International Meteor Organization

2011 Meteor Shower Calendar

compiled by Alastair McBeath [1]

1 Introduction

Welcome to the twenty-first International Meteor Organization (IMO) Meteor Shower Calendar, for 2011. The year starts brightly enough meteorically, with the Quadrantid peak perfectly-timed for new Moon, followed by favourable returns for the α–Centaurids and η–Aquariids, but the later-year major showers are all quite to very badly moonlit. The Draconids may yield some activity in October, sadly close to full Moon too, and the almost-unknown ε–Eridanids could produce equally moonlit rates in September. There are changes to some of the less active sources based on the latest IMO video analyses, including for the near-Auriga showers of September-October, and for the Southern Taurids especially. There are always other minor showers to be monitored of course, and ideally, meteor observing should be carried on throughout the year to check on all the established sources, and for any new ones. Such routine monitoring is possible now with automated video systems especially, but we appreciate not everyone is able to employ these, and that observing in other ways regularly is impractical for most people, so the Shower Calendar has been helping to highlight times when a particular effort might be most usefully employed since 1991.

The heart of the Calendar is the Working List of Visual Meteor Showers, Table 5, which has been undergoing a thorough revision in the last few years, a process that is still underway, in order to help it remain the single most accurate listing available anywhere today for naked-eye meteor observing. Of course, for all its accuracy, it is a **Working** List, so is continually subject to further checks and corrections, based on the best data we had at the time the Calendar was written, thus it is always as well to check the information here fully, taking account of any later changes noted in the IMO's journal *WGN* or on the IMO website, before going out to observe (and please notify us if you find any anomalies!).

This is a particularly dynamic time for minor shower studies, with video results detecting many weak showers too minor to be visually-observed, as well as sometimes revealing fresh aspects of those already known, and even of the low-activity phases of some of the major showers well away from their maxima. Video has established itself as a valuable tool in meteor studies in recent years, and professional radar meteor examinations have been producing excellent new results as well, but we should not forget the other instrumental techniques available to amateur observers. Telescopic observations can also separate minor shower activity from the omnipresent background sporadics, and detect showers whose meteors are too faint even for current video

[1] Based on information in *Handbook for Meteor Observers*, edited by Jürgen Rendtel and Rainer Arlt, IMO, 2009 (referred to as 'HMO' 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 (*WGN* **37:4**, 2009, pp. 98–121; referred to as 'VID' in the Calendar), as amended by subsequent discussions and additional material extracted from reliable data analyses produced since. Particular thanks are due to Rainer Arlt, Jeff Brower, David Entwistle, Esko Lyytinen, Jürgen Rendtel and Jérémie Vaubaillon for new information and comments in respect of events in 2011.

systems. Still-imaging enables a whole range of studies to be carried out on the brighter meteors particularly, and multi-station observing with still or video cameras can allow orbital data to be established, essential for meteoroid-stream examinations. Showers with radiants too near the Sun for observing by the various optical methods can be detected by forward-scatter radio or radar observations. Some of these showers are given in Table 7, the Working List of Daytime Radio Meteor Streams. Automated radio and radar work also allows 24-hour coverage of meteor activity.

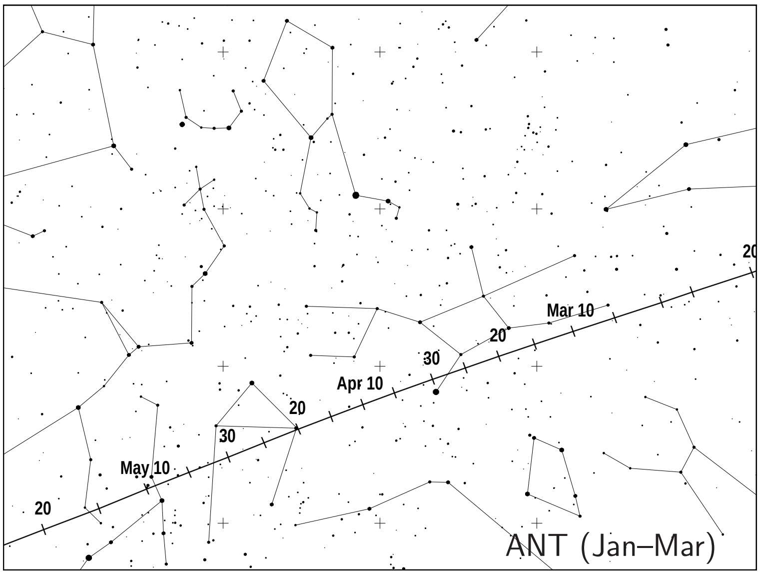
The IMO's aims are to encourage, collect, analyze, and publish combined meteor data obtained from sites all over the globe, to help better our understanding of the meteor activity detectable from the Earth's surface. Thus, we encourage these more specialist forms of observing alongside visual work. Consequently, for best effects, all meteor workers, wherever you are and whatever methods you use to record meteors, should follow the standard IMO observing guidelines when compiling your information, and submit those data promptly to the appropriate Commission for analysis (contact details are at the end of the Calendar). 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 steps towards constructing a better and more complete picture of the near-Earth meteoroid flux can proceed.

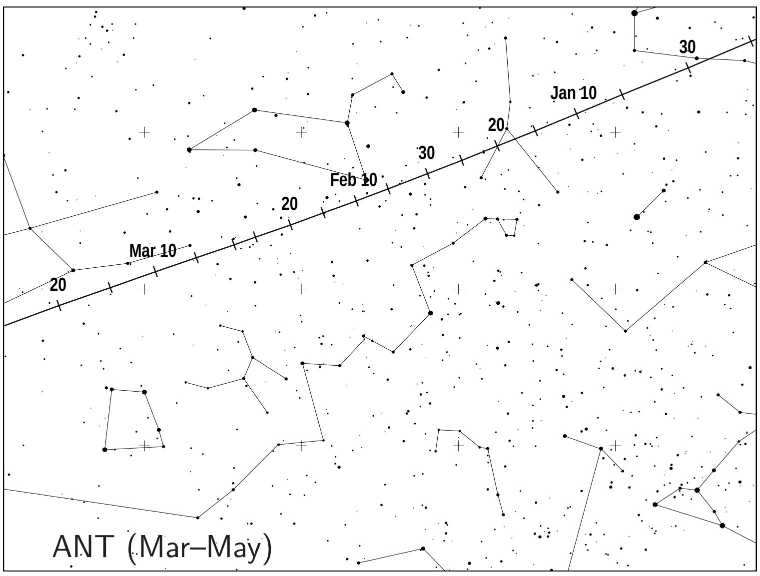
Although timing predictions are included below on all the more active night-time and daytime shower maxima, as reliably as possible, it is essential to understand that in many cases, such maxima are not known more precisely than to the nearest 1° of solar longitude (even less accurately for the daytime radio showers, which have received little regular attention until quite recently). 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, telescopic, 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. Clear skies!

2 Antihelion Source

The Antihelion Source (ANT) is a large, roughly oval area around $\alpha = 30°$ by $\delta = 15°$ in size, centred about 12° east of the solar opposition point on the ecliptic, hence its name. It is not a true shower at all, 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 from the last decade have shown why, because even instrumentally, it was impossible to define distinct radiants for many of the showers here! Thus we believe currently it is best for observers to simply identify meteors from these streams as coming from the ANT alone. At present, we think the July-August α–Capricornids (CAP), and particularly the δ–Aquariids (SDA), should remain discretely-observable visually from the ANT, so they have been retained on the Working List, but time and plenty of observations will tell, as ever. Later in the year, the strength of the Taurid showers (STA and NTA) means the ANT should be considered inactive while the Taurids are underway, from early September to early December (note this interval has been extended since the 2010 Shower Calendar). 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.



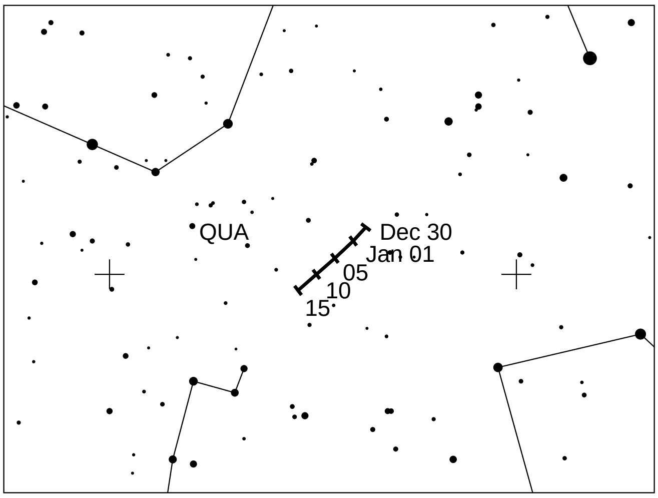


3 January to March

New Moon falls perfectly for the northern-hemisphere Quadrantid maximum, and moonlight circumstances also favour the southern-hemisphere's α–Centaurid and minor γ–Normid returns. 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 slips through southern Virgo during March. Likely ANT ZHRs will be < 2, though IMO analyses suggest there may be an ill-defined minor peak with ZHRs ~ 2 to 3 around $\lambda_\odot \sim 286°$–$293°$ (January 6 to 13 in 2011, much of which has only a waxing crescent Moon, if so), and ZHRs could be ~ 3 for most of March. The late January to early February spell, during which several new, swift-meteor, minor showers, radiating from the Coma-Leo-Virgo area have been proposed in some recent years, is spoilt by the full to waning Moon for its potential core period, January 20–27. Theoretical approximate timings (rounded to the nearest hour) for the daytime radio shower maxima this quarter are: Capricornids/Sagittariids – February 1, 21^h UT; and χ–Capricornids – February 13, 22^h UT. Recent radio results have implied the Cap/Sgr maximum may variably fall sometime between February 1–4 however, while activity near the expected χ–Capricornid 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 (QUA)

Active: December 28-January 12; Maximum: January 4, 01^h10^m UT ($\lambda_\odot = 283.°16$);
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;
TFC: $\alpha = 242°$, $\delta = +75°$ and $\alpha = 198°$, $\delta = +40°$ ($\beta > 40°$ N).
IFC: before 0^h local time $\alpha = 150°$, $\delta = +70°$; after 0^h local time $\alpha = 180°$, $\delta = +40°$ and $\alpha = 240°$, $\delta = +70°$ ($\beta > 40°$ N).



