International Meteor Organization

2021 Meteor Shower Calendar

edited by Jürgen Rendtel [1]

---

1 Introduction

This is the thirty-first edition of the International Meteor Organization (IMO) Meteor Shower Calendar, a series which was started by Alastair McBeath. 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. 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 the numerous effects occurring between the meteoroid release from their parent object and the currently observable structure of the related streams. We hope the Calendar continues to be a useful tool to plan your meteor observing activities during periods of high rates or periods of specific interest for projects or open issues which need good coverage and attention.

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 2021 we find a waning gibbous Moon for the Quadrantids, almost no moonlight interference for the Perseids and a first quarter Moon for the Geminids. Conditions for the maxima of other well-known showers are good: the Lyrid maximum falls just after the first quarter Moon, the Draconids see no moonlight and the η-Aquariids peak shortly before new Moon. The situation is poor for the Orionids as well as the Leonids with their maxima just before full Moon, the Southern δ-Aquariids coincide with the last quarter Moon and the Ursids reach their maximum shortly after full Moon.

The heart of the Calendar is the Working List of Visual Meteor Showers (Table 5) 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. Particular thanks are due to Peter Jenniskens, Esko Lyytinen, Mikhail Maslov, Mikiya Sato and Jérémie Vaubaillon for new information and comments in respect of events in 2021 (see also the *References* in section 8). Koen Miskotte summarized information for the SDA and CAP activity in late July. Last but not least thanks to David Asher, Robert Lunsford and Alastair McBeath for carefully checking the contents.

The available predictions for 2021 do not include any spectacular outbursts, but some very interesting encounters which are relevant for future predictions which are described in the text and listed in Table 6a. 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 July-August α-Capricornids, and particularly the Southern δ-Aquariids as apparently distinguishable showers separate from the ANT. Later in the year, the Taurid showers dominate the activity from the Antihelion region meaning the ANT should be considered inactive while the Taurids are underway, from early September 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

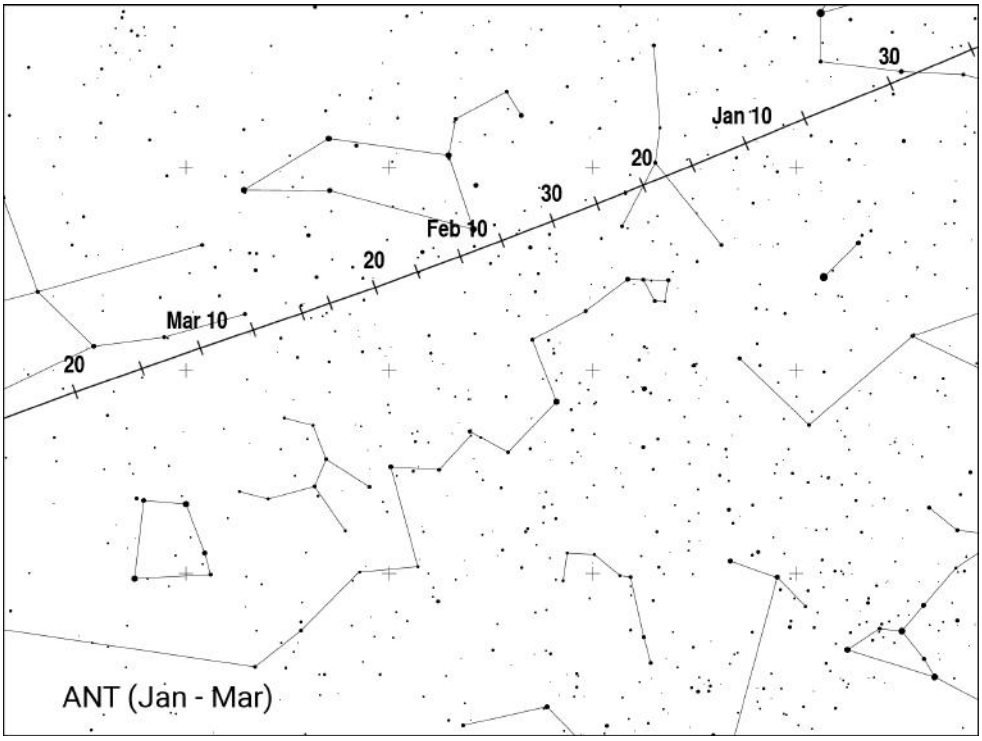
The year starts with the **Quadrantid (010 QUA)** peak for the northern hemisphere observers on January 3. The waning gibbous Moon (last quarter on January 6) illuminates the period when the radiant reached suitable elevation. The peak position based on long-term series is expected on January 3, $14^{h}30^{m}$ UT. The 2021 series allows us to monitor the late period of the shower which can be observed until January 12, together with the weak **γ Ursae Minorids (404 GUM)**. The long-lasting **December Leonis Minorids (032 DLM)** can be traced until early February. The southern hemisphere's **α-Centaurids (102 ACE)** around February 8 occur under optimal conditions. The **γ-Normids (118 GNO)** of March require careful observing because both the activity period and the radiant are uncertain.

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 $\lambda_{\odot} \approx 355°$ (2021 March 17).

On 2015 January 10 at $02^{h}50^{m}$ 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). There is no report of activity in the subsequent years. In 2021 the position is reached on January 9, $15^{h}40^{m}$ UT with no moonlight interference. The radiant of the Antihelion source centre is at $\alpha = 122°$, $\delta = +19°$, i.e. roughly 20° southeast, and the KCA meteors ($V_{\infty} = 47$ km/s) are faster than the ANT ($V_{\infty} = 30$ km/s).

A minor chance of activity caused by **meteoroids of comet C/1976 D1** is listed in Jenniskens (2006; p. 617). The timing is March 1, $09^{h}32^{m}$ UT ($\lambda_{\odot} = 340\overset{\circ}{.}729$) from a far southern radiant at $\alpha = 13°$, $\delta = -64°$ (slightly northwest of the +4 mag star ζ Phe).

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.

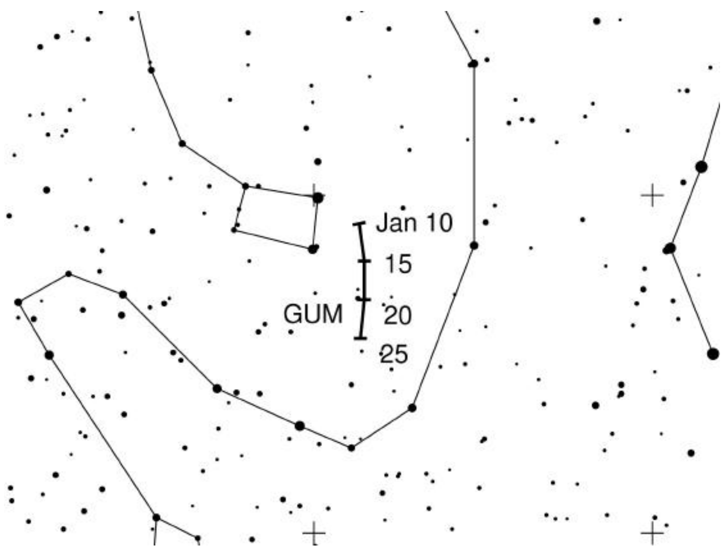


Expected approximate timings for the **daytime shower maxima** this quarter are:
Capricornids/Sagittariids (115 DCS) – February 1, 12^h UT
and χ-Capricornids (114 DXC) – February 14, 11^h UT.
Recent radio results have implied the DCS maximum may fall variably sometime between February 1–4 however, while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

γ ***Ursae Minorids (404 GUM)***

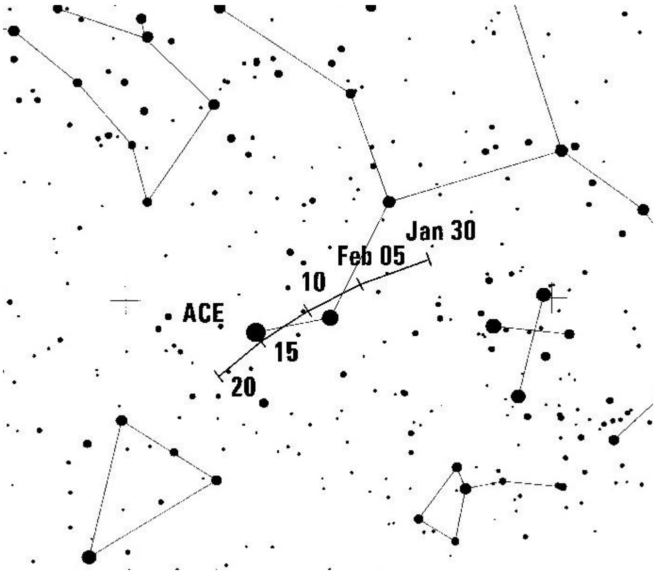
Active: January 10–22; Maximum: around January 18 ($\lambda_\odot = 298°$); ZHR ≈ 3;
Radiant: $\alpha = 228°$, $\delta = 67°$; Radiant drift: see Table 6; $V_\infty = 31$ km/s; $r = 3.0$.

