# International Meteor Organization

# 2015 Meteor Shower Calendar

*compiled by Alastair McBeath* [1]

## 1 Introduction

Welcome to the twenty-fifth International Meteor Organization (IMO) Meteor Shower Calendar, for 2015. Both Perseids and Geminids of the three stronger annual shower maxima enjoy near-perfect moonlight circumstances, leaving just the Quadrantids too close to full Moon for useful visual work, sadly along with all three of the stronger southern hemisphere showers near their best, the $\alpha$-Centaurids, $\eta$-Aquariids and Southern $\delta$-Aquariids. No particularly unusual meteoric events are predicted for the year, but the Perseids could produce some enhancement in rates ahead of their "usual" maximum, and the Leonids may give maxima on consecutive dates, plus we are hopeful that a possibly good Taurid "swarm" return may occur again around late October to early November. 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 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!). To allow for better correlation with other meteor shower data sources, for the first time we have included below the shower numbers taken from IAU's Meteor Data Center listings.

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. 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 David Asher, Esko Lyytinen, Jürgen Rendtel and Jérémie Vaubaillon for new information and comments in respect of events in 2015.

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.

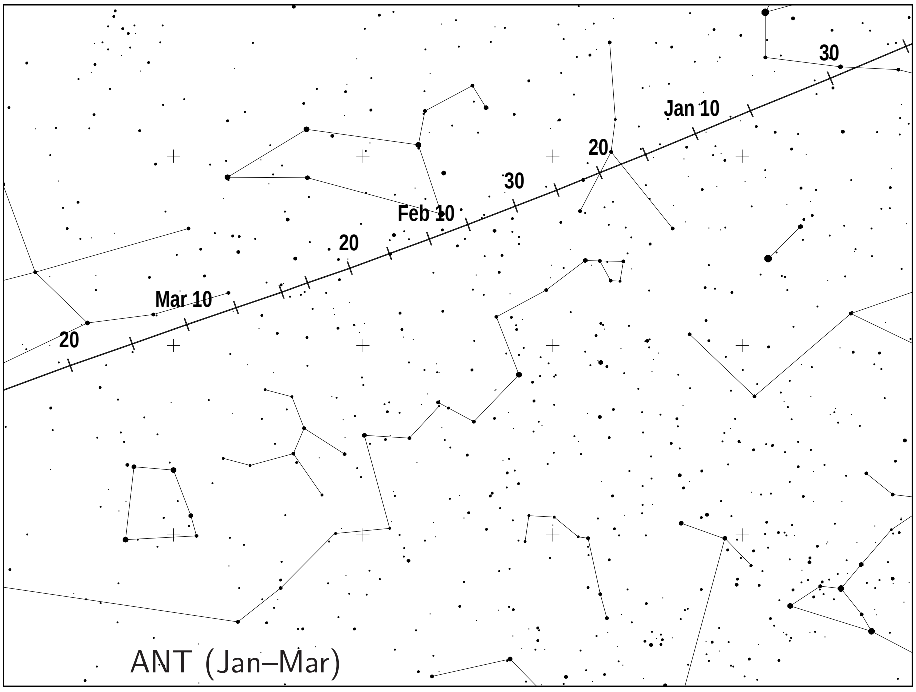
The IMO's aims are to encourage, collect, analyze, and publish combined meteor data obtained from sites all over the globe, to help better our understanding of the meteor activity detectable from the Earth's surface. Thus, we encourage these more specialist forms of observing alongside visual work. Consequently, 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.

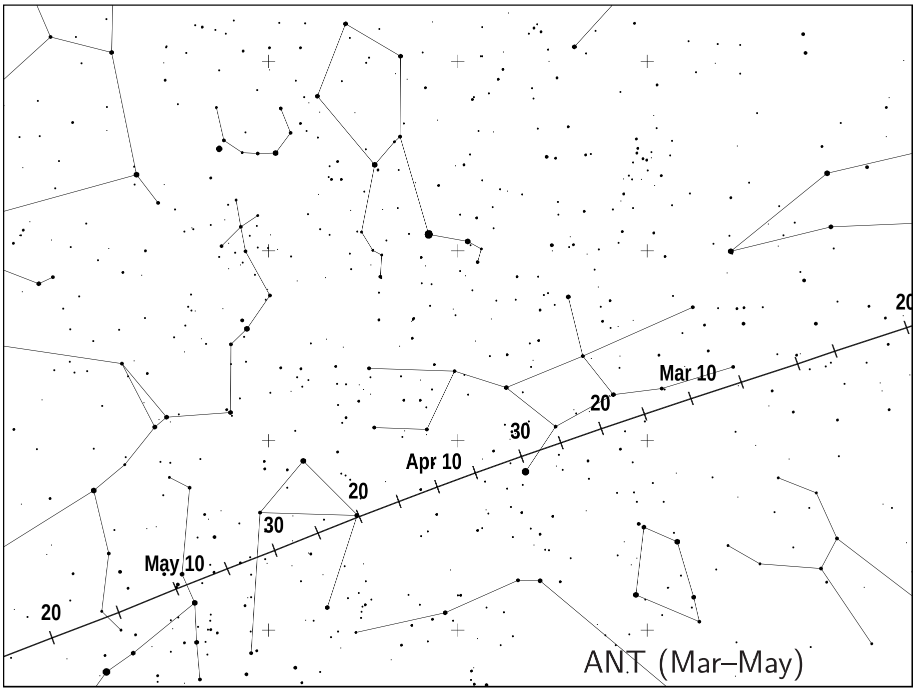
Although timing predictions are included below on all the more active night-time and daytime shower maxima, as reliably as possible, it is essential to understand that in many cases, such maxima are not known more precisely than to the nearest degree of solar longitude (even less accurately for the daytime 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, whose input is possible via the online form on the IMO's website `www.imo.net`. 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 (hence it has no IAU shower number), 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 $\alpha$-Capricornids, and particularly the Southern $\delta$-Aquariids, 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 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

A poor start to the year for northern hemisphere observers, with the peak of the **Quadrantid** (010 QUA) shower, due at around $02^{h}$ UT on January 4, very badly affected by full Moon just 27 hours later. In February, although the southern hemisphere's $\alpha$-Centaurid maximum must also contend with a bright Moon, there is the possibility of stronger activity this time, as discussed below. The minor $\gamma$-Normids of March are the only better-placed shower for moonlight conditions this quarter. 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 $\sim 2$ to 3 around $\lambda_\odot \sim 286°$–$293°$ (2015 January 6 to 13; between full to last quarter Moon, if so), and ZHRs could be $\sim 3$ for most of March. By contrast, the late January to early February spell, during which several, **minor showers radiating from the Coma-Leo-Virgo area** have been proposed in some recent years, has its potential core interval, January 20–27, enjoying January's new to first quarter Moon spell. This provides ideal circumstances, given that this region of sky is better-observed during the second half of the night. Theoretical timings (rounded to the nearest hour) for the **daytime radio shower maxima** this quarter are: Sagittariids/Capricornids (115 DSC) – February 1, $22^{\mathrm{h}}$ UT and $\chi$-Capricornids (114 DXC) – February 13, $23^{\mathrm{h}}$ UT. Recent radio results have implied the DSC maximum may fall variably sometime between February 1–4 however, while activity near the expected DXC 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.

*$\alpha$-Centaurids (102 ACE)*

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| Active: January 28–February 21; Maximum: February 8, $12^{\mathrm{h}}30^{\mathrm{m}}$ UT ($\lambda_\odot = 319.^\circ2$), see text; |
| ZHR = variable, usually $\sim 6$, 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 $\alpha$-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 persistent trains. The average peak ZHR between 1988–2007 was merely 6 though (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 can we be sure when, or if, another stronger event might happen. However, if the shower is of a long orbital period type as some analysts suspect, there is the possibility there could be a fresh outburst this year, also on February 8, but an hour or so before the nodal crossing time above, according to the modelling at $11^{\mathrm{h}}28^{\mathrm{m}}$ UT. The shower's radiant is nearly circumpolar for much of the sub-equatorial inhabited Earth, and is at a useful elevation from late evening onwards. Unfortunately, the bright waning gibbous Moon will rise by $21^{\mathrm{h}}30^{\mathrm{m}}$ local time for sites within about ten degrees of 30° S latitude on February 8. Despite this severe problem, observers are urged to be alert just in case a fresh outburst should manifest, particularly those able to attempt imaging of whatever occurs.

