International Meteor Organization

2019 Meteor Shower Calendar

edited by Jürgen Rendtel [1]

1 Introduction

Welcome to the twenty-ninth edition of the International Meteor Organization (IMO) Meteor Shower Calendar. We intend to draw the attention of observers to both regularly returning meteor showers and to events which may be possible according to model calculations. We may experience additional peaks and/or enhanced rates but also the observational evidence of no rate or density enhancement. The position of peaks and data of shower meteor magnitudes along the stream are important information. Such data may help to improve our knowledge about the effects and interactions from the release of a meteoroid from its parent object until it enters our atmosphere. Further, the Calendar hopefully continues to be a useful tool to plan your meteor observing activities.

Nowadays, video meteor networks are operational throughout the year which are less affected by moonlit skies than visual observers. So we refer to the moonlight conditions first of all for the visual observer. The moonlight circumstances for observations of the three strongest annual shower peaks bring essentially new Moon for the Quadrantids, a waxing gibbous Moon for the Perseids and full Moon for the Geminids. Conditions for the maxima of the Lyrids (shortly after full Moon), the Orionids and the Leonids (last quarter) will strongly interfere with visual observations. The η-Aquariids are well observable (new Moon), while the Southern δ-Aquariids and the Ursids reach their maxima close to the new Moon. The Draconids see a waxing gibbous Moon.

Some interesting events are announced for 2019, although no spectacular outburst is predicted. 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 improve the data for established sources, including their outer ranges. Combining data obtained with different techniques may increase the reliability of derived quantities and is helpful for calibrating purposes. Since regular visual observations may be impractical for many people, however, 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.

[1] Based on information in the *Meteor Observers Workbook 2014*, edited by Jürgen Rendtel (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 (referred to as 'VID' in the Calendar), as amended by subsequent discussions and additional material extracted from data analyses produced since. Particular thanks are due to David Asher, Peter Jenniskens, Hutch Kinsman, Esko Lyytinen, Mikhail Maslov, Mikiya Sato and Jérémie Vaubaillon for new information and comments in respect of events in 2019 (see also the *References* in section 9). Koen Miskotte provided the information for the SDA and CAP activity in late July.

The heart of the Calendar is the Working List of Visual Meteor Showers (Table 5 on page 24) which is continuously updated so that it is the most accurate listing available today for visual 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 weak sources. 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 June Bootids and the October Draconids. 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 provide us with orbital data, 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, 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 of about 30° in right ascension and 15° in declination, 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 Taurid showers dominate the activity from the Antihelion region meaning 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 (page 25), while comments on the ANT's location and likely activity are given in the quarterly summary notes.

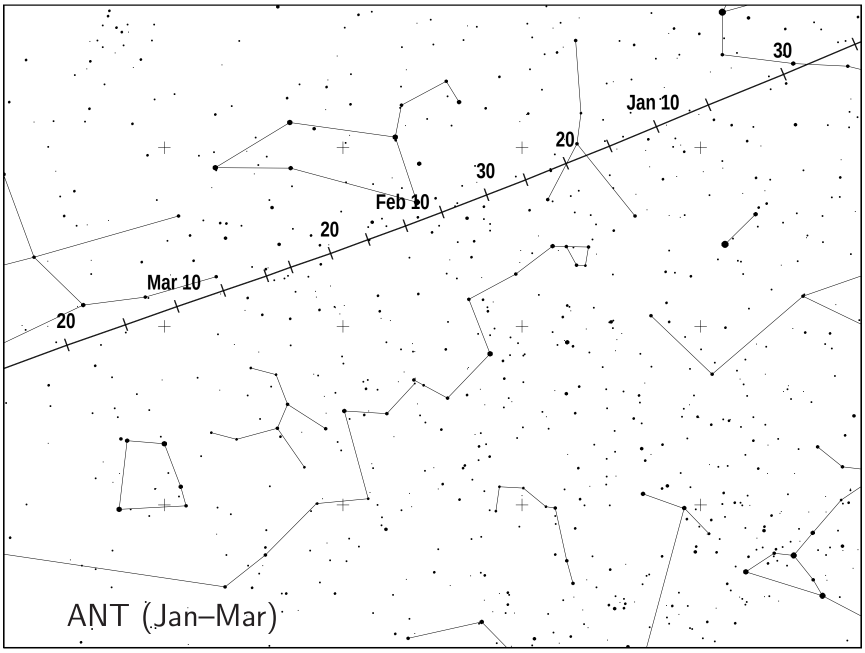
3 January to March

The year starts with two events on January 4: the **Quadrantid (010 QUA)** peak for the northern hemisphere observers probably close to 2^{h} UT. According to model calculations by Mikhail Maslov, the trail of **meteoroids ejected from comet 46P/Wirtanen** in 1974 passes the Earth at 0.00048 au distance on January 4, $18^{\mathrm{h}}26^{\mathrm{m}}$ UT. There is some similarity of the ejection of Draconid meteoroids which produced activity in 1999. The estimated ZHR may be about 10, dominated by faint optical and radio meteors. The radiant is located at $\alpha = 337°$, $\delta = -3°$, between the stars γ and κ Aquarii. At the calculated time, the Sun is below the horizon in Europe and most parts Africa. The radiant elevation is $\approx 45°$ in the western Sahara, $\approx 35°$ on the Iberian peninsula and lower further east.

Conditions regarding moon-free observations become worse towards the maximum of the **γ Ursae Minorids (404 GUM)** around January 12–15. Some late parts of the long-lasting **December Leonis Minorids (032 DLM)** can be traced until early February. The southern hemisphere's **α-Centaurids (102 ACE)** can be well observed in early February and the possible minor **γ-Normids (118 GNO)** of March are partly affected by moonlight (first quarter Moon on March 14).

In Table 3 of Peter Jenniskens' (2006) book possible activity from the 1-revolution **dust trail of comet C/1907 G1 (Grigg-Mellish)** is listed for March 31, $17^{\mathrm{h}}26^{\mathrm{m}}$ UT from a radiant at $\alpha = 309°$, $\delta = -60°$ (which is south of α Pavonis). There is no moonlight interference this time. A possible encounter of the same trail on 2018 March 31 was noted in the same source as "far" and no activity has been reported (this happened close to full Moon). It is worth to check for activity and timing as it may help us to improve our understanding of stream evolution.

The **ANT's** radiant centre is situated in south-east Gemini in January, 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. ANT ZHRs should be expected at a level of $2-3$ for most of the time. IMO analyses of visual and video data have suggested some ill-defined minor maxima with ZHRs ≈ 3 at various positions. A slight increase derived from video flux data may occur around $\lambda_{\odot} \approx 355°$ (2019 March 17).



A short outburst of the ***κ*-Cancrids (793 KCA)** was found on 2015 January 10 at 02^h50^m UT ($\lambda_\odot = 289.^\circ315$) in radar and video data. The radiant was at $\alpha = 138°$, $\delta = +9°$). Activity was also detected in the 2016 video data (Molau et al., 2016a). Although there are no visual data available yet, observers are encouraged to check especially the period around 2019 January 10, $03^h - 04^h$ UT for possible activity. The radiant of the Antihelion source centre is at $\alpha = 122°$, $\delta = +19°$, i.e. roughly 20° southeast, and the KCA meteors ($V_\infty = 47$ km/s) are faster than the ANT ($V_\infty = 30$ km/s).

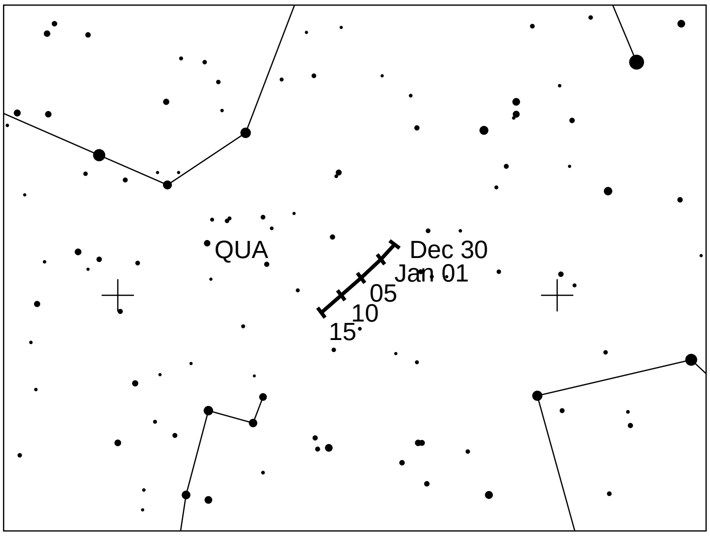
Expected approximate timings for the ***daytime shower maxima*** this quarter are: Capricornids/Sagittariids (115 DCS) – February 1, 24^h UT and χ-Capricornids (114 DXC) – February 13, 23^h UT. Recent radio results have implied the DCS maximum may fall variably sometime between February 1–4 however, 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 4, 02^h20^m UT ($\lambda_\odot = 283.^\circ16$),
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.

