International Meteor Organization

2004 Meteor Shower Calendar

compiled by Alastair McBeath[1]

1. Introduction

Welcome to the 2004 International Meteor Organization (*IMO*) Meteor Shower Calendar. The year sees two of the "big three" major shower peaks—the Perseids and Geminids—mostly or entirely free from moonlight interference, but the third, the Quadrantids, are badly moonlit, along with the α-Centaurids, η-Aquarids, and Southern δ-Aquarids. Other more active sources like the Lyrids, Orionids and Leonids, as well as many minor showers in the second half of the year, plus several uncertain sources such as the π-Puppids and June Lyrids, enjoy often moonless skies. What the June Bootids may do in 2004 needs checking too. Do not forget that monitoring of meteor activity should ideally be carried on throughout the rest of the year, however! We appreciate that this is not practical for many observers, and this Calendar was devised as a means of helping observers deal with reality by highlighting times when a particular effort may most usefully be employed. Although we include timing predictions for all the more active night-time and daytime shower maxima, based on the best available data, 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 available 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 guidelines when compiling their information, and submit their data promptly to the appropriate Commission (see page 24) for analysis.

[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.

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 the last few 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, 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

For the major showers, the year begins with a very poor northern-hemisphere Quadrantid return (the waxing gibbous Moon is above the horizon almost all night near the maximum, around 6^{h} UT on January 4), and the southern-hemisphere α-Centaurids are even worse (peak due around $16^{\mathrm{h}}40^{\mathrm{m}}$ UT on February 8; full Moon is on February 6!). The minor δ-Cancrids and δ-Leonids are significantly better-placed. 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, during which several new minor showers have been suggested in recent years, is almost entirely Moon-free, especially for most of the, perhaps core, January 20–27 period. Check your plots for potential swift-meteor radiants in the Coma-Leo-Virgo area and its surrounds particularly. Mid-March sees the southern-hemisphere γ-Normids lose out to last quarter Moon for their possible maximum on March 13, though recent results imply a later peak around March 17 may occur now (rather more favourable for checking). The shower's details are most uncertain, with ZHRs virtually undetectable more than a day or two away from the peak, whenever—or even if—it happens. Daylight radio shower peaks are theoretically due from the Capricornids/Sagittarids around February 2, 2^{h} UT, and the χ-Capricornids on February 14, 3^{h} UT. Recent radio results suggest the Cap/Sgr maximum may variably fall up to 2 or 3 days later than this however, while activity near the expected χ-Capricornid peak has tended to be slight and perhaps a day or so later in 1999–2001. Both showers have radiants $< 10°$–$15°$ west of the Sun at maximum, so cannot be regarded as visual targets even from the southern hemisphere.

δ-Cancrids

Active: January 1–24; Maximum: January 17 ($\lambda_{\odot} = 297°$); ZHR = 4;
Radiant: $\alpha = 130°$, $\delta = +20°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 28$ km/s; $r = 3.0$;
TFC: $\alpha = 115°$, $\delta = +24°$ and $\alpha = 140°$, $\delta = +35°$ ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = -03°$ and $\alpha = 140°$, $\delta = -03°$ ($\beta < 40°$ N).

This minor shower of predominantly faint meteors is well-suited to telescopic observations, with a large, complex, diffuse radiant that probably consists of several sub-centers. Visual observers should assume a minimum radiant size of roughly 20° in α by 10° in δ about the radiant point given above. This type of large, loose radiant area is similar to the Virginids, and the δ-Cancrids are probably an early part of the Virginid activity. Recent observations have suggested the peak may occur close to $\lambda_\odot = 291°$ (2004 January 11), though ZHRs do not rise above $\sim$ 3–4 even then. Last quarter Moon on January 15 means only the January 17 peak time will be observably moonless, and watches to see what occurs near this date should definitely be attempted. The long northern winter nights are ideal for making observations, while the radiant is above the horizon almost all night in either hemisphere.

δ-Leonids

Active: February 15–March 10; Maximum: February 25 ($\lambda_\odot = 336°$); 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).

Like the δ-Cancrids, this minor shower may appear to be part of the Virginid activity but it has a radiant clearly north of the ecliptic and is probably associated with an asteroid, (4450) Pan). 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 shower, but southern hemisphere watchers should not ignore it, as they are better-placed to note many of the other Virginid radiants. On February 25, the waxing crescent Moon sets between about 23^{h}–0^{h} local time for typical northern sites, and before 22^{h} for the mid-southern hemisphere. The radiant is well on view for most of the night near its peak.

3. April to June

Meteor activity picks up towards the April–May boundary, with shower peaks from the moonless Lyrids and π-Puppids. In early May, the η-Aquarids are lost to full Moon for their main broad maximum around May 5. Later in May and throughout June, most of the meteor action switches to the daytime sky, with six shower maxima expected during this time. Although 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, 2^{h}; δ-Piscids—April 24, 2^{h}; ε-Arietids—May 9, 1^{h}; May Arietids—May 16, 2^{h}; o-Cetids—May 20, 1^{h}; Arietids—June 7, 4^{h}; ζ-Perseids—June 9, 1^{h}; β-Taurids—June 28, 3^{h}. Signs of most of these peaks were found in radio data from 1994–2001, though some are difficult to define because of their proximity to other sources, 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 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, with their probable peaks in May–June. Checking for any possible June Lyrids will be very practical, and although the waxing Moon makes June Boötid hunting difficult, it is very important this year.

Lyrids

Active: April 16–25; Maximum: April 22, $4^{\mathrm{h}}10^{\mathrm{m}}$ 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 (page 23);
$V_\infty = 49$ km/s; $r = 2.9$;
TFC: $\alpha = 262°$, $\delta = +16°$ and $\alpha = 282°$, $\delta = +19°$ ($\beta > 10°$ 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 $\lambda_\odot = 32.^\circ0$–$32.^\circ45$ (equivalent to 2004 April 21, $20^{\mathrm{h}}20^{\mathrm{m}}$ UT to April 22, $7^{\mathrm{h}}20^{\mathrm{m}}$ UT), with an ideal time of $\lambda_\odot = 32.^\circ32$. Although the mean peak ZHR was 18 over the thirteen years, actual peak ZHRs varied dependent on when the maximum time 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 maximum 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 (FWHM) time. It varied from 14.8 h in 1993 to 61.7 h in 2000, with a mean value of 32.1 h. 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 the Lyrids worth watching, since we cannot say when the next unusual return may occur.

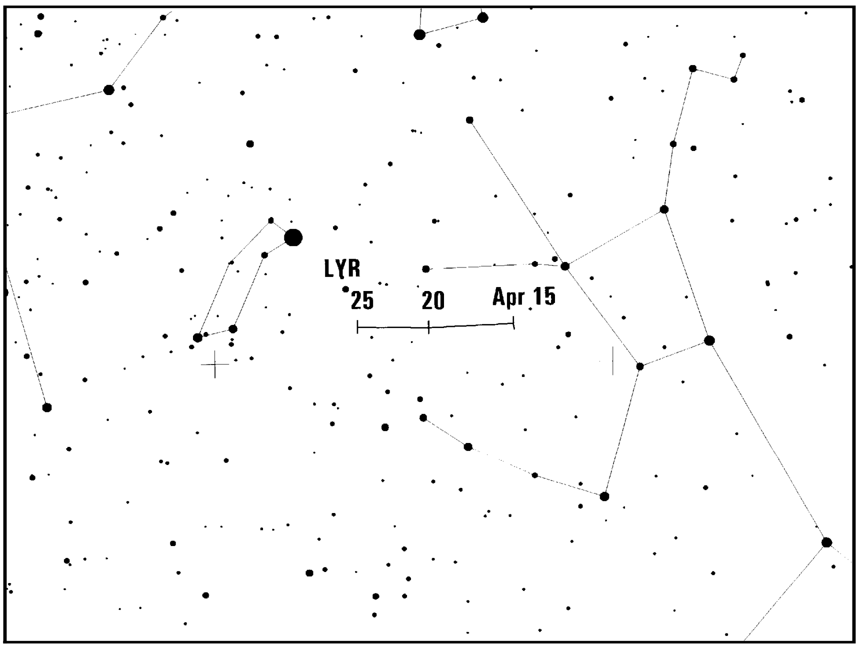

Figure 1 – Radiant position of the Lyrids.