*$\gamma$-Normids (118 GNO)*

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| Active: February 25–March 28; Maximum: March 15 ($\lambda_\odot = 354°$); ZHR = 6; |
| Radiant: $\alpha = 239°$, $\delta = -50°$, Radiant drift: see Table 6; |
| $V_\infty = 56$ km/s; $r = 2.4$; |
| TFC: $\alpha = 225°$, $\delta = -26°$ and $\alpha = 215°$, $\delta = -45°$ ($\beta < 15°$ S). |

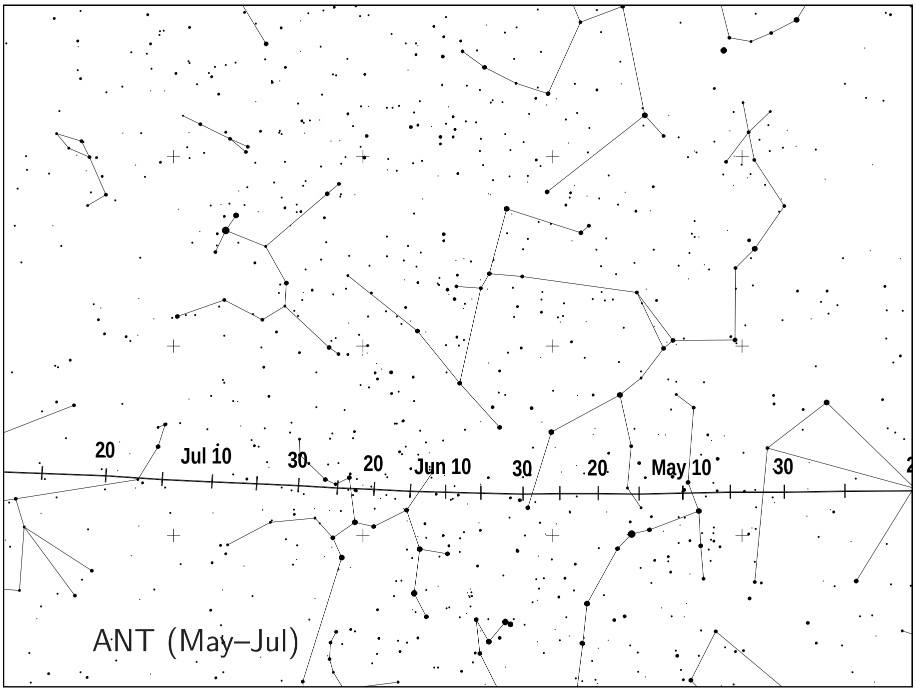
For most of their activity, $\gamma$-Normid ZHRs seem to be virtually undetectable above the background sporadic rate. The maximum itself has been reported as quite sharp, and an analysis of IMO data from 1988–2007 showed an average peak ZHR of $\sim 6$ at $\lambda_\odot = 354°$, with ZHRs $< 3$ on all other dates during the shower (HMO, pp. 131–132). Limited data means this is uncertain, and rates may vary somewhat at times, with occasional broader, or less obvious, maxima having been noted in the past. Results since 1999 have suggested the possibility of a short-lived peak alternatively between $\lambda_\odot \sim 347°$–$357°$, equivalent to 2015 March 8–18. Recent video and visual plotting information confirmed activity from that region, but a new analysis of video data obtained only from locations south of the equator has indicated that the activity occurs preferentially around March 25 ($\lambda_\odot = 4°$) instead, from a radiant at $\alpha = 246°$, $\delta = -51°$. Post-midnight watching yields better results, when the radiant is rising to a reasonable elevation from southern hemisphere sites (the radiant does not rise for many northern ones). The shower badly needs more regular attention, and March's new Moon period favours both the potential single peaks on March 15 and 25, plus the second half of the possibly extended maximum spell, with little to no moonlight interference. All observing techniques can be employed.

# 4 April to June

Meteor activity picks up towards the April-May boundary, with generally moonless conditions for both the Lyrid and $\pi$-Puppid maxima, the Lyrids perhaps providing a rare stronger return, but the **$\eta$-Aquariid** (031 ETA) peak, due around May 6 suffers from a waning gibbous Moon only two days past full. The enhanced $\eta$-Aquariid activity in 2013, when ZHRs peaked at $\sim 130$, seems unlikely to repeat this year, given the normal return in 2014, as well as results from model calculations. Theoretical considerations would otherwise indicate this shower should be close to one of its less-active periods in its possible 12-year cycle, so ZHRs could be as low as $\sim 40$. The minor **$\eta$-Lyrids** (145 ELY) will struggle against waning gibbous moonlight too, with a potential peak on May 9, or maybe May 11.

**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 $\omega$-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 (144 APS) – April 20, $22^h$; $\varepsilon$-Arietids (154 DEA) - May 9, $21^h$; May Arietids (294 DMA) – May 16, $22^h$; $o$-Cetids (293 DCE) – May 20, $21^h$; Arietids (171 ARI) – June 7, $24^h$; $\zeta$-Perseids (172 ZPE) – June 9, $24^h$; $\beta$-Taurids (173 BTA) – June 28, $23^h$. 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 – such as the Arietids and $\zeta$-Perseids, whose 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. There seems to be a modest recurring peak around April 24 as well, perhaps due to combined rates from the first two showers listed here, and possibly the $\delta$-Piscids, which we previously listed for many years as having a peak on April 24, although the IAU seems not to recognise this currently as a genuine shower. Similarly, there are problems in identifying the $o$-Cetids in the IAU stream lists, despite the fact this (possibly periodic) source was detected by radar more strongly that the $\eta$-Aquariids of early May when it was first observed in 1950–51. The current number and abbreviation given here for it is actually for the IAU source called the "Daytime $\omega$-Cetid Complex", because that seems a closer match to the $o$-Cetids as defined by earlier reports.

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 extremely favourable this year, with possible June Boötid hunting later in the month still possible with some Moon-free skies.




*Lyrids (006 LYR)*

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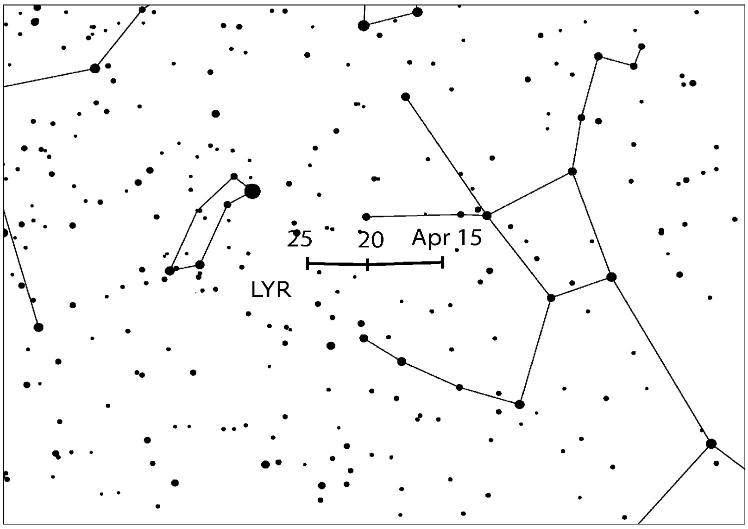
| Active: April 16–25; Maximum: April 22, $24^{\text{h}}$ UT ($\lambda_{\odot} = 32.^{\circ}32$, but may vary – see text); |
| ZHR = 18 (can be variable, up to 90); |
| Radiant: $\alpha = 271^{\circ}$, $\delta = +34^{\circ}$; Radiant drift: see Table 6; |
| $V_{\infty} = 49$ km/s; $r = 2.1$; |
| TFC: $\alpha = 262^{\circ}$, $\delta = +16^{\circ}$ and $\alpha = 282^{\circ}$, $\delta = +19^{\circ}$ ($\beta > 10^{\circ}$ S). |

The $\lambda_{\odot} = 32.^{\circ}32$ timing given above is the 'ideal' maximum found in *IMO* results from 1988–2000. However, the maximum time was variable from year to year between $\lambda_{\odot} = 32.^{\circ}0$–$32.^{\circ}45$ (equivalent to 2015 April 22, $16^{\text{h}}$ to April 23, $03^{\text{h}}$ UT). Activity was variable too. A peak at the ideal time produced the highest ZHRs, $\sim$ 23, while the further the peak happened from this, the lower the ZHRs were, down to $\sim$ 14. (The last very high maximum was in 1982, when a short-lived ZHR of 90 was recorded.) The mean peak ZHR was 18 over the thirteen years examined. While generally thought of as having a short, quite sharp, maximum, this investigation showed the shower's peak length was inconstant. Using the Full-Width-Half-Maximum time (the period ZHRs were above half the peak level), a variation between 14.8 to 61.7 hours was detected (mean 32.1 hours). The best rates are normally achieved for just a few hours even so. The analysis also confirmed that occasionally, as their highest rates occurred, the Lyrids produced a brief increase in fainter meteors. For 2015, meteor scientist Esko Lyytinen has suggested the possibility that Lyrid rates may be somewhat enhanced, although from theoretical modelling, the chances of this seem better – if still uncertain – for 2016 and 2017. The 2015 possibility is heavily dependent on what other dust trails pass closer to the Earth than the trail established from the one observed return of the shower's parent comet, C/1861 G1 Thatcher, something which cannot be modelled. Lyrid meteors are best viewed from the northern hemisphere, but are visible from many sites north and south of the equator. As the radiant rises during the night, watches can be carried out usefully after about $22^h30^m$ local time from mid-northern sites, but only well after midnight from the mid-southern hemisphere. April's waxing crescent Moon will set by the late evening hours, leaving most of the night with dark skies for observing. Should the ideal peak time recur, it should be best-seen from sites across European to Near Eastern longitudes, although of course, other maximum times may happen instead!




*π-Puppids (137 PPU)*

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| Active: April 15–28; Maximum: April 24, $05^h$ UT ($\lambda_\odot = 33.^\circ5$); |
| 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 $\sim 13$ 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 2015 had been issued when this Calendar was prepared. The π-Puppids are best-seen from the southern hemisphere, with useful observations mainly practical before midnight, as the radiant is very low to setting after $01^h$ local time. Consequently, April's waxing crescent Moon, at first quarter on the 25th, will be only a fairly minor nuisance for mid-southern sites, setting before $23^h$ local time on the 24th. 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.

*June Lyrids (166 JLY)*

Active: June 11–21; Maximum: June 16 ($\lambda_\odot = 85°$); ZHR variable;
Radiant: $\alpha = 278°$, $\delta = +35°$; $V_\infty = 31$ km/s; $r = 3.0$;
Radiant drift: June 10 $\alpha = 273°$, $\delta = +35°$,
June 15 $\alpha = 277°$, $\delta = +35°$,
June 20 $\alpha = 281°$, $\delta = +35°$.

