Visual observation of meteors

Workshop No. 2: Winchester 2003 April 26

by Neil Bone

The recent spell of enhanced activity in the Leonid shower, culminating in storms – by informal but widely-accepted definition, intervals during which the corrected rate exceeds a thousand meteors/hr – in 1999, 2001 and 2002, has generated considerable interest in meteor observing. Some of the Association's most experienced observers have used the opportunity afforded by this high activity to advance studies of the Leonid meteor stream (associated with Comet 55P/Tempel–Tuttle, which returned to perihelion in early 1998). Special mention should be made of the photographic and video work carried out in collaboration with Dutch and Czech observers by Steve Evans and Andrew Elliott, which continues to yield new orbital data for Leonid meteoroids.

For others, the spectacle was simply one to be enjoyed – an astronomical rarity to collect alongside eclipses, transits and so forth. The casual approach is nothing new – each August, amateur astronomers who otherwise take no interest in meteors will often pause and look for occasional Perseids while engaged in other pursuits such as hunting out deep sky objects. Without wishing to spoil anyone's enjoyment, I would say that the casual approach is fine if that's what you wish, but there is not a lot to be gained from apocryphal reports of the nature of 'several Leonids were seen in roughly 30 minutes'. As I hope to demonstrate, the step up from 'just looking' to making proper written records – *observing* – isn't that onerous, and there is no reason whatsoever why disciplined, systematic meteor-watching should be less enjoyable than casual viewing.

Visual meteor observing is, rightly, seen as an easy field in which to partake, but there are some important points to remember – as I shall outline here – which will make the resulting records suitable for more detailed analysis that can reveal interesting features of how the regular annual showers behave, and sometimes change, over various timescales.

Basic requirements

Visual meteor observing exploits the wide field of view of the naked eye, and entails watching a sizeable area of sky over a defined period of time, during which relevant details of all meteors seen should be recorded.

A first obvious requirement then, is an observing location which offers unobstructed viewing of the sky, preferably towards the east or south. As with most astronomical pursuits, the absence of artificial light pollution is desirable. Moonlight also has a detrimental effect on meteor observing: the strong Moon within four or five days of Full will swamp all but the brightest meteors, and unless special circumstances obtain (as during the 2002 Leonids), serious observers regard this part of the lunation as enforced 'down-time'.

The observer will ideally spend some time watching the sky. Comfort then becomes an important consideration: standing around looking up will result fairly quickly in a cricked neck, and the observer will soon be paying more attention to their discomfort than to the sky. Most meteor enthusiasts' 'observatories' are lawn chairs or recliners, which allow them to sit back and view the sky at an altitude of around 50° above the horizon – a little below that of Polaris in the British Isles – which is where most meteors tend to be seen.

Warm clothing is important, even on August nights. Some observers resort to using a sleeping bag, maybe even with a hot water bottle! A woollen hat is useful in reducing the (significant) loss of body heat through the head.

Figure 1. The author's observatory!

At one time, visual observers concentrated on plotting meteors' apparent paths on specially prepared gnomonic-projection maps. This kind of work was seen as especially important from the 1930s to the 1950s, its leading exponents being the then Meteor Section Director J. P. M. Prentice and collaborating observer George Alcock. Positional work is now far better conducted by photographic or even video means, so that today's visual observers are encouraged to concentrate on other aspects including counts and magnitude estimates. Although a set of charts is no longer part of the meteor watcher's equipment, some means of recording observations will still be required.

Some have used portable dictating machines – cheaply available from high street electrical retailers – to record their observations. This relatively 'hands-free' approach is seen by its advocates as having the advantage of speed, allowing the observer more time for watching the sky. There are pitfalls, however, and although I have a dictaphone and have used it for recording some of my astronomical observations, I would be wary of relying on a piece of battery-powered electrical equipment in the cold and damp of a British night: there are enough tales of lost data resulting from fading batteries to suggest that the traditional pen-and-paper approach still has the upper hand.

So, in terms of recording, a clipboard or notepad with plenty of paper is a good starting point. The observer should have several pens and pencils to hand (experience shows that these get dropped in the long grass, or the point breaks, or the ink gums up during times of frenetic activity, and it is therefore prudent to have plenty of spares).

Visual meteor observing relies on the eyes being well dark adapted. On going from a well-lit room to the great outdoors on a clear night, the observer may initially struggle to see stars fainter than about fourth magnitude. With time, physiological changes in the eyes, including dilation of the pupils, allows detection of fainter stars (and, of course, meteors).