New Moon on January 6 creates optimum viewing conditions for the expected Quadrantid maximum on January 4. 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 02^h UT timing for the peak will be favourable for European longitudes. The $\lambda_\odot = 283.^\circ16$ maximum timing is based on the best-observed return of the shower ever analysed, from IMO data collected in 1992, as confirmed by radio results in most years since 1996. It also coincides with the closest approach to the stream calculated by Jérémie Vaubaillon ($\lambda_\odot = 283.^\circ17$). The peak is short-lived with an average duration (full width at half-maximum) of about four hours. Hence it can be easily missed if the observer is located outside the "main observing window" (high radiant in nighttime) or just a few hours of poor northern-winter weather. An added level of complexity comes from the fact mass-sorting of particles across the meteoroid stream related to the comet 96P/Machholz and the minor planet 2003 EH_1

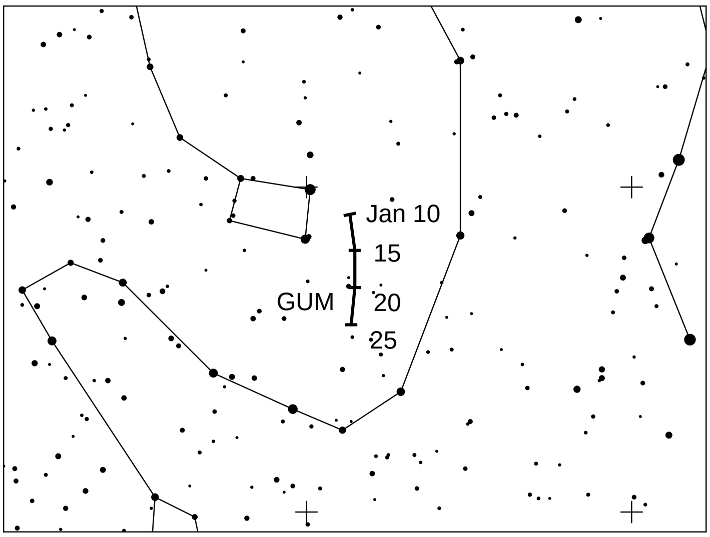
may make fainter objects (radio and telescopic meteors) reach maximum up to 14 hours before the brighter (visual and photographic) ones. Mass segregation effects have also been found for a small peak preceding the main maximum in 2016. On a few returns, a maximum following the main visual one by some 9–12 hours occurred in radio data. Visual confirmation of any repeat of such behaviour would be welcomed. Therefore observers should be alert throughout the shower activity period. QUA activity tends to be very low more than a day or so from the peak, but bright shower meteors may also occur in some nights around the peak on either side. The New Moon period leaves enough room to collect data of the outer range of the shower which is not yet well studied.



γ-Ursae Minorids (404 GUM)

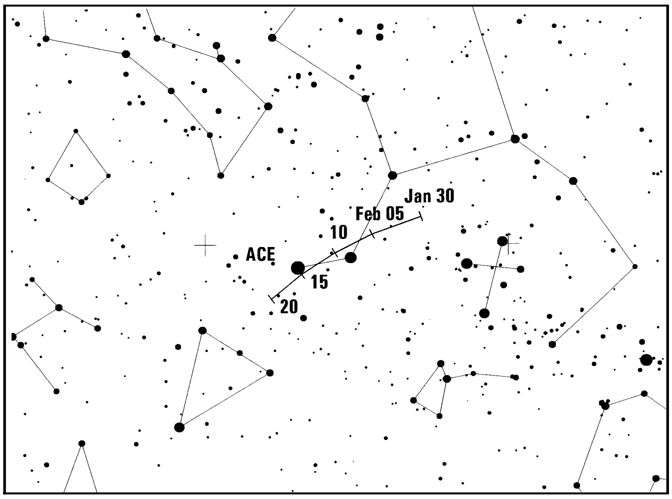
Active: January 10–22; Maximum: around January 18 ($\lambda_\odot = 298°$); ZHR $\approx$ 3;
Radiant: $\alpha = 228°$, $\delta = 67°$; Radiant drift: see Table 6;
$V_\infty = 31$ km/s; $r = 3.0$.

Little is yet known about this minor shower which has been detected in video and visual data recently and has been annually observed. Considering the velocity, meteors from this far northern radiant should be similar to the Ursids in their appearance. All data about the activity period and shower parameters should be treated as tentative and need further confirmation. First quarter Moon on January 14 allows observations mainly before the given maximum.



α-Centaurids (102 ACE)

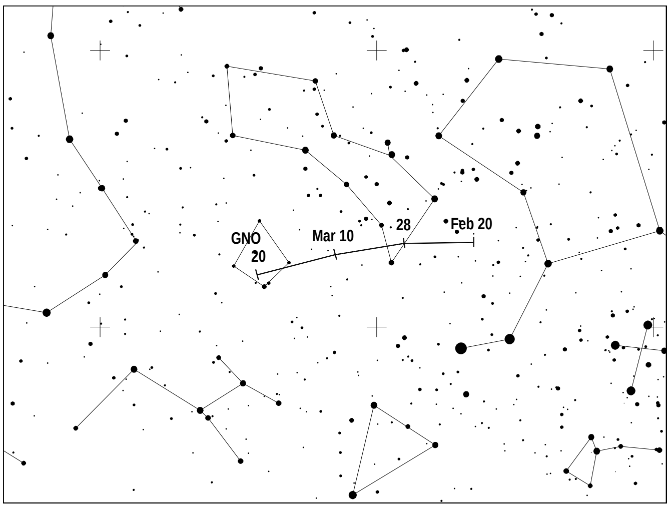
Active: January 31–February 20; Maximum: February 8, 13^h UT ($\lambda_\odot = 319\overset{\circ}{.}2$);
ZHR = variable, usually ≈ 6, but may reach 25+;
Radiant: $\alpha = 210°$, $\delta = -59°$; Radiant drift: see Table 6;
$V_\infty = 58$ km/s; $r = 2.0$.



The α-Centaurids are one of the main southern summer high points occasionally including bright meteors or fireballs. The average peak ZHR between 1988–2007 was merely 6 though (WB, p. 18), albeit coverage has often been very 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. Further data is needed to obtain information about the structure and extension of the stream. The listed activity period is based on recent video data. 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 falls a few days after new Moon and is therefore favourable for dark-sky coverage of the entire night.

γ-Normids (118 GNO)

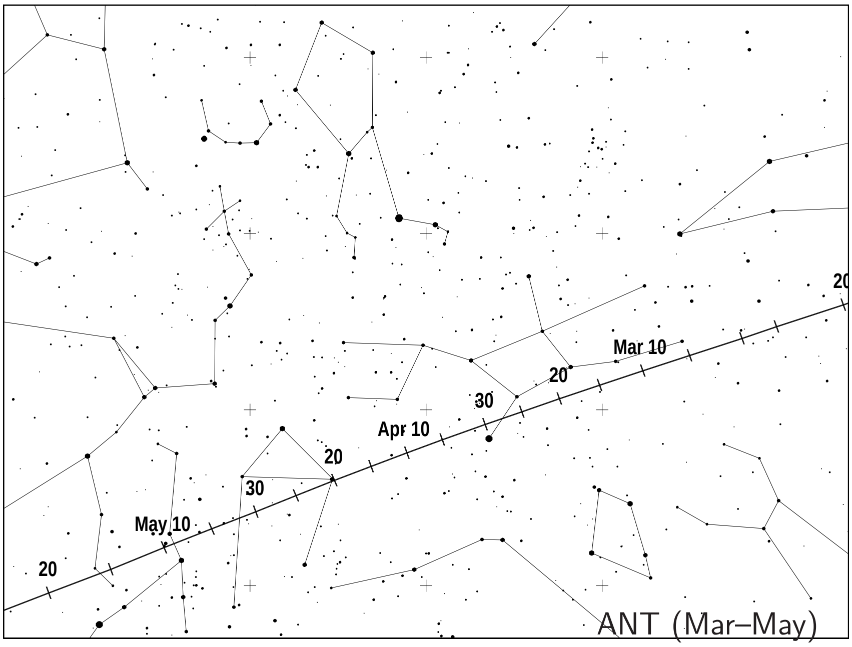
Active: February 25–March 28; Maximum: March 15 ($\lambda_\odot = 354°$); ZHR = 6;
Radiant: $\alpha = 239°$, $\delta = -50°$, Radiant drift: see Table 6;
$V_\infty = 56$ km/s; $r = 2.4$.



