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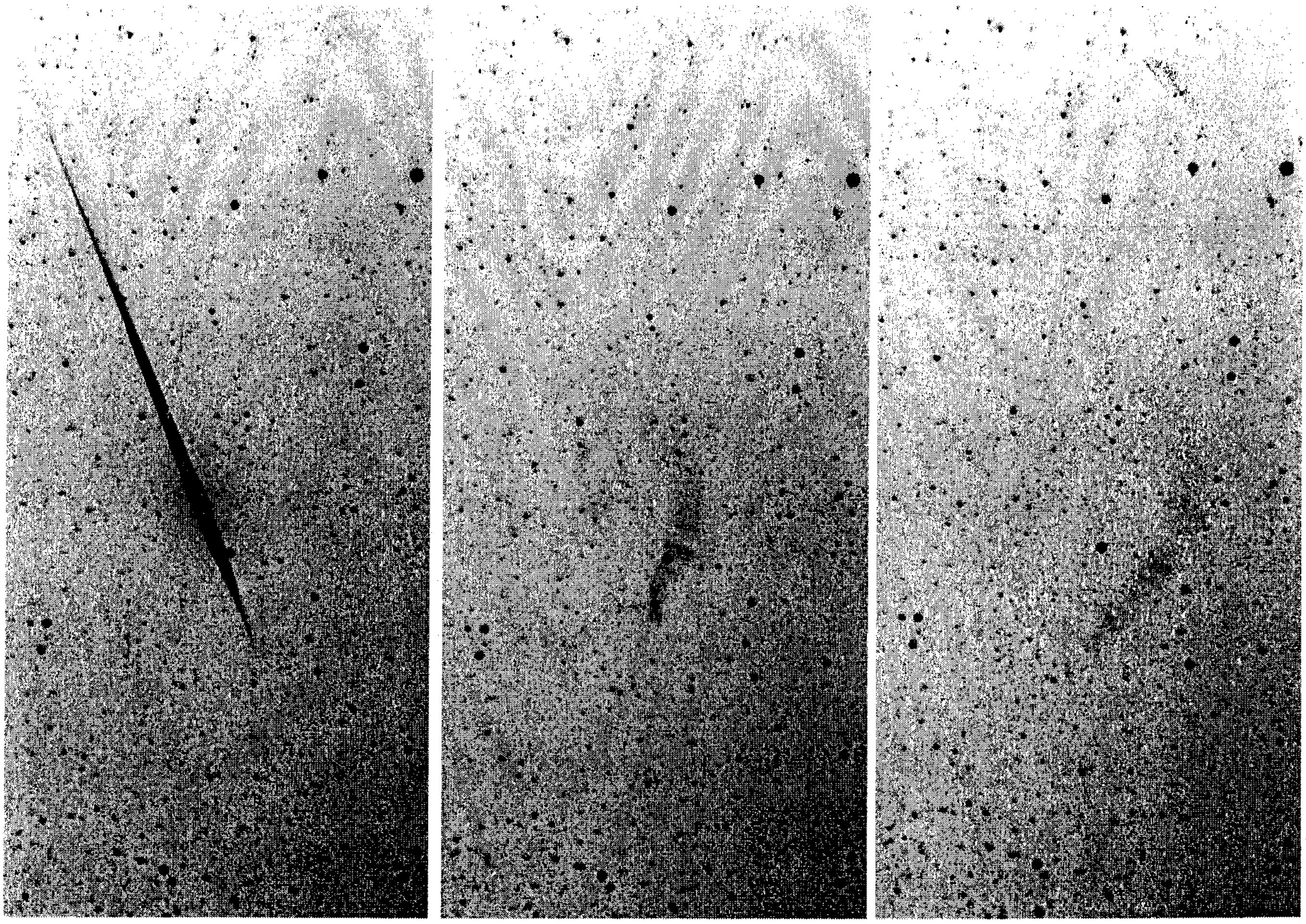

A Leonid fireball of November 18, 2000, and a sequence of the temporal change of its persistent train. The images were taken by a CCD camera from the El Arenosillo station, Huelva, of the Spanish Photographic Meteor Network (comm. by Josep M. Trigo-Rodríguez).

