International Meteor Organization

2010 Meteor Shower Calendar

compiled by Alastair McBeath[1]

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1 Introduction

Welcome to the twentieth International Meteor Organization (IMO) Meteor Shower Calendar, for 2010. Of the more active annual showers, only the Perseids, Leonids and Geminids are especially well-placed for observing as regards the Moon. Although it is one of numerous showers peaking unhelpfully close to full Moon, the irregular June Boötids may produce readily-detectable activity again this year too. There are always 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 suggesting weak showers that have apparently passed unnoticed by visual observers previously, 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 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

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[1]Based on information in *Handbook for Meteor Observers*, edited by Jürgen Rendtel and Rainer Arlt, IMO, 2008 (referred to as 'HMO' in the Calendar), and "How good is the IMO Working List of Meteor Showers?" by Sirko Molau, in *Proceedings of the IMC, Roden,* 2006, edited by Felix Bettonvil and Javor Kac, IMO, 2007, pp. 38–54 (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, David Asher, Jeff Brower and David Entwistle for helpful comments in respect of events in 2010.

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 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.

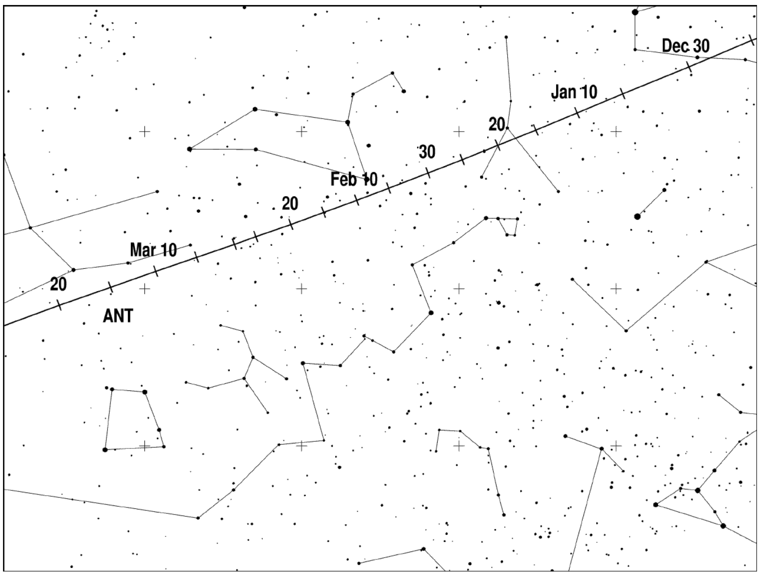
However and whenever you are able to observe, we wish you all a most successful year's work and very much look forward to receiving your data. Clear skies!

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 twin Taurid showers (STA and NTA) means the ANT should be considered inactive while the Taurids are underway, from late September to late November. 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 waning gibbous Moon ruins the northern-hemisphere Quadrantid maximum on January 3, due around 19^{h} UT, though a possible short-lived, quite strong, peak from the shower may happen instead sometime between roughly 12^{h} to 16^{h} UT on January 3 (see the diagram on HMO p. 129). Recent video data suggests too that the Quadrantids may be active, but only weakly, for longer than visual estimates have inferred, perhaps from approximately December 28 to January 12. The probable southern-hemisphere α-Centaurid peak is less moonlit, while mid-March brings a still-better minor γ-Normid return for similarly southern sites. 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 2010, much of which has only a waning 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, enjoys a waxing 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, 15^{h} UT; and χ-Capricornids - February 13, 16^{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.



α-Centaurids (ACE)

Active: January 28–February 21; Maximum: February 8, $05^{h}30^{m}$ 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, 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 will rise between about midnight and 1 a.m. local time around February 8, but will be just a waning crescent three days past last quarter, so should not be too great a distraction even late in the night.

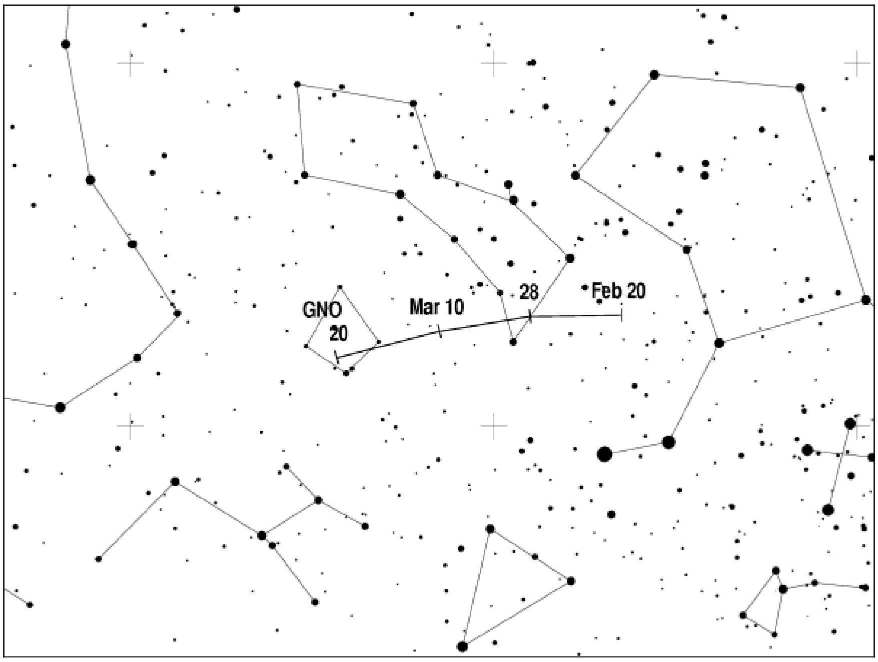
γ-Normids (GNO)

Active: February 25–March 22; Maximum: March 14 ($\lambda_\odot = 354°$); ZHR = 6;

Radiant: $\alpha = 239°$, $\delta = -50°$, Radiant drift: see Table 6;

$V_\infty = 56$ km/s; $r = 2.4$;

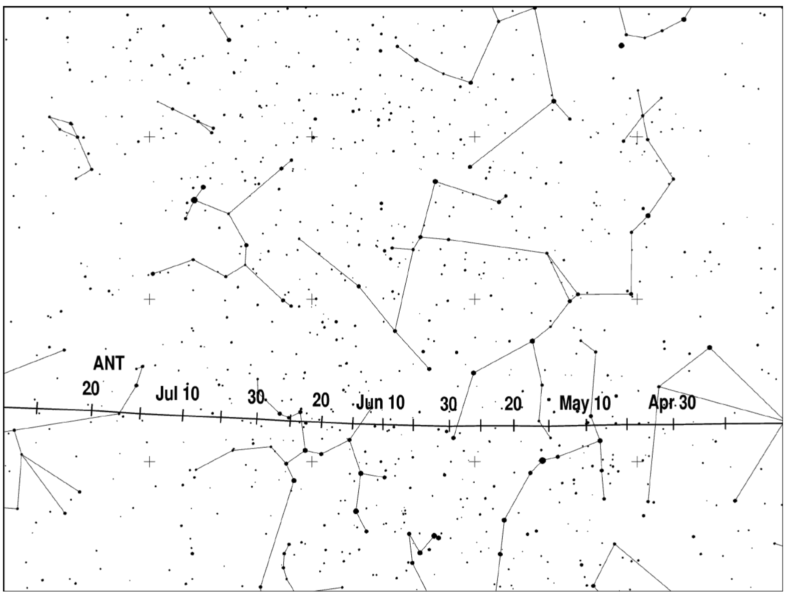
TFC: $\alpha = 225°$, $\delta = -26°$ and $\alpha = 215°$, $\delta = -45°$ ($\beta < 15°$ S).



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 of ~ 3 visible for four or five days before the maximum only. 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 2010 March 7–17, 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 observations, and March's waning Moon, new on March 15, means 2010 should be a good year to start - assuming a peak close to March 14. All observing techniques can be employed.

