International Meteor Organization

2014 Meteor Shower Calendar

compiled by Alastair McBeath [1]

1 Introduction

Welcome to the twenty-fourth International Meteor Organization (IMO) Meteor Shower Calendar, for 2014. Of the three strongest annual shower maxima, the Quadrantids enjoy the most favourable moonlight circumstances, the Geminids are partly favourable for northern-hemisphere watchers only, but the Perseid peak falls very near full Moon. By contrast, all three stronger southern hemisphere showers – α-Centaurids, η-Aquariids and δ-Aquariids – are well-placed for dark-sky observing near their best. Potential event of the year could be an unknown shower associated with Comet 209P/LINEAR, that might yield strong to even storm activity in late May. The Draconids in October could produce some fresh rates as well, albeit badly Moon-affected. Ideally of course, meteor observing should be performed throughout the year to check on all the established sources, and for any new ones. Such routine monitoring is possible now with automated video systems, but we appreciate not everyone is able to employ these, and that observing in other ways regularly is impractical for most people, so the Shower Calendar has been helping to highlight times when a particular effort might be most usefully employed since 1991.

The heart of the Calendar is the Working List of Visual Meteor Showers, Table 5, which has undergone a thorough revision in recent times to help it to remain the single most accurate listing available anywhere today for naked-eye meteor observing. Of course, for all its accuracy, it is a **Working** List, so is continually subject to further checks and corrections, based on the best data we had at the time the Calendar was written. Thus it is always as well to check the information here fully, taking account of any later changes noted in the IMO's journal *WGN* or on the IMO website, before going out to observe (and please tell us if you find any anomalies!).

This is an especially dynamic time for minor shower studies, with video results detecting many showers too weak to be observed visually, as well as sometimes revealing fresh aspects of those already known, and even of the low-activity phases of some of the major showers well away from their maxima. Video has established itself as a valuable tool in meteor studies in recent years, and professional radar meteor examinations have been producing excellent new results too, but we should not forget the other instrumental techniques available to amateur observers. Telescopic observations can also separate minor shower activity from the omnipresent background sporadics, and detect showers whose meteors are too faint even for current video systems. Still-imaging

[1] Based on information in the *Handbook for Meteor Observers*, edited by Jürgen Rendtel and Rainer Arlt, IMO, 2008 (referred to as 'HMO' in the Calendar), and "A Comprehensive List of Meteor Showers Obtained from 10 Years of Observations with the IMO Video Meteor Network" by Sirko Molau and Jürgen Rendtel (*WGN* **37:4**, 2009, pp. 98–121; referred to as 'VID' in the Calendar), as amended by subsequent discussions and additional material extracted from reliable data analyses produced since. Particular thanks are due to Rainer Arlt, Esko Lyytinen, Jürgen Rendtel and Jérémie Vaubaillon for new information and comments in respect of events in 2014.

enables a whole range of studies to be carried out on the brighter meteors particularly, and multi-station observing with still or video cameras can allow orbital data to be established, essential for meteoroid-stream examinations. Showers with radiants too near the Sun for observing by the various optical methods can be detected by forward-scatter radio or back-scatter radar observations. Some of these showers are given in Table 7, the Working List of Daytime Radio Meteor Streams. Automated radio and radar work also allows 24-hour coverage of meteor activity.

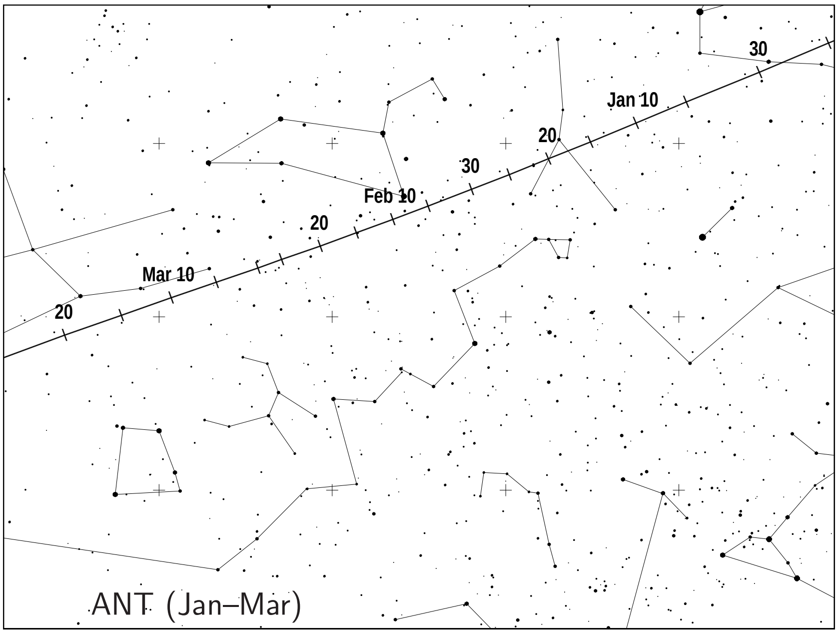
The IMO's aims are to encourage, collect, analyze, and publish combined meteor data obtained from sites all over the globe, to help better our understanding of the meteor activity detectable from the Earth's surface. Thus, we encourage these more specialist forms of observing alongside visual work. Consequently, for best effects, all meteor workers, wherever you are and whatever methods you use to record meteors, should follow the standard IMO observing guidelines when compiling your information, and submit those data promptly to the appropriate Commission for analysis (contact details are at the end of the Calendar). Thanks to the efforts of the many IMO observers worldwide since 1988 that have done this, we have been able to achieve as much as we have to date, including keeping the shower listings vibrant. This is not a matter for complacency however, since it is solely by the continued support of many people across the planet that our attempts to construct a better and more complete picture of the near-Earth meteoroid flux can proceed.

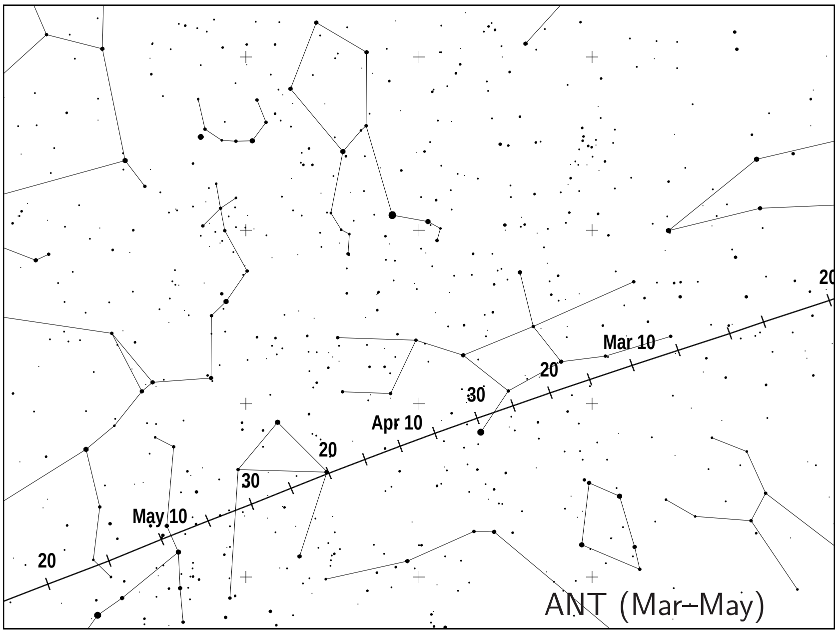
Although timing predictions are included below on all the more active night-time and daytime shower maxima, as reliably as possible, it is essential to understand that in many cases, such maxima are not known more precisely than to the nearest degree of solar longitude (even less accurately for the daytime radio showers, which have received little regular attention until quite recently). In addition, variations in individual showers from year to year mean past returns are only a guide as to when even major shower peaks can be expected. As noted already, the information given here may be updated and added-to after the Calendar has been published. Some showers are known to show particle mass-sorting within their meteoroid streams, so the radar, radio, still-imaging, telescopic, video and visual meteor maxima may occur at different times from one another, and not necessarily just in those showers. The majority of data available are for visual shower maxima, so this must be borne in mind when employing other observing techniques.

However and whenever you are able to observe, we wish you all a most successful year's work and very much look forward to receiving your data. Clear skies!

2 Antihelion Source

The Antihelion Source (ANT) is a large, roughly oval area around $\alpha = 30°$ by $\delta = 15°$ in size, centred about 12° east of the solar opposition point on the ecliptic, hence its name. It is not a true shower at all, but is rather a region of sky in which a number of variably, if weakly, active minor showers have their radiants. Until 2006, attempts were made to define specific showers within this complex, but this often proved very difficult for visual observers to achieve. IMO video results from the last two decades have shown why, because even instrumentally, it was impossible to define distinct radiants for many of the showers here! Thus we believe currently it is best for observers simply to identify meteors from these streams as coming from the ANT alone. At present, we think the July-August α-Capricornids (CAP), and particularly the Southern δ-Aquariids (SDA), should remain discretely-observable visually from the ANT, so they have been retained on the Working List, but time and plenty of observations will tell, as ever. Later in the year, the strength of the Taurid showers (STA and NTA) means the ANT should be considered inactive while the Taurids are underway, from early September to early December. To assist observers, a set of charts showing the location for the ANT and any other nearby shower radiants is included here, to complement the numerical positions of Table 6, while comments on the ANT's location and likely activity are given in the quarterly summary notes.



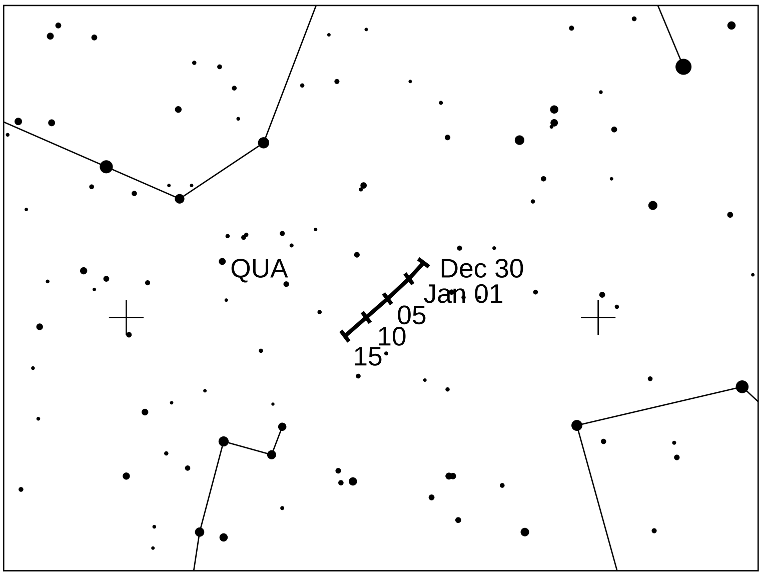


3 January to March

The year starts excellently, with a perfectly moonless Quadrantid peak for the northern hemisphere, followed by a reasonably favourable maximum from the southern hemisphere's α-Centaurids in January and February respectively. The minor **γ-Normids** are less fortunate, with a peak perhaps on March 14, but possibly at another point between March 7 and 17, accompanied by a waxing gibbous to full Moon. The **ANT's** radiant centre starts January in south-east Gemini, and crosses Cancer during much of the month, before passing into southern Leo for most of February. It then glides through southern Virgo during March. Probable ANT ZHRs will be < 2, although IMO analyses have suggested there may be an ill-defined minor peak with ZHRs ~ 2 to 3 around $\lambda_\odot \sim 286°–293°$ (2014 January 6 to 13; either side of first quarter Moon, if so), and ZHRs could be ~ 3 for most of March. By contrast, the late January to early February spell, during which several, swift-meteor, **minor showers radiating from the Coma-Leo-Virgo area** have been proposed in some recent years, has its potential core interval, January 20–27, sitting astride January's last quarter Moon, which is much less helpful as this region of sky is better-observed only during the second half of the night. Theoretical timings (rounded to the nearest hour) for the **daytime radio shower maxima** this quarter are: Capricornids/Sagittarids – February 1, 15^h UT and χ-Capricornids – February 13, 17^h UT. Recent radio results have implied the Cap/Sgr maximum may fall variably sometime between February 1–4 however, while activity near the expected χ-Capricornid peak has tended to be slight and up to a day late. Both showers have radiants $< 10°–15°$ west of the Sun at maximum, so cannot be regarded as visual targets even from the southern hemisphere.