The shower is best viewed from the northern hemisphere, but it is visible from many sites north and south of the equator, and is 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 waxing crescent Moon sets around or well before this time for mid-northern sites on April 21/22, and still sooner further south, so gives no problems. The ideal maximum time, if it recurs, would be best-seen from sites in and immediately adjacent to the North Atlantic Ocean (between roughly longitudes 10° to 70° W). Other maxmum times are perfectly feasible, as outlined earlier.

π-Puppids

Active: April 15–28; Maximum: April 23, 9^h UT ($\lambda_\odot = 33.^\circ 5$); ZHR = periodic, up to ~ 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).

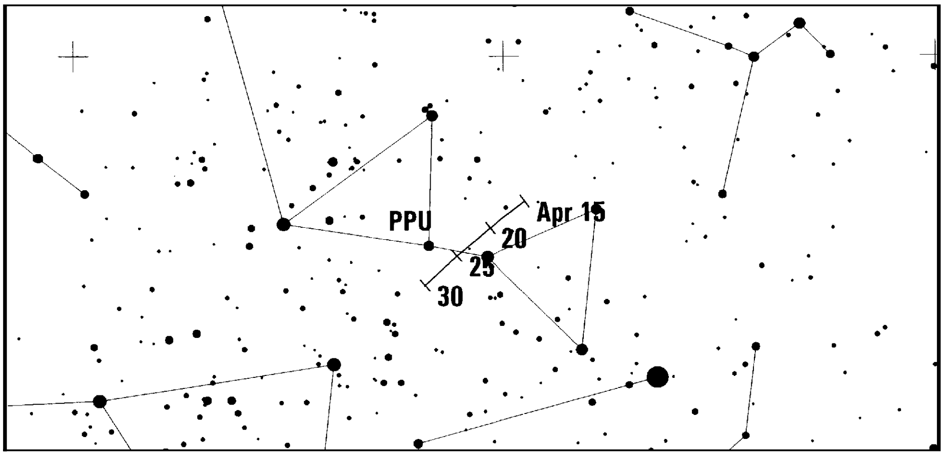

Figure 2 – Radiant position of the π-Puppids.

This is a young stream produced by Comet 26P/Grigg-Skjellerup, and shower activity has only been detected from it since 1972. Notable short-lived shower 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 October 2002, but no readily detectable rates were found in April 2003. However, regular monitoring during the shower's activity in future is vital, as coverage has commonly been patchy, and short-lived showers could have been missed in the past.

The π-Puppids are best seen from the southern hemisphere, with useful observations mainly practical before local midnight, as the radiant is very low to setting after 1^h local time. The waxing crescent Moon will be setting by roughly 19^h–20^h local time from such locations on April 22/23, allowing plenty of dark skies for watching. Well-placed sites are likely to be across the Southern Pacific Ocean, including all of New Zealand and possibly the extreme eastern part of Australia, 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.

June Lyrids

Active: June 11–21; Maximum: June 15 ($\lambda_\odot = 85°$); 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 shower 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 2004 benefits from a nearly-new Moon on June 15, and we urge all observers who can to cover this possible stream. The radiant is a few degrees south of the bright star Vega (α Lyrae), so will be 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

Active: June 26–July 2; Maximum: June 27, 1^h45^m UT ($\lambda_\odot = 95.^\circ7$); 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).

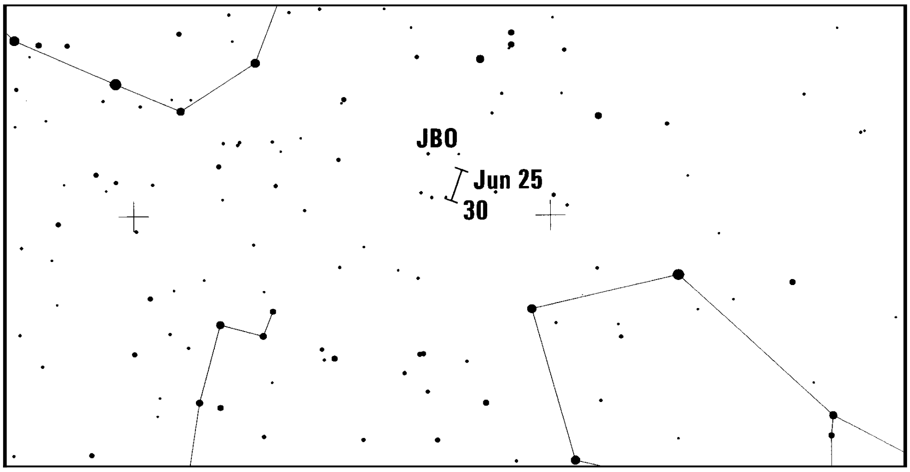

Figure 3 – Radiant position of the June Boötids.

Following the wholly unexpected strong return of this shower in 1998, when ZHRs of 50–100+ were visible for more than half a day, we reintroduced this source to the Working List of Visual Meteor Showers, and encourage all observers to routinely monitor the expected activity period 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 are poorly understood, although recent theoretical modelling has attempted to resolve this problem. The shower's parent Comet 7P/Pons-Winnecke was at perihelion in January 1996 and again in May 2002. Its orbit currently lies around 0.24 astronomical units outside the Earth's at its closest approach, so the 1998 return probably resulted from material shed by the comet in the past (the comet's perihelion returns of 1819 and 1869, or 1825, have been suggested as probable origin dates). A substantial part of these meteoroids are thought to have become trapped in a mean-motion resonance with Jupiter, and presently are in an Earth-intersecting orbit. Work by David Asher and Vasily Emel'yanenko, who favour the 1825 origin date, indicates the Earth may well encounter potentially substantial June Boötid rates again in 2004 on June 27, around 1^h UT. Thus although the waxing gibbous Moon will be a nuisance on June 26/27, it will set between local midnight and 1^h for mid-northern sites, and as the radiant is at a useful elevation for most of the short summer night in the northern hemisphere (only), every effort should be made to secure as much data as possible. Remember too that other nights during the shower may also produce unexpected activity, even if the anticipated peak does not appear, so please be alert!

4. July to September

The minor Pegasid shower is spoilt by last quarter Moon at its July 9 maximum, but the usually minor July Phoenicids are nearly Moon-free. Other minor shower activity continues from various near-ecliptic sources throughout the quarter, first from the Sagittarids till mid July, then from the Aquarids and Capricornids, and finally the Piscids into September. The two stronger sources are lost near full Moon in late July, the Southern δ-Aquarids (peak on July 27) and the α-Capricornids (maximum July 29), along with the minor Piscis Austrinids (best around July 27), and the Southern ι-Aquarids (highest ZHRs of just 2 due around August 4). However, the Northern δ-Aquarid maximum survives the Moon, and this year's Perseid peak is timed to be only slightly moonlit. Better conditions persist for the best from the minor κ-Cygnids and the very weak Northern ι-Aquarids as well. Leap-year means the α-Aurigid maximum moves up to August 31, around 18^{h} UT, too close to full Moon on August 30 to be seen, but the δ-Aurigids have fewer such problems in early September. For daylight radio observers, the interest of May–June has waned, but there remain the visually impossible γ-Leonids (peak circa August 25, 3^{h} UT, albeit not found in recent radio results), and a tricky visual shower, the Sextantids (annual maximum expected on September 27, 3^{h} UT, but possibly occurring a day earlier. In 1999 a strong return was detected at $\lambda_{\odot} \sim 186°$ though, equivalent to 2004 September 28). Full Moon gives added difficulties for visual observers hoping to catch some Sextantids in late September, though the radiant rises less than an hour before dawn in either hemisphere anyway.