4 April to June

Meteor activity picks up towards the April-May boundary, though of the two shower maxima in late April, only the Lyrids have a short Moon-free observing window. The π-Puppids, maximum due around 22^h UT on April 23, are best-observed before local midnight from the southern hemisphere, a date which sees a waxing gibbous Moon visible till around 01^h from these locations. Even the η-Aquariids in early May have last quarter Moon to contend with for their broad peak, centred around May 6. That shower can be observed usefully only from equatorial and southern hemisphere sites for a few hours before dawn, while from there, the Moon then rises around local midnight. η-Aquariid activity could be near its highest on its theoretical 12-year cycle still in 2010, however, maybe with ZHRs up to ~ 85. The minor η-Lyrids at least are largely moonless. Later in May and throughout June, most of the meteor action switches to the daylight 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, 15^h; δ-Piscids - April 24, 15^h; ϵ-Arietids - May 9, 14^h; May Arietids - May 16, 15^h; o-Cetids - May 20, 14^h; Arietids - June 7, 17^h; ζ-Perseids - June 9, 17^h; β-Taurids - June 28, 16^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 favourable this year, and although moonlight circumstances are much poorer for possible June Boötid hunting, the shower is highlighted below because it may produce detectable activity again this year.

Lyrids (LYR)

Active: April 16–25; Maximum: April 22, 17^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; $r = 2.1$;

TFC: $\alpha = 262°$, $\delta = +16°$ and $\alpha = 282°$, $\delta = +19°(\beta > 10°$ S).

The $\lambda_\odot = 32\overset{\circ}{.}32$ timing given above is the 'ideal' maximum found in the most detailed examination of the Lyrids in modern times, published in 2001 by Audrius Dubietis and Rainer Arlt, drawing on *IMO* results from 1988–2000. However, the maximum time was found to be variable from year to year between $\lambda_\odot = 32\overset{\circ}{.}0$–$32\overset{\circ}{.}45$ (equivalent to 2010 April 22, 09^h15^m to 20^h20^m UT). Activity was discovered to be variable too. A peak at the ideal time produced the highest ZHRs, ~ 23, while the further the peak happened from this, the lower the ZHRs were, down to ~ 14. (The last very high maximum occurred outside the examined interval, in 1982 over the USA, when a short-lived ZHR of 90 was recorded.) The mean peak ZHR was 18 over the thirteen years examined. While generally thought of as having a short, quite sharp, maximum, this latest work revealed the shower's peak length was inconstant too. Using the interval that ZHRs were above half the maximum amount, the Full-Width-Half-Maximum time, a variation of from 14.8 hours (in 1993) to 61.7 hours (in 2000) was detected, with a mean value of 32.1 hours. The very best rates are normally achieved for just a few hours even so. One other aspect of the analysis confirmed data from earlier in the 20th century, that occasionally, as their highest rates occurred, the Lyrids produced a short-lived increase in fainter meteors. Overall, the unpredictability of the shower in any given year always makes the Lyrids worth watching, since we cannot say when the next unusual return may take place.

Lyrids are best viewed from the northern hemisphere, but they are visible from many sites north and south of the equator, and the shower is suitable for all forms of observation. As its radiant rises during the night, watches can be carried out usefully from about 22^h30^m local time onwards from mid-northern sites, but only well after midnight from the mid-southern hemisphere. On April 22, the waxing gibbous Moon will set between 1 and 2 a.m. for most northern sites (the later times fall further north), leaving at least a short while before morning twilight begins with the radiant at a healthy elevation for dark-sky observing. If the ideal maximum time recurs, it should be best-seen from sites across the eastern half of Asia, but, as already noted, other maximum times are perfectly possible.

η-Lyrids (ELY)

Active: May 3–12; Maximum: May 9, 07^h UT ($\lambda_\odot = 48\overset{\circ}{.}4$); ZHR = 3;

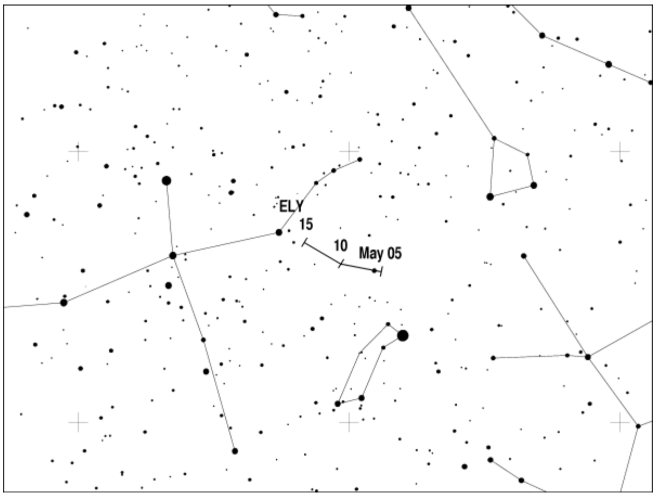
Radiant: $\alpha = 287°$, $\delta = +44°$; Radiant drift: see Table 6;

$V_\infty = 44$ 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 Working List is associated with Comet C/1983 H1 IRAS-Araki-Alcock, though it appears to be only a weak shower. Most of the data on it so far has been theoretical, or based solely on imaging results. It needs a lot more data to confirm it can be definitely observed visually, and if so, just what its parameters may be. The radiant position is likely to be around the region given above at the presumed maximum, but may be some degrees from it. The discussion on p.137 of HMO has more information. However, the VID results suggested significantly different parameters overall, with the shower detected between May 10–17, reaching a maximum around $\lambda_\odot = 50°$ (2010 May 10/11), from a radiant then centred at

$\alpha = 291°$, $\delta = +43°$. The radiant drift remains unconfirmed. Other than more video work, diligent visual or telescopic 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), from where the waning crescent Moon will rise too near dawn to cause any problems around May 8–11.



June Lyrids (JLY)

Active: June 11–21; Maximum: June 16($\lambda_\odot = 85°$); ZHR = variable, 0–5;

Radiant: $\alpha = 278°$, $\delta = +35°$;

Radiant drift: June 10$\alpha = 273°$, $\delta = +35°$,

June 15$\alpha = 277°$, $\delta = +35°$,

June 20$\alpha = 281°$, $\delta = +35°$;

$V_\infty = 31$ km/s; $r = 3.0$.

This possible source does not feature in the current IMO Working List of Visual Meteor Showers, as apart from some activity seen from northern hemisphere sites in a few years during the 1960s (first seen 1966) and 1970s, evidence for its existence has been virtually zero since. In 1996, several observers independently reported some June Lyrids, though no definite activity has been found subsequently. The probable maximum date in 2010 has only a waxing crescent Moon, yielding perfect viewing conditions for all observers who wish to check for this potential stream. The radiant may lie a few degrees south of the bright star Vega (α Lyrae), so would be well on-view throughout the short northern summer nights, but there are discrepancies in its position in the literature. All suspected visual June Lyrids should be carefully plotted, paying especial attention to the meteors' apparent velocities. Confirmation or denial of activity from this source by imaging techniques would be very useful too.

June Boötids (JBO)

Active: June 22–July 2; Maximum: June 27, 14^h30^m 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; $r = 2.2$;

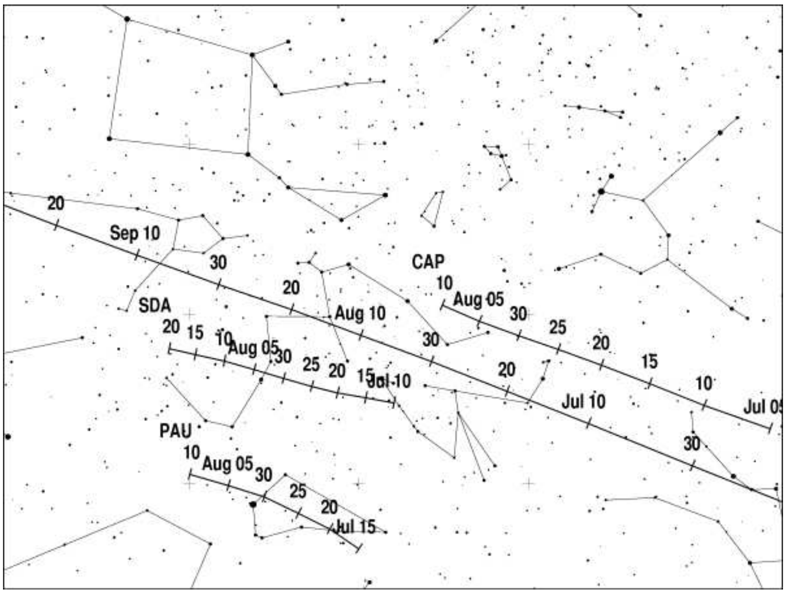
TFC: $\alpha = 156°$, $\delta = +64°$ and $\alpha = 289°$, $\delta = +67°$ ($\beta = 25°$–$60°$ N).

