International Meteor Organization

2020 Meteor Shower Calendar

edited by Jürgen Rendtel [1]

1 Introduction

This is the thirtieth edition of the International Meteor Organization (IMO) Meteor Shower Calendar, a series which was started by Alastair McBeath. Over all the years, we want to draw the attention of observers to both regularly returning meteor showers and to events which may be possible according to model calculations. We may experience additional peaks and/or enhanced rates but also the observational evidence of no rate or density enhancement. The position of peaks 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. Hopefully, 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 2020 we find the first quarter Moon for the Quadrantids, a waning crescent Moon for the Perseids and new Moon for the Geminids. Conditions for the maxima of other well-known showers are good: the Lyrids are centred around new Moon, the Draconids occur close to the last quarter Moon and the Orionids as well as the Leonids see a crescent only in the evenings. Other maximum periods are more affected by moonlight: the η-Aquariids peak shortly before full Moon, the Southern δ-Aquariids see a waxing gibbous Moon and the Ursids reach their maximum close to first quarter 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 2020 (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, Alastair McBeath and Sirko Molau for carefully checking the contents.

The available predictions for 2020 do not include any spectacular outburst, 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.

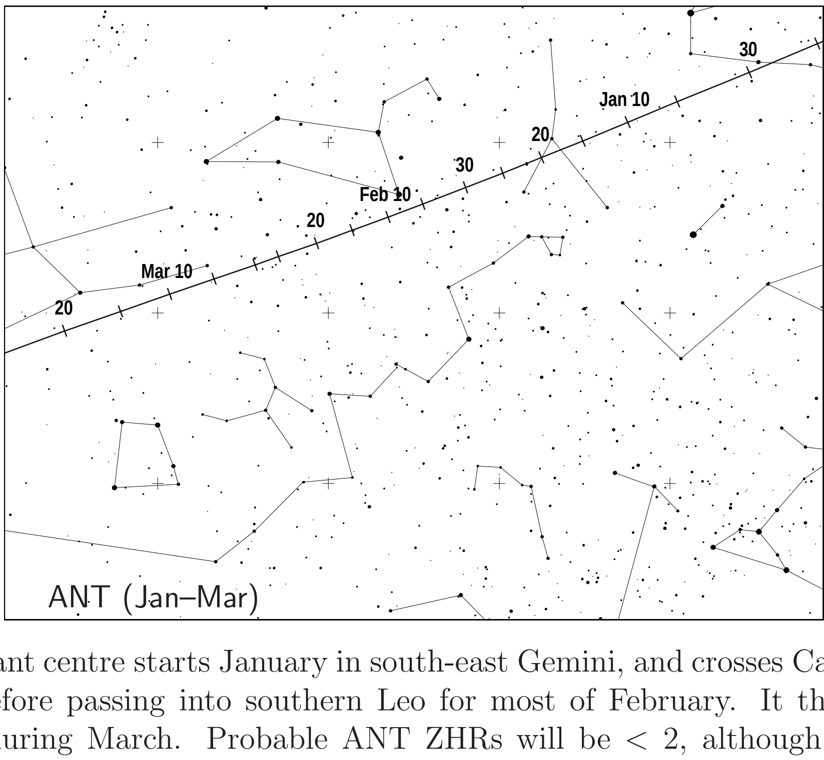
However and whenever you are able to observe, we wish you all a most successful year's work and very much look forward to receiving your data, whose input is possible via the online form on the IMO's website `www.imo.net`. Clear skies!

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 why, because even instrumentally, it was impossible to define distinct and constantly observable radiants for many of the showers here! Thus we recommend observers simply to identify meteors from these streams as coming from the ANT alone. Apart from this, we have been able to retain the July-August α-Capricornids, and particularly the Southern δ-Aquariids as apparently distinguishable showers separate from the ANT. Later in the year, the Taurid showers dominate the activity from the Antihelion region meaning the ANT should be considered inactive while the Taurids are underway, from early September to early December. To assist observers, a set of charts showing the location for the ANT and any other nearby shower radiants is included here, to complement the numerical positions of Table 6, while comments on the ANT's location and likely activity are given in the quarterly summary notes.

3 January to March

The year starts with the **Quadrantid (010 QUA)** peak for the northern hemisphere observers on January 4 just after the first quarter Moon. Conditions to collect data of the weak **γ Ursae Minorids (404 GUM)** around January 10 are very poor. The **December Leonis Minorids (032 DLM)** which can be traced until early February are well observable during the two moonless periods in early and again in late January. The southern hemisphere's **α -Centaurids (102 ACE)** around February 8 are badly affected by moonlight. A part of the **γ-Normids (118 GNO)** of March can be traced well in darker skies.



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 < 2, although IMO analyses of visual data have suggested there may be an ill-defined minor peak with ZHRs ≈ 2 to 3 around

$\lambda_\odot \approx 286°–293°$ (2020 January 6 to 13). ZHRs could be ≈ 3 for most of March with a slight increase derived from video flux data around $\lambda_\odot \approx 355°$ (2020 March 17).

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 $\lambda_\odot = 289.°315$. Activity was also found in the 2016 video data (Molau et al., 2016a). There is no report of activity in the subsequent years. In 2020 the position is reached close to full Moon. Nevertheless, observers are encouraged to check for possible meteors near 2020 January 10, $10 - 11^h$ UT. 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).

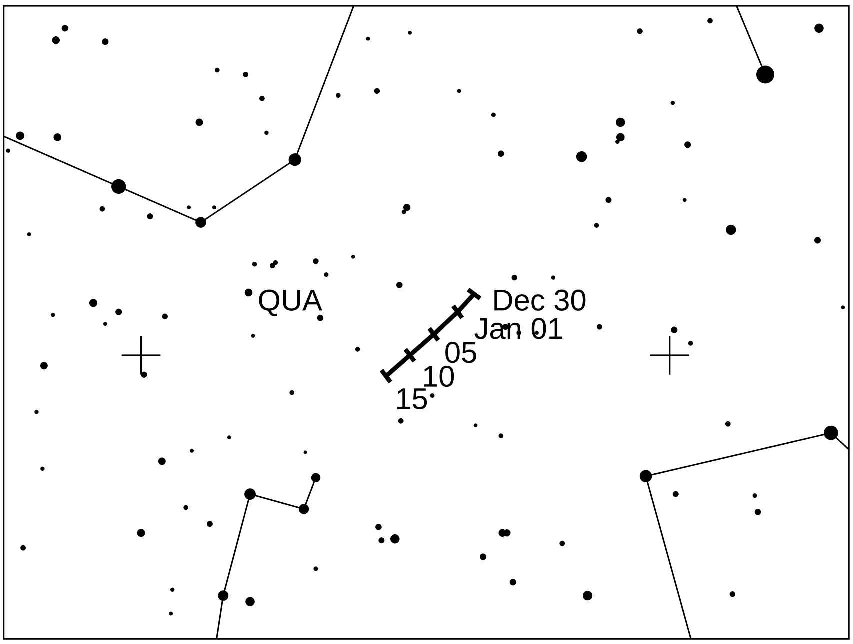
From late January until April, the general meteor activity is on its lowest level. Hence it should be possible to detect weak sources easily. Of course, video data are best suited for this purpose. But visual observers should also take notes about meteor trails in case that sources are discovered and subsequently may be confirmed by independent samples.

Expected approximate timings for the **daytime shower maxima** this quarter are: Capricornids/Sagittariids (115 DCS) – February 1, 6^h UT and χ-Capricornids (114 DXC) – February 14, 5^h UT. Recent radio results have implied the DCS maximum may fall variably sometime between February 1–4 however, while activity near the expected DXC peak has tended to be slight and up to a day late. Both showers have radiants < 10°–15° west of the Sun at maximum, so cannot be regarded as visual targets even from the southern hemisphere.

Quadrantids (010 QUA)

Active: December 28–January 12; Maximum: January 4, 08^h20^m UT ($\lambda_\odot = 283.°15$),
ZHR = 120 (can vary ≈ 60 − 200);
Radiant: $\alpha = 230°$, $\delta = +49°$; Radiant drift: see Table 6;
$V_\infty = 41$ km/s; $r = 2.1$ at maximum, but variable.

The first quarter Moon (January 3) will set near local midnight and thus leaves good viewing conditions for the expected Quadrantid maximum on January 4. For many northern hemisphere sites, the shower's radiant in northern Boötes is circumpolar. Depending on the observer's latitude, the radiant attains a useful elevation around or after local midnight and culminates close to dawn.

