International Meteor Organization

2006 Meteor Shower Calendar

compiled by Alastair McBeath[1]

1 Introduction

Welcome to the 2006 International Meteor Organization (*IMO*) Meteor Shower Calendar. A fine year is in prospect, with the major Quadrantid and Geminid maxima largely moonless, together with the Lyrid–π-Puppid period in April, the possible June Boötid spell in late June, the best from the July-August Aquarid-Capricornid sources, the α-Aurigids, and then the Orionid, Leonid–α-Monocerotid and Coma Berenicid–Ursid epochs towards the year's end. Heightened Leonid activity is again a possibility, albeit not of storm proportions. The sole major shower lunar casualty is the Perseid peak in August, but even this might yield enhanced ZHRs. Do not forget that ideally, monitoring of meteor activity should be carried on throughout the rest of the year, however! We appreciate that this is not practical for many people, and this Calendar was first devised back in 1991 as a means of helping observers deal with reality by highlighting times when a particular effort might most usefully be employed. Although we include timing predictions for all the more active night-time and daytime shower maxima, based on the best data available, please note 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 only recently begun to receive regular attention again). In addition, variations in individual showers from year to year mean past returns are at best only a guide as to when even major shower peaks can be expected, plus as some showers are known to show particle mass-sorting within their meteoroid streams, the radio, telescopic, video, visual and photographic meteor maxima may occur at different times from one another, and not necessarily just in these showers. The majority of data collected are for visual shower maxima, so this must be borne in mind when employing other observing techniques.

The heart of the Calendar is the Working List of Visual Meteor Showers (see Table 5 on page 22), thanks to regular updating from analyses using the *IMO*'s Visual Meteor Database, the single most accurate listing available anywhere today for naked-eye meteor observing. Even this can never be a complete list of all meteor showers, since there are many showers which cannot be properly detected visually, and some which only photographic, radar, telescopic, or video observations can separate from the background sporadic meteors, present throughout the year.

The *IMO*'s aims are to encourage, collect, analyze, and publish combined meteor data obtained from sites all over the globe in order to further our understanding of the meteor activity detectable from the Earth's surface. Results from only a few localized places can never provide such total comprehension, and it is thanks to the efforts of the many *IMO* observers worldwide since 1988 that we have been able to achieve as much as we have to date. This is not a matter for complacency, however, since it is solely by the continued support of many people across the whole world that our steps towards constructing a better and more complete picture of the near-Earth meteoroid flux can proceed. This means that all meteor workers, wherever they are and whatever methods they use to record meteors, should follow the standard *IMO* observing

[1] based on information in *IMO Monograph No. 2: Handbook for Visual Meteor Observers*, edited by Jürgen Rendtel, Rainer Arlt and Alastair McBeath, *IMO*, 1995, and additional material extracted from reliable data analyses produced since.

guidelines when compiling their information, and submit their data promptly to the appropriate Commission (see page 24) for analysis.

Visual and photographic techniques remain popular for nightly meteor coverage (weather permitting), although both suffer considerably from the presence of moonlight. Telescopic observations are much less popular, but they allow the fine detail of shower radiant structures to be derived, and they permit very low activity showers to be accurately detected. Video methods continue to be dynamically applied as in several recent years, and are starting to bear considerable fruit. These have the advantages, and disadvantages, of both photographic and telescopic observing, plus some of their own, but are increasing in importance. Radio receivers can be utilized at all times (suitable transmitters permitting!), regardless of clouds, moonlight, or daylight, and provide the only way in which 24-hour meteor observing can be accomplished for most latitudes. Together, these methods cover virtually the entire range of meteoroid sizes, from the very largest fireball-producing events (using all-sky photographic and video patrols or visual observations) through to tiny dust grains producing extremely faint telescopic or radio meteors.

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 January to March

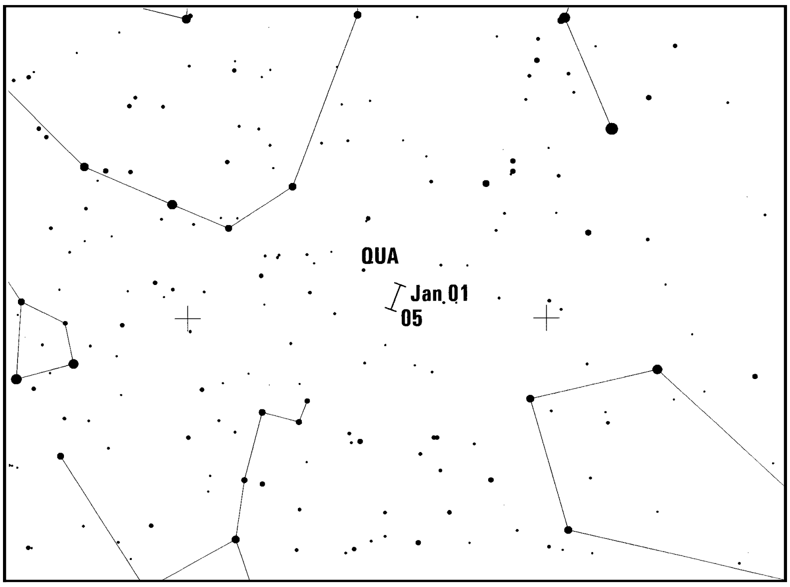
The waxing crescent Moon favours the Quadrantids in early January, while the waxing gibbous Moon still allows coverage near the probable α-Centaurid maximum in early February. Both the minor potential δ-Cancrid peak around January 11 and its more usually listed maximum on January 17 are lost to full Moon, but not so the δ-Leonids in late February. The diffuse ecliptical stream complex of the Virginids gets underway by late January, running through to mid April, probably producing several low, and poorly observed, maxima in March or early April. The interesting late January to early February spell has a waning Moon, which should cause only a few difficulties during most of the, perhaps core, January 20–27 period. Mid-March sees the possible minor γ-Normid peaks around March 13 or 17 spoilt by the Moon. Theoretical approximate timings for the two daytime radio shower maxima this quarter are: Capricornids/Sagittarids – February 1, $14^{\rm h}$ UT; and χ-Capricornids – February 13, $15^{\rm h}$ UT. Recent radio results suggest 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.

In addition to these known sources, there is a theoretical encounter with any dust-trail left by long-period comet Tago-Sato-Kosaka (C/1969T) close to $6^{\rm h}20^{\rm m}$ UT on January 2, suitable only for southern hemisphere observations. According to data published by Esko Lyytinen and Peter Jenniskens, the radiant should be in Norma (the nearest "bright" star is the 4th-magnitude β Circini, but α Centauri is only some 6°–7° away too), around $\alpha = 231°$, $\delta = -57°$ at $\lambda = 281\overset{\circ}{.}633$. Activity is unknown, possibly none at all, but the miss distance between the Earth and the comet's trail is very small, 0.00028 astronomical units inside the Earth's orbit (about 42 000 km). As usual in such cases, the theoretical radiant should be used only as a rough guide, and all potential meteors from this source plotted, or recorded by instrumental methods, for later analyses. Although circumpolar from latitude 35° S, the radiant area is best visible only well after local midnight. Helpfully, there is no Moon.

Quadrantids (QUA)

Active: January 1–5; Maximum: January 3, 18^h20^m UT ($\lambda = 283\overset{\circ}{.}16$);
ZHR = 120 (can vary $\sim$ 60–200);
Radiant: $\alpha = 230°$, $\delta = +49°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 41$ km/s; $r = 2.1$ at maximum, but variable;
TFC: $\alpha = 242°$, $\delta = +75°$ and $\alpha = 198°$, $\delta = +40° (\beta > 40°$ N).
PFC: 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).

A splendid return of the Quadrantids starts the northern observers' year very well, with an expected peak around 18^h20^m UT on January 3/4. The waxing crescent Moon was new on 2005 December 31, and will set by mid-evening in early January, so producing no significant problems at all. From many northern locations, the shower's radiant is circumpolar, in northern Boötes, but it attains a useful elevation only after local midnight, rising higher in the sky towards morning twilight. Consequently, east Asian to Far Eastern longitudes will be the most favoured places to catch the shower's best, if the peak keeps to time. An interesting challenge is to try spotting the occasional long-pathed shower member from the southern hemisphere around dawn, but sensible Quadrantid watching cannot be carried out from such places.



The maximum time given above is based on the best-observed return of the shower ever analysed, in *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 1998 persisted for over two hours at their best. An added level of complexity comes from the fact that 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 have produced a, primarily radio, maximum following the main visual one by some 9–12 hours. Visual confirmation of any repeat near this time in 2006 would fall ideally for sites in Europe, North Africa and the Near East.

Past observations have suggested the radiant is diffuse away from the maximum, contracting notably during the peak itself, although this may be a result of the very low activity outside the hours near maximum. Photographic and video observations from January 1–5 would be particularly welcomed by those investigating this topic, using the PFCs and TFCs given above, along with telescopic and visual plotting results.

