto the image intensifier, which in turn amplifies the image between 10,000 and 100,000 times. The amplified image is then captured by the video camera and fed to the computer or a camcorder for recording on tape. Figure 8.11 shows the video system used by the American Meteor Society.

In time the sensitivity of video cameras will probably reach a point where they can be used as stand-alone devices and still produce useful results. They are still far less sensitive than intensified systems (see later), but under excellent skies can record meteors as dim as third magnitude. Image intensifiers are expensive and often subject to import regulations due to their use in military applications. Depending on the lens employed in the system an intensified system can reach

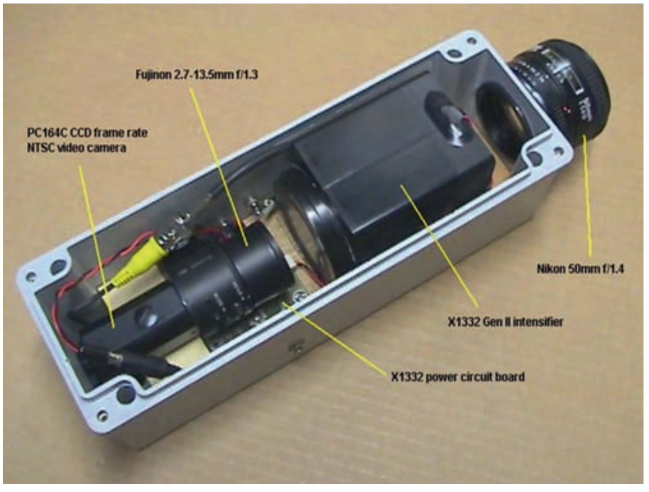

Fig. 8.11. The video system used by the American Meteor Society.

down to ninth magnitude. Fast lenses with narrow fields of view can go deeper than those that are slower and have a wider field.

If you have an intensified system you must be careful to avoid bright lights from entering it. The Moon will permanently damage the intensifier by burning the photoelectric cells it encounters as it drifts across the field of view. You must aim your camera so that there is no chance the Moon can drift across the field of view. If you are unsure, then be safe and aim it toward the north in the northern hemisphere and toward the south in the southern hemisphere. You should also never operate the system with the Sun less than 12° below the horizon, as the Sun and bright twilight can also ruin your system. It is also important to keep the system capped during the day, as the Sun can burn a streak across a tube even when the power is off.

There are two methods of analyzing video data. You can either view the videotape yourself or run it through a computer and let the software do the computing. Viewing the tapes yourself takes long periods of time, and you will miss many meteors no matter how hard you concentrate. Using the computer is much easier, plus these programs can also determine the shower association, magnitude, velocity, length, and duration. They can also save still images or sequences of the meteor. They are not perfect, but these programs have a better perception than most observers and totally rule out any chance of bias in shower associations.

There are three software packages available for analyzing video data: *MetRec* by Sirko Molau, *MeteorScan* by Peter Gural, and *UFOCapture* by SonotaCo. All three of these programs can analyze videotapes or run real-time analysis. To run *MetRec* you need a video frame grabber installed in your computer. Mr. Molau suggests using the Matrox PCI family of frame grabbers with the Matrox II being the one of choice.[3] These frame grabbers are expensive but may often be found for sale second hand on the Internet for less than half the original cost. *MetRec* runs under MS-DOS and therefore requires a PC computer running Windows 98SE or earlier. There is a network of video systems across Europe and the United States using *MetRec*. The data are pooled and analyzed by Mr. Molau, with the results comprising the list of possible new showers presented in Chap. 7 of this book.

MeteorScan was originally for Macintosh users, but may now be used on either Macintosh- or Windows-based systems. *UFOCapture* is strictly for Windows-based computers. *MetRec* is available free of charge to single users, while *MeteorScan* and *UFOCapture* are inexpensive for the many hours of work they save the observer.

8.13 Radio Observations

Using radio methods is the only way to monitor during the daylight hours or on nights of cloudy weather. Radio systems consist of a specialized antenna, usually of the Yagi design, and an FM receiver. Meteors produce a column of ionized gas as they pass through the atmosphere. This column is known to reflect radio waves from transmitters on Earth's surface. If the radio waves strike the column of ionized gas at a perpendicular angle they are reflected back to the transmitter. This is called *backscatter*, and systems that use backscatter are called *radar systems*. If the radio waves strike the column of gas at a nonperpendicular angle then the radio waves will be reflected back toward the ground away from the transmitter. This is called *forward scatter*, and systems that use this are called *forward scatter* *systems*. Most radio systems are of the forward scatter type that can monitor radio waves on FM receivers.

The columns of ionized gas created by meteors usually last for only a fraction of a second. Brighter meteors can produce columns that last for several seconds, often as visible persistent trains. A radio meteor event will occur as a sudden fragment of a broadcast where there was no signal before. When using FM receivers find an empty frequency in the low end of the FM band between 88 and 104 MHz. If you happen to have a multiband receiver then use the VHF band frequencies between 40 and 60 MHz. Channel 2, if not used in your area, is a particularly good frequency at 55.25–59.75 MHz.

Radio observers monitor the activity in two ways: they manually count the number of events or reflections or use a computer to do the monitoring. Out in the field it is often interesting to leave your radio on and listen to reflections while observing visually. The antenna attached to most vehicles is not well suited for this work, but reflections can still be heard on the brighter meteors if the geometry is right. Free or low-cost software is available on line from Ilkka Yrjola and Christian Steyaert of RMOB. (e-mail addresses are included at the end of this book.)

For your home system a six-element Yagi antenna should be used for the best reception. Do not orientate it horizontally but rather angle it slightly so that local stations do not overpower your reception. For sporadic activity the activity curve will be identical to that of the visual observer. The best radio rates for sporadic meteors will occur near 0600 LST, and the least will occur near 1800 LST. Unlike the visual observations of shower meteors, the best shower rates will occur when the radiant is located halfway or 45° in altitude and not when the radiant is located on the meridian. This means that each shower will have two peaks each 24-h period, one when the radiant is rising and reaches 45° altitude and another when the radiant is setting and reaches 45° altitude.

8.14 Fireball Observations

Fireballs are meteors that reach a magnitude of −5 during their peak brightness. This magnitude is equivalent to the planet Venus when at its brightest. Fireballs indicate a larger-than-normal meteoroid has entered the atmosphere. Many people imagine these fireballs to be as large as a house to produce such brightness. Actually, at the tremendous velocities in which these objects strike Earth, an object the size of a baseball can produce a fireball seen hundreds of miles away.

Fireballs are uncommon but not exactly rare. They commonly occur during the maximum activities of major showers. Some meteor showers produce more fireballs than others. Fireballs are common during the Geminids, Perseids, Leonids, Quadrantids, and Lyrids. They are less common during the eta Aquariids, delta Aquariids, Orionids, and Ursids.

Studies have determined that during off-peak nights only one in 1,200 observed meteors becomes brighter than magnitude −5, and only one in 12,000 becomes brighter than magnitude −8.[4] The diurnal peak of fireballs occurs near 1800, which is opposite the peak of visual meteor rates. Therefore, most fireballs occur during the early evening hours, when people are often outside, usually traveling in their vehicle. A majority of the fireball reports are from witnesses who are in fact in vehicles at the time they observed their fireball.

On an annual scale as seen from midnorthern latitudes, the peak of fireball activity occurs near the spring or vernal equinox in March. This is a time of normally slow meteor activity but rich in fireballs. For those located in the midsouthern latitudes the peak should also occur during their spring equinox in September. The lack of fireball reports from the southern hemisphere has yet to prove this fact.

