International Meteor Organization

2022 Meteor Shower Calendar

edited by Jürgen Rendtel [1]

1 Introduction

This is the thirty-second 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. 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 2022 we find moonless skies for the Quadrantids, almost full Moon for the Perseids and waning gibbous (near last quarter) Moon for the Geminids. Good conditions for the maxima of other well-known showers are found for the maximum period of the η-Aquariids, Southern δ-Aquariids Aurigids and the Ursids. The Lyrid, Orionid and Leonid maxima fall in the period after the last quarter Moon, and the October-Draconids occur at full 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, Mikiya Sato and Jérémie Vaubaillon for new information and comments in respect of events in 2022 (see also the *References* in section 8). Esko Lyytinen, who provided me with valuable hints and comments on predictions over many years, sadly passed away in December 2020. His modelling results will keep him in our memory. Koen Miskotte summarised information for the SDA and CAP activity in late July. Last but not least thanks to Robert Lunsford, Alastair McBeath and Ina Rendtel for carefully checking the contents.

The available predictions for 2022 include a potential outburst of the Tau Herculids on May 31, a shower which is at or below the detection threshold at least for visual observers in other years. 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 Bootids 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.

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 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 early 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.

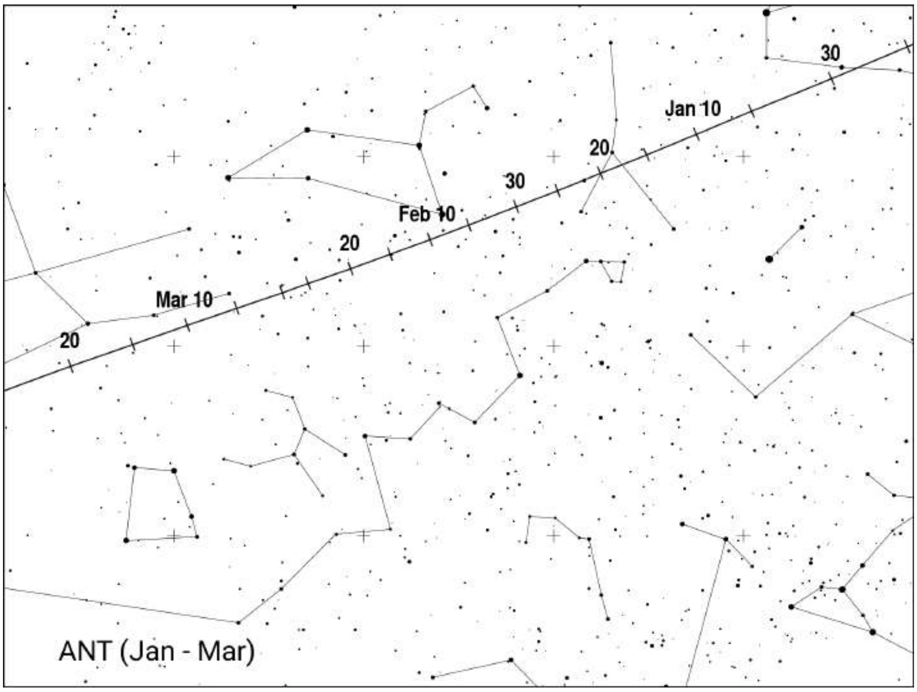
3 January to March

The year starts with the **Quadrantid (010 QUA)** peak for the northern hemisphere observers on January 3 with no moonlight interference. The long-lasting **December Leonis Minorids (032 DLM)** can be traced until early February. Full moon severely disturbs observations of the weak **γ Ursae Minorids (404 GUM)** around January 18. The southern hemisphere's **α-Centaurids (102 ACE)** reach their maximum around February 8 (first quarter Moon). The expected central part of the weak **γ-Normids (118 GNO)** of March with uncertainties of the activity period and the radiant is reached near full Moon. The maximum period should be in the interval $\lambda_\odot \approx 347°–357°$, equivalent to 2022 March 7–17.

The **ANT's** radiant centre starts January in south-east Gemini, and crosses Cancer during much of the month, before passing into southern Leo for most of February. It then shifts through southern Virgo during March. Probable ANT ZHRs will be of the order of 2 to 3 during most of the time. Video meteor flux density data indicate slight increase in March around $\lambda_\odot \approx 355°$ (2022 March 15).

On 2015 January 10 at 02^h50^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), but there is no report of activity in the subsequent years. In 2022 the position is reached on January 9, 21^h50^m UT with the first quarter Moon in Pisces. The radiant of the Antihelion source centre is 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).

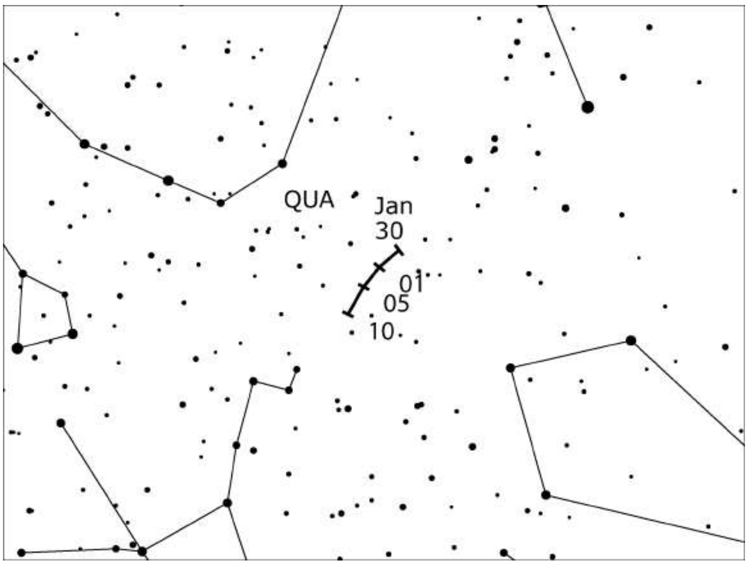
The generally low activity level from mid-January until April should allow us to detect weak sources. Of course, video data are best suited for this purpose. But visual observers should record apparent meteor trails in case that sources are discovered and subsequently may be confirmed by independent samples and possibly, rates can be derived.



Expected approximate timings for the **daytime shower maxima** this quarter are:
Capricornids/Sagittariids (115 DCS) – February 1, $12^{\rm h}$ UT
and χ-Capricornids (114 DXC) – February 14, $11^{\rm h}$ UT.
The DCS maximum may fall variably sometime between February 1–4 however, while activity near the expected DXC peak has tended to be slight and up to a day late. Both showers have radiants $< 10°$–$15°$ west of the Sun at maximum, so cannot be regarded as visual targets even from the southern hemisphere.

Quadrantids (010 QUA)

Active: December 28–January 12; Maximum: January 3, $20^{\rm h}40^{\rm m}$ UT ($\lambda_\odot = 283\overset{\circ}{.}15$),
ZHR = 120 (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.

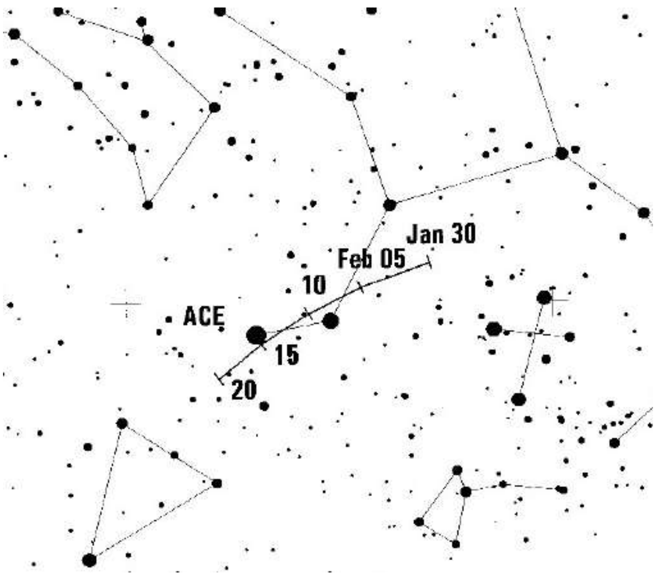


The maximum of this shower on January 3 occurs just one day after new Moon so that observers may expect optimal viewing conditions. For many northern hemisphere sites, the shower's radiant in northern Boötes is circumpolar; it is at its lowest point around $20^{\rm h}$local time. At a geographical latitude of 50° N, the radiant climbs above 20° elevation at $0^{\rm h}10^{\rm m}$ local time, while that will happen at $2^{\rm h}20^{\rm m}$ local at a latitude of 30° N, i.e. the radiant attains a useful elevation around or after local midnight and culminates close to dawn.