July Phoenicids

Active: July 10–16; Maximum: July 13 ($\lambda_{\odot} = 111°$); ZHR = variable 3–10;
Radiant: $\alpha = 032°$, $\delta = -48°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 47$ km/s; $r = 3.0$;
TFC: $\alpha = 041°$, $\delta = -39°$ and $\alpha = 066°$, $\delta = -62°$ ($\beta < 10°$ N).

This minor shower can be seen from the southern hemisphere, from where it attains a reasonable elevation above the horizon after midnight. This is a good year to watch it, since the waning crescent Moon will rise only around $3^{\mathrm{h}}30^{\mathrm{m}}$–$4^{\mathrm{h}}$ local time, and will not be much of a distraction even so. Visual activity can be quite variable, and indeed observations show it to be a richer radio meteor source (possibly also telescopically too; more results are needed). The peak has not been well-observed for some considerable time. Recent years have brought maximum ZHRs of under 4, when the winter weather has allowed any coverage at all. More data would be very welcome!

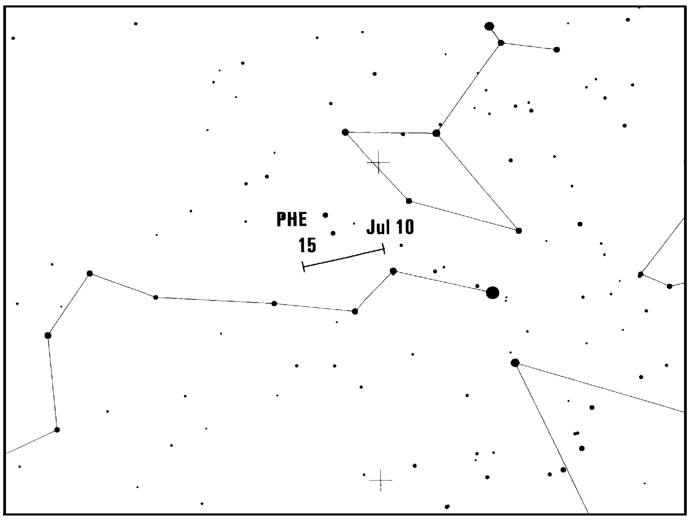

Figure 4 – Radiant position of the July Phoenicids.

Aquarid Complex

Northern δ-Aquarids

Active: July 15–August 25; Maximum: August 8 ($\lambda_{\odot} = 136°$); ZHR = 4;
Radiant: $\alpha = 335°$, $\delta = -05°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 42$ km/s; $r = 3.4$;
TFC: $\alpha = 255°$ to $0°$, $\delta = 0°$ to $+15°$, choose pairs separated by about $30°$ in α ($\beta < 30°$ N).

Northern ι-Aquarids

Active: August 11–31; Maximum: August 19 ($\lambda_{\odot} = 147°$); 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 $0°$, $\delta = 0°$ to $+15°$, choose pairs separated by about $30°$ in α ($\beta < 30°$ N).

The Aquarids are all streams rich in faint meteors, making them well-suited to telescopic work, although enough brighter members exist in the δ-Aquarids especially to make visual and photographic observations worth the effort too, primarily from more southerly sites. The concentration of radiants around Aquarius-Capricornus-Piscis Austrinus means observations with shower association in the field will be highly inaccurate. Visual watchers in particular should plot any potential members of all of these radiants rather than trying to make shower associations directly under the sky.

In 2004, less strong moonlight favours only these two sources, neither of which are particularly active. The Northern ι-Aquarids showed an ill-defined maximum between $\lambda_{\odot} = 148°$–$151°$ in 1988–1995 results, which could mean the highest rates (even so, very weak) happen several days after the suspected peak time given here. The early-setting crescent Moon on August 19 leaves plenty of dark skies for observing overnight then, even up to four days later and first quarter Moon. All these radiants are above the horizon for much of the night.

Perseids

Active: July 17–Aug 24; Maximum: Aug 12, 11^{h}–$13^{h}20^{m}$ UT ($\lambda_{\odot} = 140\overset{\circ}{.}0$–$140\overset{\circ}{.}1$), see text;
ZHR = 100;
Radiant: $\alpha = 046°$, $\delta = +58°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 59$ km/s; $r = 2.6$;
TFC: $\alpha = 019°$, $\delta = +38°$ and $\alpha = 348°$, $\delta = +74°$ before 2^{h} local time;
$\alpha = 043°$, $\delta = +38°$ and $\alpha = 073°$, $\delta = +66°$ after 2^{h} local time ($\beta > 20°$ N);
PFC: $\alpha = 300°$, $\delta = +40°$, $\alpha = 000°$, $\delta = +20°$ or $\alpha = 240°$, $\delta = +70°$ ($\beta > 20°$ 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 since 2000, it has failed to appear. This was not unexpected, as the outbursts and the primary maximum (which was not noticed before 1988), were associated with particles accompanying the parent comet 109P/Swift-Tuttle passing perihelion in 1992. The comet's orbital period is about 130 years, so it is now receding back into the outer Solar System, and theory predicts that such outburst rates should dwindle as the comet to Earth distance increases. An average annual shift of $+0\overset{\circ}{.}05$ in $\lambda_{\odot}$ had been deduced from 1991–1999 data, and allowing for this could give a possible primary peak time around 11^{h} UT on August 12 ($\lambda_{\odot} = 140\overset{\circ}{.}01$) coinciding with the most probable maximum time of the "traditional" peak always previously found, given above. Another feature, seen only in IMO data from 1997–1999, was a tertiary peak at $\lambda_{\odot} = 140\overset{\circ}{.}4$, the repeat time for which would be shortly before 21^{h} UT on August 12. Some researchers commented several years ago that 2004 might see a return of the primary peak for a year or two. Esko Lyytinen has produced more details refining this, which suggests the Earth will pass 0.0012 astronomical units (about 180 000 km) from the dust trail laid down at Comet Swift-Tuttle's 1862 return at $\lambda_{\odot} = 139\overset{\circ}{.}441$, $20^{\mathrm{h}}54^{\mathrm{m}}$ UT on August 11. While very uncertain, he indicates ZHRs could be ~ 100 then, with a slight possibility of higher rates still, perhaps even up to storm levels, although the FWHM could be very short, perhaps just 15 minutes. However, this could be set against a background of higher general Perseid activity, thanks to the influence of Jupiter on the meteoroid stream, and the date should bring strengthening pre-maximum Perseid rates in any case.

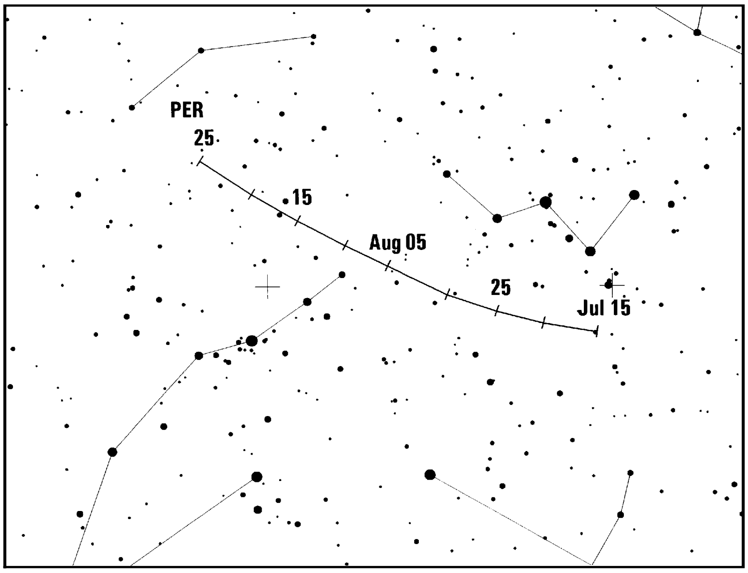

Figure 5 – Radiant position of the Perseids.