Little is yet known about this minor shower which has been detected in video and visual data recently. 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. New Moon on January 13 provides excellent conditions for all observational efforts to establish the rate and the activity period.



α-Centaurids (102 ACE)

Active: January 31–February 20; Maximum: February 8, 07^h UT ($\lambda_\odot = 319.°2$);
ZHR = variable, usually ≈ 6, but may reach 25+;
Radiant: $\alpha = 210°$, $\delta = -59°$; Radiant drift: see Table 6; $V_\infty = 58$ km/s; $r = 2.0$.

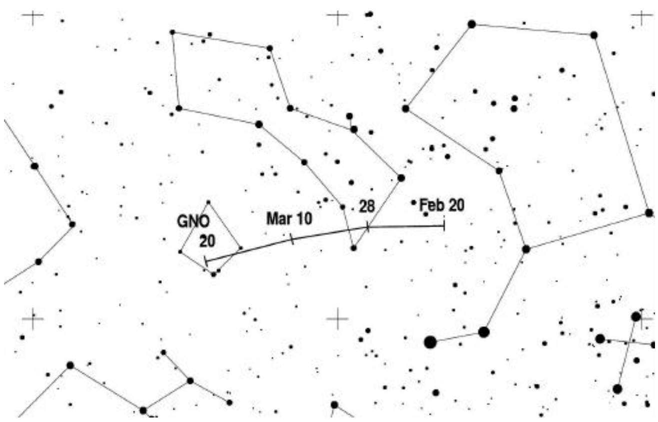


The α-Centaurids are one of the main southern summer high points, from past records supposedly producing bright objects including fireballs. The average peak ZHR between 1988–2007 was merely 6 though (WB, p. 18), albeit coverage has frequently been extremely patchy. Despite this, in 1974 and 1980, bursts of only a few hours' duration apparently yielded ZHRs closer to 20–30. Significant activity was reported on 2015 February 14 (airborne observation) although there was no confirmation of an outburst predicted for 2015 February 8.
Further data is needed to obtain information about the structure and 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 falls close to new Moon, so is favourable for dark-sky coverage increasingly later in the night.

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 2021 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. Moonlight effects increase towards the later maximum date (full Moon on March 28).

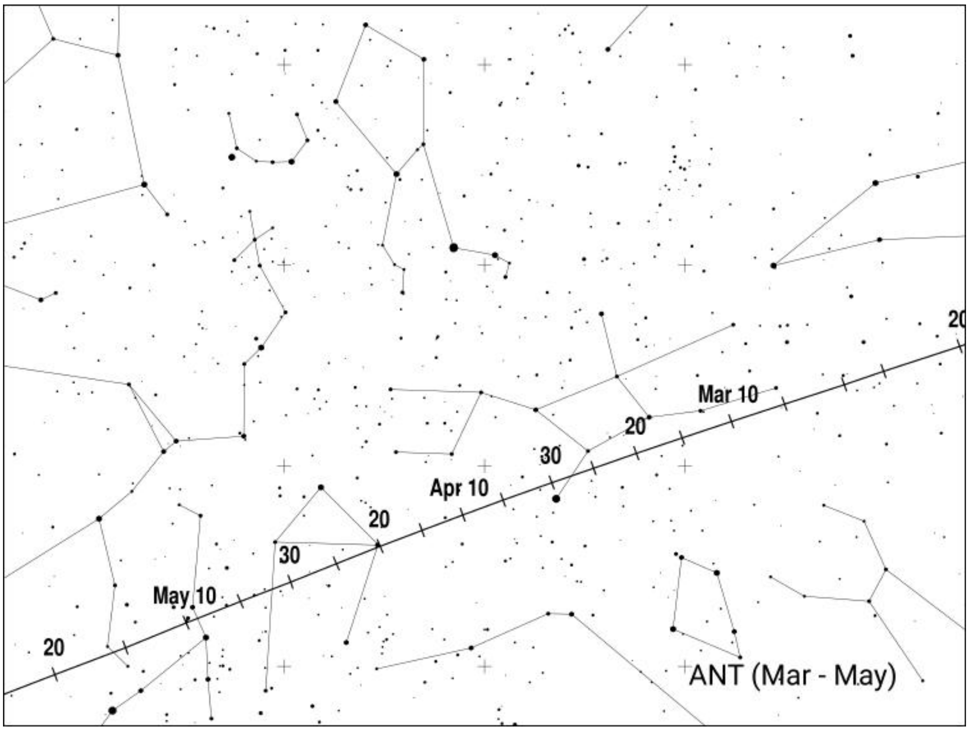
4 April to June

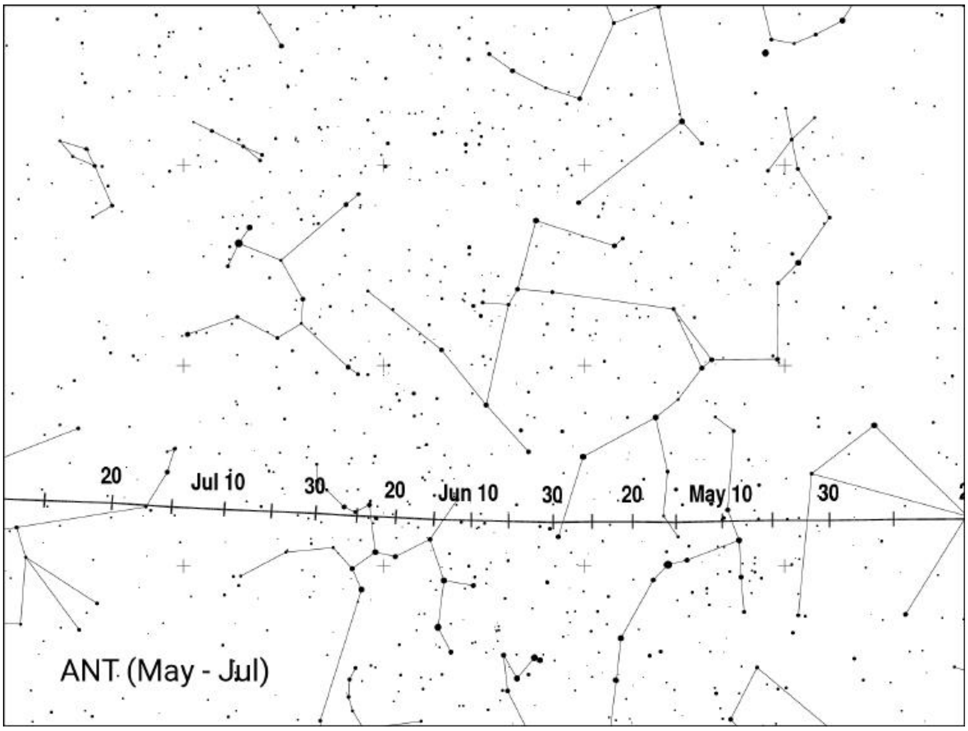
In this period the visually accessible meteor rates increase significantly, although much of the total meteor activity in late April into May remains unobservable for optical methods as it is caused by daytime showers. The respective radiants are located too close to the Sun.

The **Lyrids (006 LYR**, also called April Lyrids) reach their maximum after first quarter Moon. Most northern hemisphere observers will see almost no moon-free window remaining for the peak, due on April 22, 13^h UT ($\lambda_\odot = 32\overset{\circ}{.}32$). The situation is even worse for the **π-Puppids (137 PPU)** with a maximum time on April 23, 12^h UT ($\lambda_\odot = 33\overset{\circ}{.}5$).

The maximum of the stronger **η-Aquariids (031 ETA)** occurs under much better circumstances like the minor **η-Lyrids (145 ELY)**. The **June Bootid (170 JBO)** potential maximum period between June 23 and 27 more or less coincides with the full Moon.

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 (see chart below), and on into Sagittarius for much of June (chart see facing page).



