Astronomers' Observing Guides

For other titles published in this series, go to
www.springer.com/series/5338

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

ISBN 978-0-387-09460-1 e-ISBN 978-0-387-09461-8
DOI: 10.1007/978-0-387-09461-8

Library of Congress Control Number: 2008941004

Printed on acid-free paper

springer.com

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

Contents

Preface ... vii

Acknowledgements ... ix

Chapter 1 An Introduction to Meteorics ... **1**
1.1 Meteoroids in Space ... 1
1.2 Meteors Entering Earth's Atmosphere ... 2
1.3 Meteorites Reaching Earth's Surface ... 2
References ... 2

Chapter 2 Sporadic Meteors ... **3**
2.1 Random Meteors ... 3
2.2 Antihelion Meteors ... 6
2.3 Helion Meteors ... 8
2.4 Apex Meteors ... 8
2.5 Antiapex Meteors ... 9
2.6 Toroidal Meteors ... 10
References ... 10

Chapter 3 Major Annual Showers ... **11**
3.1 Quadrantids (QUA) #10 ... 12
3.2 Lyrids (LYR) #6 ... 18
3.3 η Aquariids (ETA) #31 ... 19
3.4 δ Aquariids (SDA) #5 ... 31
3.5 Perseids (PER) #7 ... 32
3.6 Orionids (ORI) #8 ... 44
3.7 Leonids (LEO) #13 ... 51
3.8 Geminids (GEM) #4 ... 58
3.9 Ursids (URS) #15 ... 65
References ... 71

Chapter 4 Minor Annual Showers ... **73**
4.1 α Centaurids (ACE) #102 ... 74
4.2 δ Leonids (DLE) #29 ... 75
4.3 γ Normids (GNO) #118 ... 76
4.4 η Lyrids (ELY) #145 ... 78
4.5 α Capricornids (CAP) #1 ... 79
4.6 Piscis Austrinids (PAU) #183 ... 81
4.7 κ Cygnids (KCG) #12 ... 82

4.8 Aurigids (AUR) #206 83
4.9 September Perseids (SPE) #208 85
4.10 δ Aurigids (DAU) #224 86
4.11 ε Geminids (EGE) #23 87
4.12 Leo Minorids (LMI) #22 89
4.13 Northern and Southern Taurids 90
4.14 Puppid-Velids (PUP) #255 92
4.15 Monocerotids (MON) #19 94
4.16 σ Hydrids (HYD) #16 95
4.17 Coma Berenicids (COM) #20 97
References 98

Chapter 5 Variable Showers 99
5.1 α Pyxidids (APX) #122 100
5.2 π Puppids (PPU) #137 101
5.3 Tau Herculids (THE) #61 102
5.4 α Circinids (ACI) #162 104
5.5 γ Delphinids (GDE) #65 105
5.6 June Bootids (JBO) #170 106
5.7 β Hydrusids (BHY) #198 107
5.8 Draconids or Giacobinids (GIA) #9 108
5.9 Andromedids (AND) #18 110
5.10 α Monocerotids (AMO) #246 111
5.11 Phoenicids (PHO) #254 112
References 113

Chapter 6 Daytime Showers 115
6.1 Capricornids/Sagittariids (DCS) #115 115
6.2 χ Capricornids (DXC) #114 116
6.3 April Piscids (APS) #144 116
6.4 δ Piscids 116
6.5 ε Arietids (DEA) #154 117
6.6 May Arietids (DMA) #294 117
6.7 o Cetids 117
6.8 Arietids (DAR) #171 118
6.9 ζ Perseids (ZPE) #172 118
6.10 β Taurids (BTA) #173 119
6.11 γ Leonids (GLE) #203 119
6.12 Sextantids (DSX) #221 119
References 120

Chapter 7 New Showers? 121
7.1 January Leonids (JLE) #319 121
7.2 α Hydrids (AHY) #331 123
7.3 February Sextantids (FSX) 124
7.4 April Draconids (APD) 125
7.5 North June Aquilids (NZC) #164 126
7.6 β Aquariids (BAQ) 127
7.7 August Capricornids (AUC) 128
7.8 ε Cassiopeiids (ECS) 129

7.9 August Draconids (AUD) #197 130
7.10 September Ursa Minorids (SUM) 131
7.11 Southern September Lyncids (SSL) 132
7.12 Northern September Lyncids (NSL) 133
7.13 September α Orionids (AOR) #211 134
7.14 October Camelopardalids (OCT) 135
7.15 ε Ursa Minorids (EUR) 136
7.16 τ Ursa Majorids (TUM) 136
7.17 Zeta Cancrids (ZCN) #243 137
7.18 November Orionids (NOO) #250 138
7.19 ε Virginids (EVR) 139
References 139