This possible source does not feature on the current IMO Working List, as apart from some activity seen from northern hemisphere sites in a few years during the 1960s (first seen 1966) and 1970s, evidence for its existence has been virtually zero since. In 1996, several observers independently reported some June Lyrids, though no definite activity has been found subsequently. The probable maximum date in 2015 falls perfectly for new Moon, providing the best possible conditions for all observers wishing to check for it. The radiant may lie a few degrees south of the bright star Vega ($\alpha$ Lyrae), so would be well on-view throughout the short northern summer nights, but there are discrepancies in its position in the literature. All suspected visual June Lyrids should be carefully plotted, paying especial attention to the meteors' apparent velocities. Confirmation or denial of activity from this source by imaging techniques would be very useful.

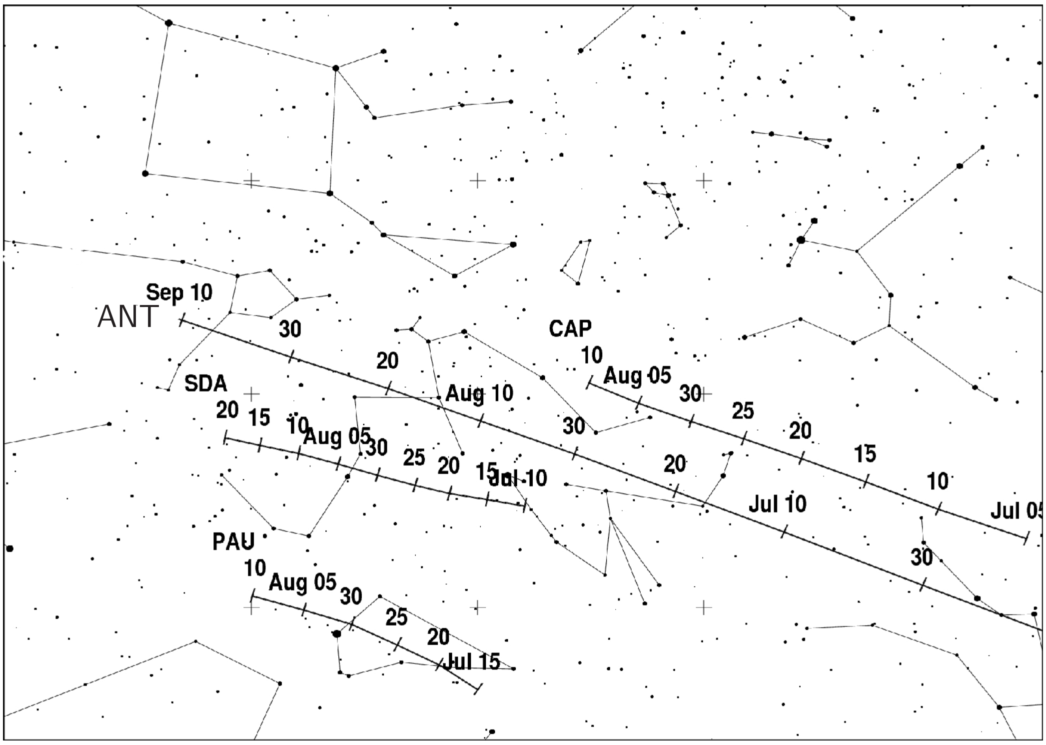
*June Boötids (170 JBO)*

Active: June 22–July 2; Maximum: June 27, $21^{\rm h}$ UT ($\lambda_\odot = 95.^\circ7$), 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 recorded previously. 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 is due on January 30 this year, but no predictions for fresh activity were in-force for 2015 when this Calendar was prepared, as 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. The radiant is best-seen at mid-northerly latitudes, from where it is usefully observable almost all night. However, first quarter Moon is on June 24, so the amount of moonless night-time decreases after then, leaving only a short observing window by June 27. The prolonged – in some places continuous – twilight overnight then will not assist either. VID suggested some June Boötids may be visible in most years around June $20-25$, but with activity largely negligible except near $\lambda_\odot = 92°$ (2015 June 24), 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 though, 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 **$\alpha$-Capricornids** (001 CAP) in July-August, but the lower apparent velocity of the CAP may help observers still separate the two. However, the **Southern $\delta$-Aquariids** (005 SDA) are strong enough, and the **Piscis Austrinids** (183 PAU) have a radiant probably distant enough from the ANT area, that both should be more easily separable from the ANT, particularly from the southern hemisphere. Unfortunately, July's second full Moon ruins coverage of all three of these shower maxima, which are otherwise anticipated as follows: PAU – July 28; SDA – July 30; CAP – July 30.



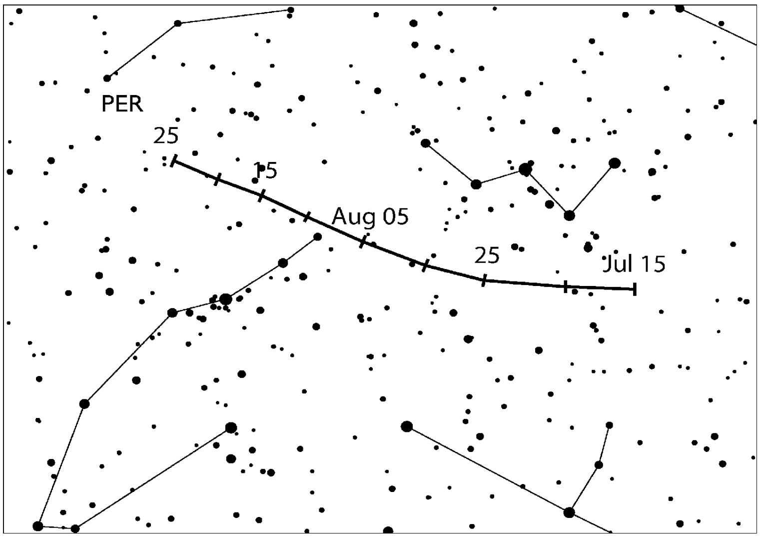

This does mean though that August's new Moon will then create excellent observing conditions for the major Perseid and minor $\kappa$-Cygnid peaks this year. **ANT** ZHRs will likely have dropped back below 2 again by late August, rising once more to $\sim$ 2–3 by early September, as the radiant tracks on through Aquarius and into western Pisces. Late August's full Moon spoils any chance of checking on the usually-minor **Aurigid** (206 AUR) peak, due around $14^{h}$ UT on September 1 (although at least no predictions for enhanced rates from this source have been made for 2015), but September's approaching new Moon is more helpful for coverage of the September $\varepsilon$-Perseids. 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 $\gamma$-Leonids (203 GLE; peak due near August 25, $23^{h}$ UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids (221 DSX). Their maximum is expected on September 27, around $23^{h}$ UT, but possibly it may occur a day earlier. However, in

1999 a strong return was detected at $\lambda_\odot \sim 186°$, equivalent to 2015 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 full Moon causes 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.

*Perseids (007 PER)*

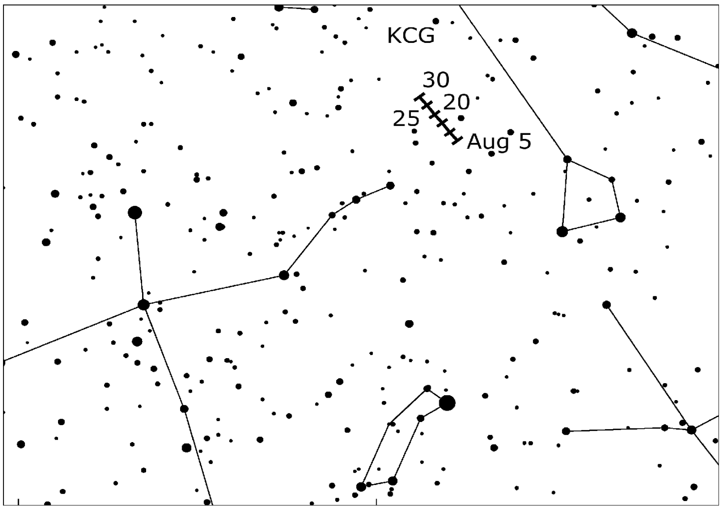
Active: July 17–August 24; Maximum: August 13, $06^h30^m$ to $09^h00^m$ UT (node at $\lambda_\odot = 140.^\circ0$–$140.^\circ1$), but see text; ZHR = 100;
Radiant: $\alpha = 48°$, $\delta = +58°$; Radiant drift: see Table 6;
$V_\infty = 59$ km/s; $r = 2.2$;
TFC: $\alpha = 19°$, $\delta = +38°$ and $\alpha = 348°$, $\delta = +74°$ before $2^h$ local time;
$\alpha = 43°$, $\delta = +38°$ and $\alpha = 73°$, $\delta = +66°$ after $2^h$ local time ($\beta > 20°$ N);
IFC: $\alpha = 300°$, $\delta = +40°$, $\alpha = 0°$, $\delta = +20°$ or $\alpha = 240°$, $\delta = +70°$ ($\beta > 20°$ N).