The 21^{h} UT timing for the peak will be favourable Asian and Eastern European longitudes. The $\lambda_\odot = 283.^\circ15$ maximum timing has been confirmed by many observations from 1992 onwards. In some video meteor flux profiles of recent years, the peak occurred at $\lambda_\odot = 283.^\circ11$ (i.e. an hour earlier). The peak is short-lived with an average duration (full width at half-maximum, FWHM – that is the period with ZHR above half of the peak level) 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. Additional complexity comes from the mass-sorting of particles across the meteoroid stream which is related to the minor planet 2003 EH_1 and to comet 96P/Machholz. Fainter (radio/radar) 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. Therefore observers should be alert throughout the shower activity period to record possible peculiarities.

α-Centaurids (102 ACE)

Active: January 31–February 20; Maximum: February 8, 07^{h} UT ($\lambda_\odot = 319.^\circ2$);
ZHR = variable, usually ≈ 6, but may reach 25+;
Radiant: $\alpha = 210^\circ$, $\delta = -59^\circ$; 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, from past records supposedly producing bright objects including fireballs. The average peak ZHR between 1988–2007 was merely 6 though (WB, p. 18), albeit coverage has frequently been extremely patchy. Bursts of only a few hours' duration reported in 1974 and 1980 apparently yielded ZHRs closer to 20–30. Significant activity was reported on 2015 February 14 (airborne observation, about 6 days after the mean peak position) although there was no confirmation of an outburst predicted for 2015 February 8 (regular maximum). Further data is needed to obtain information about the structure and extent of the stream. 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 is close to the first quarter Moon, so the second half of the night allows to observe under dark skies.

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. The respective radiants are located less than 30° distant from the Sun.

The **Lyrids (006 LYR**, also called April Lyrids) reach their maximum just before the last quarter Moon which means that the hours with a high radiant elevation are moonlit. The peak is due on April 22, 19^{h} UT ($\lambda_\odot = 32.^\circ 32$). The moon is not an issue to observe the **π-Puppids (137 PPU)** with a maximum time on April 24, 00^{h} UT ($\lambda_\odot = 33.^\circ 5$).

The maximum of the stronger **η-Aquariids (031 ETA)** occurs under favourable circumstances like the minor **η-Lyrids (145 ELY)**; this is also the case for the **June Bootid (170 JBO)** potential maximum period between June 23 and 27 (close to new Moon).

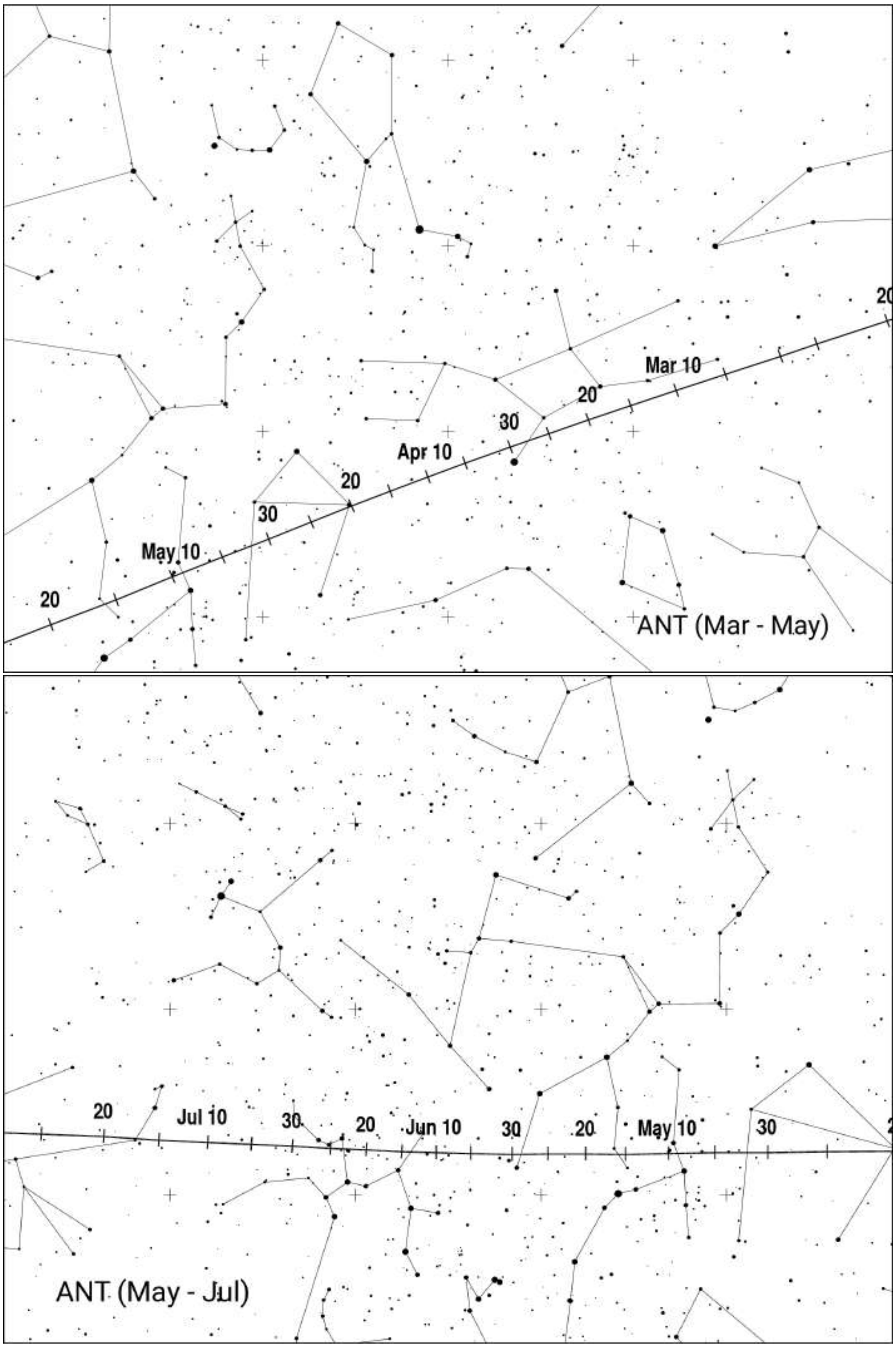
The appearance of the **τ-Herculids (061 TAH)** on May 31 is the most interesting event of this period (see page 9).

Meteoroids released from the **minor planet 2006GY$_2$** may cause activity on May 15 near $10^{\mathrm{h}}20^{\mathrm{m}}$UT ($\lambda_\odot = 54.^\circ 28$). According to Vaubaillon (2021) it is a dense stream and worth watching in that period (the density of asteroidal streams is difficult to estimate). The expected radiant is at $\alpha = 248^\circ, \delta = +46^\circ$ which is about 3° east of the star τ Her (not to be mixed up with the TAH shower); velocity 36 km/s.

On May 25 (near 08^{h} UT; $\lambda_\odot = 63.^\circ 8$), there is an encounter with meteoroids of **comet 209P/LINEAR**. Vaubaillon (2021) finds that a very dense part of the stream is located too far from the Earth, but the 1903 and 1909 trails will be encountered; however, the particle density is low. Worth checking what happens! (Radiant: $\alpha = 119^\circ, \delta = +77^\circ$, in Cam, about halfway between Polaris and o UMa); velocity 16 km/s.

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 facing page).

