International Meteor Organization

2017 Meteor Shower Calendar

compiled by Jürgen Rendtel [1]

1 Introduction

Welcome to the twenty-seventh International Meteor Organization (IMO) Meteor Shower Calendar, for 2017. The main intention is to draw the attention of observers to regularly returning meteor showers as well as to provide information about events which may be possible according to model calculations. This includes both the possibility of extra meteor activity but also the observational evidence of no rate or density enhancement. Both may help to improve our knowledge about the numerous effects and interactions between meteoroid parent objects and the streams. Further, the Calendar hopefully continues to be a useful tool to plan your meteor observing activities.

The moonlight circumstances for optical observations of the three strongest annual shower peaks bring a crescent Moon for the Quadrantids (almost first quarter), a gibbous waning Moon for the Perseids and essentially no moonlight interference for the Geminids. Conditions for the maxima of the Lyrids, the Orionids, and the Leonids are also favourable. The essential morning hours for the η-Aquariids are left with no moonlight, while the Southern δ-Aquariids reach their peak near first quarter, and the Ursids are fine, too. So 2017 is a good year to follow the activity of most strong and medium showers with little or no moonlight interference. Nowadays, video meteor networks are operational throughout the year and are less affected by moonlit skies than visual observers. So we refer to the moonlight conditions first of all for the visual observer.

Only a few showers are expected to show slight differences from the average appearance this year. Since there is always a possibility of completely unexpected events, ideally meteor observing should be performed throughout the year. While often there are many observers active during periods of high or medium activity, one should keep in mind that new events may happen at other times too. Continuous monitoring is possible with automated video systems and by radio/radar systems, but is also worthwhile for visual observers during moon-free nights. This way we can confirm the established sources, including the outer ranges of the known showers. Such regular observations may be impractical for many people, however, so one of the aims of the Shower Calendar is to highlight times when a particular effort might be most usefully employed. It indicates as well specific projects which need good coverage and attention.

The heart of the Calendar is the Working List of Visual Meteor Showers (Table 5) which has been continuously updated so that it is the single most accurate listing available anywhere today

[1]Based on information in the *Meteor Observers Workbook 2014*, edited by Jürgen Rendtel, IMO, 2014 (referred to as 'WB' 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, Mikhail Maslov, Mikiya Sato and Jérémie Vaubaillon for new information and comments in respect of events in 2017. Koen Miskotte summarized information for the SDA and CAP activity in late July. Last but not least thanks to David Asher, Alastair McBeath and Robert Lunsford for carefully checking the contents.

for naked-eye meteor observing. Nevertheless, it is a **Working** List which is subject to further modifications, based on the best data we had at the time the Calendar was written. Observers should always check for later changes noted in the IMO's journal *WGN* or on the IMO website. Vice versa, we are always interested to receive information whenever you find any anomalies! To allow for better correlation with other meteor shower data sources, we give the complete shower designation including the codes taken from IAU's Meteor Data Center listings.

Video meteor observations allow us to detect sources of low meteor activity. An increasing number of confirmed radiants provides us with more possibilities to establish relations between meteoroid streams and their parent objects. Some of the sources may produce only single events but no annual recurring showers, such as, for example, the September ε-Perseids (2009, 2013) and the κ-Cygnids (2014). From stream modelling calculations we know that one meteoroid stream may cause several meteor showers, and that a stream may be related to more than one parent object.

Observing techniques which allow the collection of useful shower data include visual, video and still-imaging along with radar and radio forward scatter methods. Visual and video data allow rate and flux density calculations as well as determination of the particle size distribution in terms of the population index r or the mass index s. Multi-station camera setups can allow orbital data to be established, essential for meteoroid-stream investigations. 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 – although attempts with optical observations can be useful too. Some of the showers are listed in Table 7 (checked by Cis Verbeeck), the Working List of Daytime Meteor Showers.

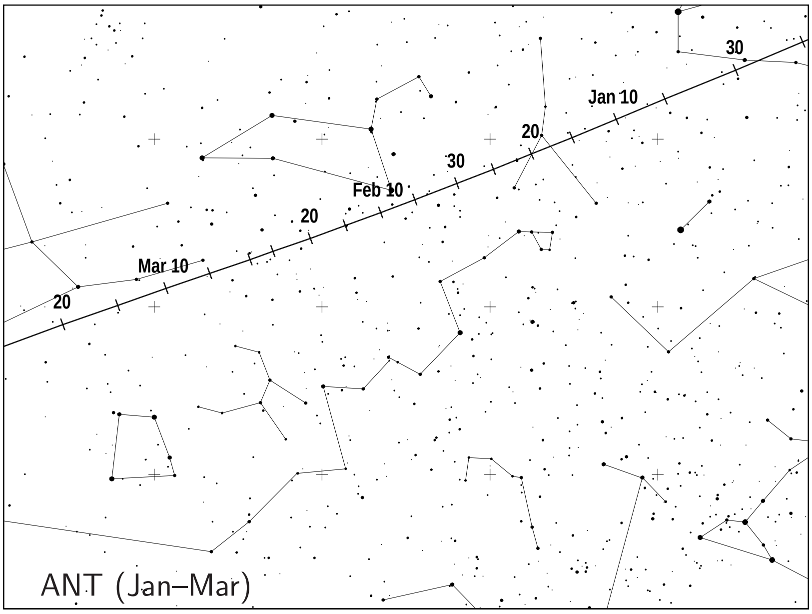
The IMO's aims are to encourage, collect, analyze, and publish combined meteor data obtained from sites all over the globe, to improve our understanding of the meteor activity detectable from the Earth's surface. For best effects, it is recommended that all observers should follow the standard IMO observing guidelines when compiling information, and submit those data promptly to the appropriate Commission for analysis (contact details are at the end of the Calendar). Many analyses try to combine data obtained by more than one method, extending the ranges and coverage but also to calibrate results from different techniques. 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.

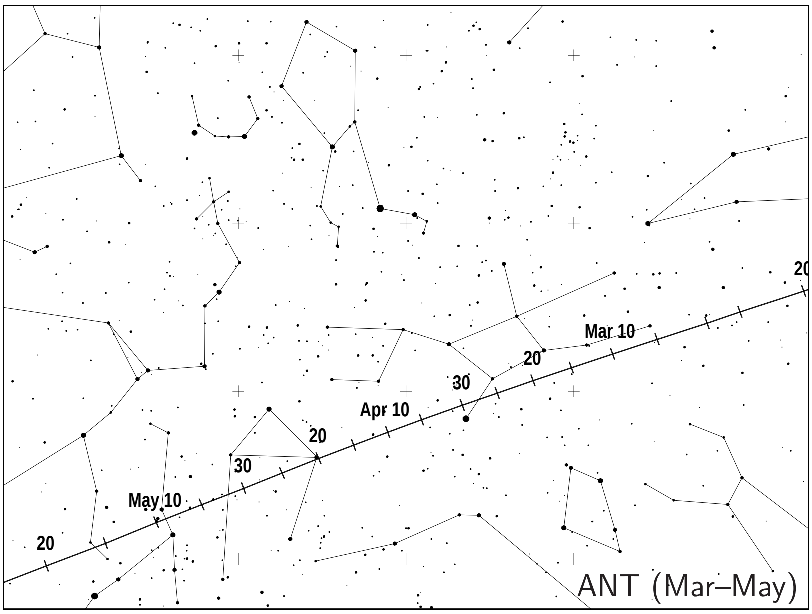
Timing predictions are included below and on all the more active night-time and daytime shower maxima as reliably as possible. However, it is essential to understand that in many cases, such maxima are not known more precisely than to the nearest degree of solar longitude. In addition, variations in 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, 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 have shown why, because even instrumentally, it was impossible to define distinct and constantly observable radiants for many of the showers here! Thus we recommend observers simply to identify meteors from these streams as coming from the ANT alone. Apart from this, we have been able to retain the July-August α-Capricornids, and particularly the Southern δ-Aquariids as apparently distinguishable showers separate from the ANT. 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.