The Perseids produced strong activity from an unexpected primary maximum throughout the 1990s, associated with the perihelion passage of their parent comet, 109P/Swift-Tuttle, in 1992. The comet's orbital period is about 130 years. Further enhanced activity ahead of the usual maximum was last seen in 2004. Recent IMO observations (see HMO p. 145) found the timing of the mean or 'traditional' broad maximum varied between $\lambda_\odot \sim 139.^\circ8$ to $140.^\circ3$, equivalent to 2015 August 13, $01^h30^m$ to $14^h00^m$ UT. Jérémie Vaubaillon anticipates from theoretical modelling that the dust trail from the comet's 1862 return should pass closest to the Earth (the separation is about 0.00053 astronomical units, only 80 000 km or so) at $18^h39^m$ UT on August 12, although the activity levels are uncertain. Enhanced rates, if they happen at all, may persist for several hours around this potential peak. Plus of course, neither this prediction, nor the nodal crossing time given in the box above, are guarantees of what **will** occur! New Moon on August 14 means whatever happens, dark skies will prevail for checking on it. Sites at mid-northern latitudes are more favourable for Perseid observing, as from here, the shower's radiant can be usefully observed from $22^h$–$23^h$ local time onwards, gaining altitude throughout the night. The August 12 peak time especially favours Asian longitudes, while the August 13 near-nodal part of the 'traditional' maximum interval would be best-viewed from North American sites, assuming either takes place when expected. All forms of observing can be carried out on the shower, though regrettably, it cannot be properly viewed from most of the southern hemisphere.

*κ-Cygnids (012 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).

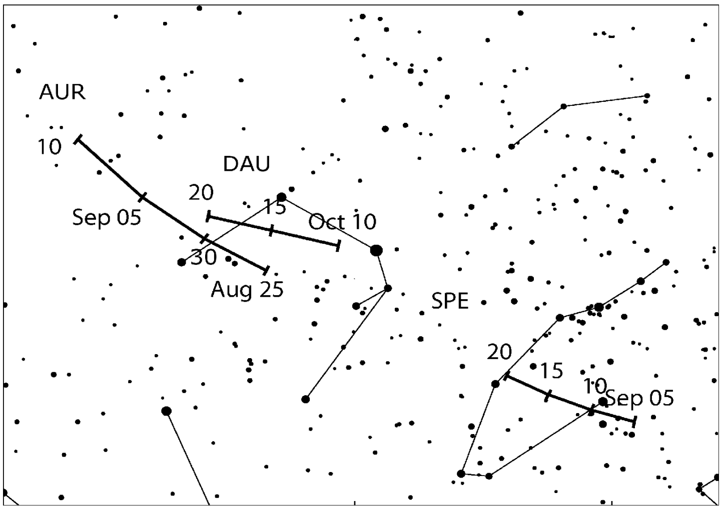



August's new Moon on the 14th creates excellent observing conditions for the expected κ-Cygnid peak. The shower is best-observed from northern hemisphere sites, from where the radiant is easily available all night. VID suggested a number of discrepancies to the currently-accepted parameters listed above, including that the peak might happen closer to August 14, from a more southerly radiant (around $\alpha = 186°$, $\delta = +51°$), and that activity might be present only from August 6–19 overall. 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.

*September ε-Perseids (208 SPE)*

Active: September 5–21; Maximum: September 9, $22^h$ UT ($\lambda_\odot = 166.°7$), but see text;
ZHR = 5;
Radiant: $\alpha = 48°$, $\delta = +40°$; Radiant drift: see Table 6;
$V_\infty = 64$ km/s; $r = 3.0$;
TFC: $\alpha = 30°$, $\delta = +55°$; $\alpha = 28°$, $\delta = +35°$ and $\alpha = 25°$, $\delta = +40°$ ($\beta > 10°$ S).

September's waning crescent Moon should be little hindrance for observing this primarily northern-hemisphere shower's maximum. The radiant area is well on-view all night from about $22^h$–$23^h$ local time for mid-northern locations. Though previously little-known, this radiant was apparently that responsible for producing an unexpected outburst of swift, bright meteors on 2008 September 9, between roughly $\lambda_\odot = 166.°894$–$166.°921$, and another bright-meteor event with a very sharp peak at $\lambda_\odot = 167.°188$ in 2013. The repeat times for those outburst intervals converted to 2015 would both be on September 10, respectively between $03^h05^m$–$03^h45^m$, and around $10^h20^m$ UT. Nothing unusual is predicted to occur however, and indeed, assuming a medium to long orbital period for the shower, Esko Lyytinen's modelling has suggested the next really impressive SPE return may not be before 2040.




With the AUR and the DAU, the SPE 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 $\beta$-Cassiopeiids is suspected of being active too during September, for example, and there may be others awaiting discovery or confirmation.

## 6 October to December

A busy quarter concludes the year, with no showers too badly affected by moonlight for possible coverage for once, and we have the chance of another Taurid "swarm" return.

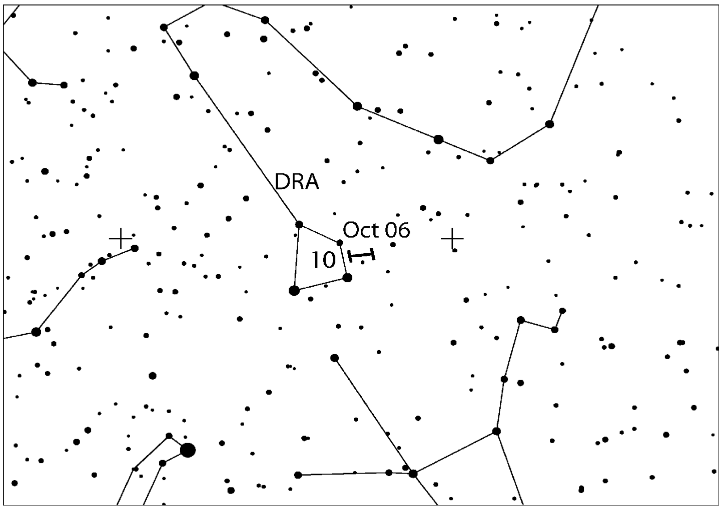
**October 5/6 meteors**: Short-lived video outbursts were recorded in 2005 and 2006 by European observers, with activity from a north-circumpolar radiant in the "tail" of Draco, around $\alpha \sim 165°$, $\delta \sim +78°$, on October 5/6 (281 OCT). The meteors showed an atmospheric velocity of $\sim$ 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, 2012 or during the extremely favourable return timing for European observers in 2013. 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. Confusingly, this apparently occasional minor shower has become known in some places as the "October Camelopardalids" or OCA, despite the radiant's location, and in fact the name was already used for a probably different shower, first detected by radar back in the 1970s. The active interval suggested by the video data lies between $\lambda_{\odot} \sim 192.^{\circ}5$–$192.^{\circ}8$, equivalent to 2015 October 6, $07^{h}10^{m}$ to $14^{h}30^{m}$ UT, and has little disturbance from the waning crescent Moon. If the active interval remains the same, parts of it should be best-observed from central Asia eastwards across the northern Pacific Ocean and North America. Esko Lyytinen has suggested on theoretical grounds that activity may be better-detectable in 2015 from this source, albeit uncertainly. Of course, as ever, such predictions are not guarantees!

**Taurid swarm return**: Model calculations by David Asher have indicated the possibility there may be a return of the Taurid "swarm" of larger particles this year, in October-November. (Note that this corrects the table in HMO, p. 160, which indicated this would happen in 2015 June instead.) Four of the last five northern autumn Taurid swarm returns have each produced unusual, if variable, activity, so there seems a good prospect something may again happen this time (the one year that failed to produce anything unusual was 2012). As for what may occur, the theoretical encounter circumstances seem favourable, quite similar to what the model suggested for 1954. There are a few records from Japan of the Taurids producing significant activity in that year. The strongest recent Taurid swarm return, in 2005, showed increased bright-meteor activity, including fireballs, from about October 29 to November 10. This same spell in 2015 comes with a waning Moon, only two days past full on October 29, but just a day before new by November 10. All observers should be alert to cover whatever happens, and fireball analysts should be prepared for the potential of increased casual bright-meteor reports from around this period. Again though, remember that nothing is ever guaranteed in meteor astronomy!

The **ANT** starts the 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.

*Draconids (009 DRA)*

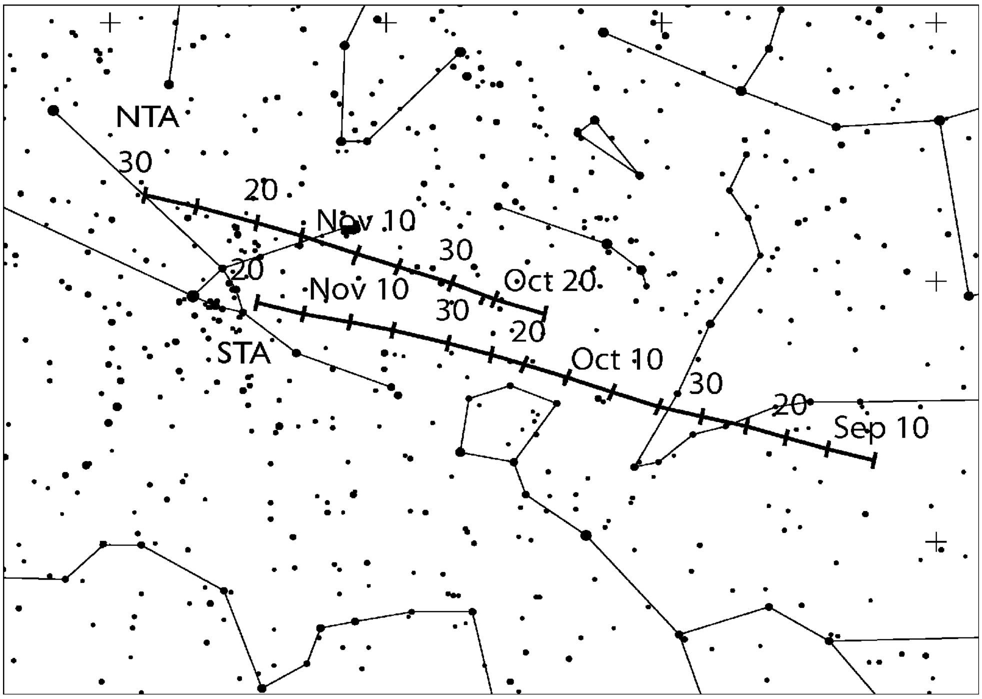
| |
|---|
| Active: October 6–10; Maximum: October 9, $05^{\mathrm{h}}40^{\mathrm{m}}$ UT ($\lambda_{\odot} = 195\overset{\circ}{.}4$), but see text; |
| ZHR = periodic, up to storm levels; |
| Radiant: $\alpha = 262°$, $\delta = +54°$; Radiant drift: negligible; |
| $V_{\infty} = 20$ km/s; $r = 2.6$; |
| TFC: $\alpha = 290°$, $\delta = +65°$ and $\alpha = 288°$, $\delta = +39°$ ($\beta > 30°$ N). |