Quadrantids (QUA)

Active: December 28–January 12; Maximum: January 3, 19^h30^m UT ($\lambda_\odot = 283.^\circ16$), but see text;
ZHR = 120 (can vary $\sim 60–200$);
Radiant: $\alpha = 230°$, $\delta = +49°$; Radiant drift: see Table 6;
$V_\infty = 41$ km/s; $r = 2.1$ at maximum, but variable;
TFC: $\alpha = 242°$, $\delta = +75°$ and $\alpha = 198°$, $\delta = +40°$ ($\beta > 40°$ N).
IFC: before 0^h local time $\alpha = 150°$, $\delta = +70°$;
after 0^h local time $\alpha = 180°$, $\delta = +40°$ and $\alpha = 240°$, $\delta = +70°$ ($\beta > 40°$ N).



New Moon on January 1 creates ideal viewing conditions for the predicted Quadrantid maximum on January 3. For many northern hemisphere sites, the shower's radiant is circumpolar, in northern Boötes, from where it first attains a useful elevation after local midnight, steadily improving through till dawn. Observing locations across the eastern half of Asia should be best-placed to record what happens in 2014, if the maximum time above is correct. However, theoretical computations by Jérémie Vaubaillon have suggested this may be earlier, around 14^h UT on January 3, and that it could last for longer than usual. If so, that would shift the visible region for the peak eastwards, to the North Pacific Ocean and land areas immediately adjacent, notably the extreme west of North America, for this prediction. A protracted peak could increase the visible zone further. The $\lambda_\odot = 283\overset{\circ}{.}16$ maximum timing is based on the best-observed return of the shower ever analysed, from IMO data collected in 1992, as confirmed by radio results in most years since 1996. Typically, the peak is normally short-lived, so can be easily missed in just a few hours of poor northern-winter weather, which may be why the ZHR level apparently fluctuates from year to year. However, some genuine variability is probably present too. An added level of complexity comes from the fact mass-sorting of particles across the meteoroid stream may make fainter objects (radio and telescopic meteors) reach maximum up to 14 hours before the brighter (visual and photographic) ones, so observers should be alert throughout the shower. A few years this century seem to have produced a, primarily radio, maximum following the main visual one by some 9–12 hours too. Visual confirmation of any repeat of such behaviour would be welcomed. QUA activity tends to be very low more than a day or so from the peak, and past observations have suggested the radiant is diffuse away from the maximum too, contracting notably during the peak itself, perhaps because of this lower activity then. Imaging observations would be welcomed to help investigate this topic, along with telescopic results.

α-Centaurids (ACE)

Active: January 28–February 21; Maximum: February 8, 06^h UT ($\lambda_\odot = 319\overset{\circ}{.}2$);
ZHR = variable, usually ~ 6, but may reach 25+;
Radiant: $\alpha = 210°$, $\delta = -59°$; Radiant drift: see Table 6;
$V_\infty = 56$ km/s; $r = 2.0$.

In theory, the α-Centaurids are one of the main southern summer high points, from past records supposedly producing many very bright, even fireball-class, objects (meteors of at least magnitude -3), commonly with fine persistent trains. However, the average peak ZHR between 1988–2007 was merely 6 (HMO, p. 130), albeit coverage has frequently been extremely patchy. Despite this, in 1974 and 1980, bursts of only a few hours' duration apparently yielded ZHRs closer to 20–30. As with many southern hemisphere sources, we have more questions than answers at present, nor do we have any means of telling when, or if, another stronger event might happen. Consequently, imaging and visual observers are urged to be alert at every opportunity. The radiant is nearly circumpolar for much of the sub-equatorial inhabited Earth, and is at a useful elevation from late evening onwards. Despite the Moon being waxing gibbous on February 7/8, it will set around midnight for mid-southern latitudes then, leaving the second part of the night with dark skies to examine whatever happens this time.

4 April to June

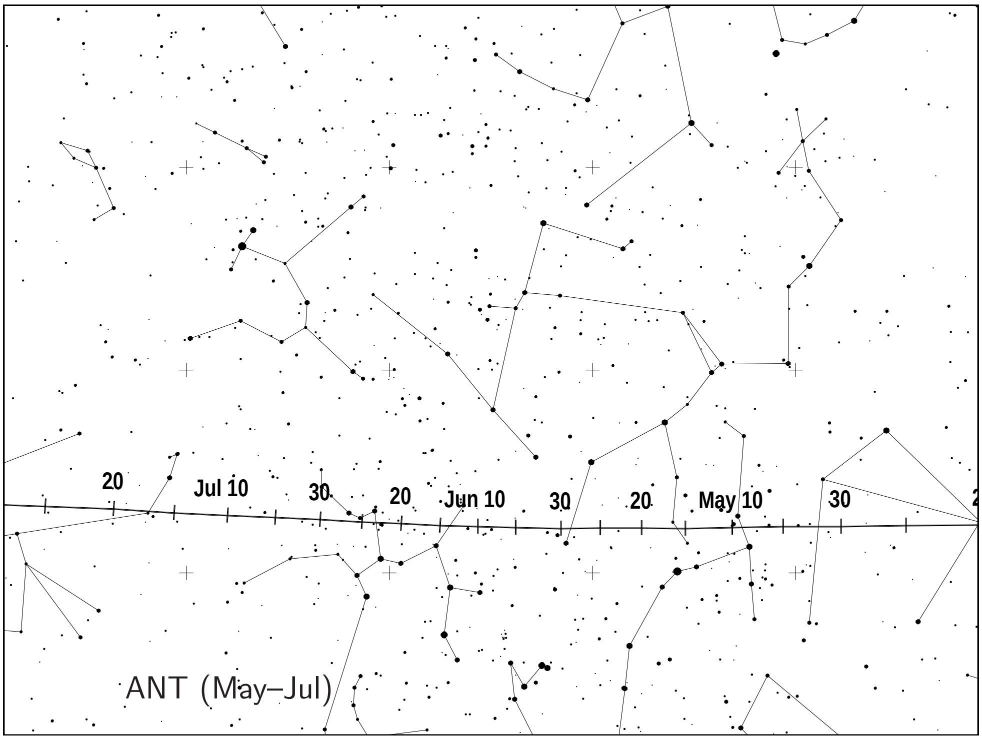
Meteor activity picks up towards the April-May boundary, although the waning gibbous Moon, at last quarter on April 22, will prevent dark-sky observing of the **Lyrid** maximum, also due on the 22nd, sometime between roughly 10^h to 21^h UT that day, with marginally higher ZHRs likely the closer the maximum happens to $\sim 18^h$ UT. The southern-hemisphere π-Puppids peak the following day, but are more favourable for visual observing, while the η-Aquariids in early May enjoy splendid circumstances, with no Moon. A few days later, the minor η-Lyrids are still partly Moon-free.

Possible meteor activity due to Comet 209P/LINEAR: Of greatest potential significance this quarter, indeed this year, is an encounter between the Earth and a number of dust trails left by Comet 209P/LINEAR at its perihelion returns within twenty years to either side of 1900 AD.

Several predictions have already been issued for what may occur, and further updates are likely nearer the event. Based on the most recent independent calculations by Esko Lyytinen, Mikhail Maslov and Jérémie Vaubaillon, the strongest activity from this source should happen on May 24, most likely between about 07^h to 08^h UT from a radiant near the borders of Lynx, Ursa Major and Camelopardalis, quite close to o UMa. The predicted radiant locations fall within a few degrees of $\alpha = 124°$, $\delta = +79°$. Timings in UT for the centre of the strongest activity overall are around 07^h03^m (Lyytinen), 07^h21^m (Maslov) and 07^h40^m (Vaubaillon) respectively. However, much is unknown about this comet, including its dust productivity and even its precise orbit. Consequently, while tentative proposals have been made that ZHRs at best could reach 100+, perhaps up to storm proportions, based purely on the relative approach distances between the Earth and the computed dust trails, these are far from certain. The strongest activity could be short lived too, lasting perhaps between a few minutes to a fraction of an hour only. In addition, the number of dust trails involved means there may be more than one peak, and that others could happen outside the "key hour" period, so observers at suitable locations are urged to be vigilant for as long as possible to either side of the predicted event to record whatever takes place. Remember, there are no guarantees in meteor astronomy! Lunar observing circumstances are very positive, with May's new Moon on the 28th. The north-circumpolar radiant area for many sites means the three main geographic zones where most radio observers are located – Europe, North America and Japan – should be able to follow all that occurs, interference permitting. The time of year means the northern nights are close to their shortest for visual and imaging work, but the predicted strongest activity timings fall perfectly for night-time coverage all across North America and the nearby oceans to its east and west. See *WGN* and watch out for online news closer to the event for additional information.

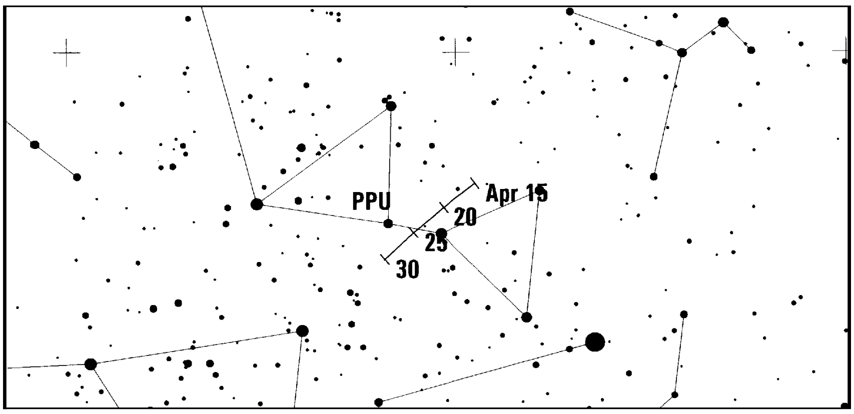
Daytime showers: In the second half of May and throughout June, most of the annual meteor action switches to the daylight sky, with six shower peaks expected during this time. Although occasional meteors from the o-Cetids and Arietids have been claimed as seen from tropical and southern hemisphere sites visually in past years, ZHRs cannot be sensibly calculated from such observations. For radio observers, the theoretical UT peak times for these showers are as follows: April Piscids – April 20, 16^h; δ-Piscids – April 24, 16^h; ϵ-Arietids - May 9, 15^h; May Arietids – May 16, 16^h; o-Cetids - May 20, 14^h; Arietids – June 7, 18^h; ζ-Perseids – June 9, 17^h; β-Taurids – June 28, 16^h. Signs of most were found in radio data from 1994–2008, though some are difficult to define individually because of their proximity to other radiants. There seems to be a modest recurring peak around April 24, perhaps due to combined rates from the first three showers listed here, for instance, while the Arietid and ζ-Perseid maxima tend to blend into one another, producing a strong radio signature for several days in early to mid June. There are indications these two June shower maxima now each occur up to a day later than indicated above.

The **ANT** should be relatively strong, with ZHRs of 3 to 4 through till mid April, and again around late April to early May, late May to early June, and late June to early July. At other times, its ZHR seems to be below $\sim$ 2 to 3. The radiant area drifts from south-east Virgo through Libra in April, then across the northern part of Scorpius to southern Ophiuchus in May, and on into Sagittarius for much of June. For northern observers, circumstances for checking on any potential **June Lyrids** are very poor this year (not currently on the Working List, but perhaps producing a minor peak around June 16), although possible June Boötid hunting later in the month is much more favourable.