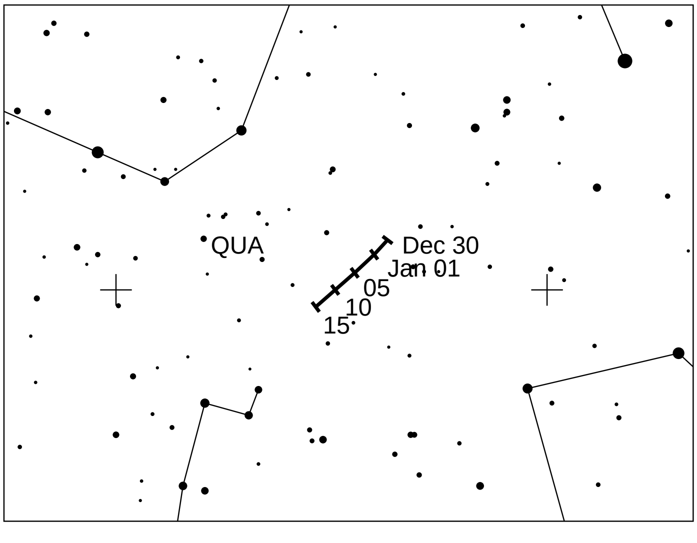
3 January to March

The year starts with the **Quadrantid (010 QUA)** peak for the northern hemisphere observers. However, both the maxima of the southern hemisphere's **α-Centaurids (102 ACE)** in February and the possible minor **γ-Normids (118 GNO)** of March (peak perhaps due around March 14) will be affected by moonlight, the α-Centaurids somewhat less (see below). Since the rates are generally low in the early part of the year, it should be possible to check for some of the relatively weaker sources too. One such example is the **γ Ursae Minorid** shower (404 GUM) between January 15 and 25 from a north-circumpolar radiant at $\alpha = 228°$, $\delta = +67°$ ($V_\infty = 33$km/s), which have been found in video and some visual data recently. The central part of its activity may occur more than a week after January's full Moon. Furthermore, the long-lasting **December Leonis Minorids (032 DLM)** can be traced until early February (see the December section on page 20). 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 of visual data have suggested there may be an ill-defined minor peak with ZHRs ≈ 2 to 3 around $\lambda_\odot \approx 286°$–$293°$ (2017 January 6 to 13). ZHRs could be ≈ 3 for most of March with a slight increase derived from video flux data around $\lambda_\odot \approx 355°$ (2017 March 17).

Timings (rounded to the nearest hour) for the **daytime shower maxima** this quarter are: Capricornids/Sagittariids (115 DCS) – February 1, 10^h UT and χ-Capricornids (114 DXC) – February 13, 11^h UT. Recent radio results have implied the DCS 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.

Quadrantids (010 QUA)

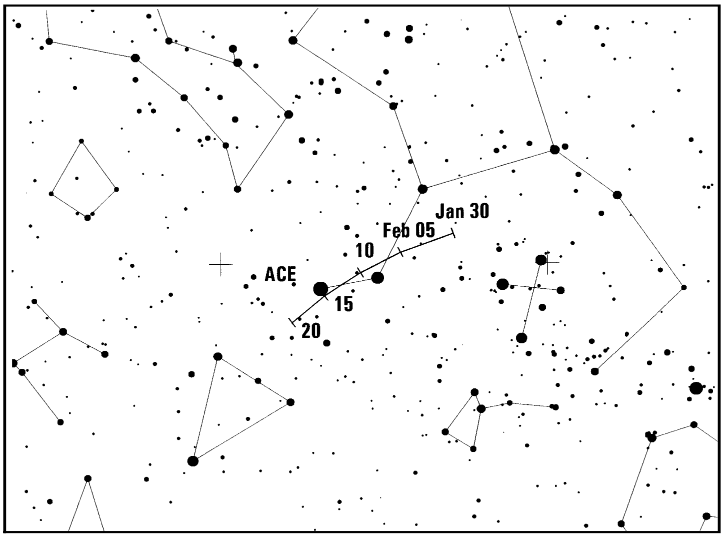
Active: December 28–January 12; Maximum: January 3, 14^h00^m UT ($\lambda_\odot = 283\overset{\circ}{.}15$), ZHR = 120 (can vary ≈ 60–200); Radiant: $\alpha = 230°$, $\delta = +49°$; Radiant drift: see Table 6; $V_\infty = 41$ km/s; $r = 2.1$ at maximum, but variable.



A first quarter Moon on January 5 creates favourable 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. The 14^h UT timing for the peak is favourable for observers in the west of North America. Observers in the north of Asia will find the radiant close to the horizon in their evening skies. The $\lambda_\odot = 283^\circ\!.15$ maximum timing is based on the best-observed return of the shower ever analysed (IMO data from 1992), and has been confirmed by optical and radio results in most years since. Typically, the peak is 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. An added level of complexity comes from the mass-sorting of particles across the meteoroid stream related to the comet 96P/Machholz and the minor planet 2003 EH_1 may make fainter objects (radio and telescopic meteors) reach maximum up to 14 hours before the brighter (visual and photographic) ones. For 2017 there are no predictions for peculiarities such as extra peaks or high rates. The graph from Jérémie Vaubaillon's modelling (WB, p. 16) indicates a density below the average. Both, the timing and rate need to be confirmed by observations. A few years this century seem to have produced a, primarily radio, maximum following the main visual one by some 9–12 hours too. Optical 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. However, this year's lunar phase favours observations of the ascending part of the Quadrantid activity.

α-Centaurids (102 ACE)

Active: January 28–February 21; Maximum: February 8, 00^h30^m UT ($\lambda_\odot = 319^\circ\!.2$);
ZHR = variable, usually ≈ 6, but may reach 25+;
Radiant: $\alpha = 210^\circ$, $\delta = -59^\circ$; Radiant drift: see Table 6;
$V_\infty = 56$ km/s; $r = 2.0$.



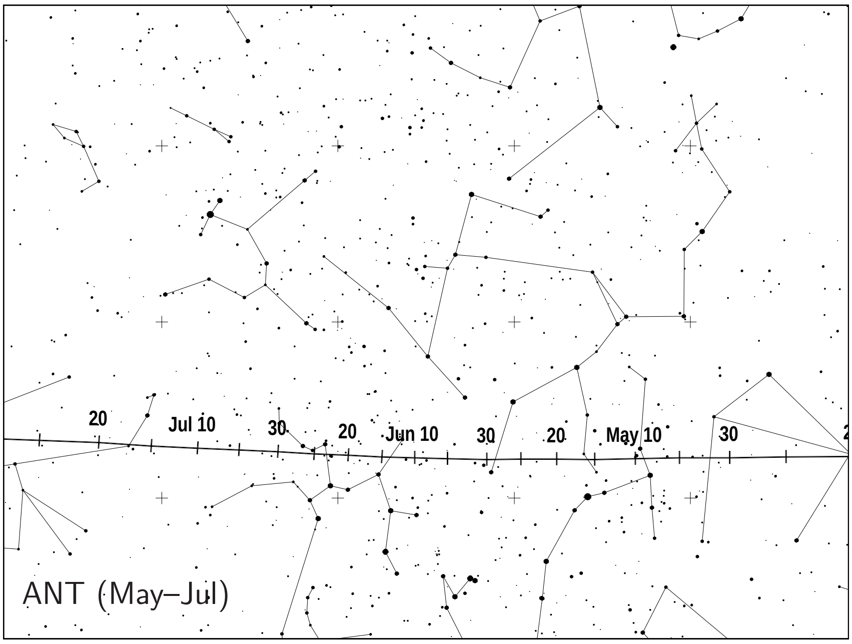
The α-Centaurids are one of the main southern summer high points, from past records supposedly producing many very bright, even fireball-class, objects (meteors of at least magnitude −3). The average peak ZHR between 1988–2007 was merely 6 though (WB, p. 18), albeit coverage has frequently been extremely patchy. Despite this, in 1974 and 1980, bursts of only a few hours' duration apparently yielded ZHRs closer to 20–30. Significant activity was reported on 2015 February 14 (airborne observation) although there was no confirmation of an outburst predicted for 2015 February 8. 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. This year the maximum period sees a waxing gibbous Moon on February 7/8 (full on February 11), leaving some hours before dawn with dark skies to examine whatever happens at the listed maximum, while the February 14 repeat interval happens shortly after full Moon.

4 April to June

Meteor activity increases towards the April-May boundary, particularly caused by optically unobservable showers. Mikhail Maslov mentions a possible weak activity from **Comet 249P/LINEAR** on April 20 at 16^h33^m UT. **If an activity occurs at all** from the radiant at 207°, −20°, it will be caused by small particles and thus might be visible in radar/radio data only. The maxima of the **Lyrids (006 LYR)** on April 22 and the **π-Puppid (137 PPU)** on April 23 occur under optimal conditions. The essential morning hours around May 6 are also moonless for the **η-Aquariid (031 ETA)** maximum period. However, the **η-Lyrids (145 ELY)** with a potential peak on May 9 or slightly later are badly affected by moonlight.

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. Occasional meteors from the Arietids have been claimed as seen from tropical and southern hemisphere sites visually in past years. Although it is not possible to calculate ZHRs and activity profiles from such observations, all available data should be collected and reported to combine observations obtained with different techniques for calibration and completeness. For radio observers, the theoretical UT peak times for these showers are as follows:
April Piscids (144 APS) – April 20, 10^h;
ε-Arietids (154 DEA) - May 9, 09^h;
May Arietids (294 DMA) – May 16, 10^h;
o-Cetids (293 DCE) – May 20, 09^h;
Arietids (171 ARI) – June 7, 10^h (more details see below);
ζ-Perseids (172 ZPE) – June 9, 12^h;
β-Taurids (173 BTA) – June 28, 11^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. The maxima of the Arietids and ζ-Perseids tend to blend into one another, producing a strong radio signature for several days in early to mid June. The shower maxima dates are not well established and may 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 δ-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 η-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 ω-Cetid Complex", because that seems a closer match to the o-Cetids as defined by earlier reports.