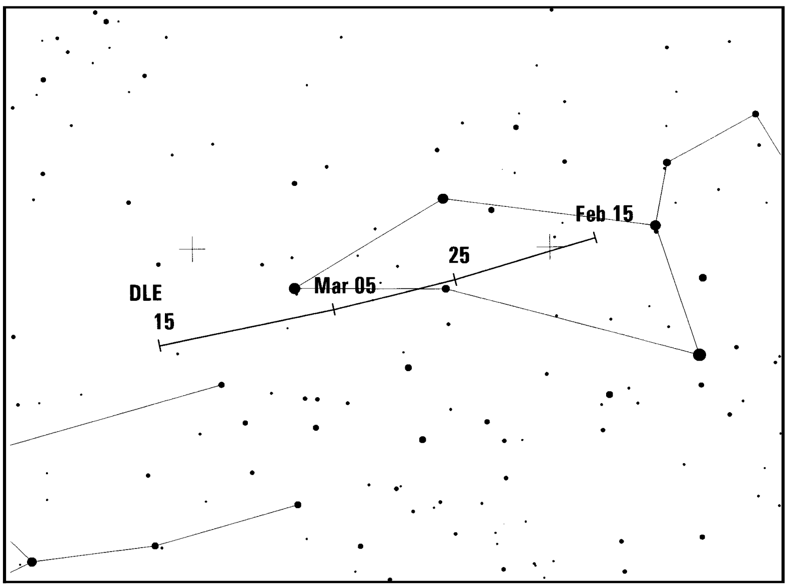
α-Centaurids (ACE)

Active: January 28–February 21; Maximum: February 8, 5^h UT ($\lambda = 319.°2$);
ZHR = variable, usually ~ 6, but may reach 25+;
Radiant: $\alpha = 210°$, $\delta = -59°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 56$ km/s; $r = 2.0$.

In theory, the α-Centaurids are one of the main southern hemisphere high points in the opening months of the year, from past records supposedly producing many very bright, even fireball-class, objects (meteors of at least magnitude -3), commonly with fine persistent trains. Peak ZHRs, though normally listed as around 5–10, have been suggested as much lower from the few sketchy reports made in more recent years. Then again, in 1974 and 1980, bursts of only a few hours' duration yielded activity 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. Thus photographic, video 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. Waxing gibbous moonset is around midnight to 1 a.m. local time this year, so providing one of those better chances to cover the shower, if skies stay clear.

δ-Leonids (DLE)

Active: February 15–March 10; Maximum: February 24 ($\lambda = 336°$); ZHR = 2;
Radiant: $\alpha = 168°$, $\delta = +16°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 23$ km/s; $r = 3.0$;
TFC: $\alpha = 140°$, $\delta = +37°$ and $\alpha = 151°$, $\delta = +22°$($\beta > 10°$ N);
$\alpha = 140°$, $\delta = -10°$ and $\alpha = 160°$, $\delta = 00°$($\beta < 10°$ N).



This minor shower is probably part of the early Virginid activity. Rates are normally low, and its meteors are predominantly faint, so it is a prime candidate for telescopic investigation. Visual observers must make very accurate plots of the meteors to distinguish them from the nearby Virginids and the sporadics. Northern hemisphere sites have an advantage for covering this stream, though southern hemisphere watchers should not ignore it, as they are better placed to note many of the other Virginid radiants. On the peak night, the waning crescent Moon rises in, or shortly before the start of, morning twilight for typical northern sites, but half an hour or so either side of 1^{h} local time for most of the mid-southern hemisphere. In neither case will it be a serious distraction. The δ-Leonid radiant is well on view for most of the night then.

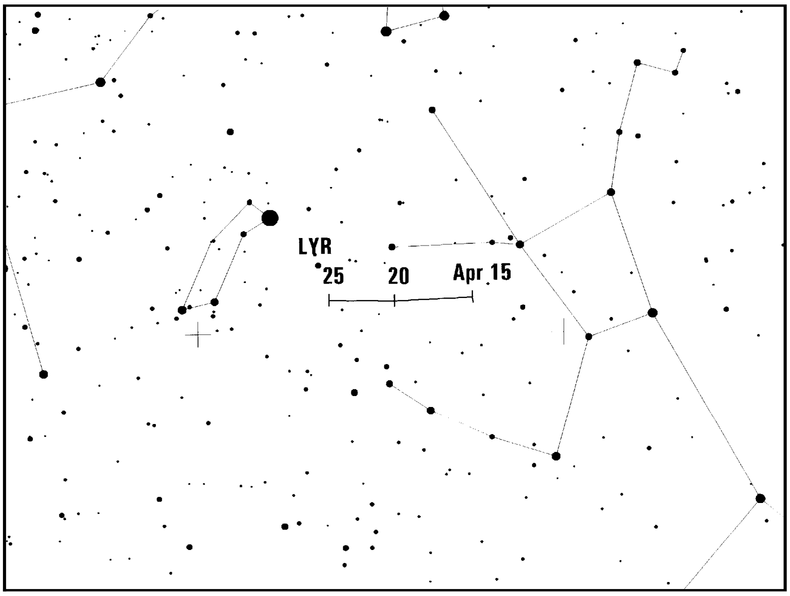
3 April to June

Meteor activity picks up towards the April-May boundary, with shower peaks from the Lyrids and π-Puppids in late April, then the η-Aquarids in early May, all readily available for observations without the Moon. Later in May and throughout June, most of the meteor action switches to the day sky, with six shower maxima expected during this time. Although a few meteors from the o-Cetids and Arietids have been reported 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, 13^{h}; May Arietids – May 16, 14^{h}; o-Cetids – May 20, 13^{h}; Arietids – June 7, 16^{h}; ζ-Perseids – June 9, 16^{h}; β-Taurids – June 28, 15^{h}. Signs of most of these were found in radio data from 1994–2004, though some are difficult to define individually because of their proximity to other radiants, while the Arietid and ζ-Perseid maxima tend to blend into one another, producing a strong radio signature for several days in early June. There are indications these two shower maxima now each occur up to a day later than indicated here too. The visual ecliptical complexes continue with some late Virginids up to mid April, after which come the minor Sagittarids, and their probable peaks in May–June. For northern observers, checking for any June Lyrids should be possible with only some lunar hindrance, while new Moon makes June Boötid hunting very favourable near their potential peak.

Lyrids (LYR)

Active: April 16–25; Maximum: April 22, $16^{\mathrm{h}}30^{\mathrm{m}}$ UT ($\lambda = 32.^{\circ}32$, but may vary – see text);
ZHR = 18 (can be variable, up to 90);
Radiant: $\alpha = 271^{\circ}$, $\delta = +34^{\circ}$; Radiant drift: see Table 6 (page 23);
$V_{\infty} = 49$ km/s; $r = 2.9$;
TFC: $\alpha = 262^{\circ}$, $\delta = +16^{\circ}$ and $\alpha = 282^{\circ}$, $\delta = +19^{\circ}$($\beta > 10^{\circ}$ S).

Audrius Dubietis and Rainer Arlt published a detailed investigation of the Lyrids in *IMO* results from 1988–2000 in 2001, the most detailed examination of the shower in modern times. Several fresh features were found, the most important of which was to redefine the maximum time as variable from year to year between $\lambda = 32.^{\circ}0$–$32.^{\circ}45$ (equivalent to 2006 April 22, $8^{\mathrm{h}}40^{\mathrm{m}}$–$19^{\mathrm{h}}00^{\mathrm{m}}$ UT), with an ideal time of $\lambda = 32.^{\circ}32$. Although the mean peak ZHR was 18 over the thirteen years, the actual highest ZHRs varied dependent on when the maximum occurred. A peak at the ideal time produced the highest ZHRs, ~ 23, while the further the peak happened from this ideal, the more the ZHRs were reduced, to as low as ~ 14. (The last very high rates occurred outside the examined interval, in 1982 over the USA, when a short-lived ZHR of 90 was recorded.) While generally thought of as having a short, quite sharp, maximum, this latest work revealed the shower's peak length was variable too. This was measured by how long ZHRs were above half the maximum value, the Full-Width-Half-Maximum time. It varied from 14.8 hours in 1993 to 61.7 hours in 2000, with a mean value of 32.1 hours. Best rates are normally achieved for just a few hours however. One other aspect found, confirming data from earlier in the 20th century, was that occasionally, as their highest rates occurred, the Lyrids produced a short-lived increase of fainter meteors. Overall, the unpredictability of the shower in any given year always makes it worth watching, since we cannot say when the next unusual return may happen.