Fireball observations are important, as they can provide information on possible meteorite falls. The percentage of fireballs that actually reach the ground is quite small. If sonic events are heard from any fireball then chances are much better indeed that it did in fact survive its plunge through the atmosphere. In these cases details provided by eyewitnesses can help determine a general area of such a possible fall.

When you witness a sporadic fireball you should try and recall as much information as possible. The time should be the first item recorded. It is amazing the spread in time that can be submitted for the same event. The Halloween fireball of 2005 is a good example. The American Meteor Society received over 100 reports of this event that occurred over the Mid-Atlantic states. All witnesses lived within the Eastern Time Zone, yet there was a spread of exactly 1 h for this event. Most reports differed by only a few minutes, yet there were some that exceeded 45 min. Try and provide the most accurate time possible.

Another important aspect of a fireball observation is your location. Try to provide accurate geographical coordinates. Usually the nearest city or town will suffice. Do not forget the state or province, as there are many duplicate names of cities. What is not helpful is providing the intersection of two streets or the nearest highway off ramp. These verbal descriptions may be a bit more precise, but the fireball recorder may be located in another state or country and will have no idea and usually no time to research street or highway names.

Other helpful but often difficult aspects to report are the directions and altitude in which the fireball appeared and disappeared. This is understandable, but a guess as to these directions is often better than none. The altitude should be simple, as the zenith has an altitude of 90° and the horizon is zero. Halfway up in the sky would be 45°, so an accuracy of 10° should not be too difficult to achieve. The directions are difficult at night unless you have a compass in your vehicle or actually know in which direction you are traveling. Reports that indicate no motion or little motion in events that last in excess of 5 s are puzzling to the recorder and make little sense unless the object was in fact moving directly toward you, a very rare incidence. Others seem confused as they state that the fireball passed overhead yet started at an altitude of 60° and ended near the horizon.

After the fireball has disappeared be sure to remain outdoors and try to listen for any sonic events. These usually occur with 1 min of the fireball and are normally limited to the brightest fireballs of magnitude −8 or brighter. They usually sound like sonic booms produced by supersonic aircraft but also have been described as sounds associated with something passing by at a high rate of speed.

There also have been reports of simultaneous sounds associated with fireballs. These sounds are called *electrophonic meteor sounds* and have been described as whistles, crackling sounds, or popping sounds. Since the speed of sound is much slower than that of light this may sound like an impossibility. However, the sounds are indeed real and are caused by very low-frequency radio waves produced by the fireball. These radio waves travel to the ground at the speed of light and are transformed into audible noise by items ranging from metal objects to frizzy hair. In my 40 years of meteor observations I have heard one delayed sonic boom produced by a meteor but am still waiting for a fireball that produces electrophonic sounds.

Other parameters of fireballs that you can record are the peak brightness, the duration, color, any persistent trains, or terminal bursts. The peak brightness or magnitude is difficult and usually not very accurate. Your best bet is to compare it to the light produced by the Moon at half-phase or full phase. This is a difference of four magnitudes and extends the brightness to a magnitude −13. Beyond that most people list it as being brighter than the full Moon or, in very rare cases, as bright as the Sun. The duration is usually grossly overestimated, as most fireballs last less than 5 s. The color is highly subjective but nonetheless interesting and worth recording. In slow fireballs it could indicate the principal content of the meteor. Persistent trains can occur in swift fireballs but are rare with those lasting in excess of 2 s. Finally, a terminal burst of light indicates a bolide, or exploding fireball.

Most meteor groups accept fireball reports, and there are several fireball report forms available online. The American Meteor Society (AMS) has an updated list of fireball reports posted on their website. Witnesses of bright fireballs are also invited to share their report on Meteorobs, the forum for meteor observers worldwide.

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Chapter 9

Meteor Activity Throughout the Year

Abstract

In this chapter the author discusses the sporadic and shower activity month by month. He advises the observer about what time to view and in which direction to face to see the best activity from each shower. Also provided are magnitude reference stars near the observers' fields of view so that they can compare the meteors they witness to stars of a known brightness. All possible showers are listed so that the observer easily knows which radiants will be active when out observing.

9.1 January Activity

After 5 months of high sporadic activity in the northern hemisphere, rates suddenly begin to fall in January. The decline is gradual, and rates are only slightly worse than those seen in December. Midmonth rates should produce a dozen sporadic meteors per hour during the late morning hours if viewing from dark rural sites. Evening rates would be 2–3 per hour. As seen from the southern hemisphere sporadic rates reach the first of two annual peaks in January. The southern observer should see 15 sporadic meteors per hour during the late morning hours if viewing from dark rural skies. A majority of this activity seems to occur in the southern half of the sky stretching from Carina, Puppis, Vela, and into Centaurus. During the evening random hourly rates should be near 3.

As seen from the northern hemisphere, the New Year is ushered in on a high note with the arrival of the *Quadrantids* or January Bootid meteor shower. The Quadrantids are weakly active New Year's morning, and rates are only marginally better the next morning. The peak occurs on the morning of the 3rd (or the 4th if a leap year), and rates can range anywhere from 25 to over 100 per hour. Evening observations of the Quadrantids are usually fruitless, so one should save his or her efforts for the morning hours. The best rates will be seen from north to east quadrant unless the Moon is present in the eastern half of the sky. If that is the case then switch to the western half of the sky and look toward the northwest. During this time of the morning zero-magnitude orange-yellow Arcturus (alpha Bootis) lies high in the east with first magnitude white Spica (alpha Virginis) 20° to its south. Good examples of second-magnitude stars are orange Kochab (beta Ursa Minoris) and Alkaid (eta Ursa Majoris). Third-magnitude stars within your field of view are Cor Caroli (alpha Canum Venaticorum) and Izar (epsilon Bootis). Fainter yet at fourth magnitude are epsilon Herculis and theta Corona Borealis. Easy-to-find fifth-magnitude reference stars include 6 Comae Berenices (just east of Denebola) and eta Ursae Minoris, the faintest star in the bowl of the Little Dipper. All of these stars and others mentioned in subsequent months may easily be identified on any quality star chart that supplies star designations.

While viewing Quadrantid activity you will also notice swift meteors from the Coma Berenices area. These are the *Coma Berenicids*, which peaked in December. If facing the northeast these meteors will enter your field of view from above, shooting downward toward the horizon. Slightly faster than the Quadrantids, these meteors provide a good percentage of persistent trains.

During January the *Antihelion* radiant travels from eastern Gemini through Cancer. It is best seen from the northern hemisphere, but the advantage is not all that great. The difference in rates' results is only one between the two locations. The first week in January provides the best Antihelion rates of the month. Observers should try to confirm activity from Leo (*January Leonids*) and western Hydra (*alpha Hydrids*) during the first week of the month, if the Moon cooperates during this period.

Shower activity is slow as seen from the southern hemisphere. Only a small trickle of the Quadrantids can be seen early in the month. The much weaker Coma Berenicids are also seen from a disadvantage from south of the equator. What a waste of warm summer nights with so little shower activity to be seen!

9.2 February Activity

February begins a 6-month period when meteor activity is best seen south of the equator. As seen from the northern hemisphere, sporadic rates are decent, but the decline of activity continues. At midmonth an observer under dark skies can expect to see ten random meteors per hour during the morning hours. Evening rates would be 2–3 per hour. Other than the Antihelions, shower activity is nearly nonexistent from north of the equator.

