International Meteor Organization

2023 Meteor Shower Calendar

edited by Jürgen Rendtel [1]

1 Introduction

This is the thirty-third edition of the International Meteor Organization (IMO) Meteor Shower Calendar. Its main goal is to draw the attention of observers to both regularly returning meteor showers and to events which may be possible according to model calculations. The publication date in the middle of the year was chosen to have the information spread early enough for inclusion into other compilations.

Observers may find additional peaks and/or enhanced rates but also the observational evidence of no rate or density enhancement. The position of peaks constitutes further important information. All data may help to improve our knowledge about meteoroid streams. We hope the Calendar continues to be a useful tool to plan your meteor observing activities.

Video meteor camera networks are collecting data throughout the year. Nevertheless, visual observations comprise an important data sample for many showers, and the well established analysing procedures allow us to derive reliable flux density data. Because visual observers are more affected by moonlit skies than video cameras, we consider the moonlight circumstances when describing the visibility of meteor showers. For the three strongest annual shower peaks in 2023 we find the Quadrantids two days before Full Moon, a waning crescent for the Perseids and New Moon for the Geminids. Good conditions for the maxima of other well-known showers are found for the maximum period of the April Lyrids (a slim waxing crescent) and the October Draconids (waning crescent) and the Orionids and Leonids near the first quarter Moon. The strongest southern showers, the η-Aquariids and the Southern δ-Aquariids, reach their maxima close to Full Moon. This also holds for the Aurigids. The Ursid maximum suffers from a waxing gibbous Moon.

The heart of the Calendar is the Working List of Visual Meteor Showers (Table 5, page 25) which is continuously updated so that it is the single most accurate listing available anywhere 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.

[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. I particularly thank Peter Jenniskens, Mikhail Maslov and Jérémie Vaubaillon for new information and comments in respect of events in 2023 (see also the *References* in section 8). Masahiro Koseki added important data about several showers which led to necessary updates. Last but not least thanks to Tim Cooper, Robert Lunsford, Alastair McBeath, Ina Rendtel and Chris Steyaert for carefully checking the contents.

A short and quite strong return of the Andromedids was observed on 2021 November 28. Modelling results of Wiegert et al. (2013) indicate, that we may observe enhanced rates also early December 2023 near $\lambda_{\odot} = 250°$ (December 2). Ten days later, the Earth may encounter meteoroids released from comet 46P/Wirtanen for the first time – for both events details are found on page 13. Further very interesting encounters are listed in Table 6a (page 27). Since there is always a possibility of completely unexpected events, ideally meteor observing should be performed throughout the year. This way we can improve the data for established meteoroid streams covering their entire activity periods. Combining data obtained with different techniques improve the reliability of derived quantities and is helpful for calibrating purposes.

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 Boötids and the October Draconids.

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 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.

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 that 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 α-Capricornids and particularly the Southern δ-Aquariids in July to August 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 late September into 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

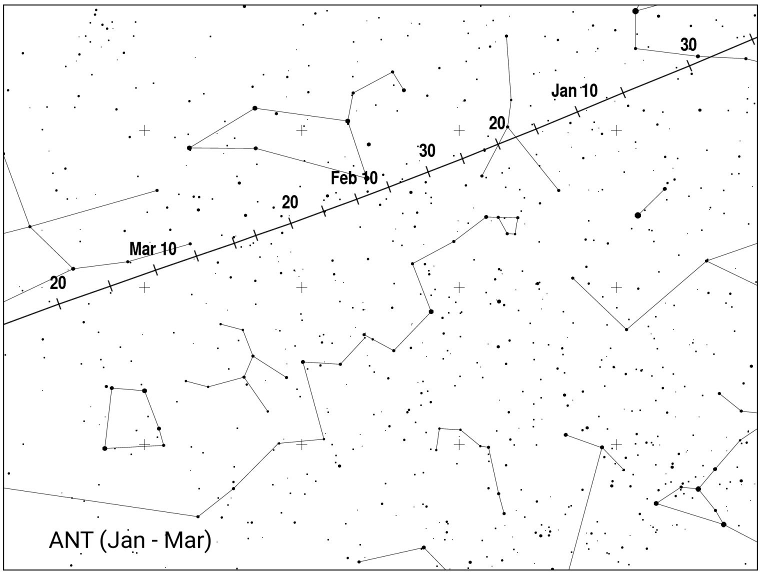
The year starts with the **Quadrantid (010 QUA)** peak for the northern hemisphere observers on January 4 close to 4^{h} UT. This is shortly before the Full Moon so that the sky is illuminated almost during the entire night (Moon in Taurus) – but see the notes below.

On 2015 January 10 at $02^{\mathrm{h}}50^{\mathrm{m}}$ UT, radar and video data showed a short outburst of the **κ-Cancrids (793 KCA**; radiant at $\alpha = 138°$, $\delta = +9°$) at $\lambda_{\odot} = 289\overset{\circ}{.}315$. Activity was also found in the 2016 video data (Molau et al., 2016a) and data of the SonotaCo network find the shower annually over the past decade around January 10. There are also hints that the KCA event of 2015 may have been an enhancement of the o-Leonids (515 OLE). Both are in the working list of the IAU MDC and require more data. The outburst position of 2015 is reached on 2023 January 10 near 04^{h} UT with a waning gibbous Moon. The radiant of the Antihelion source centre is located at $\alpha = 122°$, $\delta = +19°$, which is roughly 20° southeast of the KCA radiant; KCA meteors ($V_{\infty} = 47$ km/s) are faster than the ANT ($V_{\infty} = 30$ km/s).

The **Comae Berenicids (020 COM)** can be traced until early February. Around January 18 we find weak activity of the **γ-Ursae Minorids (404 GUM)**. The southern hemisphere's **α-Centaurids (102 ACE)** reach their maximum around February 8 shortly after the Full Moon. An outburst during 2021 February 13–15 associated with the γ-Crucids (1047 GCR) might be a return of the ACE; therefore observers should continue checking for ACE activity at least until February 15. The expected central part of the weak **γ-Normids (118 GNO)** of March with uncertainties of the activity period and the radiant is observable around mid-March.

Model calculations (Vaubaillon, 2022) show a possible encounter with meteoroids from the **minor planet 2016 $\mathbf{BA_{14}}$** on 2023 March 21 between 00^{h} and 04^{h}UT (near $\lambda_{\odot} = 0\overset{\circ}{.}0$) from a southern radiant near $\alpha = 90°$, $\delta = -51°$. The potential shower meteors should be slow ($V_{\infty} = 17$ km/s). The case is also of interest because the position of the stream seems to change from one year to another, being inside the orbit of the Earth, and then outside. The activity level is unclear as for most minor planet-related showers. All data from this moon-free period are useful for the verification of the modelling.

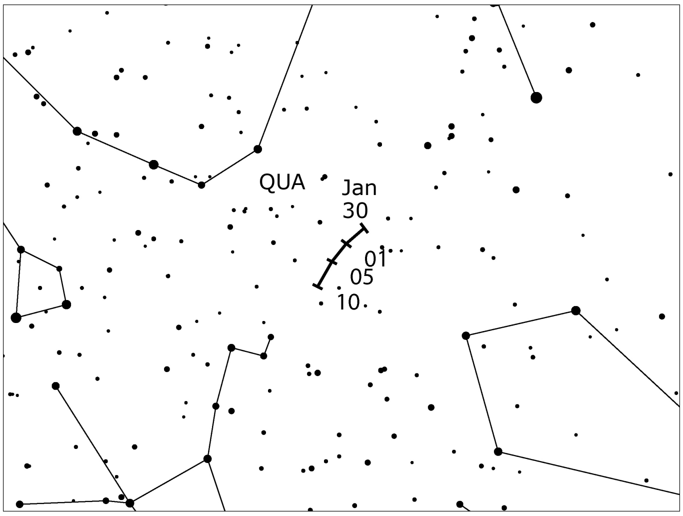
The **ANT's** radiant centre is in south-east Gemini in early January, and crosses Cancer during much of the month, before passing into southern Leo for most of February. It then shifts through southern Virgo during March – see the chart shown here. Probable ZHRs will be of the order of 2 to 3 during most of the time. Video meteor flux density data indicate a slight increase in March around $\lambda_\odot \approx 355°$ (2023 March 15).



The expected approximate date for the **Daytime Capricornids/Sagittariids (115 DCS)** is February 1–2. Data for this shower are based on older sources and will undergo modifications using more recent data soon. Radio observers are encouraged to check for activity. The radiant is approximately 10° south of the Sun at maximum, so cannot be regarded as visual target even from the southern hemisphere.

Quadrantids (010 QUA)

Active: December 28–January 12; Maximum: January 4, $03^{\mathrm{h}}40^{\mathrm{m}}$ UT ($\lambda_\odot = 283\overset{\circ}{.}15$),
ZHR = 110 (can vary $\approx 60 - 200$);
Radiant: $\alpha = 230°$, $\delta = +49°$; Radiant drift: see Table 6;
$V_\infty = 41$ km/s; $r = 2.1$ at maximum, 2.5 elsewhere.



In 2022, the highest QUA rates were below the average peak values. Modelling the stream obviously is difficult, but it may be helpful to get an idea about the QUA peak ZHR to check the current model parameters. Therefore, despite the bright moonlight, a rough estimate of the peak ZHR is of interest.