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. 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. Four similar dust trails are predicted to encounter the Earth this year, laid down by the comet in 1819, 1825, 1830 and 1836, which may produce UT maxima around June 24, $03^{\mathrm{h}}53^{\mathrm{m}}$,$01^{\mathrm{h}}22^{\mathrm{m}}$, $00^{\mathrm{h}}07^{\mathrm{m}}$ and June 23, $22^{\mathrm{h}}40^{\mathrm{m}}$ respectively. Activity is uncertain, but is not expected to be particularly high, so perhaps will be no better than at the 2004 return. Conditions for checking are very unfavourable from the mid-northern latitudes where the radiant is best-seen, with full Moon on June 26, aside from the prolonged – in some places continuous – twilight, but it is important to discover whether activity recurs at all, and if so when. The radiant is usefully accessible virtually all night, and all observing techniques can be employed. In terms of the apparently 'early' predicted peaks this time, VID suggested some June Boötids may be visible in most years around June 20–25, but that their activity was largely negligible except near $\lambda_{\odot} = 92°$ (2010 June 23). Even stranger was that this activity originated from a radiant 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. Despite the large ANT radiant area overlapping that of the minor α-Capricornids (CAP) in July-August, these ZHR levels may make it more practical to still identify CAP meteors, particularly near the CAP maximum, due around July 30 or 31. That is unlikely to be the case this year though, due to the waning gibbous Moon in late July. The δ-Aquariids (SDA) are strong enough, and the Piscis Austrinids (PAU) have a radiant probably distant enough from the ANT area, that both should still be separable from it too, particularly from the southern hemisphere. Moonlit maxima are due from both around July 28, the PAU possibly on July 29 instead, while VID indicated the SDA peak might fall alternatively around $\lambda_{\odot} = 128°$, 2010 July 31.

By the best from the major, moonless, Perseids, and the partly Moon-free κ-Cygnid peak in mid August, ANT ZHRs will likely have dropped back below 2 again, as the radiant tracks on through Aquarius, and into western Pisces by the α-Aurigid maximum on the August-September boundary, probably this year peaking around 07^{h} UT on September 1 (with a very problematic last quarter Moon). The minor September Perseids are moonless for their likely maximum, but most of the possible very weak δ-Aurigid peak, perhaps between September 24 to October 4, will be lost to the bright waning Moon. There have been significant discrepancies found in these showers' details as determined by recent video results, as discussed below. For most of September, ANT rates continue from their radiant in Pisces, albeit with ZHRs probably no better than 2–3, but remember that from September 25, Antihelion meteors are no longer to be recorded as such, as both Taurid showers take over the near-ecliptic shower baton until late November. For daylight radio observers, the interest of May-June has waned, but there remain the visually-impossible γ-Leonids (peak due near August 25, 16^{h} UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids. Their maximum is expected on September 27, around 16^{h} UT, but possibly it may occur a day earlier. In 1999 a strong return was detected at $\lambda_{\odot} \sim 186^{\circ}$, equivalent to 2010 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. The waning gibbous Moon creates additional difficulties 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.



Perseids (PER)

Active: July 17–August 24; Maximum: August 12, $23^{h}30^{m}$ to August 13, $02^{h}00^{m}$ UT ($\lambda_{\odot} = 140.^{\circ}0$–$140.^{\circ}1$), but see text; ZHR = 100;

Radiant: $\alpha = 48^{\circ}$, $\delta = +58^{\circ}$; Radiant drift: see Table 6;

$V_{\infty} = 59$ km/s; $r = 2.2$;

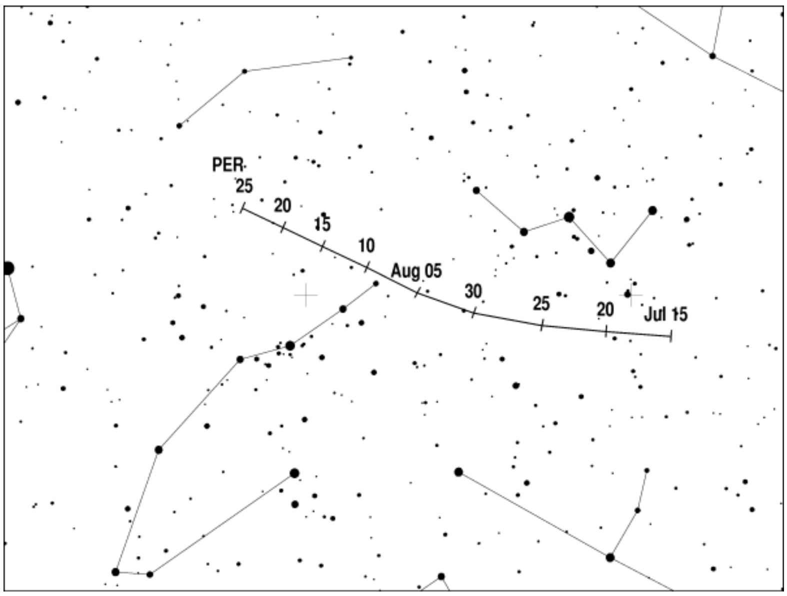
TFC: $\alpha = 019^{\circ}$, $\delta = +38^{\circ}$ and $\alpha = 348^{\circ}$, $\delta = +74^{\circ}$ before 2^{h} local time;

$\alpha = 043^{\circ}$, $\delta = +38^{\circ}$ and $\alpha = 073^{\circ}$, $\delta = +66^{\circ}$ after 2^{h} local time ($\beta > 20^{\circ}$ N);

IFC: $\alpha = 300^{\circ}$, $\delta = +40^{\circ}$, $\alpha = 000^{\circ}$, $\delta = +20^{\circ}$ or $\alpha = 240^{\circ}$, $\delta = +70^{\circ}$ ($\beta > 20^{\circ}$ N).

The Perseids were one of the most exciting and dynamic meteor showers during the 1990s, with outbursts at a new primary maximum producing EZHRs of 400+ in 1991 and 1992. Rates from this peak decreased to $\sim$ 100–120 by the late 1990s, and in 2000, it first failed to appear. This was not unexpected, as the outbursts and the primary maximum (which was not noticed before

1988), were associated with the perihelion passage of the Perseids' parent comet 109P/Swift-Tuttle in 1992. The comet's orbital period is about 130 years, so it is now receding into the outer Solar System, and theory predicts that such outburst rates should dwindle as the comet to Earth distance increases. However, predictions suggested 2004–2006 might bring a return of enhanced rates ahead of the usual maximum, and in 2004 a short, strong peak happened close to that anticipated pre-peak time. Activity seemed to be roughly normal in 2005 and 2006 (though the latter was badly moonlit). IMO observations from the last decade (see HMO p. 145) showed the timing of the mean or 'traditional' broad maximum varied between $\lambda_\odot \sim 139.^\circ 8$ to $140.^\circ 3$, equivalent to 2010 August 12, 18^h30^m to August 13, 07^h00^m UT, while the shorter, enhanced filamentary peaks all occurred between $\lambda_\odot \sim 139.^\circ 44$ to $140.^\circ 55$, 2010 August 12, 09^h30^m to August 13, 13^h30^m UT. Recent work implies only the 'traditional' peak is liable to recur in 2010 (most likely near the nodal crossing time given in the table above), but observers should be aware of these additional timings as possibilities, and plan their efforts accordingly, just in case!