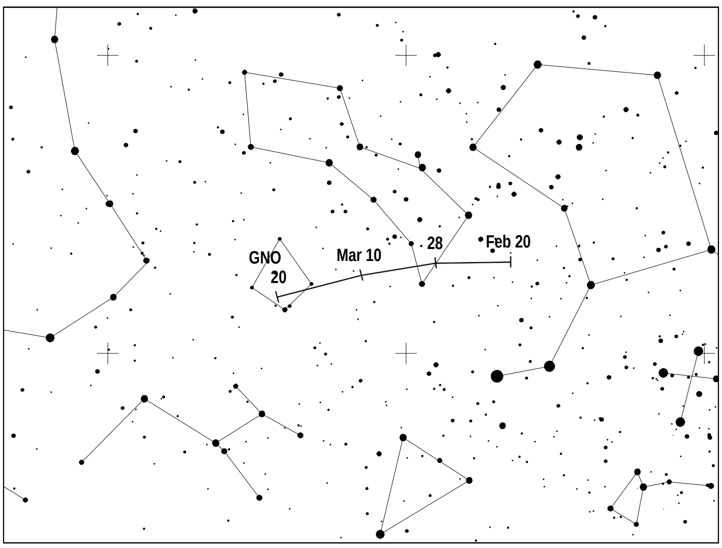


The 08^h UT timing for the peak will be favourable North America. European observers should expect a continuous increase of the rates into dawn. The $\lambda_\odot = 283\overset{\circ}{.}15$ maximum timing is based on the best-observed return of the shower ever analysed, from IMO data collected in 1992. This was confirmed by various later observations. In video meteor flux profiles of recent years, the peak occurred at $\lambda_\odot = 283\overset{\circ}{.}11$ (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.

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 short-lived peak alternatively between $\lambda_\odot \approx 347°$–$357°$, equivalent to 2020 March 7–17. Recent video and visual plotting information confirmed activity from that region, but an analysis of video data obtained only from locations south of the equator has indicated that the activity occurs preferentially around March 25 ($\lambda_\odot = 4°$) instead, from a radiant at $\alpha = 246°$, $\delta = -51°$. The situation requires data to clarify the GNO activity issue. Post-midnight watching yields better results, when the radiant is rising to a reasonable elevation from southern hemisphere sites. Moonlight disturbs the March 14 period (gibbous waning) while the possible March 25 timing occurs close to new Moon this year.



4 April to June

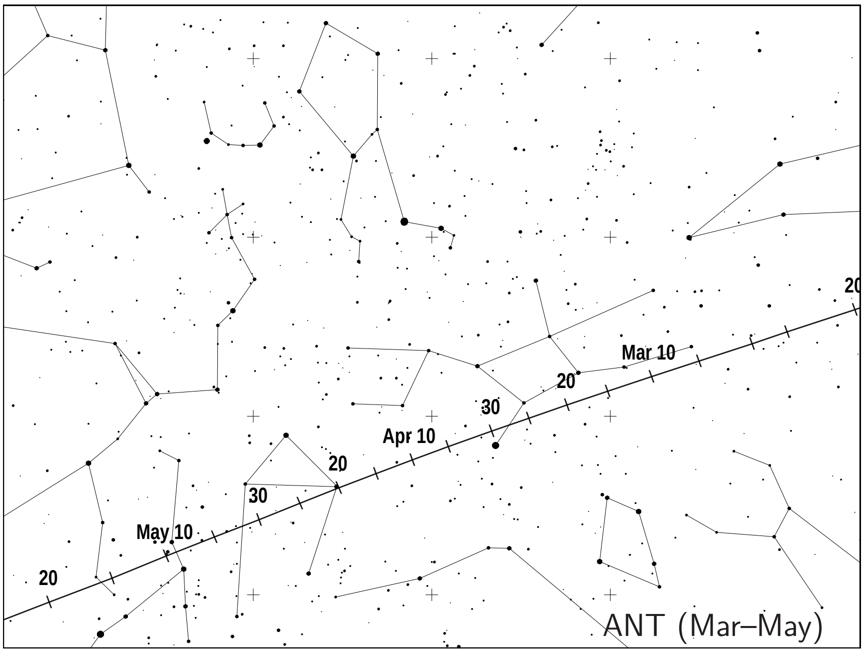
Much of the meteor activity in late April into May remains unobservable for optical methods as it is caused by daytime showers with their radiants too close to the Sun. But also the visually accessible meteor rates increase with the moon-free **Lyrids (006 LYR**, also called April Lyrids) and **π-Puppids (137 PPU)**. The ascent towards the **η-Aquariid (031 ETA)** maximum can be observed until just before the full Moon on May 7. Moonlight strongly affects the **η-Lyrids (145 ELY)** with an expected peak on May 9 or slightly later. The **June Bootids (170 JBO)** occur before the first quarter Moon on June 28.

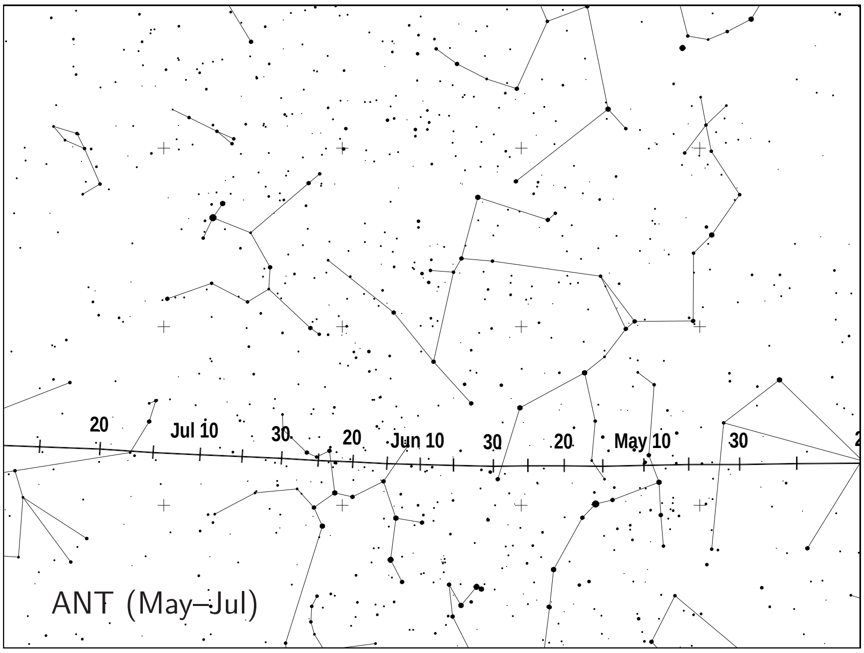
There may be weak activity from the **α-Virginids (021 AVB)** related to the minor planet 2010GE35 on 2020 April 24 near 06^h25^m UT ($\lambda_\odot = 34.^\circ273$) from a radiant $\alpha = 198^\circ$, $\delta = +7^\circ$, showing slow meteors ($V_\infty = 18$ km/s), according to theoretical modelling of Jérémie Vaubaillon. This is more than 30° apart from the ANT which is centred at $\alpha = 226^\circ$, $\delta = -17^\circ$.

Again referring to theoretical modelling of Jérémie Vaubaillon, the meteoroids of the Apollo object 461852 (2006 GY2) pass the Earth slightly outside the Earth's orbit in 2020. Nevertheless, there may be a weak activity of slow meteors ($V_\infty = 19$ km/s) on **2020 May 14** near 22^h UT ($\lambda_\odot = 54.^\circ279$) from a radiant at $\alpha = 248^\circ$, $\delta = +46^\circ$ (less than 2° east of τ Herculis). Although at best some low activity is expected, any confirmation of the existence of the shower and the link with 461852 is welcome.

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, 10^h;
ε-Arietids (154 DEA) – May 9, 3^h;
May Arietids (294 DMA) – May 16, 4^h;
o-Cetids (293 DCE) – May 20, 3^h;
Arietids (171 ARI) – June 7, 4^h (more details see page 10);
ζ-Perseids (172 ZPE) – June 9, 6^h;
β-Taurids (173 BTA) – June 28, 5^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, there are problems in identifying the o-Cetids in the IAU stream lists. The current number and abbreviation given here for it is actually for the IAU source called the "Daytime ω-Cetid Complex", because that seems a closer match to the o-Cetids as defined by earlier reports.