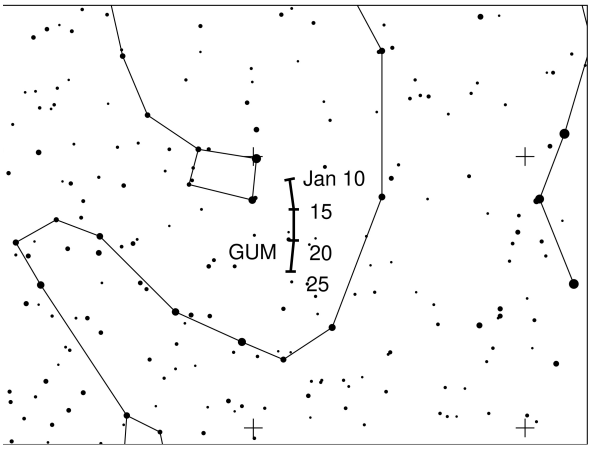
Shielding the direct view to the Moon is essential – the morning hours with lower Moon elevation and high radiant position provide the best opportunities. The timing is optimal for European observers.

In the morning of January 4, we find the Moon in Taurus. Around 04^{h} UT, it is about 10° above the western horizon at 15° eastern longitude, and it sets about an hour later. This leaves another 1–2 hours for observing, depending on the latitude. Further east, the "dark window" between peak and dawn is longer; it shortens further west.

γ-Ursae Minorids (404 GUM)

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

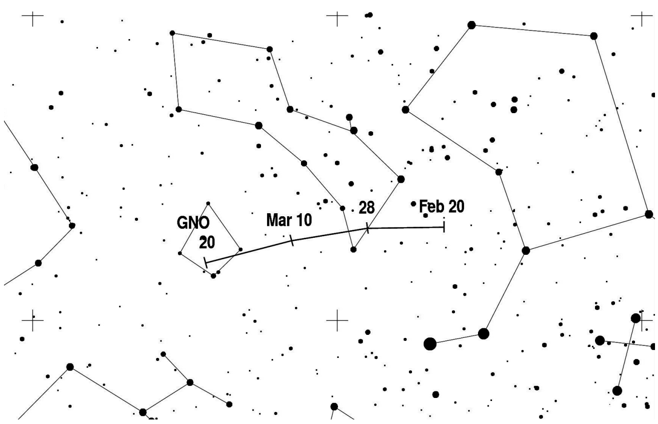
Little is yet known about this minor shower which is found in both video and visual data. It was included in our working list from 2017 onwards and has been annually observed. Considering the velocity, meteors from this far northern radiant should be similar to the Ursids in their appearance. All data about the activity period and shower parameters should be treated as tentative and need further confirmation. Last quarter Moon on January 15 allows observations around the given maximum and later.



γ-Normids (118 GNO)

Active: February 25–March 28; Maximum: March 14 ($\lambda_\odot = 354°$) – see text; ZHR = 6;
Radiant: $\alpha = 239°$, $\delta = -50°$, Radiant drift: see Table 6; $V_\infty = 56$ km/s; $r = 2.4$.

The γ-Normid ZHRs seem to be virtually undetectable above the background sporadic rate for most of the activity period. An analysis of IMO data from 1988–2007 showed an average peak ZHR ≈ 6 at $\lambda_\odot = 354°$, with ZHRs < 3 on all other dates during the shower (WB, p. 19). Results since 1999 indicate the possibility of a peak alternatively between $\lambda_\odot \approx 347°$–$357°$, equivalent to 2023 March 7–17. Recent data confirmed activity from that region, but a stable reference activity profile has not been established yet.



Analyses 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 $\alpha = 246°$, $\delta = -51°$. Like visual data, the video flux density profile is not stable for subsequent returns. Ill-defined maxima occur between $\lambda_\odot \approx 350°$–$0°$. Post-midnight watching yields better results, when the radiant is rising to a reasonable elevation from southern hemisphere sites. A last quarter Moon on March 15 affects the earlier section but is optimal for the later part of the assumed activity period.

4 April to June

In this period the visually accessible meteor rates increase significantly, although much of the total meteor activity in late April into May remains unobservable for optical methods as it is caused by daytime showers with their radiants located less than 30° distant from the Sun.

The **Lyrids (006 LYR**, also called April-Lyrids) reach their maximum just after New Moon on April 23. Only little moonlight interference occurs for the **π-Puppids (137 PPU)** with a maximum time on April 24.

Observations of the maximum of the stronger **η-Aquariids (031 ETA)** are badly affected by moonlight (Full Moon on May 5); this is also the case for the minor **η-Lyrids (145 ELY)** with activity around May 10. Although we do not give details for the ETA, we want to mention that there might be enhanced activity (Egal, 2020) related to the 1:6 mean motion resonance in 2023 and 2024 – hence observers should try to monitor the activity of the near-peak period which extends from May 4 to 6.

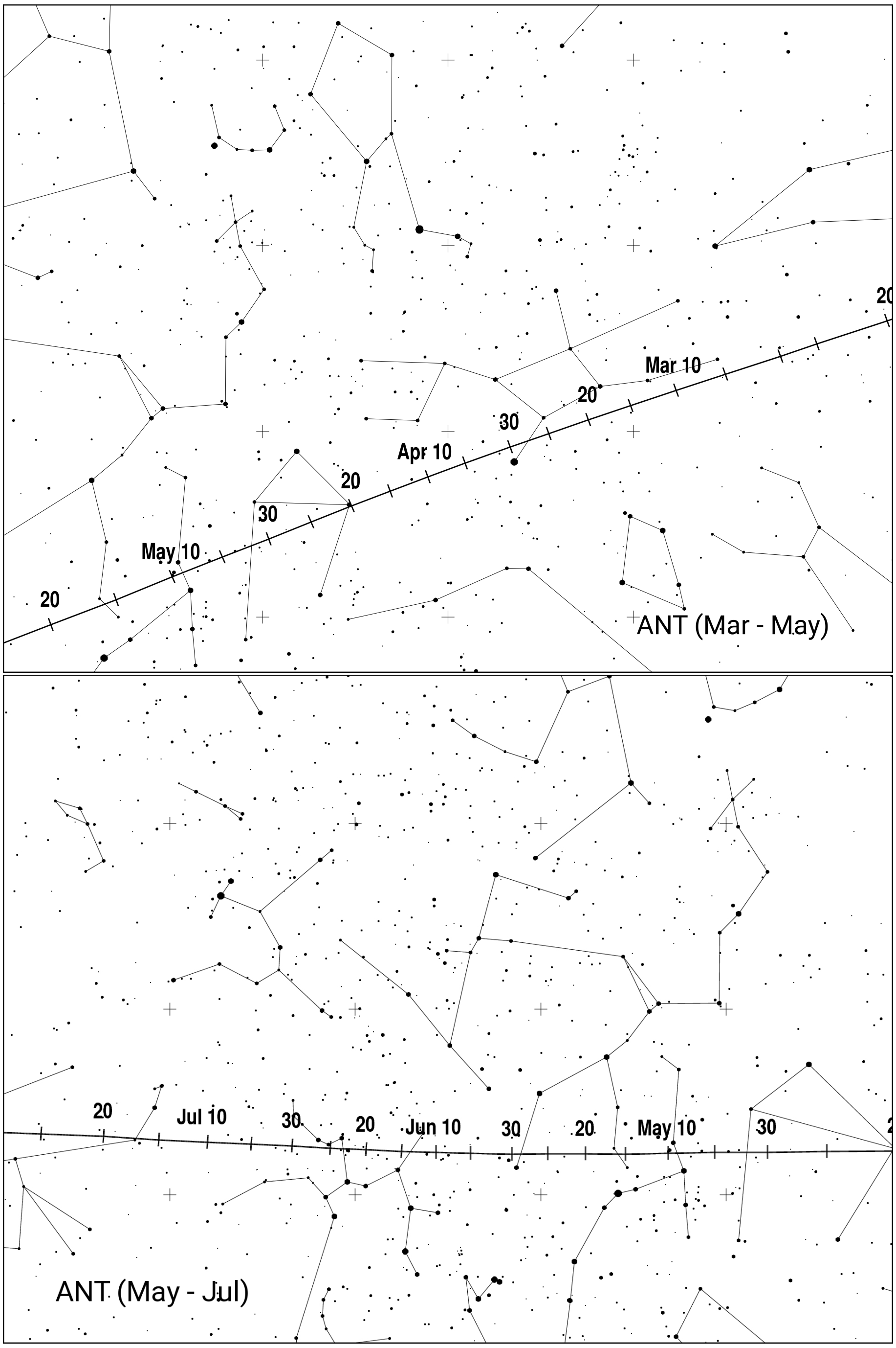
The **Camelopardalids (451 CAM)** of comet 209P/LINEAR showed a ZHR of about 15 on 2014 May 29. In 2023 the Earth may encounter meteoroids of three trails on May 24. The positions calculated by Vaubaillon (2022) are:
1873 trail: 07^h40^mUT ($\lambda_\odot = 62\overset{\circ}{.}526$),
1903 trail: 12^h40^mUT ($\lambda_\odot = 62\overset{\circ}{.}895$),
1909 trail: 13^h07^mUT ($\lambda_\odot = 62\overset{\circ}{.}895$).
The expected rate is unknown, but it is worth monitoring possible activity. (Radiant: $\alpha = 180°, \delta = +79°$, in an "apparently empty region" about 12° from Polaris towards δ UMa); $V_\infty = 16$ km/s.

Later, the **June Boötids (170 JBO)** can be observed under favourable circumstances.

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 (charts see on the facing page).

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, we list the UT peak times for these showers (see also the remark below):
April Piscids (144 APS) – April 23; Arietids (171 ARI) – June 7 (more details see below);
ζ-Perseids (172 ZPE) – June 10; β-Taurids (173 BTA) – June 28.
Signs of most are to be found in radio data of previous years, though some are difficult to define individually because of the proximity of 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. An apparent modest recurring peak around April 24 occurs perhaps due to combined rates from more than one shower. The daytime showers for the calendar will be revised soon.