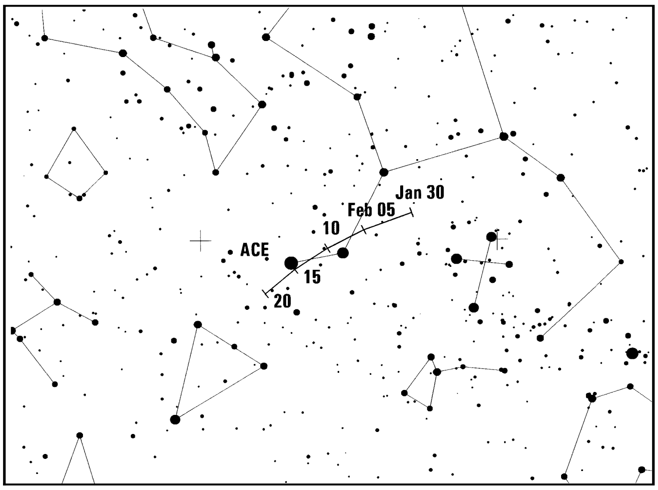
New Moon just eight hours after the predicted Quadrantid maximum creates ideal circumstances for observing the shower from northern hemisphere sites this year. From many such places, the shower's radiant is circumpolar, in northern Boötes, attaining a useful elevation only after local midnight, and rising higher in the sky towards morning twilight. This means places at European longitudes east to those of central Asia should be best-placed to record what happens. However, computations by Jérémie Vaubaillon have suggested the peak could happen at a somewhat different time between roughly 21^h UT on January 3 to 06^h UT on January 4 (see the diagram on HMO p. 129). The occasional long-pathed shower meteor might be seen from southern hemisphere sites around dawn, but sensible Quadrantid watching cannot be carried out from such places.

The maximum timing above is based on the best-observed return of the shower ever analysed, from IMO 1992 data, confirmed by radio results in most years since 1996. The peak itself is normally short-lived, and can be easily missed in just a few hours of poor northern-winter weather, which may be why the ZHR level apparently fluctuates from year to year, but some genuine variability is probably present too. For instance, visual ZHRs in 2009 persisted for almost fourteen hours at close to their best, with the predicted maximum time falling around an hour or two after the mid-point of this extended interval. An added level of complexity comes from the fact mass-sorting of particles across the meteoroid stream may make fainter objects (radio and telescopic meteors) reach maximum up to 14 hours before the brighter (visual and photographic) ones, so observers should be alert throughout the shower. A few, but apparently not all, years since 2000 seem to have produced a, primarily radio, maximum following the main visual one by some 9–12 hours. Visual confirmation of any repeat of such activity would be welcomed.

VID data recently indicated the QUA may be active weakly for longer than previous visual estimates had inferred, perhaps from December 28 to January 12, compared to just January 1–10 visually (HMO). It is not certain visual observers will be able to follow the shower for so long as yet, as the early and late activity may be too low to be separated from the visual sporadic background. Past observations have suggested the QUA radiant is diffuse away from the maximum too, contracting notably during the peak itself, although this may be a result of the very low activity outside the hours near maximum. Still-imaging and video observations would be particularly welcomed by those investigating this topic, using the IFCs and TFCs given above, along with telescopic results.

α–Centaurids (ACE)

Active: January 28–February 21; Maximum: February 8, $11^{h}30^{m}$ UT ($\lambda_{\odot} = 319\overset{\circ}{.}2$);
ZHR = variable, usually ~ 6, but may reach 25+;
Radiant: $\alpha = 210°$, $\delta = -59°$; Radiant drift: see Table 6;
$V_{\infty} = 56$ km/s; $r = 2.0$.



In theory, the α–Centaurids are one of the main southern summer high points, from past records supposedly producing many very bright, even fireball-class, objects (meteors of at least magnitude −3), commonly with fine persistent trains. However, the average peak ZHR between 1988–2007 was merely 6 (HMO, p. 130), 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.

As with many southern hemisphere sources, we have more questions than answers at present, nor do we have any means of telling when, or if, another stronger event might happen. Consequently, imaging and visual observers are urged to be alert at every opportunity. The radiant is nearly circumpolar for much of the sub-equatorial inhabited Earth, and is at a useful elevation from late evening onwards. The Moon is merely a waxing crescent on February 8, and will have set by mid-evening from mid-southerly sites.

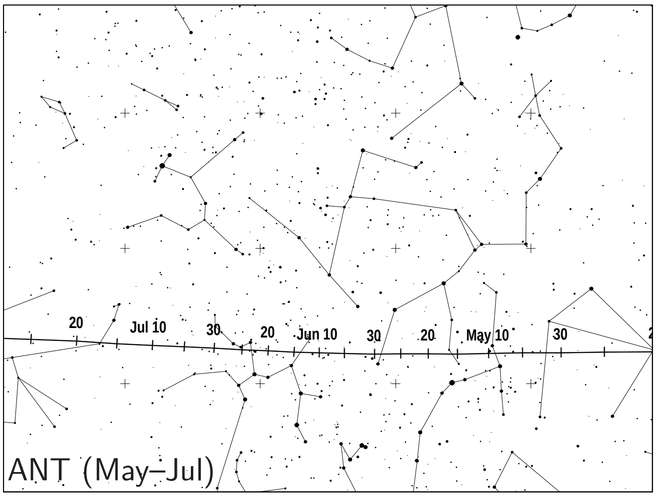
γ–Normids (GNO)

Active: February 25–March 22; Maximum: March 15 ($\lambda_\odot = 354°$); ZHR = 6;
Radiant: $\alpha = 239°$, $\delta = -50°$, Radiant drift: see Table 6;
$V_\infty = 56$ km/s; $r = 2.4$;
TFC: $\alpha = 225°$, $\delta = -26°$ and $\alpha = 215°$, $\delta = -45°$ ($\beta < 15°$ S).

For most of their activity, γ–Normid ZHRs seem to be virtually undetectable above the background sporadic rate. The maximum itself has been reported as quite sharp, and an analysis of IMO data from 1988–2007 showed an average peak ZHR of ~ 6 at $\lambda_\odot = 354°$, with ZHRs < 3 visible on all other dates during the shower (HMO, pp. 131–132). Limited data means this is uncertain, and activity may vary somewhat at times, with occasional broader, or less obvious, maxima having been noted in the past. Results since 1999 have suggested the possibility of a short-lived peak alternatively between $\lambda_\odot \sim 347°$–$357°$, equivalent to 2011 March 8–18, while video and visual plotting information from the same period agreed on the above radiant position, though this was different to that suggested earlier for the shower. Post-midnight watching yields better results, when the radiant is rising to a reasonable elevation from southern hemisphere sites (the radiant does not rise for many northern ones). The shower badly needs more regular attention, and March's waxing Moon, at first quarter on March 12, means 2011 would be a good year to start, as moonset leaves at least some dark-sky observing time after midnight for virtually the whole potentially extended peak spell. All observing techniques can be employed.

4 April to June

Meteor activity picks up towards the April-May boundary, though neither of the two shower maxima in late April are observably Moon-free. The Lyrids should peak between about 15^h30^m UT on April 22 to 02^h30^m UT on April 23 (and will probably give better rates the closer the maximum falls to 23^h UT on the 22nd), while the π–Puppid maximum is due around 04^h UT on April 24. Something of the usually-minor π–Puppids may still be visible before moonrise, however, as they are best-seen before local midnight from the southern hemisphere. No unusual activity has been predicted from them for this year. The η–Aquariids in early May are much better-placed, with some dark-sky observing possible for the minor η–Lyrids a few days afterwards as well. Later in May and throughout June, most of the meteor action switches to the daytime sky, with six shower maxima expected during this time. Although occasional meteors from the o–Cetids and Arietids have been claimed as seen from tropical and southern hemisphere sites visually in past years, ZHRs cannot be sensibly calculated from such observations. For radio observers, the theoretical UT peaks for these showers are as follows: April Piscids - April 20, 22^h; δ–Piscids - April 24, 22^h; ε–Arietids - May 9, 22^h; May Arietids - May 16, 21^h; o–Cetids - May 20, 20^h; Arietids - June 7, 23^h; ζ–Perseids - June 9, 23^h; β–Taurids - June 28, 22^h. Signs of most were found in radio data from 1994–2007, though some are difficult to define individually because of their proximity to other radiants. There seems to be a modest recurring peak around April 24, perhaps due to combined rates from the first three showers listed here, for instance, while the Arietid and ζ–Perseid maxima tend to blend into one another, producing a strong radio signature for several days in early to mid June. There are indications these two June shower maxima now each occur up to a day later than indicated above.