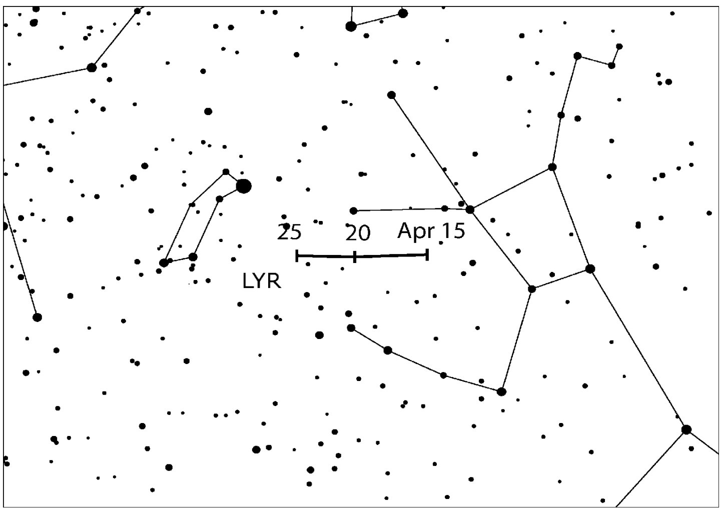
According to analyses of visual IMO data, the **ANT** should produce ZHRs of 3 to 4 until mid April, and again around late April to early May, late May to early June, and late June to early July. At other times, its ZHR seems to be below ≈ 2 to 3. Video flux data show a rather slow increase from early April to end-May followed by a decrease into July with some insignificant variations. 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.



Lyrids (006 LYR)

Active: April 16–25; Maximum: April 22, 12^h UT ($\lambda_\odot = 32.^\circ32$, 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; $r = 2.1$

The $\lambda_\odot = 32.^\circ32$ timing given above is the maximum position found in *IMO* results from 1988–2000. However, the maximum time was variable from year to year between $\lambda_\odot = 32.^\circ0$–$32.^\circ45$ (equivalent to 2017 April 22, 04^h to April 22, 15^h UT). Activity was variable too. A peak at the ideal time produced the highest ZHRs, ≈ 23, while the further the peak happened from this, the lower the ZHRs were, down to ≈ 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. Further, the shower's peak length varied: 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.

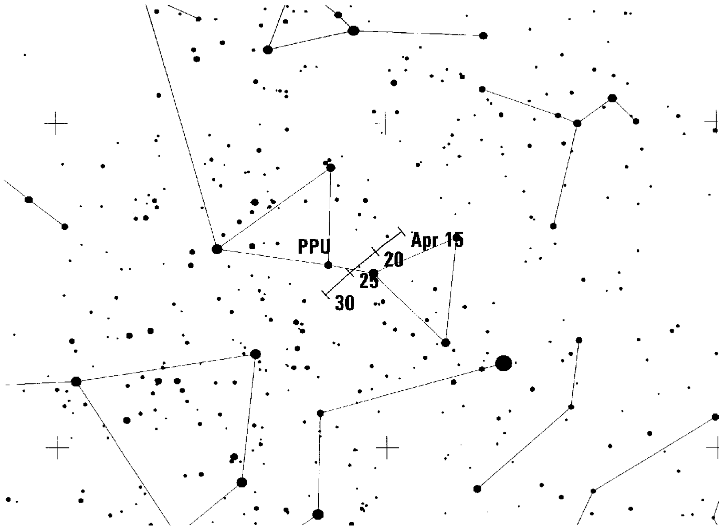


For 2017 there are no predictions for any activity increase from theoretical modelling. Lyrid meteors are best viewed from the northern hemisphere, but are visible from many sites north and south of the equator. As the radiant rises during the night, watches can be carried out usefully after about $22^{h}30^{m}$ local time from mid-northern sites, but only well after midnight from the mid-southern hemisphere. New Moon on April 26 provides excellent conditions for observing. Should the ideal peak time recur, it should be best-seen from North American longitudes, although of course, other maximum times may happen instead!

π-Puppids (137 PPU)

Active: April 15–28; Maximum: April 23, 17^{h} UT ($\lambda_{\odot} = 33\overset{\circ}{.}5$);
ZHR = periodic, up to around 40;
Radiant: $\alpha = 110°$, $\delta = -45°$; Radiant drift: see Table 6;
$V_{\infty} = 18$ km/s; $r = 2.0$.

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 perihelia in 2008 and 2013 March produced nothing meteorically significant. The comet's next perihelion will be reached in October 2018. When this Calendar was prepared, no predictions for meteor any 2017 π-Puppid meteor activity had been issued.

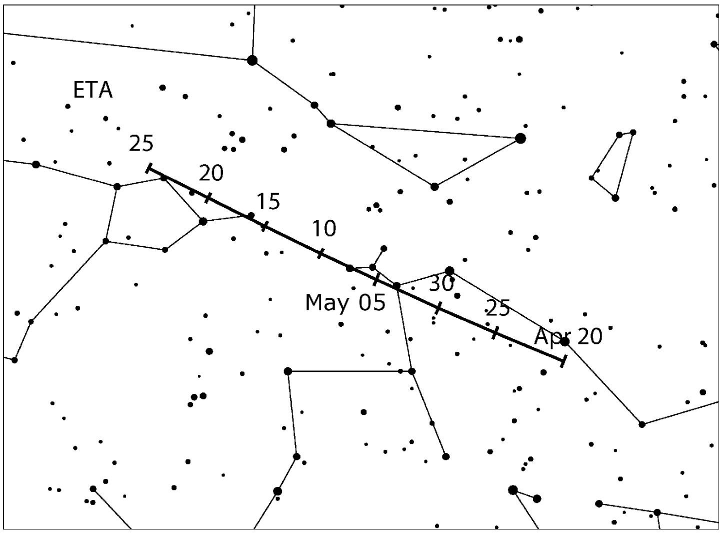


The π-Puppids are best-seen from the southern hemisphere, with useful observations mainly practical before midnight, as the radiant is very low to setting after 01^{h} local time. The lunar phase is helpful for optical observations this year. Covering whatever transpires is important, even if that is 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.

η-Aquariids (031 ETA)

Active: April 19–May 28; Maximum: May 6, 02^{h} UT ($\lambda_{\odot} = 45\overset{\circ}{.}5$);
ZHR = 50 (periodically variable, $\approx$ 40–85);
Radiant: $\alpha = 338°$, $\delta = -1°$; Radiant drift: see Table 6;
$V_{\infty} = 66$ km/s; $r = 2.4$.

This stream is associated with Comet 1P/Halley, like the Orionids of October. Shower meteors are only visible for 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. The shower is one of the best for southern observers and would benefit from increased observer activity generally. The fast and often bright meteors make the wait for radiant-rise worthwhile, and many events leave persistent trains. 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, occurs around May 5/6. IMO analyses based on data collected between 1984–2001, have shown that ZHRs are generally above 30 in the period May 3–10. The peak rates appear to be variable on a roughly 12-year timescale. Assuming this Jupiter-influenced cycle is real, the trough period was due around 2014–2016, so ZHRs may slightly exceed the previous years' rates now. Activity around the most recent ZHR peak period in circa 2008 and 2009 seemed to have been $\approx$ 85 and 65 respectively. In 2013, ZHRs up to $\approx$ 70 were recorded (WB, p. 24). The waxing gibbous Moon will set leaving the morning hours towards dawn splendidly Moon-free for the peak. All forms of observing can be used to study the shower, with radio work allowing activity to be followed even from many northern latitude sites throughout the daylight morning hours. The radiant culminates at about $08^{\rm h}$ local time.

Daytime Arietids (171 ARI)

Active: May 22–July 2 (uncertain); Maximum: June 07 ($\lambda_{\odot} = 76.^{\circ}6$);
ZHR $\approx$ 30(?);
Radiant: $\alpha = 44^{\circ}$, $\delta = +24^{\circ}$; Radiant drift: see Table 6;
$V_{\infty} = 38$ km/s; $r = 2.8$.

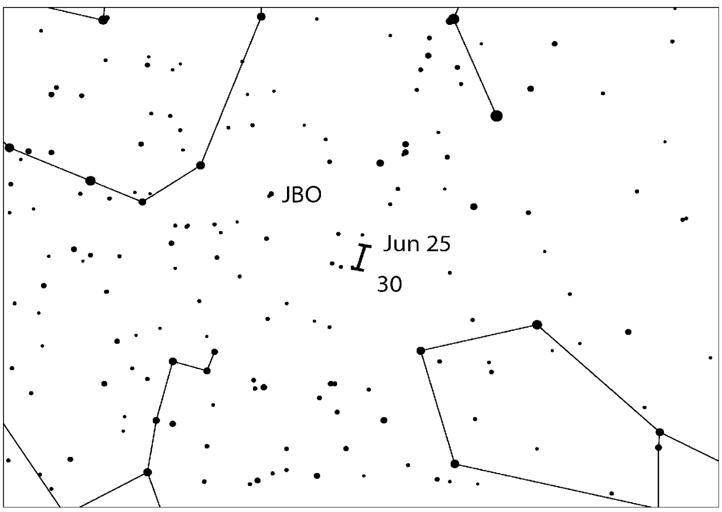
The radiant is located only about 30° west of the Sun, but despite that, a few optical observations have been repeatedly reported from it in the past. However, its low radiant elevation by the time morning twilight is too bright means the number of shower meteors recorded by individual video or visual observers is always low. Consequently, an ongoing IMO project to pool data on the shower using all techniques was initiated in 2014, to combine results from many independent observing intervals, even those periods which contain few, or even no ARI meteors. The currently available video data do not show a clear profile but a recognizable activity level over a week or so.