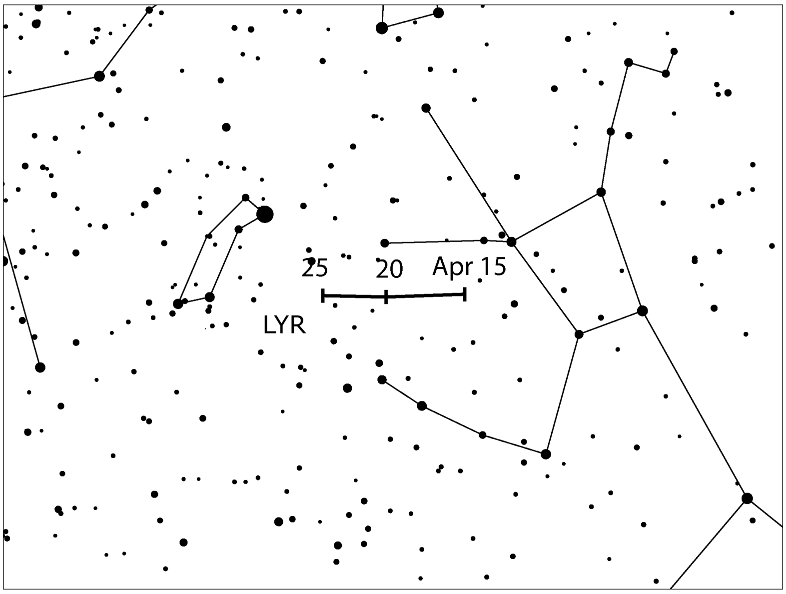
The **Daytime Arietids (171 ARI)** is subject of an ongoing IMO project to pool data on the shower using all techniques. It was initiated in 2014, to combine results from many independent observing intervals, even those periods which contain few, or even no ARI meteors. This year the expected maximum period is close to Full Moon (June 4), adding more background light than the sky at dawn has anyway.



Lyrids (006 LYR)

Active: April 14–30; Maximum: April 23, 01$^{\rm h}$ UT ($\lambda_\odot = 32.^{\circ}32$, but may vary – see text);
ZHR = 18 (can be variable, up to 90);
Radiant: $\alpha = 271^\circ$, $\delta = +34^\circ$; Radiant drift: see Table 6;
$V_\infty = 49$ km/s; $r = 2.1$.

The $\lambda_\odot = 32.^{\circ}32$ (2023 April 23, 01$^{\rm h}$ UT) timing given above refers to the ideal maximum position found in *IMO* results from 1988–2000. However, the maximum time was variable from year to year between $\lambda_\odot = 32.^{\circ}00$–$32.^{\circ}47$ (equivalent to 2023 April 22, 17$^{\rm h}$10$^{\rm m}$ to April 23, 04$^{\rm h}$45$^{\rm m}$ UT). Activity was variable too: peaks at the ideal time produced the highest ZHRs, ≈ 23. The further the peak happened from this, the lower the ZHRs were, down to ≈ 14 – a relation which needs to be confirmed. The 2022 return yielded a maximum ZHR of below 20 at a late position near $\lambda_{\odot} = 32\overset{\circ}{.}47$. The mean peak ZHR was 18 over the thirteen years examined. Further, the shower's peak length varied. A ZHR of more than half of the peak value was found on average for 32.1 hours, but this duration varied between 14.8 and 61.7 hours. The best rates are normally achieved for just a few hours. The analysis also confirmed that occasionally, as their highest rates occurred, the Lyrids produced a brief increase in fainter meteors. In 1982 a short-lived ZHR of 90 was recorded. For 2023 there are no predictions for any activity increase from theoretical modelling.

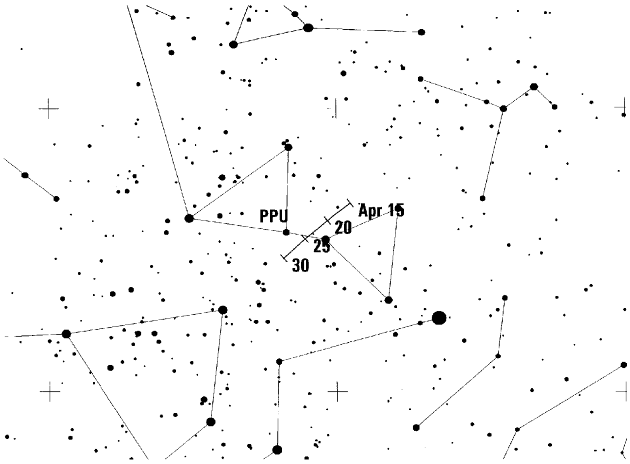


Lyrid meteors are best viewed from the northern hemisphere, but are visible from many sites north and south of the equator. As the radiant rises during the night, watches can be carried out usefully after about $22^{h}30^{m}$ local time from mid-northern sites, but only well after midnight from the mid-southern hemisphere. New Moon on April 20 provides optimal conditions for Lyrid observations in 2023.

π-Puppids (137 PPU)

Active: April 15–28; Maximum: April 24, 06^{h} UT ($\lambda_{\odot} = 33\overset{\circ}{.}5$);
ZHR = variable, up to around 40;
Radiant: $\alpha = 110°$, $\delta = -45°$; Radiant drift: see Table 6;
$V_{\infty} = 18$ km/s; $r = 2.0$.

The shower was discovered in 1972; later notable, short-lived, activity with rates around 40 meteors per hour was reported in 1977 and 1982. In both years, the 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. The comet passed its perihelion last in 2013 and 2018; the next one is due on 2023 December 25.

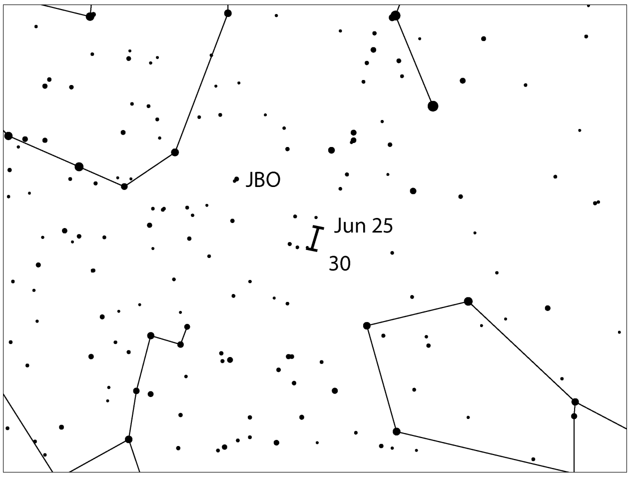


Not unexpectedly, nothing meteorically significant happened in either previous year. When this Calendar was prepared, no predictions for any 2023 π-Puppid meteor activity had been issued.

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 crescent Moon (four days old) should not disturb too much. Covering whatever transpires is important, even if that is to report no obvious activity. The IMO data over the past 17 years have only records of 2018 and 2019 which confirm low, but detectable rates.

June-Boötids (170 JBO)

Active: June 22–July 2; Maximum: June 27, 22^{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; $r = 2.2$.



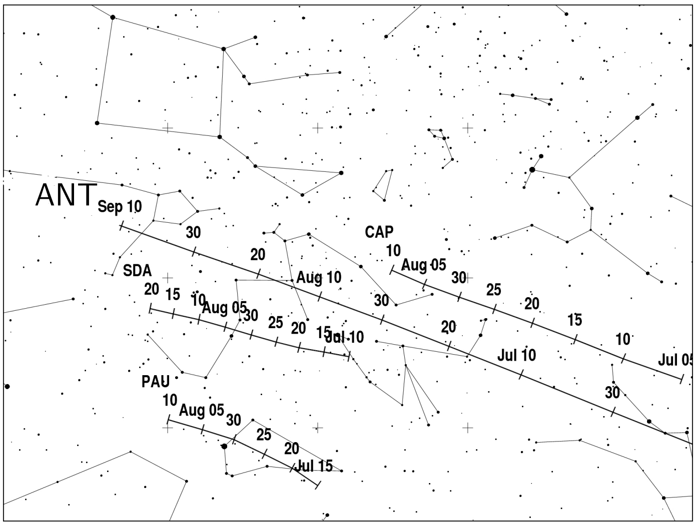
This shower is listed since its unexpected return of 1998 (ZHR 50 − 100+ for more than half a day). Another outburst of similar length (ZHR $\approx$ 20−50) was observed on 2004 June 23. The return predicted in 2010 yielded a poorly established ZHR < 10 on June 23–24. Prior to 1998, only three more probable returns had been detected, in 1916, 1921 and 1927 (however, with different reliability).

The orbit of the parent comet 7P/Pons-Winnecke (orbital period about 6.4 years, last perihelion passage on 2021 May 27) currently lies around 0.24 astronomical units outside the Earth's at its closest approach.

The 1998 and 2004 events resulted from meteoroids ejected from the comet in the past when the comet was still in a different orbit. For the 2023 return, there are no predictions of peculiar activity published. We encourage all observers to 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, reduced additionally by some moonlight (first quarter on June 26). VID suggested some June-Boötids may be visible in most years around June 20 − 25 but with activity largely negligible except near $\lambda_\odot = 92^\circ$ (2023 June 24, 01^{h} UT), radiating from $\alpha = 216^\circ$, $\delta = +38^\circ$ which is about ten degrees south of the radiant found in 1998 and 2004.

