Meteor Showers and Their Observation:
A North American Meteor Network Guide

[This guide is intended for the amateur just starting out with meteor observing and forms the basis of the training provided by the North American Meteor Network (NAMN). A complete copy of this guide is also available on the NAMN web page: http://web.infoave.net/~meteorobs/guide.html. Additional information is available by e-mailing the NAMN Coordinator, Mark Davis, at: MeteorObs@charleston.net]

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The North American Meteor Network

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The North American Meteor Network was established in June 1995 with three main purposes in mind: to recruit amateurs into the ranks of meteor observing; once recruited, provide guidance, instructions and training in the methods of meteor observing; and finally, to coordinate as many North American observations as possible to insure extensive coverage of sporadic and meteor shower activity.

There is a limited number of dedicated meteor observers worldwide. This lack of observers becomes extremely apparent when only North America is considered. Recruitment of observers is one of the primary reasons for the existence of the NAMN. Without people keeping watch for meteors, our understanding of meteor science would stagnate.

Anyone with an interest in meteors is welcome to join the network. We are an informal group with no membership applications or dues. Everything the network produces is done by volunteer efforts. We primarily use e-mail for communication among our members, but meteor watch notices and data reporting is sometimes done by letter and telephone. This Guide serves as the basic instruction manual for new observers of the North American Meteor Network. Meteor science is a constantly evolving field, so updates of this Guide will be made periodically. All of the materials NAMN publishes is made available to interested persons free of charge.

Meteor showers are known to exhibit unexpected activity and the only way to discover this is to insure complete coverage by coordinating observations. Because of this, NAMN has created what is considered a partnership with the International Meteor Organization (IMO). All of the observations we obtain are forwarded to the IMO for analysis and publishing. This insures our data is available to the international community for research purposes.

To study meteor showers, researchers need as much data from around the world as possible. As a "partner" with the IMO, we provide the data from North America longitudes. Our data is combined with that from Europe, Japan, Australia and other locations to provide a global analysis of a shower. This is the only means to provide a reliable analysis.

Meteor observing is easy, requires very little equipment, and can provide a lifetime of enjoyment. If you are interested in adding to our understanding of meteors, we invite you to begin observing with the North American Meteor Network. Once a serious interest is developed for meteor observing, it is recommended that the individual join a more formal organization devoted to the field. This allows you to share observations and experiences with others, become a more proficient observer, and see exactly how your efforts are improving our knowledge of meteor science. I recommend observers consider membership in the International Meteor Organization. More information on the IMO can be obtained by contacting:

International Meteor Organization
North American Coordinator
Robert Lunsford
161 Vance Street
Chula Vista, CA 91910

Acknowledgments:
I would like to thank Neil Bone for permission to use material from his book *Meteors* and the International Meteor Organization for making available some of the information found in the following pages and for allowing us to use material from their *Handbook for Visual Meteor Observations*.

Comment from the Coordinator:
This guide was designed with the beginner in mind. Although not covering the complete field of meteor observing, enough information is provided to learn how to begin making scientific observations. I expect to update and expand it occasionally to make the information more accurate and complete. I also expect errors to have crept in - those that have are solely my responsibility. Comments and suggestions concerning this handbook are welcome.

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CHAPTER 1: THE BASICS

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Meteor astronomy is generally neglected by amateurs. This is unfortunate as the field offers an excellent opportunity to contribute observations of scientific value and provides many enjoyable evenings of observing. There are only a few professional astronomers active in meteor research today, therefore the field relies heavily on the amateur for data. This data collected by amateurs can provide astronomers with information on the origin and evolution of meteoroids, which in turn sheds light on the origin and evolution of our solar system. With minimal equipment, and knowledge of a few basic concepts, you can begin a lifelong pursuit of meteor observing.

Meteors typically are small particles, normally no larger than a grain of sand, that enter our atmosphere at speeds of up to around 70 kilometers per second. They become visible at an altitude of about 100 kilometers due to their impact with the atmosphere. Most particles will evaporate from the effects of heat well before reaching the surface of the Earth. Those that do reach the surface of our planet are known as meteorites.

Although meteors can be seen any clear night, your chances of seeing greater numbers will increase if a few points are kept in mind. Moonlight and light-polluted skies wreak havoc upon meteors. Therefore, it is always best to observe when the moon is absent from the sky, as well as from the darkest skies possible.

Another important consideration is the time of night the meteor watch is held. Due to the rotation of the Earth, it's best to observe in the early morning hours. At this time, an individual is facing the direction the Earth is traveling in its orbit. Meteors will then collide with our atmosphere. At other times, meteors must travel at a speed that allows them to overtake the Earth. This situation is similar to a car traveling through a snowfall where more snowflakes will strike the front windshield rather than the back.

There are two broad groups of meteors. Those that arrive from random locations in the sky are termed sporadic, while others that appear to radiate from a particular region of sky come from meteor showers. The Perseids of August are an example of a meteor shower.

Sporadic meteors, also known as the sporadic background, generally produce only about 5 to 10 meteors per hour, but actually make up the bulk of meteors entering our atmosphere. It is believed that sporadics originate from unknown minor showers and meteoroids (objects which have not yet entered Earth's atmosphere) that once belonged to a shower but have left their original orbit. To increase your chances of observing these meteors, it should be kept in mind that they exhibit a diurnal variation where more occur before dawn than after dusk. There is also an annual variation where more occur in the second half of the year.

The highlight for meteor observers during any year is the nights when meteor showers are active. Although each shower is somewhat different, they normally last for several nights with a peak of activity occurring on a specific date. Chances of observing meteors are greatly increased on the night a shower is active as rates can range to 50 or more per hour depending upon the shower. These meteors can be distinguished from the sporadic background by the fact they radiate from one particular region of the sky known as the radiant. The Geminids of December, for example, appear to come from a location near the star Castor.

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CHAPTER 2: OBSERVING TECHNIQUE - VISUAL

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The best showers of the year are normally well advertised in advance through the various astronomy publications. As a result, many seasonal meteor observers join the veterans to watch the show. Whether you are a seasonal or veteran observer, most observers make some effort to record data - particularly during a major shower. Recording methods would vary from person to person if it wasn't for an attempt at standardizing the method. The International Meteor Organization was created to develop and promote meteor observing standards, and are the methods used by the North American Meteor Network. There are three reasons why all observers should follow these methods. First, they are straightforward and easy to learn. Second, the IMO represents observers worldwide, making it possible for all observations to be combined into one data set. And third, you've invested a considerable amount of personal effort into gathering your data - make sure it is accurate, useful and scientifically meaningful by adopting the IMO observing method.

There are two techniques that can be applied to visual observing. The first, known as visual counts, is the easiest for the beginner to learn. After sufficient experience has been gained, observers can begin using the second technique, that of plotting meteors.

A. VISUAL COUNTS

The counting of meteors is by far the simplest method of observation. Basically, all that is required is for an observer to watch the sky and record each meteor observed. But, for your observations to be useful, certain data must be recorded for your reports. After investing your time in collecting all of the following information, it would be a shame if you did not make your observation useable by researchers.

The NAMN Visual Summary Report should be filled out as soon as possible after your observing session. The NAMN uses a form that can be submitted electronically or by postal mail. Appendix C contains a sample of this form. The filling out of the report is where most mistakes are made. I can't stress enough the importance of correctly filling out your report, therefore, please contact the Coordinator if you are having any difficulty with reporting your data.

Since meteor researchers rely on a large quantity of data from many observers, each person should record the same data using the same methods. The following discussion covers the information needed for the Visual Summary Report as well as the proper method of gathering it. Items are discussed as they appear on the report.

1) OBSERVER INFORMATION - The standard observer information such as name, address, date, universal time, longitude and latitude of your site, and recording method is required at the top of the form.

It is standard to use a double date. For example, the observing night of August 11/12 represents the evening of August 11 and the morning of August 12. Even if the observation began after midnight, the date is still written as August 11/12. All observations should be recorded in universal time. If you are unsure of how to convert local time to universal time, then it is best if the report shows local time which can be converted later by those reviewing the report. Just insure that whatever time you use, the type is recorded along with what time zone you are located in. With this information, your local time can be converted to universal time.

Your longitude and latitude should be listed in degrees, minutes and if possible seconds for your observing location. Be sure to include your elevation above sea level. This can be obtained from topographic maps available from the U.S. Geological Service or some bookstores. Road maps are not normally accurate enough for this purpose. If you need help in determining site coordinates, please contact the NAMN Coordinator.

The data recording method may be by tape recorder or manual (paper and pencil).

2) OBSERVED SHOWERS - During your planned observing session, one or more meteor showers may be active. If you plan on trying to keep track of multiple showers, attention must be paid to the proper assigning of each meteor you see. For those just starting out, it is usually easier to watch for one shower only, recording all other meteors as sporadics.

Somewhat difficult at first, classification of a meteor becomes easier with practice. When a meteor shower occurs, all shower members radiate from a central location known as the radiant. By knowing where a shower's radiant lies, a meteor can be projected backward along the path it traveled to see if it crosses the radiant. Radiant diameters vary depending on the shower. Most are in the neighborhood of 5 degrees in size, although some are as large as 15x10 degrees. If a suspected meteor is traced back toward this radiant, count it as a shower member. Otherwise it should be considered a sporadic meteor. Care should be taken on nights when more than one meteor shower is active. On these nights, all radiants in the area of sky that is being covered should be accurately identified prior to the watch.

A handy technique for determining if a meteor belongs to a specific shower is a 3 foot long piece of rope. Tie a loop in both ends. Slip your thumbs into each end and be ready for the next meteor. When it appears, immediately line this rope up with the meteor's path. If the rope lines up with any of your active radiants and the velocity looks appropriate (see below), then you most likely have a shower member.

There are three criteria used in determining if a sighted meteor belongs to a particular meteor shower or not. The three things to consider are:

a) RADIANT - First of all, the meteor must line up with a radiant. As mentioned previously, most meteor shower radiants are about 5 degrees in diameter. As a guide, keep in mind that 10 degrees is approximately that of a fist held out at arms length.

b) VELOCITY - Each meteor shower produces meteors that are all close to the same velocity. The velocity of a meteor is dependent not only on its own velocity, but also that of our planet as it moves through space. You can use a scale of 1 - 5 to assign velocity to a meteor. Very slow (visible for several seconds) would be assigned a 1, slow a 2, 3 for medium velocity meteors, 4 for a rather fast one with a meteor head visible and 5 for those moving very fast, just leaving streaks with no visible head.

c) METEOR LENGTH TO RADIANT RELATIONSHIP - The closer a meteor emerges from its radiant, the shorter in length the meteor will appear. If it appears right in the radiant, it will appear as a star suddenly brightening and then disappearing (known as point meteors). The further a meteor appears from the radiant the longer the path of the meteor normally appears. Associating meteors with a shower using meteor length is difficult at first, but with practice becomes second-nature. A useful rule to remember is one developed by the International Meteor Organization which states:

> "For radiant elevations higher than 30° the apparent path length l of a shower meteor amounts at most to half the distance from the radiant to the start point. Consequently, the distance between radiant and start point of a plotted meteor on the chart has to be at least twice as long as the meteor path itself if the meteor is a suspected shower member."

When filling out the Visual Summary Report, list those showers that you were observing using their three-letter abbreviation. Also list the radiant location in right ascension and declination. The three-letter code and the radiant location at maximum can be obtained from the list of showers in Appendix A. Since sporadic meteors are considered random meteors, they do not need to be listed here. (Note: You will use the three-letter code Spo or SPO to identify sporadics later in the report.)

3) OBSERVING PERIOD - To make your observations worthwhile, observing periods should be a minimum of one hour or more in length. Keep in mind that if you take a break during a given observing period, you must subtract this time from the whole period. So, if you took a 10 minute break, you should make that observing period 70 minutes long so that you'll have 1 hour of "effective observing time," normally abbreviated as simply "Teff." Also, if you write your data down on paper as you observe, you must subtract that recording time from your total time observing (this is known as "dead time"). With practice you will be able to find an acceptable average, but as a guide use about 10 seconds per meteor to record all the pertinent data. Record your observing periods by universal time in this section.

The column "Field" is the center of your field of view. Although the typical field of view covers an area of sky of about 100°, where you look in the sky will affect your results. It's important to have some idea as to where you watched. Center your field of view to the south or southeast, or preferably between 20 and 40 degrees away from the radiant of an active shower. In addition, the center of your field of view should be in the range of 50 to 70 degrees above the horizon. At this elevation, you are able to see the area of sky from the horizon to the zenith, maximizing your chances of seeing meteors. The use of a lawn chair makes setting up at this angle a simple matter. Whatever location you choose as your field of the view, the center of it should be reported as a point in the sky using right ascension and declination coordinates. A handy technique to do this is to record a star or asterism near the center of your field of view. Then after the observing session is over, it is a simple matter to just look up the coordinates of this star or asterism and record them on the report.

As mentioned above, Teff is simply the total time during the observing session that you were actually watching the sky. Breaks and/or dead time are not included in the reported Teff. It is reported in decimal format such that a 60 minute observing session would be reported as Teff = 1.00. As a further example, a 72 minute observing session would be listed as Teff = 1.20. Note that for each 6 minutes of time, Teff = 0.10.