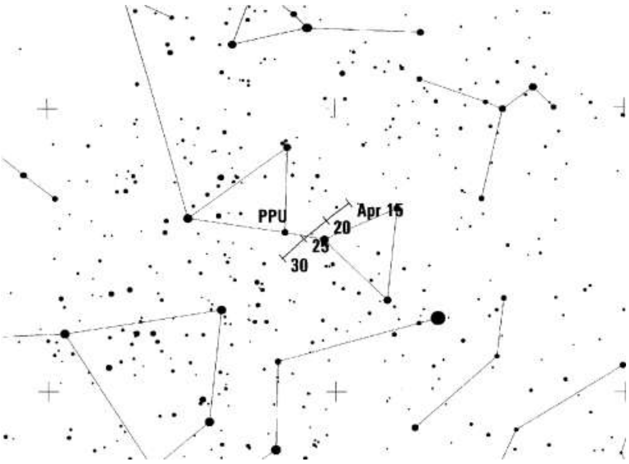
Daytime showers: In the second half of May and throughout June, most of the annual meteor action switches to the daylight sky, with several shower peaks expected during this time. For radio observers, we list the UT peak times for these showers (see also the remark below):
April Piscids (144 APS) – April 22, 22^{h}; ε-Arietids (154 DEA) – May 9, 15^{h};
May Arietids (294 DMA) – May 16, 16^{h}; o-Cetids (293 DCE) – May 20, 15^{h};
Arietids (171 ARI) – June 7, 16^{h} (more details see page 10);
ζ-Perseids (172 ZPE) – June 9, 18^{h}; β-Taurids (173 BTA) – June 28, 17^{h}.
Signs of most were found in radio data from 1994–2008, 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. Problems of shower identification concern the δ-Piscids (previously listed as having a peak on April 24). The IAU list does not recognise this currently as a genuine shower. Similarly, the o-Cetids are not listed in the IAU shower list; the number and abbreviation given here are 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.



π-Puppids (137 PPU)

Active: April 15–28; Maximum: April 24, 00^{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 on 2018 October 1.



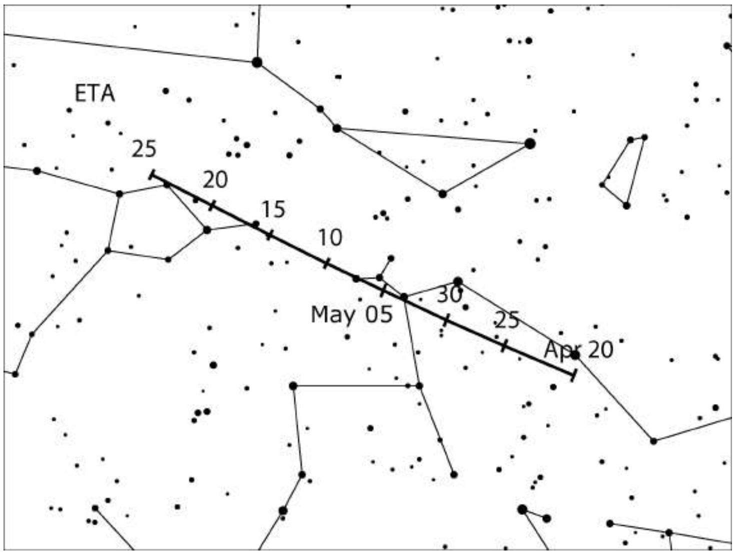
Not unexpectedly, nothing meteorically significant happened in either year. When this Calendar was prepared, no predictions for any 2022 π-Puppid meteor activity had been issued.

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 last quarter Moon (April 23) leaves the first half of the night undisturbed for optical observations this year. 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.

η-Aquariids (031 ETA)

Active: April 19–May 28; Maximum: May 6, 08^{h} UT ($\lambda_{\odot} = 45.^{\circ}5$);
ZHR = 50 (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 in the hours before dawn essentially from tropical and southern hemisphere sites. The shower is one of the best for southern observers. Useful results may be obtained even from places around 40° N latitude. The radiant culminates near 8^{h} local time. In most years, a substantial amount of optical ETA-data is collected worldwide. However, due to the relatively short observing window between radiant rise and morning twilight for each site, it remains difficult to obtain a continuous profile.



This year there is no moonlight interference during most of the activity period (first quarter Moon on May 9). IMO analyses of visual data collected since 1984 have shown that ZHRs are generally above 30 in the period May 3–10. An often claimed variability of the peak rates associated with Jupiter's orbital period close to 12 years has not been confirmed in a recent study (Egal et al., 2020) using optical and radar data.

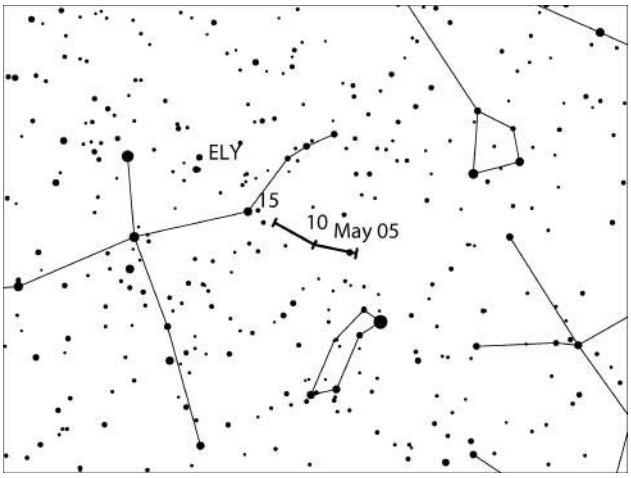
Recent peak ZHRs were:

2008	2009	2017	2018	2019	2020	2021
$\approx$ 85	$\approx$ 70	75	60	50	50	45 (preliminary)

These number might indicate rather a trend to lower ZHRs, but observations are needed to find out whether this is the case, or if the rates change in another way.

η-Lyrids (145 ELY)

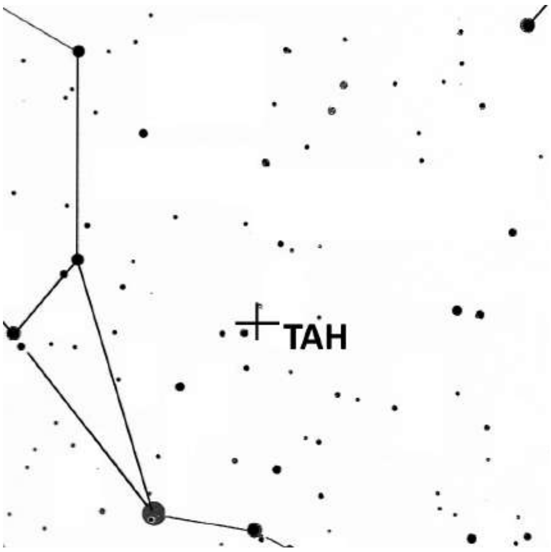
Active: May 5–14; Maximum: May 10 ($\lambda_\odot = 50°$); ZHR = 3;
Radiant: $\alpha = 291°$, $\delta = +43°$; Radiant drift: see Table 6; $V_\infty = 43$ km/s; $r = 3.0$.



This weak shower is associated with Comet C/1983 H1 IRAS-Araki-Alcock. Most of the observational data on the shower has come from video results which define the radiant and the maximum position reliably. (Note that both have been updated from the previous calendars.) Visual data obtained between 2007 and 2021 yield an average peak ZHR of 3–4 between $\lambda_\odot = 49°$ and 50°. Care needs to be taken to separate any potential η-Lyrids from the sporadics. The radiant area is usefully on-view all night from the northern hemisphere (primarily). The first quarter Moon on May 9 leaves some dark time before dawn, depending on the latitude of the observer.

Tau Herculids (061 TAH)

Active: end May to early June; Maximum: May 31 ($\lambda_\odot = 69.^\circ45$); ZHR unknown;
Radiant: $\alpha = 209°$, $\delta = +28°$; $V_\infty = 16$ km/s; r unknown.



This shower is caused by meteoroids released from comet 73P/Schwassmann-Wachmann 3 (short SW3). Shortly after SW3 was discovered in 1930, a possible meteor shower was predicted when the Earth passed close to the comets node. The available data from 1930 showed no conclusive confirmation of activity (see Rao, 2021). The assumed radiant position near τ Her led to the shower designation, although the **expected radiant now is in western Bootes** at the border to Canes Venatici. The extremely low entry velocity causes a considerable zenith attraction of the radiant position, but also makes it an obvious criterion for the shower association.