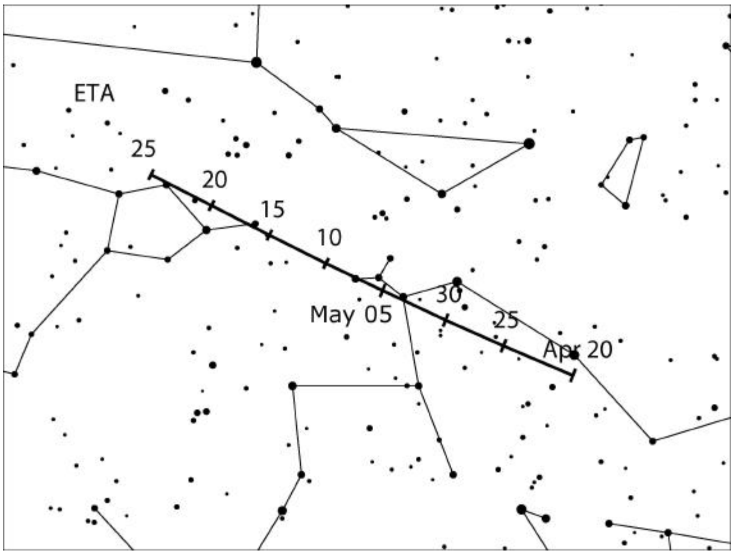


Daytime showers: In the second half of May and throughout June, most of the annual meteor action switches to the daylight sky, with several shower peaks expected during this time. For radio observers, we list the UT peak times for these showers (see also the remark below):
April Piscids (144 APS) – April 22, $16^{\rm h}$; ε-Arietids (154 DEA) – May 9, $9^{\rm h}$;
May Arietids (294 DMA) – May 16, $10^{\rm h}$; o-Cetids (293 DCE) – May 20, $9^{\rm h}$;
Arietids (171 ARI) – June 7, $10^{\rm h}$ (more details see page 9);
ζ-Perseids (172 ZPE) – June 9, $12^{\rm h}$; β-Taurids (173 BTA) – June 28, $11^{\rm h}$.
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.

η-Aquariids (031 ETA)

Active: April 19–May 28; Maximum: May 6, $03^{\rm h}$ UT ($\lambda_\odot = 45.^\circ5$);
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 for a few 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 $8^{\rm h}$ 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.



A relatively broad maximum, sometimes with a variable number of submaxima, occurs around May 5/6 which is after last quarter Moon (May 3) and thus under favourable conditions this year. 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:

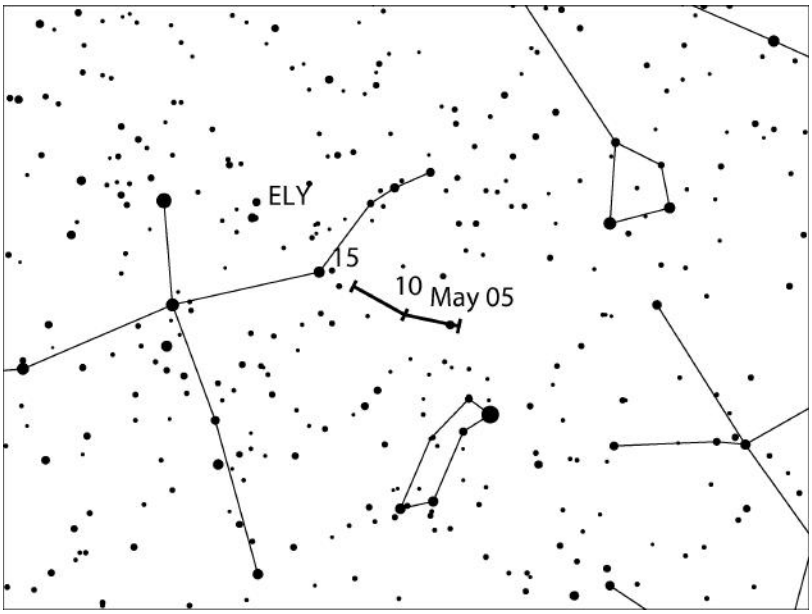
2008	2009	2017	2018	2019	2020
≈ 85	≈ 70	75	60	50	55 (preliminary)

This 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 3–14; Maximum: May 8 ($\lambda_\odot = 48\overset{\circ}{.}4$); ZHR = 3;
Radiant: $\alpha = 287°$, $\delta = +44°$; 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 it has come from video results, which have suggested the maximum might fall at $\lambda_\odot = 50°$ instead (if so, on 2021 May 10). There is little evidence from visual observations as yet, but the discussion on p. 25 of WB has more information. Video as well as careful visual plotting will be needed to separate any potential η-Lyrids from the sporadics. The general radiant area is usefully on-view all night from the northern hemisphere (primarily), with essentially no Moon interference around May 8–10 this year.



Daytime Arietids (171 ARI)

Active: May 14–June 24 (uncertain); Maximum: June 07 ($\lambda_\odot = 76.^\circ6$); ZHR $\approx$ 30(?);
Radiant: $\alpha = 44^\circ$, $\delta = +24^\circ$; Radiant drift: see Table 6; $V_\infty = 38$ km/s; $r = 2.8$.

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

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 $\approx$ 2 to 3. The large ANT radiant area overlaps that of the minor **α-Capricornids (001 CAP)** in July–August, but the lower apparent velocity of the CAP allows observers to separate the two. The **Southern δ-Aquariids (005 SDA)** are strong enough, and the **Piscis Austrinids (183 PAU)** have a radiant distant enough from the ANT area, that both should be more easily separable from the ANT, particularly from the southern hemisphere. The waning gibbous Moon (last quarter on July 31) has some impact on the observation of the southern showers. The highest rates are due on July 27 (PAU) and July 30 (CAP, SDA), respectively.

New Moon on August 8 will provide favourable conditions to follow the **Perseid (007 PER)** activity around their maximum. Favourable conditions are found for the minor **κ-Cygnids (012 KCG)**. The **Aurigid (206 AUR)** peak in the night to September 1 occurs just after the last quarter Moon with a chance of extra activity. The most interesting **September ε-Perseids (208 SPE)** occur around new Moon.

On 2016 July 28 at 00^h07^m UT ($\lambda_\odot = 125.^\circ132$) the **July γ-Draconids (184 GDR)** produced a remarkable outburst which was detected by radar and video observations (Molau et al., 2016b). The same position is reached again on 2021 July 28 near 06^h45^m UT, well worth checking in case something may be observable around this time – although there was no activity observed in 2017 – 2019 (2020 still to come). The radiant is at $\alpha = 280^\circ$, $\delta = +51^\circ$, and the meteors have rather low speed ($V_\infty = 27$ km/s).

Close to the highest Perseid activity, there is another approach to a calculated 1-revolution dust trail of **comet C/1852 K1**. This happens on 2021 August 12, 04^h22^m UT ($\lambda_\odot = 139.^\circ402$). The radiant is at $\alpha = 43^\circ$, $\delta = -13^\circ$ (in southeastern Cetus near the +4 mag star π Cet). The given minimum distance to the trail is 0.00010 au.

In 2015, several video data sets showed low rates associated to the **χ-Cygnids (757 CCY)** over much of September. A weak maximum was found on September 14/15 (ZHRs about 2 or 3). The same date occurs around the first quarter Moon in 2021 and thus provides favourable conditions for optical observations to improve our knowledge of this minor source which was also suspected in previous years. The radiant of these very slow meteors ($V_\infty = 19$ km/s) is at $\alpha = 300°$, $\delta = +31°$. For convenience, we have included the radiant drift in Table 6.

At the end of September / early October, an encounter with meteoroids of **comet 15P/Finlay** is calculated by several models (Maslov (M), Sato (S), Vaubaillon et al. (V) and Ye et al.; a summary is given in Vaubaillon et al., 2020). Results from the models differ slightly, but all hint at faint meteors which have very low velocities (11 km/s). It will be the first encounter with meteoroids of this comet, hence there is a large uncertainty of what will be observable. The *comet outburst* in 2014 may suggest the October 7 date is most interesting. The first peak caused by 1988 dust is only found by Maslov
Sep 27, $13^h58^m - 16^h22^m$UT at $\lambda_\odot = 184.^\circ43$ (ZHR 5–20+; radiant: $\alpha = 261°$, $\delta = -61°$).
The other promising positions refer to the 1995 trail (radiant $\alpha = 261°$, $\delta = -57°$):
Sep 29, $02^h30^m - 04^h17^m$UT ($\lambda_\odot = 185.^\circ92$; ZHR 50–120+; M), or 07^h20^mUT ($\lambda_\odot = 186.^\circ077$; V).
This is followed by the meteoroids of the 2014 trail (radiant $\alpha = 255°$, $\delta = -48°$) on
Oct 07, 00^h38^mUT ($\lambda_\odot = 193.^\circ677$; V) or 01^h10^m UT ($\lambda_\odot = 193.^\circ699$; ZHR 30–100; S)
the 2008 trail encounter (radiant $\alpha = 255°$, $\delta = -48°$) on **Oct 07**, 03^h15^mUT ($\lambda_\odot = 193.^\circ785$)
and finally those from the 2002 trail on
Oct 07, 21^h18^mUT ($\lambda_\odot = 194.^\circ527$)
All events are only observable from far southern latitudes. Favourable regions are between New Zealand and South America for September 29 and South America for October 7.