The NAMN, along with other observing groups, recognize the fact that the number of meteors an observer will see is reduced if any portion of their field of view is obstructed. To account for this, a correction factor is applied to all observations and is simply abbreviated as the letter "F."

Obstructions to a field of view can be caused by clouds, trees, buildings or other objects. While observing, the percentage of sky that is blocked by these obstructions is noted at the beginning of the session and at any time a change has taken place. This percentage is noted on the Visual Summary Report.

Clouds present a difficult challenge to observers since they are constantly changing. It would be almost impossible to list every change in cloud cover that takes place. Therefore, it is recommended that if clouds are present, the average cloud percentage over the last 10 to 15 minutes be reported. This will prevent an observer from spending so much time counting cloud cover that no meteors could be seen!

Due to several factors, observations when cloud cover exceeds 20 percent are not recommended. Instead, take a break or wait for another night when the clouds do not prevent observations.

After the observation is over, the percentages listed on the report form (see Section 5 – OBSERVING FIELD OBSTRUCTION) can be converted to a decimal value by using an equation provided by the International Meteor Organization. The equation that is used is:

$$F = \frac{1}{1 - k}$$

$$\text{where } k = \frac{\text{percent blockage x minutes}}{\text{total observing period}}$$

As an example, on the night of August 11/12, assume an observing period of 0500 to 0630. Teff for the period was 1.50 (90 minutes), and the sky was covered with 15% clouds for 15 minutes.

Therefore,

$$k = \frac{15\% \text{ x } 15 \text{ minutes*}}{90 \text{ minutes}} = \frac{2.25}{90} = 0.025$$

Then,

$$F = \frac{1}{1 - k} = \frac{1}{1 - 0.025} = \frac{1}{0.975} = 1.03$$

*(When calculating k, be sure to include all individual cloud cover estimates in the percent x minutes value.)

The correction factor F, equals 1.03 for the above mentioned observing period, and should be listed under the OBSERVING PERIODS section of the NAMN report. Note that when there are no obstructions to a field of view, F would then equal 1.00 and should also be listed for each observing period on the report. If you need help in recording or calculating this correction factor, contact the NAMN Coordinator.

The limiting magnitude of the sky (abbreviated as LM on the report form) determines the faintest star an observer can see. This will vary with the individual and is directly related to light pollution and/or the moon being above the horizon. It's determined by counting the number of stars within the boundaries of predetermined areas (see Appendix D). Usually one of these star count areas is near enough to the observer's center of view to make estimates accurate. After selecting the nearest star area, count all the stars you can see, including the corner stars. Later, you can determine the corresponding limiting magnitude from the appropriate table and record it on your report. Make these star counts at least every half hour, or more frequently when the sky appears to be changing. If your sky limiting magnitude drops below 5.0, either take a break or stop for the night. Corrections for a limiting magnitude this poor make observations unreliable. The LM you list on your report should be the average for that entire observing period (see Section 7 - LIMITING MAGNITUDE AND MEAN LIMITING MAGNITUDE).

Finally, note the number of meteors seen for each shower observed. Do this for the sporadics as well. Note that the number zero is used to indicate that you were watching that shower but none were seen. The slash character (/) indicates that during that period, you did not watch for meteors of that shower. This is normally done because the radiant of the shower is too low or because you were facing a direction of sky that prevented you from making reliable observations of that shower. As a check, make sure to fill out the totals columns for this section.

4) MAGNITUDE DISTRIBUTIONS - Magnitude distributions are obtained from the direct estimate of the magnitude of each meteor an observer sees. This is one of the most important contributions an observer can make to meteor science. Magnitude distributions are the first quantity determined in almost any research investigation. Therefore, always include a magnitude distribution for all meteor showers observed. This applies to sporadic meteors as well.

Everyone is probably familiar with magnitudes as it applies to astronomy. But when it comes to designating a magnitude for each meteor we see, difficulties can arise. Most people tend to overestimate their brightness when first recording magnitudes. Determining the magnitude of a meteor is done by comparing the brightness of the meteor to the brightness of a star with a known magnitude. This requires some knowledge of the locations and magnitudes of suitable comparison stars, but can be planned for prior to the observing session. To make comparisons accurate, you will need to identify a star of each magnitude between first and sixth. Also note the location and brightness of any brighter stars or planets that happen to be above the horizon. At the beginning of your observing session, take note of some stars for reference. Use the following list as a start:

(-12.0): full moon
(-8.0): quarter moon
(-6.0): crescent moon
(-4.0): Venus
(-2.0): Jupiter
(-1.5): Sirius
(-1.0): Canopus
(0.0): Vega, Arcturus, Rigel, Capella
(+1.0): Deneb, Altair, Pollux, Aldebaran, Spica
(+2.0): Polaris, Gamma Leonis, Alpha Andromeda, Gamma Geminorum, Alpha Ophiuchi
(+3.0): Beta Triangulum, Alpha Aquarii, Gamma Bootes, Epsilon Geminorum
(+4.0): Rho Leonis, Eta Persei, Delta Aurigae
(+5.0): Epsilon Lyrae

Check star charts and/or star catalogs beforehand to obtain magnitudes of other stars for reference during the night. Throughout the night, glance at stars with known magnitudes to acquire a feel for the brightness before a meteor suddenly appears. When it does, try to compare its magnitude to your chosen comparison stars, choosing the one that is closest in brightness. The magnitude of that star then becomes the magnitude of the observed meteor.

5) OBSERVING FIELD OBSTRUCTION- This is where the amount of your field covered by trees, buildings or clouds is recorded as a percentage. These percentages will be used after the observing session to calculate the value of F which is recorded under the OBSERVING PERIODS section of the Visual Summary Report.

As a reminder, estimate the percentage of field obstruction so that corrections can be applied to the data to account for meteors possibly missed. Clouds are difficult to estimate because they are constantly moving and are irregular in shape. But try to assign an accurate as possible percentage. If you reach a point in which 20 percent or more of the field is obstructed, you might as well take a break or just enjoy what you can see. Recording useful data at this point is impossible because adding the appropriate corrections to the data will make it unreliable.

6) DEAD TIME AND BREAKS - During a long observing session, breaks are a must. Recording the time that your attention is not focused on the sky for any reason is necessary as discussed in the section on OBSERVING PERIODS. Dead time is considered the time it takes you to record each meteor on paper and will be zero if using the tape recorder method of recording (assuming you have no dead batteries, tape failure, etc.).

7) LIMITING MAGNITUDE (LM) AND MEAN LIMITING MAGNITUDE - The average of the sky limiting magnitude for the entire night also needs to be reported. This requires little extra effort since the information was collected as explained in the OBSERVING PERIODS section above. On the report form, this is where each LM estimate is recorded along with the time, star count area used, and the results of the star count. List each estimate separately.

8) METEOR DATA - It is worthwhile to list each meteor you observed chronologically. For each meteor, several quantities are needed. First, record the time it appeared as well as the magnitude. The velocity is also recorded using the one to five scale previously discussed under Section 2b - VELOCITY.

The color of a meteor should also be reported on the form. Most meteors will appear white or yellow. Color can be an indication of meteor composition or the excitation of various atmospheric air molecules. Green is believed to represent oxygen molecules while blue has been suggested to indicate nitrogen. Brighter meteors often display a green or blue tint, although other colors are also reported. Some people try to assign colors to fainter classes of meteors, but there is probably not enough colored light to make the observation reliable. With anything fainter than +2.0 magnitude, it becomes increasingly difficult to assign color to a meteor.

The shower the meteor was a member of is listed using the shower association guidelines explained in Section 2 - OBSERVED SHOWERS. Meteors that are not a member of a recognized shower are listed as sporadics. For sporadics, use the three-letter abbreviation SPO.

If the meteor had a persistent train, the duration of the train is recorded. Many of the brighter meteors will leave behind this persistent train, which is simply a luminous streak of light that remains along the path of the meteor after it has passed. Usually, trains will fade rapidly and only last for a brief period of time. The typical duration of a train is in the order of a few seconds or less, although trains lasting 30 seconds or more are observed occasionally. The number of trains and their duration is valuable information for research purposes. If you can see a train for 0.5 seconds or more, record how long it lasted. If it's visible less than 0.5 second, it is referred to as a "wake." Not all meteors or meteor showers produce trains. However, some meteor showers do produce more trains than others. Among other things, train production is related to velocity. The faster the meteor enters the atmosphere, the greater the chance for meteor train production.

Historically, most observers throughout the world have recorded trains, but no central location was set up to receive the reports for train studies to be carried out. In most cases, data concerning persistent trains was either lost or collected on a regional basis only. The IMO in an effort to reverse this trend, has implemented a meteor train program where all train observations can be collected. It is hoped that this will provide a large enough database to allow more insights to be made about the phenomenon of train production. To participate in this study, a separate reporting form for meteor trains is required. To obtain a copy along with an instruction sheet, contact the NAMN Coordinator (see Appendix B).

The last two columns of the Meteor Data section of the report are Map and Accuracy. These apply to observations made using the plotting method and are discussed later in Section B of this chapter. When reporting observations using the visual count method, these columns are left blank on the NAMN Visual Summary Report.

9) SUGGESTIONS - In addition to the above, keep in mind major showers tend to bring groups of people together for observing, creating the problem of pooling data. Under no circumstances should this be done. If you prefer to observe with a group of people, insure that you record only the meteors you observed, not those pointed out by other observers. Finally, in preparing for a meteor observing night, probably the most important thing that you can do is not wear yourself out. Be sure to take a nap in the late afternoon or evening if at all possible. As the night goes on, you will find out how important this can be.

10) REPORTING - After reviewing your report for accuracy, send your reports immediately to the NAMN Coordinator (see Appendix B). Your data will be reviewed and forwarded to the International Meteor Organization.

B. PLOTTING METEORS

If you are ready to go beyond counting meteors, plotting is the next step in meteor work. Plotting is especially well suited to the minor showers of the year where only a handful of meteors are observed each hour. An active shower that produces only a few meteors per hour is difficult to distinguish from the sporadic meteors. It's one thing to observe 20 or more meteors coming from a radiant and an entirely different prospect when only three come from the radiant. Are all three of these meteors shower members? Only one? Two? Plotting can help us answer this question.

In short, plotting consists of taking the path of an observed meteor and transferring it from the sky to a map or star chart. Special charts, known as gnomonic charts are used for this purpose. Plotting the paths of meteors should only be done when shower rates are below 20 per hour. When rates are higher, many meteors will be missed while you are busy making the plots. This results in unreliable data. Another point to keep in mind is that while staring at the sky (after a meteor passes) to get a good fix on its location, additional meteors may appear. When this happens, it probably is best to get an accurate plot of the first meteor while counting the others as sporadics.

The NAMN has adopted charts that the IMO uses, which are the BRNO atlas charts. These have been specifically designed for meteor plotting. If you try plotting a meteor onto an ordinary star chart, the meteor would have to appear curved. This is not how meteors travel, so gnomonic star charts are used where the constellations are stretched out near the edges. This allows meteor paths to be plotted as a straight line. Currently, a master set of these charts can be purchased from the IMO for $4.00.

To make a plot, simply hold a piece of rope to the sky aligned with the path of a meteor trail. While holding the rope in position, take a few moments to get your bearings in the sky by using known stars or star patterns. Once confident of the meteor's position, draw an arrow to match it onto one of the charts you have previously selected for the night. Label this arrow with a number that will correspond to the data that is also recorded on the NAMN form (time, magnitude, velocity, color, train duration, map number and plotting accuracy). This information is used to complete the Meteor Data section of the Visual Summary Report. Plotting accuracy is a number you assign to your plot based on how accurate you feel the plot for any given meteor was. One (1) is very accurate, two (2) is a normal plot and three (3) represents a rough guess. Generally, an accuracy of one will be meteors that appeared near the center of your view. Meteors rated as a three are usually those that were seen out of the corner of your eyes, or one you may be confused over the location of its path. After noting the accuracy, the map that your plot appears on is recorded. Each chart has a map number stenciled onto it. In your report of each meteor, it is extremely important that you list the map number of the chart that the meteor appears on. Otherwise, the person entering your data into the computer will have to hunt through all of your charts for each meteor!

After the observing session is over, you can look at your plots to determine shower association. Normally, it is best not to know the location of any active radiants prior to observing because these may tend to bias your observations. But once inside, determine the active radiant positions based on the list of showers in Appendix A. Then draw a small circle on your chart(s) and label each active shower to show its radiant. Make shower determinations based on:

1) the meteor's alignment with the radiant,
2) the relative velocity of the meteor, and

3) the meteor's path length to radiant relationship.

Unlike when making visual counts with a tape recorder, plotting meteors WILL result in some time that you aren't actually watching the sky. And as with counting, this dead time must be accounted for. While counting using the manual recording method, dead time may have been about 10 seconds per meteor. But with plotting, it is going to take longer, somewhere around 30 seconds per meteor. If you are new at plotting, a more reasonable time may be something like 45 seconds per meteor. Total all of this dead time up. Keep in mind that breaks are not included here but are listed in the "Breaks" portion of the report.

When you complete the reports, send the NAMN Visual Summary Report to the NAMN Coordinator as done when reporting visual counts. But the charts have to be postal mailed to the Coordinator (see Appendix B) who will collect the plots and forward them to the IMO. On each of your charts, be sure to write your name and the date of the observation.