π-Puppids (PPU)

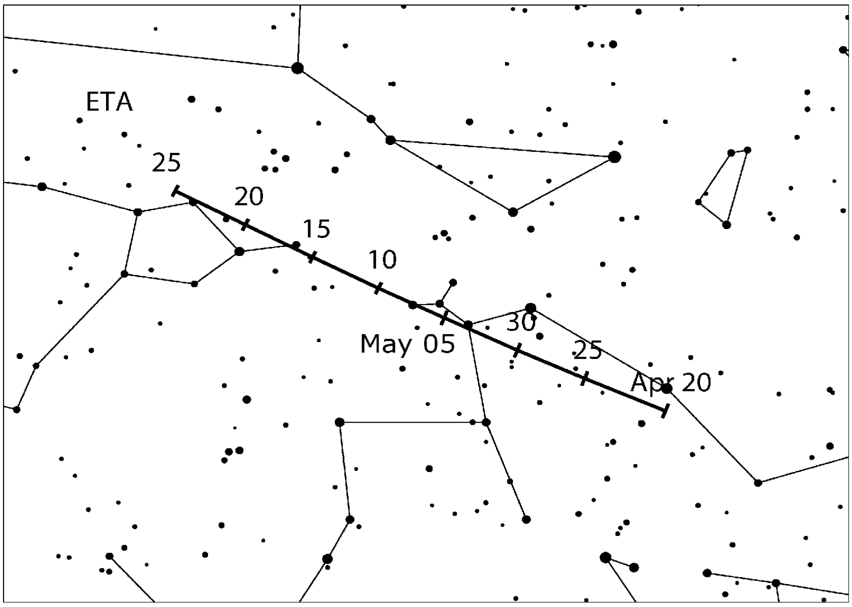
Active: April 15–28; Maximum: April 23, 23^{h} UT ($\lambda_{\odot} = 33^{\circ}\!.5$);
ZHR = periodic, up to around 40;
Radiant: $\alpha = 110°$, $\delta = -45°$; Radiant drift: see Table 6; $V_{\infty} = 18$ km/s; $r = 2.0$;
TFC: $\alpha = 135°$, $\delta = -55°$ and $\alpha = 105°$, $\delta = -25°$ ($\beta < 20°$ N).



Activity has only been detected from this source since 1972, with notable, short-lived, shower maxima of around 40 meteors per hour in 1977 and 1982, both years when its parent comet, 26P/Grigg-Skjellerup was at perihelion. Before 1982, little activity had been seen at other times, but in 1983, a ZHR of ~ 13 was reported, perhaps suggesting material has begun to spread further along the comet's orbit, as theory expects. The comet's perihelion in 2008 March produced nothing meteorically significant that April, but lunar circumstances that year were poor, and faint-meteor activity (which was predicted as likely in advance) could have been missed. The comet was due at perihelion again in July 2013. However, no predictions for activity in 2014 had been issued when this Calendar was prepared. The π-Puppids are best-seen from the southern hemisphere, with useful observations mainly practical there before midnight, as the radiant is very low to setting after 01^h local time. Consequently, April's waning Moon, just past last quarter for the peak, rises late enough then for mid-southern sites to enjoy dark skies until around or a little after midnight. Covering whatever transpires is important, even if that is to report no obvious activity, as past datasets on the shower have typically been very patchy. So far, visual and radio data have been collected on the shower, but the slow, sometimes bright nature of the meteors makes them ideal subjects for still-imaging too. No telescopic or video data have been reported in any detail as yet.

η-Aquariids (ETA)

Active: April 19–May 28; Maximum: May 6, 07^h UT ($\lambda_\odot = 45\overset{\circ}{.}5$);
ZHR = 45 (periodically variable, $\sim$ 40–85);
Radiant: $\alpha = 338°$, $\delta = -01°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.4$;
TFC: $\alpha = 319°$, $\delta = +10°$ and $\alpha = 321°$, $\delta = -23°$ ($\beta < 20°$ S).



A fine, rich stream associated with Comet 1P/Halley, like the Orionids of October, but one visible for only a few hours before dawn, essentially from tropical and southern hemisphere sites. Some useful results have come even from places around 40° N latitude at times however, and occasional meteors have been reported from further north, but the shower would benefit from increased observer activity generally. The fast and often bright meteors make the wait for radiant-rise worthwhile, and many events leave glowing persistent trains after them. While the radiant is still low, η-Aquariids tend to have very long paths, which can mean observers underestimate the angular speeds of the meteors, so extra care is needed when making such reports.

A relatively broad maximum, sometimes with a variable number of submaxima, usually occurs in early May. IMO analyses in recent years, based on data collected between 1984–2001, have shown that ZHRs are generally above 30 between about May 3–10, and that the peak rates appear to be variable on a roughly 12-year timescale. Assuming this Jupiter-influenced cycle is borne-out, the next trough is due around 2014–2016, so ZHRs should be close to their relative poorest this year. Activity around the most recent ZHR peak period in circa 2008 and 2009 seemed to have been $\sim$ 85 and 65 respectively, with ZHRs up to $\sim$ 65 recorded again in 2011. There appeared to have been no additional influence following the protracted, sometimes stronger than expected, Orionid returns from October 2006–2009 inclusive in the η–Aquarids in those years, as far as the available results allowed. Early May's waxing crescent Moon creates ideal viewing conditions for whatever the shower provides this year, setting long before the radiant can be first usefully observed for the maximum date. All forms of observing can be used to study it, with radio work allowing activity to be followed even from many northern latitude sites throughout the daylight morning hours. The radiant culminates at about 08^{h} local time.

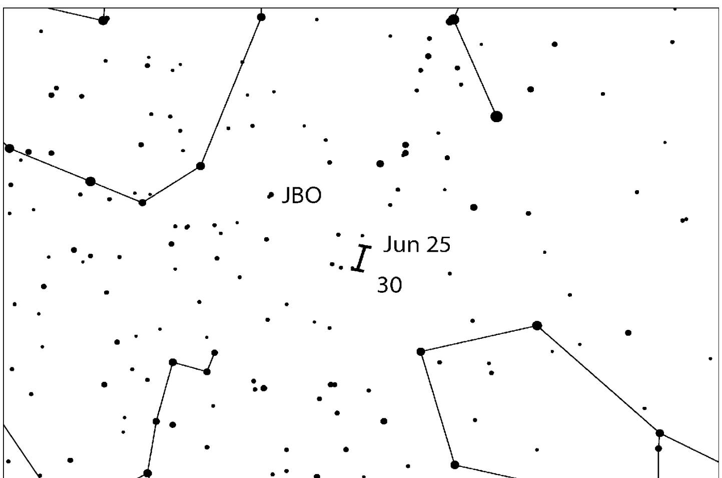
η-Lyrids (ELY)

Active: May 3–14; Maximum: May 8 ($\lambda_\odot = 48°$); ZHR = 3;
Radiant: $\alpha = 287°$, $\delta = +44°$; Radiant drift: see Table 6;
$V_\infty = 43$ km/s; $r = 3.0$;
TFC: $\alpha = 325°$, $\delta = +40°$ or $\alpha = 285°$, $\delta = +15°$, and $\alpha = 260°$, $\delta = +30°$ ($\beta > 10°$ S).

This recent introduction to the Visual Working List is associated with Comet C/1983 H1 IRAS-Araki-Alcock, though it appears to be only a weak shower. Most of the recent observational data on it has come from purely video results, which have suggested the maximum might fall at $\lambda_\odot = 50°$ instead (if so, on 2014 May 10). There is little evidence to suggest it has been definitely observed visually as yet, but the discussion on p. 137 of HMO had more information. Video work, diligent telescopic, or perhaps equally careful visual, plotting will be needed to separate any potential η-Lyrids from the sporadics. The general radiant area is usefully on-view all night from the northern hemisphere (primarily), while May's waxing Moon still leaves part of the post-midnight period with sufficiently dark skies for some observing around May 8, if a period which shortens each night thereafter.

June Boötids (JBO)

Active: June 22–July 2; Maximum: June 27, 15^{h} UT ($\lambda_\odot = 95.°7$), but see text;
ZHR = variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +48°$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.2$;
TFC: $\alpha = 156°$, $\delta = +64°$ and $\alpha = 289°$, $\delta = +67°$ ($\beta = 25°$–$60°$ N).



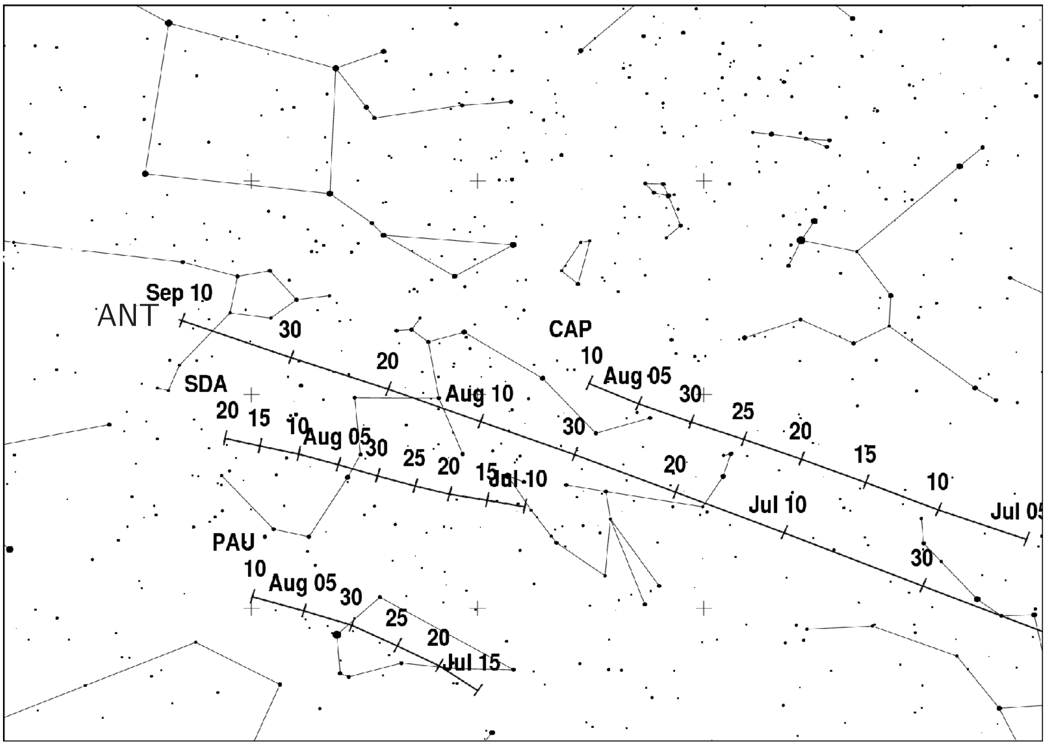
This source was reinstated on the Working List after its unexpected return of 1998, when ZHRs of 50–100+ were visible for more than half a day. Another outburst of similar length, but with

ZHRs of $\sim$ 20–50 was observed on 2004 June 23, a date before definite June Boötid activity had been previously recorded. Consequently, the shower's start date was altered to try to ensure future rates so early are caught, and we encourage all observers to routinely monitor throughout the proposed period, in case of fresh outbursts. However, the predicted return in 2010 was disappointing. ZHRs of $\sim$ 20–50 were anticipated for June 23–24, but detected ZHRs then were less than 10, and not all experienced observers confirmed even these. Prior to 1998, only three more probable returns had been detected, in 1916, 1921 and 1927, and with no significant reports between 1928 and 1997, it seemed likely these meteoroids no longer encountered Earth. The dynamics of the stream were poorly understood, although recent theoretical modelling has improved our comprehension. The shower's parent, Comet 7P/Pons-Winnecke, has an orbit that now lies around 0.24 astronomical units outside the Earth's at its closest approach. Its latest perihelion passage was in 2008 September and its next is due in early 2015. Clearly, the 1998 and 2004 events resulted from material shed by the comet in the past which now lies on slightly different orbits to the comet itself. Although no predictions for activity are in-force for 2014, conditions for checking are perfect from the mid-northern latitudes where the radiant is best-seen (indeed it is usefully-observable almost all night from here), with new Moon on June 27. The prolonged – in some places continuous – twilight will cause greater difficulties. VID suggested some June Boötids may be visible in most years around June 20–25, but with activity largely negligible except near $\lambda_\odot = 92°$ (2014 June 23), radiating from an area about ten degrees south of the radiant found in 1998 and 2004, close to $\alpha = 216°$, $\delta = +38°$.