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

For **daylight radio observers**, the high activity of May–June has waned, but there remain the **γ-Leonids (203 GLE**; possible peak near August 25, 05^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 14), too.

Piscis Austrinids (183 PAU)

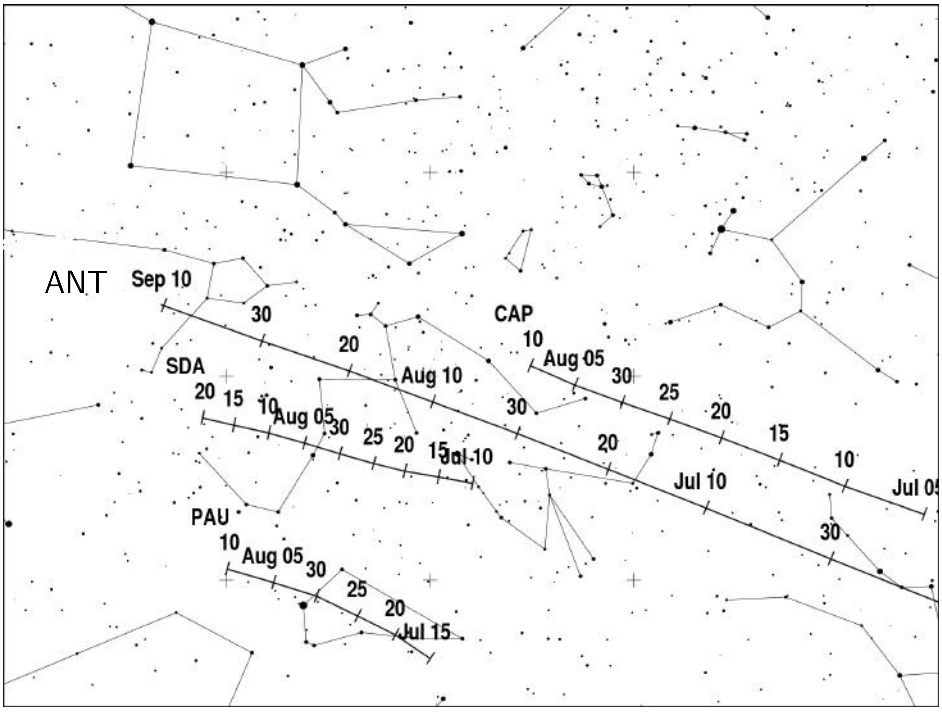
Active: July 15–August 10; Maximum: July 28 ($\lambda_\odot = 125°$); ZHR = 5;
Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 6; $V_\infty = 35$ km/s; $r = 3.2$.

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

Southern δ-Aquariids (005 SDA)

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

Radio work can pick up the SDA as well, and indeed the shower has sometimes given a surprisingly strong radio signature. 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. Last quarter Moon on July 30 is not optimal for visual work, but the considerable activity may compensate for moonlight-affected sessions. While at mid-northern latitudes only a small portion of the shower meteors is visible, conditions significantly improve the further south the location is.



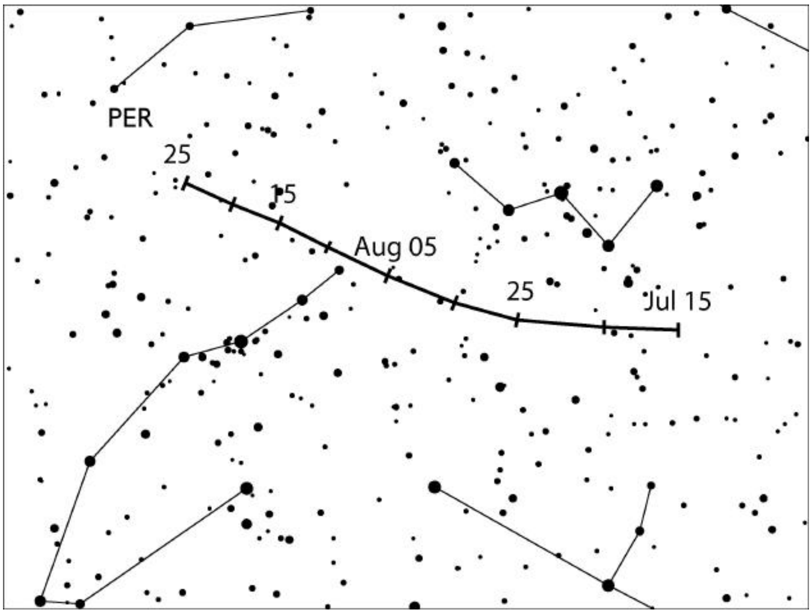
α-Capricornids (001 CAP)

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.

Perseids (007 PER)

Active: July 17–August 24; Maximum: August 12, 19^h to 22^h UT (node at $\lambda_\odot = 140.^\circ 0 - 140.^\circ 1$), but see text; ZHR = 110;
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 $\lambda_\odot \approx 139.^\circ 8$ to $140.^\circ 3$, equivalent to 2021 August 12, 14^h to August 13, 03^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 with additional peaks due to passages through separated dust trails.

A filament crossing has been recovered from the 2018 data. It occurred on August 12 around 20^h UT ($\lambda_\odot \approx 139.^\circ 79$) at the predicted position. The filament is thought to be an accumulation of meteoroids in a mean-motion resonance. For the 2021 return no dust trail encounters are predicted; a weak filament may be crossed on August 12, 15:30 UT ±5 hours (at $\lambda_\odot = 139.^\circ 85 \pm 0.^\circ 2$ (Table 5d in Jenniskens, 2006) .

New Moon on August 8 provides excellent conditions for visual observations. Generally, sites at mid-northern latitudes are best for Perseid observing, as from here, the shower's radiant can be usefully observed 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.

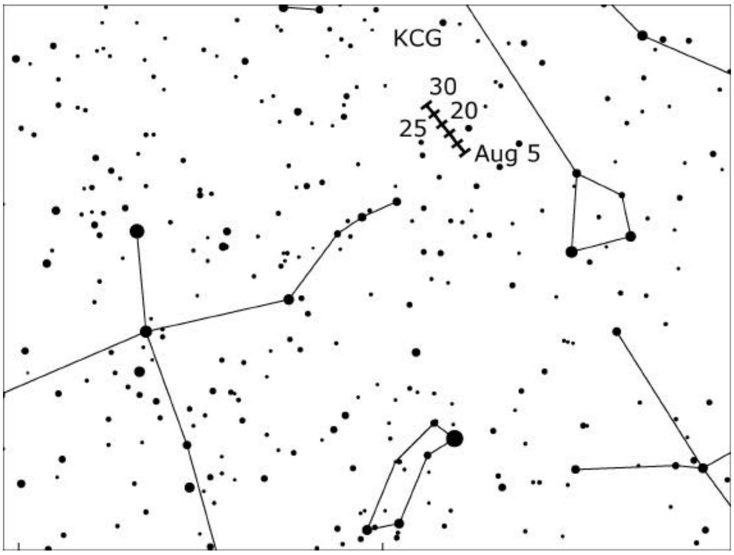
κ-Cygnids (012 KCG)

Active: August 3–25; Maximum: August 17 ($\lambda_\odot = 145^\circ$); ZHR = 3;
Radiant: $\alpha = 286^\circ$, $\delta = +59^\circ$; 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 2021 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.



Aurigids (206 AUR)

Active: August 28–September 5; Maximum: September 1, 03^h UT ($\lambda_\odot = 158.^\circ6$); ZHR = 50(?) (see text); 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. For 2021, there may be an extra activity in the maximum night indicated by independent calculations of Sato, Lyytinen and Vaubaillon which all give a small minimum distance to the Earth. Estimates of the ZHR are difficult, depending on the assumed ejection of meteoroids from the parent and may be between 50 and 100.
Sato: 0.00054 au, $\lambda_\odot = 158.^\circ383$, 2021 Aug 31, 21^h17^m UT
Lyytinen: 0.00017 au, $\lambda_\odot = 158.^\circ395$, 2021 Aug 31, 21^h35^m UT
Vaubaillon: 0.0001 au, $\lambda_\odot = 158.^\circ396$, 2021 Aug 31, 21^h35^m UT
The Aurigid radiant (chart on next page) reaches a useful elevation only after ≈ 01^h local time. At mid-northern latitudes (50° N), the radiant is only about 10° above the horizon at 22^h local time. So the most favourable region to observe the event extends from Asia westwards into the northeastern part of Europe. The morning hours are lit by a waning Moon (two days after last quarter) placed in northeastern Taurus not too far from the radiant. Both a reduced limiting magnitude and low radiant elevation will reduce the number of visible Aurigids. All efforts are welcome to collect a reasonable sample.