The Draconids are primarily a periodic shower which produced spectacular, brief, meteor storms twice last century, in 1933 and 1946, and lower rates in several other years (ZHRs $\sim$ 20–500+). Most detected showers were in years close to when the stream's parent comet, 21P/Giacobini-Zinner, returned to perihelion, as it last did in 2012 February, producing EZHRs of $\sim$ 300 in 2011 October despite bright moonlight then, and a wholly unexpected outburst of chiefly very faint meteors, detected primarily by the Canadian CMOR meteor radar system, on 2012 October 8. The comet's orbital period is currently about 6.6 years. Outlying maximum times from the recent past have spanned from $\lambda_{\odot} = 195\overset{\circ}{.}036$ (in 2011), equivalent to 2015 October 8, $20^{\mathrm{h}}50^{\mathrm{m}}$ UT, through the nodal passage time above, to the end of a minor outburst in 1999 at $\lambda_{\odot}195\overset{\circ}{.}76$ (not a perihelion-return year, but ZHRs reached $\sim$ 10–20), equating to 2015 October 9, $14^{\mathrm{h}}30^{\mathrm{m}}$ UT. No predictions for unusual activity are in-force this October. However, as activity in recent years has demonstrated, observers should be alert just in case, especially as October's new Moon on the 13th makes this a very favourable year. The Draconid radiant is north-circumpolar, at its highest during the first half of the night, and Draconid meteors are exceptionally slow-moving.

*Southern Taurids (002 STA)*

| |
|---|
| Active: September 10–November 20; Maximum: October 10 ($\lambda_\odot = 197°$); ZHR = 5; |
| Radiant: $\alpha = 32°$, $\delta = +09°$; Radiant drift: see Table 6; |
| $V_\infty = 27$ km/s; $r = 2.3$; |
| TFC: Choose fields on the ecliptic and $\sim 10°$ E or W of the radiant ($\beta > 40°$ S). |




This stream, with its Northern counterpart, forms part of the complex associated with Comet 2P/Encke. Defining its radiant is best achieved by video, telescopic or careful visual plotting, since it is large and diffuse. For shower association, assume the radiant to be an oval area, $\sim 20° \times 10°$, $\alpha \times \delta$, centred on the radiant position for any given date. The Taurid activity overall dominates the Antihelion Source area's during the northern autumn, so much so that the ANT is considered inactive while either branch of the Taurids is present. The brightness and relative slowness of many Taurid meteors makes them ideal targets for still-imaging, while these factors coupled with low, steady, Taurid rates makes them excellent subjects for newcomers to practice their visual plotting techniques on. Although long thought to combine with the Northern Taurids to produce an apparently plateau-like maximum in the first decade of November, VID and recent visual plotting work have indicated the Southern branch probably reaches its peak about a month before the Northern one, this year with a nearly-new Moon. Its near-ecliptic radiant means all meteoricists can observe the STA, albeit northern hemisphere observers are somewhat better-placed, as here suitable radiant zenith distances persist for much of the night. Even in the southern hemisphere however, 3–5 hours' watching around local midnight is possible with Taurus well clear of the horizon. See under the quarterly notes above for details on the possible Taurid "swarm" return in late October to November this year.

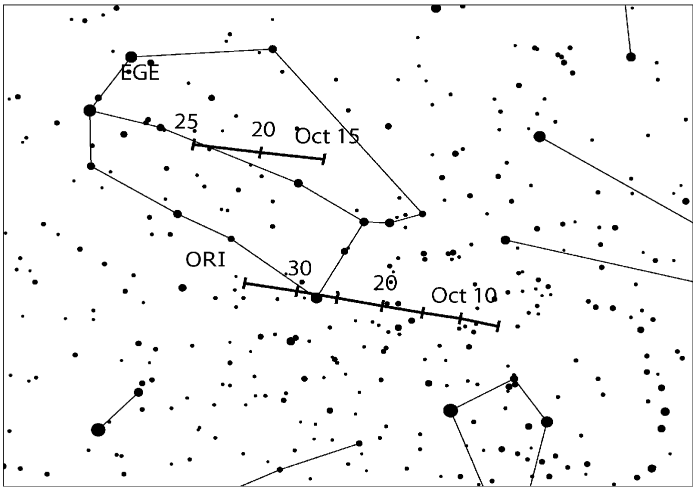
*δ-Aurigids (224 DAU)*

| |
|---|
| Active: October 10–18; Maximum: October 11 ($\lambda_\odot = 198°$); ZHR = 2; |
| Radiant: $\alpha = 84°$, $\delta = +44°$; Radiant drift: see Table 6; |
| $V_\infty = 64$ km/s; $r = 3.0$; |
| TFC: $\alpha = 80°$, $\delta = +55°$; $\alpha = 80°$, $\delta = +30°$ and $\alpha = 60°$, $\delta = +40°$ ($\beta > 10°$ S). |

The weakest of the three known near-Auriga-Perseus showers of late August to October, visual observers seem to have struggled to properly identify this minor source previously, and its current parameters are based on a detailed review of IMO video data since the late 1990s. If timed correctly, the peak will have no trouble from the Moon, only two days before new. The radiant area is visible chiefly from the northern hemisphere, from where it can be properly observed after local midnight.

*ε-Geminids (023 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: $\alpha = 90°$, $\delta = +20°$ 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 waxing crescent Moon on October 18/19 will set long before the radiant becomes usefully observable from 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 rather less favourable, though still allowing some Moon-free skies before dawn, particularly for more northerly locations.

*Orionids (008 ORI)*

| |
|---|
| Active: October 2–November 7; Maximum: October 21 ($\lambda_\odot = 208°$); ZHR = 15; |
| Radiant: $\alpha = 95°$, $\delta = +16°$; Radiant drift: see Table 6; |
| $V_\infty = 66$ km/s; $r = 2.5$; |
| TFC: $\alpha = 100°$, $\delta = +39°$ and $\alpha = 75°$, $\delta = +24°$ ($\beta > 40°$ N); |
| or $\alpha = 80°$, $\delta = +1°$ and $\alpha = 117°$, $\delta = +1°$ ($\beta < 40°$ N). |

October's waxing gibbous Moon sets between local midnight and one a.m. across much of the inhabited Earth for the peak night of October 21/22 this year, providing favourable circumstances because the shower's radiant, near the celestial equator, is at a useful elevation from local midnight or so in either hemisphere, somewhat before in the north. 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 the lower activity phase of the cycle should fall between 2014–2016, so Orionid ZHRs may be close to their weakest this time. The recent strong returns seemed to have had a separate resonant cause, with nothing fresh anticipated for 2015. 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 very favourable for covering October 17/18 this year 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 (022 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. Although the probable maximum date falls three days before full Moon, a few hours of darker skies will remain between moonset and dawn for coverage on the expected October 24/25 maximum night. Telescopic, imaging or very careful visual plotting observations are advised.

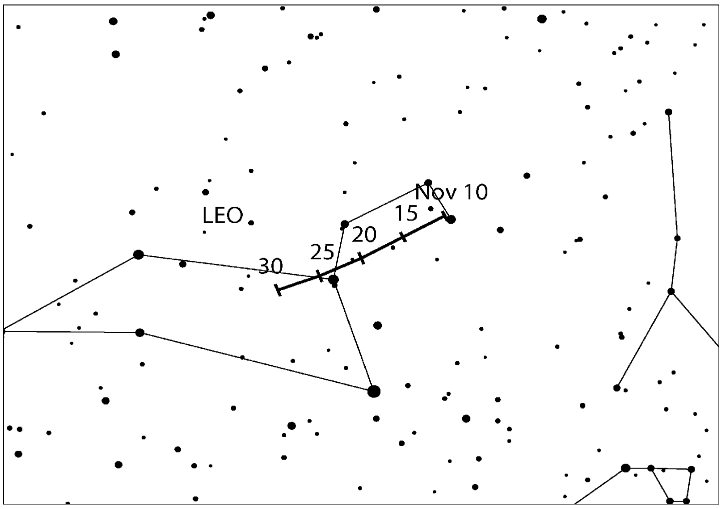
*Northern Taurids (017 NTA)*

Active: October 20–December 10; Maximum: November 12 ($\lambda_\odot = 230°$); ZHR = 5;
Radiant: $\alpha = 58°$, $\delta = +22°$; Radiant drift: see Table 6;
$V_\infty = 29$ km/s; $r = 2.3$;
TFC: Choose fields on the ecliptic and $\sim 10°$ E or W of the radiant ($\beta > 40°$ S).