Hence all contributions for this project will be most welcome! Since both the correction factor for radiant elevation and the observing conditions change rapidly in the approach to morning twilight in early June, it is recommended that visual observers break their watches into short intervals (of the order of about 15 minutes), determining the limiting magnitude frequently for each interval. Observers at latitudes south of about 30°N are better placed because of the significantly poorer twilight conditions further north in June.

June Boötids (170 JBO)

Active: June 22–July 2; Maximum: June 27, $9^{\rm h}$ UT ($\lambda_\odot = 95.^\circ7$), but see text;
ZHR = variable, 0 − 100+;
Radiant: $\alpha = 224^\circ$, $\delta = +48^\circ$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.2$.

This source is included in 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 ≈ 20 − 50 was observed on 2004 June 23. We encourage observers to monitor throughout the proposed period, in case of fresh outbursts. The return predicted in 2010 yielded ZHRs of less than 10 on June 23–24 which were not well confirmed. Prior to 1998, only three more probable returns had been detected, in 1916, 1921 and 1927. The dynamics of the stream have been subjected to theoretical modelling which 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 occurred on 2015 January 30. The 1998 and 2004 events resulted from material ejected from the comet in the past which now lies on slightly different orbits to the comet itself. From mid-northerly latitudes the radiant is observable almost all night, but the prolonged – in some places continuous – twilight overnight keeps the useable time short. This year, the activity period around New Moon offers good opportunities to observe the shower. VID suggested some June Boötids may be visible in most years around June 20 − 25, but with activity largely negligible except near $\lambda_\odot = 92^\circ$ (2017 June 23), radiating from an area about ten degrees south of the radiant found in 1998 and 2004, close to $\alpha = 216^\circ$, $\delta = +38^\circ$. There are no predictions of rate enhancements known based on model calculations.



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 that ZHRs for most of the month are < 2. Activity appears to improve somewhat, with ZHRs ≈ 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 (001 CAP)** in July-August, but the lower apparent velocity of the CAP allows observers to separate the two. The **Southern δ-Aquariids (005 SDA)** are strong enough, and the **Piscis Austrinids (183 PAU)** have a radiant distant enough from the ANT area, that both should be more easily separable from the ANT, particularly from the southern hemisphere. In 2017, the Moon (first quarter on Jul 30) will only partly disturb the period of highest rates from these southern radiants. A chance for meteor activity from Comet C/2015 D4 (Borisov) has been announced by Peter Jenniskens, Esko Lyytinen and C. Bemer in CBET 4127. Esko Lyytinen points out that the orbit is good enough for calculating the timing but not for any clue of the activity. Long period comet trails are quite narrow and information about the minimum distance for detectable rates is scarce. The latest-available orbital elements give a nominal miss-distance of 0.00054 astronomical units (au) which seems too large for a meteor event. **If** it is lower than about 0.0003 au, something may appear on July 29 at 00^h10^m UT from a radiant at $\alpha = 79°$, $\delta = -32°$ (in Columba) with $V_\infty = 47$ km/s.

Contrary to this, the full Moon on August 7 will then affect **Perseid (007 PER)** observations before and around the peak. In the maximum night the Moon is placed in Pisces and thus illuminates the time during which the radiant has a reasonable elevation. The mean or 'traditional' broad maximum varied between $\lambda_\odot \approx 139\overset{\circ}{.}8$ to $140\overset{\circ}{.}3$, equivalent to 2017 August 12, 14^h to August 13, 02^h30^m UT. The minor **κ-Cygnid (012 KCG)** maximum is observable in moonless skies this year. **ANT** ZHRs will likely have dropped back below 2 again by late August, rising once more to $\approx 2-3$ by early September, as the radiant tracks on through Aquarius and into western Pisces. Conditions are fine to check the **Aurigid (206 AUR)** peak on September 1. Most of the activity period of the **September ε-Perseids (208 SPE)** is illuminated by the Moon (full on September 6). SPE-outbursts occurred in 2008 and 2013. The respective solar longitudes are reached on September 9 at 16^h UT and 23^h UT, but no extra activity is anticipated for 2017.

In 2015, several video data sets showed well observed rates essential through the entire month from the **χ-Cygnids (757 CCY)** with a weak maximum on September 14/15 (ZHR about 2–3). The shower was also visible in the years before, but at a lower level. Hence further observations are useful. This year a large portion of the possible activity period after full Moon (September 6) until September 25 can be covered. The radiant of these very slow meteors ($V_\infty = 19$ km/s) is at $\alpha = 300°$, $\delta = +31°$. For convenience, we have included the radiant drift in Table 6.

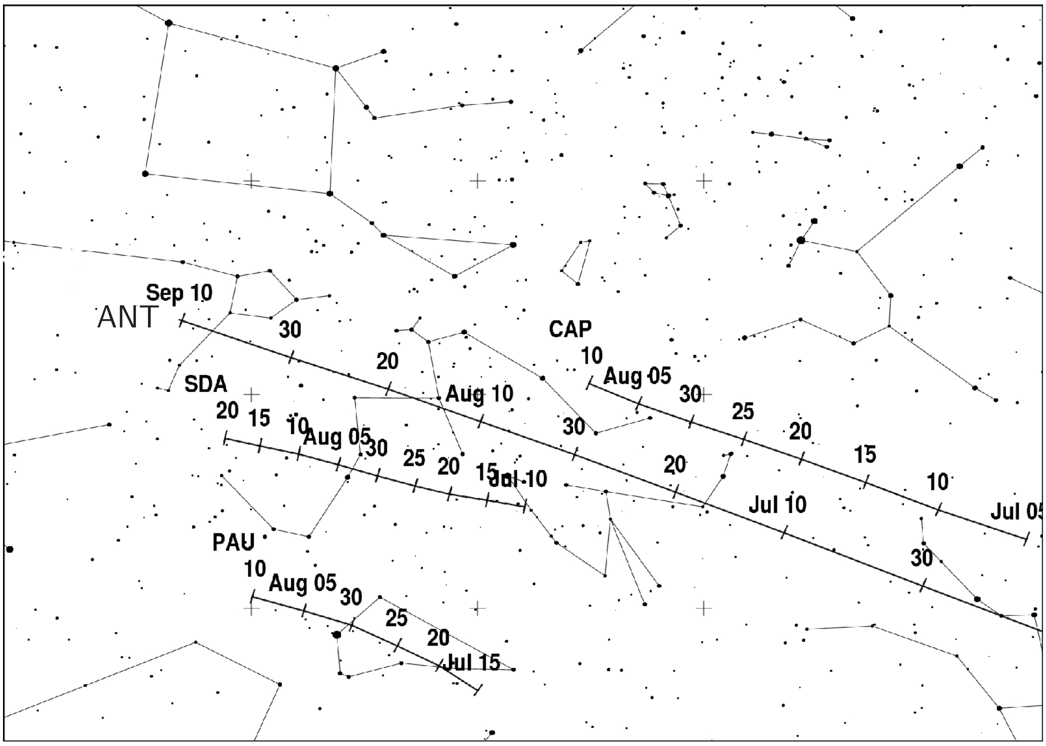
Observers are encouraged to catch some **Daytime Sextantids (221 DSX)** in the pre-dawn of late September. Remember that the **Southern Taurids (002 STA)** begin around September 10, effectively taking over the near-ecliptic activity from the ANT through to December.

For **daylight radio observers**, the high activity of May-June has waned, but there remain the γ-Leonids (203 GLE; peak due near August 25, 11^h UT, albeit not found in recent radio results), and the Sextantids (221 DSX; see below).

Piscis Austrinids (183 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; $r = 3.2$.

Very little information has been collected on the PAU over the years, so the details on the shower are not well-confirmed, mainly because of the large amount of northern hemisphere summer data, and the almost complete lack of southern hemisphere winter results, on it. Observations are needed to establish the listed parameters.



Southern δ-Aquariids (005 SDA)

Active: July 12–August 23; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 25; Radiant: $\alpha = 340°$, $\delta = -16°$; Radiant drift: see Table 6; $V_\infty = 41$ km/s; $r = 2.5$ (see text).