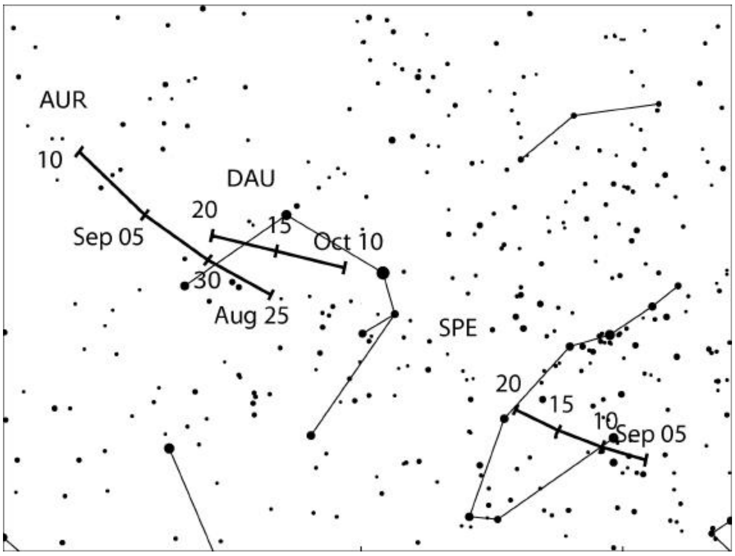
September ε-Perseids (208 SPE)

Active: September 5–21; Maximum: September 9, 11^h UT ($\lambda_\odot = 166.^\circ7$), ZHR = 5; Radiant: $\alpha = 48°$, $\delta = +40°$; Radiant drift: see Table 6; $V_\infty = 64$ km/s; $r = 3.0$.

This shower produced an outburst on 2008 September 9, between roughly $\lambda_\odot = 166.^\circ894$–$166.^\circ921$, and another bright-meteor event with a very sharp peak at $\lambda_\odot = 167.^\circ188$ in 2013 but no later unambiguous increase in the later years.

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.

New Moon on September 7 provides perfect conditions to observe the entire activity profile 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.



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 pre-dawn of late September to early October as part of the IMO project to collect and pool data obtained by all techniques for this shower. 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 last quarter Moon on September 28 adds to scattered light during the period into morning twilight to spot possible DSX meteors.

6 October to December

The most active showers of this quarter year are affected by moonlight: the **Orionids (008 ORI**; maximum October 21/22) and the **Leonids (013 LEO**; maximum November 17) reach their maxima shortly after full Moon. There is no dust trail encounter announced for the Leonids; the traditional maximum is due on November 17, close to 9^h30^m UT ($\lambda_\odot = 234.^\circ951$) with a ZHR of the order of 10 (Mikhail Maslov). The **Geminid (004 GEM)** peak night December 13/14 has a waxing gibbous Moon in Pisces (about 80% illuminated).

The **October Camelopardalids (281 OCT)** and **Draconids (009 DRA)** reach their maxima shortly after new Moon. The possible encounter with dust trails of comet 15P/Finlay has been described in the July-September section, but extends until October 7 (see page 10). Later in October, **δ-Aurigids (224 DAU)** can be observed well, while the **ε-Geminids (023 EGE)** on October 18 and the **Leonis Minorids (022 LMI)** on October 24 are as much affected as the Orionids. The **α-Monocerotids (246 AMO)**, which showed an expected outburst last in 2019, are due on November 21 just after full Moon. While the **November Orionids (250 NOO)** maximum on November 28 is still suffering from moonlight, the conditions for observations of the early December showers **Phoenicids (254 PHO)**, the complex **Puppid-Velids (301 PUP)**, the **Monocerotids (MON)** and the **σ-Hydrids (HYD)** are good. Next, the weak **Comae Berenicids (020 COM)** around December 16 occur just before the full Moon while the long-lasting **December Leonis Minorids (032 DLM)** offer better observing conditions away from their weak maximum around December 20. At the end of the year, the first **Quadrantids** can be seen.

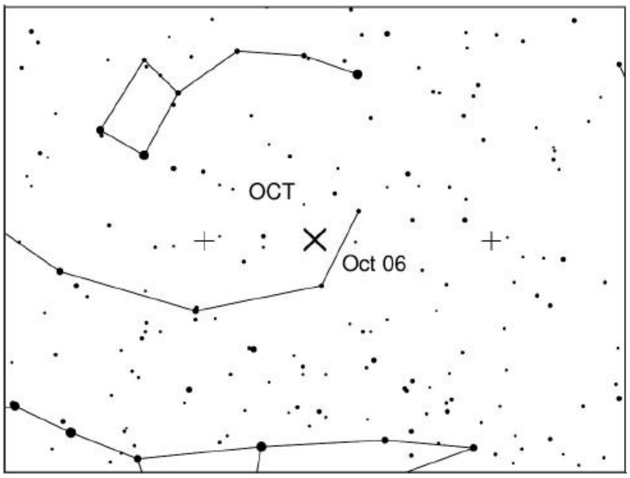
Finally, the **Ursid (URS)** maximum occurs just three days after full Moon. The 91% illuminated moon is in Cancer and thus high in the sky in the morning. There is one dust trail passage calculated for 2021 December 22, $06^{\rm h}47^{\rm m}$ UT ($\lambda_\odot = 270.^{\circ}33$) with a ZHR of 27. This is close to the numbers given for the 2009/10/13/15 returns (Table 5b, Jenniskens, 2006). The parent comet 8P/Tuttle is expected to pass its perihelion on 2021 August 28.

The two Taurid branches reach their highest rates around October 10 (STA) and November 12 (NTA), both dates close to the Moon's first quarter. The **ANT** start into the fourth quarter of the year effectively inactive in favour of the Taurids, resuming only around December 10, as the Northern Taurids fade away, from a radiant centre that tracks across southern Gemini during later December, likely producing ZHRs < 2.

October Camelopardalids (281 OCT)

Active: October 5–6; Maximum: October 5, $22^{\rm h}$ ($\lambda_\odot = 192.^{\circ}58$); ZHR = 5(?)
Radiant: $\alpha = 164^\circ$, $\delta = 79^\circ$; Radiant drift: negligible; $V_\infty = 47$ km/s; $r = 2.5$ (uncertain).

This shower produced a well detected ZHR ≈ 5 on 2018 October 6, $00^{\rm h}30^{\rm m}$UT $\pm\, 1.3^{\rm h}$ ($192.^{\circ}45 \pm 0.^{\circ}05$). The first activity from this north-circumpolar radiant was recorded by video cameras in 2005 and 2006 on October 5/6 (near $\lambda_\odot = 193^\circ$). The shower has been detected annually (Molau et al., 2017) and produced a peak at $\lambda_\odot = 192.^{\circ}58$ 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.

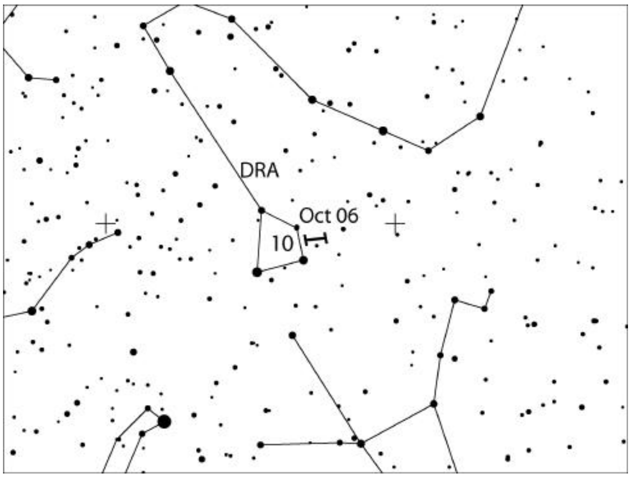


Assuming a long-period parent, and using the 2005 outburst as reference point, Esko Lyytinen's calculations indicated that we might see activity near $\lambda_\odot = 192.^{\circ}529$ in 2018 and 2019. In both years, some activity was recorded with a slightly higher rate in 2018. Surprises are possible 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 (communicated by Esko Lyytinen).