The *Antihelion* radiant spends the entire month in the large constellation of Leo. The northern hemisphere has a slight advantage in viewing this activity. There are slight peaks in the Antihelion activity near the 12th and 25th of this month. The latter date may be associated with the delta Leonids.

The weak *delta Leonids* are active during the second half of the month but are barely noticeable, even at maximum activity on February 25. An observer in the northern hemisphere, enduring the frosty February mornings, should face southward and try to catch some of the activity going on south of the celestial equator. During the first week of the month observers are encouraged to try and confirm any activity from the *February Sextantids*.

The action this month lies far south of the celestial equator, highlighted by the *alpha Centaurids*. This shower is active the first 3 weeks of the month and peaks on February 8 with an average ZHR of 5. Alpha Centaurid observers should begin their watch near midnight, when the radiant lies high in the southeast. Hourly rates may only average 4–5, but these rates can vary with some hours producing ten or more shower members. Southern observers have perhaps the most impressive stellar background this time of year with the Milky Way stretching straight across the southern sky and numerous bright stars dotting the heavens. Northern observers can only imagine this scene!

There are plenty of reference stars available for meteor magnitude estimates. Sirius (alpha Canis Majoris) and Canopus (alpha Carinae) can be used for magnitude −1. Rigel Kentaurus (alpha Centauri) itself is a fine zero-magnitude choice. The stars of Crux offer fine examples of first-magnitude stars. The stars of Triangulum Australe, just south of Rigel Kentaurus, offer stars in the second- and third-magnitude range. Beta Circini, located only a few degrees east of Rigel Kentaurus, and epsilon Muscae are of fourth magnitude. There are also numerous fifth-magnitude stars available near Rigel Kentaurus, most of these lacking common names due to their faintness. The Moon only enters this area of the sky as a waning crescent this time of year. If it is present within your field of view then shift your gaze westward toward Vela and Puppis, thus avoiding looking directly at the Moon.

Just as the alpha Centaurids are ending, the *gamma Normids* spring to life. This is somewhat a continuation of the southern action progressing eastward. Like the alpha Centaurids, they are best seen during the last few hours before dawn. The same guide stars may be used that were mentioned with the alpha Centaurids. This shower has a bit more of a northern declination; therefore, some activity may be visible from the northern tropics.

The southern sporadic rates fall a bit during February, down from the peak seen in January. Rates seen just before dawn from rural sites should be in the neighborhood of 13 per hour. Evening rates from the southern hemisphere would be 2–3 per hour. Again, most of the sporadic activity this time of year is concentrated in the southern half of the sky.

February also starts the best period for fireballs, usually seen before midnight. From now through mid-April is the peak sporadic fireball season, with spectacular fireballs being reported every few nights during this time of the year.

9.3 March Activity

As March arrives the bitter cold winter nights are less frequent in the northern hemisphere. Below the equator the heat of summer has just passed, and a hint of coolness is often evident in the morning air. Sporadic meteor activity continues its slide in the northern hemisphere. Rates that were once a dozen an hour in December are now down to only about 8 per hour during the morning hours. The evening skies are also quiet, as only 2–3 random meteors are visible per hour. Observers in the southern hemisphere also see their sporadic rates continue to fall the first half of the month. After the Ides of March, a sudden upward shift of sporadic meteor activity will occur in the southern skies. By month's end perhaps eight sporadic meteors may be visible per hour in the morning skies and 3, during the evening hours.

No matter your location, March is the least active month for shower meteor activity. No major annual showers are active this month. Only the minor showers known as the delta Leonids, gamma Normids, and the ever-present Antihelions add to the sporadic activity this month. The first week of the month sees the *delta Leonid* activity on the wane. The hourly rates have now fallen to near one shower member per hour. By the tenth, they will have fallen below one, and any activity will be scarce. The delta Leonid radiant is now located in eastern Leo, near the bright star known as Denebola (beta Leonis). This area of the sky rises near 1800 local standard time (LST) for observers in high northern latitudes, near 1830 SLT for observers in low northern latitudes, near 1900 LST for equatorial observers, and near 1930 LST for observers in low southern latitudes. No matter your location, this radiant is best observed near 0100 LST, when it is located on the meridian and highest in the sky. Delta Leonid meteors are intersecting Earth at an angle slightly from behind; therefore, they will display velocities that are slow compared to most meteors.

The second minor shower active in March is known as the *gamma Normids*. This radiant is located in the far southern constellations of Norma and Ara; therefore, the best views of this activity are from the northern tropics southward, where this radiant rises higher into the sky. The gamma Normids produce rates greater than 1 per hour for only a week, centered on March 13. At maximum activity hourly rates near 5 can be expected, but activity seems to vary year to year. As seen from high northern latitudes, this radiant never clears the horizon. Only from latitudes south or 35°N have any chance of seeing this activity. From low northern latitudes this radiant rises near 0130 LST. For equatorial observers, this radiant rises near 2300 LST. For low southern observers, this radiant rises near 2100 LST. No matter your location, this radiant is best observed during the last dark hour before dawn, since it culminates during the daylight hours. The gamma Normids strike Earth from a more head-on position when compared to the other showers active in March. Therefore, they will appear as swift meteors unless they are seen close to the radiant or near the horizon.

The last active shower during March is the *Antihelion*. This activity is also known as the Virginids, as the radiant lies within the borders of Virgo all month. The Antihelions reach an ill-defined maximum near March 24, when rates may reach three shower members per hour as seen from the equatorial regions. At that time the diffuse radiant is located in central Virgo between the bright stars Spica (alpha Virginis) and Porimma (gamma Virginis). This area of the sky rises near 1930 LST. For low northern latitudes and equatorial areas, the radiant rises near 1900 LST. For low southern latitudes, the radiant rises near 1830 LST. No matter your location, this radiant is best observed near 0100 LST, when it is located on the meridian and highest in the sky. The Antihelions intersect Earth at a perpendicular angle; therefore, these meteors are slower than average.

Observers in the northern hemisphere this month are urged to look toward the southern skies unless the Moon lies within your field of view. By looking in this direction, you can see activity from all three radiants as the constellations of Leo and Virgo parade across the sky. For southern observers, they should face northward for the delta Leonids and the Antihelions and southward for the gamma Normids.

Evening fireballs continue throughout March. They are more pronounced as seen from the northern hemisphere, perhaps because the Antapex radiant lies highest in the sky at this time. Southern observers should see a peak near their spring equinox in September, but this has yet to be verified.

9.4 April Activity

April showers may bring May flowers, but they also bring joy to meteor observers, as the long drought of major showers finally ends. Two major annual showers are active in April, along with one shower of variable strength and the Antihelion radiant. Sporadic rates are slowly declining for observers in the northern hemisphere. On a moonless morning perhaps 6–7 random meteors can be seen each hour from the northern hemisphere. Evening rates are less than half this amount. Sporadic rates continue to climb for observers south of the equator. Morning observers should be able to see at least eight random meteors per hour, while evening viewers should average 3 per hour.

The first half of April is actually sparse in overall meteor activity. Only the *Antihelion* radiant contributes to the sporadic meteor activity. This month the Antihelion radiant travels from central Virgo into the neighboring constellation of Libra. The "Virginid" portion of this activity ceases at midmonth, and a more active region, located in Libra, becomes active around the same time.

There are two periods in April when the Antihelion shower is more active than normal. These are April 4–9, with a peak on the 8th and April 16–23, with peaks on the 19th and 23rd from two different positions. Now that the radiant is located well south of the celestial equator, southern observers have the advantage, as the radiant rises earlier for them. It also culminates at a higher angle above the horizon for southern observers. Once again, the best time to view this activity is near 0100 LST or 0200 for those observing daylight saving time.