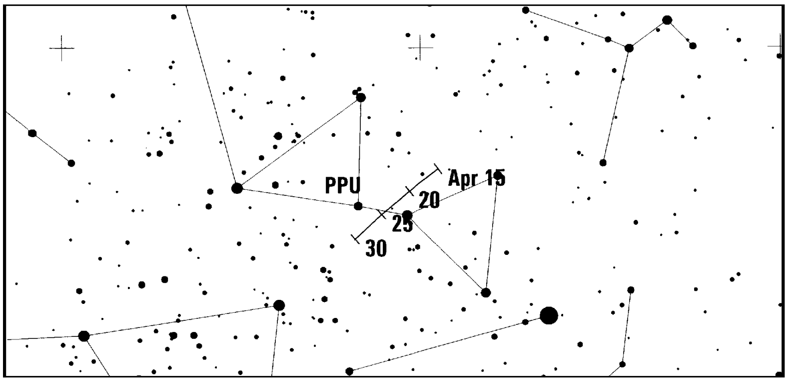


Lyrids are best viewed from the northern hemisphere, but they are visible from many sites north and south of the equator, and are suitable for all forms of observation. As the shower's radiant rises during the night, watches can be usefully carried out from about $22^{\mathrm{h}}30^{\mathrm{m}}$ local time onwards. The waning crescent Moon rises in morning twilight between $\sim 2^{\mathrm{h}}30^{\mathrm{m}}$–$3^{\mathrm{h}}30^{\mathrm{m}}$ local time for mid-northern sites on April 22, giving plenty of darker skies for observers before this. For the mid-southern hemisphere, the Moon rises earlier, between midnight to 1 a.m., but still permits some useful watching. The ideal maximum time, if it recurs, would be best-seen from sites in central Asia eastwards to the Far East and Australia, but other timings are perfectly possible, as noted above.

π-Puppids (PPU)

Active: April 15–28; Maximum: April 23, $21^{\mathrm{h}}30^{\mathrm{m}}$ UT ($\lambda = 33\overset{\circ}{.}5$);
ZHR = periodic, up to around 40;
Radiant: $\alpha = 110°$, $\delta = -45°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 18$ km/s; $r = 2.0$;
TFC: $\alpha = 135°$, $\delta = -55°$ and $\alpha = 105°$, $\delta = -25°$ ($\beta < 20°$ N).

This is a young stream produced by Comet 26P/Grigg-Skjellerup, and activity has only been detected from it since 1972. Notable short-lived maxima of around 40 meteors per hour took place in 1977 and 1982, both years when the parent comet was at perihelion, but before 1982, little activity had been seen at other times. In 1983, a ZHR of about 13 was reported, perhaps suggesting that material has begun to spread further along the comet's orbit, as theory predicts. Comet Grigg-Skjellerup reached perihelion last in late 2002, but nothing significant was detected from this source in 2003 April. The comet's next perihelion passage is in 2008, so activity this year may be unlikely. However, regular monitoring during the shower in future is vital, as coverage has commonly been patchy, and short-lived maxima could have been missed in the past.



The π-Puppids are best-seen from the southern hemisphere, with useful observations mainly practical there before midnight, as the radiant is very low to setting after 1^{h} local time. On April 23, the waning crescent Moon rises only well after this from such locations, creating a perfect observing opportunity. Well-placed sites are likely to be in southern Africa, if the maximum time proves correct. So far, visual and radio data have been collected on the shower, but the slow, bright nature of the meteors makes them ideal photographic subjects too. No telescopic or video data have been reported in any detail as yet.

η-Aquarids (ETA)

Active: April 19–May 28; Maximum: May 6, 6^{h} UT ($\lambda = 45\overset{\circ}{.}5$);
ZHR = 60 (periodically variable, $\sim$ 40–85);
Radiant: $\alpha = 338°$, $\delta = -01°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 66$ 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 sites 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-Aquarids 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 next highest rates should fall towards 2008–2010, if this Jupiter-influenced cycle is borne-out. Thus visual ZHRs should be around 50–60 in 2006, according to this idea. Whatever the case, the waxing gibbous Moon on May 5–6 will have long set for southern hemisphere viewers before the radiant is properly visible. All forms of observing can be used to study the shower, with radio work allowing activity to be followed even from many northern latitude sites throughout the daylight morning hours. The radiant culminates at about $8^{\rm h}$ local time.

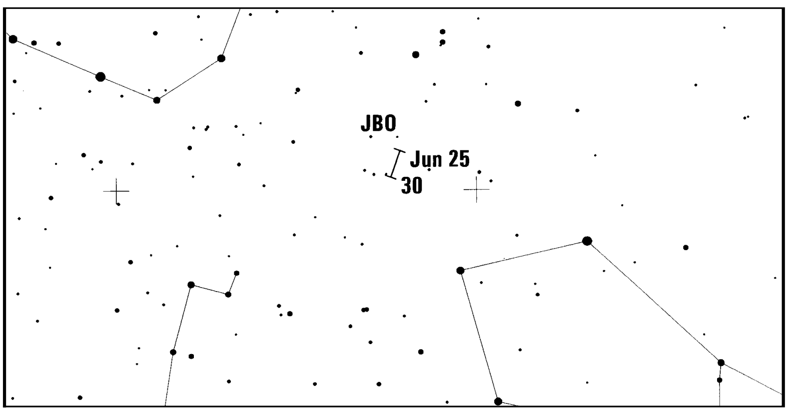
June Lyrids (JLY)

Active: June 11–21; Maximum: June 16 ($\lambda = 85°$); 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 in 2006 has a waning gibbous Moon, which rises in the half hour or so before local midnight, and we urge all observers who can to check for this possible stream in darker skies before moonrise. The radiant is a few degrees south of the bright star Vega (α Lyrae), so is well on-view throughout the short northern summer nights, but there are discrepancies in its position in the literature. All potential June Lyrids should be carefully plotted, paying especial attention to the meteors' apparent velocities. Confirmation or denial of activity from this source by photography or video would be very useful too.

June Boötids (JBO)

Active: June 26–July 2; Maximum: June 27, $14^{\rm h}00^{\rm m}$ UT ($\lambda = 95\overset{\circ}{.}7$);
ZHR = variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +47°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 14$ km/s; $r = 2.2$;
TFC: $\alpha = 156°$, $\delta = +64°$ and $\alpha = 289°$, $\delta = +67°$ ($\beta = 25°$–$60°$ N).



Following its unexpected return of 1998, when ZHRs of 50–100+ were visible for more than half a day, this source was reinstated on the Working List of Visual Meteor Showers. A further 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. We encourage all observers to routinely monitor the expected activity period at least in case of future outbursts. Prior to 1998, only three definite returns had been detected, in 1916, 1921 and 1927, and with no significant reports between 1928–1997, it seemed probable 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. Consequently, the 1998 and 2004 returns resulted from material shed by the comet in the past, and 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. There are no predictions in force for possible activity in 2006 as yet, but new Moon on June 25 means if anything does occur during the shower's possible active period, conditions will be ideal for all forms of observation. At mid-northern sites, the radiant is at a useful elevation for most of the short summer nights, so please be alert!

4 July to September

The minor Pegasids (maximum: July 9) and July Phoenicids (peak on July 13) fall prey to full Moon this year. Next, the near-ecliptic, low activity, Sagittarids end in mid-month, as the various Aquarid sources and the α-Capricornids take up the ecliptical shower complex theme until August. New Moon especially favours all the late-July shower peaks, up to the minor Southern ι-Aquarids in early August. The theoretical Northern δ-Aquarid maximum on August 8, and the major Perseids (whose maximum is most likely between 23^{h}–$1^{h}30^{m}$ UT on August 12–13, though other peaks on August 13 around 2^{h} and 9^{h} UT are also possible from recent past results), both suffer badly from August's full Moon. Simulations by Peter Brown made some years ago suggest enhanced Perseid activity is possible this year, though perhaps not as strongly as in 2004. The timing of any enhancement, though probably not far from the expected spread of possible maxima noted here, is not known. Conditions improve after then for the minor κ-Cygnid and Northern ι-Aquarid peaks. In early September, the α-Aurigid maximum in early September survives the bright Moon, but the minor δ-Aurigid peak on September 9 is lost to lunar glare. Their possible second, weaker, maximum is much better placed later in the month, as is the likely best from the Piscids. For daylight radio observers, the interest of May-June has waned, but there remain the visually impossible γ-Leonids (peak towards August 25, 15^{h} UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids. Their maximum is expected on September 27, 16^{h} UT, but may possibly occur a day earlier. In 1999 a strong return was detected at $\lambda \sim 186°$, equivalent to 2006 September 29, while in 2002, the September 27 peak was not found, but one around September 29–30 was! There is currently some debate over whether several minor maxima in early October may also be due to this radio shower. The waxing crescent Moon at least creates no additional difficulties for visual observers hoping to catch some Sextantids in late September, tricky enough with radiant-rise less than an hour before dawn in either hemisphere anyway.

Piscis Austrinids and Aquarid/Capricornid Complex

Piscis Austrinids (PAU)

Active: July 15–August 10; Maximum: July 28 ($\lambda = 125°$); ZHR = 5;
Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 35$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$,
choose pairs separated by about 30° in α ($\beta < 30°$ N).

