How to observe… Meteors

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Observing meteors is an ideal way to start observing. You don't need any fancy instrumentation; just your eyes, some items to keep you comfortable and awake and some method of recording your observations are necessary. You will soon become familiar with patterns in the sky and learn the all-important technique of estimating magnitudes. With practice you will be making useful scientific observations and be ready to branch into other observing disciplines.

1. Some Definitions

The earth is bombarded daily by tonnes of debris left behind by comets as they journey around the sun. This debris consists of small dust particles, ranging in size from a few microns upwards – about the size of a grain of sand to about the size of a stone or small pebble. The term used for one of these particles travelling through space is 'meteoroid'. When one of them enters the earth's atmosphere, generally travelling at about 20-70 km/s, it ionises the molecules in the air through intense friction and we call the resultant streak of light a 'meteor'. On occasion, larger particles enter the atmosphere and due to their greater mass result in brighter meteors. If they reach magnitude -3 or brighter then we term them 'fireballs'. In addition, these larger particles very often explode under the intense heat to which they are subjected – they literally split apart into two or more pieces which are visible separately in the sky. A bright fireball that is seen to explode is termed a 'bolide'.

Meteors are generally of two types, 'sporadic meteors' or 'shower meteors'. The meteor showers are generally formed by the debris left behind by comets. When a comet rounds the sun, its volatiles sublimate and release dust grains in their wake. These dust grains continue to orbit the sun in orbits similar to the original parent comet. If the orbits intersect that of the Earth's, then we will occasionally pass through the debris stream. As the dust particles enter the atmosphere, they become visible as meteors. Freshly laid streams are generally narrow and last for perhaps a day or two. Gradually these streams evolve over time, becoming visible over longer periods. Some streams are visible every year as the Earth encounters them at the same points in its orbit. Other streams show activity in some years and in other years may appear dormant. Sporadic meteors are due to either solitary particles passing through space, or the very thin activity left over from highly evolved and dispersed streams. When observing meteor showers, it is important to report on the different showers and sporadic meteors seen, instead of just saying "8 meteors" for example.

Major Showers

Each year there are showers that are well known for their high or consistent activity. They are summarised in this table:

Shower	Max	Duration	RA	Dec	Vel	ZHR
April Lyrids	Apr 22	Apr 16-25	18h05	+34	49	15
eta Aquarids	May 5/6	Apr 21-May 12	22h24	-02	65	60
delta Aquarids	Jul 29	Jul 21-Aug 29	22h36	-16	42	25
alpha Capricornids	Jul 30	Jul 15-Aug 25	20h28	-10	25	5-10
Orionids	Oct 21	Oct 02-Nov 07	06h20	+16	68	30
Taurids	Nov 5	Oct 01-Nov 25	03h20	+14	29	10-15
Leonids	Nov 17	Nov 12-21	10h08	+22	70	5-50
Geminids	Dec 14	Dec 4-16	07h28	+33	36	50-100

Vel is the speed in km/s that the meteor encounters the Earth, known as the geocentric velocity. ZHR is the zenithal hourly rate and is the number of meteors one would expect to see from the shower at maximum with the radiant in the zenith and skies with limiting magnitude 6.5. Under poorer conditions and with the radiant lower, the number of observed meteors reduces drastically.

In any event, give these showers a try. The most active showers from South Africa are the eta Aquarids and Geminids, followed by the Orionids. Unfortunately all these are at their best in the early morning sky.

Minor Showers

There is a whole host of showers which are periodic, show low activity or occasional activity. More details are available from the Observing Director. Try these once you have mastered the major showers or you feel like more of a challenge.

2. Counting Meteors

The simplest observation is to count the number of each type of meteor seen. This enables us to determine the activity of each shower over time.

How to Conduct a Watch

Let's look at how to observe a simple shower. Further let's take observation of the eta Aquarids as an example. We'll observe on the morning of 5 May, from 03h00 local time until sun-up. First, after setting the alarm and getting up, wrap up warm so that you are comfortable (it's almost a winter shower). There is nothing worse than freezing half way through. Set up a sleeping bag in the direction of the radiant. Allow 10-15 minutes for your eyes to dark adapt, then record your start time in Universal Time (SAST – 2h) on the notepad or tape recorder. Immediately determine the limiting magnitude, that is the faintest star visible to the naked eye, to the nearest 0.1 magnitude.