Near April 15, observers may begin to see activity from the constellation of Hercules. These medium-swift meteors announce the arrival of the *Lyrid* meteor shower. Lyrid activity slowly increases and reaches maximum activity on the morning of April 22. On that date the radiant still lies within the border of eastern Hercules, but the proximity of the prominent constellation of Lyra is a much easier marker for the radiant of these meteors. This area of the sky rises during evening twilight for observers located in high northern latitudes. From low northern latitudes it rises near 2200 local daylight time. For equatorial observers the radiant rises near 2200 LST. For low southern latitudes the radiant rises near 2300 LST. Morning twilight intervenes before the radiant reaches its highest point in the sky, so the best time to view the Lyrids would be during the last dark hour before the start of morning twilight, whenever that may be at your particular location.

Observers located in high northern latitudes have the luxury of the radiant being located very high in the sky during the morning hours. Therefore, one may look in any direction to see the best Lyrid activity. Do not look straight up at the radiant, though, as this is the worst possible direction to view meteor activity. Observers located further south should face toward the northern half of the sky to see the best rates their location provides. After the April 22 maximum, Lyrid rates fall off rapidly, and the shower virtually disappears by April 26.

The area of Cygnus is a fine area to center your view for seeing Lyrid activity. Zero-magnitude Vega (alpha Lyrae) lies westward toward the radiant. The first-magnitude star Deneb (alpha Cygni) lies in a rich Milky Way field in northern Cygnus. Kochab (beta Ursae Minoris) and gamma Cygni are good examples of second-magnitude reference stars. Delta Cygni and delta Draconis are examples of third-magnitude stars within your field of view. Eta cygni and epsilon Draconis are good fourth-magnitude guide stars. Finally, theta Ursae Minoris (in the bowl of the Little Dipper) and nu^1 Draconis are easy-to-find fifth-magnitude stars.

While viewing Lyrid activity observers may notice an occasional swift meteor darting upward from the eastern horizon. These swift meteors herald the start of the *eta Aquarid* meteor shower. Since this shower peaks in activity next month, we shall save further discussion of the eta Aquarids for our list of May showers.

Before we close April, there is one more shower of note. The *pi Puppids* are active for approximately 2 weeks, with maximum activity occurring one day after the Lyrid maximum (April 23). This shower's radiant is located in the southern constellation of Puppis, close to the brilliant star Canopus (Alpha Carinae). This area of the sky does not clear the horizon for high northern latitude observers, so this activity cannot be seen north of latitude 45°N. Conditions improve the further south one is located, as the radiant will be located higher in the sky and will also set later in the night.

Unlike most annual showers the pi Puppids are normally seen during the evening hours, as the radiant has already culminated prior to sunset. Since this is a new shower encountering Earth, activity is quite variable. In most years there will be little or no activity. Occasionally good rates will be detected from the southern hemisphere, where the radiant is located far above the southwestern horizon at dusk. These meteors are notable for their exceptionally slow velocity, often lasting several seconds before fading.

Observers should watch for activity during the first week of April from the *April Draconids*, with a radiant located between the Big Dipper and the tail of Draco. These would be extremely slow meteors are best seen near 0200 LST.

The first half of April also offers more evening fireballs than usual. This is a continuation of the activity that began in February. With the warmer weather more people are out during the evening hours; therefore, there are more possible witnesses to these events.

9.5 May Activity

The sporadic activity continues to slide for northern observers in May. Midmonth observers, even in dark rural skies, can expect no more than a half dozen random meteors per hour this time of year. At least the shower activity is good during the first half of the month. Evening rates from the northern hemisphere would be near 2 per hour. As seen from the southern hemisphere, sporadic rates climb to 15 per hour. This high count, alone with good eta Aquariid activity, provides good entertainment during the cooler autumn mornings. Evening rates for observers south of the equator would be near 3.

The first week of May is alive with activity from the *eta Aquariids*. This is definitely a postmidnight event, as the best activity is limited to the late morning hours. One should face eastward to see the best activity from this shower. The guide stars mentioned for the April Lyrids will work just fine for observers located in the northern hemisphere. Observers south of the equator should shift their field of view a bit further south and center it on the area of Sagittarius. Looking in this direction the first-magnitude star Fomalhaut (alpha Piscis Austrini) lies in the lower right or southern portion of your field of view. Two good examples of second-magnitude reference stars lie in Sagittarius, Nunki (theta Sagittarii), and Kaus Australis (epsilon Sagittarii). Pi Sagittarii and Dabih (beta^1 Capricornii) are two third-magnitude stars near the center of your field of view. Good fourth-magnitude reference stars include Rho^1 Sagittarii and alpha Coronae Australis. Easy-to-find fifth-magnitude stars include eta and upsilon Capricornii.

In some years a waning crescent Moon can interfere when you are looking in this direction. If this is the case shift your view either north or south, so that the

Moon leaves your field of view. This shower rises so late that a waxing gibbous Moon can be low in the western sky and not interfere with your session. Once the Moon has reached its full phase, there is no way to get around viewing with the Moon in the sky for the eta Aquariids. Once the Moon has reached last quarter, successful observations can again be undertaken.

While viewing the eta Aquariids some activity from the *eta Lyrids* can be seen. This radiant is situated well north of the celestial equator and so is best seen from the northern hemisphere. Centering your field of view in Cygnus will allow simultaneous views of both the eta Aquariids and the eta Lyrids. Southern observers looking toward Sagittarius can also have a good view of both showers. The eta Aquariids will come from below in the east, and the eta Lyrids will come from the left or northward.

During the month of May the *Antihelion* radiant passes through Libra, Scorpius, and into Ophiuchus. Better rates are now seen from south of the equator, where one could see up to 3 meteors per hour. Better-than-average Antihelion rates occur during the periods May 1–6, peaking on the 5th, and May 22–30, peaking on the 29th. While watching the eta Aquariids these meteors will enter your field of view from the upper right, no matter where you are located.

9.6 June Activity

Sporadic meteor rates reach their nadir in June as seen from the northern hemisphere. The hourly rates are 5–6 per hour during the late morning hours from rural sites. Evening rates are far worse, with an average of 1–2 random meteors appearing each hour. As seen from the southern hemisphere sporadic rates are similar to those of May, and perhaps a bit stronger as we approach a July maximum. From deep southern latitudes expect to see up to 16 random meteors per hour during the late morning hours. Evening rates would be near 3–4 per hour.

There are no major annual showers active in June. The only showers of significance are the *Antihelions* and the variable June Bootids. The Antihelion radiant moves from southeastern Ophiuchus to northern Sagittarius during June. It also reaches its most southerly declination during this month. Therefore, observers in the southern hemisphere will see slightly better activity from this source. There are four periods of enhanced Antihelion during June. The first occurs during the period of the 5th through the 14th, with a peak on the 13th. The second occurs during the period from the 17th through the 26th, with a peak on the 18th. The third occurs between June 24 and June 30, with a peak on the 29th. The fourth and final enhancement occurs during June 23 through July 1, with a peak on July 1. The overlapping periods have different radiants within the vast Antihelion area.

The variable *June Bootids* are active between June 22 and July 2, with a peak near June 27. This is strictly an evening shower that may be observed as soon as it becomes dark. The high northerly declination favors northern observers, even though the night is short this time of year.