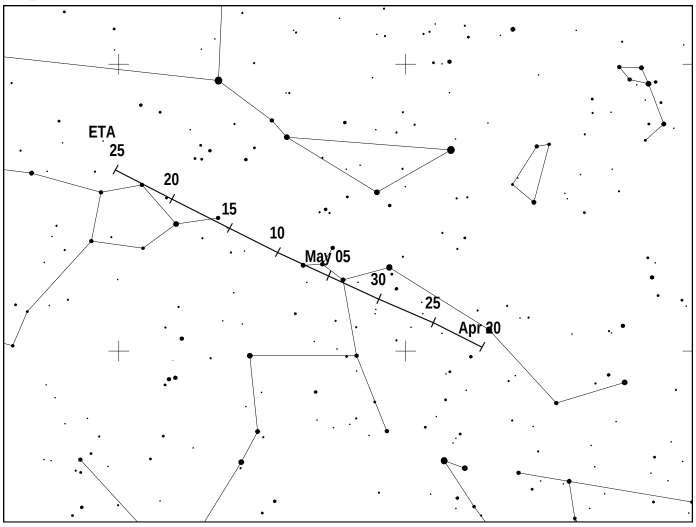
The ANT should be relatively strong, with ZHRs of 3 to 4 found in recent investigations through till mid April, and again around late April to early May, late May to early June, and late June to early July. At other times, the ZHR seems to be below ∼ 2 to 3. The radiant area drifts from south-east Virgo through Libra in April, then across the northern part of Scorpius to southern Ophiuchus in May, and on into Sagittarius for much of June.

For northern observers, circumstances for checking on any potential June Lyrids are very poor this year around their theoretical peak on June 16 (the shower is not currently given on the Working List, as it has not been found in recent investigations), but will have improved for possible June Boötid hunting later in June.

η–Aquariids (ETA)

Active: April 19–May 28; Maximum: May 6, 13^{h} UT ($\lambda_\odot = 45\overset{\circ}{.}5$);
ZHR = 70 (periodically variable, ∼ 40–85);
Radiant: $\alpha = 338°$, $\delta = -01°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.4$;
TFC: $\alpha = 319°$, $\delta = +10°$ and $\alpha = 321°$, $\delta = -23°$ ($\beta < 20°$ S).

A fine, rich stream associated with Comet 1P/Halley, like the Orionids of October, but one visible for only a few hours before dawn, essentially from tropical and southern hemisphere sites. Some useful results have come even from places around 40° N latitude in recent years however, and occasional meteors have been reported from further north, but the shower would benefit from increased observer activity generally. The fast and often bright meteors make the wait for radiant-rise worthwhile, and many events leave glowing persistent trains after them. While the radiant is still low, η–Aquariids tend to have very long paths, which can mean observers underestimate the angular speeds of the meteors, so extra care is needed when making such reports.



A relatively broad maximum, sometimes with a variable number of submaxima, usually occurs in early May. Fresh IMO analyses in recent years, based on data collected between 1984–2001, have shown that ZHRs are generally above 30 between about May 3–10, and that the peak rates appear to be variable on a roughly 12-year timescale. The most recent highest rates should have happened around 2008–2010, if this Jupiter-influenced cycle was borne-out, so ZHRs should be falling back from this peak in 2011, according to this idea.

Although activity in 2007 seemed unexpectedly weaker than normal (peak ZHRs maybe only $\sim$ 50), rates seemed to have been much better in 2008 and 2009 (ZHRs of $\sim$ 85 and 65 respectively). There seemed to have been no additional influence following the protracted, sometimes stronger than expected, Orionid returns from October 2006–2009 inclusive in the η–Aquariids in those years, as far as the available results allowed. New Moon on May 3 creates perfect viewing conditions for whatever the shower provides in 2011. All forms of observing can be used to study it, with radio work allowing activity to be followed even from many northern latitude sites throughout the daylight morning hours. The radiant culminates at about 08^{h} local time.

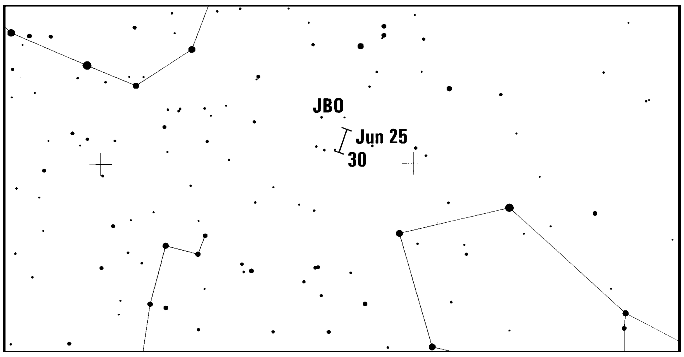
η–Lyrids (ELY)

Active: May 3–14; Maximum: May 9 ($\lambda_\odot = 48°$); ZHR = 3;
Radiant: $\alpha = 287°$, $\delta = +44°$; Radiant drift: see Table 6;
$V_\infty = 43$ km/s; $r = 3.0$;
TFC: $\alpha = 325°$, $\delta = +40°$ or $\alpha = 285°$, $\delta = +15°$, and $\alpha = 260°$, $\delta = +30°$ ($\beta > 10°$ S).

This recent introduction to the Visual Working List is associated with Comet C/1983 H1 IRAS-Araki-Alcock, though it appears to be only a weak shower. Most of the recent observational data on it has come from purely video results, which have been used to update the parameters above here, though they also suggested the maximum might fall up to two days later, at $\lambda_\odot = 50°$ (so on 2011 May 11). There is little evidence to suggest it has been definitely observed visually as yet, but the discussion on p. 137 of HMO had more information. Video work, diligent telescopic, or perhaps equally 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), while the waxing Moon, at first quarter on May 10, sets to leave most of the post-midnight sky dark enough for useful observing even by May 11.

June Boötids (JBO)

Active: June 22–July 2; Maximum: June 27, 21^{h} UT ($\lambda_\odot = 95.°7$), but see text;
ZHR = variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +48°$; Radiant drift: see Table 6;
$V_\infty = 18$ km/s; $r = 2.2$;
TFC: $\alpha = 156°$, $\delta = +64°$ and $\alpha = 289°$, $\delta = +67°$ ($\beta = 25°$–$60°$ N).

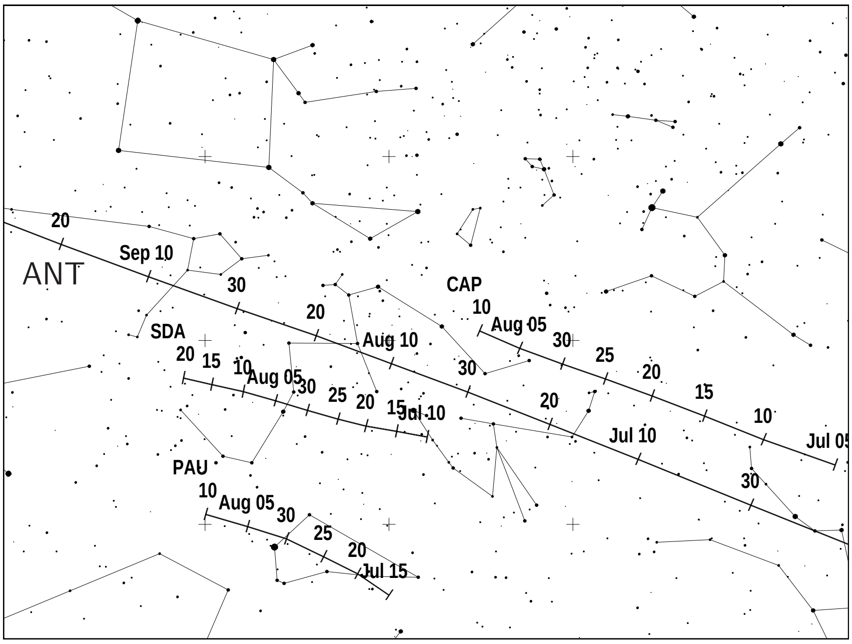


This source was reinstated on the Working List after its unexpected return of 1998, when ZHRs of 50–100+ were visible for more than half a day. Another outburst of similar length, but with ZHRs of $\sim$ 20–50 was observed on 2004 June 23, a date before definite activity had previously been recorded from this shower.

Consequently, the shower's start date was altered to try to ensure future activity so early is caught, and we encourage all observers to routinely monitor throughout the proposed activity period, in case of fresh outbursts. The predicted possible activity in 2010 was still to come when this text was prepared. Prior to 1998, only three more probable returns had been detected, in 1916, 1921 and 1927, and with no significant reports between 1928 and 1997, it seemed likely these meteoroids no longer encountered Earth. The dynamics of the stream were poorly understood, although recent theoretical modelling has improved our comprehension. The shower's parent, Comet 7P/Pons-Winnecke, has an orbit that now lies around 0.24 astronomical units outside the Earth's at its closest approach. Its most recent perihelion passage was in 2008 September. Clearly, the 1998 and 2004 returns resulted from material shed by the comet in the past which now lies on slightly different orbits to the comet itself. Dust trails laid down at various perihelion returns during the 19th century seem to have been responsible for the last two main outbursts. No predictions for activity are in-force for 2011, but conditions for checking are very favourable from the mid-northern latitudes where the radiant is best-seen (indeed it is usefully-observable almost all night from here), with only a waning crescent Moon on June 27. The prolonged – in some places continuous – twilight will cause difficulties, however. VID has suggested some June Boötids may be visible in most years around June 20–25, but with activity largely negligible except near $\lambda_\odot = 92°$ (2011 June 24), radiating from an area about ten degrees south of the visual one found in 1998 and 2004, close to $\alpha = 216°$, $\delta = +38°$.

5 July to September

The ANT is the chief focus for visual attention during most of July, as its radiant area moves steadily through eastern Sagittarius, then across northern Capricornus into south-west Aquarius. Results suggest the Source may not be especially recognisable after the first few days however, as ZHRs for most of the month seem < 2, and for a time in mid-month even < 1! Activity appears to improve somewhat, with ZHRs $\sim$ 2 to 3, by late July and through the first half of August. The large ANT radiant area now overlaps that of the minor α–Capricornids in July-August, but the δ–Aquariids are strong enough, and the Piscis Austrinids have a radiant probably distant enough from the ANT area, that both should still be separable from it, particularly from the southern hemisphere.