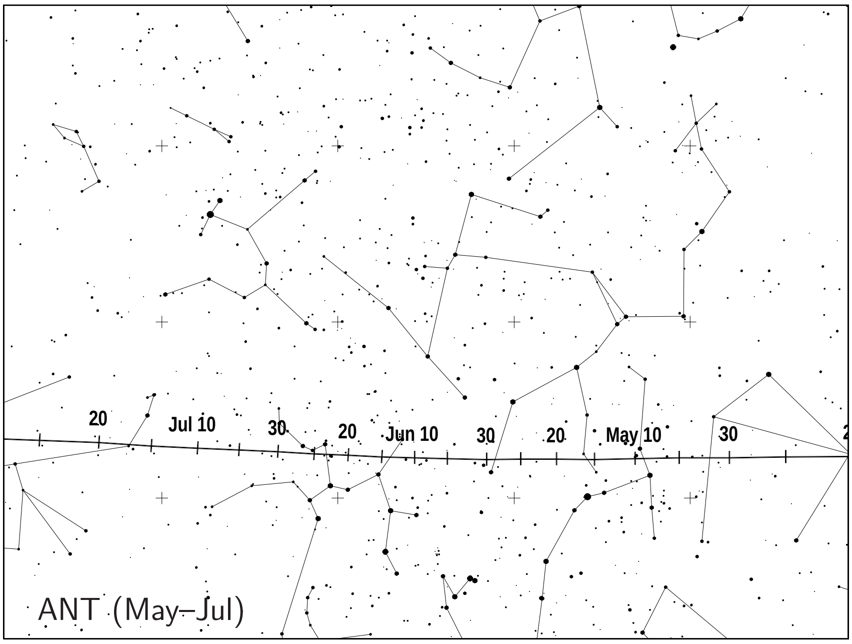
For most of their activity, γ-Normid ZHRs seem to be virtually undetectable above the background sporadic rate. An analysis of IMO data from 1988–2007 showed an average peak ZHR of ≈ 6 at $\lambda_{\odot} = 354°$, with ZHRs < 3 on all other dates during the shower (HMO, pp. 131–132). Results since 1999 have suggested the possibility of a short-lived peak alternatively between $\lambda_{\odot} \approx 347°–357°$, equivalent to 2019 March 8–18. A later 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). Moonlight circumstances are best for the March 15 period (just after first quarter) but will strongly interfere with the possible late maximum timing.

4 April to June

Meteor activity increases towards the April-May boundary, particularly caused by optically unobservable (daytime) showers. Full Moon on April 19 completely ruins the **Lyrid (006 LYR)** maximum on April 23 around 0^{h}UT (at 32°.32). The waning gibbous Moon leaves a little time in the evening for the **π-Puppid (137 PPU)** maximum which should occur near 6^{h} UT on April 24. In 2019, both the **η-Aquariid (031 ETA)** maximum period, due around May 5, and the **η-Lyrids (145 ELY)** with a potential peak on May 9 or slightly later can be perfectly observed in moonless nights. The potential peak periods of the **June Bootids (170 JBO)** see a waning crescent Moon (last quarter on June 25).



According to analyses of visual and video IMO data, the **ANT** should produce ZHRs between 2 and 4 with insignificant variations. There may be a rather slow increase towards end-May followed by a decrease into July. 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.

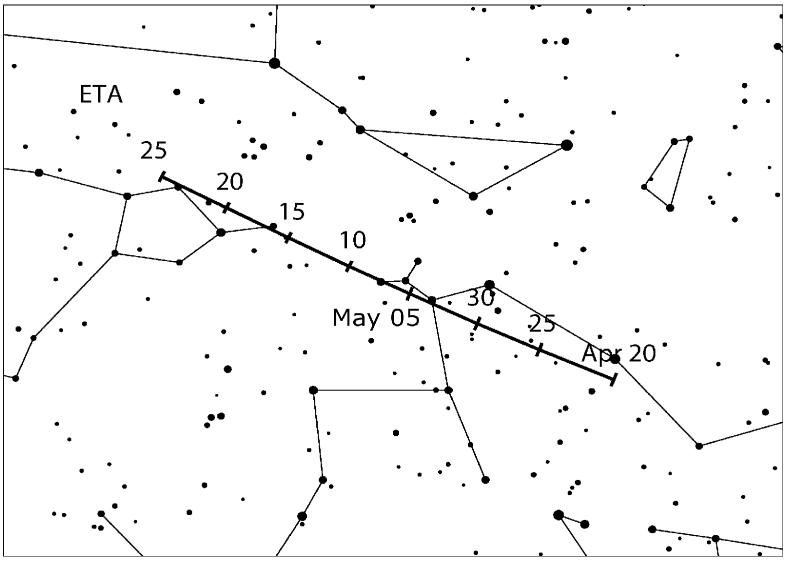


Daytime showers: In the second half of May and throughout June, most of the annual meteor action switches to the daylight sky, with several shower peaks expected during this time. For radio observers, the expected UT peak times for these showers are as follows:
April Piscids (144 APS) – April 23, 4^h;
ε-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, 22^h (more details see page 10);
ζ-Perseids (172 ZPE) – June 9, 24^h;
β-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. 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 deviate from the given times. 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 as having a peak on April 24, although the IAU seems not to recognise this as a genuine shower. Similarly, there are problems in identifying the o-Cetids in the IAU stream lists. 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.

η-Aquariids (031 ETA)

Active: April 19–May 28; Maximum: May 6, 14^h UT ($\lambda_\odot = 45.^\circ5$);
ZHR = 40 (periodically variable, $\approx$ 40–85);
Radiant: $\alpha = 338^\circ$, $\delta = -1^\circ$; 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. Further north, observers can expect only few occasional shower meteors. The ETA 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 glowing 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 for meteor shower association.



A relatively broad maximum, sometimes with a variable number of submaxima, occurs around May 5–6. IMO analyses of the general activity profile based on data collected between 1984–2001, have shown that the ZHR is 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 next "peak" is due around 2020–2022, so ZHRs should be better than in the previous years. Activity around the most recent ZHR peak period in 2008 and 2009 reached ≈ 85 and 65, respectively. In 2013, ZHRs up to ≈ 70 have been recorded (WB, p. 24), and the 2017 return yielded a peak ZHR of 75 as well.

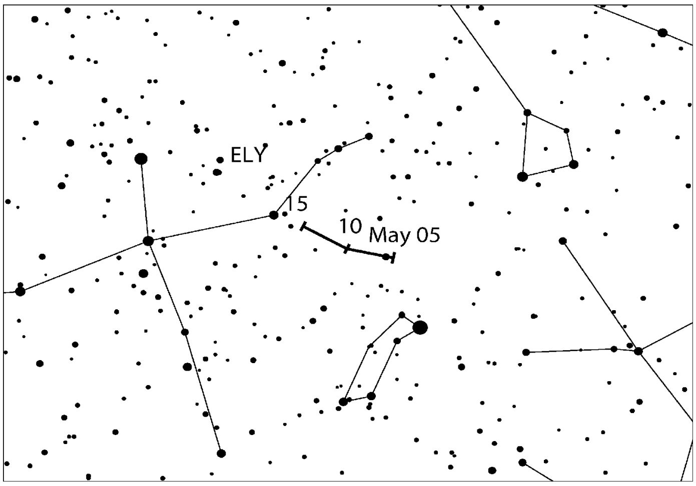
Modelling of the stream by Mikhail Maslov yields two trail encounters for 2019. The times for these are May 4, between $4-10^{\rm h}$ UT (meteors from -539) and May 6, $12-20^{\rm h}$ UT (-985 trail). Both may add $5-10$ to the general rate.