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Contents

Useful Information

The August issue *(WGN 29:4)*

The *August issue* will be mailed in early September in order to include first Perseid impressions. Contributions are, therefore, due on *August 25* at the latest. They should be sent to *Marc Gyssens.*

Subscriptions and ordering of publications

Volume 29 (2001) of *WGN* is expected to contain at least 240 pages each and costs 35 DEM or 17.90 EUR per volume, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to the Treasurer, Ina Rendtel.

All addresses can be found on the inside of the back cover.

From the Editor-in-Chief

Marc Gyssens

Many of you have wondered what has been happening to WGN *the last couple of months and inquired about it via e-mail and other means of communication, and of course you deserve an answer. Actually, a combination of minor health problems and new professional responsabilities made it virtually impossible for me to work on* WGN*. I and all of us really have to thank Rainer Arlt who temporarily took over the burden from me and completed the combined February/April issue as well as this overdue June issue. I anticipate to get involved again starting with the next issue and gradually work away the delay that has resulted from this situation.*

Of course, I offer my sincere apologies for what has happened. Nevertheless, this situation painfully illustrates what I have warned for over and over again during the past couple of years. While the IMO *is a successful organization which established its place in the meteor community in a very short span of time, and while the Organization's input in term of membership and submitted observations, its organizational basis is very small, too small, in fact. If something happens to an* IMO *officer in terms of health, professional duties, or availability in general, there is almost no buffer, no reserve to ensure that this person's* IMO *duties are continued. I must emphasize once again that what Rainer did with* WGN *is out of the ordinary.*

On the other hand, this unfortunate course of events was perhaps necessary to make our membership aware of the seriousness of the situation. I can very well imagine that my warnings in previous issues seemed very abstract if at all they were read—and I do not blame anyone for that—as everything seemed to go very well. All IMO *members will find in this issue an administrative booklet which, among other things, contains a call for candidates for Council elections. (The present term of most Council members expires at the end of the year.) Several of you expressed the intention to me or to other* IMO *Council members to get more involved in the Organization; this is a chance to make hard on this intention!*

The above paragraph may sound a bit somber; however, I want to remain optimistic. So, I see what happened with WGN *combined with the upcoming Council elections as an opportunity to correct our major weakness. I hope many of you see this the same way as I do!*

Also, meteorwise, we are living exciting times with the best-covered Leonid return ever likely reaching its climax this fall. We hope to provide you with some additional information in the August issue. However, the powerful Leonids should not make us feel blasé with regard to other showers, among which the annual Perseids, for which the data collected over the last fifteen years or so will start to enable us to compile a comprehensive picture of the activity related to the most recent return of 109P/Swift-Tuttle. So, there is much excitement still to be anticipated!

Meanwhile, happy observing, and enjoy this issue!

The 2001 International Meteor Conference

Cerkno, Slovenia, September 20–23, 2001

based on communication with Mihaela Triglav

The 2001 *International Meteor Conference* will be held in Cerkno, Slovenia, between September 20 and 23. More information about this event can be found at the Internet address `http://www2.arnes.si/~sopezakr/IMC2001/`. If you wish to participate and have not yet returned your registration form, you should no longer wait and complete and return the registration form you can find in the previous issue!

Letters to WGN

The 2000 Ursids

The report by Jenniskens and Lyytinen of a video outburst observed during the 2000 Ursids [1] was most interesting, and confirms the utility of the video technique to pick up such events for later analysis, as we have seen in other reports previously. The indication that somewhat brighter video meteors were apparent after 8^h UT on December 22, as shown by the decreasing r-values, provides some confirmation of my own finding [2] of possibly slightly brighter visual meteors and more long-duration radio meteor echoes after 7^h and 8^h UT then respectively. However, I find the corroborating evidence to support a very strong (ZHR $\approx$ 90) outburst detected also by radio and visual observers highly questionable, and would like to suggest an alternative interpretation.

The technique for analysing raw radio data employed in [1], by taking a mean of five data sets made using completely different radio systems, with no regard for the equipment sensitivities, relative meteor echo counts, or observing circumstances involved, and failing to take account of any comparison data made on days to either side, is regrettably completely unworkable. Life would be much easier for radio analyses were this not so! I have, by chance, discussed some of the problems of radio analyses elsewhere in this issue [3].