New Moon on August 10 creates perfect viewing conditions across the peak this year. The shower is best-observed from mid-northern latitudes, from where the Perseid radiant is usefully observable from 22^h–23^h local time onwards, gaining altitude throughout the night. The near-nodal part of the 'traditional' maximum interval would be best-viewed from Europe and North Africa east to central Asia, assuming it happens as expected. All forms of observing can be carried out on the shower. For example, video data has been used in recent IMO analyses to clarify and refine the radiant position for the shower - and to confirm that occasional visual suspicions the radiant may be multiple were almost certainly only illusory. The only negative aspect to the shower is the impossibility of covering it from the bulk of the southern hemisphere.

κ-Cygnids (KCG)

Active: August 3–25; Maximum: August 18($\lambda_\odot = 145°$); ZHR = 3;

Radiant: $\alpha = 286°$, $\delta = +59°$; Radiant drift: see Table 6;

$V_\infty = 25$ km/s; $r = 3.0$;

IFC: $\alpha = 330°$, $\delta = +60°$ and $\alpha = 300°$, $\delta = +30°(\beta > 20°$ N).

The waxing gibbous Moon will set between roughly 23^h to midnight local time for the expected κ-Cygnid peak this year at northern hemisphere sites, from where the shower is chiefly accessible. Its r-value suggests telescopic and video observers may benefit from the shower's presence, but visual and photographic workers should note that occasional slow fireballs from this source have been reported too. Although previously suggested as having an almost stationary radiant, due to its close proximity to the ecliptic north pole in Draco, recent IMO video data seem to have contradicted that, but it is not clear why as yet, nor is the proposed greater radiant drift yet confirmed. There has been some suggestion of a variation in *kappa*-Cygnid rates at times too, perhaps coupled with a periodicity in fireball sightings, but more data are needed on a shower that is often ignored in favour of the major Perseids during August.

Near-Auriga Showers

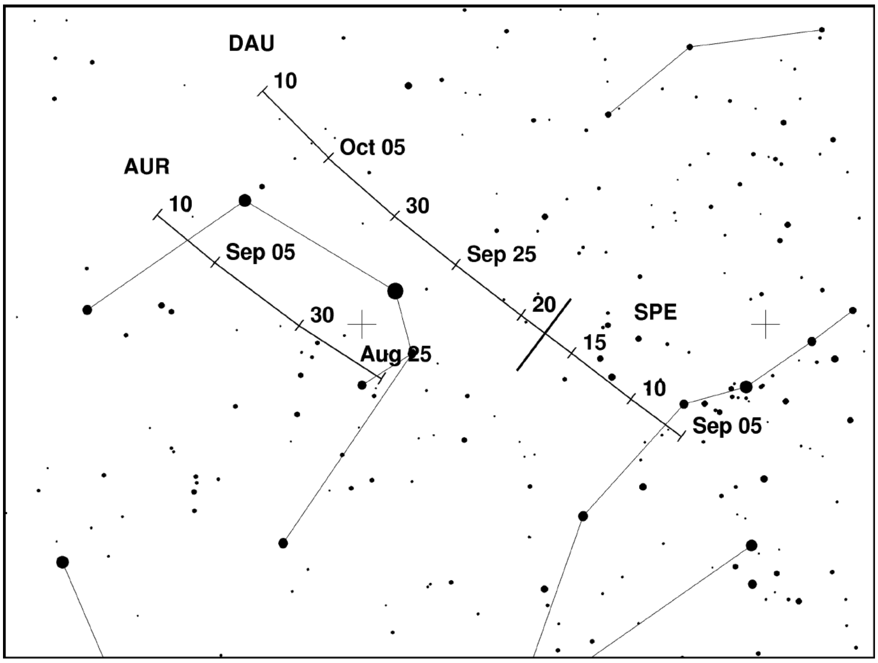
September Perseids (SPE)

Active: September 5–17; Maximum: September 9, 15^h UT ($\lambda_\odot = 166.°7$); ZHR = 5;

Radiant: $\alpha = 60°$, $\delta = +47°$; Radiant drift: see Table 6;

$V_\infty = 64$ km/s; $r = 3.0$;

TFC: $\alpha = 052°$, $\delta = +60°$; $\alpha = 043°$, $\delta = +39°$ and $\alpha = 023°$, $\delta = +41°$ ($\beta > 10°$ S).



Recent IMO analyses in HMO and VID have revealed a number of significant problems with the parameters for the three supposedly established near-Auriga showers active at times between late August and October, the α- (AUR) and δ-Aurigids (DAU), and the September Perseids. For some time, these essentially northern hemisphere showers have been suspected of simply being (perhaps the more active) part of a series of poorly-observed sources with radiants around Aries, Perseus, Cassiopeia and Auriga during the northern early autumn. The main discrepancies to what was previously thought were as follows.

VID found the AUR active from August 30 to September 3, not August 25 to September 8, with a radiant at maximum around $\alpha = 68°$, $\delta = +47°$, not $\alpha = 84°$, $\delta = +42°$. The radiant also showed a much smaller daily drift, in a different direction, than currently assumed for the shower.

The SPE radiant at maximum, as noted in the table above, supposed to be near $\alpha = 60°$, $\delta = +47°$, could not be located at all in the VID data. Instead, a radiant active from September 5 to 13, located at $\alpha = 48°$, $\delta = +39°$ at its strongest on $\lambda_\odot = 167°$ (2010 September 9) was found, a location remarkably similar to that which produced an unexpected outburst of comparably-swift, bright meteors on 2008 September 9 (whose radiant was centred somewhere between $\alpha = 47\overset{\circ}{.}5$ to $49°$, $\delta = +38°$ to $+43°$ then). That source seemed to have been the formerly-little-known ϵ-Perseid minor shower (radiant around $\alpha = 50°$, $\delta = +39°$) – though its radiant location is actually closer to β or ρ Persei than ϵ!

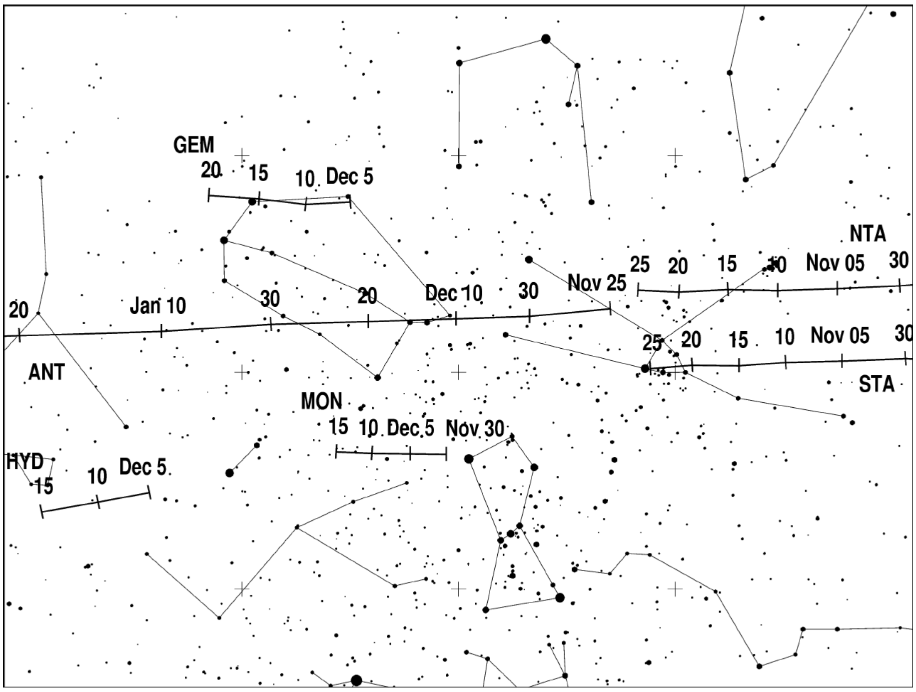
For the DAU, the HMO ZHR graph on p. 151 showed no peak at all. There was marginally higher activity (ZHRs just ~ 2, even so) from $\lambda_\odot \sim 176°$ to $181°$, not the previously-detected vague maximum around $\lambda_\odot \sim 181°$ to $191°$. Worse still, the VID results were able to define DAU activity only from October 6–12 (previously-assumed to last from September 18 to October 10), with a loose peak at $\lambda_\odot \sim 196°$ (2010 October 9), from a radiant near $\alpha = 106°$, $\delta = +46°$, substantially southeast of the expected one. Rather like the visual results, no clear activity profile was definable in the video reports.