New Moon on May 4 creates ideal viewing conditions this year. All forms of observing can be used to study it, with radio work allowing activity to be followed even from many northern latitude sites throughout the daylight morning hours. The radiant culminates at about $08^{\rm h}$ local time.

η-Lyrids (145 ELY)

Active: May 3–14; Maximum: May 9 ($\lambda_\odot = 48.^\circ4$); ZHR = 3;
Radiant: $\alpha = 287^\circ$, $\delta = +44^\circ$; Radiant drift: see Table 6;
$V_\infty = 43$ km/s; $r = 3.0$.

This weak shower is associated with Comet C/1983 H1 IRAS-Araki-Alcock. Most of the recent observational data on it has come from video results, which have suggested the maximum might fall at $\lambda_\odot = 50^\circ$ instead (if so, on 2019 May 11). There is little evidence from visual observations as yet, but the discussion on p. 25 of WB has more information. Video as well as careful visual plotting will be needed to separate any potential η-Lyrids from the sporadics. The general radiant area is usefully on-view all night from the northern hemisphere (primarily), with very little Moon interference around May 9–11 this year.



Daytime Arietids (171 ARI)

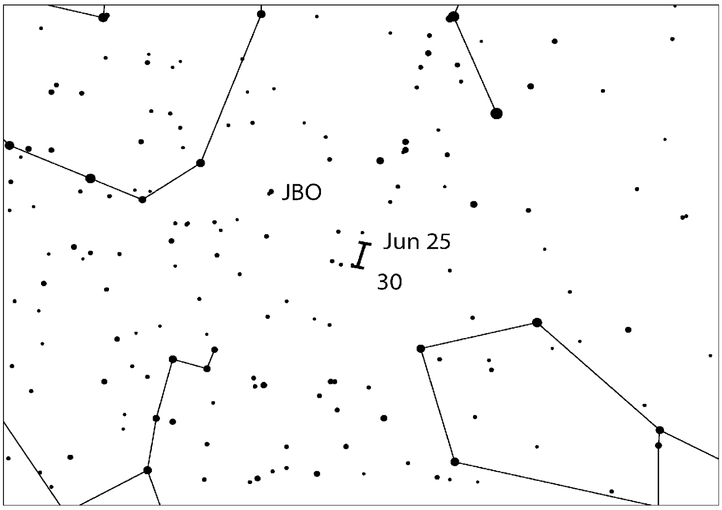
Active: May 14–June 24 (uncertain); Maximum: June 08 ($\lambda_\odot = 76.^\circ6$); ZHR $\approx$ 30(?);
Radiant: $\alpha = 44^\circ$, $\delta = +24^\circ$; Radiant drift: see Table 6;
$V_\infty = 38$ km/s; $r = 2.8$.

The radiant is located only about 30° west of the Sun. 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)

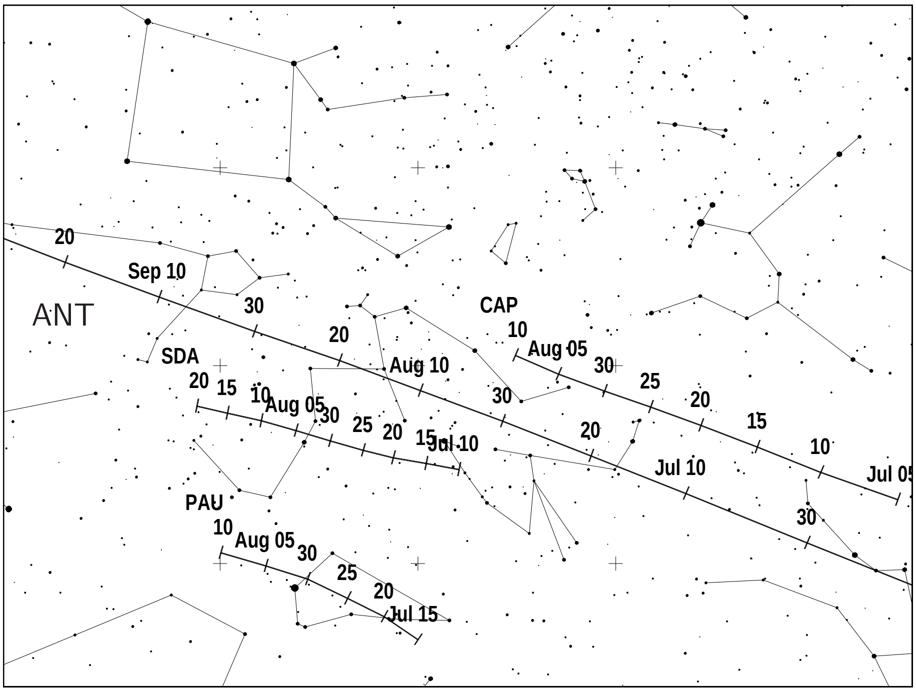
Active: June 22–July 2; Maximum: June 27, $22^{\rm h}$ UT ($\lambda_\odot = 95.^\circ7$), but see text;
ZHR = variable, 0–100+;
Radiant: $\alpha = 224^\circ$, $\delta = +48^\circ$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.2$.

This source was reinstated on the Working List only after its unexpected return of 1998 (ZHR $50 - 100+$ for more than half a day). Another outburst of similar length (ZHR $\approx 20 - 50$) was observed on 2004 June 23. The return predicted in 2010 yielded a poorly established ZHR < 10 on June 23–24. Prior to 1998, only three more probable returns had been detected, in 1916, 1921 and 1927 (however, with different reliability). Since there were no significant reports between 1928 and 1997, it seemed likely these meteoroids no longer encountered Earth. The 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 (orbital period about 6.4 years). 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. For the 2019 return, there are no predictions of peculiar activity published.



We encourage all observers to routinely monitor throughout the proposed period, in case of any activity. 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 Moon reaches its last quarter on June 25. VID suggested some June Boötids may be visible in most years around June 20 − 25 but with activity largely negligible except near $\lambda_{\odot} = 92^{\circ}$ (2019 June 24), radiating from an area about ten degrees south of the radiant found in 1998 and 2004, close to $\alpha = 216^{\circ}$, $\delta = +38^{\circ}$.

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 with ZHRs of ≈ 2 to 3. 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 faster and 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. New Moon on August 1 allows us to monitor the activity during the period of highest rates from these southern radiants which are due on July 27 (PAU) and July 30 (CAP, SDA), respectively.

On 2016 July 28 at 00^h07^m UT a remarkable outburst (ZHR probably of the order of 100) of the **July γ-Draconids (184 GDR)** was detected by radar and video observations (Molau et al., 2016b). The same position is reached again on 2019 July 28 near 18^h30^m UT. When writing this text, the return to the respective position on 2018 July 28 has still to come, but whatever happens in 2018, it is well worth a check whether something is observable around this time. The radiant is at $\alpha = 280°$, $\delta = +51°$, and the meteors have medium speed ($V_\infty = 27$ km/s).

First quarter Moon on August 7 allow the observers to record the ascend towards the maximum of the **Perseids (007 PER)** which is due between $\lambda_\odot \approx 139.°8$ to $140.°3$, equivalent to 2019 August 13 02^h to 15^h UT. Table 5d of Peter Jenniskens (2006) lists the encounter of a filament on August 13 at 02^h UT just at the beginning of the obove mentioned interval with a possible ZHR of about 110.

Full Moon on August 15 allow moon-free observations of the minor **κ-Cygnids (012 KCG)** only after their maximum on August 18. Conditions are optimal for the **Aurigids (206 AUR)** on September 1. The interesting **September ε-Perseids (208 SPE)** produced outbursts in 2008 and 2013 reach their maximum on September 9.

In 2015, several video data sets showed low rates had persisted essentially throughout September, identified as originating with the **χ-Cygnids (757 CCY)**. A weak maximum was found on September 14/15 (ZHRs about 2 or 3). The shower was also suspected in previous years, but at a lower activity level, hence further observations would be useful, although the period is very badly moonlit. 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 late September to early October. There is no moonlight interference but because the radiant appears only at dawn, the twilight is the main limiting factor.

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 **daytime radio observers**, the high activity of May-June has waned, but there remain the γ-Leonids (203 GLE; peak due near August 25, 23^h UT, albeit not found in recent radio results), and the Sextantids (221 DSX; see page 15).