Whatever happens, and whenever the peak or peaks fall on August 11 or 12, the waning crescent Moon, four days from new on August 12, will be only a minor nuisance, though it will be rising around local midnight to 1^{h} from mid-northern latitudes, in Taurus to Gemini. The radiant rises throughout the night for these more favourable locations, from where useful watching can commence an hour or two before local midnight. The various potential maxima would be best-viewed from: eastern Europe and eastern North Africa east to central Russia, India and western China (the additional August 11, $\sim 21^{\mathrm{h}}$ UT model prediction), the extreme east of Russia and possibly the Japanese island of Hokkaido east to the extreme western USA (August 12, 11^{h} UT); eastern Russia and eastern China east to Alaska (August 12, $13^{\mathrm{h}}20^{\mathrm{m}}$ UT).

Visual and photographic observers should need little encouragement to cover this stream, but telescopic and video watching near the main peak would be valuable in confirming or clarifying the possibly multiple nature of the Perseid radiant, something not detectable visually. Recent video results have shown a very simple, single radiant structure certainly. Radio data would naturally enable early confirmation, or detection, of perhaps otherwise unobserved maxima if the timings or weather conditions prove unsuitable for land-based sites. The only negative aspect to the shower is the impossibility of covering it from the bulk of the southern hemisphere.

κ-Cygnids

Active: August 3–25; Maximum: August 17 ($\lambda_{\odot} = 145°$); 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).

New Moon on August 16 creates perfect viewing conditions for the expected κ-Cygnid peak this year, but the shower is chiefly accessible from the northern hemisphere only. Its r-value suggests telescopic and video observers may benefit from its presence, but visual and photographic workers should note that occasional slow fireballs from this source have been reported too. Its 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 urgently needed on a shower that is often ignored in favour of the Perseids during August.

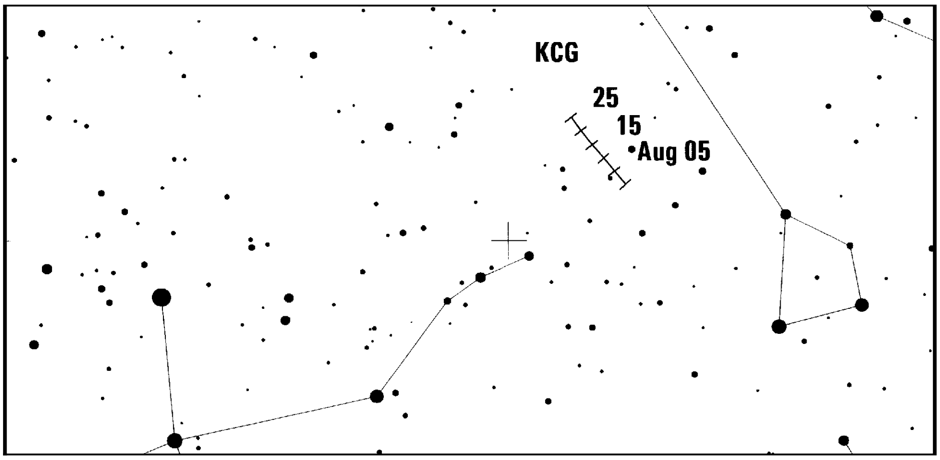

Figure 6 – Radiant position of the κ-Cygnids.

δ-Aurigids

Active: September 5–October 10; Maximum: September 9 ($\lambda_\odot = 166.^\circ7$); ZHR = 5;
Radiant: $\alpha = 060^\circ$, $\delta = +47^\circ$, Radiant drift: see Table 6 (page 23);
$V_\infty = 64$ km/s; $r = 2.9$;
TFC: $\alpha = 052^\circ$, $\delta = +60^\circ$; $\alpha = 043^\circ$, $\delta = +39^\circ$ and $\alpha = 023^\circ$, $\delta = +41^\circ$ ($\beta > 10^\circ$ S).

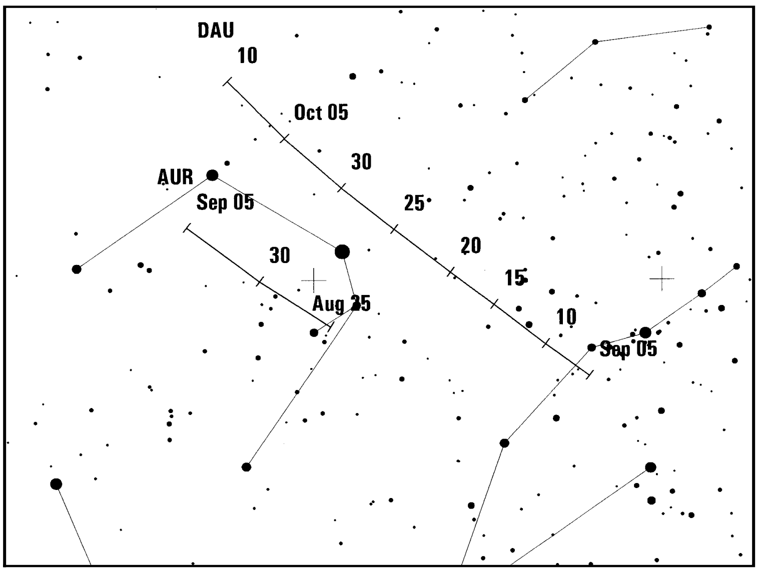

Figure 7 – Radiant position of the α-Aurigids and δ-Aurigids.

A detailed, fresh analysis of the low-activity, and little-studied, δ-Aurigids was carried out by Audrius Dubietis and Rainer Arlt using *IMO* data from 1991–2001 in 2002. This demonstrated the shower probably represents a combination of two separate, but possibly related, minor sources, the September Perseids, for which the maximum time given above holds, and the δ-Aurigids, whose activities and radiants effectively overlap one another. The showers are probably not resolvable by visual watchers, who are advised to retain the, slightly amended, shower parameters listed above. The actual δ-Aurigid phase seems to give a weak maximum around $\lambda_\odot = 181°$ (2004 September 23; ZHR $\sim$ 3, $r = 2.5$). The shower is essentially a northern hemisphere event, and it needs to be noted that there is a series of poorly observed radiants in or near Aries, Perseus, Cassiopeia and Auriga, active from late August to October. British and Italian observers independently reported a possible new radiant in Aries during late August 1997 for example.

The radiant reaches a useful elevation after 23^{h}–0^{h} local time, unfortunately around waning crescent moonrise on September 8/9, though this should not be too great a distraction. The waxing gibbous Moon sets about this time on September 23 at least! 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

Active: September 1–30; Maximum: September 19 ($\lambda_\odot = 177°$); 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).