End 1995, a breakup of SW3 was observed, producing fresh trails of dust. Shortly before the comet reaches its perihelion on 2022 August 25, the Earth may encounter SW3 dust. Several model calculations have been published, concerning dust of the 1995 trail and others. The respective results for the 1995 dust encounter in 2022 are:
May 31, 04:55 UT ($\lambda_\odot = 69.^\circ44$; min. dist. +0.0004 au; Jenniskens 2006)
May 31, 05:17 UT ($\lambda_\odot = 69.^\circ459$; −0.00214 au; Jenniskens 2006)
May 31, 05:04 UT ($\lambda_\odot = 69.^\circ451$; −0.00041 au; Sato 2021)

Sato adds: "the density of the trail is estimated to be low because of the large ejection velocity. However, we may be able to see a meteor storm [...] because a lot of dust is expected due to the breakup". Dust from the 1990 and 2001 trails which are in the vicinity of the Earth close to the same time is too far away to cause activity.

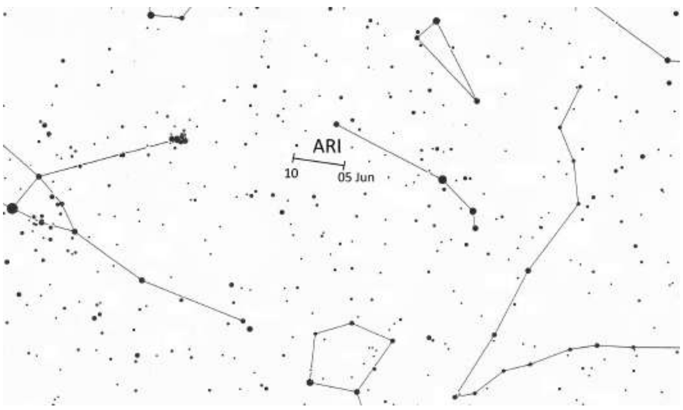
The very low entry velocity of the meteoroids ($V_\infty = 16$ km/s) will also have a significant effect. For example, a (typical) meteoroid mass range of 10 mg – 1 g causes TAH-meteors of +6.7 to +2.1 mag; the same meteoroids entering the atmosphere at Geminid velocity would appear at +3.4 to −1 mag or +0.4 to −4 mag if entering at the Leonids' velocity. However, the mass distribution of the TAH meteoroids is unknown.

The event will be best visible in parts of North and entire Central America (optimum of radiant elevation and darkness: roughly southern California, Mexico to Texas).

Since there are other trails (from previous perihelia and other fragments) approaching the Earth, it is worth to collect data between May 28 and June 1. For example, dust from the 1892 and 1897 trails may occur between May 30, about 16 UT and May 31, about 10 UT (Wiegert et al., 2005).

Daytime Arietids (171 ARI)

Active: May 14–June 24 (uncertain); Maximum: June 07 ($\lambda_\odot = 76\overset{\circ}{.}6$); ZHR ≈ 30(?);
Radiant: $\alpha = 44°$, $\delta = +24°$; Radiant drift: see Table 6;
$V_\infty = 38$ km/s; $r = 2.8$.

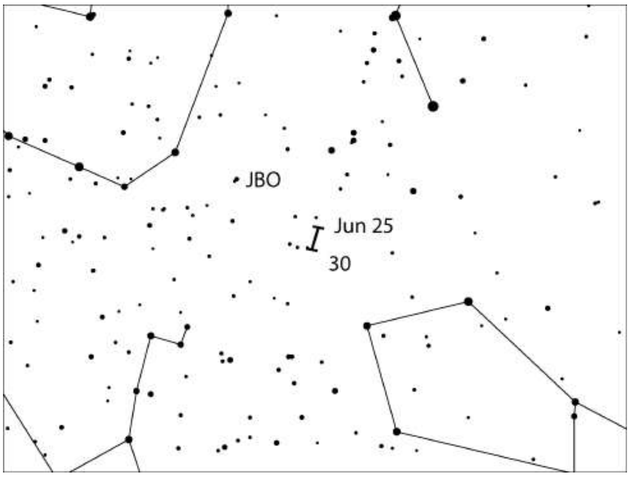


The radiant is located only about 30° west of the Sun, hence possibilities for optical observations are very limited. The low radiant elevation by the time morning twilight is too bright means the number of shower meteors recorded by individual video or visual observers is always low. Consequently, an 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 (indicating an even higher ZHR as given above) over a week or so for which we show the radiant drift. 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, 11^h UT ($\lambda_\odot = 95.^\circ7$), but see text;
ZHR = variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +48°$; Radiant drift: see Table 6; $V_\infty = 18$ km/s; $r = 2.2$.



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 ≈ 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 2022 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 but this year free from disturbing moonlight. VID suggested some June Boötids may be visible in most years around June 20 − 25 but with activity largely negligible except near $\lambda_\odot = 92°$ (2022 June 23, 19^h UT), radiating from $\alpha = 216°$, $\delta = +38°$ 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. ZHRs for most of the month should be ≈ 2 to 3. For about a week around July 10, low activity may be observed from the **July-Pegasids (175 JPE)**, this year in moonlit skies. 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. Association of meteors with one of the three radiants should be reliably possible particularly from the southern hemisphere. The highest rates are due on July 27 (PAU) and July 30 (CAP, SDA), respectively.

On 2016 July 28 at 00^h07^m UT ($\lambda_\odot = 125.^\circ132$) 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 2022 July 28 near 17^h UT, worth checking in case something may be observable around this time – although there was no activity observed in 2017 – 2020 (2021 still to come). The radiant is at $\alpha = 280°$, $\delta = +51°$, and the meteors have low speed ($V_\infty = 27$ km/s).

Full Moon on August 12 will badly affect optical observations of the **Perseid (007 PER)** activity around their maximum. The timing of the nodal maximum at $\lambda_\odot = 140\overset{\circ}{.}0$ (2022 August 13, shortly after $01^{\rm h}$ UT) favours west European locations. The moon in Aquarius perhaps allows to observe the northern sky, but with severe light pollution. Jenniskens (2006, Table 5d) lists a filament encounter at ($\lambda_\odot = 139\overset{\circ}{.}85 \pm 0\overset{\circ}{.}2$, i.e. August 12 near $22^{\rm h}$ UT) with a possible ZHR of 24. This is about 1/10 of the activity calculated and observed in the 2017 filament.

Conditions are slightly better for the **κ-Cygnids (012 KCG)**. The **Aurigid (206 AUR)** peak in the night to September 1 (see page 14). The most interesting **September ε-Perseids (208 SPE)** reach their maximum on September 9/10 just before full Moon. Vaubaillon (2021) finds encounters with the 1- and 4-revolution trails, worth to monitor although no strong display (Sep 10, $02^{\rm h}$ UT; $\lambda_\odot = 167\overset{\circ}{.}1$) is expected. A unique fragmentation of a large body was observed in 2016; further data from this shower might add to the understanding of the stream's structure.

Close to the highest Perseid activity, there is another approach to a calculated 1-revolution dust trail of **comet C/1852 $\mathbf{K_1}$**. A preceding approach is calculated for 2021 August 12 (and still awaits to be observed). The 2022 encounter on August 12, $04^{\rm h}22^{\rm m}$ UT, has a larger minimum distance between the orbits of the Earth and the comet than the 2021 approach (0.00040 au vs. 0.00010 au). Considering only this parameter, the probability of any activity may be lower in 2022, but we do not know the extension and structure of the assumed trail. The radiant is at $\alpha = 43°$, $\delta = -13°$ (in southeastern Cetus near the +4 mag star π Cet).

Remember that the **Southern Taurids (002 STA)** begin around September 10, effectively taking over the near-ecliptic activity from the ANT through to December (see chart on page 15).

For **daylight radio observers**, the high activity of May–June has waned, but there remain the **γ-Leonids (203 GLE**; possible peak near August 25, $05^{\rm h}$ UT), and the **Daytime Sextantids (221 DSX)**. From late September to early October optical observers are encouraged to collect data of the DSX (see on page 15), too.

Piscis Austrinids (183 PAU)

Active: July 15–August 10; Maximum: July 28 ($\lambda_\odot = 125°$); ZHR = 5;
Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 6; $V_\infty = 35$ km/s; $r = 3.2$.