Southern δ-Aquarids (SDA)

Active: July 12–August 19; Maximum: July 28 ($\lambda = 125°$); ZHR = 20;
Radiant: $\alpha = 339°$, $\delta = -16°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 41$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$,
choose pairs separated by about 30° in α ($\beta < 40°$ N).

α-Capricornids (CAP)

Active: Jul 3–August 15; Maximum: July 30 ($\lambda = 127°$); ZHR = 4;
Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 23$ km/s; $r = 2.5$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$,
choose pairs separated by about 30° in α ($\beta < 40°$ N);
PFC: $\alpha = 300°$, $\delta = +10°$ ($\beta > 45°$ N),
$\alpha = 320°$, $\delta = -05°$ ($\beta 0°$ to 45° N),
$\alpha = 300°$, $\delta = -25°$ ($\beta < 0°$).

Southern ι-Aquarids (SIA)

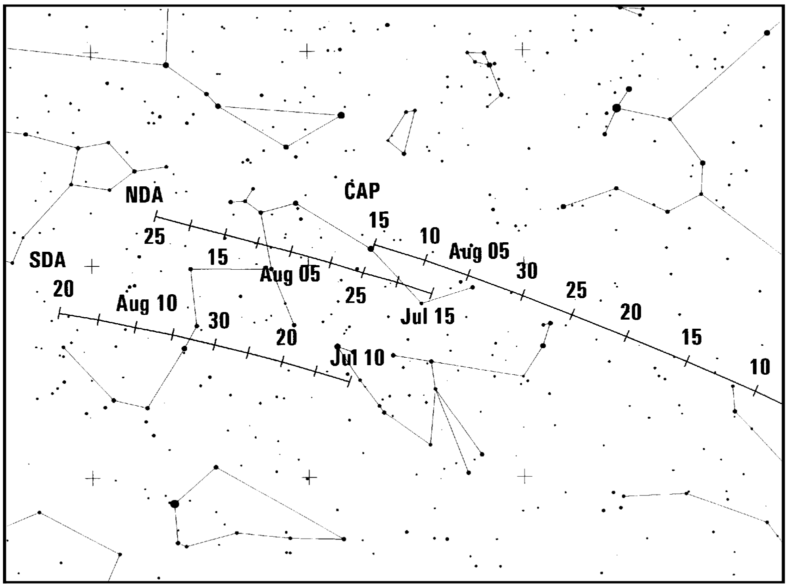
Active: July 25–August 15; Maximum: August 4 ($\lambda = 132°$); ZHR = 2;
Radiant: $\alpha = 334°$, $\delta = -15°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 34$ km/s; $r = 2.9$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$,
choose pairs separated by about 30° in α ($\beta < 30°$ N).

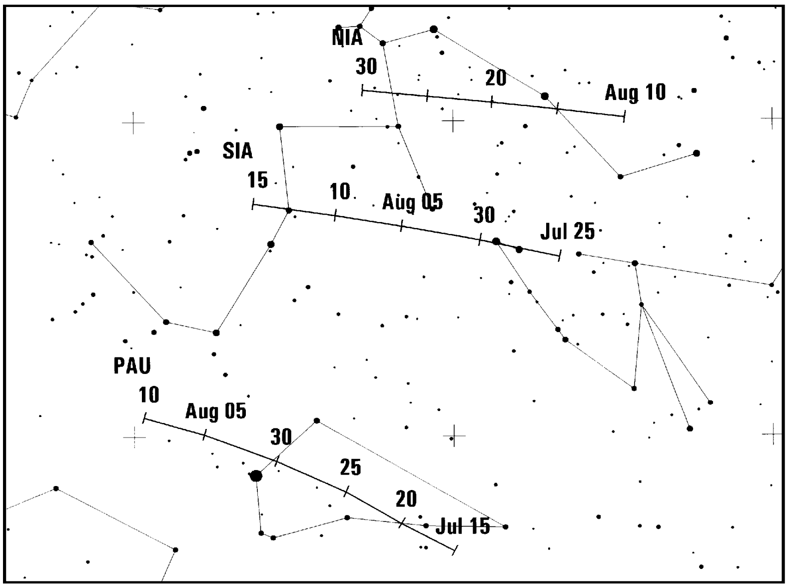
Northern ι-Aquarids (NIA)

Active: August 11–31; Maximum: August 20 ($\lambda = 147°$); ZHR = 3;
Radiant: $\alpha = 327°$, $\delta = -06°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 31$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to $000°$, $\delta = 00°$ to $+15°$,
choose pairs of fields separated by about 30° in α ($\beta < 30°$ N).

A new ten-year visual analysis of the Aquarid streams and the α-Capricornids was published by Audrius Dubietis and Rainer Arlt in the 2004 June issue of the *IMO*'s journal WGN (32:3, pp. 69–76), coupled with a video radiant analysis from 2002 by Y. and T. Shigeno in the same issue (pp. 77–80). This generally confirmed the SDA and CAP maxima as falling around July 28–30 and July 30–31, with ZHRs of around 15 and 5 respectively. The SIA and NIA did not appear at all clearly, unsurprising given their borderline-visible ZHRs, but the greatest oddity was the NDA, for which no distinct maximum could be traced. Their ZHRs were never better than ~ 3. There were also only weak signs of a vague possible radiant for this source in the Japanese video evidence. All this suggests the NDA may be a good deal less active than previously thought, and may not be producing a visually definable maximum at present. The shower parameters have not been amended as a result of these fresh findings, as there was relatively little difference to those established previously for the better sources. Observers should be alert to the fact that

SDA and CAP rates may be near their best beyond the single-date maxima listed however, and that the highest ZHRs may be slightly different to those given as well.





The PAU were not studied in this latest work, but together with the Aquarid showers, these are all streams rich in faint meteors, making them well-suited to telescopic work, although enough brighter members exist to make visual and photographic observations worth the effort too, primarily from more southerly sites. Radio work can be used to pick up the SDA especially, as the most active source, and indeed the shower can sometimes give a surprisingly strong radio signature. The CAP are noted for their bright – at times fireball-class – events, which, combined with their low apparent velocity, can make some of these objects among the most impressive and attractive an observer could wish for. A minor enhancement of CAP ZHRs to ~ 10 was noted in 1995 by European *IMO* observers, although the SDA were the only one of these streams previously suspected of occasional variability.

Such a concentration of radiants in a small area of sky makes for problems in accurate shower association. Visual watchers in particular should plot all potential stream members, rather than trying to make shower associations in the field. The only exception is when the SDA are near their peak, as from southern hemisphere sites in particular, rates may become too high for accurate plotting.

All these radiants are above the horizon for much of the night, so only those with expected peaks close to full Moon really lose out. In 2006, late July's new Moon favours the PAU, SDA and CAP maxima, while the waxing gibbous Moon will still allow some watching for the SIA in early August. The NDA are the main lunar casualty, since August's new Moon improves the chances for covering the NIA later. Although not confirmed more recently, the NIA showed an ill-defined maximum between $\lambda = 148°–151°$ in 1988–95 results, which could mean their better rates (even so, very weak) happen several days after the suspected peak on August 20. If so, those would be still more Moon-free.

κ-Cygnids (KCG)

Active: August 3–25; Maximum: August 18 ($\lambda = 145°$); ZHR = 3;
Radiant: $\alpha = 286°$, $\delta = +59°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 25$ km/s; $r = 3.0$;
PFC: $\alpha = 330°$, $\delta = +60°$ and $\alpha = 300°$, $\delta = +30°$ ($\beta > 20°$ N).

Although rising around midnight, the waning crescent Moon should create few problems for viewing the expected κ-Cygnid peak this year, from the northern hemisphere sites where the shower is chiefly accessible. The 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. The almost stationary radiant results from its close proximity to the ecliptic north pole in Draco. There has been some suggestion of a variation in its activity at times, 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.

Aurigids

α-Aurigids (AUR)

Active: August 25–September 8; Maximum: September 1, 6^h30^m UT ($\lambda = 158.^\circ6$); ZHR = 7;
Radiant: $\alpha = 84°$, $\delta = +42°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 66$ km/s; $r = 2.6$;
TFC: $\alpha = 052°$, $\delta = +60°$; $\alpha = 043°$, $\delta = +39°$ and $\alpha = 023°$, $\delta = +41°$ ($\beta > 10°$ S).

This essentially northern hemisphere shower appears to be part of a series of poorly observed sources with radiants in Aries, Perseus, Cassiopeia and Auriga, active from late August into October. British and Italian observers independently reported a possible new radiant in Aries during late August 1997 for example. Both this shower and the similarly located δ-Aurigids have recently been investigated by analysts Audrius Dubietis and Rainer Arlt, using *IMO*-standard data since 1986, and their known parameters updated accordingly.