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CHAPTER 3: OBSERVING TECHNIQUE - PHOTOGRAPHY

Contributed by: George Zay, IMO Member

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Photographing meteors involves a great deal of luck for the most part. In turn, the results have the potential for producing the most accurate data. Photographing meteors can provide accurate radiant determinations, meteor durations, velocities and approximate magnitudes. Orbits can be determined for meteors that were photographed by two different cameras separated by at least 25 to 100 miles.

In order to increase your chances of capturing a meteor on film, there are a few basic items required. These include a camera with a 28mm to 50mm lens, appropriately fast film, a sturdy tripod with a cable release and as you might guess, a lot of patience.

A. CAMERA

A standard 35mm camera is recommended, with either a 28mm f/2.8 lens or a 50mm f/1.8 lens. The camera should have a shutter that is not controlled electronically. Time exposures, especially out in the cold, can drain the battery quickly ending your photography session early.

A 50mm f/1.8 lens catches meteors of 0.0 magnitude or brighter quite well. But, the field of view of a 50mm lens is rather small. Quite often you may only get part of the meteor. On the other hand, a 28mm lens has a wider field of view, therefore increasing the odds of a meteor crossing the camera's field. But, the wider lens makes it necessary that a meteor be brighter to be captured on film, somewhere in the -2.0 range.

So what lens should you use? The choice of lens should be based upon the expected meteor showers population index (discussed in a later chapter). A useful rule of thumb is that if the population index is 2.5 or less, choose the 28mm wider angle lens, otherwise, try the 50mm normal lens.

B. FILM

The choice of film hardly gets any easier. Often color is used because that's what the film makers try to sell and that's what we remember the most. However, most of the light from a meteor is from the blue to ultraviolet part of the spectrum (therefore never use any type of UV filter while photographing meteors). However, your lens absorbs most of the UV light anyway. The visible light that is recorded is white. If the meteor appeared green, blue or red, the image will still be white. So, the only color will be from the stars, which we all will agree is appealing in itself.

Black and white film is the preferred film, especially the T-max films. On moonless nights, T-max 3200 probably is the best choice. It's fast and the grain is not as bad as one would think. Prints up to 5"x7" come out quite pleasing. T-max 3200 can be used even when there is a quarter moon, just make sure not to aim the camera in a direction where moonlight will harm the exposure. Any other time, choose the slower T-max 400 film.

When deciding on your choice of film, keep in mind that for scientific purposes, one of the things that can be determined from photographs is the magnitude of the meteor. But this can only be done with black and white films.

C. TRIPOD AND CABLE RELEASE

One thing that can't be over emphasized is the importance of a sturdy tripod and a good locking cable release. Part of the problem with a lot of tripods is that they are so light they don't rest on the ground firmly. One possible remedy is to suspend a heavy weight under the tripod's head. As to cable releases, make sure that it is the type that will lock and that it operates smoothly, even on those cold, frosty mornings.

D. METHODS OF PHOTOGRAPHING METEORS

There are two methods of photographing meteors - unguided and guided. Many people simply place a camera onto a tripod, set their camera to the bulb or "B" setting and lock the cable release for the duration of the exposure. The camera equipment stays motionless, but the sky moves. This is unguided photography. For scientific purposes, unguided exposures can be used to determine right ascension and declination coordinates for both the beginning and end points of the meteor's trajectory. But accurate times are very important here. You must know, within three seconds, the beginning and end times of the exposure as well as the time of the meteor's appearance. Also, you need to know where the camera is pointed and be able to identify at least six stars. This is much easier if you are careful to frame a couple of easy to recognize stars in the field of the camera. Using this method, experiment with exposures of 15 minutes or less.

Guiding a camera (where the camera's field moves across the sky at the same rate as the stars) is a lot more difficult, but is well worth the effort. It requires some method of allowing the camera to move at the same rate as the sky, so the equipment must be polar aligned to prevent star drift. It is still necessary to note shutter start/stop and meteor appearance times, but they can now be within thirty seconds of accuracy instead of three. It is still prudent to be as accurate as possible though. For guided exposures, it's possible to piggyback a camera onto a properly aligned telescope or use a device such as the "Vista Star Stepper". Then attach this to a sturdy tripod and make your polar alignments from there.

E. EXPOSURES

How long should you expose the film? There are several things to consider. First, what is the purpose? If you want to be creative, there is no concrete rule for exposure durations. A lot of people find longer exposures to be more pleasing so experiment with exposure times. For unguided scientific purposes however, try to keep the exposures between 5 and 15 minutes to reduce star trailing. If there is an exceptional rate of meteoric activity, keep exposures at 5 minute increments.

For guided cameras, you will have to judge first how accurate your polar alignment is. One rule of thumb is this - the wider the angle of the lens, the longer the exposure can be before the stars start to trail off. With a 28mm lens, try 25 minutes as an initial exposure (20 minutes with a 50mm lens) and go from there. If a possible bright meteor cross the camera's field of view prior to the end of any 15 minute exposure, let it run for a whole 15 minutes to give the negative some star detail. If a meteor crosses after 15 minutes but before your scheduled time to end the exposure, stop the camera as soon as possible and prepare for the next exposure. Use a similar exposure timing for a 50mm lens.

F. WHERE TO AIM THE CAMERA

Photographing meteors does involve some luck, but you can dramatically improve your chances by paying attention to where the center of the camera's field of view is positioned. Aiming the camera between 50 and 70 degrees above the horizon will insure the largest portion of sky is within the field of view.

If possible, also aim your camera about 30 to 40 degrees from the radiant itself. This zone represents a very compressed area from which a meteor will be coming from. If you aim at the radiant itself, it's even more compressed, and most meteors don't become visible until they have traveled somewhat from the radiant. Therefore, more meteors should become visible to your camera.

One last thing to consider is how you align the long axis of your film plane to the radiant. You will be able to cover more potential meteor crossing area if you align the long axis of the viewfinder so that a meteor coming from the radiant toward the center will be perpendicular to it. If the long axis is parallel, you will have less potential meteors.

G. PRINTING

If you capture a meteor, be sure to make your print at least 5"x7" in size. Whether you have the film processed commercially or do it yourself, try to include all edges of the negative in your print and make the print lighter than it normally would be. This may not look the most appealing, but is best for scientific measurements. On the back of your print, write the following information:

-- Your Name
-- Day, Month, and Year (use double date)
-- Time of Meteor Appearance (use universal time or local time with the time zone specified)
-- Apparent Magnitude

-- Apparent Velocity (Very Slow, Slow, Medium, Fast, Very Fast)
-- Location: Latitude, longitude and elevation of the site along with a verbal location (example: Yuma, Arizona etc.)
-- Camera Lens (ex. 28mm lens, f/2.8)
-- Film (ex. T-max 3200, Developed in D-76, for 13 minutes at 70 deg F)
-- Estimated Print Center (ex. RA: 8h 30m, Dec: -8 deg)
-- Identify any bright stars by taping a thin sheet of paper over the print so labeling can be done (note that this is not necessary for guided images)

It's also a good idea to keep an accurate log for each photographic night. Include all the times for each exposure. Also include where the camera was aimed and a meteor number for any captured meteors that were simultaneously observed visually. This will allow you to associate pertinent information with the photo. Keep a record of what lens and film was used and whether you had a rotating shutter in operation.

H. ROTATING SHUTTERS

These are relatively simple devices that resemble a fan. When a bright meteor passes through your camera's field, the end result will be a meteor image that is chopped up. From this, it is possible to compute the meteor's duration within ten thousandths of a second. To do this, divide shutter revolutions per second times two shutter blades, into the number of meteor breaks. An ideal RPM for a motor is probably in the 1,000 rpm range. If you happen to be working as a team with cameras separated by 25 - 100 miles and accurate times are being recorded, meteor altitudes, velocities, entry angles, and orbits can then be determined.

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CHAPTER 4: OBSERVING TECHNIQUE - TELESCOPIC

Contributed by: Malcolm Currie, IMO Telescopic Commission Director

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Observing meteors with telescopes or binoculars is one of the most valuable fields of study that the amateur astronomer can work in. It involves observation of meteor events well below the limit of either photography or naked eye observation and can cover a size range of meteor particles recorded by professional scientists using radar techniques. The restricted field of view of even wide angle telescopes and binoculars means that these observations are much more accurate than results from naked eye work. Meteor rates are rather modest but do steadily improve with experience and everyone who has taken up this field actively, agree that the long hours of patient watching are amply rewarded when a bright naked eye meteor is seen.

By observing with a telescope, we extend the size range of meteor particles recorded. This, for instance, can give insights into evolutionary effects which segregate the particles by mass. It should also be possible to determine meteor fluxes for the low-mass particles, giving a more complete picture of a shower. The restricted and magnified field of view allows the paths of meteors to be determined more accurately than visually. This lets us investigate the properties of meteor radiants, detect minor showers more easily, and find new showers. As the meteors are plotted we can always reanalyze the data, possibly comparing results from different epochs. There is less bias involved since we use analysis software to assign shower membership and to search for radiants.

A. CHOICE OF INSTRUMENT

There is no single best telescope or binocular for telescopic observing. The choice will depend on the quality of your observing site, your eyesight, observing goals, and how much you wish to spend or what is already available. However, there are two main factors that should influence a choice: the instrument should have a low power and a wide apparent field of view.

You must have a low magnification for a given size of objective lens or mirror. To put that into numbers, the magnification should be in the range of 1.4-2.0 times the aperture in centimeters. So for example, a 7x50 pair of binoculars has a magnification of 1.4 times the aperture in centimeters and a 10x50 has a magnification twice the aperture.

The apparent field of view is governed by the eyepiece design. You can derive it from the product of the magnification and the true field of view. For example, a 10x50 binocular, with a 6 degree true field, has an apparent field of 60 degrees. A wide field of view will encompass more of the sky, and hence you will see more meteors. The recommended range is 45 to 70 degrees, with 50 to 60 degrees being preferred. One of the principal reasons for observing telescopic meteors is to investigate radiant properties by plotting meteor paths accurately. As the apparent field of view enlarges, the average plotting accuracy goes down. So ultra-wide fields (>65 degrees) are best for determining rates, and hence deriving the time of maximum for a shower, whereas for field sizes of around 50 degrees rates are still reasonable and accurate positional data can be obtained. Given the choice between the two, you should err on the side of the smaller apparent field as it offers more flexibility and science. Also, ultra-wide eyepieces or binoculars are either very expensive if they give pinpoint images across the entire field, or give increasingly distorted images towards the periphery of the field. Below 50 degrees the loss of sky coverage starts to become important. If rates become too low, boredom and loss of concentration can soon set in.

Binocular vision is the natural way to look, and since comfort is a critical consideration for the telescopic observer, a binocular is preferred to a (monocular) telescope. Aperture is less critical, and IMO observers' apertures range from 40mm to 300mm, though most are in the range of 50-80mm. The intermediate apertures (50-80mm) seem to work best. The quality of the optics can make a big difference to the performance. Remember that you will be observing for long periods and considerations like accurate collimation and pinpoint images will reduce strain. This consideration can outweigh some of those mentioned already. For example, a quality 7 x 42 is going to let you see more meteors than a cheap 8 x 50.

B. OBSERVING METHOD

In the simple case where we want to follow a known shower, we select a pair of charts, preferably above the radiant, in a configuration like in this schematic. The elevation of the fields should be at least 35 degrees.

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                    ---              ---
                   / \  \           /  /\
   Field 1         \  \ /           \ / /   Field 2
                    ---              ---



                              *
                             ***   Radiant
                              *
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The idea is that if we extend back the paths of shower meteors seen in the two fields toward the radiant, they will intersect at near right angles. This gives the best definition of the radiant. The distance of the field to the radiant is about 10 to 30 degrees. For faster meteors we go closer. Normally I choose 15 to 20 degrees, but sometimes because the elevation of the radiant is low or other showers and geometrical considerations are involved, we can go towards the upper range. You can still see telescopic meteors well away from their radiant, however they are generally traveling faster through your field and hence appear dimmer and are harder to see. Also any error in your estimate of the orientation of the meteor gets magnified when extrapolated back to the radiant. The radiant distance is a compromise to yield high accuracy for the positions, but also to see sufficient shower meteors. If you looked towards the radiant, the rate would be very low. Other configurations are adopted when searching for minor showers.

Observe each field for about half an hour and alternate between the two. This enables us to pinpoint the location of nearby radiants, and gives the observer a change of scenery to help reduce boredom when rates are low and a chance to stretch, or take a short break. In practice, a few field centers around the radiant are used to try to reduce artifacts from the reductions or occlusions when looking at areas where there are many radiants in close proximity, such as in Aquarius and Capricornus during the summer.

Use a new report sheet each night (standard IMO forms are available). Items that are recorded include: the double date like "1996 September 10/11"; observer name and location; and the specification of our binocular or telescope, namely the aperture, true field diameter, and magnification. Also some remarks about the sky conditions are normally added. For each watch record the field or naked-eye limiting magnitude, the start and end times (in UT please), the sum of any breaks, and the effective observing time in hours. To compute the last of these, observers need to estimate or measure their dead time, that is the time while they are not actually looking at the sky. For me, it's about 40 seconds per meteor.