Draconids (009 DRA)

Active: October 6–10; Maximum: October 8, $18^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 195.^{\circ}4$); ZHR = 5 (?);
Radiant: $\alpha = 263^\circ$, $\delta = +56^\circ$; Radiant drift: negligible; $V_\infty = 21$ km/s; $r = 2.6$.

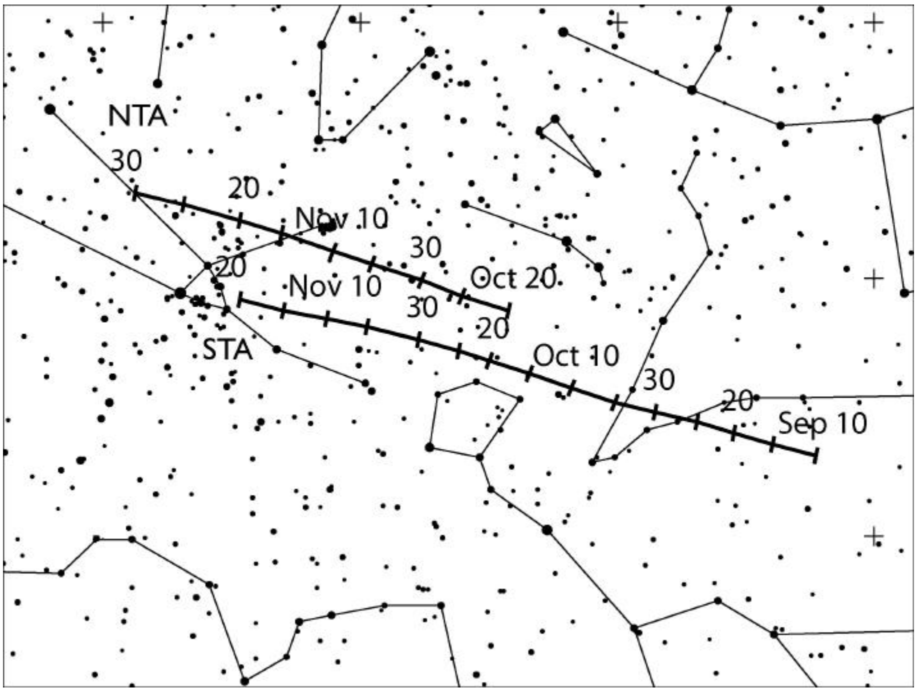
The Draconids (also called October Draconids) are known as a periodic shower which produced spectacular meteor storms in 1933 and 1946, and lower rates in several other years (ZHRs $\approx$ 20–500+). Recent outbursts happened in 2011 (ZHR $\approx$ 300) and wholly unexpectedly in 2012 (chiefly very faint meteors, detected primarily by the Canadian CMOR meteor radar system). The 2018 return yielded a ZHR of about 150 lasting for about 4 hours, much higher than the predicted values. For 2021, there are no trail encounters announced.



The parent comet 21P/Giacobini-Zinner passed its perihelion last on 2018 September 10. The Moon (last quarter on October 10) is not disturbing 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.

Southern Taurids (002 STA

Active: September 10–November 20; Maximum: October 10 ($\lambda_\odot = 197°$); ZHR = 5;
Radiant: $\alpha = 32°$, $\delta = +09°$; Radiant drift: see Table 6; $V_\infty = 27$ km/s; $r = 2.3$.



This stream, with its Northern counterpart, forms part of the complex associated with Comet 2P/Encke. For shower association, assume the radiant to be an oval area, about 20° in α by 10° in δ, centred on the radiant position for any given date. The Taurid activity overall dominates the Antihelion Source area's during the northern autumn, so much so that the ANT is considered inactive while either branch of the Taurids is present. The brightness and relative slowness of many Taurid meteors makes them ideal targets for still-imaging, while these factors coupled with low, steady, Taurid rates makes them excellent subjects for newcomers to practice their visual plotting techniques. The Southern branch of the Taurids reaches its peak about a month before the Northern one, this year around the last quarter Moon. 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.

δ-Aurigids (224 DAU)

Active: October 10–18; Maximum: October 11 ($\lambda_\odot = 198°$); ZHR = 2;
Radiant: $\alpha = 84°$, $\delta = +44°$; Radiant drift: see Table 6; $V_\infty = 64$ km/s; $r = 3.0$.

The weakest of the three known persistent near-Auriga-Perseus showers of late August to October, visual observers seem to have struggled to properly identify this minor source previously, and its current parameters are based on a detailed review of IMO video data since the late 1990s. This year the entire activity can be monitored. The radiant area is visible chiefly from the northern hemisphere (see chart on page 14), from where it can be properly observed after local midnight.

During the period from late September until mid-October, other sources from this northern region have been found active. The overall picture is not yet clear. Probably the Earth encounters a number of slightly different streams of variable number density over years. Several reports clearly state meteors e.g. of the September Lyncids (081 SLY) which are very similar in appearance and apparently 'connect' the activity periods of the SPE and DAU. Hence observers should try to apply plotting method to test association with radiants in the respective area in the sky.

Northern Taurids (017 NTA)

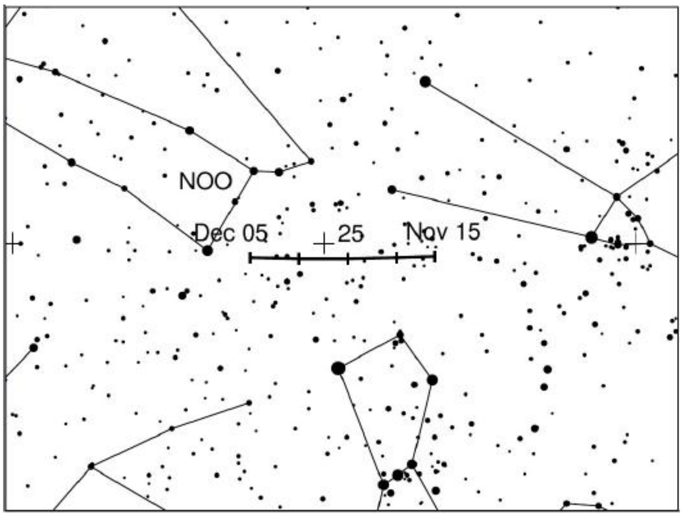
Active: October 20–December 10; Maximum: November 12 ($\lambda_\odot = 230°$); ZHR = 5;
Radiant: $\alpha = 58°$, $\delta = +22°$; Radiant drift: see Table 6; $V_\infty = 29$ km/s; $r = 2.3$.

Some details on this branch of the Taurid streams were given with the Southern Taurids above. Other aspects are the same too, such as the large, oval radiant region to be used for shower association, the shower's excellent visibility overnight, and its dominance over the ANT during September to December. As previous results had suggested seemingly plateau-like maximum rates persisted for roughly ten days in early to mid November, the NTA peak may not be so sharp as its single maximum date might imply. Whatever the case, first quarter Moon on November 4 should allow plenty of coverage. (For the radiant drift graph see page 16.)

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.

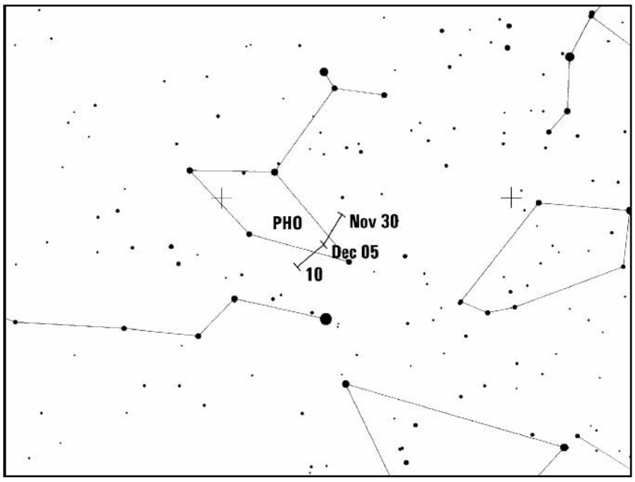


The radiant is located in northern Orion, 8° north of α Orionis. This location is close to the Northern Taurids, but far enough east to distinguish meteors from the two sources. Additionally, the faster velocity of the November Orionids should help distinguish these meteors from the slower Taurids.

The radiant culminates near 2^h local time, but is above the horizon for most of the night. The last quarter Moon on November 27 affects the collection of data before the expected maximum.