Chapter 8 Observing Meteor Showers 141
8.1 Basic Visual Observations 142
8.2 Intermediate Visual Observations 145
8.3 Advanced Visual Observations 148
8.4 Plotting Meteors 150
8.5 Using a Cassette Recorder 151
8.6 Visual Observing Forms 152
8.7 When to Observe 152
8.8 Where to Observe 157
8.9 Equipment 157
8.10 Telescopic Observations 158
8.11 Photographic Observations 159
8.12 Video Observations 161
8.13 Radio Observations 163
8.14 Fireball Observations 164
References 166

Chapter 9 Meteor Activity Throughout the Year 167
9.1 January Activity 167
9.2 February Activity 168
9.3 March Activity 169
9.4 April Activity 170
9.5 May Activity 172
9.6 June Activity 173
9.7 July Activity 174
9.8 August Activity 175
9.9 September Activity 176
9.10 October Activity 177
9.11 November Activity 178
9.12 December Activity 178

Chapter 10 Meteor Groups and Organizations 181
10.1 American Meteor Society 181
10.2 Association of Lunar and Planetary Observers Meteors Section 182
10.3 Arbeitskreis Meteore e.V. (AKM) 182
10.4 Astronomical Society Ursa Meteor Section 182

10.5 British Astronomical Association Meteor Section 182
10.6 Dutch Meteor Society (DMS) 182
10.7 International Astronomical Union Commission 22 182
10.8 International Meteor Organization 183
10.9 MBK Team 183
10.10 Meteorobs 183
10.11 Nippon Meteor Society 183
10.12 North American Meteor Network (NAMN) 183
10.13 Pracownia Komet i Meteorów 184
10.14 Radio Meteor Observers Bulletin 184
10.15 Sociedad de Observadores de Meteoros y Cometas de España (SOMYCE) 184
10.16 Spanish Photographic Meteor Network (SPMN) 184
10.17 The Society for Popular Astronomy Meteor Section 184
10.18 Unione Astrofili Italiani Sezione Meteore 185

Glossary of Terms **187**

Index **191**

Contents

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.

References

1. Petzal, David E. (1992) How fast is a speeding bullet? *Field and Stream.* 97: 23

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.

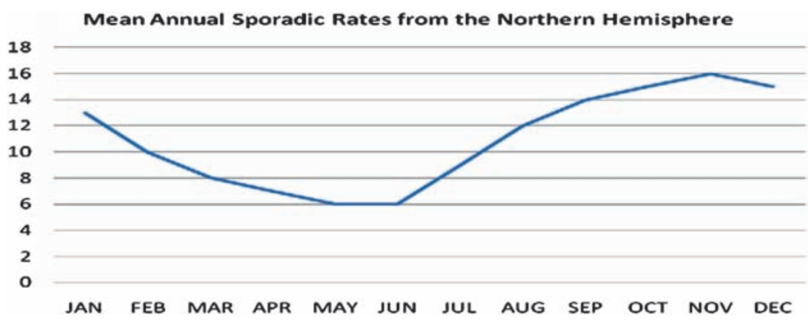

Fig. 2.1. Mean annual sporadic rates as seen from 45°N. under dark sky conditions.

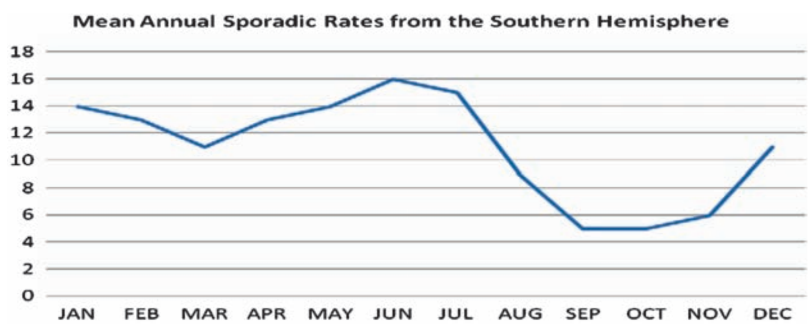

Fig. 2.2. Mean annual sporadic rates as seen from 45°S. under dark sky conditions.

Sporadic Meteors

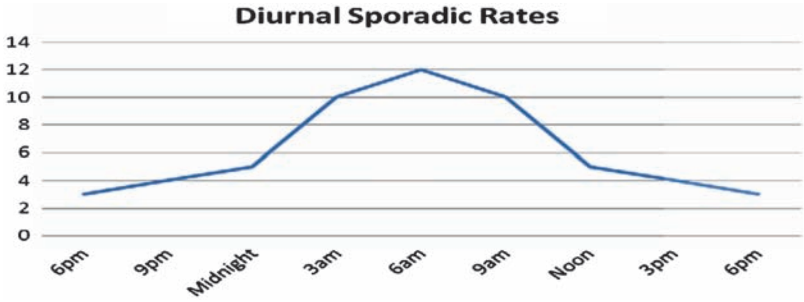

Fig. 2.3. Diurnal sporadic rates showing the peak near 6:00 a.m.

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.