When a meteor is seen, freeze and try to replay in your mind what you've just witnessed. Record the brightness, speed, the type, time of appearance, and plot the position and direction of the trail on a chart (see below) and annotate with an identification number. This starts at one (1) each night. Measure the duration of any persistent trains.

Path: use two well-separated pairs of stars. Each pair of stars should straddle closely to the meteor's path. Estimate the fractional distance of the meteor's path between the two stars in a pair, for example midway, or 30% from the lower to the upper star. Repeat for the other pair. After some practice, you will find that this comes naturally, and it gives accurate results.

Brightness: the magnitude comes from comparison with field stars, though after a while it is possible to judge the brightness of most meteors directly.

Speed: the angular speed is on a scale from A to F; A being the slowest equivalent to about 2 degrees per second, and F is the fastest corresponding to 25 or more degrees per second. Numerical estimates are too difficult given the magnification. The velocities are needed in the radiant analysis.

Type: the type is a code as to whether the meteor started and/or left the field of view. OO means it traversed the whole field. 10 means that the meteor started within the field, but moved outside.

Train: if there is a persistent train estimate its duration and occasionally make sketches of its decay.

Depending on the weather conditions and alertness of the observer, it is best to take longer and more-frequent breaks than visual observers, as telescopic observing does require more concentration, especially when the rates are low. Many new observers don't overcome this initial hurdle and give up. With a little perseverance, many fascinating avenues of research open up.

C. IMO CHARTS

The IMO Telescopic Commission has several sets of charts suitable for plotting telescopic meteors. Each set has its own limiting magnitude, field size, and orientation, and each is geared towards popular binocular and telescope specifications. Within each set there are 164 fields scattered mostly over the northern sky. The chart number defines the region of sky irrespective of the chart set. The chart centers were selected not only with specific showers in mind but also to allow searching and monitoring of new or obscure minor showers, as well as to allow the investigation of the distribution of sporadic meteors.

By measuring x-y start and end positions of the meteors from the charts, and the distance between four fiducial crosses, it is easy to calculate the R.A. and Dec. of the meteors. This data along with the other parameters is used by Rainer Arlt's *RADIANT* software to analyze the distribution of meteor radiants present in the data. Observers should make these measurements on their own. I enter the values into the computer, run a couple of programs and then they are ready for analysis.

The diameters of the stars on the charts indicate their catalog brightness in the V (visual) band, and a key is provided. Variable stars are indicated as such. Each chart has an inset showing an enlarged portion of the field to a fainter limiting magnitude. This is to allow an estimate of the field limiting magnitude during a watch.

It is best if an observer obtains the above mentioned IMO charts, but other sources will do if one is waiting for them to arrive and you want to observe with a small binocular. In these cases, there are other star atlases they will suffice. The Uranometria 2000 star atlas is a good substitute. It's best if you photocopy the relevant page, then use a correcting fluid to remove the R.A. and Dec. lines in a region slightly larger than your field diameter about the chosen center. This then becomes the master chart. Subsequent to the observing you will need to measure the start and end points of each meteor in equatorial co-ordinates, and enter these on the report form instead of x-y positions.

D. CONCLUSION

Telescopic meteor work takes quite a bit of getting used to and observers should persevere. Experience is rapidly gained and your hourly rates of meteors will climb steadily. There are enormous rewards, the most spectacular being a close view of a bright meteor. The basic principles of telescopic meteor observing are essentially the same as for visual observing since an area of sky is watched and a detailed record is made of meteors that are seen. The field of view should be chosen carefully and is usually recommended beforehand by the IMO Telescopic Commission Director.

To learn what fields should be chosen, or for more information on this method, contact the IMO Telescopic Commission Director (see Appendix B).

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CHAPTER 5: OBSERVING TECHNIQUE - RADIO

Contributed by: George Zay, IMO Member

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Currently, monitoring radio meteor activity is beyond the scope of NAMN. But to those who wish to investigate it, the following should prove to be a start.

A. BACKGROUND

Monitoring meteor activity by radio got its start right after World War II. It was then found out that meteors could reflect radio signals. There are two ways that radio meteors can be detected. One is known as back scatter. This is monitoring with radar equipment and is mostly in the realm of professional work. A simpler method, and one that amateurs can participate in, is forward scatter.

It has been learned that when a meteoroid enters the atmosphere, it produces an ionized column of gas molecules. This ionized gas has the ability to reflect radio signals between a transmitter and a distant receiver. The frequency range that this occurs at is between 40 and 150 MHz. Although the optimum lies between 40 and 70 MHz, the common FM band is frequently used for back scatter work. This FM band is between 88 and 108 MHz.

The technique used to register forward scatter meteors is actually quite simple. A receiver is tuned to a distant radio station that is located below the observer's horizon. The distance between the receiver and transmitter varies from between 200 and 1000 miles. Most often a commercial radio station is used as a transmitter. Aircraft ground beacons are also suitable transmitters. The station may not be heard, usually only background noise is apparent. At the moment a meteor appears at the correct angle, there is a short contact (usually 0.1 to 4 seconds) with that radio station. For larger meteors, it is possible to have longer lasting signals, often up to minutes in duration. This contact gives itself away as a signal increase in a piece of music, voice or noise. Since this technique uses electromagnetic waves, it can be used during the daytime, when there is a bright moon, or during cloudy and rainy weather. Therefore, this method is ideal for continuous periods of observing.

B. EQUIPMENT

The best FM radio to use is one that is digital and that has a shielded cable connection where the antenna plugs in. The digital type of radio is easier to set on the desired frequency. A Yagi style FM radio antenna is also required (at the time this was written, Radio Shack sold suitable antennas for about $16 and local TV antenna companies sell a more directional FM radio antenna for about $150). Unfortunately, which type of antenna to use depends on trial and error. It would probably be best to try the lower cost antenna first. Assuming that this type is used, hook up the antenna to the radio with a coax cable.

C. FINDING A MONITORING FREQUENCY

To find a frequency, try them one at a time from 88.0 MHz to 108.0 MHz. Write down all the frequencies where there is no music or talking. All that should be audible is static noise. Be sure to turn the antenna all the way around (360 degrees) to find this static area. Do not direct the antenna very high, because in most places in the United States, the antenna may receive unwanted, continuous reception.

If you're lucky, you'll find several or more frequencies where nothing but static is heard. These are the potential useable frequencies. For those who are unable to find any, there are two options. Move your radio equipment to another location, preferably in a valley and many miles away from the city (30 or more). Another alternative is to buy the more expensive, more directional, and most likely, larger (12 foot long antenna), and try all the frequencies again. If the directional antenna still doesn't work, try another location and/or consider a different frequency band.

On useable frequencies, it is probable someone is transmitting on it at least 200 to 1000 miles away, but at an unknown direction. The only way to determine the direction is to go to the local library and find a book that lists frequency and station locations. If the library doesn't have such a book, it may be possible to find it by looking in the phone books of different cities located within 200 to 1000 miles. Ideally, choose a station that transmits over 30 kilowatts and is located about 300 to 500 miles away.

D. SETTING UP

Next, find your location and the location of the transmitting station on a suitable map. Taking geographical north as being 0 degrees, find what degree angle the transmitting station is in relation to the observing location. This is the transmitting station's azimuth.

Then, with your antenna pole at the middle, use a compass to find true north. Be sure to do this with the pole and other metal out of the way or a false reading will result. Turn the antenna to point toward the transmitting station. Using a protractor, tilt your antenna so that it points up at a 45 degree angle instead of the traditional horizontal angle.

E. OPERATION

Now, just listen to all the static. When a meteor passes by, it may or may not (depending on the angle among other things), produce a signal. The radio can detect meteoroids down to 8th magnitude at least, with most being very short signals on the order of 1/4 second. They are actually small segments of what's being transmitted. They sound like bumps, thumps and chirps. The longer signals will register as pieces of music or talking. These are usually very sudden, loud and clear, and will begin and end abruptly. Aircraft can interfere when they fly nearby, but they usually produce signals which are gradual before getting real loud.

During observations, it is advisable to use one frequency exclusively with the antenna always pointed in the same direction and at the same elevation. This way, day to day monitoring establishes a reliable pattern that can be compared. On average, expect to hear the least amount of meteor activity around 6 pm local time and the greatest activity around 6 am local time. A typical hourly rate around 6 pm is about 7, while at 6 am it may increase to about 60 or so. Of course, a major meteor shower could change these rates.

F. RECORDING

One recording method is to purchase a small hand counter and simply press the button for each signal heard, regardless of their duration. If the signal is 1 second or longer, note them separately on paper. Do this for half hour increments during each observing hour.

Interpret signals lasting more than 5 seconds in duration as being most likely caused by a visually bright meteor. It appears that longer signals are produced by brighter meteors (-1 magnitude and up) rather than fainter ones. Also, it's been noted from some observers that signal durations tend to differ from frequency to frequency. Signal durations tend to not be as long at the FM band level as they are with frequencies near 50 MHz. Try to observe visually with a speaker close by. Sometimes, it's possible to get simultaneous events which can be noted both visually and by radio.

G. WHEN TO LISTEN

Actually, it is possible to listen for meteors any time of the day or night. Generally, the most active 12 hour period is from midnight to noon. Major shower activity usually produce exceptionally high hourly rates both audibly and visually. The radio can quickly become so saturated with radio reflections that it produces continuous radio reception. At this point, it's almost useless to maintain hourly rates. But fortunately, these moments are exceptions to the rule. Observing periods will have the greatest scientific benefit if they are carried out in one hour increments. Periods shorter than this become unreliable.

There are meteor showers that are almost exclusively monitored by radio. These are known as the daytime showers and usually peak shortly after sunrise. The IMO's list of daytime showers include:

Cap/Sagittarids	Peak on Feb 01	ZHR 15
Chi Capricornids	Peak on Feb 13	ZHR 5
Piscids (Apr)	Peak on Apr 02	
Delta Piscids	Peak on Apr 24	
e- Arietids	Peak on May 09	
Arietids (May)	Peak on May 16	
o-Cetids	Peak on May 20	ZHR 15
Arietids	Peak on Jun 07	ZHR 60
Sigma Perseids	Peak on Jun 09	ZHR 40
Beta Taurids	Peak on Jun 28	ZHR 25
Lambda Leonids	Peak on Aug 25	
Sextantids	Peak on Sep 27	ZHR 30

H. REPORTING OBSERVATIONS

As mentioned above, the NAMN is not equipped to handle radio observations. Instead, we recommend sending your data to:

Christian Steyaert
e-mail: 72650.3513@compuserve.com

It is recommended that observers contact him first so that he can specify the format data should be submitted in. Also, he will need to gather the required information about your location, radio set up, etc.

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CHAPTER 6: FIREBALLS

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Fireballs are normally millimeter-sized meteoroids that have entered the atmosphere. There are various definitions of what constitutes a fireball. The IMO has created a clearinghouse for all fireball reports known as the Fireball Data Center (FIDAC). The definition used by FIDAC for a fireball is any meteor with a brightness of -3.0 or greater, and is the definition used by the NAMN.

The frequency of fireballs throughout the year varies. If you observe every meteor shower during an entire year, you will find that some showers tend to produce more fireballs than others. In addition, fireballs exhibit a seasonal variation just as sporadic meteors. For the northern hemisphere, this amounts to about three times as many around the vernal equinox as there is around the autumnal equinox. A diurnal variation has also been observed among fireballs. More will appear around 18h local time than 06h local time. Careful readers will notice that this is directly opposite the variation of sporadic meteors. The reason is related to velocity.

A meteoroid entering the atmosphere is acted upon by friction. At a lower velocity, the meteor will penetrate to a deeper, denser level of the atmosphere because it is not as susceptible to breaking apart. This results in a brighter meteor being produced. A meteoroid of the same size, entering the atmosphere at a higher velocity, will penetrate to a shallower depth because its velocity will tend to break it apart. In this case, a fainter meteor will be produced. Since bright meteors tend to be produced at low velocities, fireballs are more frequent at 18h local time when the meteoroid must overtake the earth in its orbit. This is because to overtake the earth, a meteoroid must expend a portion of its velocity.

For a fireball to actually reach the surface of the earth, its velocity generally must be lower than 23 km/s. The initial mass must be greater than that which is lost from ablation as it penetrates lower levels of the atmosphere. At speeds greater than 23 km/s, forces normally break apart the original meteoroid into smaller particles that will not reach the surface (this does not hold true for very large particles which produce the meteorite craters of the earth). At some point along the path through the atmosphere, the meteor's velocity becomes zero, and the meteorite falls by gravity alone three or four minutes to the surface.

This brings us to the point of reporting observed fireballs. If sufficient observations are obtained, an orbit for the fireball might be computed. If the fireball was large enough to reach the earth's surface, it may then become possible to recover the meteorite for research. To aid in determining the characteristics of a fireball you observed, certain information is required. (Note: Keep in mind that really bright fireballs may draw the attention of your local media. If so, reports can also be gathered from them. It is far easier for a local meteor observer to do all the leg work here instead of relying on FIDAC to gather this information. Always be alert for media attention, follow it up and forward that data to FIDAC too.)

The following information should be included in your report:

-- Date and Time - Once again, use universal time and a double date.

-- Location of Observation, Geographic Coordinates - Name of the location, including state and country. Be as precise as possible with geographic coordinates and include the elevation. You can get this off of a topographic map.