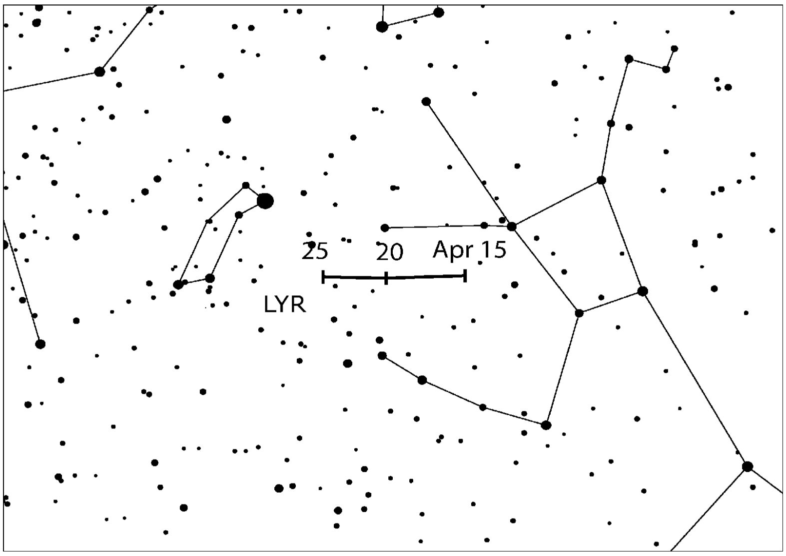




Lyrids (006 LYR)

Active: April 14–30; Maximum: April 22, $07^{\rm h}$ UT ($\lambda_\odot = 32\overset{\circ}{.}32$, but may vary – see text);
ZHR = 18 (can be variable, up to 90);
Radiant: $\alpha = 271°$, $\delta = +34°$; Radiant drift: see Table 6;
$V_\infty = 49$ km/s; $r = 2.1$

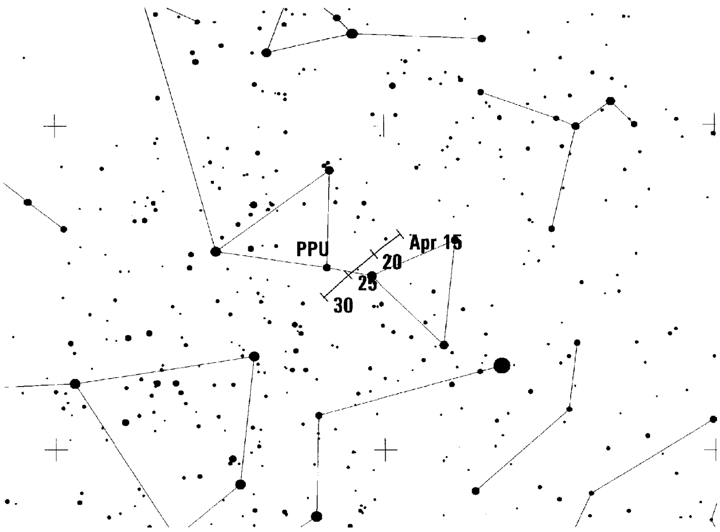
The $\lambda_\odot = 32\overset{\circ}{.}32$ (2020 April 22, $06^{\rm h}40^{\rm m}$ UT) timing given above is the ideal maximum position found in *IMO* results from 1988–2000. However, the maximum time was variable from year to year between $\lambda_\odot = 32\overset{\circ}{.}0$–$32\overset{\circ}{.}45$ (equivalent to 2020 April 21, $22^{\rm h}40^{\rm m}$ to April 22, $09^{\rm h}40^{\rm m}$ UT). Activity was variable too. Peaks at the ideal time produced the highest ZHRs, ≈ 23. The further the peak happened from this, the lower the ZHRs were, down to ≈ 14 – a relation which needs to be confirmed. The mean peak ZHR was 18 over the thirteen years examined. Further, the shower's peak length varied: using the FWHM time (for explanation see the QUA text on page 5), a variation between 14.8 to 61.7 hours was detected (mean 32.1 hours). The best rates are normally achieved for just a few hours. The analysis also confirmed that occasionally, as their highest rates occurred, the Lyrids produced a brief increase in fainter meteors. In 1982 a short-lived ZHR of 90 was recorded. For 2020 there are no predictions for any activity increase from theoretical modelling.



Lyrid meteors are best viewed from the northern hemisphere, but are visible from many sites north and south of the equator. As the radiant rises during the night, watches can be carried out usefully after about 22^h30^m local time from mid-northern sites, but only well after midnight from the mid-southern hemisphere. New Moon on April 23 provides optimal conditions for Lyrid observations in 2020. The given activity period of the Lyrids is based on recent video and visual data which report recognizable numbers of shower meteors until the end of April.

π-Puppids (137 PPU)

Active: April 15–28; Maximum: April 23, 12^h UT ($\lambda_\odot = 33.^\circ5$);
ZHR = variable, up to around 40;
Radiant: $\alpha = 110^\circ$, $\delta = -45^\circ$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.0$.

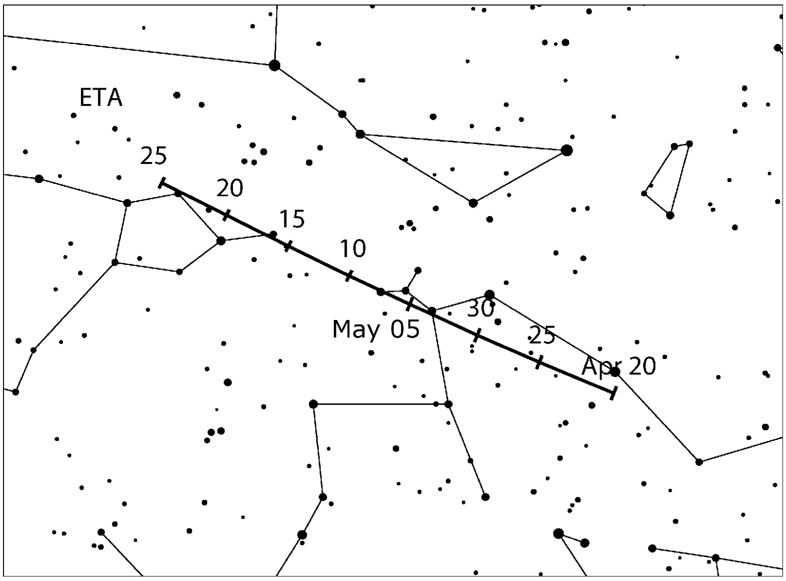


Activity has only been detected from this source since 1972, with notable, short-lived, shower maxima of around 40 meteors per hour in 1977 and 1982, both years when its parent comet, 26P/Grigg-Skjellerup was at perihelion. Before 1982, little activity had been seen at other times, but in 1983, a ZHR of ≈ 13 was reported, perhaps suggesting material has begun to spread further along the comet's orbit. 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 2020 π-Puppid meteor activity had been issued. The π-Puppids are best-seen from the southern hemisphere, with useful observations mainly practical before midnight, as the radiant is very low to setting after 01^{h} local time. The lunar phase is helpful for optical observations this year. Covering whatever transpires is important, even if that is to report no obvious activity. The IMO data over the past 15 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 5, 21^{h} UT ($\lambda_{\odot} = 45.^{\circ}5$);
ZHR = 50 (periodically variable, ≈ 40–85);
Radiant: $\alpha = 338°$, $\delta = -1°$; Radiant drift: see Table 6;
$V_{\infty} = 66$ km/s; $r = 2.4$.

This stream is associated with Comet 1P/Halley, like the Orionids of October. Shower meteors are only visible for a few hours before dawn essentially from tropical and southern hemisphere sites. The radiant culminates near 8^{h} local time. Useful results may be obtained even from places around 40° N latitude. The shower is one of the best for southern observers and would benefit from increased observer activity generally. The fast and often bright meteors make the wait for radiant-rise worthwhile, and many events leave persistent trains.



A relatively broad maximum, sometimes with a variable number of submaxima, occurs around May 5/6. IMO analyses of visual data collected since 1984 have shown that ZHRs are generally above 30 in the period May 3–10. The peak rates appear to be variable on a roughly 12-year timescale. Assuming this Jupiter-influenced cycle is real, the next high level returns may occur in the years 2020–2022. Recent peak ZHRs were:

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

The waxing gibbous Moon (full on May 7) leaves a suitable moonless morning observation window to follow the activity until the maximum night.