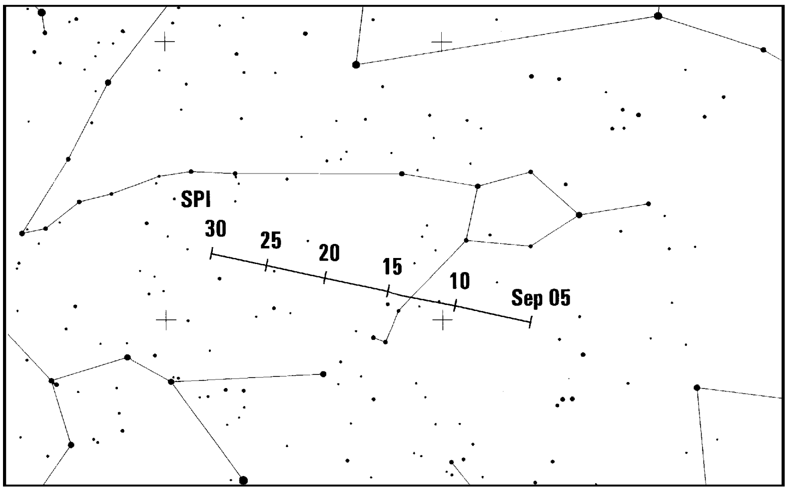
Of these two detected sources, the α-Aurigids are the more active, with short unexpected bursts having given EZHRs of $\sim$ 30–40 in 1935, 1986 and 1994, although they have not been monitored regularly until very recently, so other outbursts may have been missed. Only three watchers in total covered the 1986 and 1994 outbursts, for instance!

The δ-Aurigids probably represent a combination of two separate, but possibly related, minor sources, the September Perseids and δ-Aurigids, whose activities and radiants effectively overlap one another. The showers are not resolvable by visual watchers, who are advised to apply the parameters listed in the Working List (Table 5 below), although these primarily derive from the "September Perseid" phase. The "δ-Aurigid" phase seems to give a weak maximum around $\lambda = 181°$ (2006 September 24; ZHR ~ 3, $r = 2.5$).

The radiants in and near Auriga reach useful elevations after 23^{h}–0^{h} local time. Consequently, the α-Aurigid peak on September 1 is favoured over the main δ-Aurigid one, as the waxing Moon then sets well before this time. Conditions will be still more favourable for the δ-Aurigids' possible September 24 peak, with a waxing crescent Moon. Telescopic data to examine all the radiants in this region of sky – and possibly observe the telescopic β-Cassiopeids simultaneously – would be especially valuable, but photographs, video records and visual plotting would be welcomed too.

Piscids (SPI)

Active: September 1–30; Maximum: September 20 ($\lambda = 177°$); ZHR = 3;
Radiant: $\alpha = 005°$, $\delta = -01°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 26$ km/s; $r = 3.0$;
TFC: $\alpha = 340°$ to $020°$, $\delta = -15°$ to $+15°$,
choose pairs of fields separated by about 30° in α (β any).



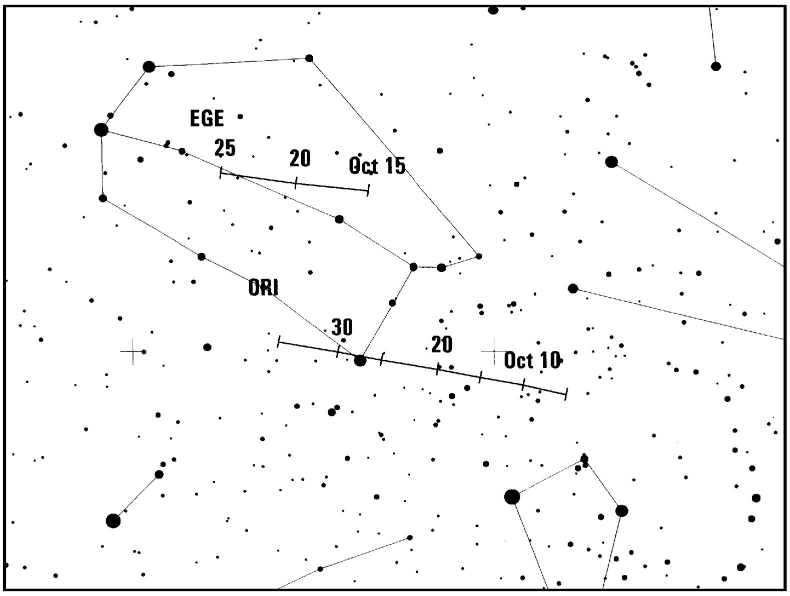
Audrius Dubietis carried out an examination of *IMO* data on the Piscids (earlier known as the Southern Piscids; no other Piscid radiant has been clearly defined as visually active for many years) between 1985–99 in early 2001, which essentially confirmed the current details on it are correct, including that this is another poorly observed minor shower! Its radiant near the maximum is very close to the March equinox point in the sky, and consequently, it can be observed equally well from either hemisphere throughout the night near the September equinox. This year, September's new Moon promises perfect observing conditions. Telescopic and video techniques can be usefully employed to study the Piscids, along with methodical visual plotting.

5 October to December

Potential Draconid hunting will be entirely impractical this year, unless there is a strong outburst (none are predicted), thanks to full Moon on October 7. If anything were to occur from them, their possible past peak timings would span October 8, $14^{h}30^{m}$ UT ($\lambda = 197\overset{\circ}{.}075$, the equivalent 1998 outburst time) and $22^{h}20^{m}$ UT (the nodal crossing time, $\lambda = 195\overset{\circ}{.}4$), to October 9, 4^{h}–7^{h} UT (the equivalent 1999 minor outburst time, $\lambda = 195\overset{\circ}{.}63$–$195\overset{\circ}{.}76$). Fortunately things improve substantially for the ε-Geminids and Orionids later in the month. November's full Moon spoils the Southern Taurid peak on November 5, and even by the Northern branch's maximum on November 12, the Moon will still be a problem for too much of the night. The October part of the potentially interesting late October to early November phase of the Taurids, which occasionally produces enhanced rates or more fireballs than usual, is favoured by a crescent to first quarter Moon at least. Later in November, the Leonids and α-Monocerotids have perfectly moonless skies. The early December mostly minor shower maxima are largely lost to the bright Moon, but this clears away for the Geminids, Coma Berenicids and Ursids. Peaks for the other December showers are: χ-Orionids – December 2; Phoenicids – December 6, $15^{\rm h}$ UT; Puppid-Velids – around December 7; Monocerotids – December 9; σ-Hydrids – December 12.

ε-Geminids (EGE)

Active: October 14–27; Maximum: October 18 ($\lambda = 205°$); ZHR = 2;
Radiant: $\alpha = 102°$, $\delta = +27°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 090°$, $\delta = +20°$ and $\alpha = 125°$, $\delta = +20°$ ($\beta > 20°$ 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 waning crescent Moon will be only a minor distraction long after midnight, so this is a good opportunity to obtain more data on them from either hemisphere. Northern observers have a radiant elevation advantage which they can usefully access from about midnight onwards, but more southerly observers have a later moonrise.

Orionids (ORI)

Active: October 2–November 7; Maximum: October 21 ($\lambda = 208°$); ZHR = 23;
Radiant: $\alpha = 095°$, $\delta = +16°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 66$ km/s; $r = 2.5$;
TFC: $\alpha = 100°$, $\delta = +39°$ and $\alpha = 075°$, $\delta = +24°$ ($\beta > 40°$ N); or $\alpha = 080°$, $\delta = +01°$ and $\alpha = 117°$, $\delta = +01°$ ($\beta < 40°$ N).

October's new Moon almost perfectly favours the Orionids at their peak. The shower's radiant, near the celestial equator, is at a useful elevation by around local midnight in either hemisphere, somewhat before in the north, so most of the world can enjoy the shower. Audrius Dubietis carried out an analysis of the shower in *IMO* data from 1984–2001 in early 2003, allowing some minor modifications to the peak ZHR and r parameters. Both these aspects were shown to vary somewhat from year to year, the maximum mean ZHR especially ranging from $\sim$ 14–31 during the examined interval. In addition, a suspected 12-year periodicity in higher returns found earlier in the 20th century appears to have been partly confirmed, which may mean stronger returns in 2008–10, and perhaps best ZHRs around 20–25 this year. The Orionids were always noted for having several lesser maxima other than the main one above, helping activity sometimes to remain roughly constant for several consecutive nights centred on this peak. In 1993 and 1998, a submaximum about as strong as the normal peak was detected on October 17–18 from Europe, for instance. All observers should be aware of these possibilities, as observing circumstances are favourable for covering much of October 17–18 in dark skies this year. Several visual subradiants were reported in the past, but recent video work suggests the radiant is far less complex; photographic, telescopic and video work to confirm this would be useful, as visual observers have clearly had problems with this shower's radiant determination before.