Some details on this branch of the Taurid streams were given with the Southern Taurids above, along with mention of the possible Taurid "swarm" return this year. Other aspects are the same too, such as the large, oval radiant region to be used for shower association, the shower's excellent visibility overnight, and its dominance over the ANT during September to December. As previous results had suggested seemingly plateau-like maximum rates persisted for roughly ten days in early to mid November, the NTA peak may not be so sharp as its single maximum date might imply. Whatever the case, new Moon on November 11 should allow plenty of coverage.

*Leonids (013 LEO)*

| |
|---|
| Active: November 6–30; Maximum: November 18, $04^h$ 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 $\alpha = 129°$, $\delta = +6°$ ($\beta > 35°$ N); |
| or $\alpha = 156°$, $\delta = -3°$ and $\alpha = 129°$, $\delta = +6°$ ($\beta < 35°$ 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 17 years ago now, but the shower's activity has continued to be fascinatingly variable at times recently. This year seems unlikely to produce strongly enhanced rates, but there may be more than one peak, as Mikhail Maslov has suggested the nodal maximum could happen around $21^h$ UT on November 17, rather than at the time given above, producing ZHRs of $\sim 20$. November's waxing crescent Moon, at first quarter on the 19th, provides perfect observing conditions for either date. The Leonid radiant 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 November 17 one would be best-detectable from Near Eastern and Asian longitudes, while the November 18 prediction would be similarly available from places between the extreme east of North America eastwards across the North Atlantic Ocean to European and North African longitudes.

*$\alpha$-Monocerotids (246 AMO)*

| |
|---|
| Active: November 15–25; Maximum: November 22, $04^h25^m$ 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 $\alpha = 98°$, $\delta = +6°$ ($\beta < 20°$ N). |

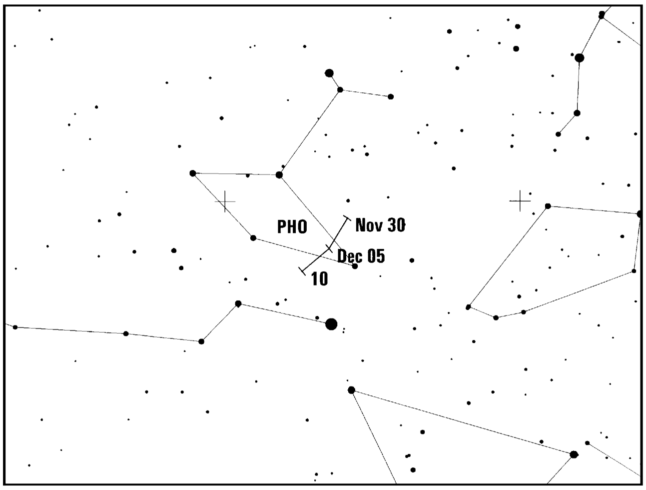
This year is the twentieth anniversary of the most recent $\alpha$-Monocerotid outburst, in 1995 (the top EZHR, $\sim 420$, lasted five minutes, the entire outburst 30 minutes). Recent modelling by

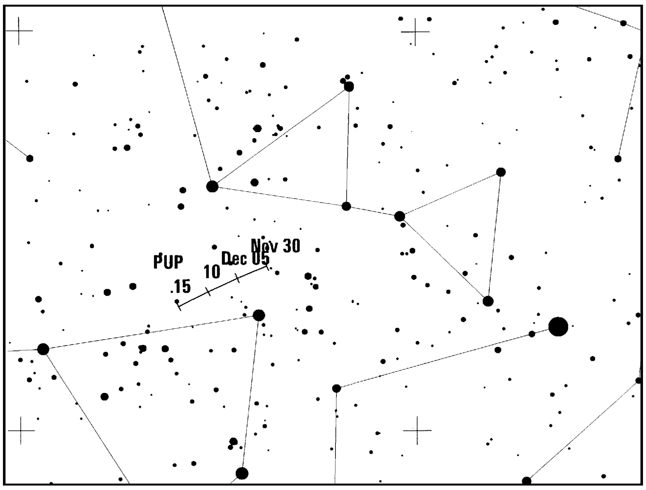
Esko Lyytinen has indicated the main AMO trail will not cross the Earth's orbit again until 2017 and 2020. However, the Earth will not be near those points in November, so nothing is likely to happen then. A weak return may occur in November 2019, ahead of the 2020 encounter, depending on how broad the 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 approaching full Moon on the 25th will set between $02^{\rm h}$ and $02^{\rm h}30^{\rm m}$ local time on the expected peak night, leaving a period through until dawn with dark skies to allow checking on whatever happens, as the shower's radiant is well on view from either hemisphere after about $23^{\rm h}$. If correct, the peak timing would fall best after moonset for sites at European longitudes.

*Phoenicids (254 PHO)*

| |
|---|
| Active: November 28–December 9; Maximum: December 6, $22^{\rm h}20^{\rm m}$ UT ($\lambda_\odot = 254.^{\circ}25$); |
| ZHR = variable, usually none, but may reach 100; |
| Radiant: $\alpha = 18°$, $\delta = -53°$; Radiant drift: see Table 6; |
| $V_\infty = 18$ km/s; $r = 2.8$; |
| TFC: $\alpha = 40°$, $\delta = -39°$ and $\alpha = 65°$, $\delta = -62°$ ($\beta < 10°$ N). |

Only one impressive Phoenicid return has been reported so far, that of its discovery in 1956, when the EZHR was probably $\sim 100$, possibly with several peaks spread over a few hours. Three other potential, if uncertain, bursts of lower activity have been claimed. Reliable IMO data has shown recent activity to have been virtually nonexistent, while a predicted possible return in 2011 seemed not to have produced anything unusual. This may be a periodic shower however, and more observations of it are needed by all methods. From the southern hemisphere (only), the Phoenicid radiant culminates at dusk, remaining well on view for most of the night. The waning crescent Moon should present no difficulties for observers on December 6. Phoenicids are extremely slow meteors.



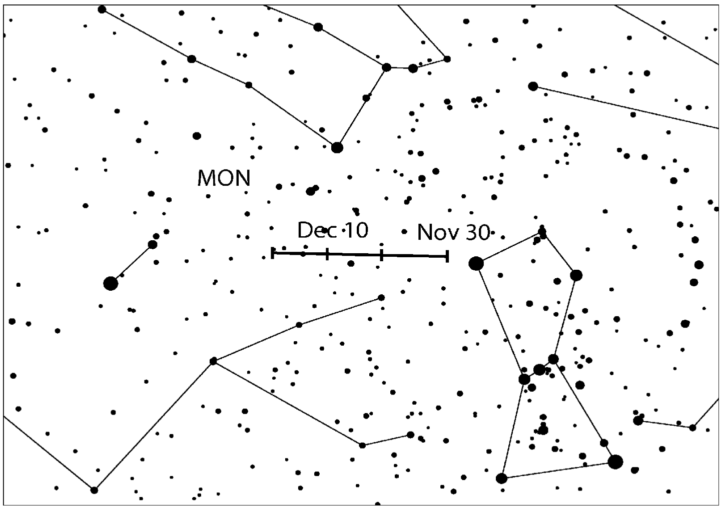

*Puppid-Velids (301 PUP)*

| |
|---|
| Active: December 1–15; Maximum: December $\sim 7$ ($\lambda_\odot \sim 255°$); ZHR $\sim 10$; |
| Radiant: $\alpha = 123°$, $\delta = -45°$; Radiant drift: see Table 6; |
| $V_\infty = 40$ km/s; $r = 2.9$; |
| TFC: $\alpha = 90°$ to $150°$, $\delta = -20°$ to $-60°$; choose pairs of fields separated by about 30° in $\alpha$, moving eastwards as the shower progresses ($\beta < 10°$ N). |

This is a complex system of poorly-studied showers, visible chiefly to those south of the equator. Up to ten sub-streams have been proposed (301 PUP representing an "average" position), with radiants so tightly clustered, visual observing cannot readily separate them. Imaging or telescopic work would thus be sensible, or very careful visual plotting. The activity is poorly-established, though the higher rates seem to occur in early to mid December, with a waning crescent to new Moon this year. Some PUP activity may be visible from late October to late January, however. Most PUP meteors are quite faint, but occasional bright fireballs, notably around the suggested maximum, have been reported previously. The radiant area is on-view all night, highest towards dawn.

*Monocerotids (019 MON)*

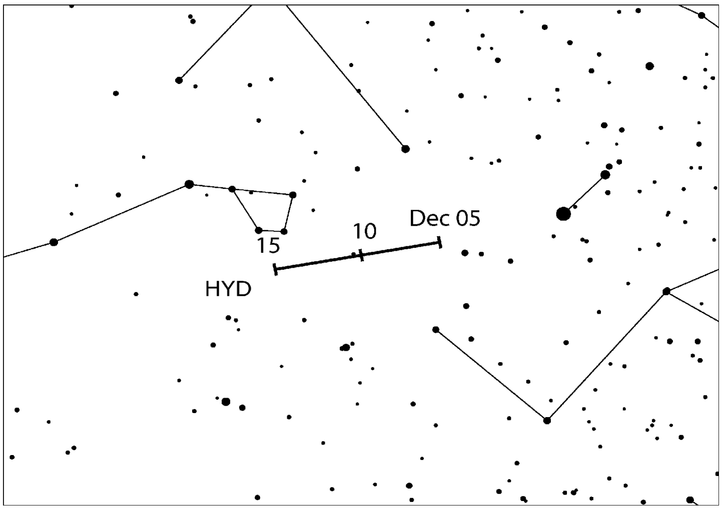
| |
|---|
| Active: November 27–December 17; Maximum: December 9 ($\lambda_\odot = 257°$); ZHR = 2; |
| Radiant: $\alpha = 100°$, $\delta = +08°$; Radiant drift: see Table 6; |
| $V_\infty = 42$ km/s; $r = 3.0$; |
| TFC: $\alpha = 88°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +48°$ ($\beta > 40°$ N); |
| or $\alpha = 120°$, $\delta = -3°$ and $\alpha = 84°$, $\delta = +10°$ ($\beta < 40°$ N). |




This very minor shower's details, including its radiant position, are rather uncertain. Telescopic results have suggested a later maximum, around $\lambda_\odot \sim 264°$ (December 16), from a radiant at $\alpha = 117°$, $\delta = +20°$, for instance. December's new Moon period creates perfect conditions for either potential maximum timing, as the radiant area is available virtually all night for much of the globe, culminating at about $01^{\mathrm{h}}30^{\mathrm{m}}$ local time.