Daytime Arietids (171 ARI)

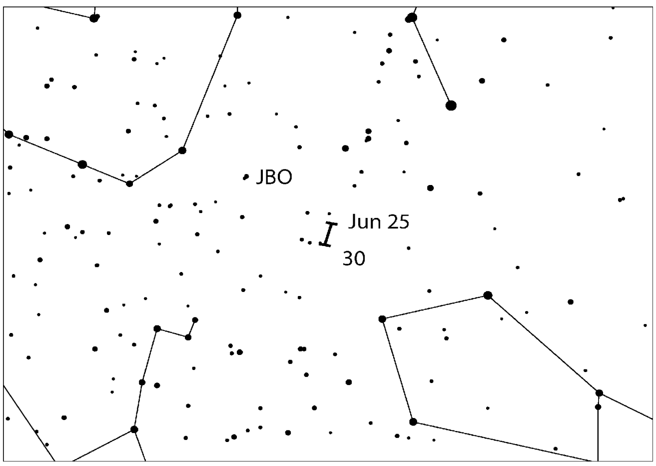
Active: May 14–June 24 (uncertain); Maximum: June 07 ($\lambda_\odot = 76\overset{\circ}{.}6$);
ZHR ≈ 30(?);
Radiant: $\alpha = 44°$, $\delta = +24°$; Radiant drift: see Table 6;
$V_\infty = 38$ km/s; $r = 2.8$.

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. 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. Since the twilight brightness is the main limiting factor, the lunar phase probably does not cause the major problem (full Moon on June 5).

June Boötids (170 JBO)

Active: June 22–July 2; Maximum: June 27, $22^{\rm h}$ UT ($\lambda_\odot = 95\overset{\circ}{.}7$), but see text;
ZHR = variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +48°$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.2$.

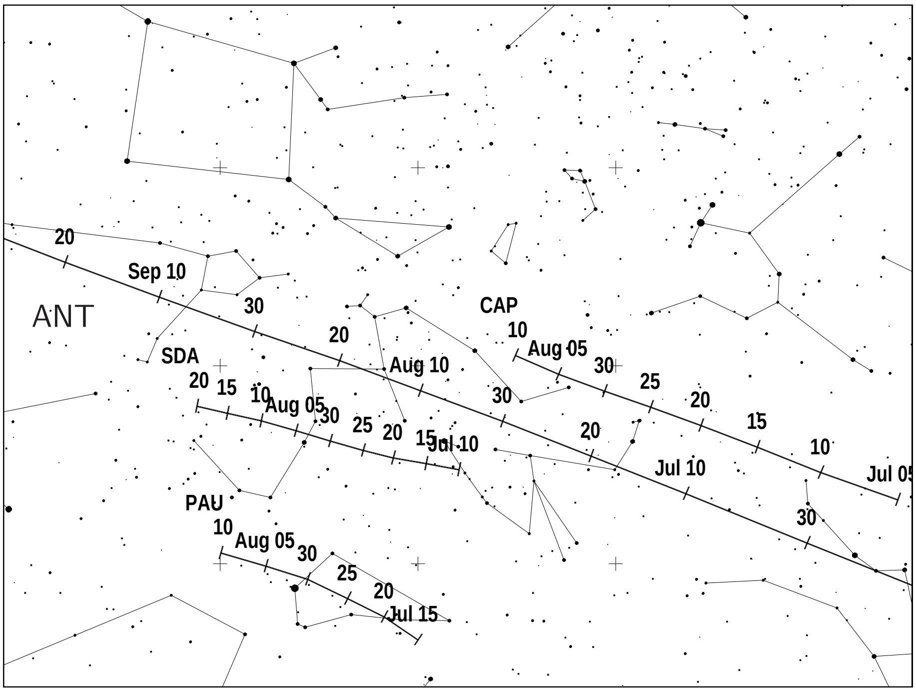
This shower is listed since its unexpected return of 1998 (ZHR $50 - 100+$ for more than half a day). Another outburst of similar length (ZHR $\approx 20 - 50$) was observed on 2004 June 23. The return predicted in 2010 yielded a poorly established ZHR < 10 on June 23–24. Prior to 1998, only three more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



The orbit of the parent comet 7P/Pons-Winnecke (orbital period about 6.4 years, last perihelion passage on 2015 January 30) 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 2020 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. This year, the Moon reaches its first quarter on June 28. VID suggested some June Boötids may be visible in most years around June 20 − 25 but with activity largely negligible except near $\lambda_\odot = 92°$ (2020 June 23), radiating from a radiant at $\alpha = 216°$, $\delta = +38°$ 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. 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 waxing gibbous Moon after July 27 will have an increasing impact in the closing days of July on the observation during the highest rates from these southern radiants, which are due on July 27 (PAU) and July 30 (CAP, SDA), respectively.



The waning Moon (at last quarter on August 11) will still allow some useful observations of the **Perseids (007 PER)** from their maximum onwards. Favourable conditions are found for the minor **κ-Cygnids (012 KCG)**. The **Aurigid (206 AUR)** peak on August 31 occurs shortly before full Moon (on September 2) and there are no predictions for known activity enhancements in 2020 from this source. The most interesting activity of the **September ε-Perseids (208 SPE)** is difficult to record this year because the last quarter Moon (September 10) in a high northern position will illuminate the essential time after local midnight. Jérémie Vaubaillon's calculations hint at possible activity caused by trails ejected in 1848 and 1375 (September 9 at 09^h55^m UT and 13^h32^m UT, respectively).

On 2016 July 28 at 00^h07^m UT ($\lambda_\odot = 125.^\circ132$) a remarkable outburst (ZHR probably of the order of 100) of the **July γ-Draconids (184 GDR)** was detected by radar and video observations (Molau et al., 2016b). The same position is reached again on 2020 July 28 near 00^h30^m UT, well worth checking in case something may be observable around this time – despite the lunar circumstances in July noted above. The radiant is at $\alpha = 280°$, $\delta = +51°$, and the meteors have rather low speed ($V_\infty = 27$ km/s).

A possible activity of the **β-Hydrusids** from a radiant at $\alpha = 23°$, $\delta = -76°$ on 2020 August 16 at 14^h18^m UT ($\lambda_\odot = 143.^\circ886$) is listed in Table 3 of Peter Jenniskens (2006). There is only one previous set of observations of this shower from 1985 August 16 from Australia (Jenniskens 2006, p. 346). The 2020 timing would be an encounter with a 1-revolution trail of an unknown Jupiter family comet. The radiant is far south and any meteors can only be recorded from the southern hemisphere. The velocity of the shower meteoroids is $V_\infty = 24$ km/s.

In 2015, several video data sets showed low rates had persisted essentially throughout September, identified as originating with the **χ-Cygnids (757 CCY)**. A weak maximum was found on September 14/15 (ZHRs about 2 or 3). The shower was also suspected in previous years, but at a lower activity level, hence further observations would be useful. New Moon on September 17 provides excellent conditions for optical observations to improve our knowledge of this minor source. 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.

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

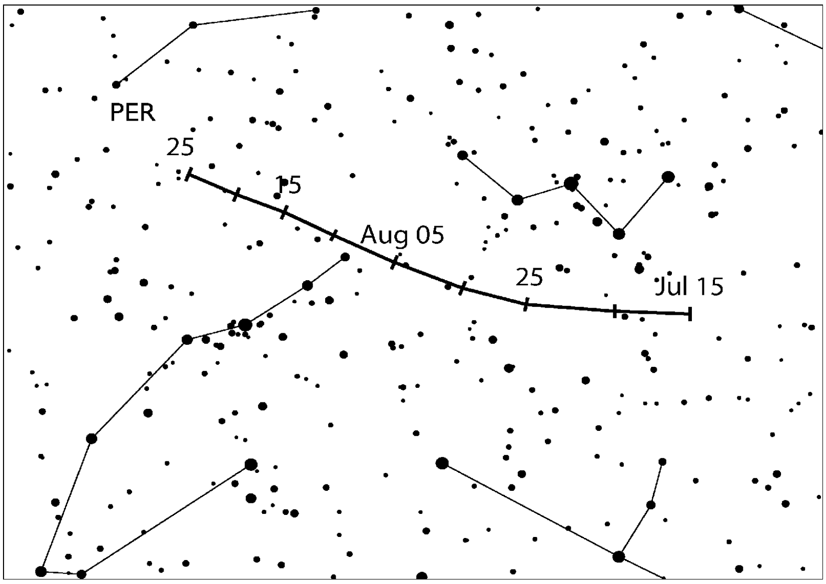
For **daylight radio observers**, the high activity of May–June has waned, but there remain the γ-Leonids (203 GLE; peak due near August 24, 23^h UT, albeit not found in recent radio results), and the **Daytime Sextantids (221 DSX)**. From late September to early October optical observers are encouraged to collect data of the DSX (see on page 14), too.