Leonids (LEO)

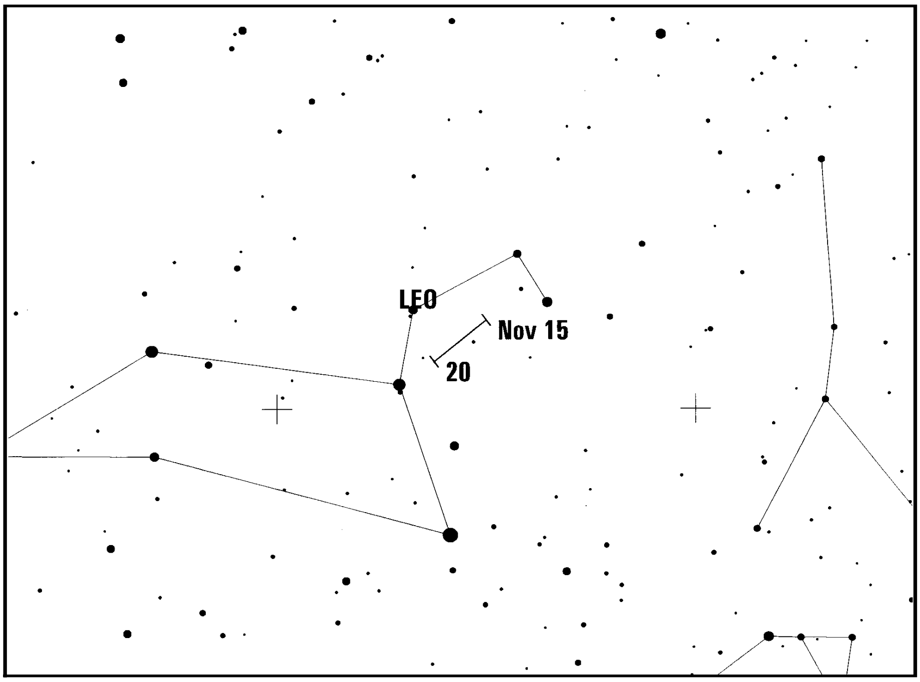
Active: November 14–21; Maximum: November 17, 20^h50^m UT ($\lambda = 235\overset{\circ}{.}27$), but see below; ZHR = 10–100+?;

Radiant: $\alpha = 153°$, $\delta = +22°$; Radiant drift: see Table 6 (page 23);

$V_\infty = 71$ km/s; $r = 2.9$;

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).

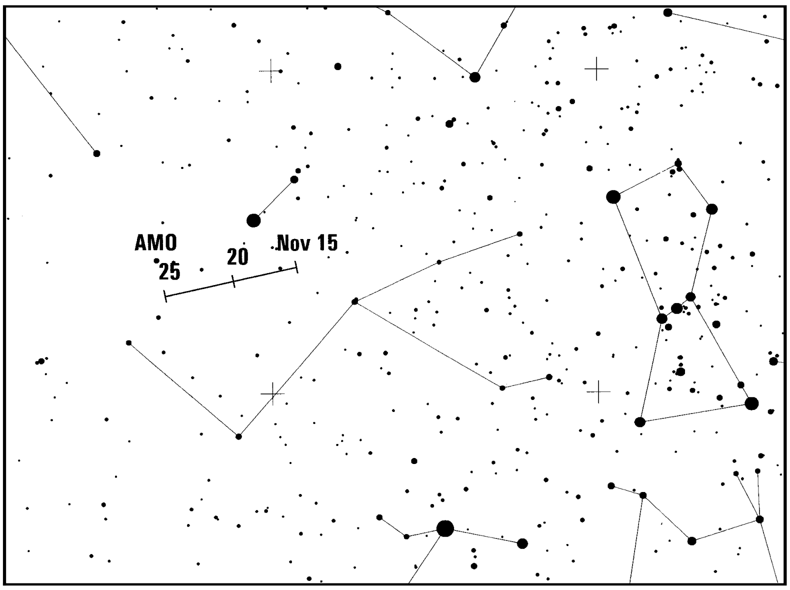
PFC: $\alpha = 120°$, $\delta = +40°$ before 0^h local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = +20°$ before 4^h local time and
$\alpha = 160°$, $\delta = 00°$ after 4^h local time ($\beta > 00°$ N);
$\alpha = 120°$, $\delta = +10°$ before 0^h local time and $\alpha = 160°$, $\delta = -10°$ ($\beta < 00°$ N).



As the events of 2003 and 2004 demonstrated, when enhanced ZHRs of $\sim$ 20–40 were found, the ending of the strong to storm Leonid returns between 1998–2002, associated with the 1998 perihelion passage of parent comet 55P/Tempel-Tuttle, have not meant an end to interest in this fascinating shower. This year may bring a return to still higher Leonid activity, perhaps with ZHRs of 100–150. The timing above is for the nodal crossing, and if recent past years are a guide, any associated activity near then may be swamped by other filaments within the stream. The prediction of higher (though not storm!) rates from the 1933 filament by Rob McNaught and David Asher is timed for November 19, $4^{\rm h}45^{\rm m}$ UT. More recent work by Esko Lyytinen and Tom van Flandern gave a fractionally different timing of $4^{\rm h}48^{\rm m}$ UT, which essentially confirmed the earlier findings. The Leonid radiant rises usefully only around local midnight (or indeed afterwards south of the equator), and with new Moon on November 20, dark skies should prevail almost all night for both potential maxima. A peak close to the nodal crossing time would favour sites across Asia, but the possibly enhanced maximum timing would be best for sites in eastern North America and all of South America eastwards to Africa and Europe. Other possible maxima are not excluded (look out for any late updates in WGN or on the IMO-News e-mailing list), and observers should be watching as often as conditions allow throughout the shower, in case something unexpected happens. All observing techniques can be usefully employed.

α-Monocerotids (AMO)

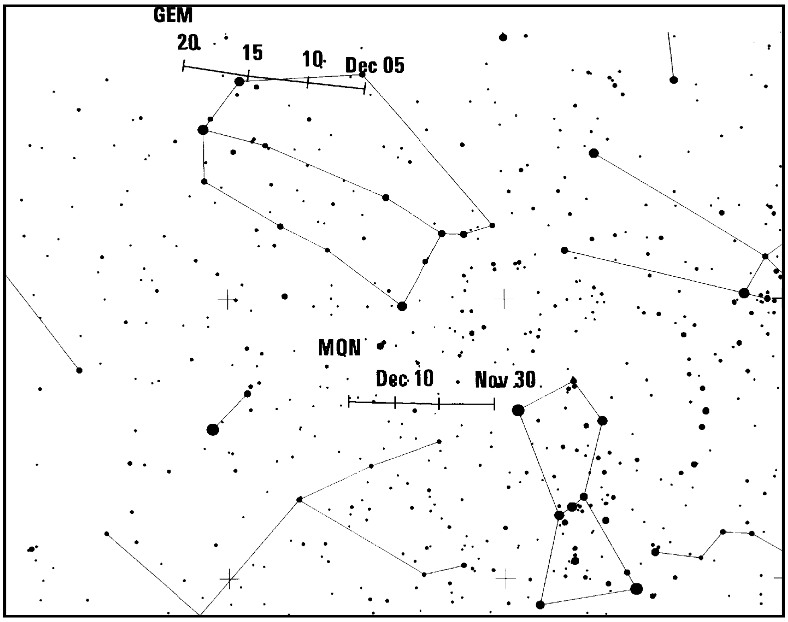
Active: November 15–25; Maximum: November 21, $21^{\rm h}05^{\rm m}$ UT ($\lambda = 239\overset{\circ}{.}32$);
ZHR = variable, usually $\sim$ 5, but may produce outbursts to $\sim$ 400+;
Radiant: $\alpha = 117°$, $\delta = +01°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 65$ km/s; $r = 2.4$;
TFC: $\alpha = 115°$, $\delta = +23°$ and $\alpha = 129°$, $\delta = +20°$ ($\beta > 20°$ N); or
$\alpha = 110°$, $\delta = -27°$ and $\alpha = 098°$, $\delta = +06°$ ($\beta < 20°$ N).



Another late-year shower capable of producing surprises, the α-Monocerotids gave their most recent brief outburst in 1995 (the top EZHR, $\sim$ 420, lasted just five minutes; the entire outburst 30 minutes). Many observers across Europe witnessed it, and we were able to completely update the known shower parameters as a result. Whether this indicates the proposed ten-year periodicity in such returns is real or not is still unknown, as this was written before the 2005 decadal return. Whatever 2005 brought, all observers should continue to monitor this shower closely, in case of other unexpected events. New Moon on November 20 is excellent news for observers this year. The radiant is well on view from either hemisphere only after about 23^{h} local time, so the peak timing would fall especially well for sites from eastern Europe and eastern Africa east across most of Asia.