Piscis Austrinids (183 PAU)

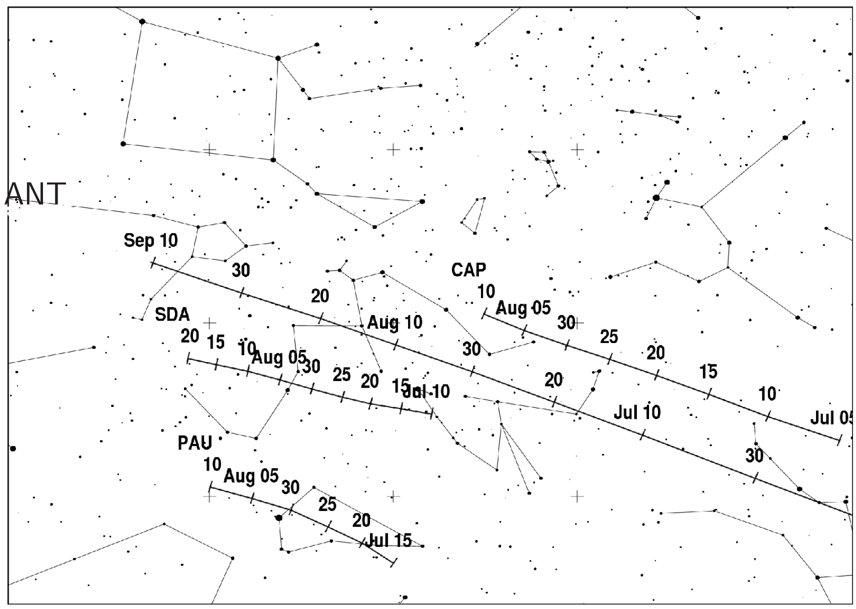
Active: July 15–August 10; Maximum: July 28 ($\lambda_\odot = 125°$); ZHR = 5; Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 6; $V_\infty = 35$ km/s; $r = 3.0$.

Information of the PAU is still scarce and details on the shower are not well-confirmed. It seems possible the ZHR may be overestimated. However, that impression could be due simply to the large amount of northern hemisphere summer data, and the almost complete lack of southern hemisphere winter results, on it. Observations are needed to establish and improve 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; $r = 2.5$.

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. New Moon on August 1 provides optimal conditions for all of the showers in the Aquarius-Capricornus region at the end of July. 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)

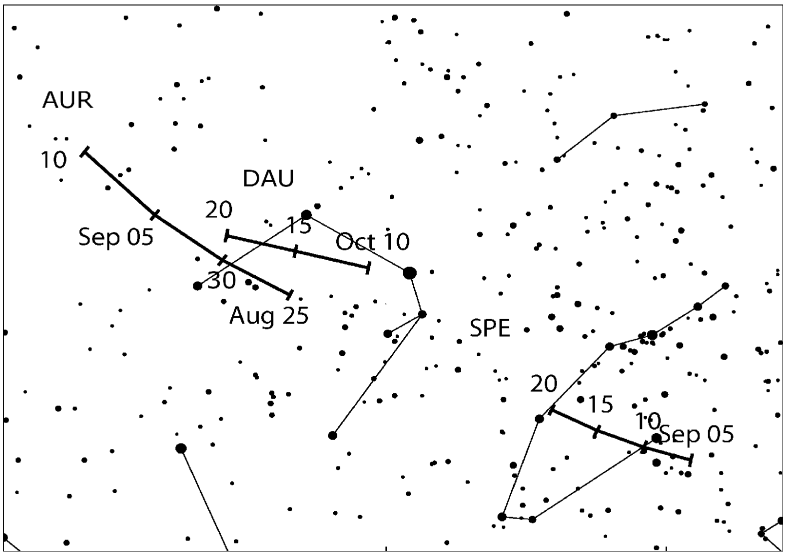
Active: July 3–August 15; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 5;
Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 6;
$V_\infty = 23$ km/s; $r = 2.5$.

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.

Aurigids (206 AUR)

Active: August 28–September 5; Maximum: September 1, 14^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; $r = 2.5$.

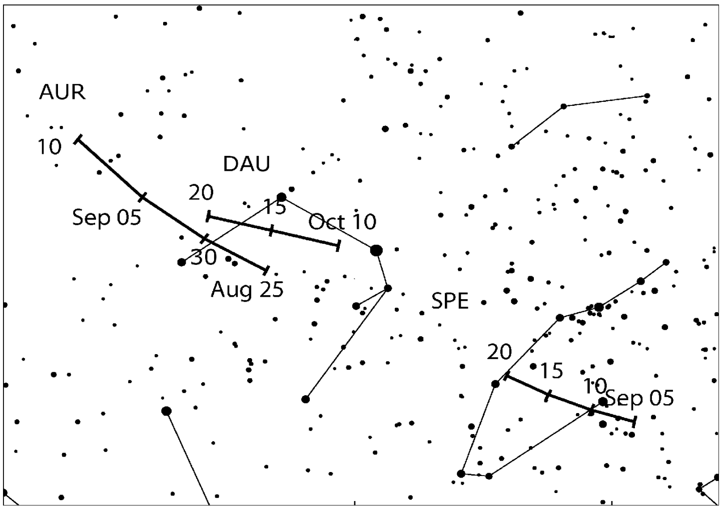
This northern-hemisphere shower has produced short, unexpected, outbursts at times, with peak ZHRs of $\approx$ 30–40 recorded in 1935, 1986 and 1994. Other events may have been missed because the shower has not been monitored regularly until very recently. Only three observers covered the 1986 and 1994 outbursts, for instance. The first predicted outburst happened roughly as expected in 2007, characterized by many bright meteors. The peak ZHR of $\approx$ 130 lasted only for about 20 minutes. Radio data suggested there was a 'tail' to that event where more faint meteors continued for maybe an hour after the strongest peak, but visual observers could not confirm this, probably due to the moonlit sky. The Aurigid radiant reaches a useful elevation only after $\approx 01^h$ local time. For 2019, there are no predictions for enhanced rates from this source, but new Moon on September 1 guarantees perfect conditions to check.



September ε-Perseids (208 SPE)

Active: September 5–21; Maximum: September 9, 23^h UT ($\lambda_\odot = 166\overset{\circ}{.}7$), and possibly September 9, 19^h UT ($\lambda_\odot = 166\overset{\circ}{.}8$) – see text; ZHR = 5;
Radiant: $\alpha = 48°$, $\delta = +40°$; Radiant drift: see Table 6;
$V_\infty = 64$ km/s; $r = 3.0$.

Full Moon on September 14 limits the conditions to observe this primarily northern-hemisphere shower to the ascending branch and the favourable morning hours. The radiant area is well on-view all night from about 22^h–23^h local time for mid-northern locations. This shower produced outbursts on 2008 September 9, between roughly $\lambda_\odot = 166\overset{\circ}{.}894$–$166\overset{\circ}{.}921$, and another bright-meteor event with a very sharp peak at $\lambda_\odot = 167\overset{\circ}{.}188$ in 2013. According to Esko Lyytinen's modelling the next impressive SPE return may not be before 2040, and the 2019 activity should be at the usual annual level. At the time of writing this text, a possible outburst based on Mikiya Sato's calculations on **2018** September 09, 19^h12^m UT ($\lambda_\odot = 166\overset{\circ}{.}801$) is still due. Mikiya Sato notes that the rate on **2019** September 10, 02^h06^m UT ($\lambda_\odot = 166\overset{\circ}{.}831$) is probably lower than in 2018. Since we do not yet know more about the position and extension of the assumed 1-revolution dust trail of the unknown parent object, monitoring of the activity is of great importance.



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: 1° per day; $V_\infty = 32$ km/s; $r = 2.5$ (uncertain).

Visual observers may observe 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 intervals no longer than about 15–20 minutes, determining the limiting magnitude frequently during each period. The timing, and even the date, of the Sextantid maximum is 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.