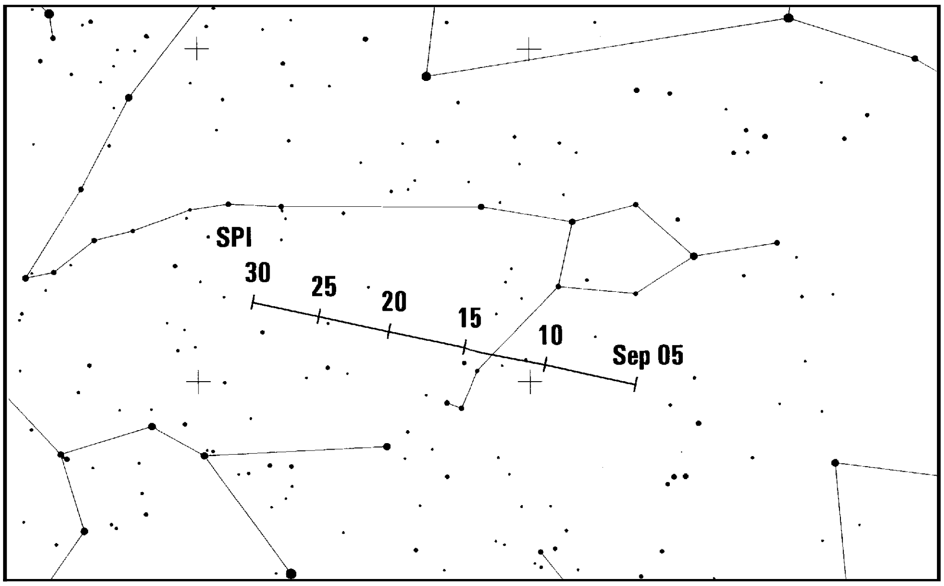

Figure 8 – Radiant position of the Piscids.

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 1985–1999 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, the waxing crescent Moon gives at least the second half of the night with dark skies for observers (longer in the northern hemisphere). Telescopic and video techniques can be usefully employed to study the Piscids, along with methodical visual plotting.

5. October to December

New Moon in these three months falls such that observations of 13 of the 15 meteor showers with potential maxima can receive some useful coverage at least. The two which lose out as too near full Moon are the χ-Orionids (maximum on December 1) and the Ursids (peak due on December 22, most likely near 7^{h} UT, but possibly up to two hours or so later).

Draconids

Active: October 6–10; Maximum: October 8, 10^{h} UT ($\lambda_\odot = 195\overset{\circ}{.}4$, 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 $\sim$ 20–500+), most recently in 1998 (when EZHRs briefly reached 700). Most detected showers were in years when the stream's parent comet, 21P/Giacobini-Zinner, returned to perihelion, as last in 1998 November. The next return of the comet is in mid 2005. The 1998 outburst happened at $\lambda_\odot = 195\overset{\circ}{.}075$, equivalent to 2004 October 8, $2^{\mathrm{h}}10^{\mathrm{m}}$ UT, although the nodal crossing time used above, close to $\lambda_\odot = 195\overset{\circ}{.}4$, may be more generally applicable. In 1999 an unexpected minor visual-radio outburst (ZHRs $\sim$ 10–20) occurred over the Far East between $\lambda_\odot = 195\overset{\circ}{.}63$–$195\overset{\circ}{.}76$. A repeat at this time would be on 2004 October 8, $15^{\mathrm{h}}40^{\mathrm{m}}$–$18^{\mathrm{h}}50^{\mathrm{m}}$ UT. The radiant is circumpolar from many northern hemisphere locations, but is higher in the pre-midnight and near-dawn hours in early October. The waning crescent Moon makes this a good year to see what the shower yields—even if this is nothing detectable. Draconid meteors are exceptionally slow-moving, a characteristic which helps separate genuine shower meteors from sporadics accidentally lining up with the radiant.

ε-Geminids

Active: October 14–27; Maximum: October 18 ($\lambda_\odot = 205°$); 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 early-setting waxing crescent Moon on October 18 presents an excellent opportunity to obtain more data on them from either hemisphere, although northern observers have an advantage, and can usefully access the radiant from about midnight onwards.

Orionids

Active: October 2–November 7; Maximum: October 21 ($\lambda_\odot = 208°$); 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 waxing gibbous Moon favours the Orionids on October 20/21, as it will be setting—or indeed have long set for the northern hemisphere—by the time the radiant is at a useful elevation (around local midnight in either hemisphere, somewhat before in the north). Most of the globe can enjoy the shower, as the radiant is quite near the celestial equator. Audrius Dubietis carried out an analysis of the shower in *IMO* data from 1984–2001 in early 2003, which has allowed some minor modifications to the peak ZHR and r parameters above. Both these aspects were also shown to vary somewhat from year to year, the maximum mean ZHR especially ranging from $\sim$ 14–31 during the last two decades. 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 2008–2010. 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 very favourable for covering October 17/18 in dark skies this year. Several subradiants have been 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.

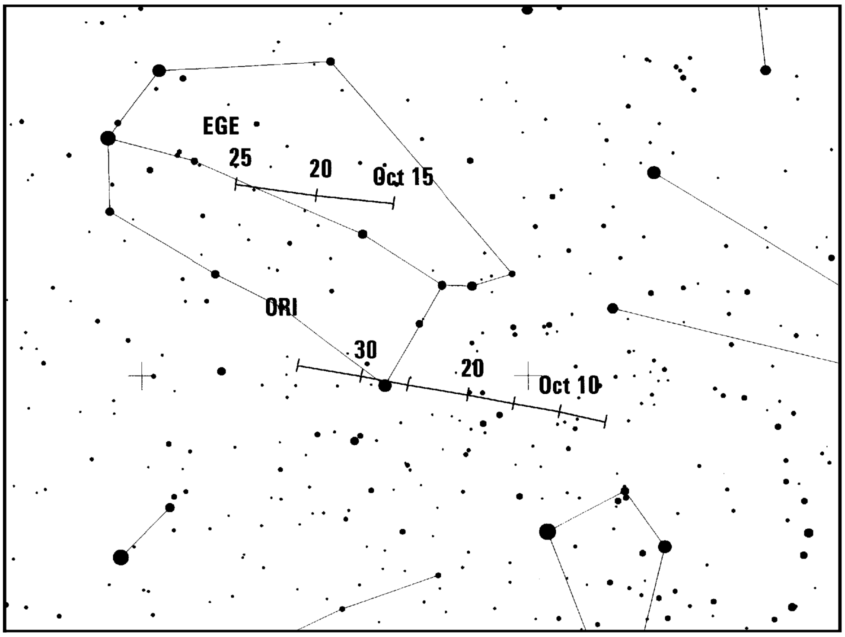

Figure 9 – Radiant position of the ε-Geminids and Orionids.

Taurids

Southern Taurids

Active: October 1–November 25; Maximum: November 5 ($\lambda_{\odot} = 223°$); ZHR = 5;
Radiant: $\alpha = 052°$, $\delta = +13°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 27$ 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

Active: October 1–November 25; Maximum: November 12 ($\lambda_{\odot} = 230°$); ZHR = 5;
Radiant: $\alpha = 058°$, $\delta = +22°$, Radiant drift: see Table 6 (page 23);
$V_{\infty} = 29$ km/s; $r = 2.3$;
TFC: as Southern Taurids.

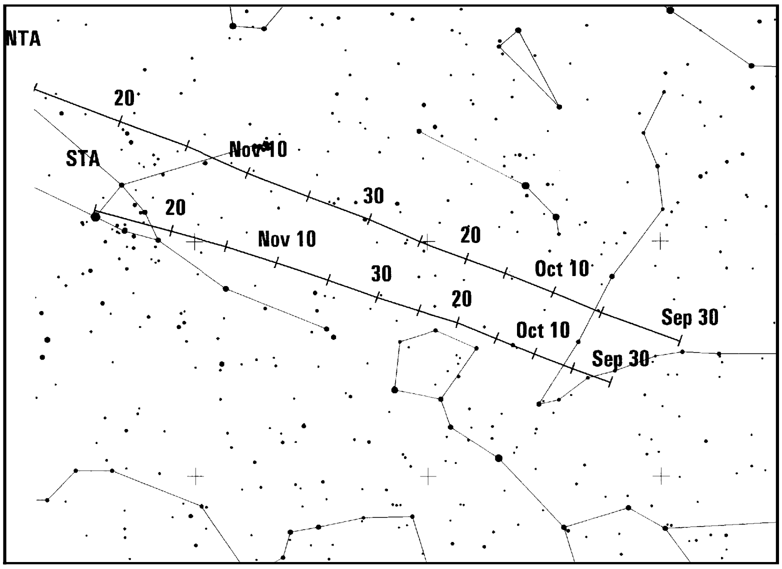

Figure 10 –Radiant position of the Northern and Southern Taurids.