Geminids (GEM)

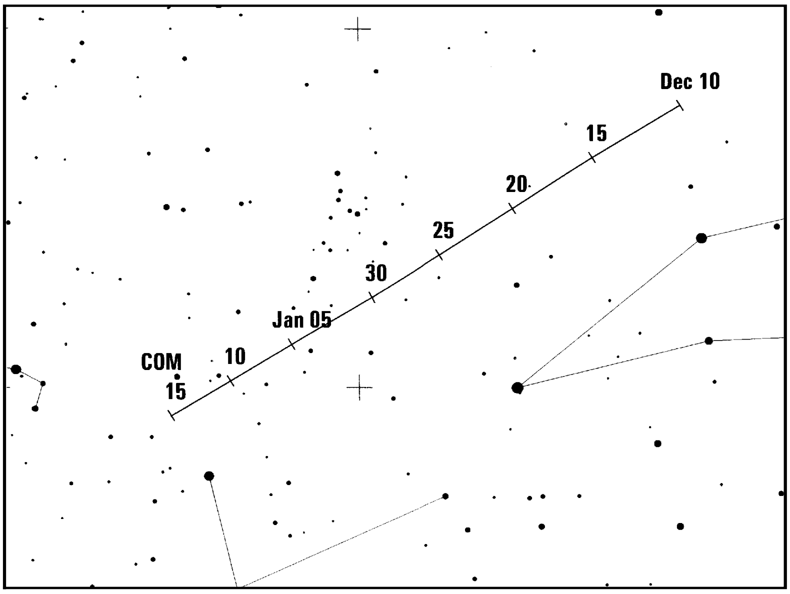
Active: December 7–17; Maximum: December 14, $10^{\mathrm{h}}45^{\mathrm{m}}$ UT ($\lambda = 262.^\circ2$) $\pm$ 2.3h;
ZHR = 120;
Radiant: $\alpha = 112^\circ$, $\delta = +33^\circ$; Radiant drift: see Table 6 (page 23);
$V_\infty = 35$ km/s; $r = 2.6$;
TFC: $\alpha = 087^\circ$, $\delta = +20^\circ$ and $\alpha = 135^\circ$, $\delta = +49^\circ$ before 23^{h} local time,
$\alpha = 087^\circ$, $\delta = +20^\circ$ and $\alpha = 129^\circ$, $\delta = +20^\circ$ after 23^{h} local time ($\beta > 40^\circ$ N);
$\alpha = 120^\circ$, $\delta = -03^\circ$ and $\alpha = 084^\circ$, $\delta = +10^\circ$ ($\beta < 40^\circ$ N).
PFC: $\alpha = 150^\circ$, $\delta = +20^\circ$ and $\alpha = 060^\circ$, $\delta = +40^\circ$ ($\beta > 20^\circ$ N);
$\alpha = 135^\circ$, $\delta = -05^\circ$ and $\alpha = 080^\circ$, $\delta = 00^\circ$ ($\beta < 20^\circ$ N).



One of the finest annual showers presently observable. This year, the waning crescent Moon rises within half an hour of 1^{h} local time across the globe on December 14, but will be a fairly minor nuisance even so. There will be some useful dark-sky observing opportunities, especially from the northern hemisphere, as while the Geminid radiant culminates around 2^{h} local time, well north of the equator it rises around sunset, and is at a usable elevation from the local evening hours onwards. In the southern hemisphere, the radiant appears only around local midnight or so, however. Even from more southerly sites, this is a splendid stream of often bright, medium-speed meteors, a rewarding sight for all watchers, whatever method they employ. The peak has shown slight signs of variability in its rates and timing in recent years, with the more reliably observed maxima during the past two decades all having occurred within 2h20m of the time given above. The main predicted timing favours places in the extreme Far East eastwards right across North and Central America particularly. An earlier or later timing would extend this best-visible zone some way eastwards or westwards respectively. Some mass-sorting within the stream means the fainter telescopic meteors should be most abundant almost 1° of solar longitude (about one day) ahead of the visual maximum, with telescopic results indicating these meteors radiate from an elongated region, perhaps with three sub-centres. Further results on this topic would be useful.

Coma Berenicids (COM)

Active: December 12–January 23; Maximum: December 20 ($\lambda = 268°$); ZHR = 5;
Radiant: $\alpha = 175°$, $\delta = +25°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 65$ km/s; $r = 3.0$;
TFC: $\alpha = 180°$, $\delta = +50°$ and $\alpha = 165°$, $\delta = +20°$ before $3^{\rm h}$ local time,
$\alpha = 195°$, $\delta = +10°$ and $\alpha = 200°$, $\delta = +45°$ after $3^{\rm h}$ local time ($\beta > 20°$ N).

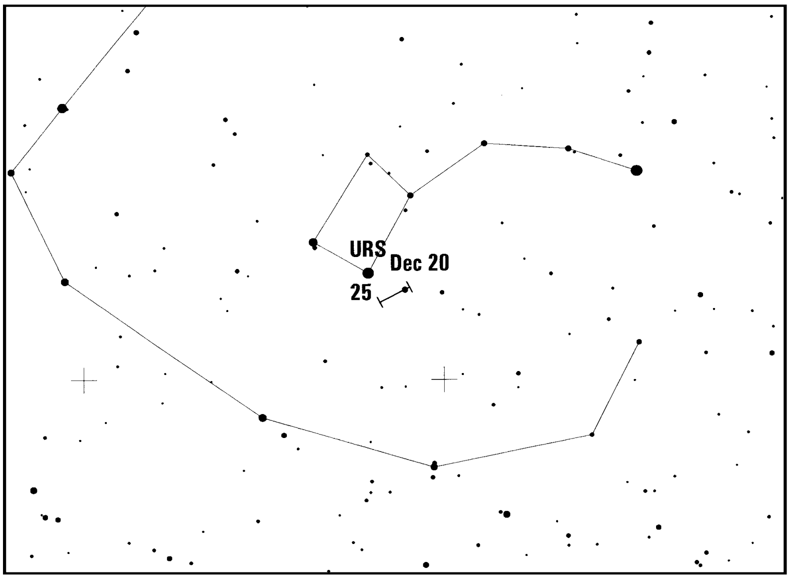


A weak minor shower that is usually observed only during the Geminid and Quadrantid epochs, but which needs more coverage at other times too, especially to better define its maximum. The shower is almost unobservable from the southern hemisphere, so northern watchers must brave the winter cold to improve our knowledge of it. The radiant is at a useful elevation from local midnight onwards, and with a peak exactly at new Moon, conditions are perfect.

Ursids (URS)

Active: December 17–26; Maximum: December 22, $19^{\rm h}$ UT ($\lambda = 270\overset{\circ}{.}7$);
ZHR = 10 (occasionally variable up to 50);
Radiant: $\alpha = 217°$, $\delta = +76°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 33$ km/s; $r = 3.0$;
TFC: $\alpha = 348°$, $\delta = +75°$ and $\alpha = 131°$, $\delta = +66°$ ($\beta > 40°$ N);
$\alpha = 063°$, $\delta = +84°$ and $\alpha = 156°$, $\delta = +64°$ ($\beta = 30°$ to $40°$ N).

A very poorly observed northern hemisphere shower, but one which has produced at least two major outbursts in the past 60 years, in 1945 and 1986. Several other rate enhancements, recently in 1988, 1994 and 2000, have been reported too. Other similar events could easily have been missed 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 $\lambda = 270\overset{\circ}{.}8$, for instance, which might suggest a slightly later maximum time in 2006 of December 22, $21^{\mathrm{h}}30^{\mathrm{m}}$ UT, while the 2000 enhancement was seen surprisingly strongly (EZHR ~ 90) by video at $\lambda = 270\overset{\circ}{.}78$ (equivalent to 2006 December 22, 21^{h} UT), although the visual enhancement was much less, ZHR ~ 30. 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. December's new Moon creates ideal conditions for observing near the maximum. If they recur as suggested, the peak timings should favour northerly sites between Europe and Africa eastwards to the Far East.



6 Radiant sizes and meteor plotting

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.

The 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.

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 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°

Table 2. Error limits for the angular velocity.

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

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

7 Abbreviations and observing tables

- 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 (page 23) 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.

- λ: Solar longitude, a precise measure of the Earth's position on its orbit which is not dependent on the vagaries of the calendar. All λ 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 PFC: Suggested telescopic and small-camera 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 PFC 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 2006.

New Moon	First Quarter	Full Moon	Last Quarter
	January 6	January 14	January 22
January 29	February 5	February 13	February 21
February 28	March 6	March 14	March 22
March 29	April 5	April 13	April 21
April 27	May 5	May 13	May 20
May 27	June 3	June 11	June 18
June 25	July 3	July 11	July 17
July 25	August 2	August 9	August 16
August 23	August 31	September 7	September 14
September 22	September 30	October 7	October 14
October 22	October 29	November 5	November 12
November 20	November 28	December 5	December 12
December 20	December 27		

Table 5. Working list of visual meteor showers. Details in this Table were correct according to the best information available in April 2005. Contact the *IMO*'s Visual Commission for more information. Maximum dates in parentheses indicate reference dates for the radiant, not true maxima. Some showers have ZHRs that vary from year to year. The most recent reliable figure is given here, except for possibly periodic showers that are noted as "var." = variable. An asterisk ("*") in the "λ" column indicates the shower may have other or additional peak times, noted in the text.