Radio work can pick up the SDA as well, and indeed the shower has sometimes given a surprisingly strong radio signature. Observations made by experienced observers under exceptional observing conditions in 2008 and 2011 show that the maximum ZHR of the southern δ-Aquariids is around 25 for about two days ($\lambda_\odot = 125° - 127°$). Between $\lambda_\odot = 124°$ and 129°, the ZHR is above 20. So the shower is even more active than the Orionids. During the maximum there are also numerous bright SDA meteors visible. This is obvious as a dip in the r-profile during the maximum period to $r \approx 2.5$ while before and after the maximum the value is much higher ($r \approx 3.1$). In the past there were also outbursts observed: Australian observers reported a ZHR of 40 in the night 1977 July 28/29; again a ZHR of 40 was observed for 1.5 hours on 2003 July 28/29 from Crete (the ZHR before and after the outburst was around 20). Unfortunately, the 2003 observation was not confirmed by other observers active in the period. The extensive 2011 data set showed no ZHR enhancement at the same solar longitude as in 2003. The activity level and variations of the shower need to be monitored. First quarter Moon on July 30 leaves the better morning hours undisturbed. While at mid-northern latitudes only a small portion of the shower meteors is visible, conditions significantly improve the further south the location is.

α-Capricornids (001 CAP)

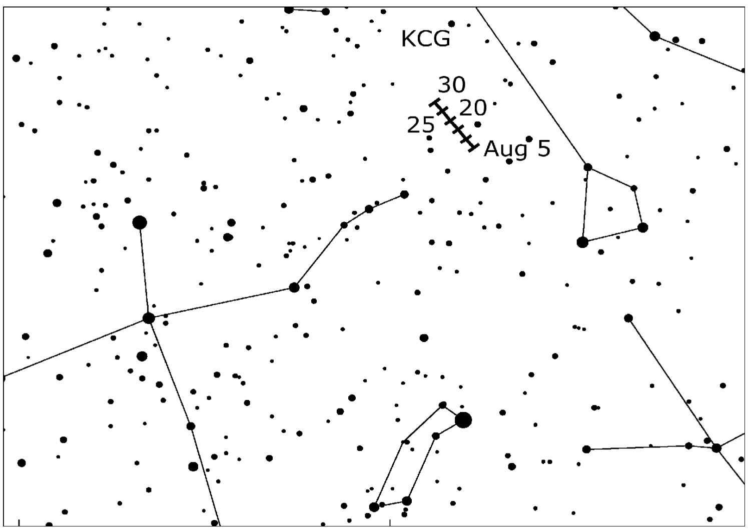
Active: July 3–August 15; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 5;
Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 6;
$V_\infty = 23$ km/s; $r = 2.5$.

The CAP and SDA radiants were both definitely detected visually in all years, standing out against those much weaker ones supposed active in Capricornus-Aquarius then. Although the radiant of the CAP partly overlaps that of the large ANT region, the low CAP velocity should allow both video and visual observers to distinguish between the two sources. Frequently, bright and at times fireball-class shower meteors are seen. Minor rate enhancements have been reported at a few occasions in the past. The highest observed ZHR of ≈ 10 dates back to 1995. Recent results suggest the maximum may continue into July 31.

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; $r = 3.0$.

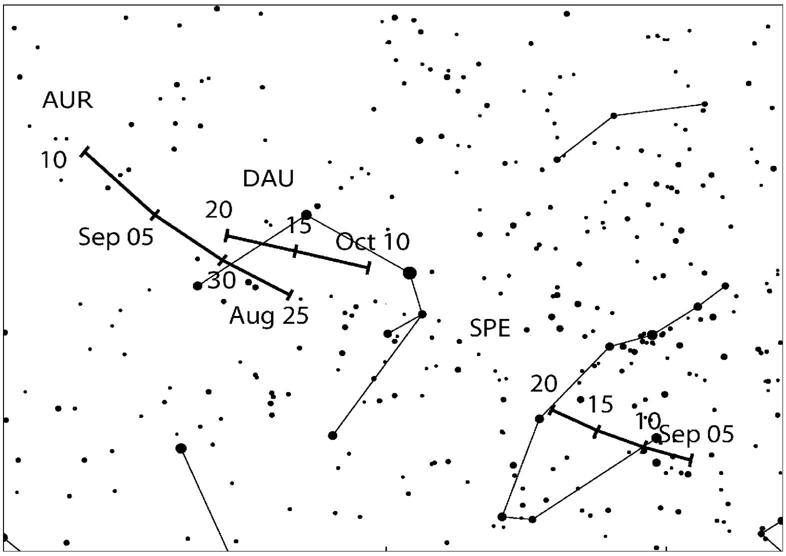
The κ-Cygnids showed enhanced activity in 2014 and 2007. Apart from these peaks, the general ZHR level seems to increase in the recent years from an apparent dip in the period 1990–2005. However, the currently available data do not confirm a periodic activity variation. For this year there are no predictions of peculiarities available. 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. The radiant has been found to be rather complex with several sub-centers around the given position towards the constellations of Draco and Lyra. Due to the low velocity of the shower meteors, the association should be possible also considering the sub-radiants. Furthermore, the activity might be present only from August 6–19 overall. Consequently observers should be aware that the shower may not behave as it is "supposed to"!



Aurigids (206 AUR)

Active: August 28–September 5; Maximum: September 01, 02^h UT ($\lambda_\odot = 158\overset{\circ}{.}6$); ZHR = 6;
Radiant: $\alpha = 91°$, $\delta = +39°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.5$.

This northern-hemisphere shower has produced short, unexpected, outbursts at times, with EZHRs of ≈ 30–40 recorded in 1935, 1986 and 1994. As it has not been monitored regularly over all years, other events may have been missed. Only three watchers in total covered the 1986 and 1994 outbursts, for instance! The first predicted outburst happened in 2007, producing short-lived EZHRs of ≈ 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 peak. This was not confirmed by visual observers, probably due to the moonlit sky. The Aurigid radiant reaches a useful elevation only after ≈ 01^h local time. For 2017, there are no predictions for enhanced rates from this shower. The waxing Moon (first quarter on August 29) leaves good conditions to check for activity in the hours before dawn.



Daytime Sextantids (221 DSX)

Active: September 9–October 9 (uncertain); Maximum: September 28 ($\lambda_\odot = 184\overset{\circ}{.}3$),
Radiant: $\alpha = 152°$, $\delta = 0°$; Radiant drift: see Table 6;
$V_\infty = 32$ km/s; $r = 2.5$ (uncertain).

At the given maximum position the moon reaches its first quarter. Hence visual observers may try catch some Sextantids in the pre-dawn of late September to early October as part of the IMO project to collect and pool data obtained by all techniques for this shower and the Arietids in early June. The DSX radiant is roughly 30° west of the Sun. Because it lies close to the equator and the activity period is shortly after the equinox, the chances to contribute results are almost equally good for observers in either hemisphere. As with the Arietids, both the radiant elevation correction and the observing conditions change rapidly as morning twilight approaches. Hence visual observers should report their data in short intervals, no longer than about 15–20 minutes, determining the limiting magnitude frequently during each period. The date and time of the Sextantid maximum are uncertain. Recent radio data have indicated that it may occur a day earlier than expected, and it seems plausible several minor radio peaks in early October may also be due to this source. Currently, optical observations hint at a rather later maximum but have not allowed us to define the activity period or the peak time.

6 October to December

During the last quarter of the year most significant showers are observable under perfect lunar conditions.

October Camelopardalids (281 OCT): Short-lived video outbursts were recorded in 2005 and 2006 on October 5/6 (near $\lambda_\odot 193°$) from a north-circumpolar radiant at $\alpha \approx 166°$, $\delta \approx +79°$ ($V_\infty = 47$ km/s). No recurrence was reported in 2007, 2008, 2011–2013 and also not in 2015. 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 the video data lies between $\lambda_\odot \approx 192\overset{\circ}{.}5$–$192\overset{\circ}{.}8$, equivalent to 2017 October 5, 19^h to October 6, 02^h UT, and coincides with the full Moon. At the time the Calendar was written, a possible activity enhancement in 2016 was still due (2016 October 5, 14^h45^m UT).

The **Draconid (009 DRA)** maximum on October 8 occurs just three days after full Moon which rises already in the evening hours when the radiant is in its highest position. So we cannot expect undisturbed visual data this year. Furthermore, there are no predictions for any rate enhancement in 2017. Maximum times from the recent past have spanned from $\lambda_\odot = 195\overset{\circ}{.}036$ (in 2011), equivalent to 2017 October 8, 09^h UT, to the end of a minor outburst in 1999 at $\lambda_\odot 195\overset{\circ}{.}76$, equating to 2017 October 9, 02^h30^m UT. Moonlight also affects the October 11 maximum of the **δ-Aurigids (224 DAU)**. The maxima of the **ε-Geminids (023 EGE)** on October 18, the **Orionids (008 ORI)** on October 21, and the **Leonids (013 LEO)** on November 17, all are close to new Moon dates and thus enjoy perfect conditions for visual observers worldwide.

The maximum periods of both the **Southern Taurids (002 STA)** and the **Northern Taurids (017 NTA)** are affected by moonlight. 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. Later, the **α-Monocerotids (246 AMO)** and the **November Orionids (250 NOO)** can be well observed.