During the watch, the observer will obviously wish to preserve night vision. The best way to do this is to employ a red torch for recording: strong white light will instantly set back your dark adaptation by 20 minutes, and you don't want to do that every time you see a meteor and wish to record it! Some astronomical equipment suppliers sell red LED-based torches, which are fine. My own solution has been to cover the front 'window' of a cheap flashlight with overlapping strips of red insulating tape, and this works well, too. Spare batteries and a spare bulb are always sensible accessories.

With these basics to hand, the observer is ready to set about conducting a meteor watch, following a few minor elements of preparation.

Before you start

Meteor activity can be followed throughout the year, though for much of the time only the ever-present random sporadic background, supplemented by minor shower activity, is in evidence: the low rates in the spring months, particularly, will prove disappointing to all but the most seasoned of die-hard observers. If you are just starting out in meteor observing, by far the best times are when one of the major annual showers like the Perseids or Geminids is active. Then rates will generally be good, and the novice observer can get some idea of the shower radiant effect, and see plenty of meteors on which to practise magnitude estimates.

Before setting out to do a watch, it is important to check which showers – if any – are expected to be active on the night, and establish where in the sky their radiants are positioned. The BAA *Handbook* Meteor Diary provides an annually-updated list of the regular showers, their activity limits, date of maximum, and radiant position and movement. Meteors from a common source (most showers, with the notable exception of the asteroid-associated Geminids, are produced by streams of cometary debris orbiting the Sun) will appear to emanate from a single part of the sky. This radiant is usually a diffuse area, taken for observational convenience to be 8° in diameter. Meteor showers are named for the constellation in which their radiant lies: the Perseids from Perseus, and so forth.

Meteors from a given shower can appear anywhere in the sky, their paths diverging away from the radiant. Shower members are identifiable by having paths which can be traced backwards to the radiant area. When observing on a night of shower activity, it is a good idea to direct the field of view 40° to one side of the shower radiant and at an altitude of 50°. Meteors appearing in this part of the sky will have reasonably long paths, and are more likely to be seen than those foreshortened (by perspective) close to the radiant itself.

It is therefore an important preparatory step ahead of the watch to establish where in the sky active radiants might be on the night in question. It should also be borne in mind that radiants move eastwards by about a degree per night as a result of Earth's orbital motion. The positions given in the BAA *Handbook* are for maximum, and on nights well away from this date, the radiant might be significantly displaced.

The meteor watch

To be useful in later analysis, the observing report needs to include a few basic general details which should be recorded as a matter of routine by anyone undertaking a watch (see Figure 3). Name and geographical location of the observer are fairly obvious. The **Date** of the observation should be given in double-date format to avoid ambiguity, regardless of whether the watch started before or after midnight – thus watches on the evening of August 12, or in the early morning hours of August 13, would both be reported as being made on August 12–13.

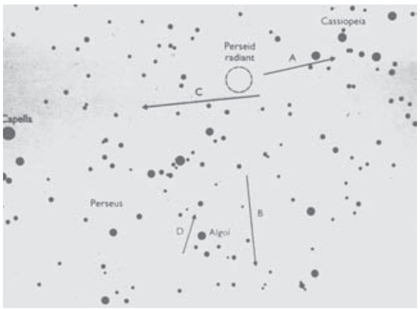


Figure 2. Use of the radiant position to determine meteor type. A and B have paths which trace back to the Perseid radiant, and are shower members; C and D are sporadics.

The **start and end times** of the watch should be recorded in Universal Time (UT= BST minus one hour in summertime). The **duration** of the watch should preferably be an hour, or perhaps multiples of two to three hours: in order to maintain observer alertness, it is recommended that breaks for refreshment be taken after a reasonable stint (remember, meteor watching is a pleasurable activity, not an endurance test as some might have it!).

Critical to the subsequent analysis are **sky conditions**. Transparency is recorded in terms of the **naked eye stellar limiting magnitude** – i.e. the brightness of the faintest star comfortably visible to the naked eye. Some observers use the Polar Sequence (a chart of this appears on the BAA Meteor Section web pages) for this, while others might use familiar bright comparison stars in variable star fields (though *not* the variable stars themselves, for obvious reasons). Limiting magnitude may change during a watch, and if it does so, this should be noted. Usually, meteor watches in skies with limiting magnitude worse than +4.5 are rather limited in terms of observed activity.

The presence of any cloud or other sky obscuration, in tenths of the field of view, should be recorded, along with the times during which it affected the observation. In general, obscuration in excess of 50% for any substantial period tends to seriously hamper observations and there is little point in persevering under such conditions.