5 July to September

The **ANT** is the chief focus for visual attention during most of July, as its radiant area moves steadily through eastern Sagittarius, then across northern Capricornus into southwest Aquarius. Results suggest the Source may not be especially recognisable after the first few days however, as ZHRs for most of the month seem < 2, and for a time in mid-month even < 1! Activity appears to improve somewhat, with ZHRs $\sim$ 2 to 3, by late July and through the first half of August. The large ANT radiant area overlaps that of the minor α-Capricornids (CAP) in July-August, but the Southern δ-Aquariids (SDA) are strong enough, and the Piscis Austrinids (PAU) have a radiant probably distant enough from the ANT area, that both should be separable from it, particularly from the southern hemisphere.

August's full Moon spoils observations of the **Perseids** this year, whose peak is due at some stage between 19^{h} UT on August 12 to 08^{h} on the 13th, perhaps most likely around 00^{h} to 03^{h} on August 13, although modelling by Jérémie Vaubaillon suggests the peak may be earlier, perhaps during the second half of August 12 instead. The probable κ-Cygnid peak is more fortunate a week later. **ANT** ZHRs will likely have dropped back below 2 again by late August, rising once more to $\sim$ 2–3 by early September, as the radiant tracks on through Aquarius and into western Pisces. Early September's waxing Moon favours the Aurigid peak, but its full phase on September 9 ruins any hope of dark skies for covering the generally minor **September ε-Perseids**, whose maximum is due around 16^{h} UT on that date (the repeat time from the 2008 outburst would be a little later, either side of $\sim 21^{\mathrm{h}}$ then). Remember that the **Southern Taurids** begin around September 10, effectively taking over the near-ecliptic activity from the ANT through to December.



For **daylight radio observers**, the interest of May-June has waned, but there remain the visually-impossible γ-Leonids (peak due near August 25, $17^{\rm h}$ UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids. Their maximum is expected on September 27, around $17^{\rm h}$ UT, but possibly it may occur a day earlier. In 1999 a strong return was detected at $\lambda_\odot \sim 186°$, equivalent to 2014 September 29, while in 2002, the September 27 peak was not found, but one around September 29–30 was! It seems plausible several minor maxima in early October may also be due to this radio shower. September's new Moon causes no further hindrance for visual observers hoping to catch some Sextantids in the pre-dawn of late September, though radiant-rise is less than an hour before sunrise in either hemisphere.

Piscis Austrinids (PAU)

Active: July 15–August 10; Maximum: July 28 ($\lambda_\odot = 125°$); ZHR = 5;
Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 6;
$V_\infty = 35$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 30°$ N).

Very little information has been collected on the PAU in recent decades, so the details on the shower are not well-confirmed, and it seems possible the ZHR may be a little optimistic. However, that impression could be due simply to the large amount of northern hemisphere summer data, and the almost complete lack of southern hemisphere winter results, on it. The stream seems to be rich in faint meteors, rather like the nearby ANT and SDA, so telescopic and video work is advisable to try to establish more about it. New Moon on July 26 favours coverage of all the southern-sky shower peaks around this time in 2014, whose radiants are available virtually all night, especially from mid-southern latitudes.

Southern δ-Aquariids (SDA)

Active: July 12–August 23; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 16; Radiant: $\alpha = 340°$, $\delta = -16°$; Radiant drift: see Table 6; $V_\infty = 41$ km/s; $r = 3.2$; TFC: $\alpha = 255°$ to 000°, $\delta = 00°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 40°$ N).

Like the PAU and ANT, SDA meteors are often faint, thus are suitable targets for telescopic observing, although enough brighter members exist to make visual and imaging observations worth the effort too, primarily from more southerly sites. Radio work can pick up the SDA as well, and indeed the shower has sometimes given a surprisingly strong radio signature. Visually, careful plotting is advised to help with accurate shower association. The SDA maximum may not be quite so sharp as the single date here could imply, with perhaps similar ZHRs from July 28–30, all equally favourable for dark-sky coverage this time. Its rates have been suspected of some variability at times too, though not in more recent investigations.

α-Capricornids (CAP)

Active: July 3–August 15; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 5; Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 6; $V_\infty = 23$ km/s; $r = 2.5$; TFC: $\alpha = 255°$ to 000°, $\delta = 00°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 40°$ N); IFC: $\alpha = 300°$, $\delta = +10°$ ($\beta > 45°$ N), $\alpha = 320°$, $\delta = -05°$ (β 0° to 45° N), $\alpha = 300°$, $\delta = -25°$ ($\beta < 0°$).

The CAP and SDA radiants were both definitely detected visually in former years, standing out against those much weaker ones supposed active in Capricornus-Aquarius then. Whether the CAP can still be detected as visually separate from the ANT radiant area is unclear, as its radiant now partly overlaps that of the large ANT region. Observers have often failed to find a clear maximum for the shower since the ANT concept was introduced, certainly. However, their bright, at times fireball-class brilliance, combined with their low apparent velocities, could still make them distinctive enough to be detected by means other than video. A minor enhancement of CAP ZHRs to ~ 10 was noted in 1995 by European IMO observers. Recent results suggest the maximum may continue into July 31.

κ-Cygnids (KCG)

Active: August 3–25; Maximum: August 18 ($\lambda_\odot = 145°$); ZHR = 3; Radiant: $\alpha = 286°$, $\delta = +59°$; Radiant drift: see Table 6; $V_\infty = 25$ km/s; $r = 3.0$; IFC: $\alpha = 330°$, $\delta = +60°$ and $\alpha = 300°$, $\delta = +30°$($\beta > 20°$ N).

Last quarter moonrise leaves a short evening dark-sky observing window for the expected κ-Cygnid peak this year. The shower is best-observed from northern hemisphere sites, from where the radiant is easily available all night. VID suggested a number of discrepancies to the currently-accepted parameters listed above, including that the peak might happen closer to August 14, from a more southerly radiant (around $\alpha = 286°$, $\delta = +51°$), and that activity might be present only from August 6–19 overall. Such a maximum timing would be much less favourable, as too near full Moon. Previous video results had implied that rather than having an almost stationary radiant, as expected due to its proximity to the ecliptic north pole in Draco, the radiant showed a discernible daily drift. Consequently observers should be aware that the shower may not behave as it is "supposed to"! There have been past suggestions of variations in κ-Cygnid rates at times as well, perhaps coupled with a periodicity in fireball sightings.

Aurigids (AUR)

Active: August 28–September 5; Maximum: September 1, 07^{h} UT ($\lambda_{\odot} = 158.^{\circ}6$); ZHR = 6;
Radiant: $\alpha = 91^{\circ}$, $\delta = +39^{\circ}$; Radiant drift: see Table 6;
$V_{\infty} = 66$ km/s; $r = 2.5$;
TFC: $\alpha = 052^{\circ}$, $\delta = +60^{\circ}$; $\alpha = 043^{\circ}$, $\delta = +39^{\circ}$ and $\alpha = 023^{\circ}$, $\delta = +41^{\circ}$ ($\beta > 10^{\circ}$ S).

This northern-hemisphere shower, formerly known as the α-Aurigids, has produced short, unexpected, outbursts at times, with EZHRs of $\sim$ 30–40 recorded in 1935, 1986 and 1994, although it has not been monitored regularly until very recently, so other events may have been missed. Only three watchers in total covered the 1986 and 1994 outbursts, for instance! While badly moonlit, the first predicted outburst happened roughly as expected in 2007, producing short-lived EZHRs of $\sim$ 130, with many bright meteors. Radio data suggested there was a 'tail' to that event where more faint meteors continued for maybe an hour after the strongest peak, but visual observers could not confirm this, probably due to the moonlit sky. The Aurigid radiant reaches a useful elevation only after $\sim 01^{h}$ local time, and although no predictions for unusual activity have been made for 2014, the waxing crescent Moon, setting by late evening, provides ideal skies for whatever may happen. With the SPE and the DAU, the Aurigids are suspected of being (perhaps simply the more active) part of a series of poorly-observed sources with radiants around Aries, Perseus, Cassiopeia and Auriga during the northern early autumn. The telescopic shower of the β-Cassiopeids is suspected of being active too during September, for example, and there may be others awaiting discovery or confirmation.

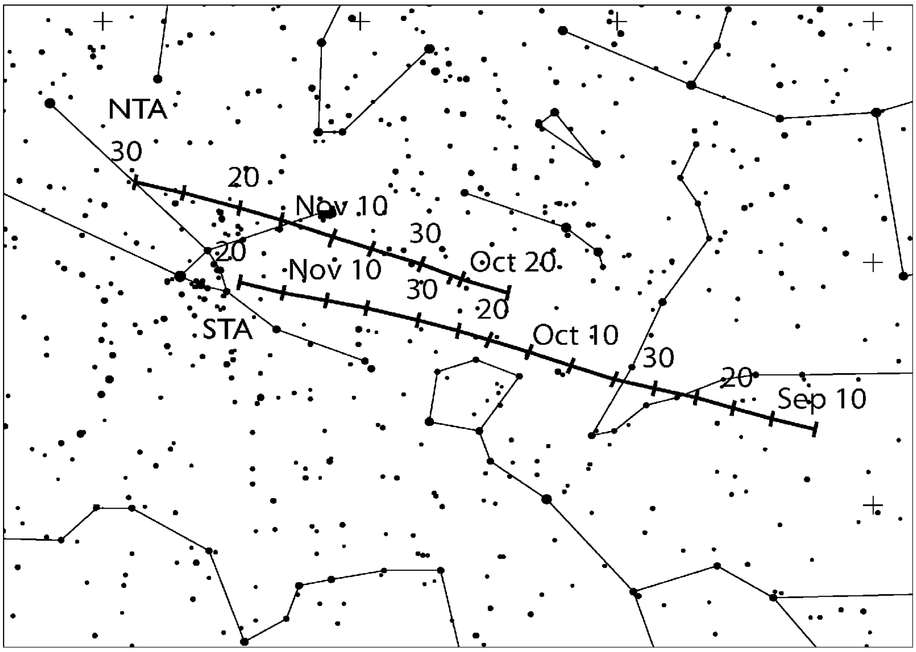
6 October to December

A mixed quarter ends the year, albeit with most of the moonlight-affected showers drawn from the less active sources.