There is a small chance for **meteor activity from Comet 46P/Wirtanen**. Mikhail Maslov found that the trails from 1915 to 1934 are 0.00019 to 0.00068 astronomical units from the Earth on November 30 – December 01. The 1934 trail is the closest one on November 30, 06^h06^m UT and may cause very slow meteors ($V_\infty = 14.9$ km/s) from a radiant $\alpha = 9°$, $\delta = 9°$ (in Pisces). The entire possible period extends from November 30, 03^h to December 01, 06^h UT.

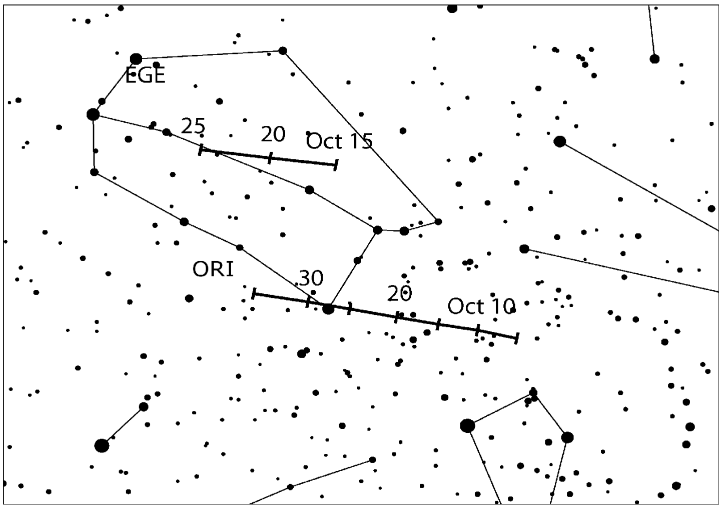
The showers in early December are then badly affected by moonlight: the **Phoenicids (254 PHO)** on December 2, the **Puppid-Velids (301 PUP)** near December 7 and the **Monocerotids (019 MON)** on December 9. Finally, the **σ-Hydrids (016 HYD)** reach their maximum (December 11) close to the last quarter Moon. Much better conditions will occur at the maxima of the **Geminids (004 GEM)** and the **Ursids (015 URS)**.

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; $r = 3.0$.

A weak minor shower with characteristics and activity nearly coincident with the Orionids, so visual observers need to take great care to separate meteors from the two sources. Due to new

Moon on October 19, observing conditions are perfect. The radiant rises during the second half of the night for either hemisphere. Northern observers have a radiant elevation advantage and may observe shower meteors 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.



Orionids (008 ORI)

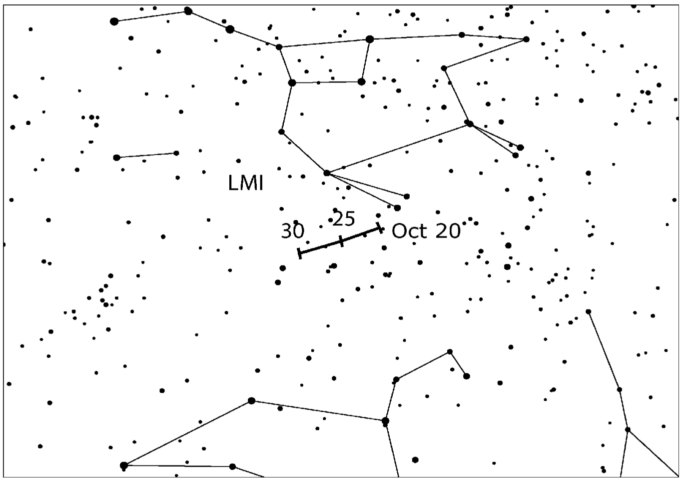
Active: October 2–November 7; Maximum: October 21 ($\lambda_\odot = 208°$); ZHR = 20;
Radiant: $\alpha = 95°$, $\delta = +16°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.5$.

October's 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, 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 and were caused by meteoroids trapped in a resonance region which is not anticipated this time. 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 $\approx$ 14–31 during the examined interval. A 12-year periodicity in stronger returns due to Jupiter's influence appeared to have been partly confirmed. That suggested lower activity should have last happened from 2014–2016. If the periodicity is real, ZHRs may now slowly increase again (about 20+ in 2017). 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 several days around the maximum this year with no lunar interference.

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; $r = 3.0$.

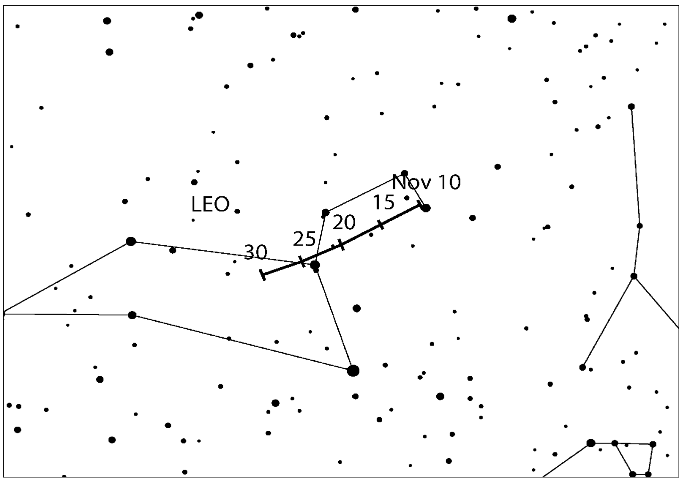
This weak minor shower has a peak ZHR apparently close to the visual threshold, found so far mainly in video data. The radiant area can be seen solely from the northern hemisphere, where it rises around midnight. The probable maximum date falls shortly after new Moon, so it is well placed for coverage! All kinds of observations are advised.



Leonids (013 LEO)

Active: November 6–30; Maximum: November 17, 16^h30^m UT (nodal crossing at $\lambda_\odot$ = 235°.27), but see text; ZHR ≈ 10 Radiant: $\alpha = 152°$, $\delta = +22°$; Radiant drift: see Table 6; $V_\infty = 71$ km/s; $r = 2.5$.

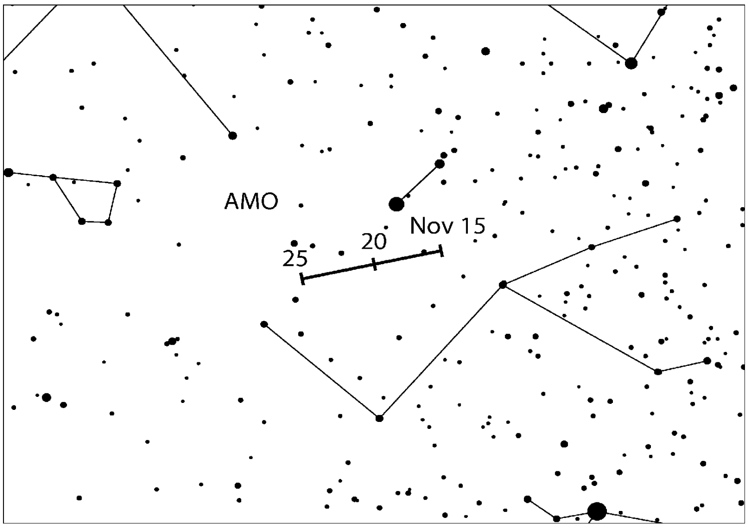
The last perihelion passage of the Leonids' parent comet, 55P/Tempel-Tuttle, in 1998 is almost two decades ago now. With the knowledge of the dust ejection and trail evolution, variable activity has been modelled and observed in several years. Mikhail Maslov's calculations indicate a chance for a rather narrow trail of meteoroids released from the parent comet in 1300 on November 16, 17^h07^m UT with a ZHR of about 10 and composed of brighter meteors. The nodal maximum at $\lambda_\odot = 235°.27$ should occur on November 17 near 16^h30^m UT, probably also with a ZHR of 10. The Leonid maximum coincides with the new Moon period. The shower's radiant first becomes usefully-observable by local midnight or so north of the equator, afterwards for places further south. Hence both of the given peak times are most favourable for observers at East Asian longitudes.



α-Monocerotids (246 AMO)

Active: November 15–25; Maximum: November 21, 17^h UT ($\lambda_\odot = 239°.32$); ZHR = variable, usually ≈ 5, but has produced an outburst to ≈ 400, see text; Radiant: $\alpha = 117°$, $\delta = +01°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 2.4$.