Consequently, although the previous parameters, with a few small amendments, have been retained here, it is clear these showers need a thorough re-examination, with fresh results to complement all the extant data, to help determine exactly what is happening in this area of sky at this time. Visual plotting has apparently struggled in the past, assuming the latest video results can be relied upon, so imaging and telescopic data would seem to offer the best hope of resolution. There is already the telescopic β-Cassiopeid shower suspected of being active simultaneously to several of the September Auriga-Perseus showers, for example. Unfortunately, any one year's data cannot be sufficient to cover everything that may be happening (aside from one-off events like the occasional strong AUR outbursts, or the unexpected possible ϵ-Perseid outburst in 2008), thus the better option would be to rely less on trying to observe only the proposed maxima, and attempt to observe as frequently as possible whenever the Moon and weather cooperate between the last week of August and the first fortnight in October, remembering that all the radiants in this area of sky are best-viewed only after about 23^h–00^h local time north of the equator.

6 October to December

A mixed final quarter concludes the year, with not all the more active showers reasonably moonless, nor all the minor sources. In October, the major Orionids (around October 21) and minor Leonis Minorids (probably on October 24) have maxima too close to full Moon for any dark-sky observations, though in November, only the usually-minor α-Monocerotids lose out completely that way (peak due at 21^h35^m UT on November 21 – full Moon is only four hours earlier!). The first half of December has showers that mostly survive the Moon, the second half mostly does not, which means the loss of the Ursid and Comae Berenicid peaks. The usual Ursid maximum is expected between 19^h30^m to 22^h00^m UT on December 22, but HMO p. 176 indicated a stream filament peak was likely earlier on December 22, centred at 13^h02^m UT, with ZHRs of ~ 23 anticipated. The publication of VID has enabled a clarification of the confusion over the Coma showers in the 2008 and 2009 Shower Calendars. Analyses of recent video data collected over several years reveal only the CBE radiant. It is detectable between December 5 and end-January ($\lambda_\odot = 253°$–$311°$) with a weak maximum near $\lambda_\odot = 268°$ (December 20) with a ZHR of ~ 5. Although the 'old' Comae Berenicids, COM, cannot be found from recent data, we add them to the list as an open issue for the current working list. The ANT starts the quarter effectively inactive in favour of the Taurids, but it resumes from November 26, as the Taurids fade away, from a radiant centre position in eastern Taurus. During December, this centre tracks across southern Gemini, and although analyses indicate its likely ZHRs are < 2 for most of this time, 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 also the minor Monocerotids a little way to its south simultaneously.

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 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. The 2009 repeat time was still to come when this was written. As the 2005–06 events happened between $\lambda_\odot \sim 192.°55$–$192.°64$, this would be equivalent to 2010 October 6, 01^h30^m–03^h40^m UT, a date with no Moon (new on October 7). The meteors showed an atmospheric velocity of ~ 45–50 km/s. If the active interval keeps to the same time, it would be best-observed by video from eastern North America eastwards across Europe to central Asia.



Draconids (DRA)

Active: October 6–10; Maximum: October 8, 22^h45^m UT ($\lambda_\odot = 195.°4$, but see below);

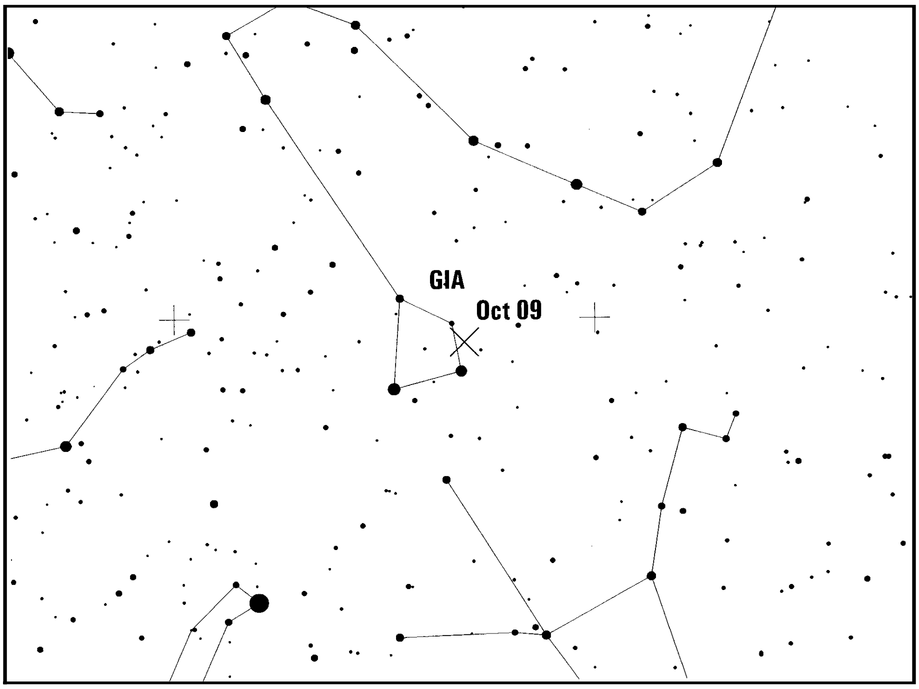
ZHR = periodic, up to storm levels;

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 ~ 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. Its orbital period is currently about 6.6 years. In 2005 October, a largely unexpected outburst happened near the comet's nodal crossing time, around $\lambda_\odot = 195.°40$–$195.°44$, 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 $\lambda_\odot = 195.^\circ075$ (in 1998; EZHRs ~ 700), equivalent to 2010 October 8, 14^h55^m UT, through the nodal passage time above, to $\lambda_\odot 195.^\circ63$–$195.^\circ76$ (a minor outburst in 1999, not a perihelion-return year; ZHRs $\sim$ 10–20), equating to 2010 October 9, 04^h20^m to 07^h30^m UT. The radiant is circumpolar from many northern hemisphere locations, but is highest during the first half of the night in early October. New Moon on October 7 makes this a perfect year to check for any activity, though none is anticipated until 2011 October, a little ahead of the comet's next return. Draconid meteors are exceptionally slow-moving, a characteristic which helps separate genuine shower meteors from sporadics accidentally lining up with the radiant.



ϵ-Geminids (EGE)

Active: October 14–27; Maximum: October 18($\lambda_\odot = 205^\circ$); ZHR = 3;

Radiant: $\alpha = 102^\circ$, $\delta = +27^\circ$; Radiant drift: see Table 6;

$V_\infty = 70$ km/s; $r = 3.0$;

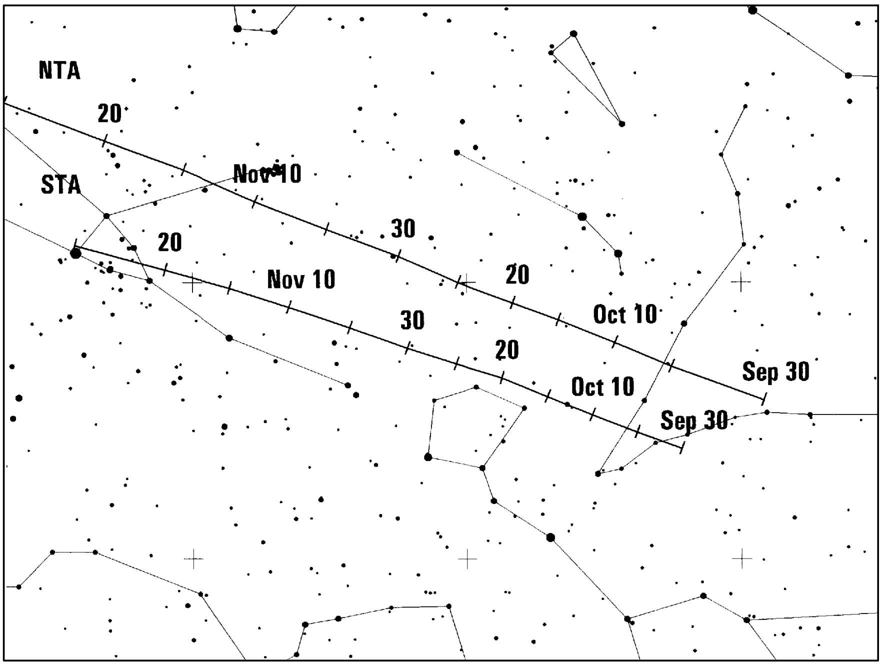
TFC: $\alpha = 090^\circ$, $\delta = +20^\circ$ and $\alpha = 125^\circ$, $\delta = +20^\circ$($\beta > 20^\circ$ S).