*σ-Hydrids (016 HYD)*

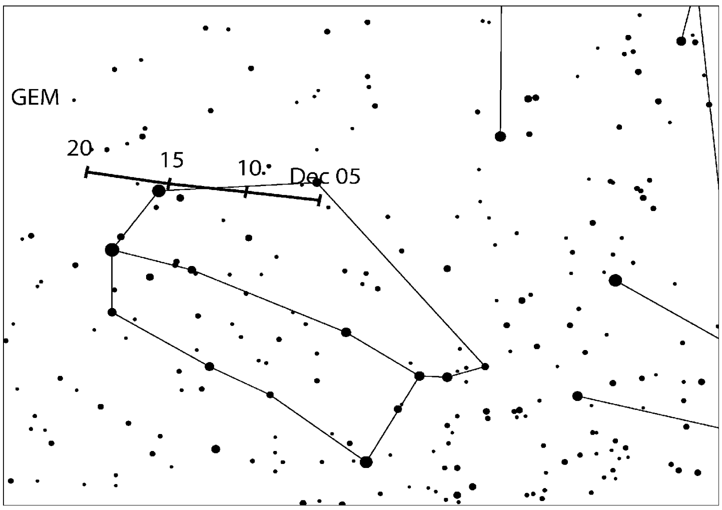
| |
|---|
| Active: December 3–15; Maximum: December 12 ($\lambda_\odot = 260°$); ZHR = 3; |
| Radiant: $\alpha = 127°$, $\delta = +02°$; Radiant drift: see Table 6; |
| $V_\infty = 58$ km/s; $r = 3.0$; |
| TFC: $\alpha = 95°$, $\delta = 0°$ and $\alpha = 160°$, $\delta = 0°$ (all sites, after midnight only). |




Although first detected in the 1960s by photography, $\sigma$-Hydrids are typically swift and faint, and rates are generally close to the visual-detection threshold. The radiant rises in the late evening hours, to be best viewed after local midnight from either hemisphere. This is a splendid year for them, thanks to new Moon on December 11. Recent IMO visual data (HMO p. 170) have indicated the maximum might happen nearer $\lambda_\odot \sim 262°$ (December 14), while VID implied a peak closer to $\lambda_\odot \sim 254°$ (December 6), and that HYD activity might persist till December 24.

*Geminids (004 GEM)*

Active: December 4–17; Maximum: December 14, $18^h$ UT ($\lambda_\odot = 262.^\circ 2$); 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,
$\alpha = 87°$, $\delta = +20°$ and $\alpha = 129°$, $\delta = +20°$ after $23^h$ local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = -3°$ and $\alpha = 84°$, $\delta = +10°$ ($\beta < 40°$ N).
IFC: $\alpha = 150°$, $\delta = +20°$ and $\alpha = 60°$, $\delta = +40°$ ($\beta > 20°$ N);
$\alpha = 135°$, $\delta = -5°$ and $\alpha = 80°$, $\delta = 0°$ ($\beta < 20°$ N).

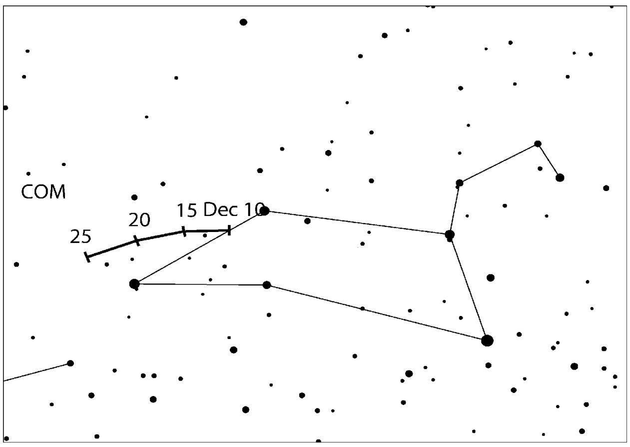


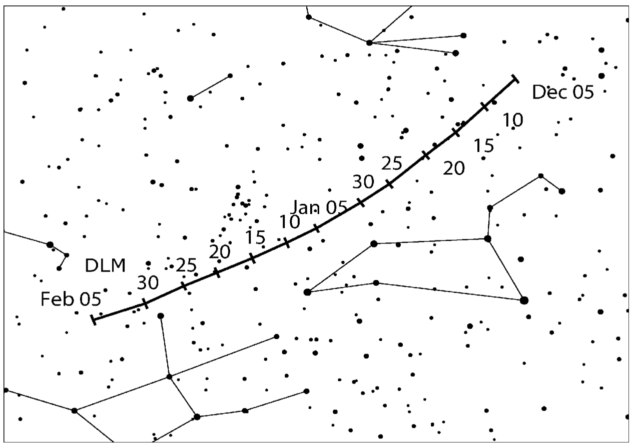

One of the finest, and probably the most reliable, of the major annual showers presently observable. Well north of the equator, the radiant rises about sunset, reaching a usable elevation from the local evening hours onwards. In the southern hemisphere, the radiant appears only around local midnight or so. It culminates near $02^{h}$. Even from more southerly sites, this is an excellent 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 $\lambda_{\odot} = 261^{\circ}\!.5$ to $262^{\circ}\!.4$, 2015 December 14, $01^{h}30^{m}$–$23^{h}$ UT. Near-peak Geminid rates usually persist for almost a day though, so much of the world has the chance to enjoy something of the shower's best, regardless of when the maximum actually happens. 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 2015 peak arrives just three days after new Moon, so observing conditions are ideal.

*Comae Berenicids (020 COM)*

| |
|---|
| Active: December 12–23; Maximum: December 16 ($\lambda_{\odot} = 264^{\circ}$); ZHR = 3; |
| Radiant: $\alpha = 175^{\circ}$, $\delta = +18^{\circ}$; Radiant drift: see Table 6; |
| $V_{\infty} = 65$ km/s; $r = 3.0$; |
| TFC: $\alpha = 180^{\circ}$, $\delta = +50^{\circ}$ and $\alpha = 165^{\circ}$, $\delta = +20^{\circ}$ before $3^{h}$ local time, |
| $\alpha = 195^{\circ}$, $\delta = +10^{\circ}$ and $\alpha = 200^{\circ}$, $\delta = +45^{\circ}$ after $3^{h}$ local time ($\beta > 20^{\circ}$ 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 waxing crescent Moon will have set long before observing can commence on the peak night.




*December Leonis Minorids (032 DLM)*

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

Like the COM, the DLM have been recently redefined. This shower too is quite weak, but is probably long-lasting, although 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 $\sim 23^{\rm h}$ local time onwards. December's waxing gibbous Moon will set before $01^{\rm h}30^{\rm m}$ local time for the peak, leaving plenty of dark skies from then till dawn for checking on it.

*Ursids (015 URS)*

Active: December 17–26; Maximum: December 23, $02^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 270\overset{\circ}{.}7$);
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);
$\alpha = 63°$, $\delta = +84°$ and $\alpha = 156°$, $\delta = +64°$ ($\beta$ 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, last at perihelion in January 2008. Other events could have been missed easily. No unusual activity had been forecast for the 2015 shower when this Calendar was being prepared. 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. The waxing Moon, full on December 25, will set to leave only a brief observing window before morning twilight begins for near-maximum observations this time.

# 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° × 10°, while that for the Antihelion Source is still larger, at 30° × 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 ($V_\infty$). 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

- $\alpha$, $\delta$: Coordinates for a shower's radiant position, usually at maximum. $\alpha$ is right ascension, $\delta$ 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. $r = 2.0$–$2.5$ implies a larger fraction of brighter meteors than average, while $r$ above 3.0 is richer in fainter meteors 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.