5 July to September

The **ANT** is the chief focus for visual attention in the first half of July, as its radiant area moves steadily through eastern Sagittarius, then across northern Capricornus into southwest Aquarius (see chart below). ZHRs for most of the month should be ≈ 2 to 3. From around September 20, the **Southern Taurids (002 STA)** effectively taking over the near-ecliptic activity from the ANT through to December (see chart on page 17).



For about a week around July 10, low activity may be observed from the **July-Pegasids (175 JPE)**, with interference from the waning Moon. After mid-July the large ANT radiant area overlaps that of the minor **α-Capricornids (001 CAP)** into August, but the lower apparent velocity of the CAP allows observers to separate the two. The stronger and faster **Southern δ-Aquariids (005 SDA)** should be distinguishable from the ANT as well. Finally, the radiant of the **Piscis Austrinids (183 PAU)** is distant enough from the ANT area. The highest rates are due on July 28 (PAU) and July 30 (CAP, SDA), respectively, although recent data hints at a later PAU-maximum (perhaps August 08) with a radiant about 5° north of the previously listed declination. Full Moon on August 1 badly affects optical observations of the showers with their maxima at the end of July.

On 2016 July 28 at $00^{h}07^{m}$ UT ($\lambda_{\odot} = 125\overset{\circ}{.}132$) the **July γ-Draconids (184 GDR)** produced an outburst detected by radar and video observations (Molau et al., 2016b). The same position is reached again on 2023 July 28 near 19^{h} UT – worth checking although there was no extra activity observed in 2017 – 2021. SonotaCo net observations indicate that the GDR is an annual shower with a sharp but variable maximum from year to year (Koseki, 2020). The radiant is at $\alpha = 280°$, $\delta = +51°$, and the meteors have low speed ($V_{\infty} = 27$ km/s).

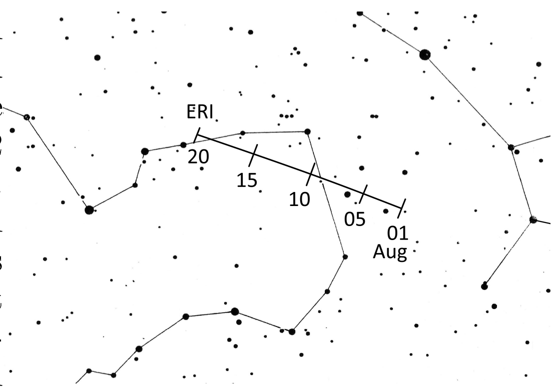
The **η-Eridanids (191 ERI)** are a new entry in the working list, visible mainly in the first half of August. New Moon on August 16 makes 2023 an almost perfect year to observe the **Perseid (007 PER)** activity around their maximum. The favourable conditions continue for the **κ-Cygnids (012 KCG)** while the **Aurigids (206 AUR)** peak in the night to September 1 is again affected by bright moonlight. The **September ε-Perseids (208 SPE)** reach their maximum on September 9/10.

For **radio observers**, the high daytime activity of May–June has waned. We may find the Daytime **ζ-Cancrids (202 ZCA)** with a possible peak near August 25. In the previous calendars we listed the γ-Leonids (203 GLE), but according to recent CMOR data, 202 ZCA is the better representation of the source. Further, there is the **Daytime Sextantid (221 DSX)** maximum on September 27. From late September to early October optical observers are encouraged to collect data of the DSX, although this occurs close to the Full Moon (September 29).

η-Eridanids (191 ERI)

Active: July 31–August 19; Maximum: August 08, $\lambda_\odot = 135^\circ$; ZHR = 3;
Radiant: $\alpha = 41^\circ$, $\delta = -11^\circ$; Radiant drift: see Table 6; $V_\infty = 64$ km/s; $r = 3.0$.

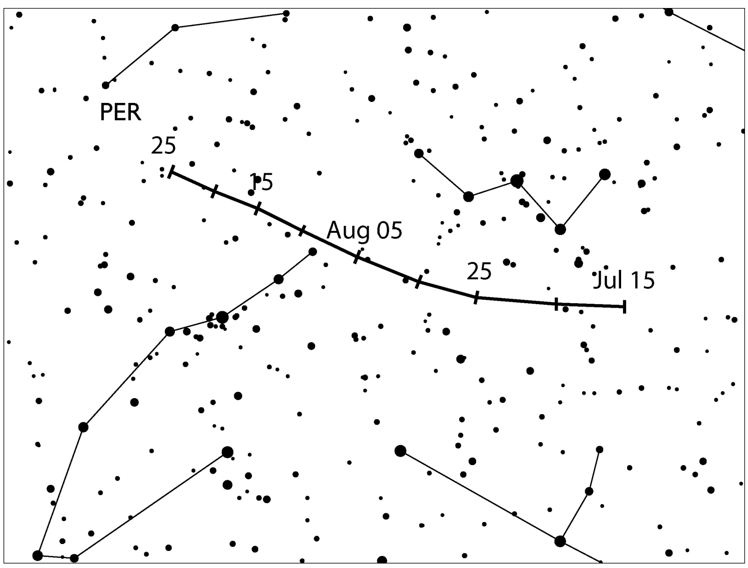
The η-Eridanids (191 ERI) may be associated with comet C/1852 K_1 (Chacornac) and were mentioned in the previous two editions of the Calendar because of possible activity related to dust trails (the 2022 encounter is still ahead when writing this section). The activity period given here has been adapted from Koseki (2021; pp. 140–141); it continues long after its maximum and needs observational data. The radiant of these fast meteors in the northwestern part of Eridanus is best observed after midnight, preferably from southern locations.



Perseids (007 PER)

Active: July 17–August 24; Maximum: August 13, 07^h to 14^h UT (node at $\lambda_\odot = 140\overset{\circ}{.}0 - 140\overset{\circ}{.}1$), but see text; ZHR = 100;
Radiant: $\alpha = 48^\circ$, $\delta = +58^\circ$; Radiant drift: see Table 6; $V_\infty = 59$ km/s; $r = 2.2$.

IMO observations (see WB pp. 32–36) found the timing of the mean or 'traditional' broad maximum varied between $\lambda_\odot \approx 139\overset{\circ}{.}8$ to $140\overset{\circ}{.}3$, equivalent to 2023 August 13, $02^h - 21^h$ UT. The orbital period of the parent comet 109P/Swift-Tuttle is about 130 years. The Perseids produced strong activity from a primary maximum throughout the 1990s. Enhanced activity was last observed in 2016 due to passages through separated dust trails.



A filament crossing occurred on 2018 August 12 around 20^h UT ($\lambda_\odot \approx 139\overset{\circ}{.}79$) at the predicted position. (A filament is thought to be an accumulation of meteoroids in a mean-motion resonance.)

High activity well after the main peak has been reported during the recent returns. On 2021 August 14, shortly after 08^hUT ($\lambda_\odot \approx 141\overset{\circ}{.}48$), a sharp increase of the ZHR – more than 100 above the basic level – was observed by different techniques. This was about 1.5 days after the nodal maximum and about 0.7 days after the lesser maxima in 2018 and 2020.

On 2023 August 14 between 01^h and 02^{h}45^{m}UT ($\lambda_\odot \approx 140.^\circ 74$), the Earth encounters a very old trail of dust released in 68 BC (Vaubaillon, 2022). It is definitively worth monitoring although a prediction of the activity level is essentially impossible. A weak filament is expected to be crossed on August 13, around 03^h UT (at $\lambda_\odot = 139.^\circ 83 \pm 0.^\circ 2$ (Table 5d in Jenniskens, 2006).

New Moon on August 16 provides excellent conditions for visual observations. As described above, include the nights around the main maximum in your observing program to record peculiarities. Mid-northern latitude sites are best for Perseid observing, as from here, the radiant has reached a reasonable elevation from 22^h–23^h local time onwards. Regrettably, the shower cannot be properly viewed from most of the southern hemisphere and from latitudes north of about 60°N.

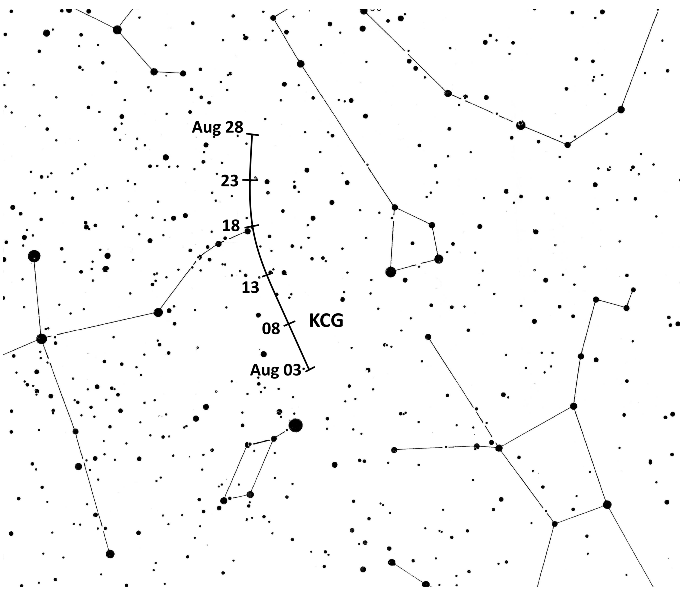
κ-Cygnids (012 KCG)

Active: August 3–28; Maximum: August 17 ($\lambda_\odot = 144°$); ZHR = 3;
Radiant: $\alpha = 288°$, $\delta = +54°$; Radiant drift: see Table 6; $V_\infty = 23$ km/s; $r = 3.0$.