If your sky is clear at midmonth you may try watching for activity from the *June Lyrids (xi Draconids)*. This shower has been off and on several lists. It has currently been deleted from most lists but has produced interesting activity in the past. The radiant(s) lies between Vega (alpha Lyrae) and the head of Draco. Activity seems to fluctuate between the two radiants. This shower again favors northern hemisphere viewers.

During early June you may wish to try and see the strongest daylight shower of the year, the *Daylight Arietids*. An occasional long meteor from this shower may be seen shooting upward from the northeastern horizon just before the break of dawn.

Observers are also urged to verify any activity from the northern *June Aquilids*, which are active during the last week of June. Rates peak on June 25.

9.7 July Activity

As seen from the northern hemisphere, sporadic rates finally begin rising in July. The first half of the month looks a lot like June, but during the second half of July, rates really take off. In mid-July the morning observer can expect to see between 9 and 10 random meteors per hour. Evening hourly rates would be near 2. From the southern hemisphere, sporadic rates reach their annual peak near midmonth. An observer in the deep southern hemisphere can see up to 17 random meteors per hour during the late morning hours. During the evening the average hourly rates should be near 4.

After a slow first half of the year, shower rates also increase dramatically during July. On July 3, the first of these showers, the *alpha Capricornids*, begin to appear. On the 12th, they are joined by the *delta Aquarids*. Three nights later, the *Piscis Austrinids* begin to appear. The rates at midmonth for these three showers is still less than half that of the sporadic rate, but that will soon change as all three showers approach maximum activity the last week of the month.

Also at midmonth, the *Perseids* begin appearing as they streak from the northeast. All the while the Antihelion radiant is producing 2–3 meteors per hour from eastern Sagittarius and on into central Capricornus. The areas of Capricornus, Aquarius, and Piscis Austrinus are a hotbed of activity this time of year. Observers in the southern tropics are best suited to see this activity as it passes overhead from their vantage point. Observers from these latitudes can begin observing this activity as soon as 2300 (11:00 p.m.) LST. This complex is best placed on the meridian near 0200 LST. You should face due north and center your field of view in western Pegasus. The first-magnitude stars Altair (alpha Aquilae) and Deneb (alpha Cygni) lie to the west. Alpheratz (alpha Andromedae) and Deneb Kaitos (beta Ceti) are good second-magnitude examples that lie to the east. Some third-magnitude stars, such as eta Pegasi and Sadalmelik (beta Aquarii), also lie close to the center of the field of view. Good fourth-magnitude reference stars consist of kappa and 1 Pegasi. Finally, easy-to-find fifth-magnitude stars are 31 Pegasi and kappa Delphini. Observers in the northern hemisphere should face due south, toward the western Pegasus, northern Aquarius area. The same magnitude reference stars can be used as those mentioned for observers in the southern hemisphere.

The *Antihelion* radiant that crosses Capricornus during July is yet another radiant that can be added to this area. Members of this shower would be slower than all but the alpha Capricornids. Enhanced Antihelion rates occur on the 16th through the 22nd, with a peak on the 21st. Another period of enhanced rates occurs from the 25th through the 31st, with the peak occurring on the 25th. Normal rates this month are only 1–2 per hour during the first half of July and 2–3 during the second half of the month.

Observers are also encouraged to look for any activity from the *beta Aquariids* between July 17 and 22. Maximum activity for this shower occurs on July 19.

The highlight of the telescopic year also occurs in July. The *alpha Lyrids* are active in mid-July, producing three times the normal rates seen by telescopic means.

9.8 August Activity

August is the best month to view meteors from the northern hemisphere. The combination of high activity and warm summer nights makes meteor observing a pleasure. Sporadic rates are near a dozen per hour during the morning hours. Evening rates offer 3–4 per hour. As seen from the southern hemisphere, rates that were as high as 17 a month ago have now dropped to 8–10 per hour. Evening rates of 2 can be expected at this time of year.

The many showers that peaked in late July are still active during the first week of August. Observers are urged to still face southward and monitor this activity until the 10th, when the Perseids kick into high gear. On the 10th, full attention should be given to the Perseids. The southern activity can still be seen darting into your field of view from above, but it will be difficult telling members of one shower from another. In this case it is suggested that all these meteors be listed as delta Aquariids, as this is the strongest radiant present in that portion of the sky.

The *Perseids* are best seen from the 10th through the 15th, with maximum activity falling on the 12th, or 13th, if it is the year before a leap year. Although Perseid activity can be seen all night long, meteors are vastly more numerous after midnight.

One should either face due east or due north to see the Perseids, whichever is the darkest direction. The lone example of a zero magnitude in this portion of the sky is Capella (alpha Aurigae). There are two first-magnitude reference stars, Deneb (alpha Cygni) and Aldebaran (alpha Tauri). Second-magnitude stars are numerous, with Polaris (alpha Ursae Minoris) and Menkalinan (beta aurigae) being well positioned. Third-magnitude reference stars include delta Persei and Pherkad (gamma Ursae Minoris). Fourth-magnitude stars include gamma Trianguli and tau Persei. Easy-to-find fifth-magnitude reference stars include eta Ursae Minoris and 42 Persei.

The other northern radiant active during this time is the *kappa Cygnids*. This shower is visible all night long, producing slow, often bright, meteors of fireball class. This shower is active most of the month and peaks on the 17th.

After midmonth all the southern showers shut down except for the *Antihelion* radiant. The Antihelion radiant now travels northeastward through Aquarius, producing 2–3 slow meteors per hour. There are three periods of slightly enhanced Antihelion rates this month. These occur July 30 through August 6, with a peak on the 2nd. Another occurs between the 10th and the 16th, with a peak on the 16th. The last period is August 8th through the 26th, with a peak on the 22nd.

There are several possible new weak showers that should be monitored in August. The first are the *August Capricornids*, which are active from 13th through the 24th. The peak occurs on the 22nd from a radiant near alpha Capricornii. These would be extremely slow meteors. The second is the *epsilon Cassiopeiids*. This weak shower is active from the 20th through the 26th, with maximum occurring on the last day of activity. These meteors would be fairly swift. The third shower is the *August Draconids*, which are active from the 26th through September 1st. Maximum activity occurs on 27th with meteors of medium velocity.

After midmonth the action slows considerably. The Perseids produce 5–10 meteors per hour during the third week of the month. After the 21st rates fall below 5 per hour, until the shower disappears altogether a few days later. As the Perseids die out the Aurigids begin. Rates for this shower are low except for the night of maximum activity, usually September 1st.

9.9 September Activity

September lacks any major annual shower activity but does offer high sporadic rates for the northern hemisphere. Average morning hourly rates are near 14 for observers under rural skies. Evening rates would be near 3 per hour. South of the equator, the sporadic action has diminished considerably. It has taken only 2 months to go from the annual high to near the annual low in sporadic activity. Morning rates are now only 4–5 sporadic meteors per hour. Evening rates would only be 1–2 sporadic meteors per hour.

The shower activity for September is clustered in the constellations of Perseus and Auriga. The first showers of the month are the *Aurigids*, which usually peak on the 1st. The shower has a narrow peak and is only noticeable on the night of maximum. Like all the showers in this portion of the sky, these meteors are swift with a high percentage of persistent trains. All of these showers are also best seen during the morning hours, when the radiant lies highest in the sky. The reference stars provided for viewing the Perseids will also do for the northern showers of September.