-- Magnitude - Give the apparent magnitude if possible, or if not known exactly, a magnitude interval (e.g. -5 to -8) or relate to known bright objects such as Jupiter, Venus or the Moon.

-- Apparent Path, Coordinates of First/Last Sighting - Please note right ascension and declination of first and last points using degrees. You can convert right ascension by multiplying each hour by 15 and add 5 degrees for each 20 minutes.

-- Duration - Give the estimated or measured duration in seconds.

-- Color - Give color and any variations, referring only to pure colors, not, for example, bluish-green.

-- Persistent Train - Note appearance and duration, and if observed, color and shape (e.g. gray, white; puffy, wavy, straight).

-- Fragmentation - Give the number of fragments, their brightness, color and position along the trajectory.

-- Apparent Velocity - Note degrees per seconds, or the description: stationary, very slow, slow, medium, fast and very fast.

-- Sounds - Description of sound (compare with: supersonic sound, like an avalanche, swishing, whistling, etc.) and the time between optical and audible observations. Note that it may take a minute or more before any sound reaches you.

-- Observer - Name and address.

-- Source - Should be given if observations of other witnesses are reported. Note the address of other observers to allow additional inquiries.

Keep in mind the following special rules for fireballs greater than -10 in magnitude. There is a very good possibility that fireballs of this brightness will be recorded by U.S. Government satellites. In an effort to retrieve pertinent data from them, all fireballs greater than magnitude -10.00 should be reported to FIDAC immediately. Satellite data is stored for a short time so immediate reports are important. As a simple rule of thumb as to what constitutes greater than -10 magnitudes, consider the following as a guide:

--If the fireball appeared during daylight hours.
--Or, if at night, it appeared to be as bright as a full moon (-12) with distinct shadows of trees, houses, etc. present.

Fireball reports should be either e-mailed or postal mailed as soon as possible to the NAMN Coordinator.

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CHAPTER 7: THE POPULATION INDEX

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In Chapter 2 it was first pointed out how important magnitude distributions were to meteor research investigations. Its importance now becomes clear as it is related to the population index of a shower. The population index in fact, is derived from these same magnitude distributions. So why is this all that important?

The raw data obtained from meteor counts may be used in such studies as hourly rate profiles, meteor colors or train percentage rates. But almost all investigations include a determination of the ZHR (zenithal hourly rate - number of shower meteors an observer would see in one hour if the radiant were in the zenith, the limiting magnitude was +6.5, and the sky was cloudless). The population index is the essential quantity to permit any further analysis, so it must be used in the ZHR calculation. But, it is sometimes difficult to understand what is meant by the population index. This does not need to be the case.

How is the population index (abbreviated simply as the letter r) defined? The following is a definition used by the International Meteor Organization:

> "The population index is an estimate of the ratio of the number of meteors in subsequent magnitude classes..."

Basically, what this is saying is that r is a value indicating how many more times meteors of magnitude m+1 appear than meteors of magnitude m. The number of meteors will increase as the magnitude gets fainter. For example, let m = 4 and r = 3. Then three times as many meteors of magnitude 5 (m+1) appear than meteors of magnitude 4 (m).

The actual calculation of the population index for a shower is beyond the scope of this guide. However, it is normally assumed that for sporadic meteors, r equals approximately 3.0. For meteor showers, if no reliable data is available, then r is assumed to equal 2.5. Still, it is best to use recent values for r if possible. These values for r can then be used in the limiting magnitude correction factor for ZHR calculations. Appendix A lists recent values for several of the annual meteor showers.

Once we know a value for r, what else does it tell us? These values can tell us how many meteors we will be missing at our observing site due to worse limiting magnitudes. The higher the population index, the more meteors we will miss due to a poor site. In the above example, if our limiting magnitude is 4.5, we miss all magnitude 5 meteors which are three times as numerous as 4th magnitude ones.

Additionally, the smaller r is, the older the stream is. This results from the fact that most of the small meteoroids which cause the high values for r have left the stream due to various causes. Thus, smaller values for r indicate the average meteor we observe will be brighter.

The population index is extremely important in meteor studies. It is the fundamental quantity needed for visual studies and it can provide us with important information on the characteristics of the meteors we observe.

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CHAPTER 8: THE ZENITHAL HOURLY RATE (ZHR)

Contributed by: George Zay, IMO Member

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The zenithal hourly rate is a means by which different observers can convey their results to each other. Of course, this is the ideal condition to observe meteors under. However, conditions are not always perfect. To make matters worse, the human factor is a variable that makes ZHR results less precise. There are several methods to finding a ZHR. Some are more accurate than others and are quite involved in calculations. Variables to consider include clouds, limiting magnitudes, observing periods, the radiant's zenith distance, geographical latitude of the observer, and the observer's own perception. The following method does not take all of these variables into account. But this method from Neil Bone's book, "Meteors" will serve our purposes here as an introduction to the subject.

With:
HR = observed hourly rate; r = population index; LM = your average limiting magnitude; and A = altitude of the shower's radiant above the horizon in degrees

a) Formula with an LM above 6.5

$$ZHR = \frac{(HR)\ (r)^{1-(LM - 6.5)}}{\text{Sine } A}$$

b) Formula with an LM below 6.5

$$ZHR = \frac{(HR)\ (r)^{6.5-LM}}{\text{Sine } A}$$

Example: Geminids with clear skies and no obstructions.

Assume:
HR = 57 meteors seen for 1 hour
r = population index for Geminids is 2.6
LM = average limiting magnitude for that hour is 5.7
A = the shower's radiant above the horizon for that hour is 60 degrees

$$ZHR = \frac{(HR)\ (r)^{6.5-LM}}{\text{Sine } A} = \frac{(57)\ (2.6)^{6.5-5.7}}{\text{Sine 60 degrees}} = \frac{(57)\ (2.6)^{0.8}}{.866025404}$$

$$= \frac{57 \text{ X } 2.14}{.866025404} = \frac{121.98}{.866025404} = 140 \text{ ZHR}$$

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APPENDIX A. LIST OF METEOR SHOWERS

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(The shower listing below, compiled in 1995, includes: shower name with three-letter code; activity period; date of maximum; position of radiant at maximum; diameter of radiant; daily radiant drift; velocity in km/s; population index; zhr and notes. Unless otherwise noted, information concerning shower characteristics and parameters has been taken from International Meteor Organization (IMO) sources. I express my appreciation to the IMO for permission to use this information.

(NOTE: THESE ARE THE SHOWERS BEST SUITED FOR BEGINNING VISUAL OBSERVATIONS!)

For additional information, contact Mark Davis.

Quadrantids (QUA) Active: Jan 01-Jan 05 Max: Jan 03
Radiant: 230 +49 Diameter: 5 Drift: +0.8 -0.2
Velocity: 41 km/s Population Index: 2.1 ZHR = 120

NOTES: The Quadrantids have the shortest duration of all the major showers. The short but intense maximum can produce rates in excess of 100 meteors per hour. The shower's radiant lies in Bootes, so is circumpolar for many northern locations, but it only attains a useful elevation after local midnight and is highest near morning. Therefore, the shower must peak near 5 am local time in order to see it at its best. Observing only 6 hours on either side of maximum will produce rates no better than 20-30 meteors per hour. It appears that mass-sorting of particles across the stream of this shower makes fainter members reach maximum up to 14 hours earlier, so observers should be alert throughout the shower. The Quadrantids are easy to photograph at maximum, with bright yellow fireballs being visible. Fainter shower members tend to be blue or white. The population index varies with solar longitude.

Delta Cancrids (DCA) Active: Jan 01-Jan 24 Max: Jan 17
Radiant: 130 +20 Diameter: 20/10 Drift: +0.9 -0.2
Velocity: 28 km/s Population Index: 3.0 ZHR = 4

NOTES: Very little is known about this stream which can be seen from either hemisphere. It is likely that this shower is an early part of the Virginid activity. The radiant is above the horizon for almost the entire night, and meteors from this shower are best seen during the early to middle part of the night. This ecliptical shower has a complex radiant structure so plotting of all meteors is recommended.

Alpha Centaurids (ACE) Active: Jan 28-Feb 21 Max: Feb 07
Radiant: 210 -59 Diameter: 4 Drift: +1.2 -0.3
Velocity: 56 km/s Population Index: 2.0 ZHR = 6

NOTES: For most of the active period for this Southern Hemisphere shower, ZHRs range between 1 and 3 meteors per hour, but at maximum rates generally rise to between 5 and 10. Every 5 to 6 years, the maximum activity seems to be enhanced and on two notable occasions in 1974 and 1980, rates exceeded 25 meteors per hour. This enhancement has always been short-lived, lasting no more than 2 to 3 hours. This shower produces fast meteors, many with trains, and are noted for their brightly colored fireballs.

Delta Leonids (DLE) Active: Feb 15-Mar 10 Max: Feb 24
Radiant: 168 +16 Diameter: 5 Drift: +0.9 -0.3
Velocity: 23 km/s Population Index: 3.0 ZHR: 2

NOTES: The Delta Leonids are thought to possibly be related to the minor planet 1987 SY and are of average brightness, slow in speed, with very few leaving a train.

Gamma Normids (GNO) Active: Feb 25-Mar 22 Max: Mar 13
Radiant: 249 -51 Diameter: 5 Drift: +1.1 +0.1
Velocity: 56 km/s Population Index: 2.4 ZHR: 8

NOTES: This shower is very similar to the sporadics in appearance, and for most of their activity period, their ZHR is almost undetectable above the background rate. The peak itself is normally quite sharp, with ZHRs of 3+ noted for only a day or two to either side of the maximum. There are suggestions that the activity may vary somewhat at times, with occasional broader, or less obvious, maxima having been reported in the past. This shower is visible mainly from the Southern Hemisphere with the radiant best placed after local midnight. Shower members are swift with the brightest meteors often having a yellow color. The Gamma Normids are difficult to photograph due to their low numbers and relative faintness.

Virginids (VIR) Active: Jan 25-Apr 15 Max: several
Radiant: 195 -04 Diameter: 15/10 Drift: +0.5 -0.3
Velocity: 30 km/s Population Index: 3.0 ZHR: 5

NOTES: As there are a large number of low activity radiants close together, it is very difficult to distinguish what branches of the Virginids are active at any one time. With this is mind, the IMO has for the time being incorporated all Virginids seen into one shower. They are known for their fireball production, though their population index of 3.0 indicates there are many fainter members as well. Radiant position listed above is for March 24.

Lyrids (LYR) Active: Apr 16-Apr 25 Max: Apr 22
Radiant: 271 +34 Diameter: 5 Drift: +1.1 0.0
Velocity: 49 km/s Population Index: 2.9 ZHR: 15

NOTES: This shower peaks on April 22, and produces 10 meteors per hour on average. Maximum rates are attained for only about an hour or two at best, and can be rather erratic at times. The Lyrids are associated with Comet Thatcher 1861 I and have produced several bursts of activity in the past. The most recent such event occurred in 1982 when rates nearly reached 100 meteors per hour. It is difficult to photograph the Lyrids due to their low numbers and only occasional fireballs. The Lyrids are visible from the Southern Hemisphere, but at a much reduced rate. Useful watches can be carried out after 2230 hours local time.

Pi Puppids (PPU) Active: Apr 15-Apr 28 Max: Apr 23
Radiant: 110 -45 Diameter: 5 Drift: +0.6 -0.2
Velocity: 18 km/s Population Index: 2.0 ZHR = variable

NOTES: The Pi Puppids are a meteor shower that has only recently become visible. In these cases, the meteoroids are clustered close to their parent comet so we see activity only when their parent comet is near the Earth. The parent comet of the Pi Puppids, 26P/Grigg-Skjellerup, returns to perihelion every five years. Their radiant can only be effectively observed from the Southern Hemisphere in the evening hours and sets shortly after midnight.

Eta Aquarids (ETA) Active: Apr 19-May 28 Max: May 05
Radiant: 338 -01 Diameter: 4 Drift: +0.9 +0.4
Velocity: 66 km/s Population Index: 2.7 ZHR: 60

NOTES: The Eta Aquarids are the outbound (post-perihelion) particles of Halley's comet. This shower is active from mid-April through the end of May with a broad maximum which can occur anytime from May 2 through May 10. This shower is not well observed from the Northern Hemisphere due to the low radiant altitude when dark skies occur. An observer may see nearly 40 meteors per hour at shower maximum from tropical latitudes, decreasing to invisibility as you approach 50 degrees north latitude. From the Southern Hemisphere the Eta Aquarids are by far the strongest annual shower, producing an average of 60 meteors per hour at maximum. This shower also produces the highest percentage of trained meteors among the major showers. Nearly one-half of all Eta Aquarids produce visible trains. There is a broad maximum with ZHRs above 30 for almost a week centered on the main maximum.

Sagittarids (SAG) Active: Apr 15-Jul 15 Max: several
Radiant: 247 -22 Diameter: 15/10 Drift: ?
Velocity: 30 km/s Population Index: 2.5 ZHR: 5

NOTES: This is the radiation area of the Scorpid-Sagittarid complex. Due to the many radiants in this area, the IMO has combined several minor showers into the Sagittarids. Observers should monitor this shower instead of the minor radiants. The radiant position listed above is for May 19.