Enhanced κ-Cygnid activity was observed in 2007, 2014 and 2021 supporting the assumed 7-year period of the stream. This indicates that we do not expect enhanced rates in 2023. Apart from the periodic peaks, a recent analysis indicates a general ZHR level increase in the recent years after an apparent dip in the period 1990–2005.

An average flux density profile for the period 2012–2018 from video data shows a clear maximum at 144° and detectable activity between August 2 and September 3.

Research by Koseki (2014) has shown a complex radiant structure extending into Draco and Lyra. The isolated radiant position and the low velocity of the meteoroids should be used to associate KCG meteors to the complex. The shower is best-observed from northern hemisphere sites, from where the radiant is easily available all night. Visual observations are not suitable to distinguish between the sub-radiants identified with other techniques.



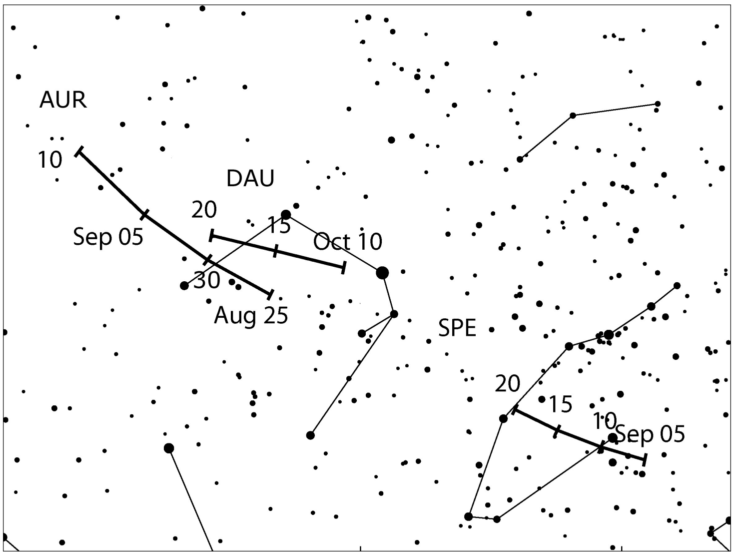
September ε-Perseids (208 SPE)

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

This shower produced high rates on 2008 September 9, between roughly $\lambda_\odot = 166.^\circ 894$–$166.^\circ 921$, and another bright-meteor event with a very sharp peak at $\lambda_\odot = 167.^\circ 188$ in 2013 but no later unambiguous increase subsequently.

According to Esko Lyytinen's modelling the next impressive SPE return may not be before 2040, but 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.

The New Moon phase is reached only on September 15 so that some interference occurs around the maximum of this primarily northern-hemisphere shower. The radiant area is well on-view all night from about 22^h–23^h local time for mid-northern locations.



6 October to December

The **Orionids (008 ORI**; maximum October 21/22) and the **Leonids (013 LEO**; maximum November 18) reach their maxima around the first quarter Moon so that the morning hours with the high radiant positions remain undisturbed. The most active **Geminid (004 GEM)** shower peaks near New Moon, while observations of the **Ursid (URS)** are somewhat affected by a waxing gibbous Moon. The two Taurid branches reach their highest rates around November 05 (Southern Taurids, 002 STA) and November 12 (Northern Taurids, 017 NTA), respectively, with little or no moonlight interference.

The **ANT** activity is resuming only around December 10, as the Northern Taurids fade away. The radiant centre tracks from Taurus across southern Gemini during later December. The typical ZHR level is < 2.

Several minor showers are active in the last quarter of the year: observations of the **October Camelopardalids (281 OCT**, maximum October 6), the **October Draconids (009 DRA**, maximum October 9) as well as the very weak **δ-Aurigids (224 DAU**, maximum October 11) are only little affectd by the waning Moon. The weak **ε-Geminids (023 EGE**, maximum October 18) and the later **Leonis Minorids (022 LMI)** have no moonlight interference. The showers which are active towards the end of November, i.e. the **α-Monocerotids (246 AMO)** – with no peculiar activity expected in 2023 – and the **November Orionids (250 NOO)** reach their maxima close to the Full Moon.

The waning gibbous Moon in Cancer allows observations of possible **Andromedid (018 AND)** activity of slow meteors on December 02, centred around 19^hUT ($\lambda_\odot = 250°$) from a radiant at $\alpha = 29°, \delta = +47°$ (Wiegert et al., 2013) which is between γ Andromedae and υ Persei. The Moon rises around 21^h local time, leaving a few hours undisturbed. Meteoroids were released from the parent 3D/Biela in 1649. On 2021 November 28 ($\lambda_\odot = 245\overset{\circ}{.}89$), an AND outburst was observed. Activity from this stream was also expected in 2018 – then listed as December φ-Cassiopeiids (446 DPC) which is due to the radiant drift in northeast direction. VID and other recent analyses indicate that weak AND activity is observable annually.

Conditions are also poor for the early December southern showers – **Phoenicids (254 PHO**, maximum December 02, and no prediction of additional activity) and the complex **Puppid-Velids (301 PUP)**. More than a week later, the **Monocerotids (019 MON**, maximum

December 09) and the **σ-Hydrids (016 HYD**, maximum December 09) can be observed in moon-free skies.

Just before the Geminid maximum there is a chance to observe meteors released from comet **46P/Wirtanen** (the initial target of the Rosetta comet exploring mission) on December 12, around $11^{\rm h}20^{\rm m}$UT ($\lambda_\odot = 260\overset{\circ}{.}11$). Vaubaillon writes: this is the first time I see a trail of this comet crossing the Earth's orbit. The 1974 trail is quite young and we have no clue concerning the flux density. Most interestingly, the *radiant is split in two very different regions in the sky* – something requiring detailed data and analysis. Most of the activity should be related to a radiant at $\alpha = 8°, \delta = -38°$ (about 10° north of α Phoenicis in Sculptor), the other radiant is at $\alpha = 346°, \delta = +7°$ (between α Pegasi and γ Piscium). Meteors should be very slow with $V_\infty = 10$km/s and $V_\infty = 13$km/s, respectively. The described activity is expected shortly before the Geminid maximum. While the Geminid meteors are preferably counted, we recommend to note to which of the two radiants potential meteors are associated (Scl or Psc). Of course, video data will provide complete data sets to investigate the radiant structure.

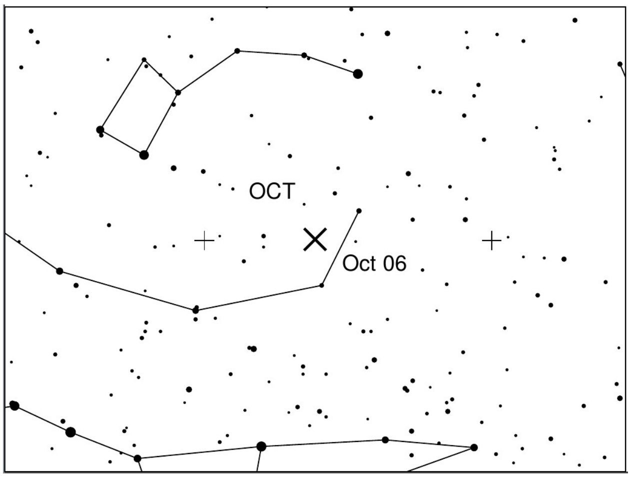
The tentative maximum of the weak and long-lasting **Comae Berenicids (020 COM)** around December 16 is little affected by moonlight. There are several showers with similar radiants and also orbital elements to the COM and previously listed **December Leonis Minorids (032 DLM)**. An activity period of over 70 degrees appears too long for a meteor shower having such a high inclination orbit. Since the case is still under investigation, we suggest to summarise all meteors from the (extended) COM/DLM-region under "COM" for the entire activity period previously given for the DLM.

At the end of the year, the first **Quadrantids (010 QUA)** can be seen.

October-Camelopardalids (281 OCT)

Active: October 5–6; Maximum: October 6, $10^{\rm h}$ ($\lambda_\odot = 192\overset{\circ}{.}58$); ZHR = 5(?)
Radiant: $\alpha = 164°$, $\delta = 79°$; Radiant drift: negligible; $V_\infty = 47$ km/s; $r = 2.5$ (uncertain).

This shower produced a well detected ZHR ≈ 5 on 2018 October 6, $00^{\rm h}30^{\rm m}{\rm UT} \pm 1.3^{\rm h}$ ($192\overset{\circ}{.}45 \pm 0\overset{\circ}{.}05$). The first activity from this north-circumpolar radiant was recorded by video cameras in 2005 and 2006 on October 5/6 (near $\lambda_\odot = 193°$). 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. Apart from the above mentioned events, enhanced activity was found on 2016 October 5 at the predicted position ($14^{\rm h}45^{\rm m}$ UT) in radio forward scatter and video camera data from Finland.

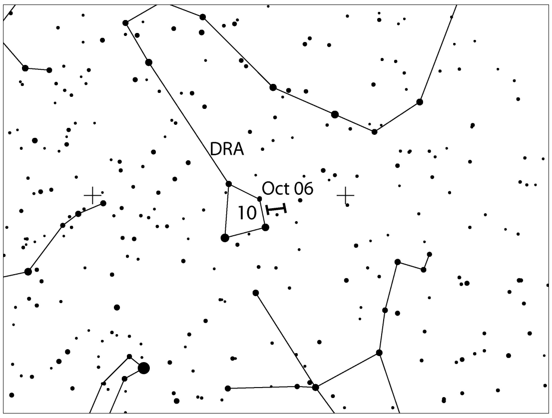


Assuming a long-period parent, and using the 2005 outburst as reference point, Esko Lyytinen's calculations indicated that we might see activity near $\lambda_\odot = 192\overset{\circ}{.}529$ in 2018 and 2019. In both years, some activity was recorded with a slightly higher rate in 2018. Surprises are possible because the stream is either a long-period case with an atypically wide 1-revolution trail *or* we have still to encounter the densest part of the trail. For 2023 no prediction has been issued.