By the best from the major, hopelessly moonlit, Perseids (whose maximum is due sometime between $\sim 01^h$–13^h30^m UT on August 13, perhaps highest near 06^h UT) and the almost equally moonlit κ–Cygnid peak (probably around August 18, though VID suggested a maximum nearer August 14, and showed there was some uncertainty in the radiant position), ANT ZHRs will likely have dropped back below 2 again, as the radiant tracks on through Aquarius, and into western Pisces by the end of August.

The September-October near-Auriga sources have been re-examined again since the 2010 Shower Calendar was published, and more changes have been suggested here for them, with alterations in radiant positions, maxima and active dates. The former September Perseids have not been detected by VID at all, but the September ϵ–Perseids and the δ-Aurigids (for a shorter period) apparently were, so we now list a "new" SPE and the DAU. Further changes have been made to the Taurids, as the Southern Taurids were detected in early September according to VID, but the Northern Taurids were not found similarly until late October. Consequently, their parameters have been changed, as has also that for the ANT, which the Taurids are now considered to replace from September 10 into early December. In the first ten days of September, ANT rates continue from their radiant in Pisces, albeit with ZHRs probably no better than 2–3.

ε–Eridanids: Scarcely nothing is known of this possible minor shower. It has been suggested as associated with Comet C/1854 L1 Klinkerfues. The IMO's Visual Meteor Database includes what little information is suspected about it, that its activity is most likely from about September 9–12, with a maximum around September 10 from a radiant at $\alpha = 57°$, $\delta = -12°$. No atmospheric velocity is known for the meteors. In 2011, Jérémie Vaubaillon has indicated the Earth may encounter the 1600 AD dust trail from Comet Klinkerfues, which could produce ZHRs of ~ 40 around $19^{\mathrm{h}}34^{\mathrm{m}}$ UT on September 12. The age of the trail, not to mention the uncertain reality of the shower, means this is extremely uncertain, but observers need to be alert to the possibility. As this proposed encounter date is at the end of the previously-suggested activity period, it may be ε–Eridanid meteors could occur beyond September 12 this year. The radiant can be observed from both hemispheres, but is more favourable from south of the equator. For mid-northern sites, it rises around local midnight, attaining a useful elevation by $\sim 02^{\mathrm{h}}$. From mid-southern latitudes, the radiant rises around 22^{h} and can be viably observed from midnight onwards. This assumes the theoretical radiant location is correct, of course! Unhappily, full Moon falls on September 12, thus visual work will be extremely difficult. If the shower is as strong as predicted though, video and radio systems may be able to detect it, and if the timing proves accurate, central Indian Ocean locations eastwards across the western half of Australia (or equivalent longitudes) would be better-placed to cover anything that happens. The shower should not be confused with other potential Eridanid minor sources, particularly the ε–Eridanids discovered in analyses of minor shower data during the 1960s by Russian analyst Alexandra Terentjeva, which was suggested as active from about November 6–28.

For **daylight radio observers**, the interest of May-June has waned, but there remain the visually-impossible γ–Leonids (peak due near August 25, 22^{h} UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids. Their maximum is expected on September 27, around 22^{h} UT, but possibly it may occur a day earlier. In 1999 a strong return was detected at $\lambda_{\odot} \sim 186°$, equivalent to 2011 September 29, while in 2002, the September 27 peak was not found, but one around September 29–30 was! It seems plausible that several minor maxima in early October may also be due to this radio shower. New Moon creates near-ideal conditions for visual observers hoping to catch some Sextantids in the pre-dawn of late September, though radiant-rise is less than an hour before sunrise in either hemisphere.

Piscis Austrinids (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; $r = 3.2$;
TFC: $\alpha = 255°$ to $0°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 30°$ N).

Very little information has been collected on the Piscis Austrinids in recent decades, so the details on the shower are not well-confirmed, and it seems possible the ZHR may be a little optimistic. However, that impression may be due simply to the large amount of northern hemisphere summer data, and the almost complete lack of southern hemisphere winter results, on it. The shower seems to be rich in faint meteors, rather like the nearby ANT and SDA, so telescopic work is advisable to try to establish more about it. July's second New Moon on the 30th means perfect viewing circumstances for all three southern-sky showers maxima this month.

δ–Aquariids (SDA)

Active: July 12–August 23; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 16;
Radiant: $\alpha = 339°$, $\delta = -16°$; Radiant drift: see Table 6;
$V_\infty = 41$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to $°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 40°$ N).

Like the PAU and ANT, SDA meteors are often faint, thus are suitable targets for telescopic observing, although enough brighter members exist to make visual and imaging observations worth the effort too, primarily from more southerly sites. Radio work can pick up the SDA as well, and indeed the shower has sometimes given a surprisingly strong radio signature. Careful visual plotting is advised, to help with accurate shower association. The SDA/PAU/ANT/CAP radiants are well above the horizon for much of the night, and the SDA enjoys identical dark-sky conditions in the second half of the nights near its maximum to the PAU. Its peak may not be quite so sharp as the single date here might imply, with perhaps similar ZHRs from July 28–30. Its rates have been suspected of some variability at times too, though not in the more recent investigations.

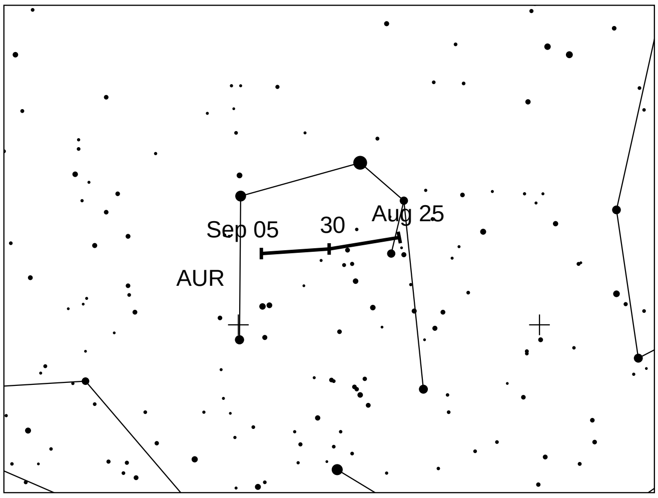
α–Capricornids (CAP)

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; $r = 2.5$;
TFC: $\alpha = 255°$ to $0°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 40°$ N);
IFC: $\alpha = 300°$, $\delta = +10°$ ($\beta > 45°$ N), $\alpha = 320°$, $\delta = -5°$ (β 0° to 45° N), $\alpha = 300°$, $\delta = -25°$ ($\beta < 0°$).

The CAP and SDA were both definitely detected visually in former years, standing out against the much weaker other radiants supposed active in Capricornus-Aquarius then. Whether the CAP can still be detected as visually separate from the new ANT radiant area is unclear, as its radiant now partly overlaps that of the large ANT region. Observers failed to find a clear maximum for the shower in 2009, which does not augur well, though it had been hoped their bright, at times fireball-class brilliance, combined with their low apparent velocities, might make them distinctive enough to still be detected by means other than video. A minor enhancement of CAP ZHRs to ~ 10 was noted in 1995 by European IMO observers. Recent results suggest the maximum may continue into July 31.

α–Aurigids (AUR)

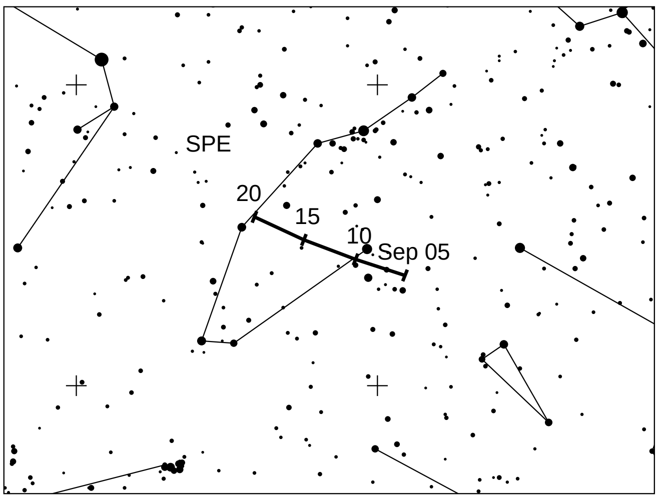
Active: August 28–September 5; Maximum: September 1, 13^{h} UT ($\lambda_\odot = 158.^{\circ}6$); ZHR = 6;
Radiant: $\alpha = 91°$, $\delta = +39°$; Radiant drift: see Table 6;
$V_\infty = 66$ km/s; $r = 2.6$;
TFC: $\alpha = 52°$, $\delta = +60°$; $\alpha = 43°$, $\delta = +39°$ and $\alpha = 23°$, $\delta = +41°$ ($\beta > 10°$ S).



The shower's active dates have been changed to be more in-line with the VID findings, and the radiant position adjusted too. In the past, the shower has produced short, unexpected, outbursts at times, with EZHRs of ∼ 30–40 recorded in 1935, 1986 and 1994, although they have not been monitored regularly until very recently, so other events may have been missed. Only three watchers in total covered the 1986 and 1994 outbursts, for instance! While badly moonlit, the first predicted outburst happened roughly as expected in 2007, producing short-lived EZHRs of ∼ 130 for western North America, with many bright meteors. Radio data suggested there was a 'tail' to that event where more faint meteors continued for maybe an hour after the strongest peak, but visual observers could not confirm this, probably due to the moonlit sky. The newly-revised AUR radiant reaches a useful elevation only after ∼ 01^{h} local time, and although no predictions for unusual activity have been made for 2011, the nearly-new Moon provides ideal skies for whatever may happen.