The Aurigids are only active until the 8th. By then, the *September Perseids* are in full swing, producing several meteors per hour during the morning hours. This shower peaks on the 9th, with ZHRs averaging 5. Activity then slowly winds down but never actually stops completely. On the 18th this activity switches to the *delta Aurigids*, as the radiant soon enters the constellation of Auriga. It remains active the remainder of the month, but rates remain low at only 1–2 shower members per hour.

The *Antihelion* radiant navigates through the constellation of Pisces this month. Rates are generally 2–3 per hour but sometimes increase a bit more during certain nights. These nights include the 5th (from two different radiants within the vast Antihelion area), the 8th, 14th, and the 18th. After the 25th the Antihelion radiant becomes intertwined with the two Taurid radiants. For the next 2 months it will be impossible to pick out the Antihelion activity from the Taurids, so it is suggested that the Antihelions be dropped for this period. The *Taurid* activity starts out in eastern Pisces and slowly migrates northeastward during October and November. These meteors are slow, very similar to the Antihelions.

There are four possible new showers that observers should keep an eye out for in September. The first two both reach maximum activity on the 1st and may be monitored along with the Aurigids. They are the *September Ursa Minorids*, which produce meteors of medium velocity, and the *Southern September Lyncids*, which produce meteors of medium-swift velocity. Other possible candidates for new showers are the *Northern September Lyncids*, which are active between the 9th and the 16th. They peak on the 13th and normally produce meteors with medium-swift velocity. Lastly, the *September alpha Orionids* are active from the 24th through the 30th. They peak on the 27th, usually providing swift meteors.

9.10 October Activity

In the northern hemisphere, October is a time of transition from the hazy skies of summer to the clear, crisp air of autumn and winter. After a bit of a lull in shower activity in September, October provides better activity along with a continuation of the strong sporadic rates. Northern sporadic rates as seen from rural sites average 16 during the morning hours and 4 during the evening. Luckily, the southern hemisphere shares in most of this shower activity, but their sporadic rates reach a nadir. Southern rates are only 4–5 during the morning and 1–2 during the evening.

The *Orionids* are active the entire month but are best seen during the period from the 18th through the 24th, with maximum activity occurring on the 21st. The Orionid radiant lies just north of the celestial equator; therefore, this shower is well seen over most of Earth. The radiant rises during the late evening hours, but observing sessions should wait until after midnight, when the radiant has achieved a decent altitude. Observers in the northern hemisphere should face south and those in the southern hemisphere should face northward.

Luckily, this portion of the sky is rich in bright stars with which to compare the brightness of each meteor. Reference stars of −1 include Sirius (alpha Canis Majoris) and Canopus (alpha Carinae). Zero-magnitude stars in this area include Rigel (beta Orionis) and Capella (alpha Aurigae). The first-magnitude stars include Aldebaran (alpha Tauri) and Pollux (beta Geminorum), and the second-magnitude reference stars include Alninak (zeta Orionis) and Mintaka (delta Orionis). Both of these are located in the belt of Orion. The third-magnitude stars in this region include Furud (zeta Canis Majoris) and zeta Tauri. The fourth-magnitude stars include theta Canis Majoris and mu Orionis. Lastly, easy-to-find fifth-magnitude reference stars include 2 Monocerotis (near Saiph or kappa Orionis) and 64 Geminorum (near Pollux).

While viewing the Orionids, members or the *Taurids* can be seen at the rate of 2–3 per hour coming from Aries and entering your field of view from the west. These meteors are much slower than the Orionids and easy to differentiate. The *epsilon Geminids* are active between the 14th and the 27th, with a peak on the 18th. This weak shower has a radiant that lies close to that of the Orionids, and the meteors are easily lost among the more numerous Orionid meteors. The *Leo Minorids* are also active near the Orionid maximum, with a radiant farther to the north in Leo Minor. These meteors are also swift, like the epsilon Geminids and the Orionids.

Near October 8, members of the elusive *Draconid* shower may be glimpsed during the evening hours. These meteors are extremely slow and radiate out of the head of Draco.

Several new showers have recently been discovered in far northern declinations, favoring northern observers. The *October Camelopardalids* are active, producing bright meteors mainly on the 5th from a radiant of only a dozen degrees from Polaris (alpha Ursae Minoris). Another radiant that lies close to Polaris is the *epsilon Ursa Minorid*. This shower is most active on the 12th. Another far northern shower is the *tau Ursa Majorids*, which peaks on the 15th. Lastly, getting down to more southern declinations, where shower members can be seen by all, are the *zeta cancrids*. This shower is weakly active the last week of the month and peaks on the 31st.

9.11 November Activity

The shower rates in November are not quite as strong as those seen in October, but the sporadic rates, at least for the northern hemisphere, continues to remain strong throughout the longer nights. Sporadic hourly rates seen north of the equator now average 16 during the morning hours and 4 during the evening. In the southern hemisphere sporadic rates now produce an average of half a dozen during the morning hours and 2 during the evening.

Both of the Taurid radiants reach maximum activity during the first half of November. Hourly rates as high as 5 can sometimes be seen near maximum. The Taurids are also known for producing impressive fireballs. These radiants cross west and central Taurus during November and are best seen during the early morning hours. The Taurid meteors are slow compared to most of the activity this month.

The Leonids are active from the 10th through the 23rd, with maximum activity occurring from the 17th to the 19th. No storms are predicted for the near future for this shower, but they are still impressive meteors, among the fastest seen. The best rates for the Leonids are usually seen with the radiant high in the sky, just before dawn.

Observers should face eastward when trying to view any Leonid activity. Northern observers should face a bit north of the radiant, and those located south of the equator should face south of it. Meteor brightness reference stars are not as plentiful in this region of the sky. Nothing brighter than first magnitude is located near your field of view. Examples of first-magnitude stars include Pollux (beta Geminorum) and Spica (alpha Virginis). Good second-magnitude reference stars include Alphard (alpha Hydrae) and Denebola (beta Leonis). The third-magnitude stars with your field of view include epsilon Leonis and epsilon Corvi. Some fourth-magnitude stars include iota Hydrae and alpha Corvi. Lastly, easy-to-find fifth-magnitude reference stars include beta Sextantis and alpha Comae Berenices.

Observers are also urged to monitor the alpha Monocerotids, which peak each November 21st with a radiant near the bright star Procyon (alpha Canis Minoris). Most years produce little activity, but an occasional outburst of this shower does occur. Possible new showers that should be monitored each November are the November Orionids. These showers are active from December 17 through December 5, and peaks on the 28th. These meteors would be slightly slower than the stronger Orionid shower, which peaked in October.

9.12 December Activity

The first half of December is a meteor watcher's paradise. Many minor showers are active during this time, leading up to the impressive Geminids, which peak on the 14th. As seen from the northern hemisphere, the sporadic rates remain high this month. One can expect to see 15–16 random meteors per hour during the morning hours if viewing from rural sites. During the evening hours 3–4 sporadic meteors should be seen. From the southern hemisphere sporadic rates are now recovering from the low in October. One should see 10–12 random meteors per hour from the southern hemisphere during the morning hours. During the evening, 2–3 can be expected.

Early December features the *Antihelions* (now traversing southern Gemini), *Puppid-Velids*, *Monocerotids*, *Sigma Hydrids*, and the beginnings of the *Geminid* shower. During the second week of the month you can add the *Coma Berenicids*. All of these showers are active during the Geminid maximum. So, in addition to the 60 plus Geminids visible each hour, an observer under dark rural skies should also be able to see at least a few sporadic meteors and 5–10 meteors from the minor showers. Therefore, it is possible to surpass 100 meteors per hour if the Geminids are in high gear and moonlight is not an issue.