Draconids (009 DRA)

Active: October 6–10; Maximum: October 9, 07^{h} UT ($\lambda_{\odot} = 195.^{\circ}4$); ZHR = 5 (?);
Radiant: $\alpha = 263^{\circ}$, $\delta = +56^{\circ}$; Radiant drift: negligible; $V_{\infty} = 21$ km/s; $r = 2.6$.

The Draconids (also called October-Draconids) are known as a periodic shower which produced spectacular meteor storms in 1933 and 1946, and lower rates in several other years (ZHRs ≈ 20–500+). Recent outbursts happened in 2011 (ZHR ≈ 300; predicted) and in 2012 (unexpected).

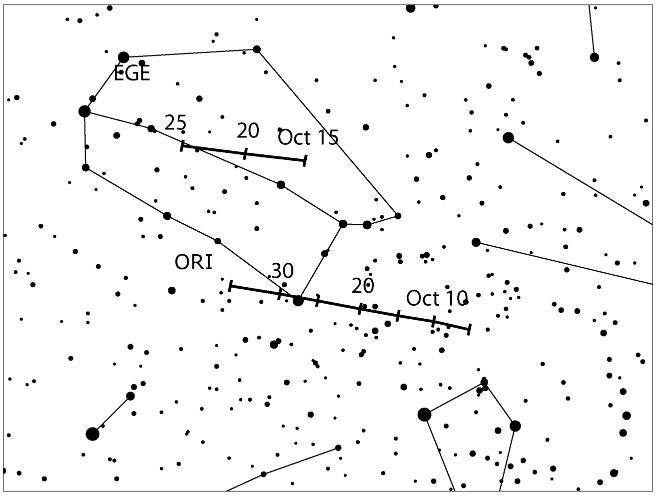


The 2018 return yielded a ZHR of about 150 lasting for about 4 hours, much higher than the predicted values. For 2023, there are no trail encounters announced.

The parent comet 21P/Giacobini-Zinner passed its perihelion last on 2018 September 10. Essentially, there is no moonlight at least in the evening hours which are best for Draconid observations. The radiant is north-circumpolar, at its highest during the first half of the night, and Draconid meteors are exceptionally slow-moving.

ε-Geminids (023 EGE)

Active: October 14–27; Maximum: October 18 ($\lambda_{\odot} = 205^{\circ}$); ZHR = 3;
Radiant: $\alpha = 102^{\circ}$, $\delta = +27^{\circ}$; 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 great care must be taken to separate meteors of the two sources. The waxing moon is not an issue. Northern observers have a radiant elevation advantage and can observe from about local midnight onwards. There is some uncertainty about the shower's parameters. Both visual and video data indicate that the maximum may be later than listed; at least it is not well defined with ZHRs of about 3 for more than one day.

Orionids (008 ORI)

Active: October 2–November 7; Maximum: October 22 ($\lambda_{\odot} = 208^{\circ}$); ZHR = 20+;
Radiant: $\alpha = 95^{\circ}$, $\delta = +16^{\circ}$; Radiant drift: see Table 6; $V_{\infty} = 66$ km/s; $r = 2.5$.

The shower's radiant is at a useful elevation from local midnight or so in either hemisphere, somewhat before in the north. The first quarter Moon on October 22 leaves the second half of the night undisturbed.

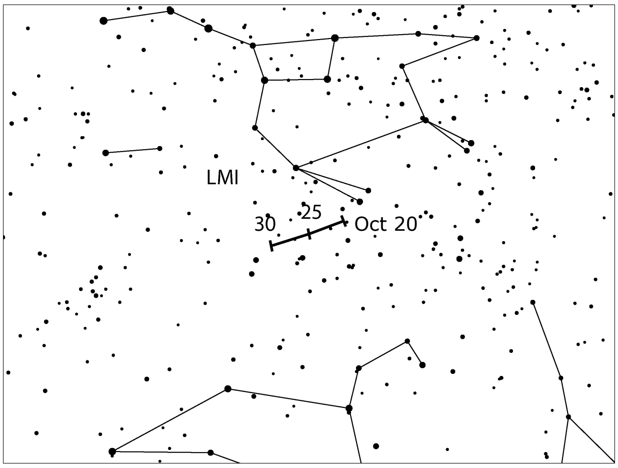
Each return from 2006 to 2009 produced unexpectedly strong ZHRs of around 40–70 on two or three consecutive dates. An earlier IMO analysis of the shower, using data from 1984–2001, found both the peak ZHR and r parameters varied somewhat from year to year, with the highest mean ZHR ranging from $\approx$ 14–31 during the examined interval.

A suspected 12-year periodicity in stronger returns claimed earlier in the 20th century is not detectable from visual data but seems to occur in CMOR radar data since 2002 (Egal et al., 2020). Higher activity due to the suspected cycle was mentioned for the period between 2020–2022 in the previous calendars. The average maximum Orionid ZHRs in the years 2012–2020 was in the range of 20–30. The available data do not allow us to draw a conclusion about the periodicity question.

The Orionids may also provide several lesser maxima and sometimes the activity may be similar 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.

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 shower was first found in photographic orbital data and comet C/1739 K1 (Zanotti) is suggested as parent object. The activity was established from video data and over the past years, a suitable sample of visual data has been collected as well.

Visual data from 2017–2021 yield a maximum ZHR of the order of 5 around October 24 or perhaps slightly earlier. The radiant area can be seen solely from the northern hemisphere, where it rises around midnight. The given maximum date is shortly after the first quarter Moon, leaving the morning sky moon-free for collection of optical data.

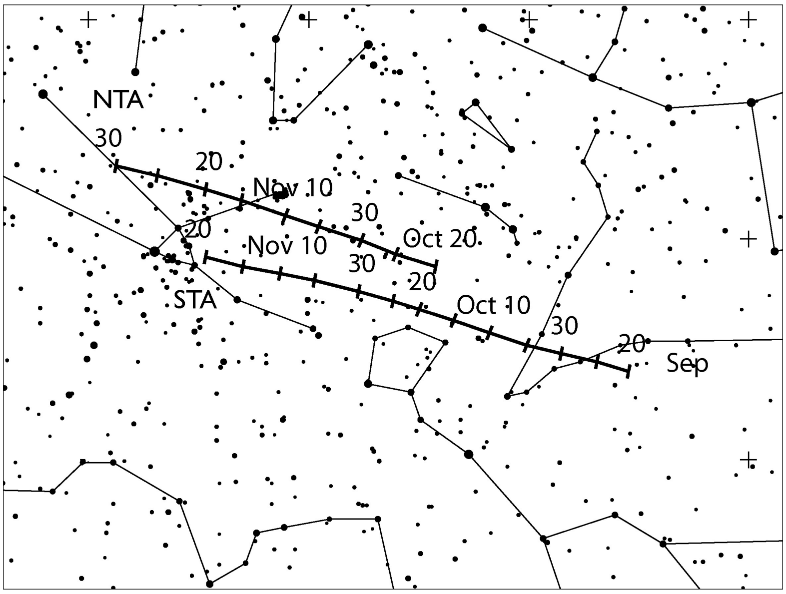
Southern Taurids (002 STA)

Active: September 20–November 20; Maximum: November 05 ($\lambda_\odot = 223°$); ZHR = 5–10;
Radiant: $\alpha = 52°$, $\delta = +15°$; 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. Consequently, we find a superposition of activities. For shower association, assume the radiant to be an oval area, about 20° in α by 10° in δ, centred on the radiant position for any given date. Its near-ecliptic radiant makes the shower a target for observers at all latitudes, albeit those in the northern hemisphere are somewhat better-placed, as here suitable radiant zenith distances persist for much of the night.

The Taurid activity overall dominates the Antihelion Source area's during the northern autumn, so much so that the ANT is considered inactive while either branch of the Taurids is present.

The brightness and relative slowness of many Taurid meteors makes them ideal targets for still-imaging, while these factors coupled with low, steady, Taurid rates makes them excellent subjects for newcomers to practice their visual plotting techniques. The main maximum (ZHR 5–10) of the STA is found around November 05, but there is an early maximum (ZHR near 5) around October 13 – a date which often was listed as actual STA maximum.



Northern Taurids (017 NTA)

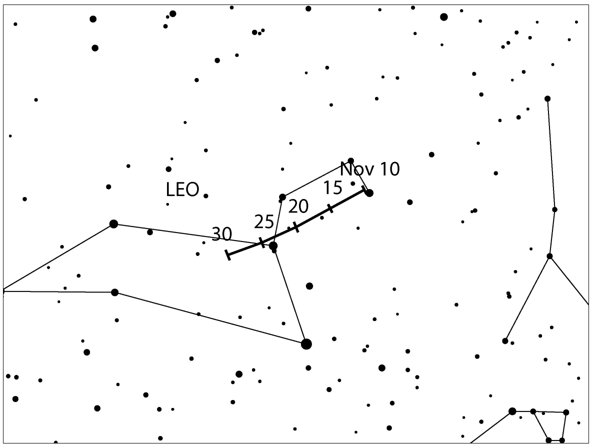
Active: October 20–December 10; Maximum: November 12 ($\lambda_\odot = 230°$); ZHR = 5;
Radiant: $\alpha = 58°$, $\delta = +22°$; Radiant drift: see Table 6; $V_\infty = 29$ km/s; $r = 2.3$.