A weak minor shower with characteristics and activity nearly coincident with the Orionids, so great care must be taken to separate the two sources by instrumental techniques – especially video or telescopic work – or visual plotting. The waxing gibbous Moon sets between about 1^h30^m and 2^h30^m a.m. local time for northern to southern mid-latitudes (later timings further south), so presenting a good opportunity to obtain more data on them from either hemisphere. Northern observers have a radiant elevation advantage, as this area of sky can be usefully accessed here from about midnight onwards. Note the parameters have been questioned by the latest IMO data. HMO p. 154 suggested the visual peak may fall closer to $\lambda_\odot \sim 208^\circ$–$209^\circ$ (2010 October 21–22), though ZHRs remained above 2 from roughly October 18–23, while VID found the shower was active between October 5–22 with a maximum at $\lambda_\odot = 200^\circ$ instead (October 14).

Taurids

Southern Taurids (STA)
Active: September 25–November 25; Maximum: November 5 ($\lambda_\odot = 223°$); ZHR = 5;
Radiant: $\alpha = 52°$, $\delta = +15°$; Radiant drift: see Table 6;
$V_\infty = 27$ km/s; $r = 2.3$;
TFC: Choose fields on the ecliptic and $\sim 10°$ E or W of the radiants ($\beta > 40°$ S).

Northern Taurids (NTA)
Active: September 25–November 25; Maximum: November 12 ($\lambda_\odot = 230°$); ZHR = 5;
Radiant: $\alpha = 58°$, $\delta = +22°$; Radiant drift: see Table 6;
$V_\infty = 29$ km/s; $r = 2.3$;
TFC: as Southern Taurids.



These two streams form part of the complex associated with Comet 2P/Encke. Defining their radiants is best achieved by careful visual or telescopic plotting, or imaging recordings, since they are large and diffuse. For shower association, each radiant should be considered an oval area of $\sim 20° \times 10°$, $\alpha \times \delta$, centred on the radiant position for any given date. Their activity clearly dominates the ANT's during the northern autumn, so much so that the ANT is considered inactive while they are present. The brightness and relative slowness of many of these shower meteors makes them ideal targets for still-imaging, while these factors coupled with low, steady, combined Taurid rates make them excellent subjects for newcomers to practice their plotting techniques on. The activity of both showers produces an apparently plateau-like maximum for about ten days in early November, and they have a reputation for producing some excellently bright fireballs at times, although seemingly not in every year. Meteoricist David Asher's studies have indicated that increased Taurid fireball rates probably result from a 'swarm' of larger particles within the Taurid stream, which in 2005 most recently produced a lot of, occasionally very brilliant, fireballs, and enhanced combined ZHRs of $\sim$ 10–15 that persisted from about

October 29 to November 10. Another 'swarm' return in 2008 gave a less-clear signature, with little or no significant increase in fireball numbers, but probably better than normal Taurid activity, ZHRs $\sim$ 10–20, for a few days in late October and early November. No 'swarm' return is predicted for this year. November's new Moon favours coverage of the whole probable maximum spell however, and with near-ecliptic radiants, all can observe these streams. Northern hemisphere observers are somewhat better-placed, as here suitable radiant zenith distances persist for much of the night. Even from the southern hemisphere, a good 3–5 hours' watching around local midnight is possible with Taurus well above the horizon. The VID data largely confirmed the lengthy active periods for both sources, but suggested the STA might show two minor maxima, around October 31 and November 8, and the NTA three, near October 3, November 9 and 16. Note the first STA and last NTA video peaks originated from radiants respectively some way north and northeast of the expected positions at those times.

Leonids (LEO)

Active: November 10–23; Maximum: November 17, $21^{h}15^{m}$ 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 $\alpha = 156°$, $\delta = -03°$ and $\alpha = 129°$, $\delta = +06° (\beta < 35°$ N).

IFC: $\alpha = 120°$, $\delta = +40°$ before 0^{h} local time ($\beta > 40°$ N);

$\alpha = 120°$, $\delta = +20°$ before 4^{h} local time and $\alpha = 160°$, $\delta = 00°$ after 4^{h} local time ($\beta > 00°$ N);

$\alpha = 120°$, $\delta = +10°$ before 0^{h} local time and $\alpha = 160°$, $\delta = -10° (\beta < 00°$ 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 is not expected to produce enhanced rates, but theoretical work by Mikhail Maslov suggested peak ZHRs of $\sim$ 20 might occur around November 17, 15^{h} UT instead of at the usual nodal crossing time above. ZHRs from that later possible peak are likely to be $\sim$ 10–20. The waxing gibbous Moon will not set until 2 to 3 a.m. local time on November 17 across the mid-latitude globe (later moonsets for places further north). As the Leonid radiant rises usefully only around local midnight (or indeed afterwards south of the equator), there will still be plenty of dark-sky time between moonset and the onset of morning twilight to observe whatever happens this year. The $\sim 15^{h}$ UT peak timing would coincide with moonless skies from the extreme east of Russia east to Alaska and places at similar longitudes on the Pacific Ocean. The $\sim 21^{h}$ UT timing would favour locations at comparable longitudes to central-eastern Asia, from roughly India east to Japan/western Australia. Other possible maxima are not excluded, and observers should be alert as often as conditions allow throughout the shower, in case something unexpected happens. All observing techniques can be usefully employed. VID indicated Leonid activity might be detected that way from about November 8–28, though this remains unconfirmed visually.

Phoenicids (PHO)

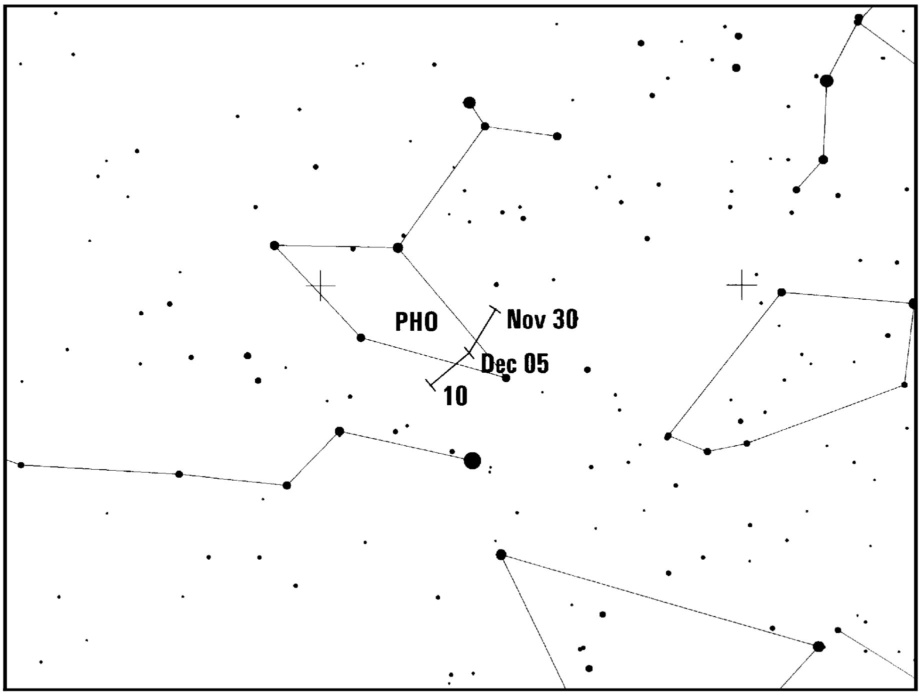
Active: November 28–December 9; Maximum: December 6, $15^{h}30^{m}$ UT ($\lambda_{\odot} = 254\overset{\circ}{.}25$);

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 $\sim$ 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. New Moon on December 5 creates ideal viewing circumstances this year.