The Geminid radiant lies near the zenith at 0200 LST for observers situated at midnorthern latitudes. These observers can face in the darkest direction to witness the best rates. Good rates can also be observed as early as 2200 (10:00 p.m.) LST. Observers south of the equator should face northward to see the best Geminid activity. Luckily, the Milky Way passes though Gemini, and many bright reference stars are available to compare with meteors. Sirius (alpha Canis Majoris) shines at magnitude −1. Rigel (beta Orionis) and Capella (alpha Aurigae) shine at zero magnitude. Good representatives of first-magnitude stars include Pollux (beta Geminorum) and Aldebaran (alpha Tauri). The second-magnitude stars with your field of view would include Menkalinan (beta Aurigae) and Alphard (alpha Hydrae). Good examples of third-magnitude stars would be epsilon Leonis and zeta Tauri. Stars that could be used as a good example of fourth magnitude could be nu Aurigae and iota Cancrid. Easy-to-find fifth-magnitude stars would be omega Aurigae and omega Hydrae.

After midmonth the shower rates suddenly become rather poor. The Antihelion radiant still produces 2–3 shower members on average while drifting through southern Gemini. The Ursids become active near the 17th and peak on the 22nd. Ursid rates are usually low, but small outbursts have been known to occur. Observers are also encouraged to monitor a possible new shower in Virgo from the 19th through the 24th. The epsilon Virginids peak on the 20th and produce swift meteors from northern Virgo.

Chapter 10

Meteor Groups and Organizations

Abstract

Potential meteor observers are encouraged to join a national or international group specializing in meteor observing. These groups provide updated news of meteor showers to come plus they often list results from members who have shared data. This chapter discusses groups that are currently active on a national or international scale. The author also provides details of each group and their specialties.

Observers are encouraged to join local, national, and international meteor groups. These groups can provide valuable information on locations to hold your observing sessions. They also allow observers to share data and information. The groups listed below, in alphabetical order, specialize in meteors and are easily located on the internet. Basic information, including websites and/or e-mail addresses is provided so that you may contact them. Your local astronomy group may also have an interest in meteor showers, so it would also be wise to contact them.

The Leonid storms of 1998–2002 were an important time for meteor groups. Many sprang up in that time period to provide information on the Leonids and meteor showers in general. After 2002 interest began to wane, and some of those running these websites moved on to other things. Unfortunately, some of the websites below may be somewhat dated. Still, most of the e-mail links within them are still good and connect you with those you seek.

10.1 American Meteor Society

This is the oldest meteor group in the United States, having been founded in 1911. American Meteor Society (AMS) offers tips on viewing shower activity plus tables of recent observations and fireballs. The AMS also has an active video section and lists results from their video systems. They also produce a quarterly journal titled *Meteor Trails*. There is a wealth of information listed on their website, including forms to e-mail for fireball sightings (*http://www.amsmeteors.org/*).

10.2 Association of Lunar and Planetary Observers Meteors Section

Association of Lunar and Planetary Observers (ALPO) has a section devoted to providing information on viewing meteor showers throughout the year. They also publish a quarterly newsletter with updated information on meteor activity (*http://alpo-astronomy.org/*).

10.3 Arbeitskreis Meteore e.V. (AKM)

This is an advanced German group specializing in the observation of meteors, halos, and other atmospheric phenomena. They publish an impressive newsletter titled *Meteoros* (*http://www.meteoros.de/*).

10.4 Astronomical Society Ursa Meteor Section

This Finnish group began in 1976 and encourages members to observe for 50 h annually and record 500 meteors. They publish articles under *Bolides* in the ASU Journal (*http://www.ursa.fi/ursa/jaostot/meteorit/indexeng.html*).

10.5 British Astronomical Association Meteor Section

British Astronomical Association (BAA) encourages meteor observations through the use of newsletters and section meetings. Prospects of upcoming activity are available on the website: *http://www.britastro.org/info/meteor.html*.

10.6 Dutch Meteor Society (DMS)

This is an advanced group specializing in many facets of meteor observing. They are well known for cutting-edge technology in meteor photography and video work. They cover all fields of meteor observation and offer an impressive newsletter titled *Radiant* (*http://home.planet.nl/~terkuile/index.html*).

10.7 International Astronomical Union Commission 22

Commission 22 of International Astronomical Union (IAU) studies bodies in the Solar System smaller than asteroids and comets. Their website provides details on many of the showers mentioned in this book (*http://meteor.asu.cas.cz/IAU/*).

10.8 International Meteor Organization

International Meteor Organization (IMO) was founded in 1988 to provide standards and universal methodologies in the observation and reduction of meteors and resulting data. In the beginning there was some resistance, as many groups worldwide wished to keep their own methods. With a truly international staff many of these objections were overcome, and most active meteor groups throughout the world now align themselves with the IMO. The IMO website is a valuable source of information, especially the analysis of recent meteor showers. The IMO journal, *WGN*, is also viewed as one of the best throughout the world. The IMO also sponsors annual meetings called International Meteor Conferences. During these meetings meteor enthusiasts from all over the globe unite to share their passion. These IMC's are usually held in different European countries each September (*http://www.imo.net/*).

10.9 MBK Team

MBK Team is a group of active meteor observers in Slovenia with special interests in comets, eclipses, aurora, and the Sun. The team was formed in 1999 with the intent to further their passion for these fields and to pursue extraordinary events, such as meteor outbursts, around the world (*http://www.orion-drustvo.si/MBKTeam/mbkteam.htm*)

10.10 Meteorobs

Meteorobs is a worldwide e-mail forum dedicated to discussions relating to meteor astronomy and observing. Observers of all levels of experience are invited to join and to share their ideas and data (*http://www.meteorobs.org/*).

10.11 Nippon Meteor Society

The Nippon Meteor Society (NMS) is a group that is organized and managed by professional scientists and many amateur observers. The purpose of the society is to promote observation, research, and diffusion of meteor astronomy and to cultivate friendships among meteor observers (*http://www.nms.gr.jp/en/*).

10.12 North American Meteor Network (NAMN)

This group was founded in 1995 to publicize the coverage of sporadic and shower activity. This group is strictly online, with no dues or fees. Much useful information is available on their website, including publications and observing aids (*http://www.namnmeteors.org/*).

10.13 Pracownia Komet i Meteorów

The Polish Fireball Network provides an impressive website loaded with information for the Polish meteor observer. They also publish a journal titled *Cyrqlarz* (*http://www.pkim.org/*).

10.14 Radio Meteor Observers Bulletin

Radio Meteor Observers Bulletin (RMOB) was started in 1993 to share radio observations by e-mail. Since then it has expanded to not only include radio data but to include all facets of radio observing. The website is useful and constantly updated (*http://visualrmob.free.fr/index.php*).

10.15 Sociedad de Observadores de Meteoros y Cometas de España (SOMYCE)

The Spanish Meteor Society is a group of astronomers and dedicated observers of meteors, comets, and asteroids. It was founded in 1987 and remains one of the most active groups in the world (*http://www.iac.es/AA/SOMYCE/somycee.html*).

10.16 Spanish Photographic Meteor Network (SPMN)

This group is also known as the Spanish Fireball Network. They were first organized in 1997 and aim to study interplanetary matter. They are best known for their development of an all-sky high-resolution camera (*http://www.spmn.uji.es/*).

10.17 The Society for Popular Astronomy Meteor Section

The Society for Popular Astronomy (SPA) Meteor Section aims to turn its members into proficient meteor observers providing valuable data. They provide a well organized website with useful information for the meteor observer (*http://www.popastro.com/sections/meteor.htm*).