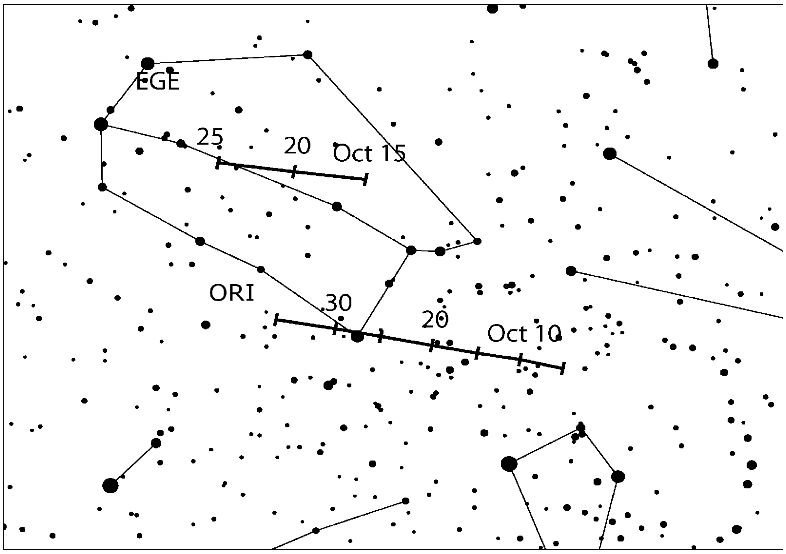
October 5/6 meteors: Short-lived video outbursts were recorded in 2005 and 2006 by European observers, with activity from a north-circumpolar radiant near the "tail" of Draco, around $\alpha \sim 165^{\circ}$, $\delta \sim +78^{\circ}$, on October 5/6. The meteors showed an atmospheric velocity of $\sim$ 45–50 km/s. The 2005 event (only) was recorded very weakly by radio, but no visual results confirmed either occurrence, and no recurrence was reported in 2007, 2008, 2011 or 2012. Weak video rates were claimed detected near the 2009 and 2010 repeat times, but again, no other method confirmed these, and the shower was not found by the full ten-year VID analysis. The active interval suggested by video data lies between $\lambda_{\odot} \sim 192.^{\circ}5$–$192.^{\circ}8$, equivalent to 2014 October 6, 01^{h} to $08^{h}30^{m}$ UT, when the waxing gibbous Moon will set leaving a few hours of darker skies before dawn. If the active interval remains the same, it should be best-observed from the east of North America eastwards across Europe to central Asia. Esko Lyytinen has suggested on theoretical grounds that activity may be better-detectable in 2014 from this source, albeit the likely ZHRs are uncertain and could be visually low. He also determined that such activity should happen around $02^{h}20^{m}$ to $03^{h}10^{m}$ UT on October 6. Of course, as ever, these predictions are not guarantees!

Draconids: Their usual potential maximum interval, probably at some point between $\sim 15^{h}$ UT on October 8 to 08^{h} on October 9 (the nodal crossing point is at $23^{h}30^{m}$ UT on the 8th), will be very badly affected by full Moon also on October 8, although no activity has been predicted for these dates. However, Jérémie Vaubaillon has suggested the Earth may encounter two Draconid dust trails on October 6 instead, the first from 1900 AD at $19^{h}10^{m}$ UT, which could, based on the 2011 Draconid activity, produce ZHRs up to $\sim$ 30, the second from 1907 at $19^{h}53^{m}$ UT, which might yield ZHRs around 10. Mikhail Maslov's calculations made some time earlier, and apparently not taking the actual more recent events into account, had indicated these two trail encounters could happen at 20^h10^m and 20^h16^m UT instead, with ZHRs of $\sim$ 10–15, the meteors possibly very faint, so maybe detectable only by radio/radar. October 6 thus has the possibility of being a very interesting meteoric day, despite the reduced dark-sky interval then thanks to the waxing Moon! The post-moonset period would allow full coverage of the $\sim 19^h$–20^h30^m interval then from northern-hemisphere sites at east Asian longitudes especially, although the importance of confirming what, if anything, occurs means all observers at suitable locations with clear skies that night should be on alert.

October's full Moon spoils two other shower maxima, those of the **Southern Taurids** on or about October 10, and the minor **δ-Aurigids** due on October 11. A month later, and November's waning gibbous Moon largely wipes out the **Northern Taurid** peak around November 12, but at least it leaves the later month activity alone. The lunar casualty-count among the minor sources rises again during the first half of December, with little to no dark-sky time available for the probable peaks of the **Phoenicids** on December 6 around 16^h UT, the **Puppid-Velids** perhaps near December 7, the **Monocerotids** on December 9 (their possible telescopic maximum on December 16 is much more favourable) and the **σ-Hydrids** on December 12 (although VID suggested December 6 instead, while HMO, p. 170, preferred December 14, neither of which are significantly freer of moonlight).



The **ANT** starts the year's final quarter effectively inactive in favour of the Taurids, resuming only around December 10, as the Northern Taurids fade away, from a radiant centre that tracks across southern Gemini during later December, likely producing ZHRs < 2, although some of this apparent inactivity may be due to the strength of the Geminids close-by to the north during part of December, plus the minor Monocerotids a little way to its south simultaneously.



ε-Geminids (EGE)

Active: October 14–27; Maximum: October 18 ($\lambda_\odot = 205°$); ZHR = 3;
Radiant: $\alpha = 102°$, $\delta = +27°$; Radiant drift: see Table 6;
$V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 090°$, $\delta = +20°$ and $\alpha = 125°$, $\delta = +20°$($\beta > 20°$ S).

A weak minor shower with characteristics and activity nearly coincident with the Orionids, so great care must be taken to separate the two sources, preferably by video or telescopic work, or perhaps visual plotting. The waning crescent Moon five days from new on October 18 gives few problems this year, even after it rises during the second half of the night for either hemisphere. Northern observers have a radiant elevation advantage, with observing practical there from about midnight onwards. There is some uncertainty about the shower's parameters, with both visual and video data indicating the peak may be up to four or five days later than suggested above, which would be still less Moon-affected.

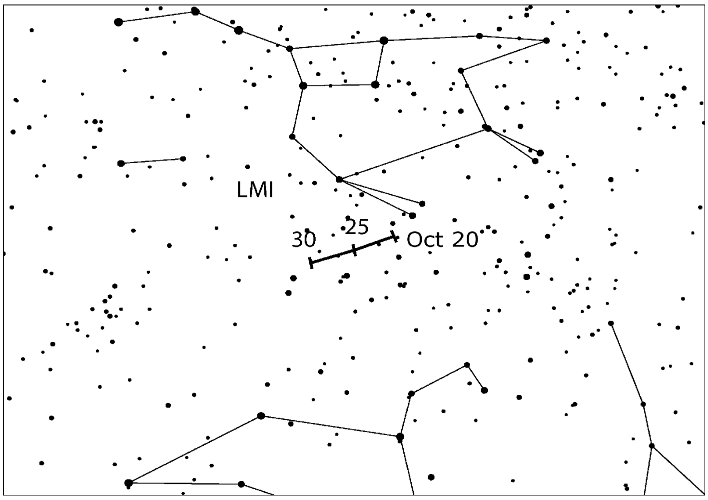
Orionids (ORI)

Active: October 2–November 7; Maximum: October 21 ($\lambda_\odot = 208°$); ZHR = 18;
Radiant: $\alpha = 95°$, $\delta = +16°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.5$;
TFC: $\alpha = 100°$, $\delta = +39°$ and $\alpha = 075°$, $\delta = +24°$($\beta > 40°$ N);
or $\alpha = 080°$, $\delta = +01°$ and $\alpha = 117°$, $\delta = +01°$($\beta < 40°$ N).

October's nearly-new Moon nicely treats the Orionid peak to dark skies this year. The shower's radiant, near the celestial equator, is at a useful elevation by local midnight or so in either hemisphere, somewhat before in the north, thus most of the world can enjoy the shower. Each return from 2006 to 2009 produced unexpectedly strong ZHRs of around 40–70 on two or three consecutive dates. An earlier IMO analysis of the shower, using data from 1984–2001, found both the peak ZHR and r parameters varied somewhat from year to year, with the highest mean ZHR ranging from $\sim$ 14–31 during the examined interval. In addition, a suspected 12-year periodicity in stronger returns found earlier in the 20th century appeared to have been partly confirmed. That suggested better activity should have happened from 2008–2010, falling thereafter towards 2014–2016, so perhaps ZHRs may be less than 20 in 2014. The recent strong returns seemed to have had a separate resonant cause, with nothing further anticipated this time. The Orionids often provide several lesser maxima, helping activity sometimes remain roughly constant for several consecutive nights centred on the main peak. In 1993 and 1998, a submaximum about as strong as the normal peak was detected on October 17/18 from Europe, for instance. All observers should be aware of these possibilities, as circumstances are favourable for covering October 17/18 this year with little lunar interference too. Several visual subradiants had been reported in the past, but recent video work has found the radiant to be far less complex.

Leonis Minorids (LMI)

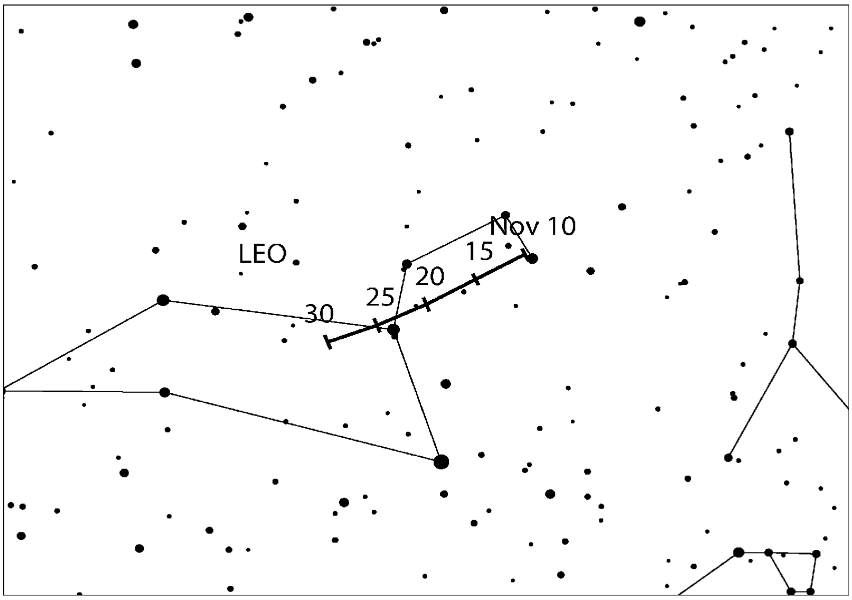
Active: October 19–27; Maximum: October 24 ($\lambda_{\odot} = 211°$); ZHR = 2;
Radiant: $\alpha = 162°$, $\delta = +37°$; Radiant drift: See Table 6;
$V_{\infty} = 62$ km/s; $r = 3.0$;
TFC: $\alpha = 190°$, $\delta = +58°$ and $\alpha = 135°$, $\delta = +30°$ ($\beta > 40°$ N).



This weak minor shower has a peak ZHR apparently on or below the visual threshold, found so far by video only. The radiant area can be seen solely from the northern hemisphere, where it rises around midnight. The probable maximum date falls just one day after new Moon, so it could be scarcely better-placed for coverage! Telescopic, imaging or very careful visual plotting observations are advised.

Leonids (LEO)

Active: November 6–30; Maximum: November 17, 22^{h} UT (nodal crossing at $\lambda_{\odot} = 235\overset{\circ}{.}27$), but see text; ZHR = 15?
Radiant: $\alpha = 152°$, $\delta = +22°$; Radiant drift: see Table 6;
$V_{\infty} = 71$ km/s; $r = 2.5$;
TFC: $\alpha = 140°$, $\delta = +35°$ and $\alpha = 129°$, $\delta = +06°$($\beta > 35°$ N);
or $\alpha = 156°$, $\delta = -03°$ and $\alpha = 129°$, $\delta = +06°$($\beta < 35°$ N).
IFC: $\alpha = 120°$, $\delta = +40°$ before 0^{h} local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = +20°$ before 4^{h} local time and $\alpha = 160°$, $\delta = 0°$ after 4^{h} local time ($\beta > 0°$ N);
$\alpha = 120°$, $\delta = +10°$ before 0^{h} local time and $\alpha = 160°$, $\delta = -10°$($\beta < 0°$ N).