Phoenicids (254 PHO)

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

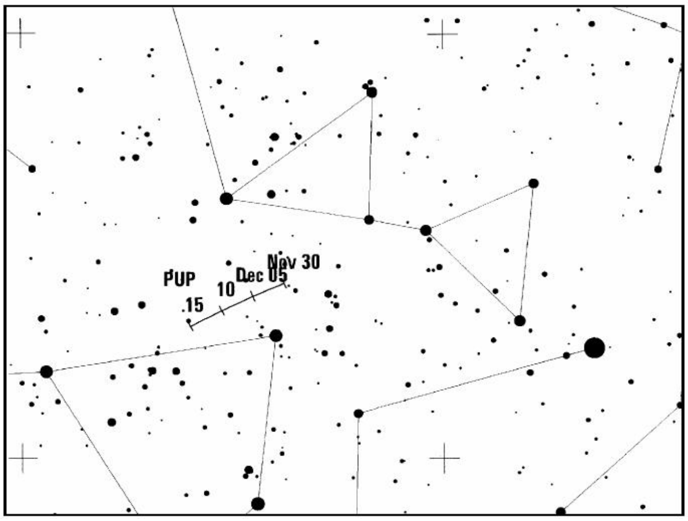


Only one impressive Phoenicid return has been reported, that of its discovery in 1956, when the peak ZHR probably reached ≈ 100, possibly with several peaks spread over a few hours. Recent significant activity was observed on 2014 December 1 which occurred at the position predicted by Sato and Watanabe (2010). For 2021 there is no indication for extra activity – nevertheless, observers are encouraged to check for possible Phoenicids. The activity of the shower is centred around December 2, i.e. close to new Moon this year. From the southern hemisphere (only), the Phoenicid radiant culminates at dusk, remaining well on view for most of the night. Phoenicids are extremely slow meteors.

Puppid-Velids (301 PUP)

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

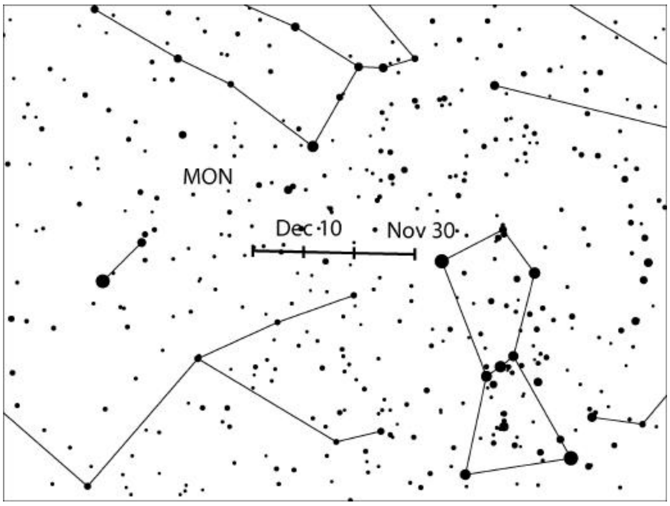
This is a complex system of poorly-studied showers, visible chiefly from locations south of the equator. Several sub-streams have been proposed (301 PUP representing an "average" position), with radiants so tightly clustered, visual observing cannot readily separate them.



The activity is poorly-established, though the higher rates seem to occur in early to mid December, with no moonlight interference this year (new Moon on December 4). Some PUP activity may be visible prior and after the given period. Occasional bright fireballs, notably around the suggested maximum, have been reported regularly. The radiant area is on-view all night, highest towards dawn.

Monocerotids (019 MON)

Active: November 27–December 20; Maximum: December 9 ($\lambda_\odot = 257°$); ZHR = 3;
Radiant: $\alpha = 100°$, $\delta = +08°$; Radiant drift: see Table 6; $V_\infty = 42$ km/s; $r = 3.0$.



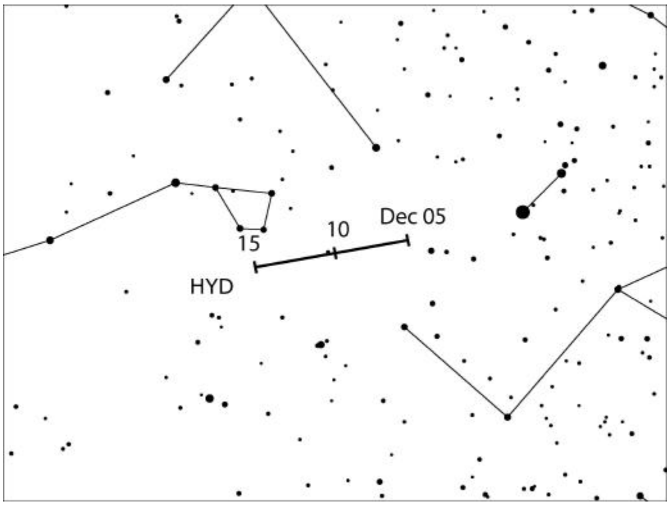
Although well known for a long time (also as December Monocerotids), this minor shower's details need further improvement by observational data. In most years, visual data give a maximum ZHR = 3 at $\lambda_\odot \approx 257°$ while the general ZHR level is about 2. In a few years, we also find an apparent slight enhancement in the Geminid peak night. This is assumed to be an effect of Geminids erroneously classified as MON. Video data (2011–2018) show a peak of roughly $0.°4$ width centred at $\lambda_\odot \approx 262.°0$ (i.e. December 14) with a ZHR of the order of 8 coinciding with the Geminid peak. 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.) Conditions are favourable to observe the ascent until about the Geminid peak. The radiant area is available virtually all night for much of the globe, culminating at about 01^h30^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; $r = 3.0$.

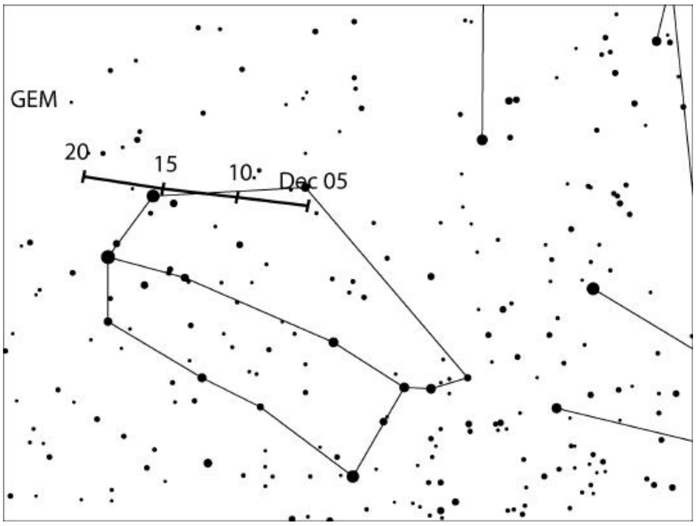
The σ-Hydrids are often thought to be a very minor shower with rates close to the visual detection threshold for much of the activity period. However, some bright meteors are repeatedly seen and the maximum ZHR reaches 5–8. IMO visual data (WB p. 65) have indicated the maximum might happen nearer $\lambda_\odot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



Visual IMO data from the period 2010–2018 show a maximum close to $\lambda_\odot \sim 257°$ (December 9) and the Geminid-related feature only in a few years. VID implied a peak closer to $\lambda_\odot \sim 254°$ (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. First quarter Moon on December 11 allows to record the activity until the Geminid maximum.

Geminids (004 GEM)

Active: December 4–17; Maximum: December 14, 07^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 maximum on December 14 centred at 07^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. Even from more southerly sites, this is a splendid stream of often bright, medium-speed meteors, a rewarding event for all observers, whatever method they employ.

The peak has shown 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 2021 December 13, 14^h to December 14, 12^h UT. The peak ZHRs have shown a slight increase over a longer period and reached 140–150 in all recent years. Usually, near-peak Geminid rates persist for several hours, so much of the world has the chance to enjoy something of the shower's best. Mass-sorting within the stream means fainter meteors should be most abundant almost a day ahead of the visual maximum. The 2021 return occurs only four days before full Moon. Depending on the latitude, the moon sets around 02^h local time and leaves about 3–5 hours for observations in a dark sky.

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:

Egal A., Brown P.G., Rendtel J., Campbell-Brown M., Wiegert P., 2020: Activity of the Eta-Aquariid and Orionid meteor showers, *Astron. Astrophys.*, accepted.

Jenniskens P., 2006: Meteor showers and their parent comets. Cambridge Univ. Press.

Koseki M., 2014: Various meteor scenes II: Cygnid-Draconid Complex (κ-Cygnids), *WGN* **42**, pp. 181–197.