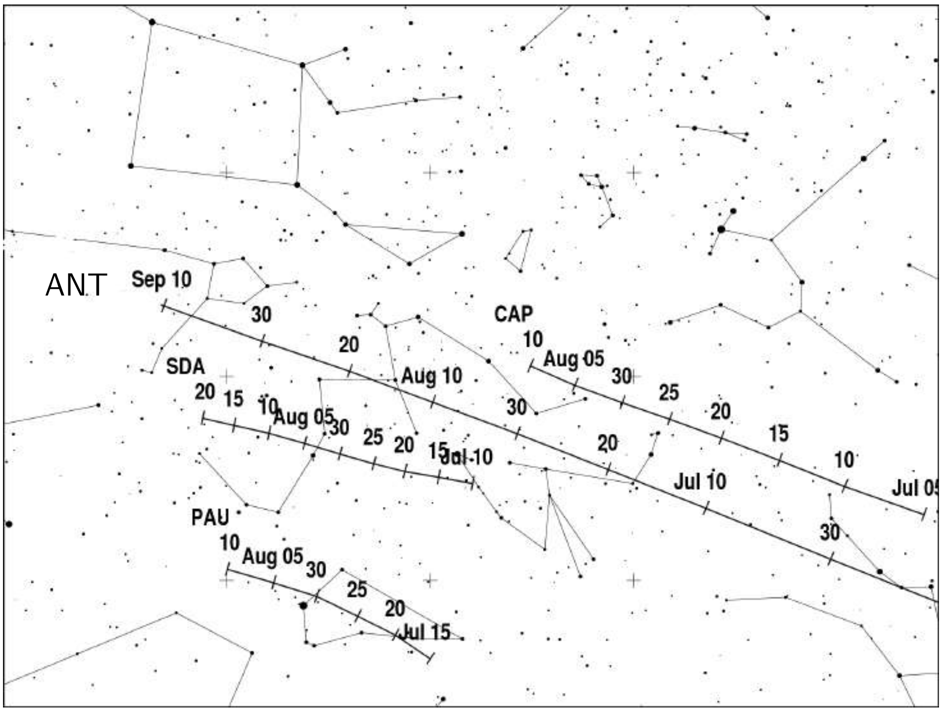
Still very little information has been collected on the PAU over the years although the shower is in all working lists (and "established" in the IAU list). Details on the shower are not well-confirmed, mainly because of the large amount of northern hemisphere summer data, and the relatively small number of southern hemisphere winter results, on it.

Southern δ-Aquariids (005 SDA)

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

The shower belongs to the most active sources in the southern hemisphere. Radio work can pick up the SDA as well, and indeed the shower has sometimes given a surprisingly strong radio signature. Data collected by experienced observers under exceptional conditions in 2008 and

2011 show that the maximum ZHR of the southern δ-Aquariids is around 25 for about two days ($\lambda_\odot = 125° - 127°$). The ZHR exceeds 20 between $\lambda_\odot = 124°$ and 129°. During the maximum there are numerous bright SDA meteors visible, causing $r \approx 2.5$ around the maximum and $r \approx 3.1$ away from the peak period. 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 July 28 is optimal for all optical observations. While at mid-northern latitudes only a small portion of the shower meteors is visible, conditions significantly improve the further south the location is.



α-*Capricornids (001 CAP)*

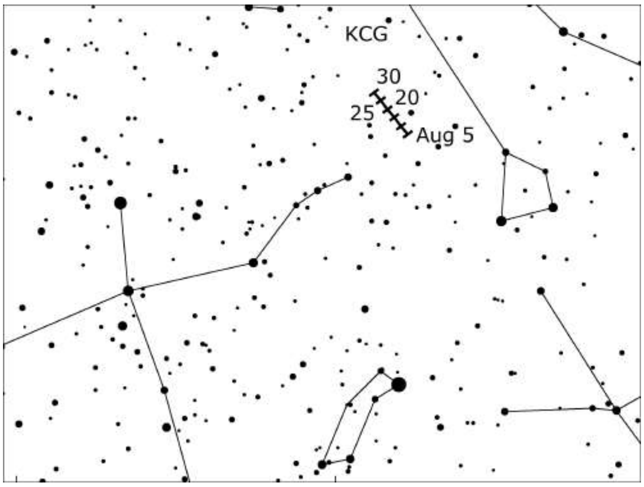
Active: July 3–August 15; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 5;
Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 6; $V_\infty = 23$ km/s; $r = 2.5$.

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

κ-Cygnids (012 KCG)

Active: August 3–25; Maximum: August 17 ($\lambda_\odot = 145°$); ZHR = 3;
Radiant: $\alpha = 286°$, $\delta = +59°$; Radiant drift: see Table 6; $V_\infty = 25$ km/s; $r = 3.0$.

Enhanced κ-Cygnid activity was observed in 2014 and 2007. Apart from these events, a recent analysis indicates a general ZHR level increase in the recent years after an apparent dip in the period 1990–2005. However, the currently available data do not confirm a periodic activity variation in the visual activity range, and for 2022 there are no available predictions suggesting further peculiarities may occur.

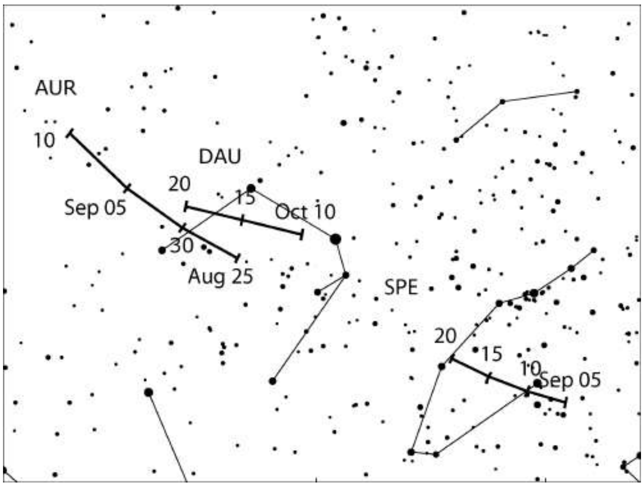


An average flux density profile for the period 2012–2018 from video data shows a clear maximum at 145°and detectable activity between August 2 and 18.

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; in 2022 best before midnight because of the waning Moon.

Aurigids (206 AUR)

Active: August 28–September 5; Maximum: September 1, 09^h UT ($\lambda_\odot = 158.°6$) – see text;
ZHR = 10; Radiant: $\alpha = 91°$, $\delta = +39°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.5$.

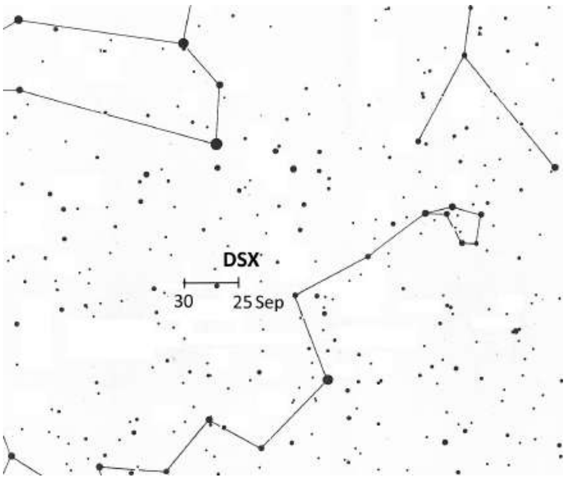


This northern-hemisphere shower has produced short, unexpected, outbursts at times, with peak ZHRs of ≈ 30–50 recorded in 1935, 1986, 1994 and 2019. Other events may have been missed because the shower has not been monitored regularly. Only three observers covered the 1986 and 1994 outbursts, for instance. Observations of the first *predicted* outburst in 2007 confirmed the calculated values widely. This outburst was characterized by many bright meteors. The peak ZHR of ≈ 130 lasted only for about 20 minutes. The possible extra activity calculated for the **2021** return was still to come when this Calendar was prepared.

Sato (2021) computed a one revolution dust trail and found that the minimum distance between Earth and the trail in **2022** is larger than in 2021. If the trail width is extended as indicated by previous observations, there may be **weak activity on September 1 at 00^h55^m UT.** The Aurigid radiant reaches a useful elevation only after $\approx 01^h$ local time – this year with no moonlight interference.