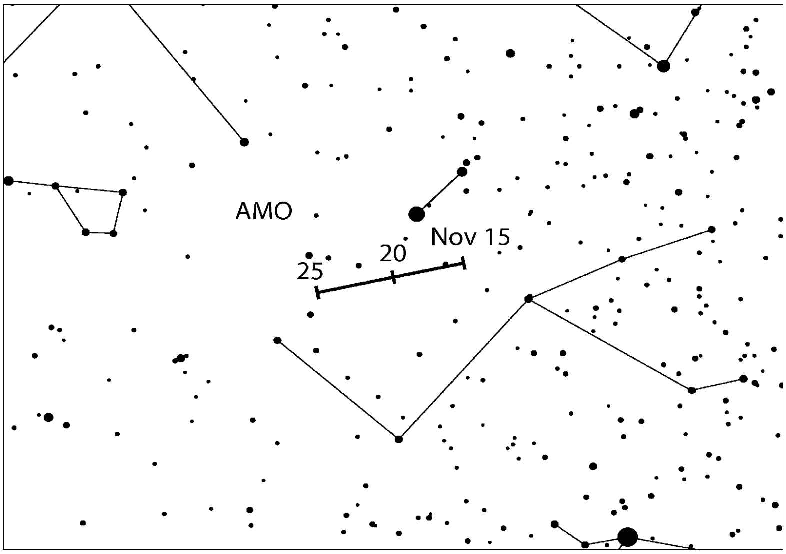


The most recent perihelion passage of the Leonids' parent comet, 55P/Tempel-Tuttle, in 1998 may be more than 15 years ago now, but the shower's activity has continued to be fascinatingly variable from year to year recently. This year seems unlikely to produce enhanced rates, but there may be more than one peak. Mikhail Maslov has suggested the nodal maximum could happen around 16^{h} UT on November 17, rather than at the time given above, producing ZHRs of $\sim$ 10–15, while Jérémie Vaubaillon has indicated the Earth could encounter the 1567 AD Leonid dust trail at $09^{\mathrm{h}}17^{\mathrm{m}}$ UT on November 21, albeit he noted too that ZHRs might prove undetectable from this event. November's waning crescent Moon, at last quarter on the 14th, means virtually no moonlight interference on either date. The Leonid radiant first becomes usefully-observable by local midnight or so north of the equator, afterwards for places further south, and all observing methods can be employed. While these potential maximum timings do not exclude all others, if they prove correct, the two November 17 ones would be best-detectable from east Asian to western Pacific longitudes ($\sim 16^{\mathrm{h}}$ peak), and east European to central-eastern Asian longitudes (22^{h} maximum), while that on November 21 would be similarly available from places at North American longitudes.

α-Monocerotids (AMO)

Active: November 15–25; Maximum: November 21, $22^{\mathrm{h}}25^{\mathrm{m}}$ UT ($\lambda_{\odot} = 239\overset{\circ}{.}32$);
ZHR = variable, usually $\sim$ 5, but may produce outbursts to $\sim$ 400+;
Radiant: $\alpha = 117°$, $\delta = +01°$; Radiant drift: see Table 6;
$V_{\infty} = 65$ km/s; $r = 2.4$;
TFC: $\alpha = 115°$, $\delta = +23°$ and $\alpha = 129°$, $\delta = +20°$ ($\beta > 20°$ N);
or $\alpha = 110°$, $\delta = -27°$ and $\alpha = 098°$, $\delta = +06°$ ($\beta < 20°$ N).

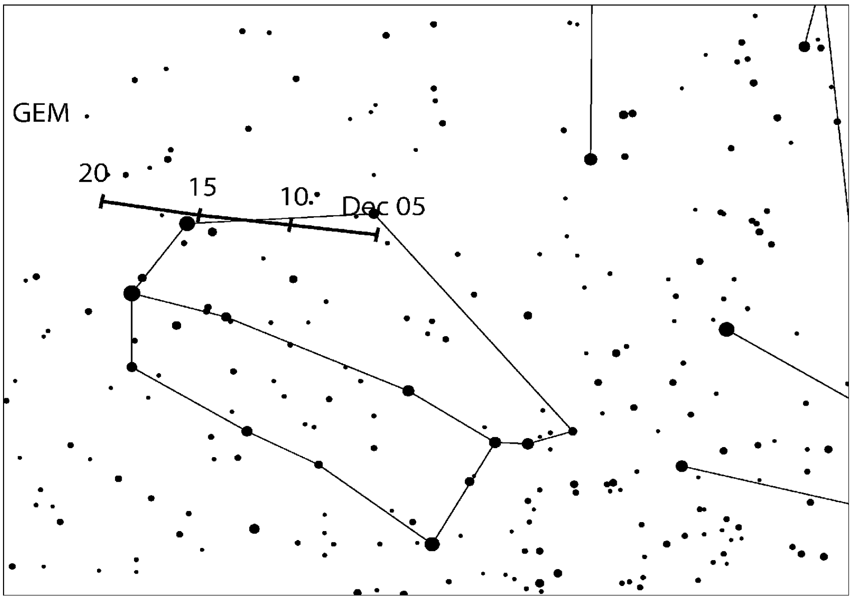
The α-Monocerotids gave their most recent brief outburst in 1995 (the top EZHR, $\sim$ 420, lasted five minutes, the entire outburst 30 minutes). Recent modelling by Esko Lyytinen has indicated the main AMO trail will not cross the Earth's orbit again until 2017 and 2020. However, the Earth will not be near those points in November, so nothing is likely to happen then. A weak return may occur in November 2019, ahead of the 2020 encounter, depending on how broad the trail may be. The next strong AMO outburst is unlikely before 2043. Despite this, observers should monitor the AMO closely in every year possible, in case of unanticipated events. The brevity of all past outbursts means breaks under clear skies should be kept to a minimum near the predicted peak. November's new Moon on the 22nd creates perfect observing circumstances this year, and the shower's radiant is well on view from either hemisphere after about 23^{h} local time. If correct, the peak timing would fall well for sites at eastern European to Asian longitudes.



Geminids (GEM)

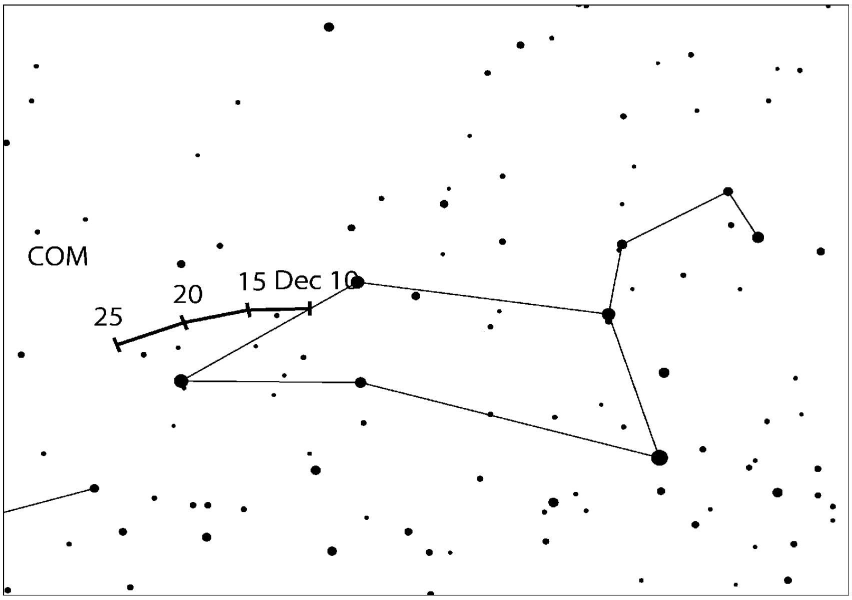
Active: December 4–17; Maximum: December 14, 12^{h} UT ($\lambda_{\odot} = 262\overset{\circ}{.}2$); ZHR = 120;
Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6;
$V_{\infty} = 35$ km/s; $r = 2.6$;
TFC: $\alpha = 087°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +49°$ before 23^{h} local time, $\alpha = 087°$, $\delta = +20°$ and $\alpha = 129°$, $\delta = +20°$ after 23^{h} local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = -03°$ and $\alpha = 084°$, $\delta = +10°$($\beta < 40°$ N).
IFC: $\alpha = 150°$, $\delta = +20°$ and $\alpha = 060°$, $\delta = +40°$($\beta > 20°$ N);
$\alpha = 135°$, $\delta = -05°$ and $\alpha = 080°$, $\delta = 00°$($\beta < 20°$ N).

One of the finest, and probably the most reliable, of the major annual showers presently observable. Well north of the equator, the radiant rises about sunset, reaching a usable elevation from the local evening hours onwards. In the southern hemisphere, the radiant appears only around local midnight or so. It culminates near 02^{h}. Even from more southerly sites, this is a splendid stream of often bright, medium-speed meteors, a rewarding event for all observers, whatever method they employ. The peak has shown slight signs of variability in its rates and timing in recent years, with the more reliably-reported maxima during the past two decades (HMO, p. 171) all having occurred within $\lambda_{\odot} = 261\overset{\circ}{.}5$ to $262\overset{\circ}{.}4$, 2014 December 13, 19^{h} to December 14, 17^{h} UT. Theoretical modelling by Jérémie Vaubaillon has implied the greatest dust particle density could be encountered during the UT daylight hours of December 15 instead this time, something observers should be aware of to help refine future modelling work for this source. Whatever the case, near-peak Geminid rates usually persist for almost a day, so much of the world has the chance to enjoy something of the shower's best. Mass-sorting within the stream means fainter telescopic meteors should be most abundant almost a day ahead of the visual maximum, with telescopic results indicating such meteors radiate from an elongated region, perhaps with three sub-centres. Further results on this topic would be useful. The 2014 return comes with a last quarter Moon, which rises a little after local midnight for most of the inhabited Earth on December 14, thus leaving the first half of the night with dark-skies for northern hemisphere observers (only).



Comae Berenicids (COM)

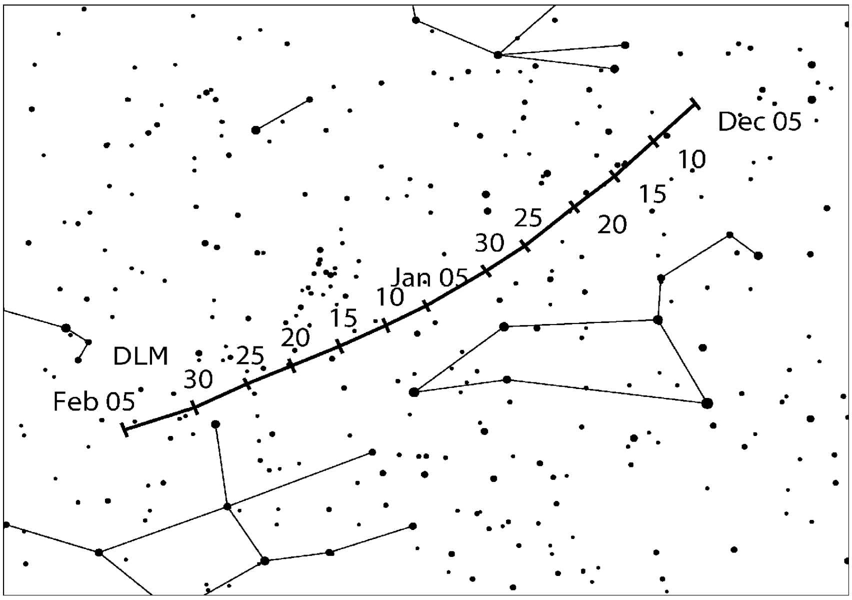
Active: December 12–23; Maximum: December 16 ($\lambda_\odot = 264°$); ZHR = 3; Radiant: $\alpha = 175°$, $\delta = +18°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 3.0$; TFC: $\alpha = 180°$, $\delta = +50°$ and $\alpha = 165°$, $\delta = +20°$ before 3^h local time, $\alpha = 195°$, $\delta = +10°$ and $\alpha = 200°$, $\delta = +45°$ after 3^h local time ($\beta > 20°$ N).