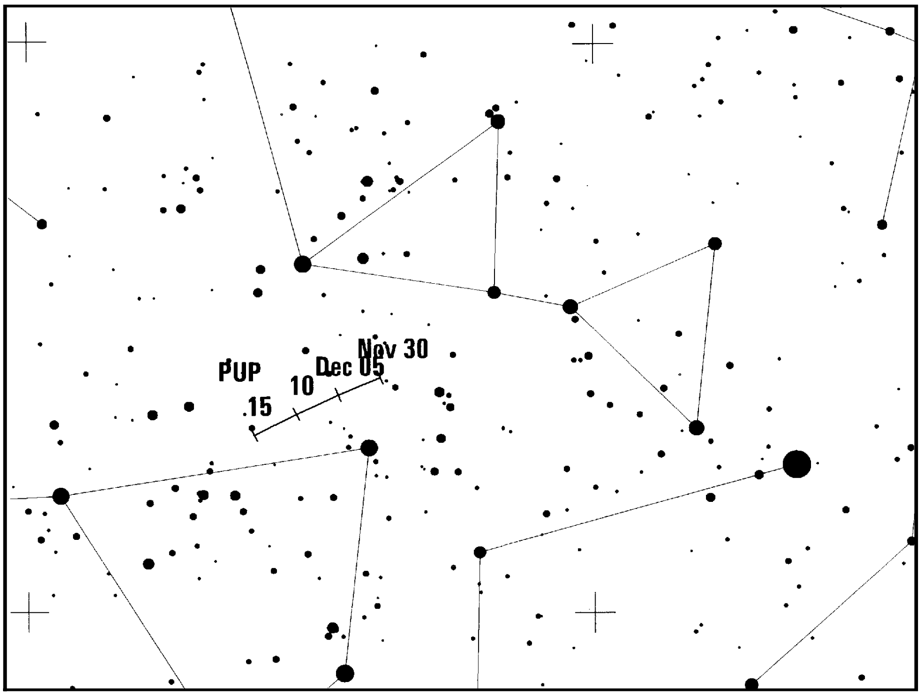
Puppid-Velids (PUP)

Active: December 1–15; Maximum: December $\sim 7(\lambda_{\odot} \sim 255°)$; ZHR $\sim$ 10;

Radiant: $\alpha = 123°$, $\delta = -45°$; Radiant drift: see Table 6;

$V_{\infty} = 40$ km/s; $r = 2.9$;

TFC: $\alpha = 090°$ 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, coincident with the dark of the 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.

Monocerotids (MON)

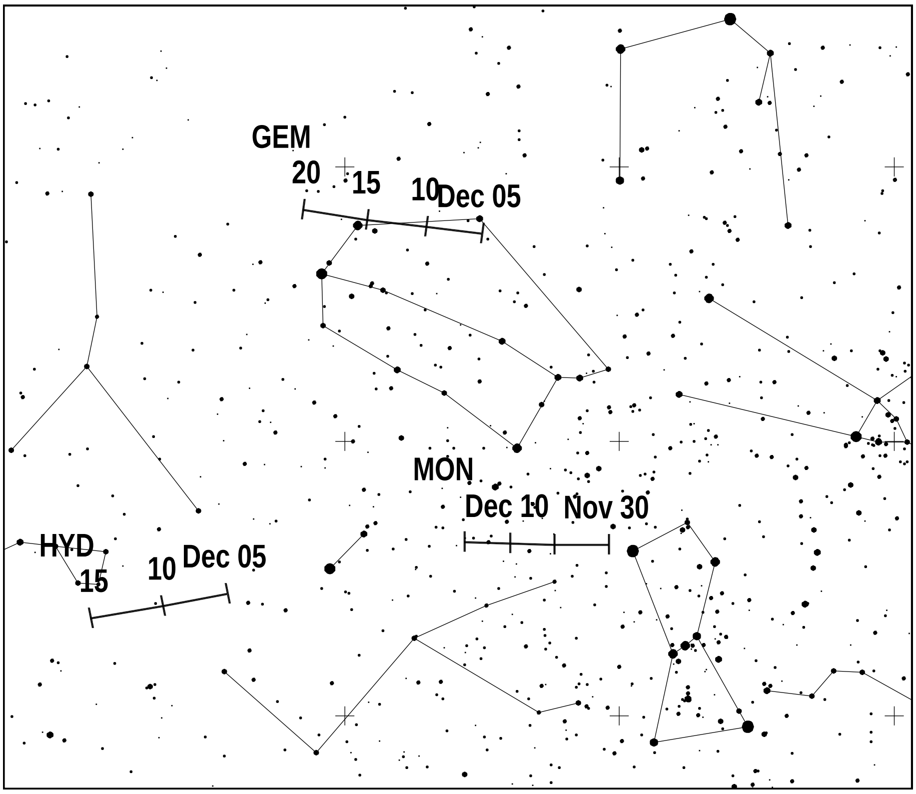
Active: November 27–December 17; Maximum: December 9 ($\lambda_\odot = 257°$); ZHR = 2;

Radiant: $\alpha = 100°$, $\delta = +08°$; Radiant drift: see Table 6;

$V_\infty = 42$ km/s; $r = 3.0$;

TFC: $\alpha = 088°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +48°$ ($\beta > 40°$ N);

or $\alpha = 120°$, $\delta = -03°$ and $\alpha = 084°$, $\delta = +10°$ ($\beta < 40°$ N).



HMO (p. 169) confirmed only low, but persistent, rates are likely from this very minor source, with little clear sign of a maximum, making accurate visual plotting, telescopic or video work essential, particularly because its meteors are normally faint. The shower's details, even including the radiant position, are rather uncertain. VID suggested there may be actually two minor radiants involved, the other about 10° northwest of that given here, active from November 17 to December 5, at maximum near $\lambda_\odot = 246°$ (November 28). That radiant then was at $\alpha = 91°$, $\delta = +15°$. The MON parameters suggested by VID were slightly different to those here too, with activity found between December 6–19, and a maximum at $\lambda_\odot = 254°$ (December 6), right at the beginning of its reported activity, from a radiant nearly coincident with that for the December 9 MON one. In addition, telescopic results have suggested a later maximum, around $\lambda_\odot \sim 264°$ (December 16), from a radiant at $\alpha = 117°$, $\delta = +20°$. Assuming a constant radiant drift for the shower that gave November's VID Monocerotid peak, beyond the period it was detected, might suggest it is related to this telescopic radiant, and perhaps that, if only one Monocerotid shower is involved overall, it has a dual, northern and southern, radiant. December's new Moon leaves plenty of dark-sky observing time for most of these proposed peaks, given that the radiant area is on-show virtually all night, culminating at about 1^h30^m local time. The December 16 peak would be less favourable, but waxing gibbous moonset then will still leave several hours before dawn for observing.

σ-Hydrids (HYD)

Active: December 3–15; Maximum: December 12($\lambda_\odot = 260°$); ZHR = 3;

Radiant: $\alpha = 127°$, $\delta = +02°$; Radiant drift: see Table 6;

$V_\infty = 58$ km/s; $r = 3.0$;

TFC: $\alpha = 095°$, $\delta = 00°$ and $\alpha = 160°$, $\delta = 00°$ (all sites, after midnight only).

Although first detected in the 1960s by photography, σ-Hydrids are typically swift and faint, and rates are generally very low, close to the visual detection threshold. Since their radiant, a little over 10° east of the star Procyon (α Canis Minoris), is near the equator, all observers can cover this shower. The radiant rises in the late evening hours, but is best viewed after local midnight, so this is a perfect year for them, with a waxing crescent Moon setting around midnight on December 12. Recent IMO data used in the HMO p. 170 graph indicated the maximum may happen near $\lambda_\odot \sim 262°$ (December 14) however, while VID implied a peak closer to $\lambda_\odot \sim 257°$ (December 9), and that HYD activity may be present from November 30 to December 18, or perhaps even till December 24. Moon-free watching should be practical for at least part of their better-visible time on all the potential maximum nights. The shower would benefit from visual plotting, telescopic or additional video work to pin it down more accurately.