Pegasids (JPE) Active: Jul 07-Jul 13 Max: Jul 10
Radiant: 340 +15 Diameter: 5 Drift: +0.8 +0.2
Velocity: 70 km/s Population Index: 3.0 ZHR: 3

NOTES: This shower is easily missed by observers since this time of the year most northern observers are preparing for the Perseids. The short Pegasid activity period is characterized by the radiant being well above the horizon only in the morning hours. ZHRs are usually low. Meteors from this stream tend to be swift and faint.

July Phoenicids (PHE) Active: Jul 10-Jul 16 Max: Jul 14
Radiant: 32 -48 Diameter: 7 Drift: ?
Velocity: 47 km/s Population Index: 3.0 ZHR: variable 3-10, usually ~2

NOTES: Occasionally, this shower produces enhanced activity with a ZHR of around 10, but on average, expect ZHRs to be 4 or less. Activity is quite variable, observations show it as a richer radio meteor source. This shower is best observed from the Southern Hemisphere after midnight.

Pisces Austrinids (PAU) Active: Jul 15-Aug 10 Max: Jul 28
Radiant: 341 -30 Diameter: 5 Drift: +1.0 +0.2
Velocity: 35 km/s Population Index: 3.2 ZHR: 5

NOTES: Only observers at a latitude lower than 45 degrees north should attempt observations of this shower. Observers north of this latitude will encounter a radiant that is too low to allow reliable observations. Expect to see only 1 or 2 meteors per hour, perhaps rising to 6 to 8 per hour at maximum.

S. Delta Aquarids (SDA) Active: Jul 12-Aug 19 Max: Jul 28
Radiant: 339 -16 Diameter: 5 Drift: +0.75 +0.21
Velocity: 41 km/s Population Index: 3.2 ZHR: 20

NOTES: This is another shower best seen from the Southern Hemisphere, where the radiant is high in the sky during their long winter nights. This is the strongest radiant of about 6 that are active in this region during July and August. In late July the combined count of these radiants approaches 30 meteors per hour under dark skies. Like many streams that lie close to the ecliptic, this one possesses a double radiant. The southern branch provides a majority of the activity and reaches maximum activity two weeks earlier than the northern branch. The average meteor from this shower is faint and therefore difficult to photograph.

Alpha Capricornids (CAP) Active: Jul 03-Aug 15 Max: Jul 30
Radiant: 307 -10 Diameter: 8 Drift: +0.9 +0.3
Velocity: 23 km/s Population Index: 2.5 ZHR: 4

NOTES: This is a long-lasting shower active throughout July and August. A broad maximum occurs during the last week of July and the first week of August centered on July 30. This shower produces the slowest meteors of all major annual showers. Due to its southerly declination this shower is better placed for observers in the Southern Hemisphere. This shower is noted for its bright, highly colored fireballs that often fragment during flight. The combination of slow, bright meteors is ideal for photography but unfortunately rates are low.

S. Iota Aquarids (SIA) Active: Jul 25-Aug 15 Max: Aug 04
Radiant: 334 -15 Diameter: 5 Drift: +1.07 +0.18
Velocity: 34 km/s Population Index: 2.9 ZHR: 2

NOTES: This shower is noted for its many faint meteors, making it ideal for telescopic work. It is very difficult to distinguish members of this shower from the Delta Aquarids which are also active. This requires careful plotting, angular velocity estimates and a center of the field of view close to the radiant. If you do not plot meteors, it is best not to try to distinguish the different Aquarid radiants, simply count all meteors as "Aquarids." Depending on the phase of the moon, either the Northern or Southern branch can be observed.

N. Delta Aquarids (NDA) Active: Jul 15-Aug 25 Max: Aug 08
Radiant: 335 -05 Diameter: 5 Drift: +0.75 +0.21
Velocity: 42 km/s Population Index: 3.4 ZHR: 4

NOTES: See Southern Delta Aquarids.

Perseids (PER) Active: Jul 17-Aug 24 Max: Aug 12
Radiant: 46 +57 Diameter: 5 Drift: +1.4 +0.18
Velocity: 59 km/s Population Index: 2.6 ZHR: see Notes

NOTES: This is the most popular meteor shower of the year due to the combination of high rates and fair weather this time of year in much of the Northern Hemisphere. A majority of activity is produced on August 11, 12, and 13. The shower's primary maximum has produced rates of 400+ in 1991 and 1992, around 300 in 1993, 220 in 1994 and about 160 in 1995. The return of the parent comet, 109P/Swift-Tuttle in late 1992 is almost certainly responsible for these recent outbursts, although the material was probably laid down during the comet's previous perihelion passage in 1862. A secondary maximum occurs with ZHRs often approaching 100 or more. The brighter members of this shower are often colorful and produce long-lasting trains. The Perseids are easy to photograph near the date of maximum activity. Unfortunately this shower is nearly invisible from the Southern Hemisphere due to the northerly declination of its radiant.

Kappa Cygnids (KCG) Active: Aug 03-Aug 25 Max: Aug 17
Radiant: 286 +59 Diameter: 6 Drift: +0.2 +0.1
Velocity: 25 km/s Population Index: 3.0 ZHR: 3

NOTES: There is very little information concerning this shower due to its low activity. The meteors tend to be very slow and medium bright to faint. It has been suggested that this is a fireball shower with a periodicity of 6.6 years. But this is unproven at the present time, so many more observations will be needed to determine if this is true. This shower is best observed from the Northern Hemisphere.

N. Iota Aquarids (NIA) Active: Aug 11-Aug 31 Max: Aug 19
Radiant: 327 -06 Diameter: 5 Drift: +1.03 +0.13
Velocity: 31 km/s Population Index: 3.2 ZHR: 3

NOTES: See Southern Iota Aquarids.

Alpha Aurigids (AUR) Active: Aug 25-Sep 05 Max: Aug 31
Radiant: 84 +42 Diameter: 5 Drift: +1.1 0.0
Velocity: 66 km/s Population Index: 2.5 ZHR: 10

NOTES: Just as the last of the Perseid meteors are seen, the Alpha Aurigids become active. Rates are usually low for this shower except for a period of about one hour on the morning of August 31. If you are situated in dark morning skies when this sharp maximum occurs, you may see up to 50 shower members radiating from the "Pentagon" of Auriga. Shower members seen during this peak of activity are often bright and leave long-lasting trains. Notable displays were seen in 1935, 1986, and 1994. The Alpha Aurigids may be particles from Comet Kiess, last seen in 1911. Photographing the Alpha Aurigids is difficult except during the time of maximum activity.

Delta Aurigids (DAU) Active: Sep 05-Oct 10 Max: Sep 08
Radiant: 60 +47 Diameter: 5 Drift: +1.0 +0.1
Velocity: 64 km/s Population Index: 3.0 ZHR: 6

NOTES: The meteors from this shower are fast moving and better situated for mid-northern latitudes where the radiant reaches a suitable elevation earlier in the night. Plotting is recommended for this shower as much more information needs to be obtained. Observers are urged to face the direction of the radiant in order to obtain a well-distributed sample of paths.

Piscids (SPI) Active: Sep 01-Sep 30 Max: Sep 19
Radiant: 05 -01 Diameter: 5 Drift: +0.8 +0.2
Velocity: 26 km/s Population Index: 3.0 ZHR: 3

NOTES: The radiant of the Piscids is well situated for Northern and Southern Hemisphere observers. Activity is very low so care must be taken in identification to avoid sporadics being incorrectly counted as Piscids. Meteors tend to be slow with a velocity of about 26 km/s.

Draconids (GIA) Active: Oct 06-Oct 10 Max: Oct 9
Radiant: 262 +54 Diameter: 2 Drift: ?
Velocity: 20 km/s Population Index: 2.6 ZHR: variable

NOTES: This is a PERIODIC shower which is visible during a short period before or after the perihelion passage of its parent comet, 21P/Giacobini-Zinner. The radiant is circumpolar for northern latitudes, but best placed in the early parts of the night. The theory of the evolution of meteoroid streams support the idea that this will become an annual shower at some point, probably several centuries in the future. But planetary perturbations may cause the stream to miss the Earth entirely. Periodic showers such as this one prove how much regular observing is necessary to catch unexpected returns. Negative observations are equally valuable since this helps to modify our understanding of how meteoroid streams evolve. Outbursts of the Draconids occurred in 1933, 1946 and 1985.

Epsilon Geminids (EGE) Active: Oct 14-Oct 27 Max: Oct 18
Radiant: 102 +27 Diameter: 5 Drift: +1.0 +0.1
Velocity: 70 km/s Population Index: 3.0 ZHR: 2

NOTES: The maximum of this shower is not distinct and occurs around October 20. Meteors from this shower will be very fast. Care must be used in distinguishing meteors from this radiant and that of the Orionids.

Orionids (ORI) Active: Oct 02-Nov 07 Max: Oct 21
Radiant: 95 +16 Diam: 10 Drift: +0.65 +0.11
Velocity: 66 km/s Population Index: 2.9 ZHR: 20

NOTES: The Orionids are the incoming (pre-perihelion) particles from Halley's comet. This shower is active throughout October and reaches its maximum activity between October 17 and 25. The highest hourly rates average near 15 but occasionally reaches 40. Most Orionid meteors are faint and therefore difficult to photograph. This shower's radiant is located near the Celestial Equator allowing it to be seen equally well from both hemispheres.

S. Taurids (STA) Active: Oct 01-Nov 25 Max: Nov 05
Radiant: 50 +13 Diameter: 20/10 Drift: +0.79 +0.15
Velocity: 27 km/s Population Index: 2.3 ZHR: 5

NOTES: These are slow, bright meteors visible during the months of October and November. This shower has two radiants of nearly equal activity 10 degrees apart. The southern radiant reaches its maximum activity during the first week of November, while the northern radiant peaks one week later. The activity of this and the related Southern branch (see below) produce an apparent plateau-like maximum for about 10 days in early November. With the radiant position reaching culmination just after midnight, Taurid meteors can be observed for most of the night. The stream is noted for its many brightly colored meteors although this seems to not be the case in every year.. Although the dominant color is yellow, many orange, green, red and blue fireballs have been recorded. The Taurids are produced by debris from Comet 2P/Encke.

N. Taurids (NTA) Active: Oct 01-Nov 25 Max: Nov 12
Radiant: 58 +22 Diameter: 20/10 Drift: +0.76 +0.10
Velocity: 29 km/s Population Index: 2.3 ZHR: 5

NOTES: See notes for Southern Taurids.

Leonids (LEO) Active: Nov 14-Nov 21 Max: Nov 17
Radiant: 153 +22 Diameter: 5 Drift: +0.7 -0.4
Velocity: 71 km/s Population Index: 2.5 ZHR: 40+

NOTES: The Leonids are a shower of short duration, lasting only one week centered on November 18. The Leonids are particles from Comet Temple-Tuttle, which will reach perihelion in 1998. A great concentration of particles exists near the parent comet. In years when the comet is far from the inner solar system the activity remains below 10 meteors per hour. However, for approximately 10 years centered on the perihelion passage of Temple-Tuttle, the Leonids can produce marvelous displays of celestial fireworks. We are now within this period of enhanced activity and one should not miss the opportunity to watch the Leonids. During periods of high activity, the Leonids are easy to photograph. Many shower members are bright and leave long lasting trains. The Leonid stream collides with the earth from a head-on position that produces the highest velocity of all major showers: 71 km/s, often producing blue, green or white meteors that frequently leave a train. Fortunately the Leonid radiant is located close enough to the Celestial Equator that these displays may be enjoyed by both hemispheres.

Alpha Monocerotids (AMO) Active: Nov 15-Nov 25 Max: Nov 21
Radiant: 110 +03 Diameter: 5 Drift: +0.8 -0.2
Velocity: 65 km/s Population Index: 2.4 ZHR: variable

NOTES: The Alpha Monocerotids are noted for their variable activity which in some years is virtually non-existent while in others the maximum ZHR has exceeded 100 meteors per hour. Outbursts have occurred in 1925, 1935, 1985 and 1995, suggesting a 10 year periodicity.

Chi Orionids (XOR) Active: Nov 26-Dec 15 Max: Dec 02
Radiant: 82 +23 Diameter: 8 Drift: +1.2 0.0
Velocity: 28 km/s Population Index: 3.0 ZHR: 3

NOTES: These meteors are well placed in the sky for both Northern and Southern Hemisphere observers and allow many hours of observing each night. The shower has a double radiant but its southern branch has rarely been detected. Members of this stream may be a continuation of the ecliptic complex after the Taurids end. The radiant above is a combined one, suitable for visual work. Rates are usually low but occasionally fireballs will occur.

Phoenicids (PHO) Active: Nov 28-Dec 09 Max: Dec 06
Radiant: 18 -53 Diameter: 5 Drift: ?
Velocity: 18 km/s Population Index: 2.8 ZHR: variable

NOTES: This is possibly a PERIODIC shower only visible from the Southern Hemisphere. There is a gradual rise to a maximum on December 5, and although the maximum ZHR is usually below 3, on some occasions much greater rates have been recorded. Only one impressive return has been reported, that of its discovery in 1956 when rates were about 100. Three other potential bursts of lower activity have been reported, but never by more than one observer. IMO observers have noted rates barely at the detection limit between the years of 1988-1995, making the normal current activity almost nonexistent.