Perseids (007 PER)

Active: July 17–August 24; Maximum: August 12, 13^h to 16^h UT (node at $\lambda_\odot = 140.^\circ0$–$140.^\circ1$), but see text; ZHR = 110; Radiant: $\alpha = 48°$, $\delta = +58°$; 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 $\lambda_\odot \approx 139.^\circ8$ to $140.^\circ3$, equivalent to 2020 August 12, 08^h to August 12, 21^h UT. The orbital period of the parent comet 109P/Swift-Tuttle is about 130 years. The Perseids produced strong activity from a primary maximum throughout the 1990s. Enhanced activity was last observed in 2016 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 ($\lambda_\odot \approx 139.^\circ79$) at the predicted position. The filament is thought to be an accumulation of meteoroids in a mean-motion resonance. A similar filament encounter (ZHR about 100) is listed in Table 5d of Jenniskens (2006) for 2020. Its calculated position is close to the early maximum period at $\lambda_\odot \leq 139.^\circ89$ (2020 August 12, $\approx 10^h$ UT).

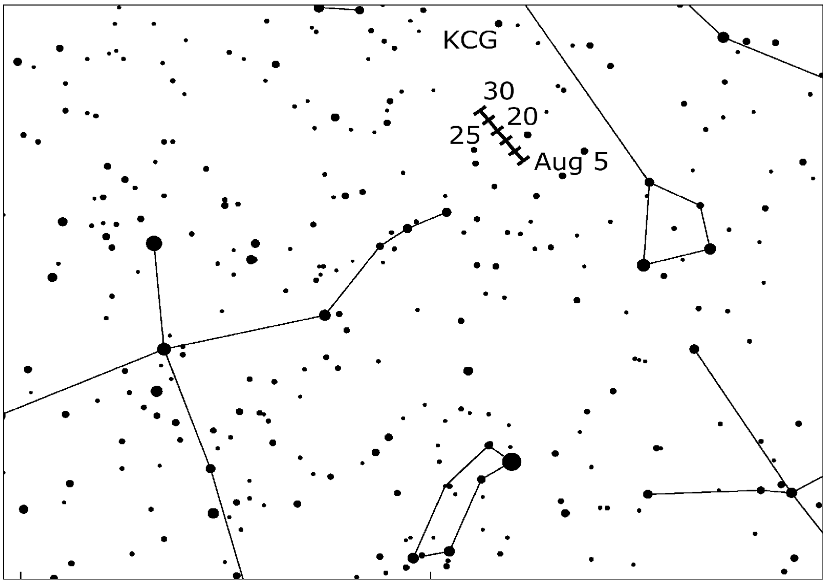
The last quarter Moon on August 11 illuminates the favourable hours after local midnight. Visual observers should try to block the direct moonlight. Generally, sites at mid-northern latitudes are best for Perseid observing, as from here, the shower's radiant can be usefully observed from 22^h–23^h local time onwards. Regrettably, the shower cannot be properly viewed from most of the southern hemisphere.



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; $r = 3.0$.

The κ-Cygnids showed enhanced activity in 2014 and 2007. Apart from these events, the general ZHR level seems to increase in the recent years, from an apparent dip in the period 1990–2005. However, the currently-available data do not confirm a periodic activity variation in the visual activity range, and for 2020 there are no available predictions suggesting further peculiarities may occur.



VID suggested a number of discrepancies to the currently-accepted parameters listed above, including that the peak might happen closer to August 14, and that activity might be present only from August 6–19 overall. Research by Koseki (2017) has shown a complex radiant structure extending into Draco and Lyra. The isolated radiant position and the low velocity 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.

Daytime Sextantids (221 DSX)

Active: September 9–October 9 (uncertain); Maximum: September 27 ($\lambda_\odot = 184\overset{\circ}{.}3$),
Radiant: $\alpha = 152°$, $\delta = 0°$; Radiant drift: 1° per day;
$V_\infty = 32$ km/s; $r = 2.5$ (uncertain).

Visual observers may observe some Sextantids in the pre-dawn of late September to early October as part of the IMO project to collect and pool data obtained by all techniques for this shower. The DSX radiant is roughly 30° west of the Sun. Because it lies close to the equator and the activity period is shortly after the equinox, the chances to contribute results are almost equally good for observers in either hemisphere. As with the Arietids, both the radiant elevation correction and the observing conditions change rapidly as morning twilight approaches. Hence visual observers should report their data in intervals no longer than about 15–20 minutes, determining the limiting magnitude frequently during each period. The timing, and even the date, of the Sextantid maximum is uncertain. The waxing gibbous Moon (at first quarter on September 24) will not affect pre-dawn DSX observing attempts.

6 October to December

During the last quarter of the year the most active showers are observable under good lunar conditions: both the **Orionids (008 ORI)** and the **Leonids (013 LEO)** reach their maxima shortly after new Moon and the **Geminid (004 GEM)** peak coincides with the new Moon.

The **October Camelopardalids (281 OCT)** produced a well detected ZHR ≈ 5 on 2018 October 6, 00^h30^mUT ± 1.3^h ($192\overset{\circ}{.}45 \pm 0\overset{\circ}{.}05$). The same position is reached again on 2020 October 5, 12^h40^m UT which is just four days after full Moon. Hence any activity will be difficult to observe. On October 8, the **Draconids** may show some additional activity. Further good targets – moonlight considering – are the **ε-Geminids (023 EGE)** on October 18 and the **Leonis Minorids (022 LMI)** on October 24. A month later, the **α-Monocerotids (246 AMO)** on November 21 are promising, and in December we find favourable conditions to observe the **Monocerotids (MON)** and the **σ-Hydrids (HYD)**, both with their maxima close to the Geminids. Suffering from moonlit skies are the **δ-Aurigids (224 DAU)** on October 11. This also holds for the **November Orionids (250 NOO**, maximum on November 28) and the **Phoenicids (254 PHO**, maximum on December 2). Bright moonlight affects observations of the complex **Puppid-Velids (301 PUP)** around December 7. Next, the weak **Comae Berenicids (020 COM)** on December 16 can be traced well while the long-lasting **December Leonis Minorids (032 DLM)** offer better observing conditions away from their weak maximum around December 20. During the **Ursid (URS)** maximum the waxing gibbous Moon leaves a rather short morning observation window to observe interesting regions of the stream.

The two Taurid branches reach their highest rates around October 10 (STA) and November 12 (NTA), both dates close to the Moon's last 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.

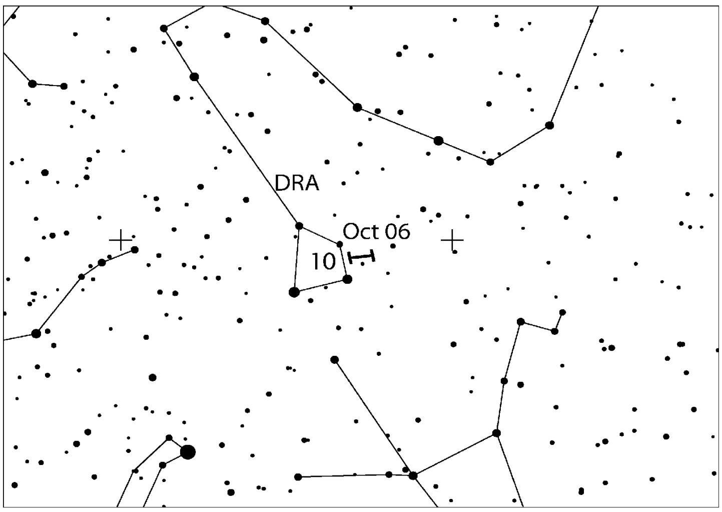
The Near Earth Object 2015 TB_{145} is suspected to be an extinct comet nucleus. If it was recently active, the Earth may encounter the associated meteoroid stream on **2020 October 20** at 22^h09^m UT ($\lambda_\odot = 217\overset{\circ}{.}659$) according to the calculations of Jérémie Vaubaillon. The theoretical radiant is at $\alpha = 64°$, $\delta = -3°$, less than 5° west of ν Eridani. Depending on the latitude, the radiant rises at about 21^h local time. The shower meteors have medium velocity ($V_\infty = 34$ km/s).