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, photography or video work, since they are large and diffuse. They are currently being studied using *IMO* data by Mihaela Triglav. The brightness and relative slowness of many shower meteors makes them ideal targets for photography, while these factors coupled with low, steady, combined Taurid rates makes them excellent targets for newcomers to practice their plotting techniques on. The activity of both streams produces an apparently plateau-like maximum for about ten days in early November, and the showers have a reputation for producing some excellently bright fireballs at times, although seemingly not in every year. David Asher has indicated that increased Taurid fireball rates may result from a "swarm" of larger particles within the Taurid stream complex, and he suggested such "swarm" returns might happen in 1995 and 1998 most recently. In 1995, an impressive crop of bright Taurids occurred between late October to mid November, while in 1998, Taurid ZHRs reached levels comparable to the usual maximum rates in late October, together with an increased flux of brighter Taurids generally. The next potential October–November "swarm" return is not predicted until 2005, but we cannot be sure how correct this is as yet. Unfortunately, full Moon ruins this period in 2004, but this does mean a last quarter waning to new Moon for the regular early November maxima.

The near-ecliptic radiants for both shower branches mean all meteoricists can observe the streams. Northern hemisphere observers are somewhat better-placed, as here suitable radiant zenith distances persist for much of the late autumnal nights. Even in the southern hemisphere, a good 3–5 hours' watching around local midnight is possible with Taurus well above the horizon, however.

Leonids

Active: November 14–21; Maximum: November 17, $8^{\mathrm{h}}25^{\mathrm{m}}$ UT ($\lambda_{\odot} = 235.^{\circ}27$); ZHR = 10–50+
Radiant: $\alpha = 153^{\circ}$, $\delta = +22^{\circ}$; Radiant drift: see Table 6 (page 23);
$V_{\infty} = 71$ km/s; $r = 2.9$;
TFC: $\alpha = 140^{\circ}$, $\delta = +35^{\circ}$ and $\alpha = 129^{\circ}$, $\delta = +06^{\circ}$ ($\beta > 35^{\circ}$ N); or
$\alpha = 156^{\circ}$, $\delta = -03^{\circ}$ and $\alpha = 129^{\circ}$, $\delta = +06^{\circ}$ ($\beta < 35^{\circ}$ N).
PFC: $\alpha = 120^{\circ}$, $\delta = +40^{\circ}$ before 0^{h} local time ($\beta > 40^{\circ}$ N);
$\alpha = 120^{\circ}$, $\delta = +20^{\circ}$ before 4^{h} local time and
$\alpha = 160^{\circ}$, $\delta = 00^{\circ}$ after 4^{h} local time ($\beta > 00^{\circ}$ N);
$\alpha = 120^{\circ}$, $\delta = +10^{\circ}$ before 0^{h} local time and
$\alpha = 160^{\circ}$, $\delta = -10^{\circ}$ ($\beta < 00^{\circ}$ N).

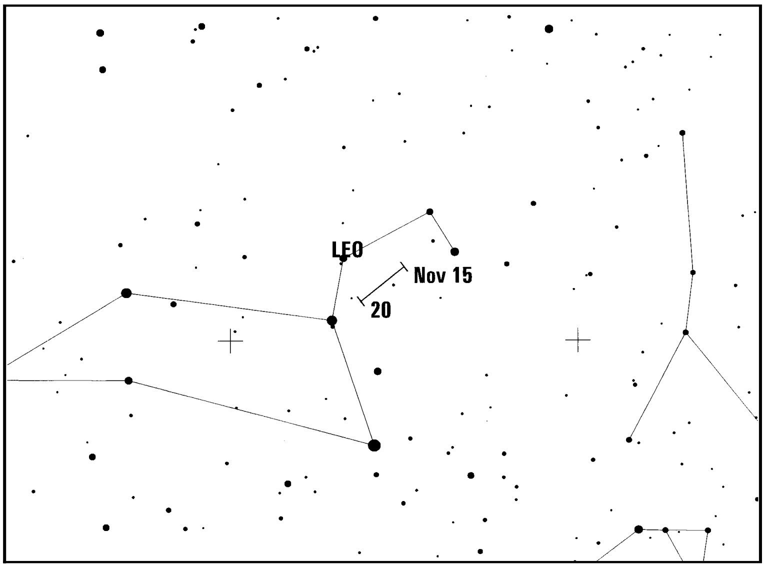

Figure 11 –Radiant position of the Leonids.

In theory, the ending of the strong to storm Leonid returns between 1998–2002 associated with particles accompanying the shower's parent comet, 55P/Tempel-Tuttle, which had returned to its perihelion in 1998, should mean 2004 will see a continuing decline in activity back towards its earlier ZHRs of $\sim$ 10–15. Certainly, no enhanced activity is predicted, although as meteor enthusiasts know well, surprises can occur from even the best-known showers on occasion! Observers should be alert to covering whatever the shower produces, as following the post-storm phases after this best-ever observed run of storm returns is as vital to our understanding of the stream as seeing the storms themselves. The Leonid radiant rises usefully only around local midnight (or indeed afterwards south of the equator), splendid news, as the waxing crescent Moon will have set long before this time on November 16/17. If the peak occurs close to the nodal crossing time above, it will favour sites across the Americas, but other peak times cannot be excluded, 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

Active: November 15–25; Maximum: November 21, $8^{\mathrm{h}}45^{\mathrm{m}}$ UT ($\lambda_{\odot} = 239.^{\circ}32$);
ZHR = variable, usually $\sim$ 5, but may produce outbursts to $\sim$ 400+;
Radiant: $\alpha = 117^\circ$, $\delta = +01^\circ$; Radiant drift: see Table 6 (page 23);
$V_\infty = 65$ km/s; $r = 2.4$;
TFC: $\alpha = 115^\circ$, $\delta = +23^\circ$ and $\alpha = 129^\circ$, $\delta = +20^\circ$ ($\beta > 20^\circ$ N); or
$\alpha = 110^\circ$, $\delta = -27^\circ$ and $\alpha = 098^\circ$, $\delta = +06^\circ$ ($\beta < 20^\circ$ 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 have been 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, only the future will tell (next year!), so all observers should continue to monitor this source closely. The waxing gibbous Moon on November 20/21 will have set by 1^{h}–2^{h} local time across much of the world, so observing is eminently practical, because the radiant is well on view from either hemisphere after about 23^{h} local time. The expected peak falls especially well for sites in the Americas, except for the more easterly parts of South America.