All this information pertaining to the entire watch is recorded at the top of the first sheet of the report, using the back of the form if necessary if the details become extensive.

Once underway, the watch consists principally of noting details for individual meteors. The two most basic are time and type:

Time of appearance: To the nearest minute in UT is usually sufficient.

Type: If its path can be traced backwards across the sky to intersect the 8° diameter circle centred on a radiant expected to be active on the night, a meteor should be recorded as belonging to that shower. Meteors whose back-projected paths don't associate with any known radiant are almost certainly sporadics.

Observers should record both shower and sporadic meteors: the latter provide a useful 'control' population against which to assess various facets of shower activity.

The next few details to record may take a little more thought, and at first seem daunting. However, as the observer becomes more experienced, estimating meteor magnitudes becomes almost second nature, while having to decide where against the stellar background a meteor occurred is a great way of learning the constellations.

Magnitude: Like stars, meteors come in a range of brightness. Observers should, indeed, use background stars as comparisons. So, a meteor as bright as Capella or Vega is magnitude 0; as bright as Altair, Deneb or Spica mag +1; the Plough's Pointers or Orion's Belt stars mag +2, Delta UMa (the faint star in the Plough) mag +3, and so on. The planets Venus (mag –4) and Jupiter (mag –2) are also useful, though estimating the magnitudes of very bright meteors is a bit hit-and-miss. Meteors brighter than Venus are by long-established convention described as *fireballs*. Bear in mind that an accuracy to the nearest magnitude is as good as can be attained with an event lasting typically only a tenth or two-tenths of a second.

The Meteor Section web page at **http://www.britastro.org/meteor** offers a list of comparison stars, and observers soon become accustomed to using these.

Constellation in which seen: Exactly that! This can be useful if one is running a camera in parallel with a visual watch, and may later be trying to identify meteor trails on film.

Persistent train phenomena: Many bright meteors, particularly from streams like the Perseids, Orionids or Leonids which have high atmospheric entry velocities, leave behind a brief, fading 'ghost image' lasting up to several seconds after the meteor's extinction. Recording the presence and duration of these trains yields further information on the nature of the incoming meteoroids. Very short-duration trains are recorded as *wakes*.

Notes: Other comments may include a record of pronounced colour, flaring and/or fragmentation in flight, or apparent speed (very slow, slow, medium, fast, very fast).

During the actual watch, experienced observers will tend to record in a form of shorthand to save time, transcribing the details neatly to the formal report the next day while events are still fresh in memory. For example, my rough record might read:

2247 1 P Y F 1ST And

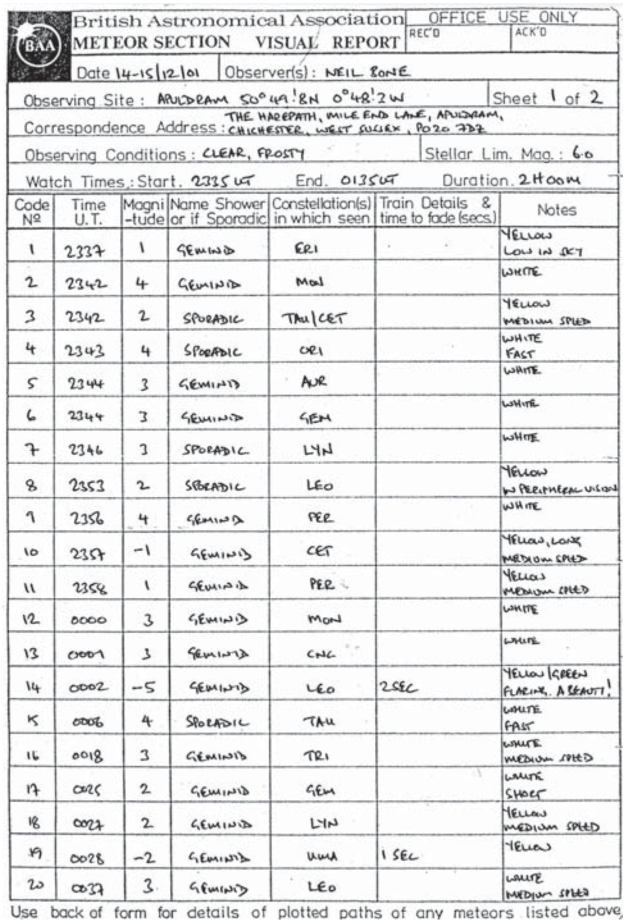
translating to:

2247 UT, mag +1 Perseid, yellow, fast.
1 second duration persistent train.
In Andromeda.

These details are, of course, entered in the appropriate boxes in the Meteor Section report form, allowing the analyst to extract the information as and when required at a later date.