Drawing on a larger radio data sample than [1], I found that the majority of radio reports favoured a main Ursid peak between $\approx 5^h$–7^h UT on December 22 [2]. This was followed by a less well-defined secondary peak from about 8^h–11^h UT, though the reports allow an interpretation suggesting echo rates may have settled into a fluctuating, loose, "plateau" from around 7^h–11^h UT, when rates were generally somewhat below those found before 7^h UT. The lack of a clear consensus on a single radio peak time, and the shape and character of the echo count graphs generally, argue greatly against a strong Ursid peak in 2000, since there is little to separate the 2000 Ursid signature from that seen in most years since 1993. It is also worth recalling that Jiří Borovička reported no unusually enhanced radar rates between 6^h–9^h UT on December 22 from the Czech system at Ondřejov Observatory [4].

Visually, despite a very limited data sample from Europe and North America, I found ZHRs of $\approx 20 \pm 5$ between 5^h–6^h UT, and $\approx 30 \pm 5$ between 8^h–9^h UT on December 22 [2]. Tentatively, a visual peak over North America at $\approx 8^h15^m \pm 10$ min UT can be suggested in the reports I have seen so far, which is not far removed from the video peak's suggested timing in [1] at $\approx 8^h06^m \pm 7$ min UT. The maximum visual ZHRs though remain far below those indicated by the video data. EZHRs using very short time-bins ($<$ 5–10 min) could be inflated towards such high levels perhaps, but this is not a valid technique given the small dataset.

The video data in [1] do not appear to have been recalibrated to visual levels to allow for the extra infra-red sensitivity of most CCD video meteor systems. Consequently, the quoted video magnitude range for most Ursids of +3 to +5 is likely to have been +4 to +7 or so when converted to the brightnesses a normal visual observer could have recorded, making most of the Ursids too faint for the visual watchers to see. This would easily account for the apparent discrepancy between the video and visual rates after 8^h UT, and would help account for the relative paucity of photographed Ursids too, since typical camera films are similar in spectral sensitivity to what the unaided eye perceives, while having a significantly higher minimum brightness threshold than the eye. A comparable problem was encountered during a very short-lived video outburst of Leonids detected from Hawaii in 1997, where of $\approx$ 100–150 video Leonids, only one was seen by a visual observer, and just two were recorded by still cameras [5].

If the Ursid magnitude distribution showed a sharp cutoff at both upper and lower ends, as was seen during the height of the 1999 Leonid storm (see the two papers in *WGN* 27:6 (December 1999) between pp. 286–300), with a fainter end at around visual magnitude equivalent +7, this could well account for the failure of radio and radar to sensibly detect the event. Most radio systems currently in operation detect, to a first approximation, chiefly similar meteors to what a visual observer would see (see [3] for discussion), thus most systems are relatively insensitive to meteors fainter than about visual magnitude +5. The unclear pattern in radio rates on December 22 would fit to this, where some fraction of the increased "video Ursid flux" was being detected differently by the different systems. For radar, where the vast majority of detected events are far below the naked-eye threshold, it may be too few very faint Ursids occurred to raise the activity above normal levels, and the increased "video flux" was insufficient on its own to make a detectable impact.

Overall, the available evidence shows the Ursids in 2000 produced a moderate visual enhancement, with highest ZHRs of $\approx$ 25–35, comparable to other modest events seen from the shower in recent decades. The stronger video outburst was a video event only, and in all probability could not have been detected visually at its video-equivalent strength. Telescopic or binocular observers might well have found it impressive, however. It is unfortunate that no video observations from previous years were available for comparison with the 2000 event, since at present this means we cannot be sure such a video enhancement is not part of other (perhaps many) Ursid maxima, though hopefully that omission can be remedied at future returns.

References

[1] P. Jenniskens, E. Lyytinen, "2000 Ursid Outburst Confirmed", *WGN* 29:1/2 (February/April 2001), pp. 41–45.

[2] A. McBeath, "SPA Meteor Section Results: November–December 2000", *WGN* 29:3 (June 2001), pp. 96–103.

[3] A. McBeath, "The Forward Scatter Meteor Year: 2001 Update", *WGN* 29:3 (June 2001), pp. 85–92.

[4] J. Borovicka, "No Ursid enhancement", *IMO-News e-mailing list*, December 22, 2000.