The large, oval radiant region to be used for shower association, the shower's excellent visibility overnight, and its dominance over the ANT during September to December are essentially the same as discussed in the STA section above. As previous results had suggested seemingly plateau-like maximum rates persisted for roughly ten days in early to mid November, the NTA peak may not be so sharp as its single maximum date might imply. Whatever the case, last quarter Moon on November 5 should allow plenty of coverage.

Leonids (013 LEO)

Active: November 6–30; Maximum: November 18, 05^h UT (nodal crossing at $\lambda_\odot = 235^\circ\!.27$), but see text; ZHR $\approx 10 - 15$
Radiant: $\alpha = 152°$, $\delta = +22°$; Radiant drift: see Table 6; $V_\infty = 71$ km/s; $r = 2.5$.

The parent comet of this shower, 55P/Tempel-Tuttle, passed its perihelion last in 1998, more than two decades ago now. Meanwhile the comet has passed its aphelion; the next perihelion is only due on 2031 May 20. Meteoroids we observe now are ahead of the comet. The knowledge of the dust ejection mechanisms and trail evolution allowed us to predict and verify variable activity in numerous years until recently.



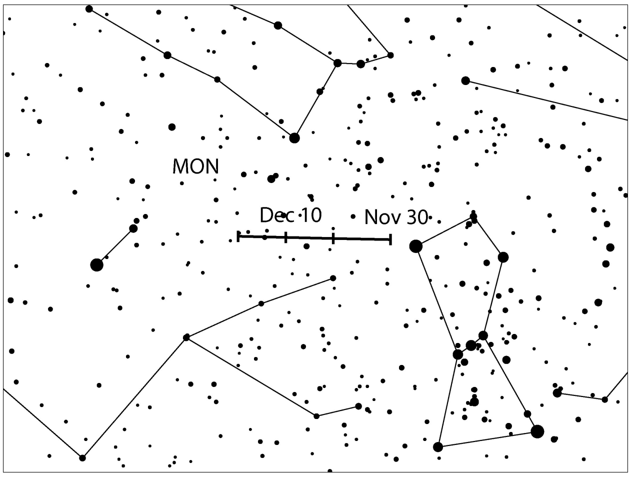
The ("regular") nodal Leonid maximum should occur on 2023 November 18, 05^{h} UT. Maslov (2007) gives November 17, 22^{h} UT with an expected moderate rate of about 15.

On 2023 November 21, 12^{h} UT, Maslov's model calculations hint at possible activity from the 1767 trail, which may add about 10–15 to the ZHR, composed of brighter than average meteors.

Monocerotids (019 MON)

Active: November 27–December 20; 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 shower (also called December Monocerotids) is well known for a long time, but the amount of data is not sufficient to investigate details. In most years, visual data give a maximum ZHR = 3 at $\lambda_\odot \approx 257°$ while the general ZHR level is about 2. In a few years, we also find an apparent slight enhancement in the Geminid peak night – perhaps an effect of Geminids erroneously classified as MON.



Video data (2011–2021) show a peak of roughly $0\overset{\circ}{.}4$ width centred at $\lambda_\odot \approx 262\overset{\circ}{.}3°$ (i.e. December 14) with a ZHR of the order of 8 coinciding with the Geminid peak. A much weaker ZHR $\approx$ 3 appears near $\lambda_\odot 255\overset{\circ}{.}5°$. This needs to be clarified.

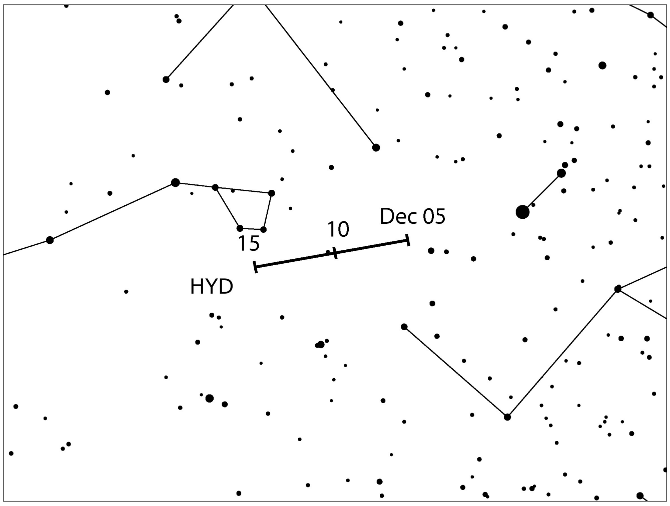
Care needs to be taken to clearly distinguish MON from GEM and NOO. Visual observers should choose their field of view such, that the radiants do not line up. (Field centres north of Taurus in the evening or near Leo in the morning are possible choices.)

The radiant area is available virtually all night for much of the globe, culminating at about $01^{h}30^{m}$ local time.

σ-Hydrids (016 HYD)

Active: December 3–20; Maximum: December 9 ($\lambda_\odot = 257°$); ZHR = 7;
Radiant: $\alpha = 125°$, $\delta = +02°$; Radiant drift: see Table 6; $V_\infty = 58$ km/s; $r = 3.0$.

The σ-Hydrids are often thought to be a very minor shower with rates close to the visual detection threshold for much of the activity period. However, some bright meteors are repeatedly seen and the maximum ZHR reaches 5–8. IMO visual data (WB p. 65) have indicated the maximum might happen nearer $\lambda_\odot \approx 262°$ (December 14). This is probably an effect as described for the MON caused by mis-aligned Geminids.



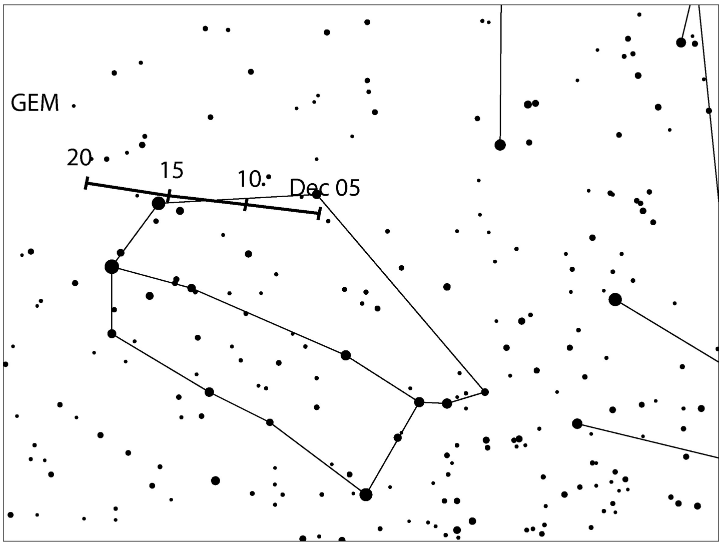
Visual IMO data from the period 2010–2021 show a maximum at $\lambda_\odot 257° - 258°$ (December 9–10) and a Geminid-related feature only in a few years.

Video data from 2010 to 2021 imply a peak close to $\lambda_\odot \approx 255\overset{\circ}{.}5$ (December 6), and that HYD activity might persist till December 24. A careful choice of the observing field is necessary to distinguish HYD from GEM and MON which are active at the same time (see notes in the MON section above). Since the HYD radiant rises in the late evening hours, it is best viewed after local midnight from either hemisphere.

Geminids (004 GEM)

Active: December 4–17; Maximum: December 14, 19^h UT ($\lambda_\odot = 262\overset{\circ}{.}2$); ZHR = 150;
Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6;
$V_\infty = 35$ km/s; $r = 2.6$.

The best and most reliable of the major annual showers presently observable reaches its broad moon-free maximum on December 14 centred at 19^h 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 local time.

The peak has shown little variability in its 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 $262\overset{\circ}{.}4$, that is 2023 December 14, 03^h to 24^h UT. During high activity, observers should report their count data for short intervals (no longer than 15 minutes).

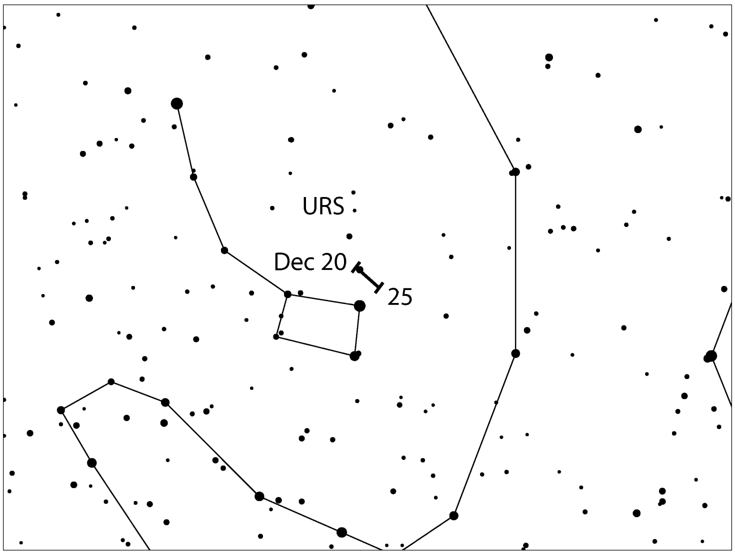
Remember that there may be activity related to comet 46P/Wirtanen (see the note on page 14) on December 12, perhaps from two different radiants. While counting is the best method to record the major GEM activity, notes are advised about the apparent trails and angular velocities of possible "Wirtanen-meteors".

Ursids (015 URS)

Active: December 17–26; Maximum: December 23, 04^h UT ($\lambda_\odot = 270\overset{\circ}{.}7$) and see text;
ZHR = 10 (occasionally variable up to 50);
Radiant: $\alpha = 217°$, $\delta = +76°$; Radiant drift: see Table 6; $V_\infty = 33$ km/s; $r = 2.8$.