10.18 Unione Astrofili Italiani Sezione Meteore

The Italian Union of Astro Enthusiast's meteor section provides updated information to the Italian meteor observer. This group has an impressive fireball network also (*http://meteore.uai.it/*).

Glossary of Terms

Meteor shower calendar

Shower	Activity period	Maximum		Radiant		Velocity (km/s)	r	ZHR	Class
		Date	SL	RA	Dec				
Antihelion source	Nov 25–Sep 30	–	–	–	–	30	3.0	3	II
Quadrantids (QUA)	Jan 01–Jan 05	Jan 04	283°16	15:20	+49°	41	2.1	120	I
α Centaurids (ACE)	Jan 28–Feb 21	Feb 08	319°2	14:00	−59°	56	2.0	5	II
δ Leonids (DLE)	Feb 15–Mar 10	Feb 25	336°	11:12	+16°	23	3.0	2	II
γ Normids (GNO)	Feb 25–Mar 22	Mar 13	353°	16:36	−51°	56	2.4	4	II
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	032°32	18:04	+34°	49	2.1	18	I
π Puppids (PPU)	Apr 15–Apr 28	Apr 23	033°5	07:20	−45°	18	2.0	var	III
η Aquarids (ETA)	Apr 19–May 28	May 05	045°5	22:32	−01°	66	2.4	60	I
Eta Lyrids (ELY)	May 03–May 12	May 08	048.4°	19:08	+44°	44	3.0	3	II
June Bootids (JBO)	Jun 22–Jul 02	Jun 27	095°7	14:56	+48°	18	2.2	var	III
P. Austrinids (PAU)	Jul 15–Aug 10	Jul 27	125°	22:44	−30°	35	3.2	5	II
δ Aquarids (SDA)	Jul 12–Aug 19	Jul 27	125°	22:36	−16°	41	3.2	20	I
α Caps. (CAP)	Jul 03–Aug 15	Jul 29	127°	20:28	−10°	23	2.5	4	II
Perseids (PER)	Jul 17–Aug 24	Aug 12	140°	03:04	+58°	59	2.6	100	I
κ Cygnids (KCG)	Aug 03–Aug 25	Aug 17	145°	19:04	+59°	25	3.0	3	II
Aurigids (AUR)	Aug 25–Sep 08	Sep 01	158°6	05:36	+42°	66	2.6	7	II
Sep. Perseids (SPR)	Sep 05–Sep 16	Sep 09	166°7	04:00	+47°	64	2.9	5	II
δ Aurigids (DAU)	Sep 18–Oct 10	Oct 03	191°	05:52	+49°	64	2.9	2	II
Draconids (GIA)	Oct 06–Oct 10	Oct 08	195°4	17:28	+54°	20	2.6	var	III
ε Geminids (EGE)	Oct 14–Oct 27	Oct 18	205°	06:48	+27°	70	3.0	2	II
Orionids (ORI)	Oct 02–Nov 07	Oct 21	208°	06:20	+16°	66	2.5	23	I
Leo Minorids (LMI)	Oct 23–Oct 25	Oct 24	211°	10:48	+37°	61	2.7	2	II
South Taurids (STA)	Sep 25–Nov 25	Nov 05	223°	03:28	+13°	27	2.3	5	II
North Taurids (NTA)	Sep 25–Nov 25	Nov 12	230°	03:52	+22°	29	2.3	5	II
Leonids (LEO)	Nov 10–Nov 23	Nov 17	235°27	10:12	+22°	71	2.5	var	III
α Monocero. (AMO)	Nov 15–Nov 25	Nov 21	239°32	07:48	+01°	65	2.4	var	III
Dec Phoe. (PHO)	Nov 28–Dec 09	Dec 06	254°25	01:12	−53°	18	2.8	var	III
Puppid/Velids (PUP)	Dec 01–Dec 15	Dec 06	255°	08:12	−45°	40	2.9	10	II
Monocero. (MON)	Nov 27–Dec 17	Dec 08	257°	06:40	+08°	42	3.0	2	II
σ Hydrids (HYD)	Dec 03–Dec 15	Dec 11	260°	08:28	+02°	58	3.0	3	II
Geminids (GEM)	Dec 07–Dec 17	Dec 13	262°2	07:28	+33°	35	2.6	120	I
C. Berenicids (COM)	Dec 12–Jan 23	Dec 20	268°	11:40	+25°	65	3.0	5	II
Ursids (URS)	Dec 17–Dec 26	Dec 22	270°7	14:28	+76°	33	3.0	10	I

Lunar conditions for the major annual showers at maximum activity 2008–2040

Year	QUA	LYR	ETA	SDA	PER	ORI	LEO	GEM	UMI
2008	24	16	00	23	11	21	20	16	24
2009	06	26	12	06	20	03	02	26	05
2010	17	7	20	15	02	12	12	08	15
2011	27	18	02	27	13	22	21	18	25
2012	09	01	13	08	24	06	06	01	09
2013	19	11	24	19	05	17	15	12	18
2014	02	21	05	01	16	27	25	21	00
2015	12	04	15	10	26	08	06	03	11
2016	22	14	26	22	09	20	18	14	22
2017	05	24	09	04	18	02	00	25	03
2018	15	07	18	14	01	11	10	06	14
2019	25	17	01	23	11	21	20	16	24
2020	07	00	12	07	22	05	03	00	07
2021	18	09	23	17	04	15	13	10	17
2022	01	20	03	28	14	25	23	19	27
2023	11	02	14	09	25	06	05	02	10
2024	20	13	25	20	07	18	17	13	21
2025	04	21	08	02	17	00	27	24	01
2026	14	05	17	12	00	10	08	04	12
2027	24	15	27	22	10	20	18	15	23
2028	05	27	10	06	20	03	01	26	06
2029	17	07	21	16	01	13	11	09	16
2030	28	18	02	26	13	23	22	19	25
2031	09	01	12	07	23	05	04	00	08
2032	19	12	24	19	05	18	15	12	19
2033	02	21	06	01	16	27	26	22	01
2034	13	04	16	11	26	08	06	03	11
2035	23	14	26	20	09	19	18	13	22
2036	04	24	09	02	18	28	00	24	03
2037	14	07	18	12	10	09	10	04	14
2038	24	17	01	22	11	19	20	15	24
2039	05	00	12	06	22	02	03	26	07
2040	17	09	23	16	04	12	13	09	17

Numbers indicate the age of the Moon in days

New = 0; first quarter = 7; full moon = 14; last quarter = 21

Activity period
The dates in which a shower equals or exceeds a ZHR of 1.

Altitude
The angle in the sky of an object with 0 being on the horizon and 90 at the zenith.

Class
I (Major Annual Showers), II (Minor Annual Showers), and III (Variable Showers)

Declination
Celestial latitude expressed in degrees north or south of the celestial equator.

Local Standard Time (LST)
Your local time no matter location or time zone. Those who observe daylight saving time or summer time must add 1 h to the quoted times.

Nadir
Lowest point in the sky.

"*r*"
The ratio between one magnitude and the next. A higher "r" value indicates a fainter shower.

Right ascension
Celestial longitude expressed in degrees or hours/minutes.

Solar longitude
Dates expressed in degrees with zero commencing at the exact moment of the northern hemisphere's vernal equinox (March 21).

Zenith
Straight up, or 90° altitude.

Zenith hourly rate (ZHR)
The standard conditions in which the limiting magnitude is +6.5 and the radiant lies in the zenith.

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