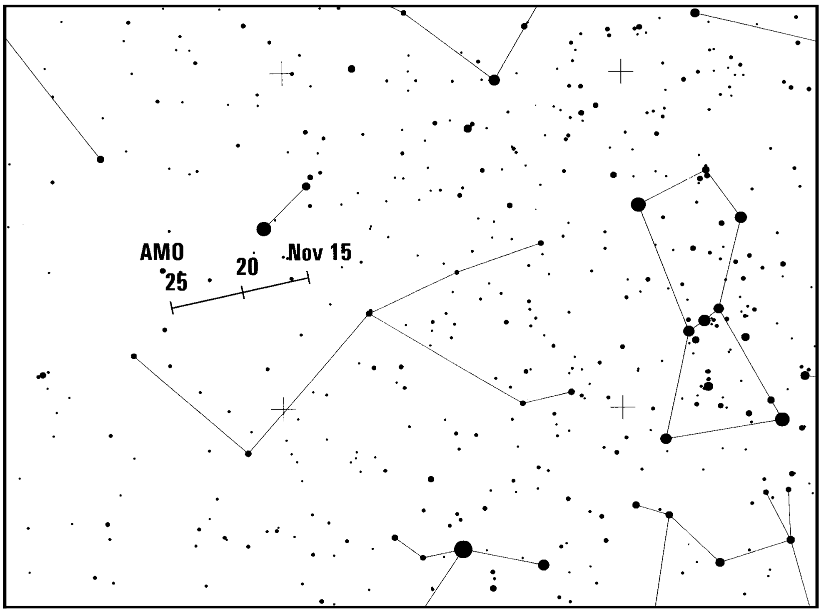

Figure 12 –Radiant position of the α-Monocerotids.

Phoenicids

Active: November 28–December 9; Maximum: December 6, 2^h35^m UT ($\lambda_\odot = 254.°25$);
ZHR = variable, usually 3 or less, may reach 100;
Radiant: $\alpha = 018°$, $\delta = -53°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 18$ km/s; $r = 2.8$;
TFC: $\alpha = 040°$, $\delta = -39°$ and $\alpha = 065°$, $\delta = -62°$ ($\beta < 10°$ N).

Only one impressive Phoenicid return has so far been reported, that of its discovery in 1956, when the ZHR was ~ 100. Three other potential bursts of lower activity have been reported, but never by more than one observer, under uncertain circumstances. Reliable *IMO* data shows recent activity to be virtually nonexistent. This may be a periodic shower however, and more observations of it are needed by all methods. Radio workers may find difficulties, as radar echoes from the 1956 event were only 30 per hour, perhaps because these low-velocity meteors produce too little radio-reflecting ionization. Observing conditions for all southern hemisphere watchers are moderate, with last quarter Moon rising only around 1^h local time on December 5/6, while the radiant culminates at dusk, remaining well on view for most of the night.

Puppid-Velids

Active: December 1–15; Maximum: December ~ 6 ($\lambda_\odot \sim 255°$); ZHR ~ 10;
Radiant: $\alpha = 123°$, $\delta = -45°$, Radiant drift: see Table 6 (page 23);
$V_\infty = 40$ 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. Photographic, video 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 highest rates occur in early to mid December, coincident with a waning Moon this year. Some of these showers may be visible from late October to late January. 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.

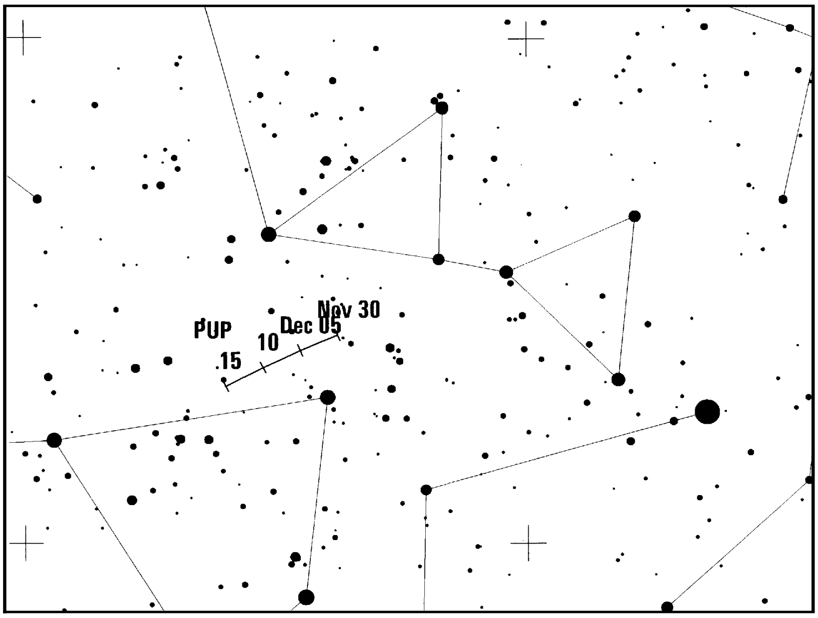

Figure 13 –Radiant position of the Puppid-Velids.

Monocerotids

Active: November 27–December 17; Maximum: December 8 ($\lambda_\odot = 257°$); ZHR = 3;
Radiant: $\alpha = 100°$, $\delta = +08°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 42$ 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).

Only low visual rates are likely from this minor source, making accurate visual plotting, telescopic or video work essential, particularly because the meteors are normally faint. The shower's details, even including its radiant position, are rather uncertain. Recent *IMO* data show only weak signs of a maximum as indicated above. Telescopic results suggest a later maximum, around December 16 ($\lambda_\odot \sim 264°$) from a radiant at $\alpha = 117°$, $\delta = +20°$. This is a reasonable year for making observations, as the waning crescent Moon rises by 2^h–3^h local time for all observers on December 8, while the radiant is on-show virtually all night, culminating about 1^h30^m local time.

σ-Hydrids

Active: December 3–15; Maximum: December 11 ($\lambda_\odot = 260°$); ZHR = 2;
Radiant: $\alpha = 127°$, $\delta = +02°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 58$ km/s; $r = 3.0$;
TFC: $\alpha = 095°$, $\delta = 00°$ and $\alpha = 160°$, $\delta = 00°$ (all sites, after midnight only).

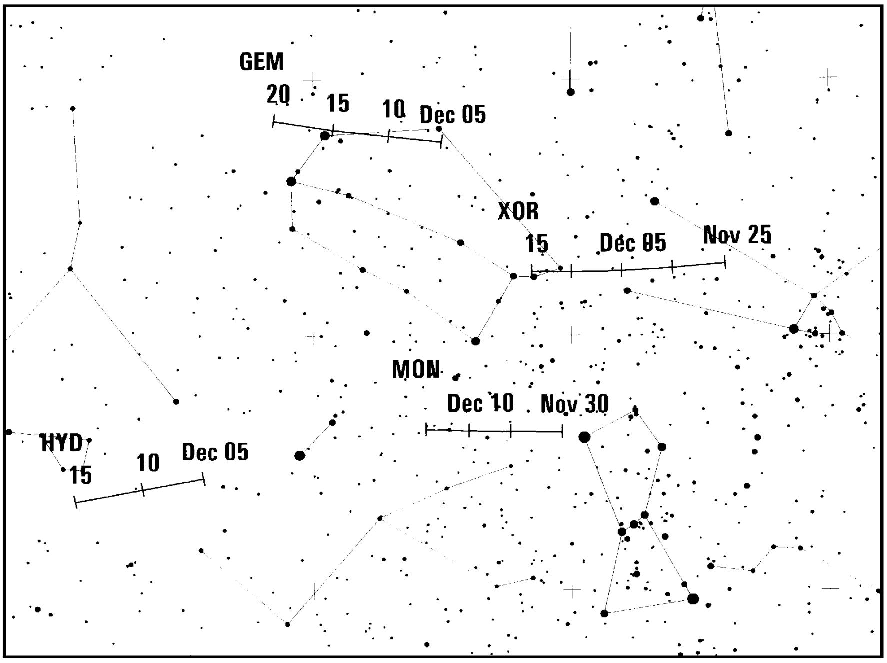

Figure 14 –Radiant position of the Monocerotids, Geminids, σ-Hydrids and χ-Orionids.