This poorly-observed northern hemisphere shower has produced at least two major outbursts (in 1945 and 1986), and further events could have been missed due to weather conditions. The maximum is rather narrow and fluctuates from year to year. Several lesser rate enhancements have been reported from 2006 to 2008, in 2011, 2014, 2015, 2017 and 2020 (visual and video data). The parent comet 8P/Tuttle has an orbital period of 13.6 years. It passed its perihelion last on 2021 August 27. In the past, many Ursid peaks occurred when the comet was close to its *aphelion,* indicating that predictions are difficult.

In 2023 there is a **filament encounter on December 22,** 14^h29^m **UT** ($\lambda_\odot = 270\overset{\circ}{.}14$) listed by Jenniskens (2006, Table 5b), noted with a ZHR of 23 which is less than 1/3 of the value given for filaments in the years 2016/17/18. The rates are expected to be lower than 2017 according to Vaubaillon (2022), who gives $\lambda_\odot = 270\overset{\circ}{.}24$ (i.e. 17^h UT) for the highest rates.



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.

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. The optimum $\alpha \times \delta$ size to be assumed for the STA and NTA is instead $20° \times 10°$, while that for the ANT 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 References and Abbreviations

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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.

9 Tables: lunar and shower data

Table 4. Lunar phases for 2023.

New Moon	First Quarter	Full Moon	Last Quarter
		January 6	January 15
January 21	January 28	February 5	February 13
February 20	February 27	March 7	March 15
March 21	March 29	April 6	April 13
April 20	April 27	May 5	May 12
May 19	May 27	June 4	June 10
June 18	June 26	July 3	July 10
July 17	July 25	August 1	August 8
August 16	August 24	August 31	September 6
September 15	September 22	September 29	October 6
October 14	October 22	October 28	November 5
November 13	November 20	November 27	December 5
December 12	December 19	December 27	

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in May 2022, with maximum dates accurate only for 2023. The parenthesized maximum date for the Puppids-Velids indicates a reference date for the radiant only, not necessarily a true maximum. The given ZHR is based on recent oberved returns. Possibly periodic showers 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 20 –	March–April, late May, late June		see Table 6		30	3.0	4
Quadrantids (010 QUA)	Dec 28–Jan 12	Jan 04	283°.15	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 14	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 10	50°.0	291°	+43°	43	3.0	3
Dayt. Arietids (171 ARI)	May 14–Jun 24	Jun 07	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
July Pegasids (175 JPE)	Jul 04–Jul 14	Jul 10	107°.5	340°	+15°	61	3.0	5
Piscis Austr. (183 PAU)	Jul 15–Aug 10	Jul 28	125°	341°	−25°	35	3.2	5
July γ-Draconids (184 GDR)	Jul 25–Jul 31	Jul 28	125°.3	280°	+51°	27	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
η-Eridanids (191 ERI)	Jul 31–Aug 19	Aug 08	135°	41°	−11°	64	3.0	3
Perseids (007 PER)	Jul 17–Aug 24	Aug 13	140°.0	48°	+58°	59	2.2	100
κ-Cygnids (012 KCG)	Aug 03–Aug 28	Aug 17	144°	286°	+59°	23	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 27	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
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 22	208°	95°	+16°	66	2.5	20
Leonis Minorids (022 LMI)	Oct 19–Oct 27	Oct 24	211°	162°	+37°	62	3.0	2
S. Taurids (002 STA)	Sep 20–Nov 20	Nov 05	223°	52°	+15°	27	2.3	7
N. Taurids (017 NTA)	Oct 20–Dec 10	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (013 LEO)	Nov 06–Nov 30	Nov 18	235°.27	152°	+22°	71	2.5	10
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 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 09	257°	100°	+08°	41	3.0	3
σ-Hydrids (016 HYD)	Dec 03–Dec 20	Dec 09	257°	125°	+02°	58	3.0	7
Geminids (004 GEM)	Dec 04–Dec 20	Dec 14	262°.2	112°	+33°	35	2.6	150
Comae Berenicids (020 COM)	Dec 05–Feb 04	Dec 16	264°	158°	+30°	64	3.0	3
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	COM				
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°	286° +43°		
May 10	242° −21°			341° +1°	291° +43°		
May 15	247° −22°			345° +3°	296° +44°		
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**			**JPE**	
Jul 5	296° −20°		285° −16°	**SDA**		335° +14°	
Jul 10	300° −19°	**PER**	289° −15°	325° −19°	**PAU**	340° +15°	
Jul 15	305° −18°	6° +50°	294° −14°	329° −19°	330° −34°	345° +16°	
Jul 20	310° −17°	11° +52°	299° −12°	333° −18°	334° −33°		**GDR**
Jul 25	315° −15°	22° +53°	303° −11°	337° −17°	338° −31°		277° +51°
Jul 30	319° −14°	29° +54°	307° −10°	340° −16°	343° −29°	**KCG**	282° +51°
Aug 5	325° −12°	37° +56°	313° −8°	345° −14°	348° −27°	281° +45°	39° −14°
Aug 10	330° −10°	45° +57°	318° −6°	349° −13°	352° −26°	284° +49°	44° −12°
Aug 15	335° −8°	51° +58°		352° −12°		287° +53°	48° −10°
Aug 20	340° −7°	57° +58°	**AUR**	356° −11°		289° +56°	52° −9°
Aug 25	344° −5°	63° +58°	85° +40°			291° +59°	**ERI**
Aug 30	349° −3°		90° +39°	**SPE**		293° +62°	
Sep 5	355° −1°		96° +39°	43° +40°			
Sep 10	0° +1°		102° +39°	48° +40°			
Sep 15	5° +2°	**STA**		53° +40°			
Sep 20		18° +5°	**DSX**	59° +41°			
Sep 25		21° +6°	150° 0°				
Sep 30		25° +7°	155° 0°	**ORI**		**OCT**	
Oct 5		28° +8°		85° +14°	**DAU**	164° +79°	**DRA**
Oct 10		32° +9°	**EGE**	88° +15°	82° +45°		262° +54°
Oct 15	**NTA**	36° +11°	99° +27°	91° +15°	87° +43°	**LMI**	
Oct 20	38° +18°	40° +12°	104° +27°	94° +16°	92° +41°	158° +39°	
Oct 25	43° +19°	43° +13°	109° +27°	98° +16°		163° +37°	
Oct 30	47° +20°	47° +14°		101° +16°		168° +35°	
Nov 5	52° +21°	52° +15°		105° +17°	**LEO**		
Nov 10	56° +22°	56° +15°	**NOO**		147° +24°		**AMO**
Nov 15	61° +23°	60° +16°	81° +16°		150° +23°		112° +2°
Nov 20	65° +24°	64° +16°	84° +16°		153° +21°		116° +1°
Nov 25	70° +24°		88° +16°	**PHO**	156° +20°	**PUP**	120° 0°
Nov 30	74° +24°	**GEM**	92° +16°	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°		130° +1°	128° −45°	105° +7°
Dec 20	101° +23°	118° +32°	161° +31°		134° 0°	217° +76°	108° +7°
Dec 25	106° +22°		166° +28°		**HYD**	217° +74°	**MON**
Dec 30	111° +21°	226° +50°	170° +26°			**URS**	
	ANT	**QUA**	**COM**				

Table 6a. Dates and radiant positions (in α and δ) for the sources of possible or additional activity described in the text.

Shower (or parent)	Activity Date	$\lambda_\odot$ 2000.0	Radiant α	Radiant δ	Details see page
κ-Cancrids (793 KCA)	Jan 10	289°315	138°	+9°	3
2016 BA_{14}	Mar 21	0°0	90°	−51°	3
Camelopardalids (451 CAM) – 209P/LINEAR	May 29	62°7	180°	+79°	6
July γ-Draconids (184 GDR)	Jul 28	125°132	280°	+51°	10
Perseids (007 PER)	Aug 13	139°83	48°	+58°	12
Perseids (007 PER)	Aug 14	140°74	48°	+58°	12
Andromedids (018 AND)	Dec 02	250°	29°	+47°	13
46P/Wirtanen (two possible radiants)	Dec 12	260°11	8°	−38°	14
			346°	+7°	14
Ursids (015 URS)	Dec 22	270°14	218°	+76°	20

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. The list needs a revision, hence all activity information may help to update it for the next 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. I thank Masahiro Koseki and Chris Steyaert for their comments on the data compiled in this Table.

Shower	Activity	Max Date	$\lambda_\odot$ 2000.0	Radiant α	Radiant δ	Rate
Capricornids/Sagittariids (115 DCS)	Jan 13–Feb 04	Feb 01*	312°5	299°	−15°	M*
April Piscids (144 APS)	Apr 20–Apr 26	Apr 23	32°5	9°	+11°	L
Arietids (171 ARI)	May 14–Jun 24	Jun 07	76°6	42°	+25°	H
ζ-Perseids (172 ZPE)	May 20–Jul 05	Jun 10*	78°6	62°	+23°	H
β-Taurids (173 BTA)	Jun 05–Jul 17	Jun 28	96°7	86°	+19°	M
ζ-Cancrids (202 ZCA)	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

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, 84 Woodwynd, Kilwinning, KA13 7DJ, Scotland, U.K.; e-mail: bill_meteor@yahoo.com

Radio Commission: Christian Steyaert, Kruisven 66, B-2400 Mol, Belgium; e-mail: steyaert@vvs.be

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

Visual Commission: Jürgen Rendtel, Eschenweg 16, D-14476 Potsdam, Germany; e-mail: jrendtel@web.de

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