What can we learn from such observations?

The Meteor Section collects together reports from observers spread across the UK and beyond, sometimes amounting to very comprehensive coverage over many nights during the major annual showers. The


British Astronomical Association
METEOR SECTION VISUAL REPORT
OFFICE USE ONLY — REC'D — ACK'D

Date 14-15/12/01 — Observer(s): NEIL BONE
Observing Site: APULDRAM 50°49'.8N 0°48'.2W — Sheet 1 of 2
Correspondence Address: THE HAREPATH, MILE END LANE, APULDRAM, CHICHESTER, WEST SUSSEX, PO20 7DZ
Observing Conditions: CLEAR, FROSTY — Stellar Lim. Mag.: 6.0
Watch Times: Start. 2335 UT End. 0135 UT Duration. 2H 00M

Code №	Time U.T.	Magni-tude	Name Shower or if Sporadic	Constellation(s) in which seen	Train Details & time to fade (secs.)	Notes
1	2337	1	GEMINID	ERI		YELLOW LOW IN SKY
2	2342	4	GEMINID	MON		WHITE
3	2342	2	SPORADIC	TAU/CET		YELLOW MEDIUM SPEED
4	2343	4	SPORADIC	ORI		WHITE FAST
5	2344	3	GEMINID	AUR		WHITE
6	2344	3	GEMINID	GEM		WHITE
7	2346	3	SPORADIC	LYN		WHITE
8	2353	2	SPORADIC	LEO		YELLOW IN PERIPHERAL VISION
9	2356	4	GEMINID	PER		WHITE
10	2357	−1	GEMINID	CET		YELLOW, LONG MEDIUM SPEED
11	2358	1	GEMINID	PER		YELLOW MEDIUM SPEED
12	0000	3	GEMINID	MON		WHITE
13	0001	3	GEMINID	CNC		WHITE
14	0002	−5	GEMINID	LEO	2 SEC	YELLOW/GREEN FLARING. A BEAUTY!
15	0006	4	SPORADIC	TAU		WHITE FAST
16	0018	3	GEMINID	TRI		WHITE MEDIUM SPEED
17	0025	2	GEMINID	GEM		WHITE SHORT
18	0027	2	GEMINID	LYN		YELLOW MEDIUM SPEED
19	0028	−2	GEMINID	UMA	1 SEC	YELLOW
20	0037	3	GEMINID	LEO		WHITE MEDIUM SPEED

Use back of form for details of plotted paths of any meteors listed above,

Figure 3. A completed report form, showing the relevant information which can make a watch useful in later analysis.

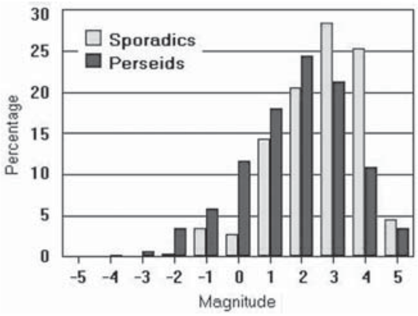


Figure 4. Histogram comparing Perseid and sporadic magnitudes in 2002.

pooled data from this team can be processed to yield a lot of useful information. For instance, we can take the magnitude estimates and compare those for shower meteors with the contemporaneous sporadic activity. Crude averages tell only part of the story – often giving, for example, a value about a magnitude brighter for showers like the Perseids or Geminids relative to the background. Histograms of the proportions in each magnitude interval might be more informative (Figure 4): comparing the Perseids and sporadics in a typical year shows the shower to be enriched in the brighter end of the range and depleted in the fainter. Larger meteoroids produce brighter meteors, and this distribution is taken to indicate that the Perseid stream is old enough to have begun losing its smaller material to solar radiation effects and gravitational perturbations. The difference is particularly marked for very old streams like the Taurids.

From the magnitude distribution, we can determine the population index (r) – a measure of the relative abundances of meteors in each magnitude interval. For the Perseids, the population index is about 2.25 – i.e., mag +2 meteors are 2.25 times as abundant as mag +1, which are 2.25 times as abundant as mag 0, and so on. For the sporadic background, $r = 3.42$. A high r value indicates a large proportion of faint meteors/small particles, usually indicative of a young stream. The various 'storm' filaments in the Leonid stream showed differing r values, reflecting their respective ages (who can forget the aged, low r value debris strand which gave the 1998 'Night of the Fireballs'?).