- $V_{\infty}$: 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. $\beta$ 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 2015.

| New Moon | First Quarter | Full Moon | Last Quarter |
|---|---|---|---|
| | | January 5 | January 13 |
| January 20 | January 27 | February 3 | February 12 |
| February 18 | February 25 | March 5 | March 13 |
| March 20 | March 27 | April 4 | April 12 |
| April 18 | April 25 | May 4 | May 11 |
| May 18 | May 25 | June 2 | June 9 |
| June 16 | June 24 | July 2 | July 8 |
| July 16 | July 24 | July 31 | August 7 |
| August 14 | August 22 | August 29 | September 5 |
| September 13 | September 21 | September 28 | October 4 |
| October 13 | October 20 | October 27 | November 3 |
| November 11 | November 19 | November 25 | December 3 |
| December 11 | December 18 | December 25 | |

**Table 5.** Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in June 2014, with maximum dates accurate only for 2015. 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 $\alpha$ | $\delta$ | $V_\infty$ km/s | $r$ | ZHR |
|---|---|---|---|---|---|---|---|---|
| Antihelion Source (ANT) | Dec 10–Sep 10<br>– | March–April,<br>late May, late June | | see Table 6 | | 30 | 3.0 | 4 |
| Quadrantids (010 QUA) | Dec 28–Jan 12 | Jan 04 | 283°.16 | 230° | +49° | 41 | 2.1 | 120 |
| $\alpha$-Centaurids (102 ACE) | Jan 28–Feb 21 | Feb 08 | 319°.2 | 210° | −59° | 56 | 2.0 | 6 |
| $\gamma$-Normids (118 GNO) | Feb 25–Mar 28 | Mar 15 | 354° | 239° | −50° | 56 | 2.4 | 6 |
| Lyrids (006 LYR) | Apr 16–Apr 25 | Apr 22 | 32°.32 | 271° | +34° | 49 | 2.1 | 18 |
| $\pi$-Puppids (137 PPU) | Apr 15–Apr 28 | Apr 24 | 33°.5 | 110° | −45° | 18 | 2.0 | Var |
| $\eta$-Aquariids (031 ETA) | Apr 19–May 28 | May 06 | 45°.5 | 338° | −01° | 66 | 2.4 | 40* |
| $\eta$-Lyrids (145 ELY) | May 03–May 14 | May 09 | 48°.0 | 287° | +44° | 43 | 3.0 | 3 |
| June Bootids (170 JBO) | Jun 22–Jul 02 | Jun 27 | 95°.7 | 224° | +48° | 18 | 2.2 | Var |
| Piscis Austr. (183 PAU) | Jul 15–Aug 10 | Jul 28 | 125° | 341° | −30° | 35 | 3.2 | 5 |
| S. $\delta$-Aquariids (005 SDA) | Jul 12–Aug 23 | Jul 30 | 127° | 340° | −16° | 41 | 3.2 | 16 |
| $\alpha$-Capricornids (001 CAP) | Jul 03–Aug 15 | Jul 30 | 127° | 307° | −10° | 23 | 2.5 | 5 |
| Perseids (007 PER) | Jul 17–Aug 24 | Aug 13 | 140°.0 | 48° | +58° | 59 | 2.2 | 100 |
| $\kappa$-Cygnids (012 KCG) | Aug 03–Aug 25 | Aug 18 | 145° | 286° | +59° | 25 | 3.0 | 3 |
| Aurigids (206 AUR) | Aug 28–Sep 05 | Sep 01 | 158°.6 | 91° | +39° | 66 | 2.5 | 6 |
| Sept. $\varepsilon$-Perseids (208 SPE) | Sep 05–Sep 21 | Sep 09 | 166°.7 | 48° | +40° | 64 | 3.0 | 5 |
| Draconids (009 DRA) | Oct 06–Oct 10 | Oct 09 | 195°.4 | 262° | +54° | 20 | 2.6 | Var |
| S. Taurids (002 STA)* | Sep 10–Nov 20 | Oct 10 | 197° | 32° | +09° | 27 | 2.3 | 5 |
| $\delta$-Aurigids (224 DAU) | Oct 10–Oct 18 | Oct 11 | 198° | 84° | +44° | 64 | 3.0 | 2 |
| $\varepsilon$-Geminids (023 EGE) | Oct 14–Oct 27 | Oct 18 | 205° | 102° | +27° | 70 | 3.0 | 3 |
| Orionids (008 ORI) | Oct 02–Nov 07 | Oct 21 | 208° | 95° | +16° | 66 | 2.5 | 15* |
| Leonis Minorids (022 LMI) | Oct 19–Oct 27 | Oct 24 | 211° | 162° | +37° | 62 | 3.0 | 2 |
| N. Taurids (017 NTA)* | Oct 20–Dec 10 | Nov 12 | 230° | 58° | +22° | 29 | 2.3 | 5 |
| Leonids (013 LEO)* | Nov 06–Nov 30 | Nov 18 | 235°.27 | 152° | +22° | 71 | 2.5 | 15* |
| $\alpha$-Monocerotids (246 AMO) | Nov 15–Nov 25 | Nov 22 | 239°.32 | 117° | +01° | 65 | 2.4 | Var |
| Phoenicids (254 PHO) | Nov 28–Dec 09 | Dec 06 | 254°.25 | 18° | −53° | 18 | 2.8 | Var |
| Puppid-Velids (301 PUP) | Dec 01–Dec 15 | (Dec 07) | (255°) | 123° | −45° | 40 | 2.9 | 10 |
| Monocerotids (019 MON) | Nov 27–Dec 17 | Dec 09 | 257° | 100° | +08° | 42 | 3.0 | 2 |
| $\sigma$-Hydrids (016 HYD) | Dec 03–Dec 15 | Dec 12 | 260° | 127° | +02° | 58 | 3.0 | 3 |
| Geminids (004 GEM) | Dec 04–Dec 17 | Dec 14 | 262°.2 | 112° | +33° | 35 | 2.6 | 120 |
| Comae Ber. (020 COM) | Dec 12–Dec 23 | Dec 16 | 264° | 175° | +18° | 65 | 3.0 | 3 |
| Dec. L. Minorids (032 DLM) | Dec 05–Feb 04 | Dec 20 | 268° | 161° | +30° | 64 | 3.0 | 5 |
| Ursids (015 URS) | Dec 17–Dec 26 | Dec 23 | 270°.7 | 217° | +76° | 33 | 3.0 | 10 |

**Table 6** (next page). Radiant positions during the year in $\alpha$ and $\delta$.

| Date | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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° | 250° | −49° | | | | | | | | | | |
| Mar 30 | 202° | −9° | 255° | −49° | | | | | | | | | | |
| 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 Showers. According to the naming rules, the shower names should all have 'Daytime' added (it is omitted in this Table). 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. Rates are expected to be low (L), medium (M) or high (H). An asterisk in the 'Rate' column shows the suggested rate may not recur in all years.

| Shower | Activity | Max Date | $\lambda_\odot$ 2000 | Radiant $\alpha$ | Radiant $\delta$ | Best observed 50° N | Best observed 35° S | Rate |
|---|---|---|---|---|---|---|---|---|
| Sgr/Cap `(115 DSC)` | Jan 13–Feb 04 | Feb 01* | 312.°5 | 299° | −15° | $11^h$–$14^h$ | $09^h$–$14^h$ | M* |
| $\chi$-Cap `(114 DXC)` | Jan 29–Feb 28 | Feb 13* | 324.°7 | 315° | −24° | $10^h$–$13^h$ | $08^h$–$15^h$ | L* |
| April Piscids `(144 APS)` | Apr 20–Apr 26 | Apr 22 | 32.°5 | 9° | +11° | $07^h$–$14^h$ | $08^h$–$13^h$ | L |
| $\varepsilon$-Arietids `(154 DEA)` | Apr 24–May 27 | May 09 | 48.°7 | 44° | +21° | $08^h$–$15^h$ | $10^h$–$14^h$ | L |
| May Arietids `(294 DMA)` | May 04–Jun 06 | May 16 | 55.°5 | 37° | +18° | $08^h$–$15^h$ | $09^h$–$13^h$ | L |
| $o$-Cetids `(293 DCE)` | May 05–Jun 02 | May 20 | 59.°3 | 28° | −04° | $07^h$–$13^h$ | $07^h$–$13^h$ | M* |
| Arietids `(171 ARI)` | May 14–Jun 24 | Jun 07 | 76.°5 | 42° | +25° | $06^h$–$14^h$ | $08^h$–$12^h$ | H |
| $\zeta$-Perseids `(172 ZPE)` | May 20–Jul 05 | Jun 09* | 78.°6 | 62° | +23° | $07^h$–$15^h$ | $09^h$–$13^h$ | H |
| $\beta$-Taurids `(173 BTA)` | Jun 05–Jul 17 | Jun 28 | 96.°7 | 86° | +19° | $08^h$–$15^h$ | $09^h$–$13^h$ | M |
| $\gamma$-Leonids `(203 GLE)` | Aug 14–Sep 12 | Aug 25 | 152.°2 | 155° | +20° | $08^h$–$16^h$ | $10^h$–$14^h$ | L* |
| Sextantids `(221 DSX)` | Sep 09–Oct 09 | Sep 27* | 184.°3 | 152° | 0° | $06^h$–$12^h$ | $06^h$–$13^h$ | M* |

# 9 Useful addresses

For more information on observing techniques, to see the latest results from well-observed major meteor showers and unusual shower outbursts, or when you wish to submit your results, please use the IMO's website, `www.imo.net` as your first stop. Questions can be mailed to the appropriate address (note the word "meteor" **must** feature in your message's "subject" line to pass the anti-spam filters):

For especially bright meteors: `fireball@imo.net`
For meteor still imaging: `photo@imo.net`
For forward-scatter radio observing: `radio@imo.net`
For meteor moving-imaging: `video@imo.net`
For visual observing: `visual@imo.net`

The IMO has Commssions for various fields, about which you may enquire with the respective director:

**Photographic Commission:** William Ward, School of Engineering, Rankine Building, Oakfield Avenue, Glasgow G12 8LT, Scotland, U.K.; e-mail: `William.Ward@glasgow.ac.uk`

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

**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`

For **IMO membership** applications, please contact the Secretary-General `lunro.imo.usa@cox.net`. Those unable to access the Internet may write for information to Robert Lunsford, IMO Secretary-General, 1828 Cobblecreek Street, Chula Vista, CA 91913-3917, USA.

When using ordinary mail, please try to enclose return postage, either in the form of stamps (same country *only*) or as an International Reply Coupon (I.R.C. – available from main postal outlets). Thank you!