Each time you see a meteor, record the time and details such as shower, magnitude, colour, speed and any persistent train or fragmentation. A typical recording on my tapes might sound like:

01h15UT	eta Aquarid	magnitude 3	white	fast	train
01h18UT	sporadic	magnitude 1	yellow	slow	
01h25UT	Capricornid	magnitude 2	yellow	medium	
01h30UT	eta Aquarid	magnitude 1	white	fast	train

… and so on, for the duration of the watch. At the end of the watch again record the time and limiting magnitude. Then submit your observations for processing. It's that simple!

Activity Profile

In order to determine the activity of the shower, each observer provides hourly counts of the main showers, sporadics and other meteors from minor showers active during each watch. Each observer determines the average naked eye limiting magnitude for each watch period. This data is the absolute minimum required for analysis. From this data the zenithal hourly rate for each shower is determined using the formula shown below.

What is definite is that amateurs can contribute to the study of meteor streams by careful visual observation. With sufficient observations, it is then possible to construct an activity profile for the stream. The simplest way would be to observe for 60 minutes and count the number of shower meteors. The rate per hour would then simply be:

$$\text{Rate} = \frac{N}{T} \qquad (1)$$

where N is the number of shower meteors and T is the time in hours. However this method says nothing about the conditions under which the observations were made, the altitude of the radiant, the reduction in visibility of sky due to obstructions or clouds or the proficiency of the observer. Hence it is normal to determine the zenithal hourly rate (ZHR) according to the formula:

$$\text{ZHR} = \frac{N \times F \times r^{(6.5-\text{LM})}}{T_{eff} \times \sin(h) \times C_p} \qquad (2)$$

where;

N = number of shower meteors observed

F = factor correcting for obscuration by clouds etc.

r = population index

h = mean altitude of radiant above horizon

LM = limiting magnitude

T_{eff} = observing time in hours corrected for breaks

C_p = perception coefficient for the observer

It is then possible to plot the derived ZHR for each watch against not time, but solar longitude, to derive the true activity profile for the shower versus position of the earth in its orbit around the sun. In order to do this we need to consider each term given in equation (2) in more detail.

Number of Shower Meteors

In order to determine the density of the stream we need to count the number of meteors from the designated shower radiant. As the earth intersects the orbit of a meteor stream, meteors enter the earth's atmosphere from a certain direction and with a certain geocentric velocity. They thus appear to emanate from a certain point in the heavens, termed the radiant. In the case of a new compact swarm, the apparent radiant may be small and circular. In the case of old, diffuse streams, the radiant may be quite large, with a diameter of a few degrees and elongated. Association of meteors with such streams needs to be made carefully. In the case of ecliptic streams the radiant may be split into southern and northern branches.

There could be several meteor showers active at any one time and so it is important to differentiate counts of meteors from the different shower radiants. In addition there will be meteors observed which, when the paths are traced backwards, cannot be traced to any known radiant. These meteors are recorded as sporadic.

In the event that several showers are active whose radiants are in close proximity or in the case when a shower is active but with low rates whose members could be confused with sporadic activity, we need to carefully assign associations to a particular shower for counting purposes. In order to correctly determine shower association we can use the following techniques:

- By plotting meteors on a gnomonic chart and tracing the path back to known radiants which should be marked on the chart after the plotting exercise (to avoid bias in aligning the plotted paths). Meteors appearing close to the radiant will tend to have short paths, while those appearing further from the radiant will have longer paths.
- By comparing meteor characteristics. Meteors from specific showers tend to show the same characteristics in terms of apparent speed, colour, brightness and tendency to leave trains etc.

By following the above procedures we arrive at the number of meteors for each active shower and sporadics (e.g. Nshwr1, Nshwr2, Nspo, etc.).