Puppid/Velids (PUP) Active: Dec 01-Dec 15 Max: Dec 07
Radiant: 123 -45 Diameter: 20 Drift: +0.5 0.0
Velocity: 40 km/s Population Index: 2.9 ZHR: 10

NOTES: There are indications of a number of radiants active in the Puppis-Vela region from late October to the end of January. Generally, this shower produces about 2 meteors per hour but rates can exceed 5 per hour. Since several sub-centers exist, a radiant diameter of 20 degrees should be used. Plotting is recommended. This shower is noted for its spectacular fireballs. The Puppid/Velids are in desperate need of many more observations.

Dec. Monocerotids (MON) Active: Nov 27-Dec 17 Max: Dec 8
Radiant: 100 +08 Diameter: 5 Drift: +0.77 +0.24
Velocity: 42 km/s Population Index: 3.0 ZHR: 3

NOTES: The Monocerotids are observable from both the Northern and Southern Hemispheres. They tend to produce low rates, on the order of 1 or 2 per hour. Care must be used when distinguishing these meteors from the Geminids which are also active at the same time.

Sigma Hydrids (HYD) Active: Dec 03-Dec 15 Max: Dec 11
Radiant: 127 +02 Diameter: 5 Drift: +0.7 -0.2
Velocity: 58 km/s Population Index: 3.0 ZHR: 2

NOTES: Although first detected in the 1960s by photography, these meteors are typically swift and faint, with rates generally low, often close to the visual detection limit. This shower is observable from both hemispheres since the radiant is located just to the southwest of the "head" asterism of Hydra. It is noted for production of meteors with trains, and the shower can be best observed after local midnight right up through dawn.

Geminids (GEM) Active: Dec 07-Dec 17 Max: Dec 13
Radiant: 112 +33 Diameter: 5 Drift: +0.97 -0.08
Velocity: 35 km/s Population Index: 2.6 ZHR: 110

NOTES: The Geminids, with their high rates and reliability from year to year, are the shower of choice of veteran meteor observers. This is usually the strongest shower of the year and produces nearly 100 meteors per hour on the morning of December 14. The Geminids are visible for one week prior to maximum, but the great majority of activity is limited to December 13 and 14. The peak has shown slight signs of variability in time and maximum rates, and the true maximum may fall a few hours before or after the published time. Some mass-sorting across the stream means that fainter telescopic meteor rates are at their highest almost one degree of solar longitude ahead of the visual peak. Telescopic observations show these meteors radiate from an elongated region, with up to three possible sub-centers. This shower produces many bright meteors, but persistent trains are rare. Near maximum there are many fireballs with vivid colors, especially their many bright yellow-orange meteors, making this shower easy to photograph. The Geminids are visible from the Southern Hemisphere, but at a greatly reduced rate. The parent object of the Geminids was unknown until recently. However, the asteroid 3200 Phaethon, discovered by IRAS (Infrared Astronomical Satellite) in 1983, is now known to be the source of the Geminid meteors and it is also the only non-cometary object associated with the evolution of a major annual stream.

Coma Berenicids (COM) Active: Dec 12-Jan 23 Max: Dec 19
Radiant: 175 +25 Diameter: 5 Drift: +0.8 -0.3
Velocity: 65 km/s Population Index: 3.0 ZHR: 5

NOTES: The Coma Berenicids are best seen the last few hours before sunrise from the Northern Hemisphere. Northern observers should endeavor to monitor this shower after the period of maximum Geminid activity. Although maximum occurs in December, rates are still moderate during January.

Ursids (URS) Active: Dec 17-Dec 26 Max: Dec 22
Radiant: 217 +76 Diameter: 5 Drift: 0.0 -0.4
Velocity: 33 Population Index: 3.0 ZHR: 10

NOTES: This shower has been poorly observed although at least two major outburst have occurred in 1945 and 1986, and several other enhanced rates, most recently in 1988 and 1994. The parent comet of this shower is Comet Tuttle, which last reached perihelion in 1994. An odd feature of this shower is the apparent existence of a small condensation of material opposite the comet. A short but strong display has been seen three times while Comet Tuttle was near aphelion, with the last burst of activity occurring in 1986. Thus the year 2000 may provide the next possible strong display of Ursid meteors. A great majority of the Ursid activity occurs on the morning of December 22. The Ursids display variable activity with ZHRs of around 50 being recorded on occasion. This shower is difficult to photograph due to the low numbers and the faintness of its meteors. This shower is invisible in the Southern Hemisphere.

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APPENDIX B. USEFUL ADDRESSES

****

North American Meteor Network
Mark Davis
101 Margate Circle
Goose Creek, SC 29445
(e-mail) MeteorObs@charleston.net

International Meteor Organization (IMO)
Robert Lunsford
161 Vance Street
Chula Vista, CA 91910
(e-mail) LUNRO.IMO.USA@prodigy.com

International Meteor Organization Commissions:

Commission	Director	E-mail
Photographic	Juergen Rendtel	photo@imo.net
Radio	Vacant	radio@imo.net
Telesopic	Malcolm Currie	tele@imo.net
Video	Sirko Molau	video@imo.net
Visual	Rainer Arlt	visual@imo.net

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APPENDIX C. METEOR REPORT FORM FOR ELECTRONIC REPORTING

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The following meteor report form can be used to report observations either electronically or by postal mail. A filled out report has been included as a sample. Following the sample form is a blank one that may be used as a "template" for future observations. A blank form is also located on the NAMN homepage, along with other related meteor observing forms. The URL to the WWW site is: http://web.infoave.net/~meteorobs/index.html

<SAMPLE REPORT>

```
***************************
NAMN VISUAL SUMMARY REPORT
***************************
DATE:  Feb 12/13, 1996   BEGIN: 0018 UT END: 0318 UT
OBSERVER : Mark Davis
LOCATION : Long: 79o 36' 48.0" West; Lat: 33o 02' 15.0" North
City & State: Awendaw, SC, USA;  Elevation: 6 meters
RECORDING METHOD: Tape Recorder

---------------------------------------------------------------------
OBSERVED SHOWERS: 3-letter code; radiant position; radiant diameter
VIR   167 +09   15/10

---------------------------------------------------------------------
OBSERVING PERIODS: 0 = none seen;    / = shower not watched.

PERIOD(UT)  FIELD   Teff   F     LM   VIR   SPO
0018-0118  125 +25  1.00  1.05  6.20   /     4
0118-0318  125 +25  2.00  1.06  6.20   1     8
-----------------------------------------------
TOTALS              3.00               1     12

---------------------------------------------------------------------
MAGNITUDE DISTRIBUTIONS:

SHOWER    -6  -5  -4  -3  -2  -1   0  +1  +2  +3  +4  +5  +6  TOTAL
VIR        0   0   0   0   0   0   0   0   1   0   0   0   0     1
SPO        0   0   0   0   1   0   1   1   2   3   2   2   0     12

---------------------------------------------------------------------
OBSERVING FIELD OBSTRUCTION:
__15__%         __5__%
FROM: 0100 UT  FROM:  0130 UT
  TO: 0130 UT  TO  :  0306 UT

---------------------------------------------------------------------
DEAD TIME:  0
BREAKS   :  0

---------------------------------------------------------------------
LIMITING MAGNITUDE:
       STAR      STAR
TIME   AREA      COUNT         LM
0018    2         15          6.2
0100    2         15          6.2
0130    2         15          6.2
```

0200	2	15	6.2
0230	2	15	6.2
0300	2	15	6.2

MEAN LIMITING MAGNITUDE: 6.2

METEOR DATA:

#	TIME(UT)	MAG	VEL.	COLOR	SHOWER	TRAIN	MAP	ACCURACY
1	0045	-2.0	2	Y	SPO	1.0		
2	0048	3.0	3	W	SPO			
3	0105	3.0	4	W	SPO			
4	0110	2.0	4	W	SPO			
5	0131	2.0	2	W	VIR			
6	0134	4.0	2	W	SPO			
7	0136	5.0	2	W	SPO			
8	0145	1.0	3	Y	SPO			
9	0149	4.0	3	W	SPO			
10	0152	0.0	2	Y	SPO	0.5		
11	0221	5.0	3	W	SPO			
12	0238	3.0	4	W	SPO			
13	0256	2.0	4	W	SPO			

VELOCITY (VEL.) SCALE:
0 = Stationary
1 = Very Slow
2 = Slow
3 = Medium
4 = Fast
5 = Very Fast

REMARKS:

1. Any trains designated as 0.5 seconds were wakes left by meteors and quickly disappeared after meteors passage.

<END OF REPORT>

```
***************************
NAMN VISUAL SUMMARY REPORT
***************************
DATE:                         BEGIN:     UT    END:     UT
OBSERVER:
LOCATION: Long:               West; Lat:               North
City & State:                          Elevation:
RECORDING METHOD:

---------------------------------------------------------------------
OBSERVED SHOWERS: 3-letter code; radiant position; radiant diameter




---------------------------------------------------------------------
OBSERVING PERIODS: 0 = none seen;    / = shower not watched.

PERIOD(UT)  FIELD   Teff   F     LM   XXX   XXX   XXX   SPO
XXX
XXX
-----------------------------------------------------------
TOTALS              XXXX              XXX   XXX   XXX   XXX

---------------------------------------------------------------------
MAGNITUDE DISTRIBUTIONS:

SHOWER   -7  -6  -5  -4  -3  -2  -1  0  +1  +2  +3  +4  +5  +6  TOTAL
XXX
XXX
XXX
SPO

---------------------------------------------------------------------
OBSERVING FIELD OBSTRUCTION:
      _____%                _____%
FROM:         UT      FROM:         UT
  TO:         UT        TO:         UT

---------------------------------------------------------------------
DEAD TIME:
BREAKS:

---------------------------------------------------------------------
LIMITING MAGNITUDE:

          STAR      STAR
TIME      AREA      COUNT     LM




MEAN LIMITING MAGNITUDE:

---------------------------------------------------------------------
```

```
METEOR DATA:

#  TIME(UT)  MAG  VEL.  COLOR  SHOWER  TRAIN  MAP  ACCURACY
----------------------------------------------------------------------
1
2
3
4
5
6
7

VELOCITY (VEL.) SCALE:
0 = Stationary
1 = Very Slow
2 = Slow
3 = Medium
4 = Fast
5 = Very Fast

----------------------------------------------------------------------
REMARKS:
1.
2.
3.

----------------------------------------------------------------------
<END OF REPORT>
```

****

APPENDIX D. USING STAR COUNTS FOR SKY LIMITING MAGNITUDE ESTIMATES

****

Currently the NAMN has no way to send the necessary reference maps electronically that allow an observer to estimate the limiting magnitude of their sky. The IMO Handbook for Visual Meteor Observers contains the necessary charts.

To obtain the limiting magnitude estimates, use these maps along with the following information and tables. First, obtain the count of stars as discussed in Chapter 2. When completing your reports, compare the star count numerical values to the corresponding area of the charts on the following pages. For instance: if you count six stars in area 1, then your corresponding limiting magnitude would be 4.9. Should your count not be listed, then choose the magnitude that corresponds to the next lower star count. When averaging two or more counts together from the same area, be sure to use the resulting magnitudes and not the number of stars visible.

Note that it is advisable to observe meteors only when the limiting magnitude is +5.0 or better.

AREA	CORNER STARS
1	CHI, ZETA, DELTA, XI DRACO
2	BETA, DELTA, ZETA PERSEUS
3	23, THETA, BETA URSA MAJOR
4	ALPHA, EPSILON, BETA GEMINI
5	ZETA, GAMMA, DELTA AQUILA
6	ALPHA ANDROMEDA, GAMMA, ALPHA PEGASUS
7	ALPHA, DELTA, BETA CEPHEUS
8	ALPHA, BETA, ZETA TAURUS
9	ALPHA, BETA, DELTA, GAMMA LEO
10	ALPHA, ZETA, GAMMA VIRGO
11	ALPHA CORONA BOREALIS, GAMMA, ALPHA BOOTES
12	ALPHA SERPENS, BETA LIBRA, DELTA OPHIUCHUS
13	BETA, ZETA LYRA, THETA, NU HERCULES
14	EPSILON, ETA, GAMMA CYGNUS
15	BETA DRACO, TAU, PI HERCULES
16	ALPHA CANES VENATICI, EPSILON, ETA URSA MAJOR
17	EPSILON, THETA, DELTA AURIGA
18	MU, GAMMA, PHI ANDROMEDA
19	KAPPA, ALPHA DRACO, BETA URSA MINOR
20	42, BETA, GAMMA CAMELEOPARDALIS
21	ALPHA PISCES AUSTRINUS, 98, DELTA AQUARIUS
22	BETA LEPUS, BETA ORION, 53 ERIDANUS
23	DELTA, GAMMA, EPSILON, BETA CORVUS
24	BETA, GAMMA, SIGMA, ALPHA LIBRA
25	ALPHA, EPSILON, SCORPIUS, CHI LUPUS
26	GAMMA, ALPHA, TRIANGULUM, ETA ARA, ALPHA CENTAURUS
27	BETA CENTAURUS, ALPHA, GAMMA CRUX
28	BETA, EPSILON, IOTA CARINA
29	GAMMA, ALPHA, BETA HYDRUS
30	ALPHA TUCANA, ALPHA, EPSILON PAVO