Shower	Activity	Maximum Date	Maximum λ	Radiant α	Radiant δ	V_∞ km/s	r	ZHR
Quadrantids (QUA)	Jan 01–Jan 05	Jan 03	283.°16	230°	+49°	41	2.1	120
δ-Cancrids (DCA)	Jan 01–Jan 24	Jan 17	297°	130°	+20°	28	3.0	4
α-Centaurids (ACE)	Jan 28–Feb 21	Feb 08	319.°2	210°	−59°	56	2.0	6
δ-Leonids (DLE)	Feb 15–Mar 10	Feb 24	336°	168°	+16°	23	3.0	2
γ-Normids (GNO)	Feb 25–Mar 22	Mar 13	353°	249°	−51°	56	2.4	8
Virginids (VIR)	Jan 25–Apr 15	(Mar 24)	(4°)	195°	−04°	30	3.0	5
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-Aquarids (ETA)	Apr 19–May 28	May 06	45.°5	338°	−01°	66	2.4	60
Sagittarids (SAG)	Apr 15–Jul 15	(May 20)	(59°)	247°	−22°	30	2.5	5
June Bootids (JBO)	Jun 26–Jul 02	Jun 27	95.°7	224°	+48°	18	2.2	var
Pegasids (JPE)	Jul 07–Jul 13	Jul 09	107.°5	340°	+15°	70	3.0	3
Jul Phoenicids (PHE)	Jul 10–Jul 16	Jul 13	111°	32°	−48°	47	3.0	var
Piscis Austrinids (PAU)	Jul 15–Aug 10	Jul 28	125°	341°	−16°	35	3.2	5
South. δ-Aquarids (SDA)	Jul 12–Aug 19	Jul 28	125°	339°	−30°	41	3.2	20
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	4
South. ι-Aquarids (SIA)	Jul 25–Aug 15	Aug 04	132°	334°	−15°	34	2.9	2
North. δ-Aquarids (NDA)	Jul 15–Aug 25	Aug 08	136°	335°	−05°	42	3.4	4
Perseids (PER)*	Jul 17–Aug 24	Aug 12	140.°0	46°	+58°	59	2.6	100
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 18	145°	286°	+59°	25	3.0	3
North. ι-Aquarids (NIA)	Aug 11–Aug 31	Aug 20	147°	327°	−06°	31	3.2	3
α-Aurigids (AUR)	Aug 25–Sep 08	Sep 01	158.°6	84°	+42°	66	2.6	10
δ-Aurigids (DAU)*	Sep 05–Oct 10	Sep 09	166.°7	60°	+47°	64	2.9	5
Piscids (SPI)	Sep 01–Sep 30	Sep 20	177°	5°	−01°	26	3.0	3
Draconids (GIA)	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	2
Orionids (ORI)	Oct 02–Nov 07	Oct 21	208°	95°	+16°	66	2.5	23
Southern Taurids (STA)	Oct 01–Nov 25	Nov 05	223°	52°	+13°	27	2.3	5
Northern Taurids (NTA)	Oct 01–Nov 25	Nov 12	230°	58°	+22°	29	2.3	5
Leonids (LEO)	Nov 14–Nov 21	Nov 19	235.°27	153°	+22°	71	2.5	100+
α-Monocerotids (AMO)	Nov 15–Nov 25	Nov 21	239.°32	117°	+01°	65	2.4	var
χ-Orionids (XOR)	Nov 26–Dec 15	Dec 02	250°	82°	+23°	28	3.0	3
Dec 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	3
σ-Hydrids (HYD)	Dec 03–Dec 15	Dec 12	260°	127°	+02°	58	3.0	2
Geminids (GEM)	Dec 07–Dec 17	Dec 14	262.°2	112°	+33°	35	2.6	120
Coma Berenicids (COM)	Dec 12–Jan 23	Dec 20	268°	175°	+25°	65	3.0	5
Ursids (URS)	Dec 17–Dec 26	Dec 22	270.°7	217°	+76°	33	3.0	10

Table 6. Radiant drift positions during the year in α and δ.

	COM	**DCA**	**QUA**					
Jan 0	186 +20	112 +22	228 +50					
Jan 5	190 +18	116 +22	231 +49					
Jan 10	194 +17	121 +21						
Jan 20	202 +13	130 +19		**ACE**	**VIR**			
Jan 30				200 -57	157 +16	**DLE**		
Feb 10				214 -60	165 +10	155 +20	**GNO**	
Feb 20				225 -63	172 +6	164 +18	225 -53	
Feb 28					178 +3	171 +15	234 -52	
Mar 10					186 0	180 +12	245 -51	
Mar 20					192 -3		256 -50	
Mar 30					198 -5			
Apr 10	**SAG**	**LYR**	**PPU**		203 -7			
Apr 15	224 -17	263 +34	106 -44	**ETA**	205 -8			
Apr 20	227 -18	269 +34	109 -45	323 -7				
Apr 25	230 -19	274 +34	111 -45	328 -5				
Apr 30	233 -19			332 -4				
May 5	236 -20			337 -2				
May 10	240 -21			341 0				
May 20	247 -22			350 +5				
May 30	256 -23							
Jun 10	265 -23							
Jun 15	270 -23							
Jun 20	275 -23	**JBO**						
Jun 25	280 -23	223 +48						
Jun 30	284 -23	225 +47	**CAP**			**JPE**		
Jul 5	289 -22		285 -16	**SDA**		338 +14		
Jul 10	293 -22	**PHE**	289 -15	325 -19	**NDA**	341 +15	**PER**	**PAU**
Jul 15	298 -21	032 -48	294 -14	329 -19	316 -10		012 +51	330 -34
Jul 20			299 -12	333 -18	319 -9	**SIA**	018 +52	334 -33
Jul 25			303 -11	337 -17	323 -9	322 -17	023 +54	338 -31
Jul 30	**KCG**		308 -10	340 -16	327 -8	328 -16	029 +55	343 -29
Aug 5	283 +58	**NIA**	313 -8	345 -14	332 -6	334 -15	037 +57	348 -27
Aug 10	284 +58	317 -7	318 -6	349 -13	335 -5	339 -14	043 +58	352 -26
Aug 15	285 +59	322 -7		352 -12	339 -4	345 -13	050 +59	
Aug 20	286 +59	327 -6	**AUR**	356 -11	343 -3		057 +59	
Aug 25	288 +60	332 -5	076 +42		347 -2		065 +60	
Aug 30	289 +60	337 -5	082 +42	**DAU**	**SPI**			
Sep 5			088 +42	055 +46	352 -4			
Sep 10			092 +42	060 +47	356 -3			
Sep 15				066 +48	000 -2			
Sep 20				071 +48	005 -1			
Sep 25	**NTA**	**STA**		077 +49	010 0			
Sep 30	021 +11	023 +5	**ORI**	083 +49	015 +1			
Oct 5	025 +12	027 +7	085 +14	089 +49		**GIA**		
Oct 10	029 +14	031 +8	088 +15	095 +49	**EGE**	262 +54		
Oct 15	034 +16	035 +9	091 +15		099 +27			
Oct 20	038 +17	039 +11	094 +16		104 +27			
Oct 25	043 +18	043 +12	098 +16		109 +27			
Oct 30	047 +20	047 +13	101 +16					
Nov 5	053 +21	052 +14	105 +17					
Nov 10	058 +22	056 +15		**LEO**	**AMO**			
Nov 15	062 +23	060 +16		150 +23	112 +2			
Nov 20	067 +24	064 +16	**XOR**	153 +21	116 +1			
Nov 25	072 +24	069 +17	075 +23		120 0	**MON**	**PUP**	**PHO**
Nov 30			080 +23	**HYD**		091 +8	120 -45	014 -52
Dec 5	**COM**	**GEM**	085 +23	122 +3		096 +8	122 -45	018 -53
Dec 10	169 +27	108 +33	090 +23	126 +2		100 +8	125 -45	022 -53
Dec 15	173 +26	113 +33	094 +23	130 +1	**URS**	104 +8	128 -45	
Dec 20	177 +24	118 +32			217 +75			

Table 7. Working list of daytime radio meteor streams. 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.

Shower	Activity	Max Date	λ 2000	Radiant α	Radiant δ	Best observed 50° N	Best observed 35° S	Rate
Cap/Sagittarids	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

8 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: fidac@imo.net

Photographic Commission:
Marc de Lignie, Steve Bikostraat 298, NL-3573 BH Utrecht, The Netherlands.
e-mail: `m.c.delignie@xs4all.nl`

Radio Commission: Temporarily vacant.
e-mail: `radio@imo.net`

Telescopic Commission:
Malcolm Currie, 25 Collett Way, Grove, Wantage, Oxfordshire, OX12 0NT, UK.
e-mail: `tele@imo.net`

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

Visual Commission:
Rainer Arlt, Friedenstr. 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, 161 Vance Street, Chula Vista, CA 91910-4828, USA. e-mail: `lunro.imo.usa@cox.net`

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