[5] M. Kinoshita, T. Maruyama, T. Sagayama, "Preliminary activity of Leonid meteor storm observed with a video camera in 1997", *Geophysical Research Letters* 26:1 (January 1, 1999), pp. 41–44.

Alastair McBeath, June 6, 2001

Meteor Shower Calendar: October–December 2001

compiled by Alastair McBeath and Rainer Arlt

Early October's waning gibbous Moon allows only a short period before moonrise to cover any potential Draconid activity (which might peak at some stage between October 8, 7^h UT to October 9, 0^h UT, based on results from 1998 and 1999, if anything at all happens), so observing will be very difficult. October's new Moon makes the epsilon-Geminids and Orionids extremely favorable however. Ecliptical minor shower activity reaches another peak in early to mid November, thanks to the Taurids. Unfortunately, the Southern Taurid maximum (November 5) and the interesting late October to early November period which sometimes produces more Taurid fireballs, are both badly affected by November's first full Moon, so this will not be a good year to check for a repeat of the unusual Taurid activity seen in late October 1998, when ZHRs reached levels comparable to the usual maximum rates. The Northern Taurid peak (November 12) is more usefully moonless. Another Leonid storm may occur later in November, and will be Moon-free if so, as will be the α-Monocerotid peak. The χ-Orionid maximum (December 2) loses out as November's second full Moon wanes. Pre-moonrise Phoenicid checking should be possible in early December, but useful late-night Puppid-Velid watching then will still be hampered by the waning Moon. The other December showers all have maxima reasonably to well clear of moonlight interference in 2001.

ϵ-Geminids

Active: October 14–27; Maximum: October 18, ($\lambda = 205°$); ZHR = 2;
Radiant: $\alpha = 102°$, $\delta = +27°$; Radiant drift: Table 6; $V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 90°$, $\delta = +20°$ 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. New Moon on October 16 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, 8^h UT ($\lambda = 208°$); ZHR = 20;
Radiant: $\alpha = 95°$, $\delta = +16°$; Radiant drift: see Table 6; $V_\infty = 66$ km/s; $r = 2.9$;
TFC: $\alpha = 100°$, $\delta = +39°$ and $\alpha = 75°$, $\delta = +24°$ ($\beta > 40°$ N); or
$\alpha = 80°$, $\delta = +1°$ and $\alpha = 117°$, $\delta = +1°$ ($\beta < 40°$ N).

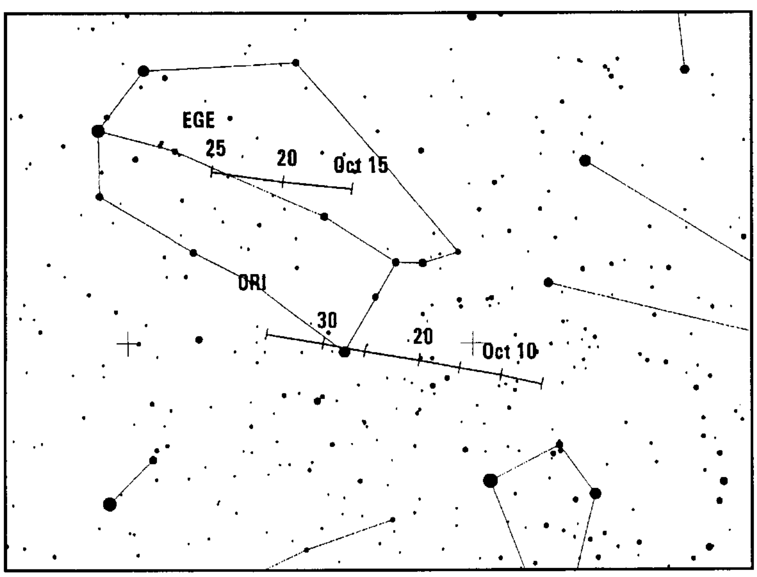

Figure 1 – Radiant position of the Orionids and epsilon-Geminids.

October's waxing crescent Moon enhances the Orionids this year too. They are noted for having several maxima other than the main weekend one detailed above, with activity sometimes remaining almost constant for several consecutive nights centred on this peak. In 1993 and 1998, a submaximum as strong as the normal peak was detected on October 17-18 from Europe, for instance. All observers should be aware of these possibilities. 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. With a radiant almost on the celestial equator, the shower can be seen from most of the globe, and observations are possible from midnight onwards in both hemispheres, perhaps a little before in the north.