6 October to December

During the last quarter of the year, most of the more significant showers are observable under rather poor lunar conditions. The **Draconids (009 DRA)** – for which no activity peculiarities are announced – on October 9 close to $06^{\rm h}$ UT are badly affected by a waxing gibbous Moon. It illuminates the evening hours with a high radiant position. At mid-northern latitudes, the radiant is below 20° elevation after local midnight. For both, the **Orionids (008 ORI)** on October 22 and the **Leonis Minorids (022 LMI)** on October 25 (just after last quarter Moon) the "dark window" between radiant rise and moonlight interference is limited. This also holds for the **Leonids (013 LEO)** on November 18 (waning gibbous). The best and most interesting shower of the entire year, the **Geminids (004 GEM)**, reaches its maximum just after full Moon. The peak period is expected between $\lambda_\odot = 261\overset{\circ}{.}5$ and $\lambda_\odot = 262\overset{\circ}{.}4$ (corresponds to 2019 December 14 between $02^{\rm h}$ and $23^{\rm h}$ UT). During this period, the moon is located in the constellation Gemini only a few degrees south of the radiant. Due to the observed increase of the peak ZHR over the last decades (Ryabova & Rendtel, 2017) observations are of interest. Assuming a transparent sky and shielding the moonlight, an observer may still see about 20+ Geminids per hour after midnight with a high radiant position.

The conditions are better for the **November Orionids (250 NOO)** on November 28, the **Phoenicids (254 PHO)** on December 2, the **Puppid-Velids (301 PUP)** early December, the **December Leonis Minorids (032 DLM)** on December 20 and particularly for the **Ursids (015 URS)** on December 23.

The two Taurid branches dominate most of the activity from the Antihelion region in the last quarter as described above. The **ANT** resume only around December 10, as the Northern Taurids (maximum around November's full Moon) fade away, from a radiant centre that tracks across southern Gemini during later December, likely producing ZHRs < 2.

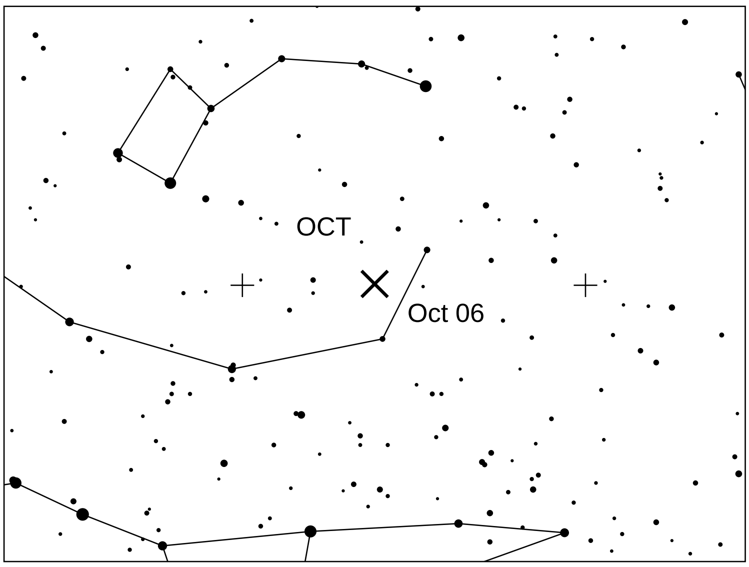
October Camelopardalids (281 OCT)

Active: October 5–6; Maximum: October 6, 09^h40^m ($\lambda_\odot = 192\overset{\circ}{.}58$); ZHR = 5(?)
Radiant: $\alpha = 164°$, $\delta = 79°$; Radiant drift: negligible;
$V_\infty = 47$ km/s; $r = 2.5$ (uncertain).

Short-lived video outbursts were first recorded in 2005 and 2006 on October 5/6 (near $\lambda_\odot 193°$) from this north-circumpolar radiant. The shower has been detected annually (Molau et al., 2017) and produced a peak at $\lambda_\odot = 192\overset{\circ}{.}58$ repeatedly with an estimated ZHR of about 5. Enhanced activity was found last on 2016 October 5 at the predicted position at 14^h45^m UT in radio forward scatter data and video camera data from Finland.

Assuming a long-period parent, and using the 2005 outburst as reference point, Esko Lyytinen mentions that we might see activity near $\lambda_\odot = 192\overset{\circ}{.}529$ in 2018 and 2019. The return on 2018 October 6, 02^h17^m UT, still has to come. The same position is reached on 2019 October 6 08^h25^m UT. Surprises are possible because the stream is quite reliably a long-period case with an untypical wide 1-revolution trail *or* we have not yet encountered the densest part of the trail (communicated by Esko Lyytinen). Data of the 2018 return possibly shed more light on this.

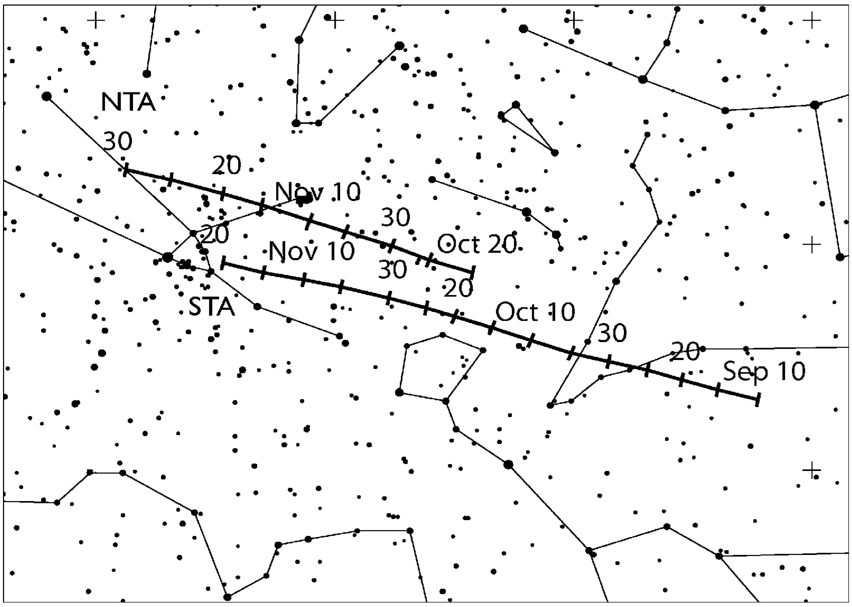
Both the recurrent maximum given in the box and the calculated position are favourable for observers at (North) American longitudes. The first quarter Moon mainly disturbs the evening hours.



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; $r = 2.3$.

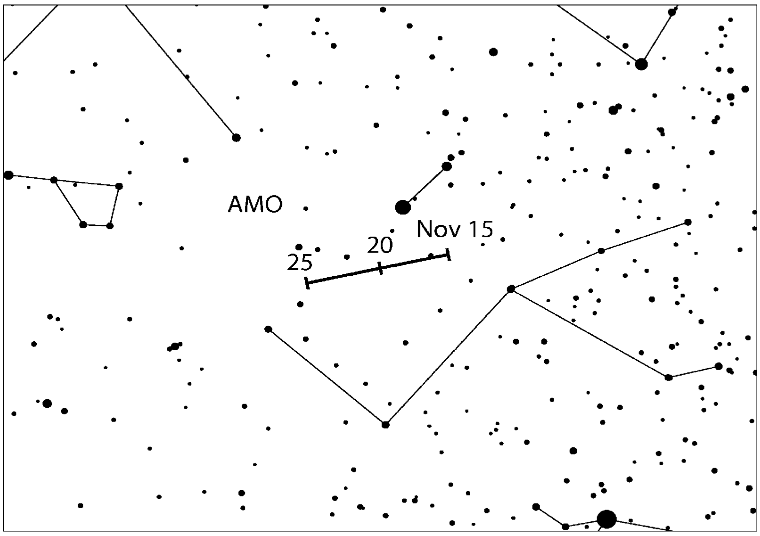
This stream, with its Northern counterpart, forms part of the complex associated with Comet 2P/Encke. For shower association, assume the radiant to be an oval area, extending about 20° in α and about 10° in δ, centred on the radiant position for any given date. The Taurid activity overall dominates the 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 to practice 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 visual plotting work have indicated the Southern branch reaches its peak about a month before the Northern one, this year only shortly before October's full Moon. Its near-ecliptic radiant means all meteoricists can observe the STA, albeit northern hemisphere observers are somewhat better-placed, as here suitable radiant elevations 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.



α-Monocerotids (246 AMO)

Active: November 15–25; Maximum: November 22, 06^{h} UT ($\lambda_\odot = 239\overset{\circ}{.}32$);
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; $r = 2.4$.