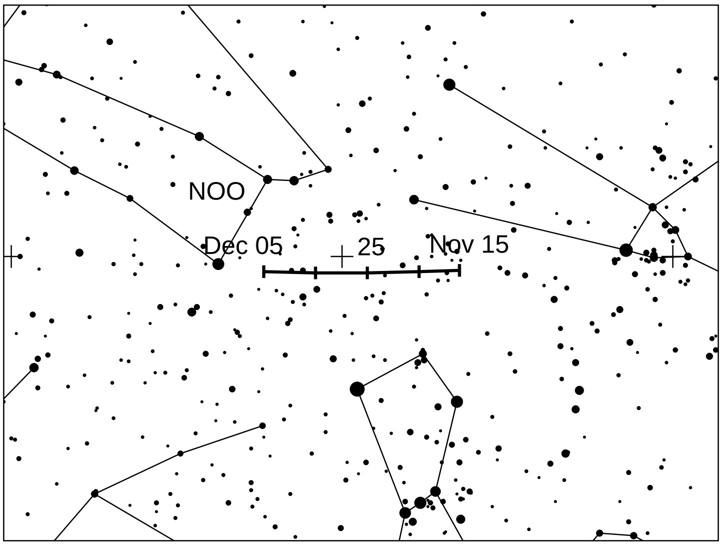
The most recent α-Monocerotid outburst was observed in 1995. The top EZHR, ≈ 420, lasted five minutes, the entire outburst 30 minutes. Recent modelling by Esko Lyytinen has indicated the main AMO trail will not cross the Earth's **orbit** again until 2017 and 2020. However, the Earth will not be near 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. Mikiya Sato's very recent modelling hints at a possible dust trail approach on November 21, 21^h26^m UT. Activity may expected **if some activity occurs a year ahead on 2016 November 21, 18^h30^m UT**. The possible rates will be lower than in 1985 and 1995. The 2016 event is still five months ahead from the moment this Calendar was written and needs to be confirmed by observations. Both timings in 2016 and 2017 favour Asian longitudes while the radiant is too low for European observers particularly in 2016. 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 18th creates perfect observing circumstances this year, and the shower's radiant is well on view from either hemisphere after about 23^h local time.



November Orionids (250 NOO)

Active: November 14–December 6; Maximum: November 28 ($\lambda_\odot = 246°$); ZHR = 3;
Radiant: $\alpha = 91°$, $\delta = +16°$; Radiant drift: see Table 6;
$V_\infty = 41$ km/s; $r = 3.0$.

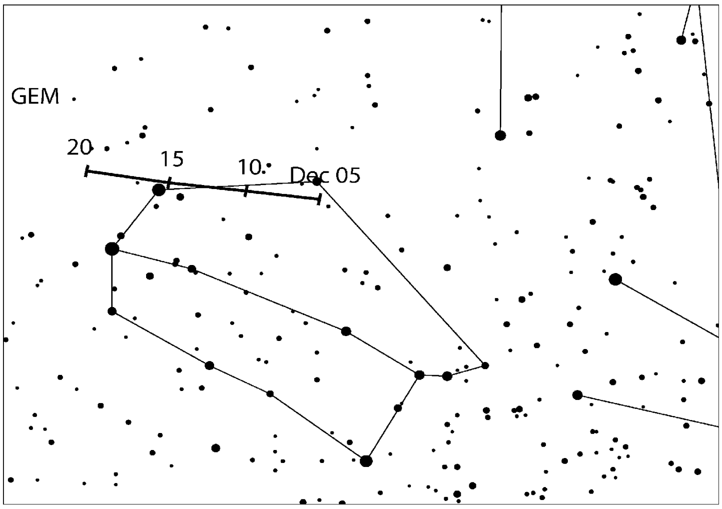
This shower is easily detected in video data. The detailed analysis reveals that there are two consecutive, very similar showers whose activity intervals overlap by only two degrees in solar longitude: the first is the November Orionids (250 NOO), followed by the Monocerotids (019 MON). In the last days of November the shower is the strongest source in the sky. The radiant is located in northern Orion, 4° north of α Orionis. This location is close to the Northern Taurids, but far enough east to be distinguishable. The faster velocity of the November Orionids should help distinguish these meteors from the slower Taurids. The radiant culminates near 2^h local time, but is above the horizon for most of the night. The Moon reaches first quarter on November 26, hence there are a few hours before dawn with dark skies to collect data.



Geminids (004 GEM)

Active: December 4–17; Maximum: December 14, 06^h30^m UT ($\lambda_\odot = 262\overset{\circ}{.}2$); ZHR = 120;
Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6;
$V_\infty = 35$ km/s; $r = 2.6$.

One of the best, and probably the most reliable, of the major annual showers presently observable reaches its broad maximum on December 14 centered at 06^h30^m UT. 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.

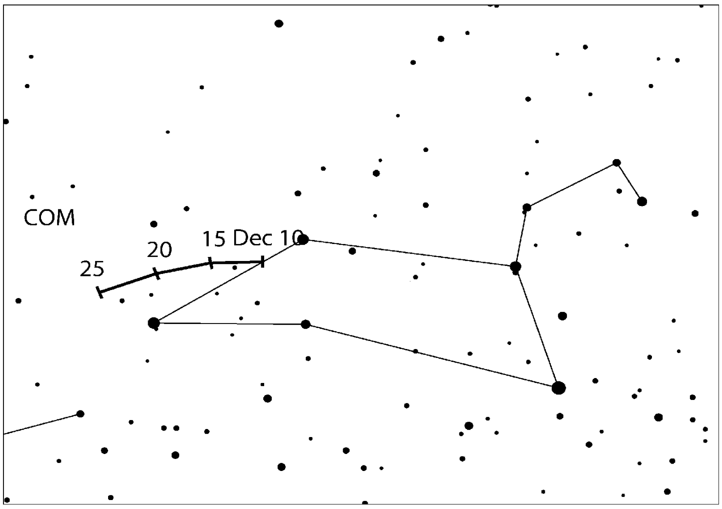


The peak has shown slight signs of variability in its rates and timing in recent years, with the more reliably-reported maxima during the past two decades (WB, p. 66) all having occurred within $\lambda_\odot = 261\overset{\circ}{.}5$ to $262\overset{\circ}{.}4$, 2017 December 13, 14^h to December 14, 11^h UT. Usually, near-peak Geminid rates 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 meteors should be most abundant almost a day ahead of the visual maximum. The 2017 return comes with a thin waning crescent (new Moon December 18) – almost optimal conditions for all observers.

Comae Berenicids (020 COM)

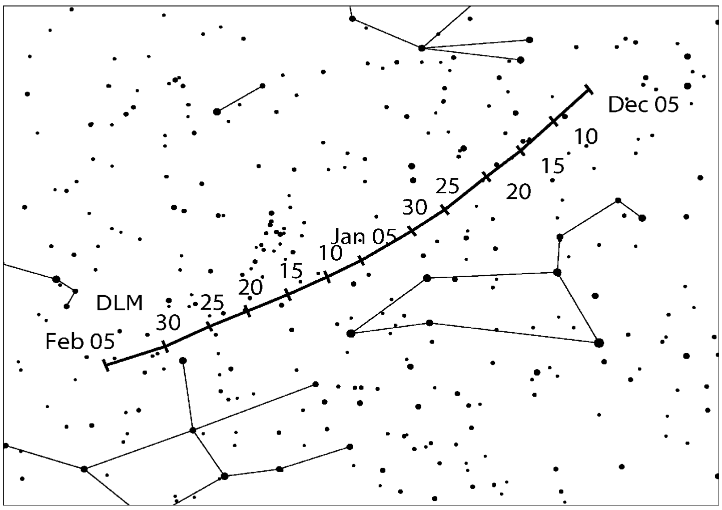
Active: December 12–23; Maximum: December 16 ($\lambda_\odot = 264°$); ZHR = 3; Radiant: $\alpha = 175°$, $\delta = +18°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 3.0$.

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 $06^{\rm h}$, but it is almost unobservable from the mid southern hemisphere until near dawn. December's new Moon makes the probable peak favourable for observing.



December Leonis Minorids (032 DLM)

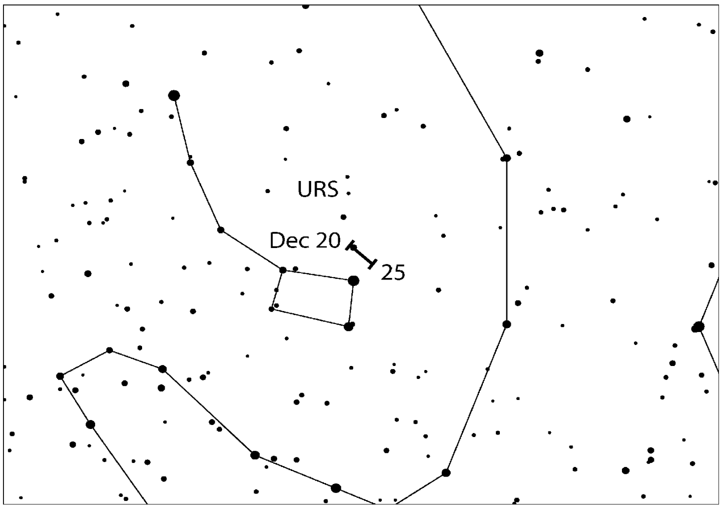
Active: December 5–February 4; Maximum: December 20 ($\lambda_\odot = 268°$); ZHR = 5; Radiant: $\alpha = 161°$, $\delta = +30°$; Radiant drift: see Table 6; $V_\infty = 64$ km/s; $r = 3.0$.