Leonids

Active: November 14–21; Maximum: November 17, 13^h UT ($\lambda = 235.^\circ27$, nodal passage), but see accompanying text; ZHR = storm (about 360? in 1998, about 3700 in 1999, may reach storm level again in 2001);
Radiant: $\alpha = 153^\circ$, $\delta = +22^\circ$; Radiant drift: see Table 6; $V_\infty = 71$ km/s; $r = 2.9$;
TFC: $\alpha = 140^\circ$, $\delta = +35^\circ$ and $\alpha = 129^\circ$, $\delta = +6^\circ$ ($\beta > 35^\circ$ N); or
$\alpha = 156^\circ$, $\delta = -3^\circ$ and $\alpha = 129^\circ$, $\delta = +6^\circ$ ($\beta < 35^\circ$ N);
PFC: before 0^h local time $\alpha = 120^\circ$, $\delta = +40^\circ$ ($\beta > 40^\circ$ N);
before 4^h local time $\alpha = 120^\circ$, $\delta = +20^\circ$ ($\beta > 0^\circ$ N);
and after 4^h local time $\alpha = 160^\circ$, $\delta = 0^\circ$ ($\beta > 0^\circ$ N);
before 4^h local time $\alpha = 120^\circ$, $\delta = +10^\circ$ ($\beta < 0^\circ$ N) and
after 4^h local time $\alpha = 160^\circ$, $\delta = -10^\circ$ ($\beta < 0^\circ$ N).

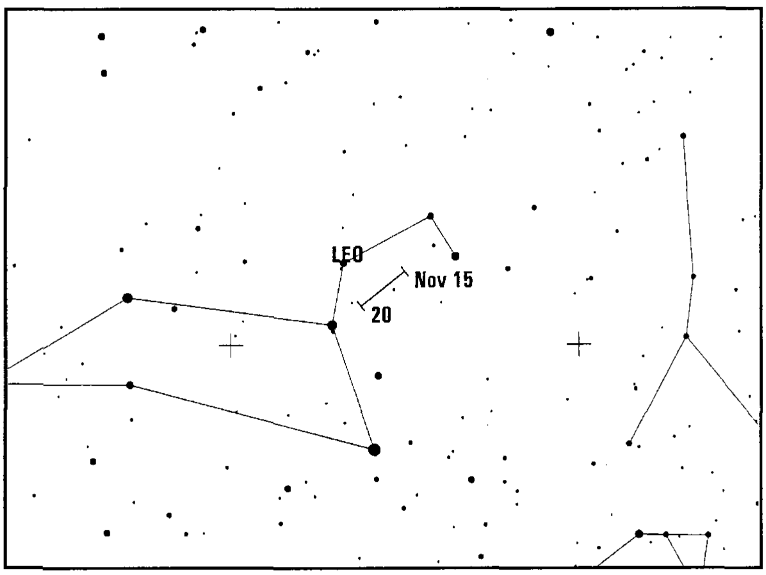

Figure 2 – Radiant position and drift of the Leonids.

The Leonids' parent comet, 55P/Tempel-Tuttle, reached perihelion last in 1998 February, and a storm was well-seen in 1999 from the Near East westwards to the Canary Isles, but recent stream evolution studies suggest high to storm-level Leonid activity may still occur in 2001 or 2002. There are no guarantees that this will happen, but even observing an absence of unusual Leonid activity would be valuable information, though not very interesting to witness! The peak time given above is based on the Earth's closest approach to the comet's node. The 1999 storm peaked $\lambda = 0.^\circ035$ (50 minutes) later than this nodal time then. However, other predictions based on different meteor stream filament theories for 2001 suggest maxima at: November 17, 16^h30^m UT (Ignacio Ferrin; ZHR about 350); November 18, 10^h01^m UT (ZHR about 2500?), 17^h31^m UT (ZHR about 9000?) or 18^h19^m UT (ZHR about 15000?; these latter three by David Asher and Rob McNaught); or November 18, 16^h54^m UT (Peter Brown). Peter Brown's work further suggests a possible bright meteor peak around November 18, 11^h UT. Any or all of these are liable to be amended following the 2000 Leonid return, and the *IMO*'s Journal *WGN* will have updates after that occurs.