September ε–Perseids (SPE)

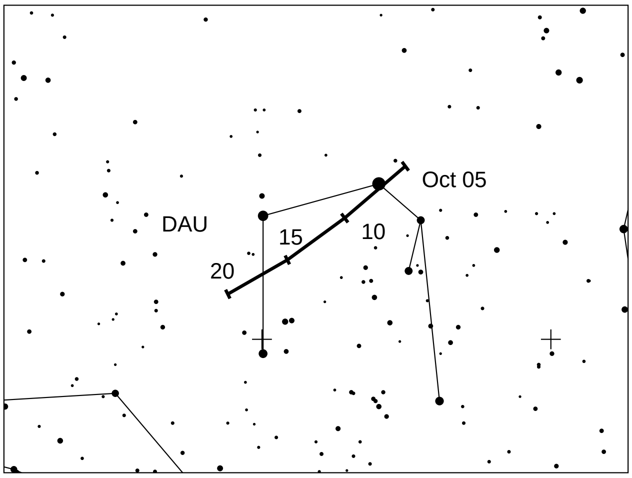
Active: September 5–21; Maximum: September 9, 22^{h} UT ($\lambda_\odot = 166.^{\circ}7$); ZHR = 5;
Radiant: $\alpha = 48°$, $\delta = +40°$; Radiant drift: see Table 6;
$V_\infty = 64$ km/s; $r = 3.0$;
TFC: $\alpha = 30°$, $\delta = +55°$; $\alpha = 28°$, $\delta = +35°$ and $\alpha = 25°$, $\delta = +40°$ ($\beta > 10°$ S).



The radiant listed in the previous calendar could not be located by VID at all. Instead, what seems to be the formerly-little-known September ε–Perseid minor shower, or a radiant close to its expected position, was detected. This radiant was apparently that responsible for producing an unexpected outburst of swift, bright meteors on 2008 September 9 (from a radiant centred somewhere between $\alpha = 47.^{\circ}5$ to $49°$, $\delta = +38°$ to $+43°$). Consequently, the September Perseids have been dropped from the Working List, now replaced by the September ε–Perseids, with adjusted activity dates and radiant position. The maximum timing was detected from the recent video analysis and was virtually coincident with the 2008 bright-meteor outburst. The waxing gibbous Moon, though just three days from full on September 9, will set for mid-northern sites in time to leave several hours of dark skies for watching still, as the radiant area remains well on-view all night from about 22^h–23^h local time onwards.

δ–Aurigids (DAU)

Active: October 10–October 18; Maximum: October 11 ($\lambda_\odot = 198°$); ZHR = 2;
Radiant: $\alpha = 84°$, $\delta = +44°$; Radiant drift: see Table 6;
$V_\infty = 64$ km/s; $r = 2.9$;
TFC: $\alpha = 70°$, $\delta = +55°$; $\alpha = 70°$, $\delta = +30°$ and $\alpha = 60°$, $\delta = +40°$ ($\beta > 10°$ S).

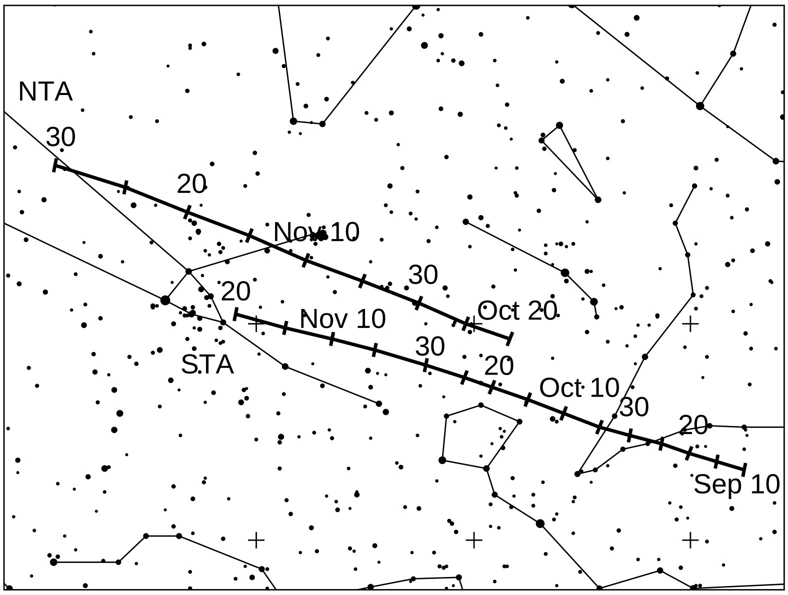


Neither HMO nor VID were able to confirm the previously-suspected parameters for this minor source, so the parameters have been completely revised based on what 'δ–Aurigid' activity VID was able to find, as amended by a more thorough examination of this in recent months. This fresh information is given above, with significant changes to the active dates (shorter period in particular), maximum and radiant position. The 2011 October 11 peak will be strongly affected by bright moonlight, but we give the updated information for completeness here.

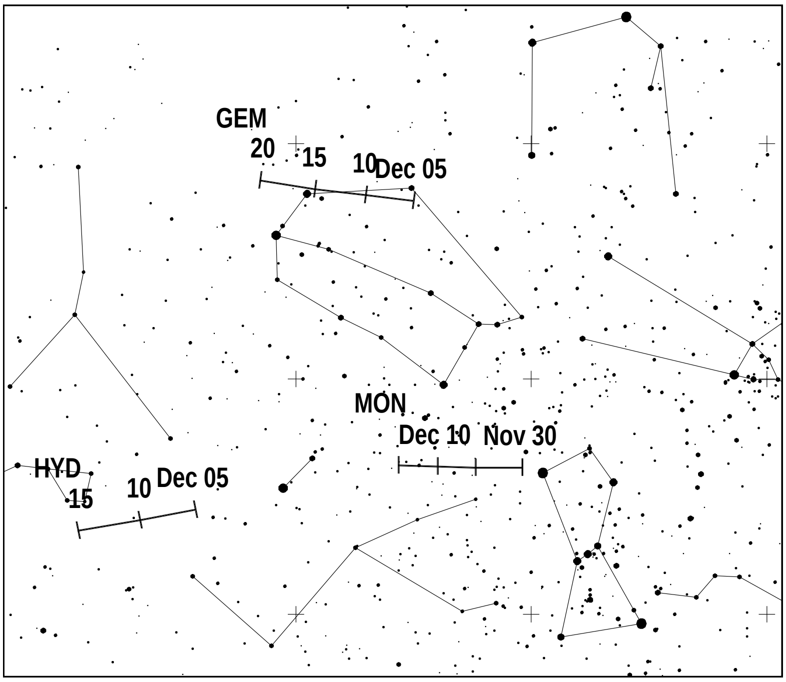
6 October to December

A fairly poor final quarter concludes the year, with the more active or interesting showers having moonlight problems to a greater or lesser extent, leaving dark skies only for some of the lesser sources. In October, the Draconids peak near full Moon, but may produce an outburst this year, so are discussed below. The minor Southern Taurid peak is now thought on VID evidence to happen around October 10 (previous long-standing visual findings suggested November 5), but it will be very badly moonlit, as also the minor ε–Geminids (peak on October 18). The major Orionids should reach maximum on October 21, with a last quarter Moon that may be more of a nuisance than a true deterrent to observers. Their rates are not expected to continue the enhancements seen from 2006–2009 inclusive, but that is not a guarantee! The minor Leonis Minorids are the only really Moon-free shower peak in the month.

October 5/6 meteors: Short-lived video outbursts were recorded in 2005 and 2006 by European observers, with activity from a north-circumpolar radiant near the 'tail' of Draco, around $\alpha \sim 165°$, $\delta \sim +78°$, on October 5/6. The meteors showed an atmospheric velocity of ∼ 45–50 km/s. The 2005 event (only) was recorded very weakly by radio, but no visual results confirmed either occurrence, and no recurrence was reported in 2007 or 2008. Weak video rates were claimed detected near the 2009 repeat time, but again, no other method confirmed these, and the shower was not found by the full ten-year VID analysis. The active interval suggested by video data lies between $\lambda_\odot \sim 192.°5$–$192.°8$, equivalent to 2011 October 6, 06^h30^m–13^h50^m UT, a date with a waxing gibbous Moon that will set between midnight and 1 a.m. local time for most mid-northern sites. If the active interval remains the same this time, it would be best-observed post-moonset, likely by video only, across North America, the northern Pacific Ocean and the extreme Far East of Asia.



November sees the Northern Taurid peak, probably still to be found near November 12, too close to full Moon for observations this year. The Leonids then have a last quarter Moon to contend with, but might produce unusual activity, possibly on more than one date, so are discussed below. The Moon will be a waning crescent by the α–Monocerotid peak, around 04^{h} UT on November 22, but with no strong outburst expected from them, unless something unanticipated chances-by, their usual low annual activity may well pass virtually unseen in the nuisance-value moonlight.



Some of the early December minor showers survive the waxing Moon, but the minor Monocerotids (peak around December 9), σ–Hydrids (December 12) and major Geminids (December 14, probably between 01^{h}–22^{h} UT) do not. The December Leonis Minorids and Comae Berenicids (both with maxima on December 20) have a waning crescent Moon, again liable to be a particular nuisance because of their expected weak activity, best-visible for northern hemisphere sites only later in the night, but the Ursids end the year on a more positively Moon-free note. The ANT starts the quarter 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, although some of this apparent inactivity may be due to the strength of the Geminids very close-by to the north during part of December, plus the minor Monocerotids a little way to its south simultaneously.