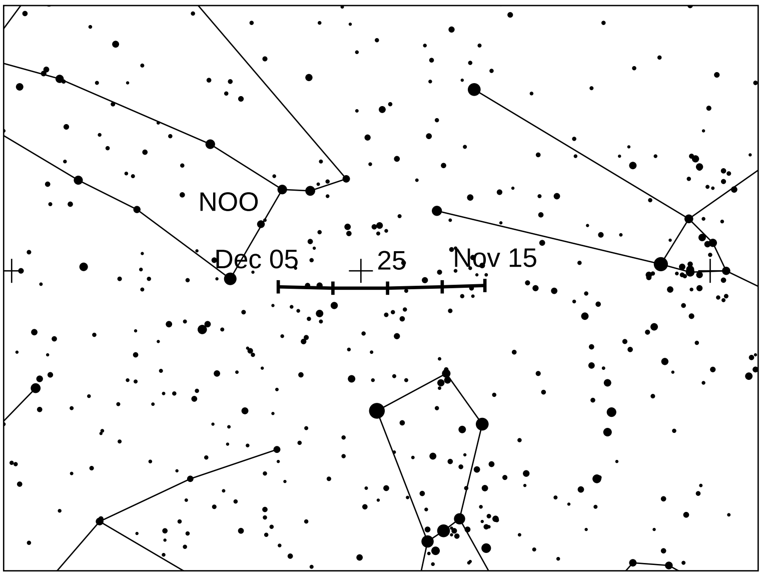
The most recent α-Monocerotid outburst was observed in 1995. The peak ZHR of ≈ 420 lasted for just five minutes, the entire outburst 30 minutes. Recent modelling by Esko Lyytinen has indicated the main AMO trail crosses the Earth's **orbit** in 2017 and 2020. However, the Earth is not near those points in November, so no strong outburst 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 modelling hints at a possible dust trail approach at $\lambda_\odot = 239^\circ\!.310$ (2019 November 22, 04^h56^m UT) – perhaps the highest rate in the 2016–2019 interval. The same trail encounter (classified as "far") is listed in Table 3 of Peter Jenniskens' (2006) book ($\lambda_\odot = 239^\circ\!.306$; 2019 November 22, 04^h52^m UT).



Seen the small activity mainly found in radio data close to the positions expected to Mikiya Sato's previous calculations in 2016 and 2017, observers are advised to monitor the AMO annually. The brevity of all past outbursts means breaks under clear skies should be kept to a minimum near the predicted peak. The waning Moon (last quarter on the 18th) should allow useful observations when 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 ($\lambda_\odot = 246^\circ$); ZHR = 3; Radiant: $\alpha = 91^\circ$, $\delta = +16^\circ$; Radiant drift: see Table 6; $V_\infty = 41$ km/s; $r = 3.0$.



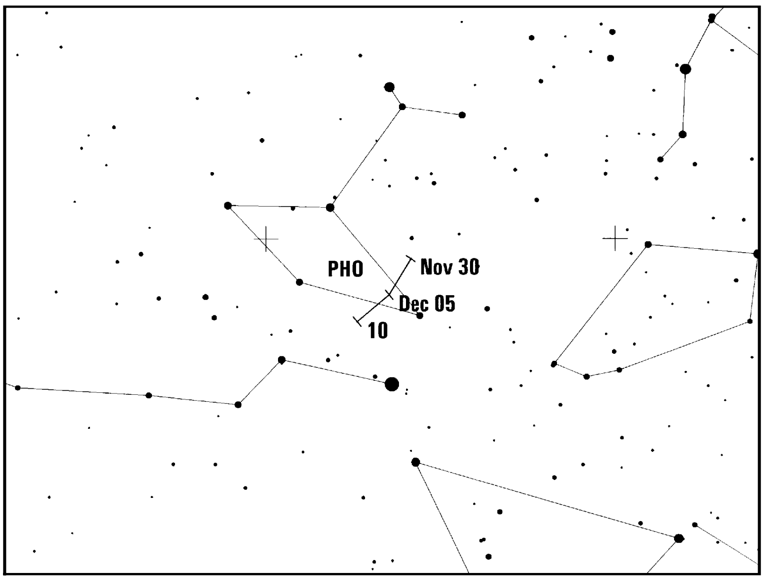
Detailed analysis of video data revealed that there are two consecutive, very similar showers whose activity intervals overlap by only two degrees in solar longitude: the November Orionids (250 NOO), followed by the Monocerotids (019 MON). In the last days of November the shower is the strongest source 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 distinguish meteors from the two sources. Additionally, 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. New Moon on November 26 offers best circumstances to collect data.

Phoenicids (254 PHO)

Active: November 22–December 9; Maximum: December 2, 19^h UT ($\lambda_\odot = 250\overset{\circ}{.}0$);
ZHR = variable, usually none, see text;
Radiant: $\alpha = 18°$, $\delta = -53°$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.8$.

Only one impressive Phoenicid return has been reported, that of its discovery in 1956, when the peak ZHR probably reached ≈ 100, possibly with several peaks spread over a few hours. Recent significant activity was observed on 2014 December 1. This was predicted by Sato and Watanabe (2010). In the same paper, several encounters with dust trails are calculated for the 2019 return. The Earth comes closest to the 1898 dust trail at $\lambda_\odot = 250\overset{\circ}{.}132$ (2019 December 2, 21^h29^m). The estimated ZHR may reach 12. A weaker trail may be encountered at $\lambda_\odot = 240\overset{\circ}{.}140$ already on November 23, 00^h39^m

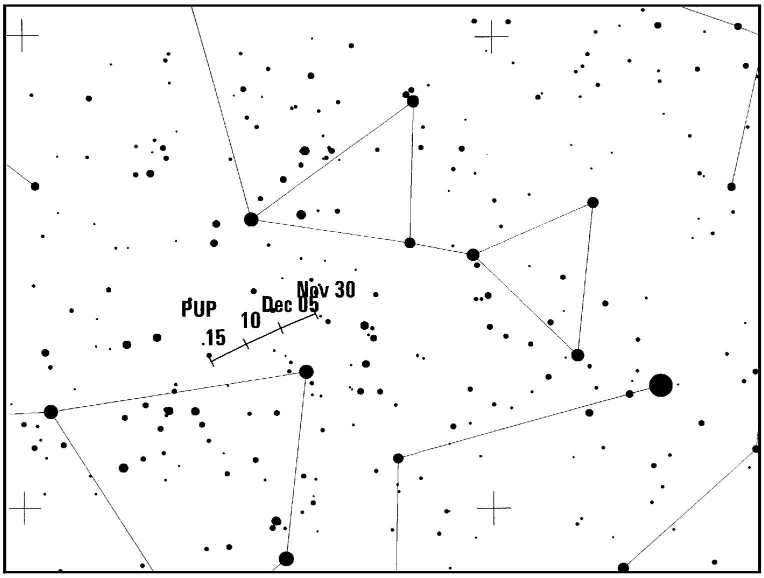
As the dates are around new Moon (November 26), observers should check for possible Phoenicids throughout the entire period given above. From the southern hemisphere (only), the Phoenicid radiant culminates at dusk, remaining well on view for most of the night. Phoenicids are extremely slow meteors.



Puppid-Velids (301 PUP)

Active: December 1–15; Maximum: December ≈ 7 ($\lambda_\odot \approx 255°$); ZHR ≈ 10;
Radiant: $\alpha = 123°$, $\delta = -45°$; Radiant drift: see Table 6;
$V_\infty = 40$ km/s; $r = 2.9$.

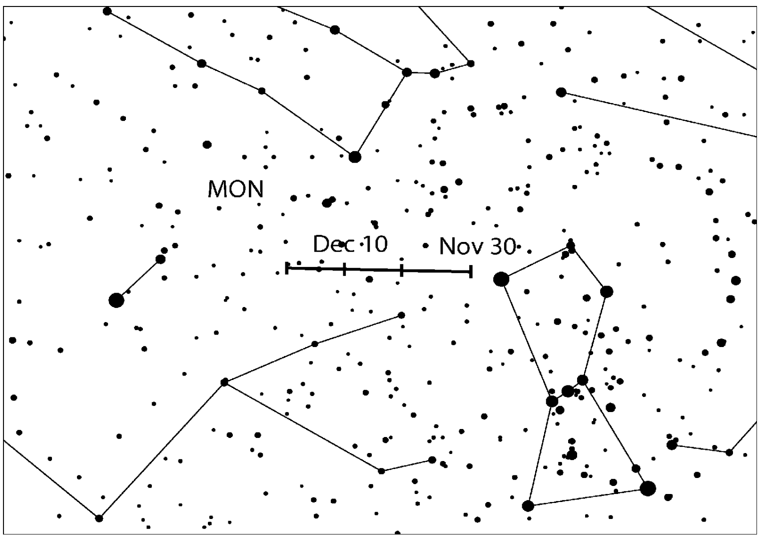
This is a complex system of poorly-studied showers, visible chiefly from locations south of the equator. Several sub-streams have been proposed (301 PUP representing an "average" position), with radiants so tightly clustered, visual observing cannot readily separate them. The activity is poorly-established, though the higher rates seem to occur in early to mid December, with a waxing Moon this year (first quarter on December 4). Some PUP activity may be visible prior and after the given period. Occasional bright fireballs, notably around the suggested maximum, have been reported regularly. The radiant area is on-view all night, highest towards dawn.