Like the COM, the DLM shower 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 $\approx 23^{\rm h}$ local time onwards. Almost new Moon means dark skies will prevail for covering the northern midwinter maximum night.

Ursids (015 URS)

Active: December 17–26; Maximum: December 22, 15^{h} 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; $r = 3.0$.



A very poorly-observed northern hemisphere shower which has produced at least two major outbursts in the past 70 years, in 1945 and 1986. Some events could have been missed due to weather conditions. Several lesser rate enhancements have been reported from 2006 to 2008 which might have been influenced by the relative proximity of the shower's parent comet, 8P/Tuttle, last at perihelion in January 2008. Many peaks, however, occurred when the parent was close to its aphelion, and so the slightly enhanced rates found in video data in 2014 and 2015 indicate that predictions are difficult. No unusually strong activity has been forecasted for the 2017 shower when this Calendar was being prepared. However, Jérémie Vaubaillon's model calculations show that there is an approach to a dust trail ejected in 884 AD on 2017 December 22, $14^{\mathrm{h}}43^{\mathrm{m}}$ UT. Although the trail has seen little perturbations only, the possible activity seems not to be high but detectable. 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 new Moon on December 18 provides undisturbed observing 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.

	$V_\infty = 25$ km/s					$V_\infty = 40$ km/s					$V_\infty = 60$ km/s				
$h\backslash D$	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 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_∞: 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.

9 Tables: lunar and shower data

Table 4. Lunar phases for 2017.

New Moon	First Quarter	Full Moon	Last Quarter
	January 5	January 12	January 19
January 28	February 4	February 11	February 18
February 26	March 5	March 12	March 20
March 28	April 3	April 11	April 19
April 26	May 3	May 10	May 19
May 25	June 1	June 9	June 17
June 24	July 1	July 9	July 17
July 23	July 30	August 7	August 15
August 21	August 29	September 6	September 13
September 20	September 28	October 5	October 12
October 19	October 27	November 4	November 10
November 18	November 26	December 3	December 10
December 18	December 26		

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in June 2016, with maximum dates accurate only for 2017. Except for the Antihelion Source, all other showers are listed in order of their maximum solar longitude. 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 which are noted as 'Var' = variable. For more information check the updates published e.g. in the IMO Journal WGN.

Shower	Activity	Maximum Date	Maximum $\lambda_\odot$	Radiant α	Radiant 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 (010 QUA)	Dec 28–Jan 12	Jan 03	283°.15	230°	+49°	41	2.1	120
γ-Ursae Minorids (404 GUM)	Jan 15–Jan 25	Jan 20	299°	228°	+67°	31	3.0	3
α-Centaurids (102 ACE)	Jan 28–Feb 21	Feb 08	319°.2	210°	−59°	56	2.0	6
γ-Normids (118 GNO)	Feb 25–Mar 28	Mar 14	354°	239°	−50°	56	2.4	6
Lyrids (006 LYR)	Apr 16–Apr 25	Apr 22	32°.32	271°	+34°	49	2.1	18
π-Puppids (137 PPU)	Apr 15–Apr 28	Apr 23	33°.5	110°	−45°	18	2.0	Var
η-Aquariids (031 ETA)	Apr 19–May 28	May 06	45°.5	338°	−01°	66	2.4	50
η-Lyrids (145 ELY)	May 03–May 14	May 09	48°.0	287°	+44°	43	3.0	3
Dayt. Arietids (171 ARI)	May 14–Jun 24	Jun 07	76°.6	44°	+24°	38	2.8	50
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. δ-Aquariids (005 SDA)	Jul 12–Aug 23	Jul 30	127°	340°	−16°	41	2.5	25
α-Capricornids (001 CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	5
Perseids (007 PER)	Jul 17–Aug 24	Aug 12	140°.0	48°	+58°	59	2.2	150
κ-Cygnids (012 KCG)	Aug 03–Aug 25	Aug 17	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. ε-Perseids (208 SPE)	Sep 05–Sep 21	Sep 09	166°.7	48°	+40°	64	3.0	5
Dayt. Sextantids (221 DSX)	Sep 09–Oct 09	Sep 27	184°.3	152°	+00°	32	2.5	5
Draconids (009 DRA)	Oct 06–Oct 10	Oct 08	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
δ-Aurigids (224 DAU)	Oct 10–Oct 18	Oct 11	198°	84°	+44°	64	3.0	2
ε-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 17	235°.27	152°	+22°	71	2.5	15
α-Monocerotids (246 AMO)	Nov 15–Nov 25	Nov 21	239°.32	117°	+01°	65	2.4	Var
Nov. Orionids (250 NOO)	Nov 13–Dec 06	Nov 28	246°	91°	+16°	44	3.0	3
Phoenicids (254 PHO)	Nov 28–Dec 09	Dec 02	250°.0	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)	Dec 05–Dec 20	Dec 08	257°	100°	+08°	41	3.0	2
σ-Hydrids (016 HYD)	Dec 03–Dec 15	Dec 11	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 22	270°.7	217°	+76°	33	3.0	10

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

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°			**GUM**					
Jan 15	127°	+17°			185°	+19°			224°	+69°				
Jan 20	132°	+16°			189°	+17°			228°	+67°				
Jan 25	138°	+15°			193°	+15°	**ACE**		232°	+65°				
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°	**ARI**											
Jun 5	267°	−23°	42°	+24°										
Jun 10	272°	−23°	47°	+24°										
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**		**CCY**		289°	+60°		
Sep 5	355°	−1°	**STA**		96°	+39°	43°	+40°	293°	+29°				
Sep 10	0°	+1°	12°	+3°	102°	+39°	48°	+40°	297°	+30°				
Sep 15			15°	+4°			53°	+40°	301°	+31°				
Sep 20			18°	+5°	**DSX**		59°	+41°	305°	+32°				
Sep 25			21°	+6°	150°	0°			309°	+33°				
Sep 30			25°	+7°	155°	0°	**ORI**				**OCT**			
Oct 5			28°	+8°			85°	+14°	**DAU**		165°	+78°	**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	**NOO**		56°	+15°	56°	+22°			147°	+24°			**AMO**	
Nov 15	81°	+16°	60°	+16°	61°	+23°			150°	+23°			112°	+2°
Nov 20	84°	+16°	64°	+16°	65°	+24°			153°	+21°			116°	+1°
Nov 25	88°	+16°			70°	+24°	**PHO**		156°	+20°	**PUP**		120°	0°
Nov 30	92°	+16°	**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°	98°	+9°
Dec 10	90°	+23°	108°	+33°	153°	+35°	22°	−53°	126°	+2°	125°	−45°	101°	+8°
Dec 15	96°	+23°	113°	+33°	157°	+33°	174°	+19°	130°	+1°	128°	−45°	105°	+7°
Dec 20	101°	+23°	118°	+32°	161°	+31°	177°	+18°	**HYD**		217°	+76°	108°	+7°
Dec 25	106°	+22°	**QUA**		166°	+28°	180°	+16°			217°	+74°	**MON**	
Dec 30	111°	+21°	226°	+50°	170°	+26°	**COM**				**URS**			
	ANT				**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. See also the details given for the Arietids (171 ARI) and the Sextantids (221 DSX) in the text part of the Calendar. 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. (Thanks to Jean-Louis Rault and Cis Verbeeck for comments on the Table.)

Shower	Activity	Max Date	$\lambda_\odot$ 2000	Radiant α	Radiant δ	Rate
Capricornids/Sagittariids (115 DCS)	Jan 13–Feb 04	Feb 01*	312.°5	299°	−15°	M*
χ-Capricornids (114 DXC)	Jan 29–Feb 28	Feb 13*	324.°7	315°	−24°	L*
April Piscids (144 APS)	Apr 20–Apr 26	Apr 22	32.°5	9°	+11°	L
ε-Arietids (154 DEA)	Apr 24–May 27	May 09	48.°7	44°	+21°	L
May Arietids (294 DMA)	May 04–Jun 06	May 16	55.°5	37°	+18°	L
o-Cetids (293 DCE)	May 05–Jun 02	May 20	59.°3	28°	−04°	M*
Arietids (171 ARI)	May 14–Jun 24	Jun 07	76.°6	42°	+25°	H
ζ-Perseids (172 ZPE)	May 20–Jul 05	Jun 09*	78.°6	62°	+23°	H
β-Taurids (173 BTA)	Jun 05–Jul 17	Jun 28	96.°7	86°	+19°	M
γ-Leonids (203 GLE)	Aug 14–Sep 12	Aug 25	152.°2	155°	+20°	L*
Sextantids (221 DSX)	Sep 09–Oct 09	Sep 27*	184.°3	152°	0°	M*

10 Useful addresses

A new feature on the IMO's website, introduced in 2015, is the online fireball form, which allows the submission of data on bright meteors. It also allows access to a database of fireball events, including graphical overviews showing observer locations, with details from witnesses' reports. This can be found here: `http://fireballs.imo.net/members/imo/report`

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. The web page also allows to access the data for own analyses. 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, F-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!