Draconids (DRA)

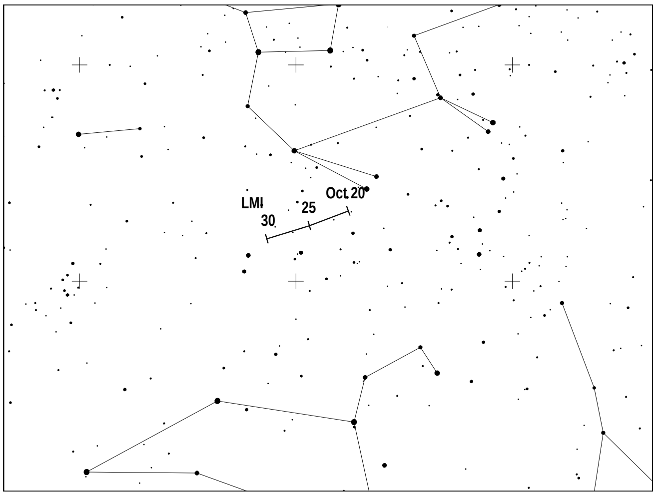
Active: October 6–10; Maximum: October 8, various potential timings - see below;
ZHR = periodic, up to storm levels;
Radiant: $\alpha = 262°$, $\delta = +54°$; Radiant drift: negligible;
$V_\infty = 20$ km/s; $r = 2.6$;
TFC: $\alpha = 290°$, $\delta = +65°$ and $\alpha = 288°$, $\delta = +39°$ ($\beta > 30°$ N).

The Draconids are primarily a periodic shower which produced spectacular, brief, meteor storms twice last century, in 1933 and 1946, and lower rates in several other years (ZHRs $\sim$ 20–500+). Most detected showers were in years when the stream's parent comet, 21P/Giacobini-Zinner, returned to perihelion, as it did last in 2005 July. Since its orbital period is currently about 6.6 years, it should return next in 2012 February. In 2005 October, a largely unexpected outburst happened near the comet's nodal crossing time, around $\lambda_\odot = 195\overset{\circ}{.}40$–$195\overset{\circ}{.}44$, probably due to material shed in 1946. Visual ZHRs were ~ 35, though radar detections suggested a much higher estimated rate, closer to ~ 150. The peak was found in radio results too, but it did not record especially strongly that way. Outlying maximum times from the recent past have spanned from $\lambda_\odot = 195\overset{\circ}{.}075$ (in 1998; EZHRs ~ 700), equivalent to 2011 October 8, 21^h10^m UT, through the nodal passage time ($\lambda_\odot = 195\overset{\circ}{.}4$, October 9, 05^h UT), to $\lambda_\odot 195\overset{\circ}{.}63$–$195\overset{\circ}{.}76$ (a minor outburst in 1999, not a perihelion-return year; ZHRs $\sim$ 10–20), equating to 2011 October 9, 10^h40^m to 13^h50^m UT. However, of greater note are predictions suggesting that a number of dust trails laid down between 1873 and 1907 may be encountered this year, in some cases quite closely, by the Earth on October 8 between $\sim 16^h15^m$–20^h10^m UT. These were first proposed by Japanese analyst Mikiya Sato, who indicated too the activity might be quite strong and possibly persistent for some time during this interval, particularly after 17^h. Russian theoretician Mikhail Maslov has proposed a single peak of not very bright meteors may occur at 20^h42^m UT, again on October 8. Of perhaps greatest interest is the still on-going work by Jérémie Vaubaillon, Juinichi Watanabe and Mikiya Sato, which was not completed at the time the Calendar was written, but had shown ZHRs might reach ~ 200 near 19^h56^m UT on October 8. The strength and timing of the activity is heavily dependent on assumptions regarding the comet's orbit, so caution is advisable, but there is a general consensus that the evening UT hours of October 8 should produce whatever activity the Draconids are likely to in 2011, sometime between $\sim 16^h$–21^h. Further predictions and refinements should follow nearer the event.

The Draconid radiant is circumpolar from many northern hemisphere locations, but is highest during the first half of the night in early October. As noted already, full Moon on October 12 makes this a difficult year to observe the shower, but the predicted possibly good activity needs to be checked-for regardless of this. Consequently, observers must just make the best of things, and observe facing away from the Moon, but not too close to the Draconid radiant, hoping for high rates of meteors that are not too faint to be hidden in the bright sky! European, west to central Atlantic Ocean, longitudes would be most-favoured by the better radiant elevations nearest the main peak times, but anywhere in the northern hemisphere with clear night skies could see something of whatever happens. Draconid meteors are exceptionally slow-moving, a characteristic which helps separate genuine shower members from sporadics accidentally lining up with the radiant.

Leonis Minorids (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; $r = 3.0$;
TFC: $\alpha = 190°$, $\delta = +58°$ and $\alpha = 135°$, $\delta = +30°$ ($\beta > 40°$ N).



This weak minor shower has a peak ZHR apparently on or below the visual threshold, found so far by video only. The radiant area can be seen solely from the northern hemisphere, where it rises around midnight. The probable maximum date has scarcely any Moon, just two days from new, so conditions are about as perfect as possible to confirm whether the shower can be usefully detected visually. Telescopic, imaging or very careful visual plotting observations are advised.

Leonids (LEO)

Active: November 6–30; Maximum: November 18, 03^h40^m UT (nodal crossing at $\lambda_\odot = 235\overset{\circ}{.}27$), but see below; ZHR = 20+?;
Radiant: $\alpha = 152g$, $\delta = +22°$; Radiant drift: see Table 6;
$V_\infty = 71$ km/s; $r = 2.5$;
TFC: $\alpha = 140°$, $\delta = +35°$ and $\alpha = 129°$, $\delta = +06°$($\beta > 35°$ N);
or $\alpha = 156°$, $\delta = -3°$ and $\alpha = 129°$, $\delta = +6°$($\beta < 35°$ N).
IFC: $\alpha = 120°$, $\delta = +40°$ before 0^h local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = +20°$ before 4^h local time and $\alpha = 160°$, $\delta = 0°$ after 4^h local time ($\beta > 0°$ N);
$\alpha = 120°$, $\delta = +10°$ before 0^h local time and $\alpha = 160°$, $\delta = -10°$($\beta < 0°$ N).

The most recent perihelion passage of the Leonids' parent comet, 55P/Tempel-Tuttle, in 1998 may be more than a decade ago now, but the shower's activity has continued to be fascinatingly variable from year to year recently. This year might produce enhanced rates (though these may be observable using only particularly sensitive radio and radar systems), and theoretical work has suggested there may be several peaks. Jérémie Vaubaillon has indicated part of the 1800 AD dust trail may be encountered around 22^h36^m UT on November 16, and could produce ZHRs of ~ 200. Unfortunately, the dust particles involved are expected to be exceptionally small, of order 10–100 microns, and this could mean no optically-detectable meteors at all. This activity may be observable instead as an increase in underdense radio meteor echoes, by those systems capable of recording the equivalent of such 'invisibly-faint' meteors, and by sensitive radar meteor systems. Mikhail Maslov has proposed that there may be two peaks, one on November 17, around 21^h UT, when ZHRs may be $\sim$ 5–10 above the underlying 'normal' activity, the second on November 18 near 23^h UT, with ZHRs of ~ 10 above normal. Taking the typical ZHR to be $\sim$ 10–15 could suggest ZHRs at either might be $\sim 20 \pm 5$. The second peak he noted may produce somewhat fainter than average meteors, however. Another potential maximum time is that given above for the nodal crossing, when ZHRs are liable to be simply 'normal'.

Whatever the case, the Moon is bright and waning from full on all three dates, with last quarter on November 18. Thus it will be on-view throughout the time the Leonid radiant is usefully-observable, from about local midnight onwards (or indeed afterwards south of the equator). This will make even the typical activity difficult enough to see, but if there are any faint to very faint meteor maxima as well, these could pass entirely unobserved by optical or imaging methods. The November 16, and November 18 $\sim 23^{\mathrm{h}}$, peak timings would be best-detectable for sites at eastern European longitudes eastwards across most of central Asia. That on November 17 would be similarly available from places with longitudes equivalent to the Near East east to eastern Asia, while the $\sim 04^{\mathrm{h}}$ peak on November 18 would be ideal for European longitudes. Note that other possible maxima are not excluded by these expectations! All observing techniques can be usefully employed, avoiding facing the Moon for optical and imaging work, naturally. VID has indicated weak Leonid activity might be detected for a much longer interval than had been previously suspected, and though this remains unconfirmed visually, the active dates for the shower have been expanded accordingly this year.

Phoenicids (PHO)

Active: November 28–December 9; Maximum: December 6, $21^{\mathrm{h}}40^{\mathrm{m}}$ UT ($\lambda_{\odot} = 254\overset{\circ}{.}25$), but see below;
ZHR = variable, usually none, but may reach 100;
Radiant: $\alpha = 18°$, $\delta = -53°$; Radiant drift: see Table 6;
$V_{\infty} = 18$ km/s; $r = 2.8$;
TFC: $\alpha = 040°$, $\delta = -39°$ and $\alpha = 065°$, $\delta = -62°$($\beta < 10°$ N).

Only one impressive Phoenicid return has been reported so far, that of its discovery in 1956, when the EZHR was probably ~ 100, possibly with several peaks spread over a few hours. Three other potential bursts of lower activity have been reported, but never by more than one observer, under uncertain circumstances. Reliable IMO data has shown recent activity to have been virtually nonexistent. This may be a periodic shower however, and more observations of it are needed by all methods. From the southern hemisphere (only), the Phoenicid radiant culminates at dusk, remaining well on view for most of the night. The waxing gibbous Moon sets to leave several pre-dawn hours with dark skies available for observers around December 6. Jérémie Vaubaillon has indicated there is the possibility of a Phoenicid return in 2011, from a dust trail left in 1870. The activity could be so low as to be undetectable regrettably, but it would be worthwhile checking-for just in case. He suggested this might happen around $09^{\mathrm{h}}30^{\mathrm{m}}$ UT on December 1, from a radiant rather different to the 'usual' one, perhaps near $\alpha = 6°$, $\delta = -25°$. Note that this position is quite uncertain, and actually lies on the border between Sculptor and Cetus, around 8° southwest of the star β Ceti, which could make any activity detectable from places further north than is normally possible. December 1 also has a more favourable waxing crescent Moon, and that peak's timing, if correct, would favour sites across the southern Pacific Ocean from New Zealand east to South America especially.