Monocerotids (019 MON)

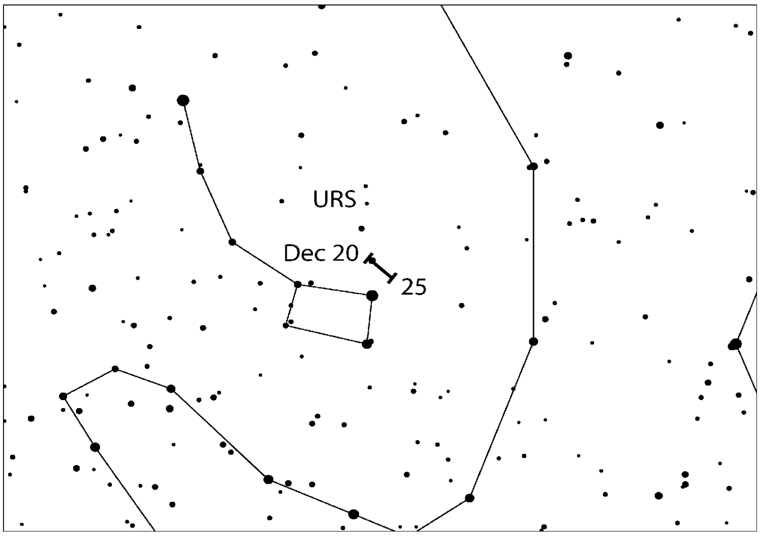
Active: November 27–December 17; Maximum: December 9 ($\lambda_\odot = 257°$); ZHR = 3; Radiant: $\alpha = 100°$, $\delta = +08°$; Radiant drift: see Table 6; $V_\infty = 42$ km/s; $r = 3.0$.

This very minor shower's details need further improvement by observational data. Visual data give a maximum of ZHR 2–3 at $\lambda_\odot \approx 257°$. Video data (2011–2016) show a peak at $\lambda_\odot \approx 262\overset{\circ}{.}0$ (i.e. December 14) with a ZHR of the order of 8 coinciding with the Geminid peak. Care needs to be taken to clearly distinguish MON from GEM. Visual observers should choose their field of view such, that the radiants do not line up. (Field centres near Taurus in the evening or near Leo in the morning are possible choices.) 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^h30^m local time.



Ursids (015 URS)

Active: December 17–26; Maximum: December 23, 03^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; $r = 2.8$.



A 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, which were possibly influenced by the relative proximity of the shower's parent comet, 8P/Tuttle, last at perihelion on 2008 January 27. Slightly enhanced rates have also been reported in 2011 and 2014. Other events could have been missed easily. For 2019, an encounter of an Ursid filament is announced by Peter Jenniskens (2006; Table 5b) at $\lambda_\odot = 270\overset{\circ}{.}49$ (2019 December 22, 21^h39^m) with a possible ZHR of the order of 30. At this time, there is rather little interference by the waning Moon (last quarter on December 19). Recent data analyses have shown that the population index is rather $r = 2.2$ around the maximum, i.e. the portion of slightly brighter shower meteors is higher than in the outer sections of the shower, although the Ursids are not known for fireball events. The Ursid radiant is circumpolar from most northern sites, while the shower is not observable from most southern locations. The radiant culminates after daybreak, and is highest in the sky after midnight.

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 Tables: lunar and shower data

Table 4. Lunar phases for 2019.

New Moon	First Quarter	Full Moon	Last Quarter
January 6	January 14	January 21	January 27
February 4	February 12	February 19	February 26
March 6	March 14	March 21	March 28
April 5	April 12	April 19	April 26
May 4	May 12	May 18	May 26
June 3	June 10	June 17	June 25
July 2	July 9	July 16	July 25
August 1	August 7	August 15	August 23
August 30	September 6	September 14	September 22
September 28	October 5	October 13	October 21
October 28	November 4	November 12	November 19
November 26	December 4	December 12	December 19
December 26			

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in June 2018, with maximum dates accurate only for 2019. 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	$\lambda_\odot$	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 04	283°.16	230°	+49°	41	2.1	110
γ-Ursae Minorids (404 GUM)	Jan 10–Jan 22	Jan 18	298°	228°	+67°	31	3.0	3
α-Centaurids (102 ACE)	Jan 31–Feb 20	Feb 08	319°.2	210°	−59°	58	2.0	6
γ-Normids (118 GNO)	Feb 25–Mar 28	Mar 15	354°	239°	−50°	56	2.4	6
Lyrids (006 LYR)	Apr 14–Apr 30	Apr 23	32°.32	271°	+34°	49	2.1	18
π-Puppids (137 PPU)	Apr 15–Apr 28	Apr 24	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 08	76°.6	44°	+24°	38	2.8	30
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	3.0	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 13	140°.0	48°	+58°	59	2.2	110
κ-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
Sep. 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 28	184°.3	152°	+00°	32	2.5	5
Oct. Camelopard. (281 OCT)	Oct 05–Oct 06	Oct 06	192°.58	164°	+79°	47	2.5	5
Draconids (009 DRA)	Oct 06–Oct 10	Oct 09	195°.4	262°	+54°	20	2.6	10
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 19	205°	102°	+27°	70	3.0	3
Orionids (008 ORI)	Oct 02–Nov 07	Oct 22	208°	95°	+16°	66	2.5	20
Leonis Minorids (022 LMI)	Oct 19–Oct 27	Oct 25	211°	162°	+37°	62	3.0	2
N. Taurids (017 NTA)	Oct 20–Dec 10	Nov 13	230°	58°	+22°	29	2.3	5
Leonids (013 LEO)	Nov 06–Nov 30	Nov 18	235°.27	152°	+22°	71	2.5	15
α-Monocerotids (246 AMO)	Nov 15–Nov 25	Nov 22	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 22–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 09	257°	100°	+08°	41	3.0	2
σ-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	140
Comae Berenic. (020 COM)	Dec 12–Dec 23	Dec 16	264°	175°	+18°	65	3.0	3
Dec. Leonis Min. (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	2.8	10

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

Date	ANT		QUA		DLM									
Jan 0	112°	+21°	228°	+50°	172°	+25°								
Jan 5	117°	+20°	231°	+49°	176°	+23°			**GUM**					
Jan 10	122°	+19°	234°	+48°	180°	+21°			220°	+71°				
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°	279°	+34°			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**		164°	+79°	**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°	**PHO**		153°	+21°			116°	+1°
Nov 25	88°	+16°			70°	+24°	10°	−52°	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*
Daytime Sextantids (221 DSX)	Sep 09–Oct 09	Sep 27*	184°.3	152°	0°	M*

9 References and Abbreviations

References:

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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_∞: Pre-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 (reference limiting magnitude +6.5) with the shower radiant overhead. This figure is given in terms of meteors per hour.

10 Useful addresses

On the IMO's website http://www.imo.net you find online forms to submit visual reports and reports of fireball sightings. It is also possible to submit reports of visual observation sessions for other observers. You can also access all reports in the database, both of visual data and fireball reports.
Visual reports: http://www.imo.net → Observations → Add a visual observation session
Fireball reports: http://www.imo.net → Observations → Report a fireball

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, Leibniz-Institut f. Astrophysik, An der Sternwarte 16, D-14482 Potsdam, Germany; e-mail: rarlt@aip.de

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As an alternative or to obtain additional information, you may contact the Secretary-General via lunro.imo.usa@cox.net.
Those unable to access the Internet may write for information to Robert Lunsford, IMO Secretary-General, 14884 Quail Valley Way, El Cajon, CA 92021-2227, 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!