In December 2016, observers had been alerted that some meteors of the **66-Draconids** associated with the minor planet 2001 XQ could be possible. In visual data the activity remained below the detection limit. According to dynamical modelling results for 2020 by Jérémie Vaubaillon, there might be another encounter of a highly perturbed trail. The calculated time is on December 4, $05^{h}55^{m}$ UT ($\lambda_{\odot} = 252.^{\circ}26$), and the theoretical radiant is at $\alpha = 314^{\circ}$, $\delta = +60^{\circ}$, i.e. between Draco and Cepheus in a circumpolar position for most mid-Northern latitudes. The meteors are very slow with $V_{\infty} = 17$ km/s so that shower association should be easy. Any reports around the predicted period are welcome.

Draconids (009 DRA)

Active: October 6–10; Maximum: October 8, $12^{h}30^{m}$ UT ($\lambda_{\odot} = 195.^{\circ}4$), but see text;
ZHR = 10+ (?);
Radiant: $\alpha = 263^{\circ}$, $\delta = +56^{\circ}$; Radiant drift: negligible;
$V_{\infty} = 21$ km/s; $r = 2.6$.

The Draconids (also called October Draconids) are known as a periodic shower which produced spectacular meteor storms in 1933 and 1946, and lower rates in several other years (ZHRs ≈ 20–500+). Recent outbursts happened in 2011 (ZHR ≈ 300) 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 2020, there will be two trail encounters based on calculations by Jéremie Vaubaillon, both with no rate estimate. The respective times are from Jenniskens (2006):
1704 trail: 2020 October 7, $01^{h}25^{m}$ UT,
1711 trail: 2020 October 7, $01^{h}57^{m}$ UT.
Both are significantly ahead of the near-nodal period. 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.

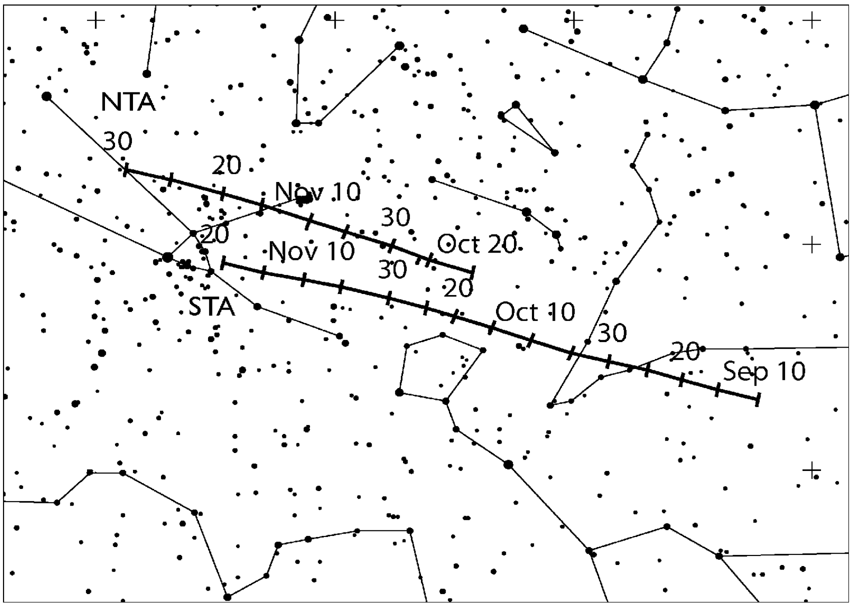


Southern Taurids (002 STA

Active: September 10–November 20; Maximum: October 10 ($\lambda_{\odot} = 197^{\circ}$); ZHR = 5;
Radiant: $\alpha = 32^{\circ}$, $\delta = +09^{\circ}$; 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 on. 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.



ε-Geminids (023 EGE)

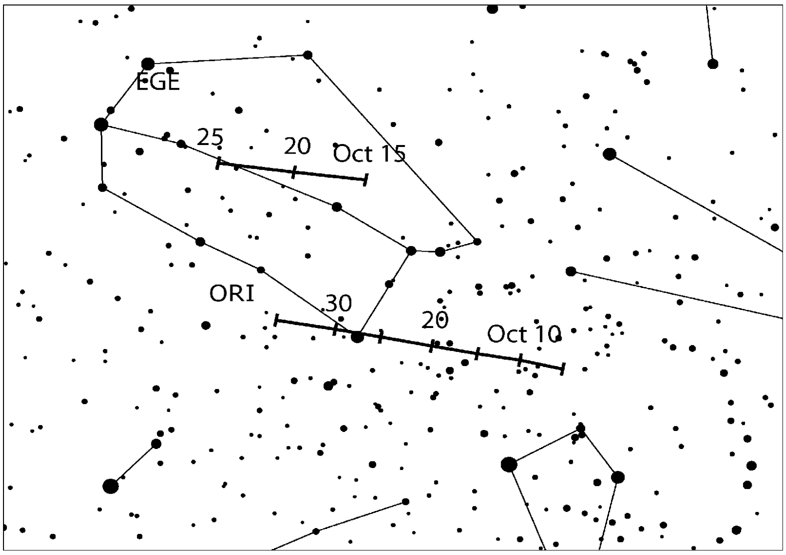
Active: October 14–27; Maximum: October 18 ($\lambda_\odot = 205°$); ZHR = 3;
Radiant: $\alpha = 102°$, $\delta = +27°$; Radiant drift: see Table 6;
$V_\infty = 70$ km/s; $r = 3.0$.

A weak minor shower with characteristics and activity nearly coincident with the Orionids, so great care must be taken to separate the two sources (chart see on page 17). Visual observers may prefer plotting to improve the shower association. The waxing crescent Moon on October 18/19 will set before the radiant becomes usefully observable from either hemisphere. Northern observers have a radiant elevation advantage, with observing practical there from about midnight onwards. There is some uncertainty about the shower's parameters, with both visual and video data indicating the peak may be up to four or five days later than suggested above.

Orionids (008 ORI)

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

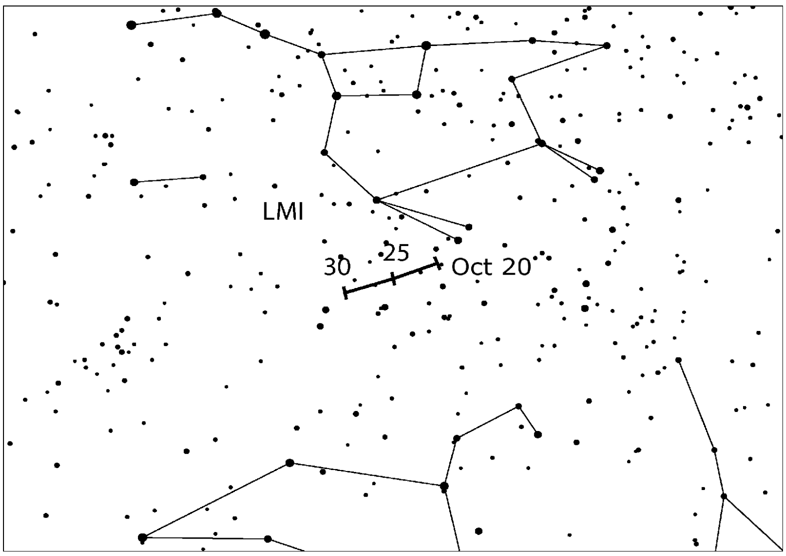
October's waxing crescent Moon sets well before local midnight for the peak night of October 20/21 this year. The shower's radiant is at a useful elevation from local midnight or so in either hemisphere, somewhat before in the north. Each return from 2006 to 2009 produced unexpectedly strong ZHRs of 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 $\approx$ 14–31 during the examined interval. In addition, a suspected 12-year periodicity in stronger returns found earlier in the 20th century appeared to have been partly confirmed. That suggested the higher activity phase of the cycle should fall between 2020–2022. The average maximum Orionid ZHRs in the years 2014–2018 was in the range of 20–25. The Orionids often provide several lesser maxima, helping activity sometimes remain roughly constant for several consecutive nights centred on the main peak. In 1993 and 1998, a submaximum about as strong as the normal peak was detected on October 17/18 from Europe, for instance.



Leonis Minorids (022 LMI)

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

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



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; $r = 2.3$.