Molau S., Crivello S., Goncalves R., Saraiva C., Stomeo E., Kac J., 2016a: Results of the IMO Video Meteor Network – February 2016, *WGN* **44**, pp. 116–119.

Molau S., Crivello S., Goncalves R., Saraiva C., Stomeo E., Kac J., 2016b: Results of the IMO Video Meteor Network – July 2016, *WGN* **44**, pp. 205–210.

Molau S., Rendtel, J., 2009: A comprehensive list of meteor showers obtained from 10 years of observations with the IMO Video Meteor Network, *WGN* **37:4**, pp. 98–121.

Rendtel J., 2014: Meteor Observers Workbook 2014 (ed.: Jürgen Rendtel), IMO, 2014.

Vaubaillon J., Egal E., Desmars J., Baillié K., 2020: Meteor shower output caused by comet 15P/Finlay, *WGN* **48:2**, pp. 29–35.

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 2021.

New Moon	First Quarter	Full Moon	Last Quarter
			January 6
January 13	January 20	January 28	February 4
February 11	February 19	February 27	March 6
March 13	March 21	March 28	April 4
April 12	April 20	April 27	May 3
May 11	May 19	May 26	June 2
June 10	June 18	June 24	July 1
July 10	July 17	July 24	July 31
August 8	August 15	August 22	August 30
September 7	September 13	September 21	September 29
October 6	October 13	October 20	October 28
November 4	November 11	November 19	November 27
December 4	December 11	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 June 2020, with maximum dates accurate only for 2021. The parenthesized maximum date for the Puppids-Velids indicates a reference date for the radiant only, not necessarily a true maximum. Some showers have ZHRs that vary from year to year. The most recent reliable figure is given here, except for possibly periodic showers which are noted as 'Var' = variable. For more information check the updates published e.g. in the IMO Journal WGN.

Shower	Activity	Maximum Date	$\lambda_\odot$	Radiant α	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 19	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 05	45.°5	338°	−01°	66	2.4	50
η-Lyrids (145 ELY)	May 03–May 14	May 08	48.°0	287°	+44°	43	3.0	3
Dayt. Arietids (171 ARI)	May 14–Jun 24	Jun 07	76.°6	44°	+24°	38	2.8	30
June Bootids (170 JBO)	Jun 22–Jul 02	Jun 27	95.°7	224°	+48°	18	2.2	Var
Piscis Austr. (183 PAU)	Jul 15–Aug 10	Jul 29	125°	341°	−30°	35	3.2	5
S. δ-Aquariids (005 SDA)	Jul 12–Aug 23	Jul 30	127°	340°	−16°	41	2.5	25
α-Capricornids (001 CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	5
Perseids (007 PER)	Jul 17–Aug 24	Aug 12	140.°0	48°	+58°	59	2.2	100
κ-Cygnids (012 KCG)	Aug 03–Aug 25	Aug 17	145°	286°	+59°	25	3.0	3
Aurigids (206 AUR)	Aug 28–Sep 05	Sep 01	158.°6	91°	+39°	66	2.5	6
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 05	192.°58	164°	+79°	47	2.5	5
Draconids (009 DRA)	Oct 06–Oct 10	Oct 08	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 19	268°	161°	+30°	64	3.0	5
Ursids (015 URS)	Dec 17–Dec 26	Dec 22	270.°7	217°	+76°	33	3.0	10

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

Date	ANT		QUA		DLM									
Jan 0	112°	+21°	228°	+50°	172°	+25°								
Jan 5	117°	+20°	231°	+49°	176°	+23°			**GUM**					
Jan 10	122°	+19°	234°	+48°	180°	+21°			220°	+71°				
Jan 15	127°	+17°			185°	+19°			224°	+69°				
Jan 20	132°	+16°			189°	+17°			228°	+67°				
Jan 25	138°	+15°			193°	+15°	**ACE**		232°	+65°				
Jan 30	143°	+13°			198°	+12°	200°	−57°						
Feb 5	149°	+11°			203°	+10°	208°	−59°						
Feb 10	154°	+9°					214°	−60°						
Feb 15	159°	+7°					220°	−62°						
Feb 20	164°	+5°	**GNO**				225°	−63°						
Feb 28	172°	+2°	225°	−51°										
Mar 5	177°	0°	230°	−50°										
Mar 10	182°	−2°	235°	−50°										
Mar 15	187°	−4°	240°	−50°										
Mar 20	192°	−6°	245°	−49°										
Mar 25	197°	−7°	250°	−49°										
Mar 30	202°	−9°	255°	−49°										
Apr 5	208°	−11°												
Apr 10	213°	−13°	**LYR**		**PPU**									
Apr 15	218°	−15°	263°	+34°	106°	−44°	**ETA**							
Apr 20	222°	−16°	269°	+34°	109°	−45°	323°	−7°						
Apr 25	227°	−18°	274°	+34°	111°	−45°	328°	−5°						
Apr 30	232°	−19°	279°	+34°			332°	−3°	**ELY**					
May 05	237°	−20°					337°	−1°	283°	+44°				
May 10	242°	−21°					341°	+1°	288°	+44°				
May 15	247°	−22°					345°	+3°	293°	+45°				
May 20	252°	−22°					349°	+5°						
May 25	256°	−23°					353°	+7°						
May 30	262°	−23°	**ARI**											
Jun 5	267°	−23°	42°	+24°										
Jun 10	272°	−23°	47°	+24°										
Jun 15	276°	−23°												
Jun 20	281°	−23°	**JBO**											
Jun 25	286°	−22°	223°	+48°										
Jun 30	291°	−21°	225°	+47°	**CAP**									
Jul 5	296°	−20°			285°	−16°	**SDA**							
Jul 10	300°	−19°	**PER**		289°	−15°	325°	−19°	**PAU**					
Jul 15	305°	−18°	6°	+50°	294°	−14°	329°	−19°	330°	−34°				
Jul 20	310°	−17°	11°	+52°	299°	−12°	333°	−18°	334°	−33°				
Jul 25	315°	−15°	22°	+53°	303°	−11°	337°	−17°	338°	−31°				
Jul 30	319°	−14°	29°	+54°	307°	−10°	340°	−16°	343°	−29°	**KCG**			
Aug 5	325°	−12°	37°	+56°	313°	−8°	345°	−14°	348°	−27°	283°	+58°		
Aug 10	330°	−10°	45°	+57°	318°	−6°	349°	−13°	352°	−26°	284°	+58°		
Aug 15	335°	−8°	51°	+58°			352°	−12°			285°	+59°		
Aug 20	340°	−7°	57°	+58°	**AUR**		356°	−11°			286°	+59°		
Aug 25	344°	−5°	63°	+58°	85°	+40°					288°	+60°		
Aug 30	349°	−3°			90°	+39°	**SPE**		**CCY**		289°	+60°		
Sep 5	355°	−1°	**STA**		96°	+39°	43°	+40°	293°	+29°				
Sep 10	0°	+1°	12°	+3°	102°	+39°	48°	+40°	297°	+30°				
Sep 15			15°	+4°			53°	+40°	301°	+31°				
Sep 20			18°	+5°	**DSX**		59°	+41°	305°	+32°				
Sep 25			21°	+6°	150°	0°			309°	+33°				
Sep 30			25°	+7°	155°	0°	**ORI**				**OCT**			
Oct 5			28°	+8°			85°	+14°	**DAU**		164°	+79°	**DRA**	
Oct 10			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. Radiant positions during the year in α and δ for the sources of possible activity described in the text.

Shower (or parent)	Activity Date	$\lambda_\odot$ 2000	Radiant α	δ
κ-Cancrids (793 KCA)	Jan 10	289°315	138°	+9°
C/1976 D1	Mar 01	340°729	13°	−64°
July γ-Draconids (184 GDR)	Jul 28	125°132	280°	+51°
C/1852 K1	Aug 12	139°402	43°	−13°
Aurigids (206 AUR)	Aug 31	158°395	91°	+39°
15P/Finlay	Sep 27 – Oct 07 (see page 10)			

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

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

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

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

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

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

You can join the International Meteor Organization by visiting the web page www.imo.net → "Join the IMO".
As an alternative or to obtain additional information, you may contact the Secretary-General via lunro.imo.usa@cox.net.
Those unable to access the Internet may write for information to Robert Lunsford, IMO Secretary-General, 14884 Quail Valley Way, El Cajon, CA 92021-2227, USA. When using ordinary mail, please try to enclose return postage, either in the form of stamps (same country *only*) or as an International Reply Coupon (I.R.C. – available from main postal outlets). Thank you!