Correction for obscuration

The calculation of the ZHR assumes the observer has an unobstructed view of the sky in the area where the meteors appear. In the event the view is obstructed by buildings, trees, or by clouds, a correction must be made for the degree by which the observed field is obstructed. This correction, F, is given by the equation:

$$F = \frac{1}{1 - K} \qquad (3)$$

where

$$K = \frac{\sum (\text{\% obstruction} \times \text{duration in minutes})}{\text{Total watch duration in minutes}} \qquad (4)$$

The percentage of obstruction due to fixed items like trees or buildings should be carefully estimated. They may contribute considerable obstruction where the radiant is at low altitude, while they may have negligible effect on radiants which are nearly overhead. For shower radiants which are initially at low altitude but get higher during the night the value of F will gradually diminish towards culmination and then increase again as the radiant gets lower in the sky. Poor estimation of the degree of obstruction will lead to over or under correction of ZHR. Similarly, observers need to carefully estimate the varying effect of clouds on the watch, logging the number of minutes and percentage of sky obscured in the area of observation.

Determining the Population Index

The Population Index (r) of a meteor shower is an estimation of how many more meteors of magnitude m+1 appear compared to magnitude m. It can be derived from the magnitude distribution of the observed meteors, hence the importance of reporting the magnitudes of all meteors observed. Depending on the parent body, different meteor streams will have different particle sizes and compositions as well as different entry velocities, leading to differences in the brightness of observed meteors. Hence a stream comprising larger particles may appear to be visually more active than a stream with fainter meteors, which are missed by the observer, even though the particle density may be the same. The author will determine the value from your observations.

Correction for radiant altitude

The ZHR represents the activity of a stream assuming the radiant is at the zenith. If the radiant is lower then a correction needs to be applied to take care of meteors which were lost below the observers horizon or at low altitude. This factor escalates dramatically at very low altitude, such that watches on showers below 15° are unreliable and should be avoided. The correction is given by sin(h), where h is the mean altitude of the radiant during the watch in degrees. The author will determine the altitude from your location and watch times.

Determining the Limiting Magnitude

The ZHR is computed assuming the naked eye can just discern stars of magnitude 6.5. Under conditions where the naked eye visibility is lower, fewer meteors will be observed and a correction is applied as follows:

$$\text{Correction} = r^{(6.5-LM)} \qquad (5)$$

It can be seen that the population index (r) is raised to the power of 6.5 less the limiting magnitude for the watch to arrive at this correction. Again under poor conditions this factor causes unreliable corrections and generally watches where the limiting magnitude is poorer than 5.0 are discouraged.

The limiting magnitude is simply the faintest star visible in the area being watched. It can be determined in one of two ways:

- By checking the visibility of pre-selected stars of known magnitude. Convenient stars can be found from recognised magnitude sources. The stars and reference catalogue used should be identified in the report and for consistency the same stars should be used each year for the same showers
- By the star count method, where the observer counts the number of stars visible within a pre-designated area. There are 30 such pre-designated LM count areas, mainly triangles, but occasionally with four boundary stars. The stars delineating the boundaries are included in the count. The LM is then read off from the table from the area number and star count for that area. The areas and table are available from the Director on request.

The LM should be determined at the beginning and end of the watch and frequently during the watch if conditions are variable. From this the average LM for the watch is determined.

Determining the Perception Coefficient
When observing the same shower from the same location, separate observers will see differing numbers of meteors. This is largely determined by the experience of the observer. Hence it is necessary to reduce the observations to a standard observers perception, which is determined from your observed sporadic meteors. The author will make the determination from your observations.

3. Plotting Meteors

Once you become more advanced you can start to plot the observed meteors on special charts, which helps us determine radiant structure. The plots are made on specially prepared gnomonic charts - you can't use an ordinary star chart like Nortons or Sky Atlas 2000, since meteor paths plotted on these maps would be curved lines.

The observations are made in exactly the same way as counts, except that the meteor path is plotted on the map and numbered. The corresponding number is entered on the observing report. It is of paramount importance to plot accurately the start and end points of the path, in order to accurately define the meteor vector (its direction and path length).

You then submit your observing report and plots in the normal manner. For each meteor plotted you must subtract the dead time during which you were plotting and not watching the sky. This is typically half to one minute per meteor depending on experience. ☆