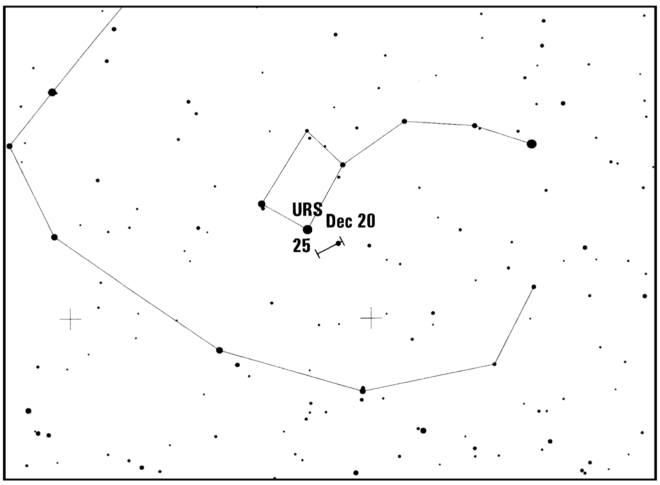
Puppid-Velids (PUP)

Active: December 1–15; Maximum: December ~ 7($\lambda_{\odot} \sim 255°$); ZHR ~ 10;
Radiant: $\alpha = 123°$, $\delta = -45°$; Radiant drift: see Table 6;
$V_{\infty} = 40$ km/s; $r = 2.9$;
TFC: $\alpha = 90°$ to $150°$, $\delta = -20°$ to $-60°$; choose pairs of fields separated by about 30° in α, moving eastwards as the shower progresses ($\beta < 10°$ N).

This is a very complex system of poorly-studied showers, visible chiefly to those south of the equator. Up to ten sub-streams have been identified, with radiants so tightly clustered, visual observing cannot readily separate them. Imaging or telescopic work would thus be sensible, or very careful visual plotting. The activity is so badly-known, we can only be reasonably sure that the higher rates occur in early to mid December, with a waxing gibbous Moon this year. Some of these showers may be visible from late October to late January, however. Most Puppid-Velid meteors are quite faint, but occasional bright fireballs, notably around the suggested maximum here, have been reported previously. The radiant area is on-view all night, but is highest towards dawn.

Ursids (URS)

Active: December 17–26; Maximum: December 23, 02^{h} UT ($\lambda_\odot = 270^\circ\!.7$), but see below;
ZHR = 10 (occasionally variable up to 50);
Radiant: $\alpha = 217^\circ$, $\delta = +76^\circ$; Radiant drift: see Table 6;
$V_\infty = 33$ km/s; $r = 3.0$;
TFC: $\alpha = 348^\circ$, $\delta = +75^\circ$ and $\alpha = 131^\circ$, $\delta = +66^\circ$ ($\beta > 40^\circ$ N); $\alpha = 063^\circ$, $\delta = +84^\circ$ and $\alpha = 156^\circ$, $\delta = +64^\circ$ (β 30° to 40° N).



A very poorly-observed northern hemisphere shower, but one which has produced at least two major outbursts in the past 70 years, in 1945 and 1986. Several other rate enhancements have been reported as well, recently in 1988, 1994, 2000, 2006, 2007 and 2008 (which latter apparently produced at least two peaks with EZHRs of ~ 30–35, and activity around half this level or better for perhaps nine to ten hours). Other similar events could have been missed easily due to poor weather or too few observers active.
All forms of observation can be used for the shower, since many of its meteors are faint, but with so little work carried out on the stream, it is impossible to be precise in making statements about it. The radio maximum in 1996 occurred around $\lambda_\odot = 270^\circ\!.8$, for instance, which might suggest a slightly later maximum time in 2011 of December 23, $\sim 04^{\text{h}}$ UT. Models developed by Esko Lyytinen and Jérémie Vaubaillon have suggested the relative proximity of the shower's parent comet, 8P/Tuttle, last at perihelion in January 2008, seems to have been what has influenced some of the recent events. Jérémie's model has further indicated there could be another peak this year, around $16^{\text{h}}11^{\text{m}}$ UT on December 22, with fairly typical ZHRs of ~ 12. VID indicated a maximum around $\lambda_\odot = 270^\circ\!.5$, equal to December 22, $\sim 21^{\text{h}}$ UT. The Ursid radiant is circumpolar from most northern sites (thus fails to rise for most southern ones), though it culminates after daybreak, and is highest in the sky later in the night. New Moon on December 24 means observing conditions are perfect for checking whatever takes place. The $\sim 16^{\text{h}}$ timing would be available overnight to observers from eastern European longitudes east across all of Asia; the $\sim 21^{\text{h}}$ peak would be good for European sites east across most of Asia; and the 02^{h}–04^{h} peaks would fall best for places from North America east across Europe.

7 Radiant sizes and meteor plotting for visual observers

by Rainer Arlt

If you are not observing during a major-shower maximum, it is essential to associate meteors with their radiants correctly, since the total number of meteors will be small for each source. Meteor plotting allows shower association by more objective criteria after your observation than the simple imaginary back-prolongation of paths under the sky. With meteors plotted on gnomonic maps, you can trace them back to their radiants by extending their straight line paths. If a radiant lies on another chart, you should find common stars on an adjacent chart to extend this back-prolongation correctly.

How large a radiant should be assumed for shower association? The real physical radiant size is very small, but visual plotting errors cause many true shower meteors to miss this real radiant area. Thus we have to assume a larger effective radiant to allow for these errors. Unfortunately, as we enlarge the radiant, so more and more sporadic meteors will appear to line up accidentally with this region. Hence we have to apply an optimum radiant diameter to compensate for the plotting errors loss, but which will not then be swamped by sporadic meteor pollution. Table 1 gives this optimum diameter as a function of the distance of the meteor from the radiant.

Table 1. Optimum radiant diameters to be assumed for shower association of minor-shower meteors as a function of the radiant distance D of the meteor.

D	optimum diameter
15°	14°
30°	17°
50°	20°
70°	23°

Note that this radiant diameter criterion applies to all shower radiants *except* those of the Southern and Northern Taurids, and the Antihelion Source, all of which have notably larger radiant areas. The optimum $\alpha \times \delta$ size to be assumed for each radiant of the two Taurid showers is instead $20° \times 10°$, while that for the Antihelion Source is still larger, at $30° \times 15°$.

Path-direction is not the only criterion for shower association. The angular velocity of the meteor should match the expected speed of the given shower meteors according to their geocentric velocities. Angular velocity estimates should be made in degrees per second (°/s). To do this, make the meteors you see move for one second in your imagination at the speed you saw them. The path length of this imaginary meteor is the angular velocity in °/s. Note that typical speeds are in the range 3°/s to 25°/s. Typical errors for such estimates are given in Table 2.

Table 2. Error limits for the angular velocity

angular velocity [°/s]	5	10	15	20	30
permitted error [°/s]	3	5	6	7	8

If you find a meteor in your plots which passes the radiant within the diameter given by Table 1, check its angular velocity. Table 3 gives the angular speeds for a few geocentric velocities, which can then be looked up in Table 5 for each shower.

Table 3. Angular velocities as a function of the radiant distance of the meteor (D) and the elevation of the meteor above the horizon (h) for three different geocentric velocities (V_∞). All velocities are in °/s.

$h \backslash D$	$V_\infty = 25$ km/s					$V_\infty = 40$ km/s					$V_\infty = 60$ km/ s				
	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 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 is brighter than average, while r above 3.0 is fainter 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_∞: 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 with the shower radiant overhead. This figure is given in terms of meteors per hour. Where meteor activity persisted at a high level for less than an hour, or where observing circumstances were very poor, an estimated ZHR (EZHR) is used, which is less accurate than the normal ZHR.
- TFC and IFC: Suggested telescopic and still-imaging (including photographic) field centres respectively. β is the observer's latitude ('$<$' means 'south of' and '$>$' means 'north of'). *Pairs* of telescopic fields must be observed, alternating about every half hour, so that the positions of radiants can be defined. The exact choice of TFC or IFC depends on the observer's location and the elevation of the radiant. Note that the TFCs are also useful centres to use for video camera fields as well.

Table 4. Lunar phases for 2011.

New Moon	First Quarter	Full Moon	Last Quarter
January 4	January 12	January 19	January 26
February 3	February 11	February 18	February 24
March 4	March 12	March 19	March 26
April 3	April 11	April 18	April 25
May 3	May 10	May 17	May 24
June 1	June 9	June 15	June 23
July 1	July 8	July 15	July 23
July 30	August 6	August 13	August 21
August 29	September 4	September 12	September 20
September 27	October 4	October 12	October 20
October 26	November 2	November 10	November 18
November 25	December 2	December 10	December 18
December 24			

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in May 2010, with maximum dates accurate only for 2011. Except for the Antihelion Source, all other showers are listed in order of their maximum solar longitude. An asterisk (‘*’) in the ‘Shower’ column indicates that source may have additional peak times, as noted in the text above. 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. These are either are noted as ‘Var’ = variable, where there is considerable uncertainty over the likely maximum rates, or with an asterisk to indicate the value is that suggested from theoretical considerations for the current year. For more information, contact the IMO’s Visual Commission.