Changes in the r value over the several hours centred on maximum activity indicate sorting of Geminid stream meteoroids by size – a feature which became evident from study of simple visual observations.

Counts, of course, give an indication of the changing rates in a shower over time (related to meteoroid density within the stream, of course). Sometimes – as during very high Leonid activity – the changes are very rapid. More typically, the rates profile changes gradually from hour to hour and night to night. In assessing shower activity, we use for convenience the Zenithal Hourly Rate (ZHR), which standardises observed counts to what might be expected for a single observer under perfectly clear skies with limiting magnitude +6.5 and the radiant in the zenith. This of course, is why observing intervals of an hour, or blocks of several complete hours, are desirable. In practice, skies are hazy and the radiant under study midway up the sky, but allowance can be made for this so long as the observer provides the necessary details on the report form – this is why the time and geographical location matter!

ZHR is calculated from:

$$ZHR = [1/\sin a \times r^{6.5-LM} \times 1/(1-c) \times N_{met}] / T_{eff}$$

where a is the radiant altitude in degrees at the mid-point of the observation, c is the amount of sky obscuration as a decimal, N_{met} is the number of meteors observed, and T_{eff} the (decimal) amount of effective watch time in hours. Pooling several observers' more or less simultaneous watches together is preferable, in giving a larger sample to work with (thereby reducing the error, given by the square root of N_{met}/N_{met}).

As an example, given below are some results from the 1999 Geminids (Dec 12–13):

Mid-watch	T_{eff}	*LM*	N_{Sp}	N_{Gem}	*Lat*	*Long*
0330	1.00	5.6	7	19	51	0
0330	1.00	6.4	5	16	52	0
0320	1.00	5.5	5	10	52	0

Mean UT = 0327, LM 5.83; adopting latitude 52°N, longitude 0°W, gives radiant altitude 66.1°. Total N_{Sp}= 17, N_{Gem}= 45.

$$ZHR = [1/0.934 \times 1.817 \times 1 \times 45] / 3.00 = 29.8 \pm 4.4$$

For the same interval, the sporadic Corrected Hourly Rate (CHR) is given by:

$$CHR = [3.42^{6.5-LM} \times 1/(1-c) \times N_{Sp}] / T_{eff} = 12.9 \pm 3.1$$

Unusually high or low CHR values may flag unreliable ZHR estimates. Also, of course, it should be borne in mind that the ostensible high accuracy of ZHR/CHR values is subject to interpretation – no-one ever saw 0.3 of a meteor, for example!

Plotted over time, ZHRs give an activity profile for a shower. Some may have short, sharp maxima; others are more drawn out and flat in their profile. Activity can vary from year to year. We have seen, since the 1970s, a broadening of the Geminids' maximum, accompanied by a two- to three-fold increase in the peak ZHR, for example. Showers like this are evolving as we watch them, and a big part of the appeal of meteor observing comes from the fact that things *do* change.

The American 'glossies' may give the impression that showers like the Perseids are predictable and as well understood as possible: the reality is that, as in the late 1980s and early 1990s, the 'Old Faithful' of meteor

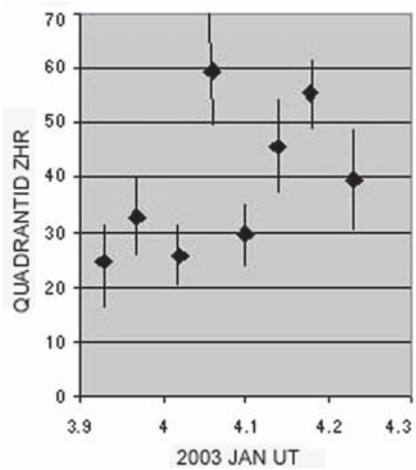


Figure 5. Activity profile for the Quadrantids in 2003.

showers can still throw tantrums. This is the real value of visual meteor watching – all showers need year on year coverage to follow their sometimes less than predictable long-term behaviour. Observers equipped with little more than the naked eye, a bit of patience, and the discipline to make simple standard records can contribute enormously to our understanding of meteor streams and their associated showers.

Observing can be carried out alone (I enjoy the tranquillity late at night) or as part of a group (many local societies have tales to tell of group meteor watches, which may be memorable for more than just the celestial delights). Above all, meteor watching can be enormously pleasant and rewarding, especially at times of high activity, or when a particularly bright event leavens an otherwise fairly 'routine' watch. To be able to derive results of scientific interest from such an enjoyable activity can be regarded as a bonus.

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