Geminids (GEM)

Active: December 7–17; Maximum: December 14, 11^h UT ($\lambda_\odot = 262\overset{\circ}{.}2$); ZHR = 120;

Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6;

$V_\infty = 35$ km/s; $r = 2.6$;

TFC: $\alpha = 087°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +49°$ before 23^h local time,

$\alpha = 087°$, $\delta = +20°$ and $\alpha = 129°$, $\delta = +20°$ after 23^h local time ($\beta > 40°$ N);

$\alpha = 120°$, $\delta = -03°$ and $\alpha = 084°$, $\delta = +10°$($\beta < 40°$ N).

IFC: $\alpha = 150°$, $\delta = +20°$ and $\alpha = 060°$, $\delta = +40°$($\beta > 20°$ N);

$\alpha = 135°$, $\delta = -05°$ and $\alpha = 080°$, $\delta = 00°$($\beta < 20°$ N).

One of the finest, and probably the most reliable, of the major annual showers presently observable, whose peak this year falls just after first quarter Moon. Moonset is within half an hour of local midnight across the globe for the maximum, while the Geminid radiant culminates around 02^h local time. Well north of the equator, the radiant rises at 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. 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 slight signs of variability in its rates and timing in recent years, with the more reliably-reported maxima during the past two decades (data from HMO, p. 171) all having occurred within the range $\lambda_\odot = 261\overset{\circ}{.}5$ and $262\overset{\circ}{.}4$, equivalent to December 13, 18^h40^m to December 14, 16^h00^m UT this year. Stronger activity has been found to begin occasionally as early as $\lambda_\odot = 260\overset{\circ}{.}8$ (December 13, 02^h UT) and to persist until $\lambda_\odot = 262\overset{\circ}{.}5$ (December 14, 18^h). VID suggested Geminid activity was detectable from November 30 to December 18, the earlier start for the shower rather unexpected from past visual investigations. The tabulated predicted timing above coincides with post-moonset skies across most of North America on December 14, but with the likelihood of near-peak rates persisting for almost a day, most of the world should have the chance to see something of the Geminids' best under dark skies. Some mass-sorting within the stream means fainter telescopic meteors should be most abundant almost 1° of solar longitude (about one day) ahead of the visual maximum, with telescopic results indicating such meteors radiate from an elongated region, perhaps with three sub-centres. Further results on this topic would be useful.

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° × 10°, while that for the Antihelion Source 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.

$h\backslash D$	$V_\infty = 25$ 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 2010.

New Moon	First Quarter	Full Moon	Last Quarter
			January 7
January 15	January 23	January 30	February 5
February 14	February 22	February 28	March 7
March 15	March 23	March 30	April 6
April 14	April 21	April 28	May 6
May 14	May 20	May 27	June 4
June 12	June 19	June 26	July 4
July 11	July 18	July 26	August 3
August 10	August 16	August 24	September 1
September 8	September 15	September 23	October 1
October 7	October 14	October 23	October 30
November 6	November 13	November 21	November 28
December 5	December 13	December 21	December 28

Table 5. Working List of Visual Meteor Showers. Details in this Table were correct according to the best information available in May 2009, with maximum dates accurate only for 2010. 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	$\lambda_\odot$	Radiant α	δ	V_∞ km/s	r	ZHR
Antihelion Source (ANT)	Nov 26–Sep 24 –	March–April, late May, late June		see Table 6		30	3.0	4
Quadrantids (QUA)	Dec 28–Jan 12	Jan 03	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 14	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 23	33.°5	110°	−45°	18	2.0	Var
η-Aquariids (ETA)	Apr 19–May 28	May 06	45.°5	338°	−01°	66	2.4	85*
η-Lyrids (ELY)	May 03–May 12	May 09	48.°4	287°	+44°	44	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 19	Jul 28	125°	339°	−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 12	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 25–Sep 08	Sep 01	158.°6	84°	+42°	66	2.5	6
Sept. Perseids (SPE)	Sep 05–Sep 17	Sep 09	166.°7	60°	+47°	64	3.0	5
δ-Aurigids (DAU)	Sep 18–Oct 10	Sep 29	186°	82°	+49°	64	3.0	2
Draconids (DRA)	Oct 06–Oct 10	Oct 08	195.°4	262°	+54°	20	2.6	Var
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	30*
Leonis Minorids (LMI)	Oct 19–Oct 27	Oct 23	211°	161°	+38°	62	3.0	2
Southern Taurids (STA)	Sep 25–Nov 25	Nov 05	223°	52°	+15°	27	2.3	5
Northern Taurids (NTA)	Sep 25–Nov 25	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (LEO)	Nov 10–Nov 23	Nov 17	235.°27	152°	+22°	71	2.5	20*
α-Monocerotids (AMO)	Nov 15–Nov 25	Nov 21	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 07–Dec 17	Dec 14	262.°2	112°	+33°	35	2.6	120
Comae Berenicids (CBE)[2]	Dec 05–Jan 31	Dec 20	268°	161°	+30°	65	3.0	5
Ursids (URS)	Dec 17–Dec 26	Dec 22	270.°7	217°	+76°	33	3.0	10
Comae Berenicids (COM)[2]	Dec 12–Jan 23	Dec 29	278°	185°	+21°	65	3.0	5

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

Date		ANT		QUA		CBE		COM							
Jan	0	112°	+21°	228°	+50°	171°	+26°	186°	+20°						
Jan	5	117°	+20°	231°	+49°	175°	+24°	190°	+18°						
Jan	10	122°	+19°	234°	+48°	181°	+22°	194°	+16°						
Jan	15	127°	+17°			185°	+19°	198°	+15°						
Jan	20	132°	+16°			189°	+17°	202°	+13°						
Jan	25	138°	+15°			193°	+15°	**ACE**							
Jan	30	143°	+13°			197°	+13°	200°	−57°						
Feb	5	149°	+11°					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°	76°	+42°					288°	+60°		
Aug	30	349°	−3°			82°	+42°	**SPE**				289°	+60°		
Sep	5	355°	−1°			88°	+42°	55°	+46°						
Sep	10	0°	+1°			92°	+42°	60°	+47°						
Sep	15	5°	+3°					66°	+48°	**DAU**					
Sep	20	10°	+5°	**NTA**		**STA**		71°	+48°	71°	+48°				
Sep	25	14°	+7°	19°	+11°	21°	+6°			77°	+49°				
Sep	30			22°	+12°	25°	+7°	**ORI**		83°	+49°				
Oct	5			26°	+14°	28°	+8°	85°	+14°	89°	+49°			**DRA**	
Oct	10	**EGE**		30°	+15°	32°	+9°	88°	+15°	95°	+49°			262°	+54°
Oct	15	99°	+27°	34°	+16°	36°	+11°	91°	+15°			**LMI**			
Oct	20	104°	+27°	38°	+18°	40°	+12°	94°	+16°			158°	+39°		
Oct	25	109°	+27°	43°	+19°	43°	+13°	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°			147°	+24°			**AMO**	
Nov	15			61°	+23°	60°	+16°			150°	+23°			112°	+2°
Nov	20	**ANT**		65°	+24°	64°	+16°			153°	+21°			116°	+1°
Nov	25	75°	+23°	70°	+24°	72°	+17°	**MON**		**PHO**		**PUP**		120°	0°
Nov	30	80°	+23°	**GEM**		**CBE**		91°	+8°	14°	−52°	120°	−45°	**HYD**	
Dec	5	85°	+23°	103°	+33°	149°	+33°	18°	−53°	96°	+8°	122°	−45°	122°	+3°
Dec	10	90°	+23°	108°	+33°	153°	+33°	22°	−53°	100°	+8°	125°	−45°	126°	+2°
Dec	15	96°	+23°	113°	+33°	157°	+32°	173°	+26°	104°	+8°	128°	−45°	130°	+1°
Dec	20	101°	+23°	118°	+32°	161°	+30°	177°	+24°			217°	+76°		
Dec	25	106°	+22°			166°	+28°	181°	+23°			217°	+74°		
Dec	30	111°	+21°			170°	+26°	185°	+21°			**URS**			
								COM							

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 Potsdam, 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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