Daytime Sextantids (221 DSX)

Active: September 9–October 9 (uncertain); Maximum: September 27 ($\lambda_\odot = 184.^\circ3$), Radiant: $\alpha = 152°$, $\delta = 0°$; Radiant drift: 1° per day; $V_\infty = 32$ km/s; $r = 2.5$ (uncertain).



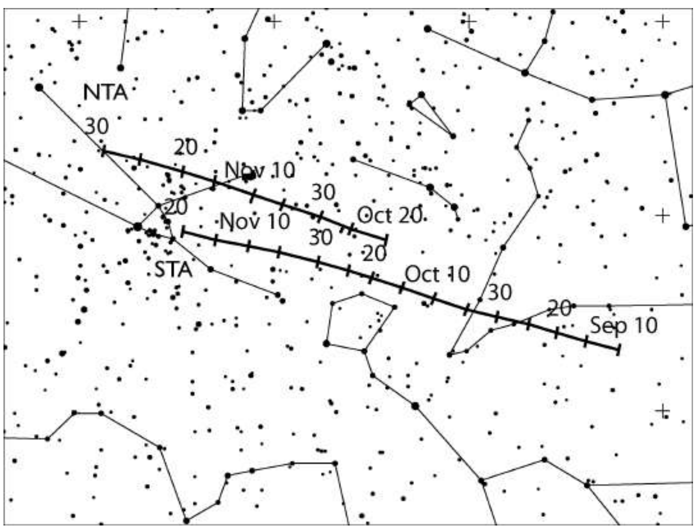
Visual observers may note few Sextantids in the predawn of late September to early October as part of the IMO project to collect and pool data obtained by all techniques for this shower. The radiant is roughly 30° west of the Sun. Because it lies close to the equator and the activity period is shortly after the equinox, observers in either hemisphere may contribute results. 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. The supposed maximum period is around new Moon, so there is no additional light for sessions into morning twilight to spot possible DSX meteors.

6 October to December

The **Orionids (008 ORI**; maximum October 21/22) and the **Leonids (013 LEO**; maximum November 17) reach their maxima between last quarter and new Moon whereas the most active **Geminid (004 GEM)** shower peak night December 13/14 has a waning gibbous Moon in western Leo. The **Ursid (URS)** maximum occurs at new Moon.

The two Taurid branches reach their highest rates around October 10 (Southern Taurids, 002 STA) and November 12 (Northern Taurids, 017 NTA), respectively. Both dates are close to the Moon's full phase. Hence we only show the chart of the radiant drifts for both branches. However, observers should be alert as 2022 is again a **"Taurid swarm"** year after 2012 and 2016. Meteoroids concentrated in resonant orbits may result in higher rates and may include larger objects, causing bright fireballs between end October and about November 10.

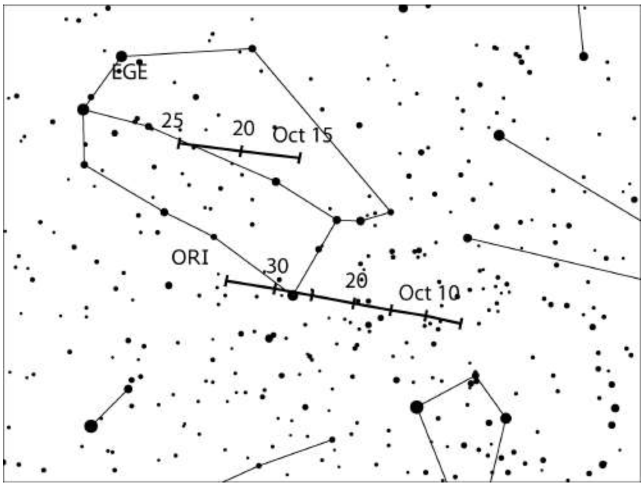


The **ANT** activity is resuming only around December 10, as the Northern Taurids fade away. The radiant centre tracks from Taurus across southern Gemini during later December. The typical ZHR level is < 2.

Several minor showers are active in the last quarter of the year. The **October Camelopardalids (281 OCT**, maximum October 6, 04^hUT), the **Draconids (009 DRA**, maximum October 9, 01^hUT) as well as the **δ-Aurigids (224 DAU**, maximum October 11) reach their maxima close to full Moon. No predictions of peculiar activity are known for any of these showers in 2022. The maximum of the weak **ε-Geminids (023 EGE**, maximum October 18) occurs just after last quarter Moon which lights up the morning skies. Only the later **Leonis Minorids (022 LMI)** have no moonlight interference. This also holds for the showers which are active towards the end of November, i.e. the **α-Monocerotids (246 AMO)** and the **November Orionids (250 NOO)**. The early December southern showers – **Phoenicids (254 PHO**, maximum December 02) and the complex **Puppid-Velids (301 PUP)** suffer from increasing moonlight. This particularly affects the PHO which are observable only in the evening hours. Towards the full Moon (December 8) the conditions become worse for the **Monocerotids (019 MON**, maximum December 10) and the **σ-Hydrids (016 HYD**, maximum December 10). The weak **Comae Berenicids (020 COM)** around December 16 can be observed well like the long-lasting **December Leonis Minorids (032 DLM)** with no moonlight especially around their weak maximum around December 20. At the end of the year, the first **Quadrantids (010 QUA)** can be seen.

Orionids (008 ORI)

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

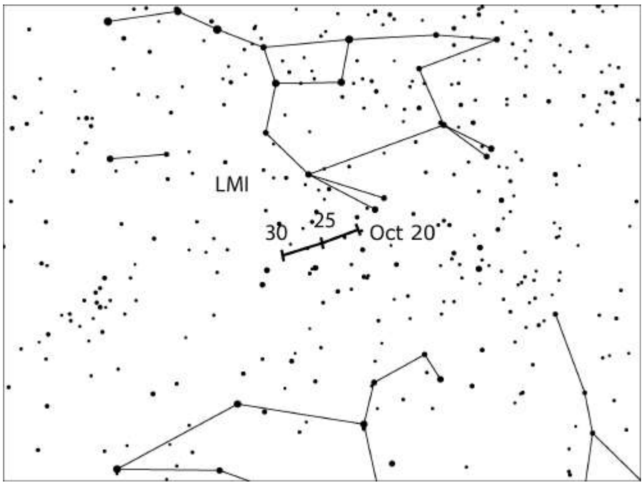


Some moonlight interference (new Moon only on October 25) will require to shield its light in the last hours before dawn. The shower's radiant is at a useful elevation from local midnight or so in either hemisphere, somewhat before in the north. Each return from 2006 to 2009 produced unexpectedly strong ZHRs of around 40–70 on two or three consecutive dates. An earlier IMO analysis of the shower, using data from 1984–2001, found both the peak ZHR and r parameters varied somewhat from year to year, with the highest mean ZHR ranging from ≈ 14–31 during the examined interval.
A suspected 12-year periodicity in stronger returns found 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). So the question of a periodicity in the rate is still open. 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 2012–2019 was in the range of 20–30.

The Orionids may provide several lesser maxima. So the activity sometimes 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, for instance.

Leonis Minorids (022 LMI)

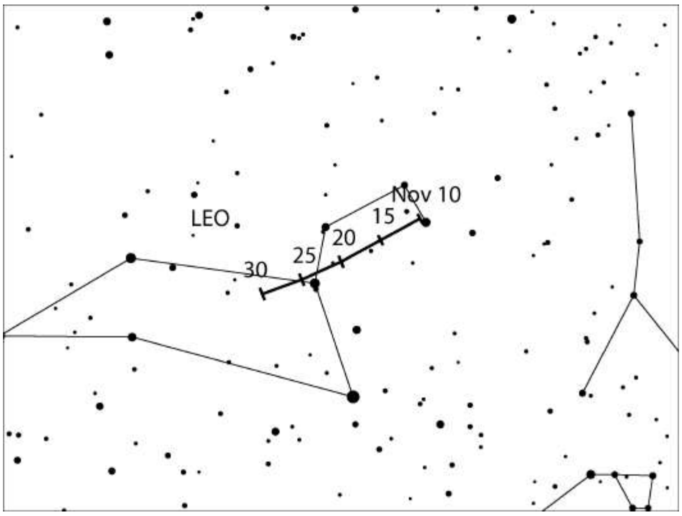
Active: October 19–27; Maximum: October 24 ($\lambda_\odot = 211°$); ZHR = 2;
Radiant: $\alpha = 162°$, $\delta = +37°$; Radiant drift: See Table 6;
$V_\infty = 62$ km/s; $r = 3.0$.