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 (QUA)	Dec 28–Jan 12	Jan 04	283°.16	230°	+49°	41	2.1	120
α-Centaurids (ACE)	Jan 28–Feb 21	Feb 08	319°.2	210°	−59°	56	2.0	6
γ-Normids (GNO)	Feb 25–Mar 22	Mar 15	354°	239°	−50°	56	2.4	6
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	32°.32	271°	+34°	49	2.1	18
π-Puppids (PPU)	Apr 15–Apr 28	Apr 24	33°.5	110°	−45°	18	2.0	Var
η-Aquariids (ETA)	Apr 19–May 28	May 06	45°.5	338°	−01°	66	2.4	70*
η-Lyrids (ELY)	May 03–May 14	May 09	48°.0	287°	+44°	43	3.0	3
June Bootids (JBO)	Jun 22–Jul 02	Jun 27	95°.7	224°	+48°	18	2.2	Var
Piscis Austrinids (PAU)	Jul 15–Aug 10	Jul 28	125°	341°	−30°	35	3.2	5
South. δ-Aquariids (SDA)	Jul 12–Aug 23	Jul 30	127°	340°	−16°	41	3.2	16
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	5
Perseids (PER)*	Jul 17–Aug 24	Aug 13	140°.0	48°	+58°	59	2.2	100
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 18	145°	286°	+59°	25	3.0	3
α-Aurigids (AUR)	Aug 28–Sep 10	Sep 01	158°.6	93°	+39°	67	2.5	6
Sept. ε-Perseids (SPE)	Sep 05–Sep 21	Sep 10	166°.7	48°	+40°	66	3.0	5
δ-Aurigids (DAU)	Oct 10–Oct 18	Oct 12	198°	84°	+44°	67	3.0	2
Draconids (DRA)	Oct 06–Oct 10	Oct 08	195°.4	262°	+54°	20	2.6	Var
Southern Taurids (STA)	Sep 10–Nov 20	Oct 10	197°	32°	+09°	27	2.3	5
ε-Geminids (EGE)	Oct 14–Oct 27	Oct 18	205°	102°	+27°	70	3.0	3
Orionids (ORI)	Oct 02–Nov 07	Oct 21	208°	95°	+16°	66	2.5	25*
Leonis Minorids (LMI)	Oct 19–Oct 27	Oct 24	211°	161°	+38°	62	3.0	2
Northern Taurids (NTA)	Oct 20–Dec 10	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (LEO)	Nov 06–Nov 30	Nov 18	235°.27	152°	+22°	71	2.5	20+*
α-Monocerotids (AMO)	Nov 15–Nov 25	Nov 22	239°.32	117°	+01°	65	2.4	Var
Phoenicids (PHO)	Nov 28–Dec 09	Dec 06	254°.25	18°	−53°	18	2.8	Var
Puppid/Velids (PUP)	Dec 01–Dec 15	(Dec 07)	(255°)	123°	−45°	40	2.9	10
Monocerotids (MON)	Nov 27–Dec 17	Dec 09	257°	100°	+08°	42	3.0	2
σ-Hydrids (HYD)	Dec 03–Dec 15	Dec 12	260°	127°	+02°	58	3.0	3
Geminids (GEM)	Dec 04–Dec 17	Dec 14	262°.2	112°	+33°	35	2.6	120
Dec. Leonis Minorids (DLM)	Dec 05–Feb 04	Dec 20	268°	161°	+30°	64	3.0	5
Comae Berenicids (COM)	Dec 12–Dec 23	Dec 16	264°	175°	+18°	65	3.0	3
Ursids (URS)	Dec 17–Dec 26	Dec 23	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°	232°	+49°	176°	+23°								
Jan 10	122°	+19°	234°	+48°	180°	+21°								
Jan 15	127°	+17°			185°	+19°								
Jan 20	132°	+16°			189°	+17°								
Jan 25	138°	+15°			193°	+15°	**ACE**							
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°												
Mar 30	202°	−9°												
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°					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°												
Jun 5	267°	−23°												
Jun 10	272°	−23°												
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**				289°	+60°		
Sep 5	355°	−1°	**STA**		96°	+39°	43°	+40°						
Sep 10	0°	+1°	12°	+3°	102°	+38°	48°	+40°						
Sep 15			15°	+4°			53°	+40°						
Sep 20			18°	+5°			59°	+41°						
Sep 25			21°	+6°										
Sep 30			25°	+7°			**ORI**							
Oct 5			28°	+8°			85°	+14°	**DAU**				**DRA**	
Oct 10	**EGE**		32°	+9°			88°	+15°	82°	+45°			262°	+54°
Oct 15	99°	+27°	36°	+11°	**NTA**		91°	+15°	87°	+43°	**LMI**			
Oct 20	104°	+27°	40°	+12°	38°	+18°	94°	+16°	92°	+41°	158°	+39°		
Oct 25	109°	+27°	43°	+13°	43°	+19°	98°	+16°			163°	+37°		
Oct 30			47°	+14°	47°	+20°	101°	+16°			168°	+35°		
Nov 5			52°	+15°	52°	+21°	105°	+17°	**LEO**					
Nov 10			56°	+15°	56°	+22°			147°	+24°			**AMO**	
Nov 15			60°	+16°	61°	+23°			150°	+23°			112°	+2°
Nov 20			64°	+16°	65°	+24°			153°	+21°			116°	+1°
Nov 25					70°	+24°	**PHO**		156°	+20°	**PUP**		120°	0°
Nov 30	**ANT**		**GEM**		74°	+24°	14°	−52°	159°	+19°	120°	−45°	91°	+8°
Dec 5	85°	+23°	103°	+33°	149°	+37°	18°	−53°	122°	+3°	122°	−45°	96°	+8°
Dec 10	90°	+23°	108°	+33°	153°	+35°	22°	−53°	126°	+2°	125°	−45°	100°	+8°
Dec 15	96°	+23°	113°	+33°	157°	+33°	174°	+19°	130°	+1°	128°	−45°	104°	+8°
Dec 20	101°	+23°	118°	+32°	161°	+31°	177°	+18°	**HYD**		217°	+76°	**MON**	
Dec 25	106°	+22°	**QUA**		166°	+28°	180°	+16°			217°	+74°		
Dec 30	111°	+21°	226°	+50°	170°	+26°	**COM**				**URS**			
					DLM									

Table 7. Working List of Daytime Radio Meteor Showers. An asterisk ('*') in the 'Max date' column indicates that source may have additional peak times, as noted in the text above. The 'Best Observed' columns give the approximate local mean times between which a four-element antenna at an elevation of 45° receiving a signal from a 30 kW transmitter 1000 km away should record at least 85% of any suitably positioned radio-reflecting meteor trails for the appropriate latitudes. Note that this is often heavily dependent on the compass direction in which the antenna is pointing, however, and applies only to dates near the shower's maximum. An asterisk in the 'Rate' column shows the suggested rate may not recur in all years.

Shower	Activity	Max Date	$\lambda_{\odot}$ 2000	Radiant α	Radiant δ	Best observed 50° N	Best observed 35° S	Rate
Cap/Sagittariids	Jan 13–Feb 04	Feb 01*	312.°5	299°	−15°	11^h–14^h	09^h–14^h	Medium*
χ-Capricornids	Jan 29–Feb 28	Feb 13*	324.°7	315°	−24°	10^h–13^h	08^h–15^h	Low*
Piscids (Apr)	Apr 08–Apr 29	Apr 20	30.°3	7°	+07°	07^h–14^h	08^h–13^h	Low
δ-Piscids	Apr 24–Apr 24	Apr 24	34.°2	11°	+12°	07^h–14^h	08^h–13^h	Low
ε-Arietids	Apr 24–May 27	May 09	48.°7	44°	+21°	08^h–15^h	10^h–14^h	Low
Arietids (May)	May 04–Jun 06	May 16	55.°5	37°	+18°	08^h–15^h	09^h–13^h	Low
o-Cetids	May 05–Jun 02	May 20	59.°3	28°	−04°	07^h–13^h	07^h–13^h	Medium*
Arietids	May 22–Jul 02	Jun 07*	76.°7	44°	+24°	06^h–14^h	08^h–12^h	High
ζ-Perseids	May 20–Jul 05	Jun 09*	78.°6	62°	+23°	07^h–15^h	09^h–13^h	High
β-Taurids	Jun 05–Jul 17	Jun 28	96.°7	86°	+19°	08^h–15^h	09^h–13^h	Medium
γ-Leonids	Aug 14–Sep 12	Aug 25	152.°2	155°	+20°	08^h–16^h	10^h–14^h	Low*
Sextantids	Sep 09–Oct 09	Sep 27*	184.°3	152°	00°	06^h–12^h	06^h–13^h	Medium*

9 Useful addresses

For more information on observing techniques, and when submitting results, please contact the appropriate IMO Commission Director:

Fireball Data Center (FIDAC): André Knöfel, Am Observatorium 2, D-15848 Lindenberg, Germany; e-mail: `aknoefel@minorplanets.de`

Photographic Commission: Vacant. Questions can be sent to e-mail: `photo@imo.net`

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

Telescopic Commission: Malcolm Currie, 25 Collett Way, Grove, Wantage, Oxfordshire, OX12 0NT, UK; e-mail: `mjc@star.rl.ac.uk`

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

Visual Commission: Rainer Arlt, Friedenstraße 5, D-14109 Berlin, Germany; e-mail: `rarlt@aip.de`

or contact IMO's Homepage on the World-Wide-Web at: `http://www.imo.net`

For further details on **IMO membership**, please write to: Robert Lunsford, IMO Secretary-General, 1828 Cobblecreek Street, Chula Vista, CA 91913-3917, USA; `lunro.imo.usa@cox.net`

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