STAR COUNT/LIMITING MAGNITUDE CONVERSION TABLES: AREAS 1 - 6

AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6	
N	LM	N	LM	N	LM	N	LM	N	LM	N	LM
5	4.2	6	5.0	5	4.5	5	4.3	4	4.6	4	4.7
6	4.9	7	5.1	6	4.6	6	5.0	5	5.1	5	5.2
8	5.0	8	5.4	7	4.8	7	5.1	6	6.2	6	5.4
9	5.2	10	5.6	8	5.2	8	5.3	7	5.4	7	5.7
10	5.3	11	5.7	9	5.4	9	5.6	8	6.0	8	5.9
11	6.0	12	5.8	11	5.7	10	5.7	10	6.2	9	6.2
12	6.1	13	6.0	13	5.8	11	5.9	11	6.4	12	6.3
15	6.3	14	6.1	14	6.0	12	6.1	12	6.5	14	6.4
16	6.4	15	6.2	15	6.1	13	6.2	13	6.6	17	6.5
17	6.5	17	6.3	16	6.2	14	6.3	19	6.9	20	6.6
18	6.6	20	6.4	17	6.3	15	6.4	22	7.0	25	6.7
20	6.7	23	6.6	18	6.4	16	6.5	24	7.1	29	6.8
23	6.8	26	6.7	19	6.5	18	6.6	25	7.2	30	6.9
28	6.9	27	6.8	20	6.6	20	6.7	26	7.3	33	7.0
34	7.0	29	6.9	23	6.7	22	6.9	27	7.4	35	7.1
41	7.1	31	7.0	25	6.8	23	7.0			40	7.2
46	7.2	35	7.1	27	6.9	25	7.2			43	7.3
55	7.3	42	7.2	29	7.0	26	7.3			46	7.4
60	7.4	44	7.3	33	7.1	30	7.5			49	7.5
73	7.5	54	7.4	37	7.2						
		59	7.5	44	7.3						
				49	7.4						
				54	7.5						

STAR COUNT/LIMITING MAGNITUDE CONVERSION TABLES: AREAS 7 - 12

AREA 7		AREA 8		AREA 9		AREA 10		AREA 11		AREA 12	
N	LM	N	LM	N	LM	N	LM	N	LM	N	LM
3	4.0	4	4.7	7	4.4	4	4.5	6	4.5	6	5.2
4	4.5	5	4.8	8	5.0	5	5.8	7	4.7	7	5.3
5	4.6	7	5.1	11	5.6	7	5.9	9	4.9	9	5.4
7	4.9	8	5.3	13	5.7	8	6.0	10	5.0	11	5.6
8	5.2	9	5.5	15	6.0	11	6.1	11	5.3	13	5.7
10	5.4	10	5.9	18	6.1	12	6.4	13	5.7	14	6.4
12	5.5	11	6.0	20	6.3	15	6.5	14	5.8	17	6.5
13	5.9	12	6.1	21	6.4	16	6.7	17	5.9	19	6.7
14	6.0	15	6.2	24	6.6	17	6.8	19	6.0	20	6.8
15	6.1	16	6.3	25	6.7	19	7.0	21	6.1	22	6.9
17	6.2	17	6.4	29	6.9	22	7.1	23	6.2	23	7.0
18	6.3	20	6.5	32	7.0	23	7.2	25	6.3	24	7.1
20	6.4	21	6.6	34	7.1	25	7.3	27	6.4	30	7.2
22	6.5	23	6.7	38	7.2	26	7.4	30	6.5		
23	6.8	26	6.8	40	7.3	31	7.5	32	6.6		
26	6.9	28	6.9	44	7.4			36	6.7		
33	7.0	29	7.0	45	7.5			39	6.8		
41	7.1	31	7.4					45	6.9		
48	7.2	32	7.5					52	7.0		
49	7.3							55	7.1		
57	7.4							60	7.2		
65	7.5							69	7.3		
								73	7.4		
								86	7.5		

STAR COUNT/LIMITING MAGNITUDE CONVERSION TABLES: AREAS 13 - 18

AREA 13		AREA 14		AREA 15		AREA 16		AREA 17		AREA 18	
N	LM	N	LM	N	LM	N	LM	N	LM	N	LM
2	4.0	3	4.0	4	4.9	4	4.6	6	4.2	3	4.2
4	4.3	4	4.8	5	5.1	5	5.1	8	4.6	4	4.3
5	4.5	6	4.9	6	5.5	6	5.7	9	5.1	6	5.0
6	5.0	7	5.0	8	5.8	7	5.9	10	5.5	7	5.1
7	5.5	8	5.2	10	6.0	9	6.0	11	5.9	9	5.2
8	5.7	11	5.5	12	6.1	11	6.2	12	6.0	10	5.5
12	5.9	12	5.7	18	6.3	13	6.3	14	6.1	11	5.7
13	6.0	13	5.9	21	6.4	14	6.4	16	6.2	12	5.9
15	6.1	14	6.0	22	6.6	17	6.6	17	6.3	13	6.1
16	6.2	15	6.1	26	6.7	19	6.8	20	6.4	14	6.3
17	6.3	16	6.2	32	6.9	22	6.9	26	6.5	17	6.4
18	6.5	18	6.3	33	7.0	24	7.0	30	6.6	18	6.5
20	6.8	20	6.4	35	7.1	26	7.1	35	6.7	24	6.6
23	6.9	24	6.5	38	7.2	27	7.2	37	6.8	27	6.7
27	7.0	28	6.6	48	7.3	28	7.3	41	6.9	31	6.9
32	7.1	32	6.7	54	7.4	33	7.4	44	7.0	33	7.0
36	7.2	34	6.8	61	7.5	36	7.5	50	7.1	37	7.2
42	7.3	36	6.9					55	7.2	41	7.3
43	7.4	41	7.0					60	7.3	46	7.4
52	7.5	46	7.1					68	7.4	52	7.5
		49	7.2					81	7.5		
		54	7.3								
		61	7.4								
		65	7.5								

STAR COUNT/LIMITING MAGNITUDE CONVERSION TABLES: AREAS 19 - 24

AREA 19		AREA 20		AREA 21		AREA 22		AREA 23		AREA 24	
N	LM	N	LM	N	LM	N	LM	N	LM	N	LM
4	5.2	1	4.2	4	4.0	5	4.3	6	5.2	5	4.5
5	5.4	2	4.4	5	4.5	6	4.4	7	5.8	7	5.2
6	5.7	4	4.7	6	4.7	7	4.5	8	6.0	8	5.6
8	6.1	5	5.0	7	5.6	8	4.8	9	6.4	9	5.7
11	6.4	6	5.4	8	5.7	9	5.5	10	6.5	11	5.8
12	6.6	7	5.7	9	6.0	13	5.7	11	6.9	12	6.0
14	6.7	9	5.8	10	6.4	15	6.0	13	7.3	13	6.1
15	6.8	10	5.0	11	6.5	16	6.2	14	7.4	14	6.2
16	7.0	13	6.0	14	6.8	17	6.3	17	7.5	16	6.3
17	7.1	15	6.1	15	7.0	18	6.4			17	6.6
18	7.2	16	6.2	18	7.4	19	6.5			19	6.7
21	7.3	18	6.3	20	7.5	21	6.6			20	6.8
28	7.4	23	6.4			22	6.7			21	6.9
32	7.5	28	6.6			23	6.8			24	7.0
		33	6.7			24	6.9			26	7.1
		37	6.8			25	7.2			27	7.3
		45	6.9			27	7.3			30	7.4
		50	7.0			29	7.4			31	7.5
		56	7.1								
		60	7.2								
		67	7.3								
		74	7.4								
		82	7.5								

STAR COUNT/LIMITING MAGNITUDE CONVERSION TABLES: AREAS 25 - 30

AREA 25		AREA 26		AREA 27		AREA 28		AREA 29		AREA 30	
N	LM	N	LM	N	LM	N	LM	N	LM	N	LM
4	4.0	7	4.1	5	4.6	4	4.0	4	4.1	5	4.0
5	5.2	8	4.9	6	4.7	5	5.4	5	4.7	6	4.2
6	5.6	12	5.1	7	5.8	6	5.5	6	4.8	7	4.8
7	6.0	14	5.2	9	6.2	7	5.8	7	5.0	8	4.9
8	6.1	17	5.5	11	6.4	8	6.4	8	5.6	9	5.1
9	6.2	18	5.7	14	6.7	10	6.5	9	5.7	10	5.2
10	6.3	22	5.8	15	6.8	14	7.0	10	6.4	11	5.4
11	6.6	24	5.9	17	7.0	15	7.2	11	6.5	12	5.6
12	6.9	31	6.2	18	7.1	16	7.3	13	6.6	13	5.7
14	7.0	32	6.3	19	7.2	17	7.4	17	6.7	14	5.8
15	7.1	34	6.4	22	7.4	18	7.5	20	6.9	15	5.9
		37	6.5					23	7.0	16	6.2
		38	6.6					24	7.1	18	6.3
		40	6.7					26	7.2	19	6.4
		42	6.8					29	7.5	20	6.5
		43	6.9							22	6.6
		44	7.0							23	7.0
		46	7.1							28	7.1
		49	7.2							31	7.3
		50	7.4							32	7.5
		51	7.5								

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APPENDIX E. GLOSSARY

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The following definitions are those used by the IMO in their Handbook for Visual Meteor Observers:

ABLATION - removal of material by attrition, e.g., by passage through the atmosphere.

ABSOLUTE MAGNITUDE - the stellar magnitude any meteor would have if placed in the observer's zenith at a height of 100 km.

ALTITUDE - the angular distance of a celestial body above or below the horizon, measured along the great circle passing through the body and the zenith. Altitude is 90 degrees minus zenith distance.

ASTEROID - one of a number of objects ranging in size from sub-kilometer to about 1,000 kilometers, most of which lie between the orbits of Mars and Jupiter; also called "minor planets".

AZIMUTH - the angular distance measured clockwise along the horizon from a specified reference point (usually north) to the intersection with the great circle drawn from the zenith through a body on the celestial sphere.

BROWNLEE PARTICLES - interplanetary dust particle (IDP), also known as a micrometeoroid or, after entry into the Earth's atmosphere, a micrometeorite.

DECLINATION - angular distance north or south of the celestial equator.

ECLIPTIC - plane of the Earth's orbit.

ESCAPE VELOCITY - the velocity required to escape entirely from the gravitational field of an orbit; also the minimum impact velocity for any body arriving from a very great distance.

FALL - a meteorite that was seen to fall. Such meteorites are usually recovered soon after the fall and are relatively free of terrestrial contamination and weathering effects.

FIND - a meteorite that was not seen to fall but was found and recognized subsequently.

FIREBALL - a bright meteor. Several definitions have been used by various authors. In the IMO's Fireball Data Center (FIDAC) all meteors of at least -3.0 magnitude are stored as fireballs.

GEOCENTRIC - Earth-centered.

HELIOCENTRIC - Sun-centered.

MAGNITUDE - an arbitrary number, measured on a logarithmic scale, used to indicate the brightness of an object. The brighter the star, the lower the numerical value of the magnitude and very bright objects have negative magnitudes.

METEOR - the light phenomenon produced by a meteoroid experiencing frictional heating when entering a planetary atmosphere; also used for the glowing meteoroid itself. If particularly bright, it is described as a fireball.

METEORIC - the adjective form pertaining to meteor or meteoroid.

METEORITE - a natural object of extraterrestrial origin that survives passage through the atmosphere.

METEOROID - a natural small solid object in an independent orbit in the Solar System.

METEOROID STREAM - stream of solid particles released from a parent body (comet or asteroid). Various ejection directions and velocities for individual meteoroids cause the width of a stream and the gradual distribution of meteoroids over the entire average orbit.

METEOR SHOWER - many meteors appearing to radiate from a common point in the sky caused by the collision of the Earth with a swarm of meteoroids.

MINOR PLANET - asteroid.

PARENT BODY - a comet or asteroid which released meteoroids (as well as dust and gas) when passing the inner Solar System and which may form a meteoroid stream.

PERSISTENT TRAIN - remaining glow due to ionization in the upper atmosphere after the passage of a meteoroid. The intensity and duration depends on the meteoroid's atmospheric entry velocity, its size, and its composition.

RADIANT - the point where the backward prolongation of the meteor trajectory intersect the celestial sphere, or the backwards prolongation of the apparent trails of a given meteor as seen by observers at different locations.

RADIANT DRIFT - shift of a radiant position due to the Earth's passage through the meteoroid stream.

RIGHT ASCENSION - angular distance east of the vernal equinox, as measured on the celestial equator.

SOLAR LONGITUDE - angular distance along the Earth's orbit, measured from the vernal equinox. It gives the position of the Earth at its orbit and hence is more appropriate for designating a meteor shower's maximum than the date.

SPORADIC METEOR - a meteor which cannot be associated with any known or detectable meteor shower.

TRAJECTORY - path of a meteor in the Earth's atmosphere.

UNIVERSAL TIME - the local mean time of the prime meridian. It is the same as Greenwich mean time, counted from 0 hour beginning at Greenwich mean midnight.

ZENITH ATTRACTION - the effect of the Earth's gravity on a meteoric body increasing the velocity and moving the radiant toward the zenith.

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APPENDIX F. RECOMMENDED READING

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****** END OF GUIDE ******
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