Years of work to resolve uncertainties have now shown this source to be weak, shorter in duration than was once thought, and with a maximum significantly earlier than previously believed. From the mid northern hemisphere, its radiant reaches a useful elevation by about one a.m. local time in mid December, culminating around 06^h, but it is almost unobservable from the mid southern hemisphere until near dawn. December's waning crescent Moon makes the probable peak favourable for observing.

December Leonis Minorids (DLM)

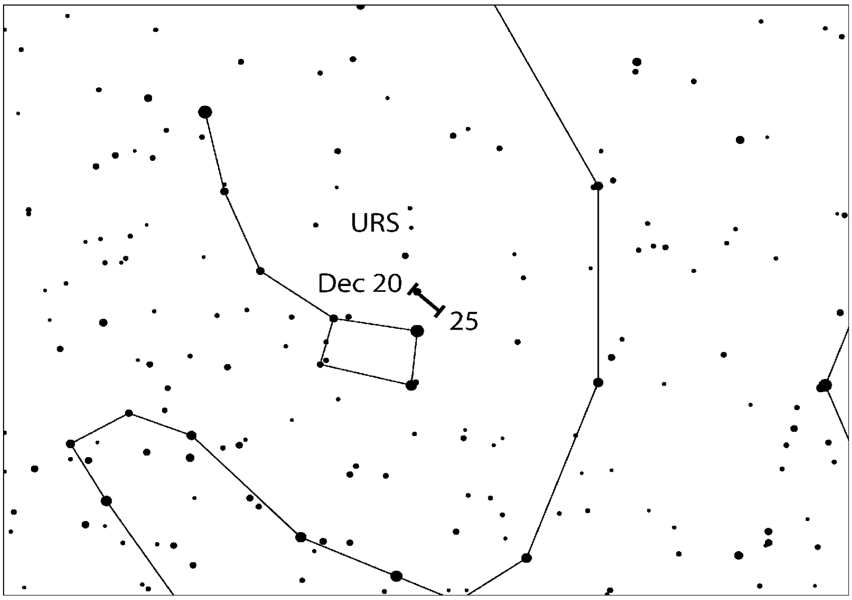
Active: December 5–February 4; Maximum: December 20 ($\lambda_\odot = 268°$); ZHR = 5;
Radiant: $\alpha = 161°$, $\delta = +30°$; Radiant drift: see Table 6;
$V_\infty = 64$ km/s; $r = 3.0$;
TFC: $\alpha = 180°$, $\delta = +50°$ and $\alpha = 165°$, $\delta = +20°$ before 3^h local time,
$\alpha = 195°$, $\delta = +10°$ and $\alpha = 200°$, $\delta = +45°$ after 3^h local time ($\beta > 20°$ N).



Like the COM, the DLM have been recently redefined. This shower too is quite weak, but is probably long-lasting, though more coverage after the Quadrantid epoch in January would be valuable. The shower is primarily a northern hemisphere target, from where its radiant can be properly observed from $\sim 23^h$ local time onwards. Almost new Moon means dark skies will prevail for covering the northern midwinter maximum night.

Ursids (URS)

Active: December 17–26; Maximum: December 22, 20^h UT ($\lambda_\odot = 270.°7$), but see text;
ZHR = 10 (occasionally variable up to 50);
Radiant: $\alpha = 217°$, $\delta = +76°$; Radiant drift: see Table 6;
$V_\infty = 33$ km/s; $r = 3.0$;
TFC: $\alpha = 348°$, $\delta = +75°$ and $\alpha = 131°$, $\delta = +66°$ ($\beta > 40°$ N);
$\alpha = 063°$, $\delta = +84°$ and $\alpha = 156°$, $\delta = +64°$ (β 30° to 40° N).



A very poorly-observed northern hemisphere shower, but one which has produced at least two major outbursts in the past 70 years, in 1945 and 1986. Several lesser rate enhancements have been reported as well, most recently from 2006–2008 inclusive which were probably influenced by the relative proximity of the shower's parent comet, 8P/Tuttle, at perihelion in January 2008. Other events could have been missed easily. Jérémie Vaubaillon's stream modelling has found a possible encounter with the 1392 AD dust trail for 2014, which could produce activity around $00^{\mathrm{h}}40^{\mathrm{m}}$ UT on December 23, although the age of this dust trail means the potential ZHRs are highly uncertain (so perhaps nothing unusual may occur). The Ursid radiant is circumpolar from most northern sites, so fails to rise for most southern ones, though it culminates after daybreak, and is highest in the sky later in the night. New Moon on December 22 creates perfect viewing conditions.

7 Radiant sizes and meteor plotting for visual observers

by Rainer Arlt

If you are not observing during a major-shower maximum, it is essential to associate meteors with their radiants correctly, since the total number of meteors will be small for each source. Meteor plotting allows shower association by more objective criteria after your observation than the simple imaginary back-prolongation of paths under the sky. With meteors plotted on gnomonic maps, you can trace them back to their radiants by extending their straight line paths. If a radiant lies on another chart, you should find common stars on an adjacent chart to extend this back-prolongation correctly.

How large a radiant should be assumed for shower association? The real physical radiant size is very small, but visual plotting errors cause many true shower meteors to miss this real radiant area. Thus we have to assume a larger effective radiant to allow for these errors. Unfortunately, as we enlarge the radiant, so more and more sporadic meteors will appear to line up accidentally with this region. Hence we have to apply an optimum radiant diameter to compensate for the plotting errors loss, but which will not then be swamped by sporadic meteor pollution. Table 1 gives this optimum diameter as a function of the distance of the meteor from the radiant.

Table 1. Optimum radiant diameters to be assumed for shower association of minor-shower meteors as a function of the radiant distance D of the meteor.

D	optimum diameter
15°	14°
30°	17°
50°	20°
70°	23°

Note that this radiant diameter criterion applies to all shower radiants *except* those of the Southern and Northern Taurids, and the Antihelion Source, all of which have notably larger radiant areas. The optimum $\alpha \times \delta$ size to be assumed for each radiant of the two Taurid showers is instead $20° \times 10°$, while that for the Antihelion Source is still larger, at $30° \times 15°$.

Path-direction is not the only criterion for shower association. The angular velocity of the meteor should match the expected speed of the given shower meteors according to their geocentric velocities. Angular velocity estimates should be made in degrees per second (°/s). To do this, make the meteors you see move for one second in your imagination at the speed you saw them. The path length of this imaginary meteor is the angular velocity in °/s. Note that typical speeds are in the range 3°/s to 25°/s. Typical errors for such estimates are given in Table 2.

Table 2. Error limits for the angular velocity.

angular velocity [°/s]	5	10	15	20	30
permitted error [°/s]	3	5	6	7	8

If you find a meteor in your plots which passes the radiant within the diameter given by Table 1, check its angular velocity. Table 3 gives the angular speeds for a few geocentric velocities, which can then be looked up in Table 5 for each shower.

Table 3. Angular velocities as a function of the radiant distance of the meteor (D) and the elevation of the meteor above the horizon (h) for three different geocentric velocities (V_∞). All velocities are in °/s.

$h \backslash D$	$V_\infty = 25$ km/s					$V_\infty = 40$ km/s					$V_\infty = 60$ km/ s				
	10°	20°	40°	60°	90°	10°	20°	40°	60°	90°	10°	20°	40°	60°	90°
10°	0.4	0.9	1.6	2.2	2.5	0.7	1.4	2.6	3.5	4.0	0.9	1.8	3.7	4.6	5.3
20°	0.9	1.7	3.2	4.3	4.9	1.4	2.7	5.0	6.8	7.9	1.8	3.5	6.7	9.0	10
40°	1.6	3.2	5.9	8.0	9.3	2.6	5.0	9.5	13	15	3.7	6.7	13	17	20
60°	2.2	4.3	8.0	11	13	3.5	6.8	13	17	20	4.6	9.0	17	23	26
90°	2.5	4.9	9.3	13	14	4.0	7.9	15	20	23	5.3	10	20	26	30

8 Abbreviations

- α, δ: Coordinates for a shower's radiant position, usually at maximum. α is right ascension, δ is declination. Radiants drift across the sky each day due to the Earth's own orbital motion around the Sun, and this must be allowed for using the details in Table 6 for nights away from the listed shower maxima.

- r: The population index, a term computed from each shower's meteor magnitude distribution. $r = 2.0$–2.5 is brighter than average, while r above 3.0 is fainter than average.

- $\lambda_{\odot}$: Solar longitude, a precise measure of the Earth's position on its orbit which is not dependent on the vagaries of the calendar. All $\lambda_{\odot}$ are given for the equinox 2000.0.

- V_{∞}: Atmospheric or apparent meteoric velocity, given in km/s. Velocities range from about 11 km/s (very slow) to 72 km/s (very fast). 40 km/s is roughly medium speed.

- ZHR: Zenithal Hourly Rate, a calculated maximum number of meteors an ideal observer would see in perfectly clear skies with the shower radiant overhead. This figure is given in terms of meteors per hour. Where meteor activity persisted at a high level for less than an hour, or where observing circumstances were very poor, an estimated ZHR (EZHR) is used, which is less accurate than the normal ZHR.

- TFC and IFC: Suggested telescopic and still-imaging (including photographic) field centres respectively. β is the observer's latitude ('$<$' means 'south of' and '$>$' means 'north of'). *Pairs* of telescopic fields must be observed, alternating about every half hour, so that the positions of radiants can be defined. The exact choice of TFC or IFC depends on the observer's location and the elevation of the radiant. Note that the TFCs are also useful centres to use for video camera fields as well.

Table 4. Lunar phases for 2014.

New Moon	First Quarter	Full Moon	Last Quarter
January 1	January 8	January 16	January 24
January 30	February 6	February 14	February 22
March 1	March 8	March 16	March 24
March 30	April 7	April 15	April 22
April 29	May 7	May 14	May 21
May 28	June 5	June 13	June 19
June 27	July 5	July 12	July 19
July 26	August 4	August 10	August 17
August 25	September 2	September 9	September 16
September 24	October 1	October 8	October 15
October 23	October 31	November 6	November 14
November 22	November 29	December 6	December 14
December 22	December 28		

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in May 2013, with maximum dates accurate only for 2014. Except for the Antihelion Source, all other showers are listed in order of their maximum solar longitude. An asterisk ('*') in the 'Shower' column indicates that source may have additional peak times, as noted in the text above. The parenthesized maximum date for the Puppids-Velids indicates a reference date for the radiant only, not necessarily a true maximum. Some showers have ZHRs that vary from year to year. The most recent reliable figure is given here, except for possibly periodic showers. These are either are noted as 'Var' = variable, where there is considerable uncertainty over the likely maximum rates, or with an asterisk to indicate the value is that suggested from theoretical considerations for the current year. For more information, contact the IMO's Visual Commission.