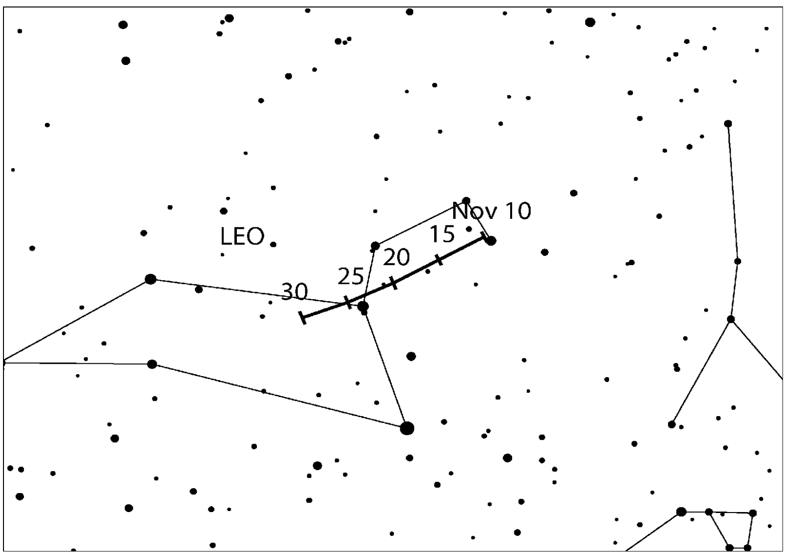
Some details on this branch of the Taurid streams were given with the Southern Taurids above. Other aspects are the same too, such as the large, oval radiant region to be used for shower association, the shower's excellent visibility overnight, and its dominance over the ANT during September to December. 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, last quarter Moon on November 8 should allow plenty of coverage. (For the radiant drift graph see page 16.)

Leonids (013 LEO)

Active: November 6–30; Maximum: November 17, 11^h UT (nodal crossing at $\lambda_\odot = 235\overset{\circ}{.}27$);
ZHR $\approx 10 - 20$
Radiant: $\alpha = 152°$, $\delta = +22°$; Radiant drift: see Table 6;
$V_\infty = 71$ km/s; $r = 2.5$.

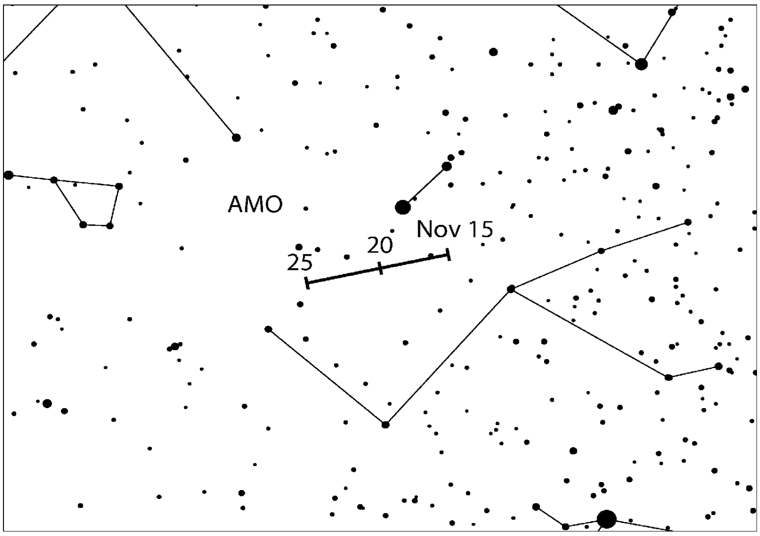
The latest perihelion passage of the Leonids' parent comet, 55P/Tempel-Tuttle, in 1998 is more than two decades ago now and meanwhile the comet has passed its aphelion. The knowledge of the dust ejection mechanisms and trail evolution allowed us to predict and verify variable activity in numerous years until recently. The nodal Leonid maximum occurs on November 17 just after new Moon.

Mikiya Sato's model calculation shows that there are a few dust trail approaches in 2020. Some activity of predominantly faint meteors may occur on November 17 between $06^h50^m - 08^h13^m$ UT ($\lambda_\odot = 235\overset{\circ}{.}100 - 235\overset{\circ}{.}158$). The meteoroids of the 1600-trail are leading the comet, like the trails due in the following years. Hence the data of 2020 have high relevance for the next predictions. Further approaches in 2020 concern trails of 901 (November 18, 00^h58^m UT, $\lambda_\odot = 235\overset{\circ}{.}852$) and 1234 (November 20, 15^h28^m UT, $\lambda_\odot = 238\overset{\circ}{.}490$). Both are probably at the detection limit because perturbations reduced the density a lot. The shower's radiant is usefully observable only by local midnight or so north of the equator, afterwards for places further south.



α-Monocerotids (246 AMO)

Active: November 15–25; Maximum: November 21, 12^h UT ($\lambda_\odot = 239.^\circ32$);
ZHR = variable, usually ≤ 5, but see text;
Radiant: $\alpha = 117^\circ$, $\delta = +01^\circ$; Radiant drift: see Table 6;
$V_\infty = 65$ km/s; $r = 2.4$.

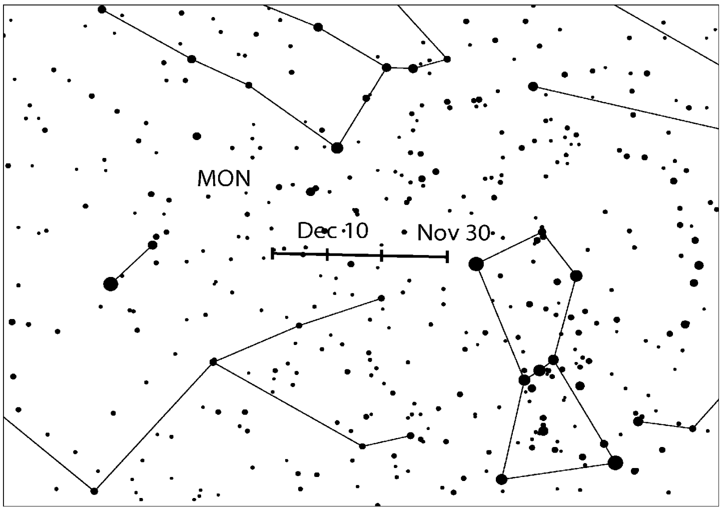


The most recent α-Monocerotid outburst was observed in 1995. The peak ZHR of ≈ 420 lasted for just five minutes, the entire outburst 30 minutes. Recent modelling by Esko Lyytinen has indicated the main AMO trail crosses the Earth's **orbit** in 2017 and 2020. However, the Earth is not near those points in November, so no strong outburst is likely to happen then. The possible return of November 2019 still had to come when the Calendar was written. Observable rates in 2019 may indicate some low activity also on 2020 November 21, 09^h50^m UT ($\lambda_\odot = 239.^\circ264$). 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. First quarter Moon on the maximum date sets around local midnight when the radiant reaches suitable elevation above the horizon.

Monocerotids (019 MON)

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

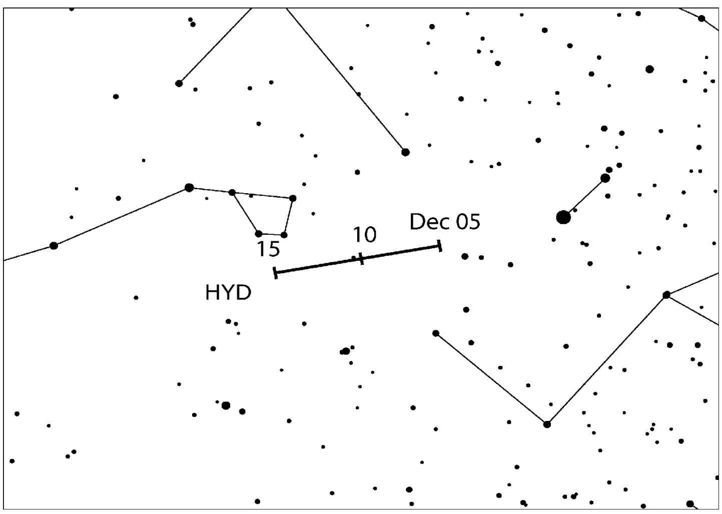
This minor shower's details need further improvement by observational data. In most years, visual data give a maximum ZHR = 3 at $\lambda_\odot \approx 257^\circ$ while the general ZHR level is about 2. In a few years, we also find an apparent slight enhancement in the Geminid peak night. This is assumed to be an effect of Geminids erroneously classified as MON. Video data (2011–2018) show a peak of roughly $0.^\circ4$ width centred at $\lambda_\odot \approx 262.^\circ0^\circ$ (i.e. December 14) with a ZHR of the order of 8 coinciding with the Geminid peak. Care needs to be taken to clearly distinguish MON from GEM. Visual observers should choose their field of view such, that the radiants do not line up. (Field centres near Taurus in the evening or near Leo in the morning are possible choices.) December's new Moon period creates perfect conditions for either potential maximum timing, as the radiant area is available virtually all night for much of the globe, culminating at about 01^h30^m local time.