This weak minor shower was first found in video meteor data. Comet C/1739 K1 (Zanotti) is suggested as parent object. Over the past years, a suitable sample of visual data has been collected. Visual data from 2017–2020 yield a maximum ZHR of the order of 5 around October 24. The radiant area can be seen solely from the northern hemisphere, where it rises around midnight. The given maximum date is close to new Moon, favourable for collection of optical observations.

Leonids (013 LEO)

Active: November 6–30; Maximum: November 17, $23^{\rm h}$ UT (nodal crossing at $\lambda_\odot = 235\overset{\circ}{.}27$);
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 knowledge of the dust ejection mechanisms and trail evolution allowed us to predict and verify variable activity in numerous years until recently. The nodal Leonid maximum occurs on 2022 November 17.

Additionally, there are a few encounters with dust trails in the following days:

Model calculations of Maslov (2007) and Sato (2021) show an approach of the **1733 dust trail on November 19**. Maslov gives $06^{\rm h}$ UT, Sato obtains $06^{\rm h}20^{\rm m} - 06^{\rm h}27^{\rm m}$ UT ($\lambda_\odot = 236\overset{\circ}{.}576$ and $\lambda_\odot = 236\overset{\circ}{.}581$; different ejection velocities).

The possible activity level depends on the ejection velocity (which has a negative sign in this case and observations of meteors from such trails are scarce). Maslov adds: meteors should be bright, a ZHR of 200+ seems possible despite the uncertainties. Sato comments: ZHR may reach 50+ because the model suggests that the dust tends to be concentrated.

An encounter with the **1600 trail** (weak rate possible near **November 18, 07$^{\text{h}}$ UT**; $\lambda_\odot = 235\,\overset{\circ}{.}6$) is found by Vaubaillon (2021). A weak rate enhancement may be visible due to the **1800 trail** later on **November 21, 15$^{\text{h}}$ UT** (Maslov, 2007).

The nodal maximum occurs just after the Moon's last quarter phase, and the conditions are slightly better for the later encounters. Visual observers need to shield the direct moonlight. The shower's radiant is usefully observable only after local midnight or so north of the equator, later for places further south.

α-Monocerotids (246 AMO)

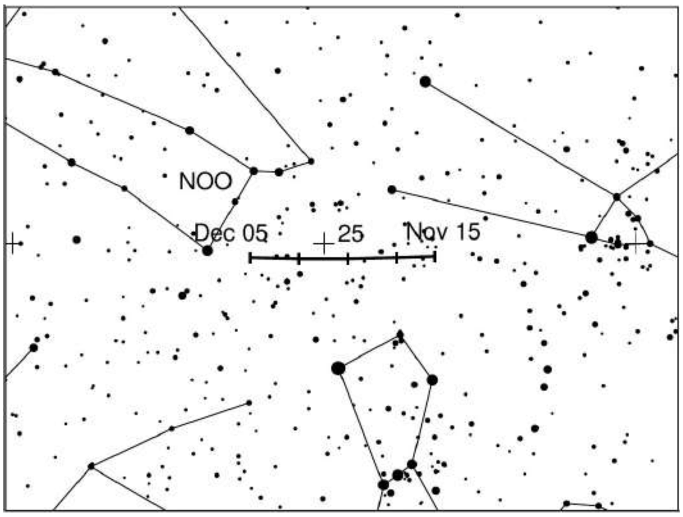
Active: November 15–25; Maximum: November 21, 23$^{\text{h}}$30$^{\text{m}}$ UT ($\lambda_\odot = 239\,\overset{\circ}{.}32$);
ZHR = variable, usually ≤ 5, see text;
Radiant: $\alpha = 117°$, $\delta = +01°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 2.4$.

The most recent α-Monocerotid outbursts have been observed in 1995 (ZHR $\approx$ 420) and 2019 (ZHR $\approx$ 120). In both cases, the peak lasted for just five minutes, the entire outbursts 30 minutes. The next strong AMO outburst is unlikely before 2043. Despite all this, observers are advised to monitor the AMO annually to complete our knowledge about this stream. New Moon on November 23 provides us with favourable observing conditions. The radiant reaches suitable elevation above the horizon from about local midnight.

November Orionids (250 NOO)

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

Detailed analysis of video data revealed that there are two consecutive, very similar showers whose activity intervals partially overlapeach other: the November Orionids (250 NOO), followed by the Monocerotids (019 MON). In the last days of November the NOO shower is the strongest source in the sky.



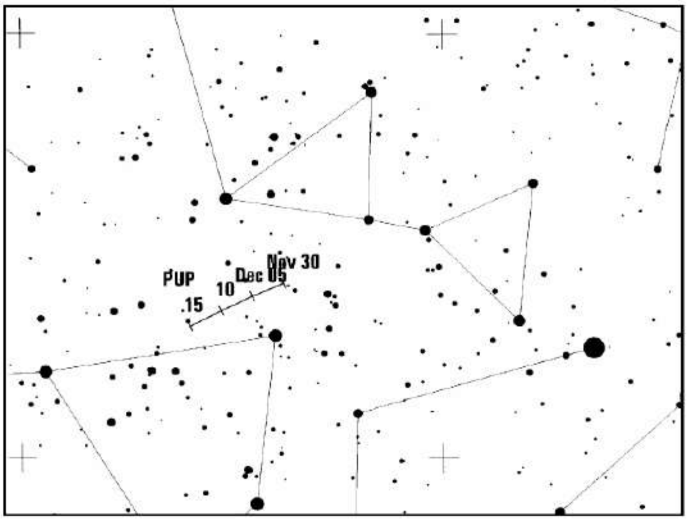
The radiant is located in northern Orion, 8° north of α Orionis. This location is close to the Northern Taurids, but far enough east to distinguish meteors from the two sources. Additionally, the faster velocity of the November Orionids should help distinguish these meteors from the slower Taurids.

The radiant culminates near 2$^{\text{h}}$ local time, but is above the horizon for most of the night. The first quarter Moon on November 30 sets early enough to allow observations when the radiant is high in the sky.

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.

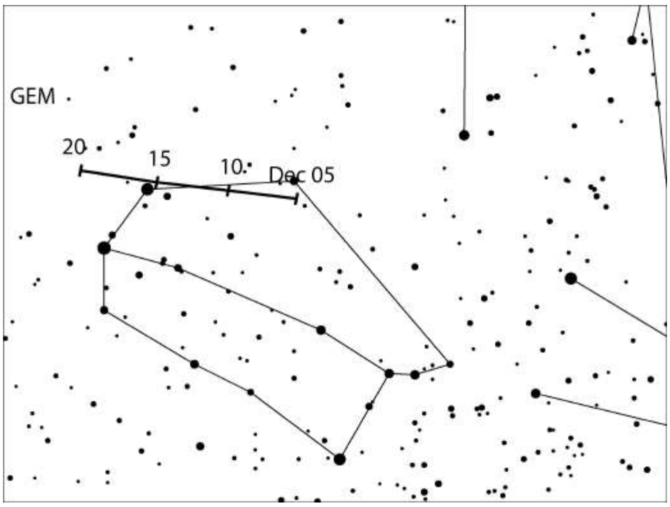


The activity is poorly-established, though the higher rates seem to occur in early to mid December. Full Moon on December 8 allows to follow the early part of the complex activity. The radiant area is on-view all night from tropical and southern locations, highest towards dawn.

Some PUP activity may be visible prior and after the given period. Occasional bright fireballs, notably around the suggested maximum, have been reported regularly.

Geminids (004 GEM)

Active: December 4–17; Maximum: December 14, 13^h UT ($\lambda_\odot = 262.^\circ 2$); 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 maximum on December 14 centred at 13^h UT. In 2022, this is only six days after full Moon. Hence the conditions are rather poor particularly for visual observations as the waning gibbous Moon is in Leo during the maximum period. Nevertheless, the high rate and number of bright Geminid meteors may be attractive for observers. Furthermore, we may obtain a reasonable sample of data which cover a large range of limiting magnitudes but about constant rates. This is of interest e.g. for calibration of correction factors.