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. New Moon creates a perfect viewing opportunity for the peak date given above this year. Recent data indicates the maximum may happen up to six days earlier than this, which would be much less favourable for Moon-free watching. The shower would benefit from visual plotting, telescopic or video work to pin it down more accurately.

Geminids

Active: December 7–17; Maximum: December 13, 22^h20^m UT ($\lambda_\odot = 262\overset{\circ}{.}2$) ±2.3 h;
ZHR = 120;
Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6 (page 23);
$V_\infty = 35$ 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).
PFC: $\alpha = 150°$, $\delta = +20°$ and $\alpha = 060°$, $\delta = +40°$ ($\beta > 20°$ N);
$\alpha = 135°$, $\delta = -05°$ and $\alpha = 080°$, $\delta = 00°$ ($\beta < 20°$ N).

One of the finest annual showers presently observable. This year, new Moon on December 12 gives perfect observing conditions across the expected maximum on December 13/14. The Geminid radiant culminates around 2^h local time. Well north of the equator, the radiant 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. Even here, this is a splendid shower of often bright, medium-speed meteors, a rewarding sight for all watchers. The peak has shown slight signs of variability in its maximum rates and peak timing in recent years, with the six most reliably observed maxima over the past 15 years having all occurred within 2h20m of the time above. The main predicted timing favours European and North African locations eastwards to central Russian and Chinese longitudes. 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-centers. Further results on this topic would be useful, but all methods can be employed to observe the shower.

Coma Berenicids

Active: December 12–January 23; Maximum: December 19 ($\lambda_\odot = 268°$); 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^h local time,
$\alpha = 195°$, $\delta = +10°$ and $\alpha = 200°$, $\delta = +45°$ after 3^h local time ($\beta > 20°$ N).

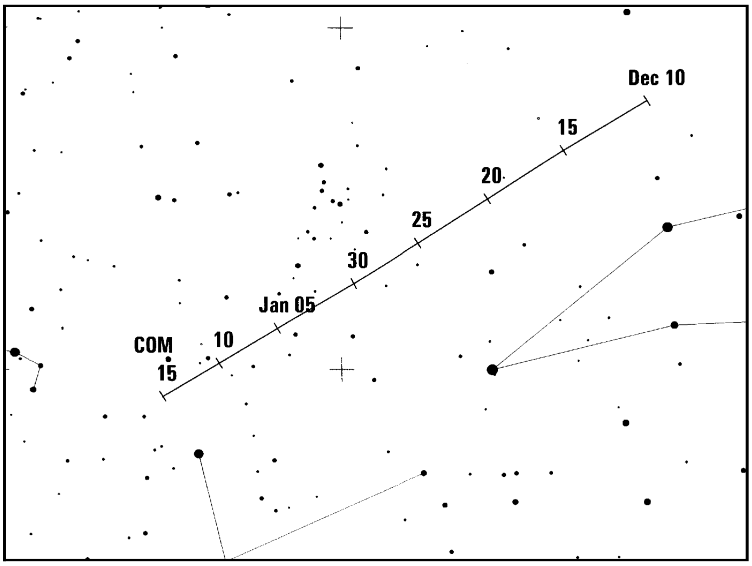

Figure 15 –Radiant position of the Coma Berenicids.

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, conveniently after waxing gibbous moonset in 2004.

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.

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

D	Diameter	D	Diameter
15°	14°	50°	20°
30°	17°	70°	23°

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.

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 atmospheric entry velocities (v_∞). All angular 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 tables for observers

- 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.
- $\lambda_{\odot}$: 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 meteoric entry 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, an equivalent ZHR (EZHR) is used measuring the activity as if it would have lasted for an hour.
- TFC and PFC: Suggested telescopic and small-camera photographic field centers 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 centers to use for video camera fields as well.

Table 4 – Lunar phases for 2004.

New Moon	First Quarter	Full Moon	Last Quarter
		January 7	January 15
January 21	January 29	February 6	February 13
February 20	February 28	March 6	March 13
March 20	March 28	April 5	April 12
April 19	April 27	May 4	May 11
May 19	May 27	June 3	June 9
June 17	June 25	July 2	July 9
July 17	July 25	July 31	August 7
August 16	August 23	August 30	September 6
September 14	September 21	September 28	October 6
October 14	October 20	October 28	November 5
November 12	November 19	November 26	December 5
December 12	December 18	December 26	

Table 5 – Working list of visual meteor showers. Details in this Table were correct according to the best information available in June 2003. 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 "Shower" column indicates the shower may have other or additional peak times, noted in the text.

Shower	Activity	Maximum		Radiant		V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	km/s		
Quadrantids (QUA)	Jan 01–Jan 05	Jan 04	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 25	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 23	32°32	271°	+34°	49	2.1	18
π-Puppids (PPU)	Apr 15–Apr 28	Apr 24	33°5	110°	−45°	18	2.0	var
η-Aquarids (ETA)*	Apr 19–May 28	May 05	45°5	338°	−01°	66	2.4	60
Sagittarids (SAG)	Apr 15–Jul 15	(May 19)	(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 27	125°	341°	−16°	35	3.2	5
South. δ-Aquarids (SDA)	Jul 12–Aug 19	Jul 27	125°	339°	−30°	41	3.2	20
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 29	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 17	145°	286°	+59°	25	3.0	3
North. ι-Aquarids (NIA)	Aug 11–Aug 31	Aug 19	147°	327°	−06°	31	3.2	3
α-Aurigids (AUR)	Aug 25–Sep 08	Aug 31	158°6	84°	+42°	66	2.6	7
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 09	166°7	60°	+47°	64	2.9	5
Piscids (SPI)	Sep 01–Sep 30	Sep 19	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 17	235°27	153°	+22°	71	2.5	50+
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 01	250°	82°	+23°	28	3.0	3
Dec Phoenicids (PHO)	Nov 28–Dec 09	Dec 06	254°25	18°	−53°	22	2.8	var
Puppid/Velids (PUP)	Dec 01–Dec 15	(Dec 06)	(255°)	123°	−45°	40	2.9	10
Monocerotids (MON)	Nov 27–Dec 17	Dec 08	257°	100°	+08°	42	3.0	3
σ-Hydrids (HYD)	Dec 03–Dec 15	Dec 11	260°	127°	+02°	58	3.0	2
Geminids (GEM)	Dec 07–Dec 17	Dec 13	262°2	112°	+33°	35	2.6	120
Coma Berenicids (COM)	Dec 12–Jan 23	Dec 19	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**				
Sep 5			088 +42	055 +46	**SPI**			
Sep 10				060 +47	357 −5			
Sep 15				066 +48	001 −3			
Sep 20				071 +48	005 −1			
Sep 25	**NTA**	**STA**		077 +49	009 0			
Sep 30	021 +11	023 +5	**ORI**	083 +49	013 +2			
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	$\lambda_\odot$	Radiant		Best Observed		Rate
		Date	2000.0	α	δ	50° N	35° S	
Cap/Sagittarids	Jan 13–Feb 04	Feb 02	312°5	299°	−15°	11^h–14^h	09^h–14^h	medium
χ-Capricornids	Jan 29–Feb 28	Feb 14	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, Saarbrücker Strasse 8, D-40476 Düsseldorf, Germany.
e-mail: `fidac@imo.net`

Photographic Commission:
Marc de Lignie, Prins Hendrikplein 42, NL-2264 SN Leidschendam, 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, Verbindungsweg 7, D-15366 Hönow, Germany. e-mail: `video@imo.net`

Visual Commission:
Rainer Arlt, Friedenstrasse 5, D-14109 Potsdam, Germany. email: `visual@imo.net`

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

For further details on **IMO membership**, please write to: Ina Rendtel, *IMO* Treasurer, Mehlbeerenweg 5, D-14469 Potsdam, Germany. e-mail: `treasurer@imo.net`

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