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; $r = 3.0$.

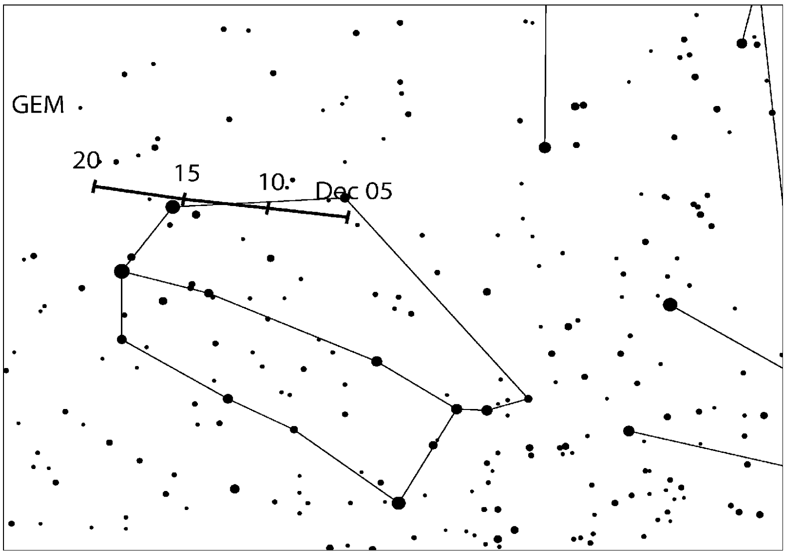
The σ-Hydrids are often thought to be a very minor shower with rates close to the visual detection threshold for much of the activity period. However, some bright meteors are repeatedly seen and the maximum ZHR reaches 5–8. IMO visual data (WB p. 65) have indicated the maximum might happen nearer $\lambda_\odot \sim 262°$ (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. 2020 is a splendid year for them, thanks to new Moon on December 14.



Geminids (004 GEM)

Active: December 4–17; Maximum: December 14, 00^h50^m 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 01^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.

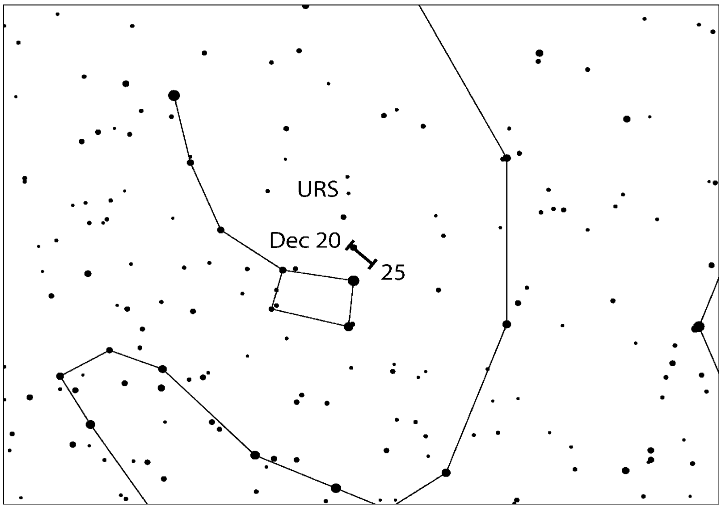


The peak has shown little variability in its timing in recent years, with the more reliably-reported maxima during the past two decades (WB, p. 66) all having occurred within $\lambda_\odot = 261\overset{\circ}{.}5$ to $262\overset{\circ}{.}4$, that is 2020 December 13, 08^h to December 14, 06^h UT. 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 2020 return coincides with new Moon and is therefore optimally placed.

Ursids (015 URS)

Active: December 17–26; Maximum: December 22, 09^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; $r = 3.0$.

A poorly-observed northern hemisphere shower which has produced at least two major outbursts in the past 70 years, in 1945 and 1986. Some events could have been missed due to weather conditions. Several lesser rate enhancements have been reported from 2006 to 2008. Many peaks occurred when the parent was close to its aphelion, and so the slightly enhanced rates found in video data in 2014 and 2015 indicate that predictions are difficult.



For 2020, Jenniskens (2006) lists encounters of two dust trails based on Lyytinen's calculations and one filament of meteoroids in a mean-motion resonance. The respective times are:
829 dust trail, December 22, 06^h10^m UT (270.°57)
815 dust trail, December 22, 03^h – 22^h UT (270.°44)
filament, December 22, 05^h27^m UT (270.°54)
The listed ZHRs are 490 and 420 for the trails and 34 for the filament, respectively. Both, the timing and the rates may include valuable information about the modelling parameters.
Mikiya Sato finds two periods when some detectable activity is to be expected:
719 + 733 dust trails, December 22, 03^h15^m – 03^h40^m UT (270.°449 – 270.°463)
801 dust trail, December 22, 17^h31^m UT (271.°053)
Comparing the condition with previous returns, the rates will be low.

The Ursid radiant is circumpolar from most northern sites, so fails to rise for most southern ones, though it culminates after daybreak, and is highest in the sky later in the night. The Moon (first quarter on December 21) and the long northern nights allow observations for several hours at each suitable location.

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° × 10°, while that for the ANT is still larger, at 30° × 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:

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.

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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

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 2020.

New Moon	First Quarter	Full Moon	Last Quarter
	January 3	January 10	January 17
January 24	February 2	February 9	February 15
February 23	March 2	March 9	March 16
March 24	April 1	April 8	April 14
April 23	April 30	May 7	May 14
May 22	May 30	June 5	June 13
June 21	June 28	July 5	July 13
July 20	July 27	August 3	August 11
August 19	August 25	September 2	September 10
September 17	September 24	October 1	October 10
October 16	October 23	October 31	November 8
November 15	November 22	November 30	December 8
December 14	December 21	December 30	

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in June 2019, with maximum dates accurate only for 2020. The parenthesized maximum date for the Puppids-Velids indicates a reference date for the radiant only, not necessarily a true maximum. Some showers have ZHRs that vary from year to year. The most recent reliable figure is given here, except for possibly periodic showers which are noted as 'Var' = variable. For more information check the updates published e.g. in the IMO Journal WGN.

Shower	Activity	Maximum Date	Maximum $\lambda_\odot$	Radiant α	Radiant δ	V_∞ km/s	r	ZHR
Antihelion Source (ANT)	Dec 10–Sep 10 –	March–April, late May, late June		see Table 6		30	3.0	4
Quadrantids (010 QUA)	Dec 28–Jan 12	Jan 04	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 27	125°	341°	−30°	35	3.2	5
S. δ-Aquariids (005 SDA)	Jul 12–Aug 23	Jul 29	127°	340°	−16°	41	2.5	25
α-Capricornids (001 CAP)	Jul 03–Aug 15	Jul 29	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	Aug 31	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	15
α-Monocerotids (246 AMO)	Nov 15–Nov 25	Nov 21	239°.32	117°	+01°	65	2.4	Var
Nov. Orionids (250 NOO)	Nov 13–Dec 06	Nov 28	246°	91°	+16°	44	3.0	3
Phoenicids (254 PHO)	Nov 28–Dec 09	Dec 02	250°.0	18°	−53°	18	2.8	Var
Puppid-Velids (301 PUP)	Dec 01–Dec 15	(Dec 07)	(255°)	123°	−45°	40	2.9	10
Monocerotids (019 MON)	Dec 05–Dec 20	Dec 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	Radiant δ
κ-Cancrids (793 KCA)	Jan 10	289°.315	138°	+9°
α-Virginids (021 AVB)	Apr 24	34°.273	198°	+7°
461852 (τ Her)	May 14	54°.279	248°	+46°
July γ-Draconids (184 GDR)	Jul 28	125°.132	280°	+51°
β-Hydrusids	Aug 16	143°.886	23°	−76°
2015 TB145 (ν Eri)	Oct 20	217°.659	64°	−3°
2001XQ (66 Draconids)	Dec 04	252°.26	314°	+60°

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	Radiant δ	Rate
Capricornids/Sagittariids (115 DCS)	Jan 13–Feb 04	Feb 01*	312°.5	299°	−15°	M*
χ-Capricornids (114 DXC)	Jan 29–Feb 28	Feb 14*	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

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