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. For northern latitude observers, the evening of December 14 will have some dark period of roughly three hours with a sufficient radiant elevation until the Moon rises. Additionally, during the late part of the maximum often bright meteors occurred.

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 2022 December 13, 21^h to December 14, 18^h UT.

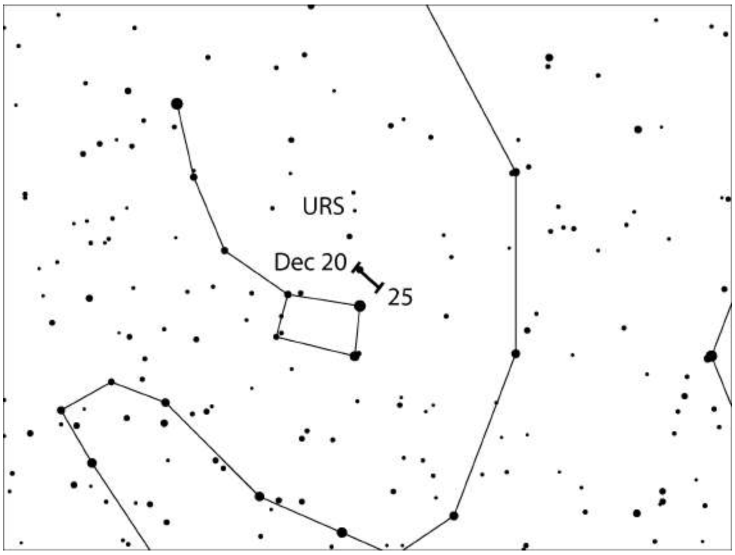
Ursids (015 URS)

Active: December 17–26; Maximum: December 22, 22^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. Several lesser rate enhancements have been reported from 2006 to 2008 as well as in 2014 and 2015 (video data). The parent comet 8P/Tuttle has an orbital period of 13.6 years. It passes perihelion 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 2022, there are two periods which are of special interest. The first is a **filament encounter on December 22,** $10^\mathrm{h}21^\mathrm{m}$ **UT** ($\lambda_\odot = 270\overset{\circ}{.}22$) listed by Jenniskens (2006, Table 5b), noted with a ZHR of 28; this is about 1/3 of the value given for filaments in the years 2016/17/18.

Sato (2021) calculated an encounter with a **dust trail ejected in 843 for December 22 at** $14^\mathrm{h}22^\mathrm{m}$ **UT** ($\lambda_\odot = 270\overset{\circ}{.}391$)**.** Observational data is needed to find out the activity level.



Both timings favour North American locations, but also the adjacent periods should be used for observations to establish a full profile and to detect possible differences in the meteoroid populations (magnitude distributions).

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. Moon-free and long northern nights allow observations for several hours at each suitable location. If possible, both the regular maximum and the filament encounter period should be target of observations.

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

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.

9 Tables: lunar and shower data

Table 4. Lunar phases for 2022.

New Moon	First Quarter	Full Moon	Last Quarter
January 2	January 9	January 18	January 25
February 1	February 8	February 16	February 23
March 2	March 10	March 18	March 25
April 1	April 9	April 16	April 23
April 30	May 9	May 16	May 22
May 30	June 7	June 14	June 21
June 29	July 7	July 13	July 20
July 28	August 5	August 12	August 19
August 27	September 3	September 10	September 17
September 25	October 3	October 9	October 17
October 25	November 1	November 8	November 16
November 23	November 30	December 8	December 16
December 23	December 30		

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in June 2021, with maximum dates accurate only for 2022. 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 10 –	March–April, late May, late June		see Table 6		30	3.0	4
Quadrantids (010 QUA)	Dec 28–Jan 12	Jan 03	283°.15	230°	+49°	41	2.1	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 22	32°.32	271°	+34°	49	2.1	18
π-Puppids (137 PPU)	Apr 15–Apr 28	Apr 23	33°.5	110°	−45°	18	2.0	Var
η-Aquariids (031 ETA)	Apr 19–May 28	May 06	45°.5	338°	−01°	66	2.4	50
η-Lyrids (145 ELY)	May 03–May 14	May 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°	−30°	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
Perseids (007 PER)	Jul 17–Aug 24	Aug 13	140°.0	48°	+58°	59	2.2	100
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 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
S. Taurids (002 STA)	Sep 10–Nov 20	Oct 10	197°	32°	+09°	27	2.3	5
δ-Aurigids (224 DAU)	Oct 10–Oct 18	Oct 11	198°	84°	+44°	64	3.0	2
ε-Geminids (023 EGE)	Oct 14–Oct 27	Oct 18	205°	102°	+27°	70	3.0	3
Orionids (008 ORI)	Oct 02–Nov 07	Oct 21	208°	95°	+16°	66	2.5	20
Leonis Minorids (022 LMI)	Oct 19–Oct 27	Oct 24	211°	162°	+37°	62	3.0	2
N. Taurids (017 NTA)	Oct 20–Dec 10	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (013 LEO)	Nov 06–Nov 30	Nov 17	235°.27	152°	+22°	71	2.5	10
α-Monocerotids (246 AMO)	Nov 15–Nov 25	Nov 21	239°.32	117°	+01°	65	2.4	Var
Nov. Orionids (250 NOO)	Nov 13–Dec 06	Nov 28	246°	91°	+16°	44	3.0	3
Phoenicids (254 PHO)	Nov 28–Dec 09	Dec 02	250°.0	18°	−53°	18	2.8	Var
Puppid-Velids (301 PUP)	Dec 01–Dec 15	(Dec 07)	(255°)	123°	−45°	40	2.9	10
Monocerotids (019 MON)	Dec 05–Dec 20	Dec 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 Berenic. (020 COM)	Dec 12–Dec 23	Dec 16	264°	175°	+18°	65	3.0	3
Dec. L. Minorids (032 DLM)	Dec 05–Feb 04	Dec 20	268°	161°	+30°	64	3.0	5
Ursids (015 URS)	Dec 17–Dec 26	Dec 22	270°.7	217°	+76°	33	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°	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°	283°	+58°		
Aug	10	330°	−10°	45°	+57°	318°	−6°	349°	−13°	352°	−26°	284°	+58°		
Aug	15	335°	−8°	51°	+58°			352°	−12°			285°	+59°		
Aug	20	340°	−7°	57°	+58°	**AUR**		356°	−11°			286°	+59°		
Aug	25	344°	−5°	63°	+58°	85°	+40°					288°	+60°		
Aug	30	349°	−3°			90°	+39°	**SPE**				289°	+60°		
Sep	5	355°	−1°	**STA**		96°	+39°	43°	+40°						
Sep	10	0°	+1°	12°	+3°	102°	+39°	48°	+40°						
Sep	15			15°	+4°			53°	+40°						
Sep	20			18°	+5°	**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°	174°	+19°	130°	+1°	128°	−45°	105°	+7°
Dec	20	101°	+23°	118°	+32°	161°	+31°	177°	+18°	134°	0°	217°	+76°	108°	+7°
Dec	25	106°	+22°			166°	+28°	180°	+16°	**HYD**		217°	+74°	**MON**	
Dec	30	111°	+21°	226°	+50°	170°	+26°	**COM**				**URS**			
		ANT		**QUA**		**DLM**									

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	Radiant α	δ	Details see page
κ-Cancrids (793 KCA)	Jan 10	289°315	138°	+9°	3
2006 GY_2	May 15	54°28	248°	+46°	6
209P/LINEAR	May 25	63°8	119°	+77°	6
τ-Herculids (061 TAH)	May 31	69°451	209°	+28°	9
July γ-Draconids (184 GDR)	Jul 28	125°132	280°	+51°	11
C/1852 K_1	Aug 12	139°402	43°	−13°	12
Perseids (007 PER)	Aug 12	139°85	48°	+58°	12
Aurigids (206 AUR)	Sep 01	158°289	91°	+39°	14
Leonids (013 LEO)	Nov 19	236°58	154°	+21°	17
Ursids (015 URS)	Dec 22	270°391	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. 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 Chris Steyaert for comments on the data compiled in this Table.

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

10 Useful addresses

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

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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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