Shower	Activity	Maximum Date	$\lambda_\odot$	Radiant α	δ	V_∞ km/s	r	ZHR
Antihelion Source (ANT)	Dec 10–Sep 10 –	March–April, late May, late June		see Table 6		30	3.0	4
Quadrantids (QUA)	Dec 28–Jan 12	Jan 03	283°.16	230°	+49°	41	2.1	120
α-Centaurids (ACE)	Jan 28–Feb 21	Feb 08	319°.2	210°	−59°	56	2.0	6
γ-Normids (GNO)	Feb 25–Mar 22	Mar 14	354°	239°	−50°	56	2.4	6
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	32°.32	271°	+34°	49	2.1	18
π-Puppids (PPU)	Apr 15–Apr 28	Apr 23	33°.5	110°	−45°	18	2.0	Var
η-Aquariids (ETA)	Apr 19–May 28	May 06	45°.5	338°	−01°	66	2.4	45*
η-Lyrids (ELY)	May 03–May 14	May 08	48°.0	287°	+44°	43	3.0	3
June Bootids (JBO)	Jun 22–Jul 02	Jun 27	95°.7	224°	+48°	18	2.2	Var
Piscis Austrinids (PAU)	Jul 15–Aug 10	Jul 28	125°	341°	−30°	35	3.2	5
South. δ-Aquariids (SDA)	Jul 12–Aug 23	Jul 30	127°	340°	−16°	41	3.2	16
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	5
Perseids (PER)	Jul 17–Aug 24	Aug 13	140°.0	48°	+58°	59	2.2	100
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 18	145°	286°	+59°	25	3.0	3
Aurigids (AUR)	Aug 28–Sep 05	Sep 01	158°.6	91°	+39°	66	2.5	6
Sept. ε-Perseids (SPE)	Sep 05–Sep 21	Sep 09	166°.7	48°	+40°	64	3.0	5
Draconids (DRA)	Oct 06–Oct 10	Oct 08	195°.4	262°	+54°	20	2.6	Var
Southern Taurids (STA)*	Sep 10–Nov 20	Oct 10	197°	32°	+09°	27	2.3	5
δ-Aurigids (DAU)	Oct 10–Oct 18	Oct 11	198°	84°	+44°	64	3.0	2
ε-Geminids (EGE)	Oct 14–Oct 27	Oct 18	205°	102°	+27°	70	3.0	3
Orionids (ORI)	Oct 02–Nov 07	Oct 21	208°	95°	+16°	66	2.5	18*
Leonis Minorids (LMI)	Oct 19–Oct 27	Oct 24	211°	162°	+37°	62	3.0	2
Northern Taurids (NTA)*	Oct 20–Dec 10	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (LEO)*	Nov 06–Nov 30	Nov 17	235°.27	152°	+22°	71	2.5	15*
α-Monocerotids (AMO)	Nov 15–Nov 25	Nov 21	239°.32	117°	+01°	65	2.4	Var
Phoenicids (PHO)	Nov 28–Dec 09	Dec 06	254°.25	18°	−53°	18	2.8	Var
Puppid/Velids (PUP)	Dec 01–Dec 15	(Dec 07)	(255°)	123°	−45°	40	2.9	10
Monocerotids (MON)	Nov 27–Dec 17	Dec 09	257°	100°	+08°	42	3.0	2
σ-Hydrids (HYD)	Dec 03–Dec 15	Dec 12	260°	127°	+02°	58	3.0	3
Geminids (GEM)	Dec 04–Dec 17	Dec 14	262°.2	112°	+33°	35	2.6	120
Comae Berenicids (COM)	Dec 12–Dec 23	Dec 16	264°	175°	+18°	65	3.0	3
Dec. Leonis Minorids (DLM)	Dec 05–Feb 04	Dec 20	268°	161°	+30°	64	3.0	5
Ursids (URS)	Dec 17–Dec 26	Dec 22	270°.7	217°	+76°	33	3.0	10

Table 6 (next page). Radiant positions during the year in α and δ.

Date	**ANT**	**QUA**	**DLM**				
Jan 0	112° +21°	228° +50°	172° +25°				
Jan 5	117° +20°	231° +49°	176° +23°				
Jan 10	122° +19°	234° +48°	180° +21°				
Jan 15	127° +17°		185° +19°				
Jan 20	132° +16°		189° +17°				
Jan 25	138° +15°		193° +15°	**ACE**			
Jan 30	143° +13°		198° +12°	200° −57°			
Feb 5	149° +11°		203° +10°	208° −59°			
Feb 10	154° +9°			214° −60°			
Feb 15	159° +7°			220° −62°			
Feb 20	164° +5°	**GNO**		225° −63°			
Feb 28	172° +2°	225° -51°					
Mar 5	177° 0°	230° -50°					
Mar 10	182° −2°	235° -50°					
Mar 15	187° −4°	240° -50°					
Mar 20	192° −6°	245° -49°					
Mar 25	197° −7°						
Mar 30	202° −9°						
Apr 5	208° −11°						
Apr 10	213° −13°	**LYR**	**PPU**				
Apr 15	218° −15°	263° +34°	106° −44°	**ETA**			
Apr 20	222° −16°	269° +34°	109° −45°	323° −7°			
Apr 25	227° −18°	274° +34°	111° −45°	328° −5°			
Apr 30	232° −19°			332° −3°	**ELY**		
May 05	237° −20°			337° −1°	283° +44°		
May 10	242° −21°			341° +1°	288° +44°		
May 15	247° −22°			345° +3°	293° +45°		
May 20	252° −22°			349° +5°			
May 25	256° −23°			353° +7°			
May 30	262° −23°						
Jun 5	267° −23°						
Jun 10	272° −23°						
Jun 15	276° −23°						
Jun 20	281° −23°	**JBO**					
Jun 25	286° −22°	223° +48°					
Jun 30	291° −21°	225° +47°	**CAP**				
Jul 5	296° −20°		285° −16°	**SDA**			
Jul 10	300° −19°	**PER**	289° −15°	325° −19°	**PAU**		
Jul 15	305° −18°	6° +50°	294° −14°	329° −19°	330° −34		
Jul 20	310° −17°	11° +52°	299° −12°	333° −18°	334° −33		
Jul 25	315° −15°	22° +53°	303° −11°	337° −17°	338° −31		
Jul 30	319° −14°	29° +54°	307° −10°	340° −16°	343° −29	**KCG**	
Aug 5	325° −12°	37° +56°	313° −8°	345° −14°	348° −27	283° +58°	
Aug 10	330° −10°	45° +57°	318° −6°	349° −13°	352° −26	284° +58°	
Aug 15	335° −8°	51° +58°		352° −12°		285° +59°	
Aug 20	340° −7°	57° +58°	**AUR**	356° −11°		286° +59°	
Aug 25	344° −5°	63° +58°	85° +40°			288° +60°	
Aug 30	349° −3°		90° +39°	**SPE**		289° +60°	
Sep 5	355° −1°	**STA**	96° +39°	43° +40°			
Sep 10	0° +1°	12° +3°	102° +39°	48° +40°			
Sep 15		15° +4°		53° +40°			
Sep 20		18° +5°		59° +41°			
Sep 25		21° +6°					
Sep 30		25° +7°		**ORI**			
Oct 5		28° +8°		85° +14°	**DAU**		**DRA**
Oct 10	**EGE**	32° +9°		88° +15°	82° +45°		262° +54°
Oct 15	99° +27°	36° +11°	**NTA**	91° +15°	87° +43°	**LMI**	
Oct 20	104° +27°	40° +12°	38° +18°	94° +16°	92° +41°	158° +39°	
Oct 25	109° +27°	43° +13°	43° +19°	98° +16°		163° +37°	
Oct 30		47° +14°	47° +20°	101° +16°		168° +35°	
Nov 5		52° +15°	52° +21°	105° +17°	**LEO**		
Nov 10		56° +15°	56° +22°		147° +24°		**AMO**
Nov 15		60° +16°	61° +23°		150° +23°		112° +2°
Nov 20		64° +16°	65° +24°		153° +21°		116° +1°
Nov 25			70° +24°	**PHO**	156° +20°	**PUP**	120° 0°
Nov 30	**ANT**	**GEM**	74° +24°	14° −52°	159° +19°	120° −45°	91° +8°
Dec 5	85° +23°	103° +33°	149° +37°	18° −53°	122° +3°	122° −45°	96° +8°
Dec 10	90° +23°	108° +33°	153° +35°	22° −53°	126° +2°	125° −45°	100° +8°
Dec 15	96° +23°	113° +33°	157° +33°	174° +19°	130° +1°	128° −45°	104° +8°
Dec 20	101° +23°	118° +32°	161° +31°	177° +18°	**HYD**	217° +76°	**MON**
Dec 25	106° +22°	**QUA**	166° +28°	180° +16°		217° +74°	
Dec 30	111° +21°	226° +50°	170° +26°	**COM**		**URS**	
			DLM				

Table 7. Working List of Daytime Radio Meteor Streams. An asterisk ('*') in the 'Max date' column indicates that source may have additional peak times, as noted in the text above. The 'Best Observed' columns give the approximate local mean times between which a four-element antenna at an elevation of 45° receiving a signal from a 30 kW transmitter 1000 km away should record at least 85% of any suitably positioned radio-reflecting meteor trails for the appropriate latitudes. Note that this is often heavily dependent on the compass direction in which the antenna is pointing, however, and applies only to dates near the shower's maximum. An asterisk in the 'Rate' column shows the suggested rate may not recur in all years.

Shower	Activity	Max Date	$\lambda_\odot$ 2000	Radiant α	Radiant δ	Best observed 50° N	Best observed 35° S	Rate
Cap/Sagittariids	Jan 13–Feb 04	Feb 01*	312°.5	299°	−15°	11^h–14^h	09^h–14^h	Medium*
χ-Capricornids	Jan 29–Feb 28	Feb 13*	324°.7	315°	−24°	10^h–13^h	08^h–15^h	Low*
Piscids (Apr)	Apr 08–Apr 29	Apr 20	30°.3	7°	+07°	07^h–14^h	08^h–13^h	Low
δ-Piscids	Apr 24–Apr 24	Apr 24	34°.2	11°	+12°	07^h–14^h	08^h–13^h	Low
ε-Arietids	Apr 24–May 27	May 09	48°.7	44°	+21°	08^h–15^h	10^h–14^h	Low
Arietids (May)	May 04–Jun 06	May 16	55°.5	37°	+18°	08^h–15^h	09^h–13^h	Low
o-Cetids	May 05–Jun 02	May 20	59°.3	28°	−04°	07^h–13^h	07^h–13^h	Medium*
Arietids	May 22–Jul 02	Jun 07*	76°.7	44°	+24°	06^h–14^h	08^h–12^h	High
ζ-Perseids	May 20–Jul 05	Jun 09*	78°.6	62°	+23°	07^h–15^h	09^h–13^h	High
β-Taurids	Jun 05–Jul 17	Jun 28	96°.7	86°	+19°	08^h–15^h	09^h–13^h	Medium
γ-Leonids	Aug 14–Sep 12	Aug 25	152°.2	155°	+20°	08^h–16^h	10^h–14^h	Low*
Sextantids	Sep 09–Oct 09	Sep 27*	184°.3	152°	00°	06^h–12^h	06^h–13^h	Medium*

9 Useful addresses

For more information on observing techniques, and when submitting results, please contact the appropriate IMO Commission Director:

Fireball Data Center (FIDAC): André Knöfel, Am Observatorium 2, D-15848 Lindenberg, Germany; e-mail: aknoefel@minorplanets.de

Photographic Commission: Vacant. Questions can be sent to e-mail: photo@imo.net

Radio Commission: Jean-Louis Rault, Société Astronomique de France, 16 Rue de la Valleé, 91360 Epinay sur Orge, France; e-mail: f6agr@orange.fr

Telescopic Commission: Malcolm Currie, 25 Collett Way, Grove, Wantage, Oxfordshire, OX12 0NT, UK; e-mail: mjc@star.rl.ac.uk

Video Commission Sirko Molau, Abenstalstraße 13b, D-84072 Seysdorf, Germany; e-mail: sirko@molau.de

Visual Commission: Rainer Arlt, Bahnstraße 11, D-14974 Ludwigsfelde, Germany; e-mail: rarlt@aip.de

or visit the IMO's Homepage on the World-Wide-Web at: http://www.imo.net

For further details on **IMO membership**, please write to: Robert Lunsford, IMO Secretary-General, 1828 Cobblecreek Street, Chula Vista, CA 91913-3917, USA; lunro.imo.usa@cox.net

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