The radiant rises only around local midnight (or indeed afterwards south of the equator), so the waxing crescent Moon will present no problems at all. The two November 17 peak timings would favor locations from west-central

North America westwards to the extreme east of Russia (13^h UT) or Alaska and Oceania westwards to eastern Asia (16^h30^m UT). The various November 18 timings would be best for sites in North and Central America (10^h–11^h UT), eastern Asia and Australasia (17^h–18^h UT), or western Australia westwards to central Asia (18h UT). Even minor variations from these timings would mean places outside these zones may see something of the shower's best too. For instance in 1999, a resurgence producing ZHRs about 180 occurred some 13–14 hours after the main storm peak, and rates remained above the ZHR = 1000 storm level for over an hour near the storm's height. ZHRs were above 50 for more than a day nearest the main peak too, so even non-storm activity is worth seeing. All observing methods should be utilized, especially photography and video if another storm manifests.

α-Monocerotids

Active: November 15–25; Maximum: November 21, 14^h20^m UT ($\lambda = 239\overset{\circ}{.}32°$);
ZHR = variable, usually around 5 but may produce outbursts to around 400+;
Radiant: $\alpha = 117°$, $\delta = +1°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 2.4$;
TFC: $\alpha = 115°$, $\delta = +23°$ and $\alpha = 129°$, $\delta = +20°$ ($\beta > 20°$ N); or
$\alpha = 110°$, $\delta = -27°$ and $\alpha = 98°$, $\delta = +6°$ ($\beta < 20°$ N);

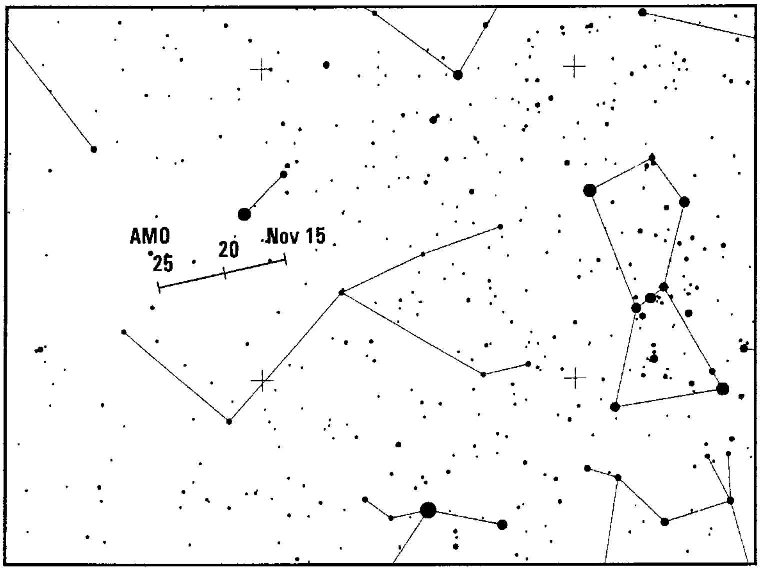

Figure 3 – Radiant position and drift of the α-Monocerotids.

Another late-year shower capable of producing surprises, the α-Monocerotids gave their most recent brief outburst in 1995 (the top EZHR, about 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, so all observers should continue to monitor this source closely. We are currently near the mid-point of any decade-long cycle. The waxing crescent Moon on November 21 makes this a splendid year for such scrutiny, as it will have set before the radiant is well on view from either hemisphere after about 23^h local time (but note moonset is after midnight on November 21-22 for sites south of −30° latitude). The expected peak time falls especially well for sites from Alaska to extreme eastern Russia and Japan, including Australia, New Zealand and most of the central and western Pacific Ocean.

Phoenicids

Active : November 28-December 9; Maximum: December 6, 7^h UT ($\lambda = 254\overset{\circ}{.}25$);
ZHR = variable, usually 3 or less, may reach 100;
Radiant: $\alpha = 18°$, $\delta = -53°$; Radiant drift: see Table 6; $V_\infty = 18$ km/s; $r = 2.8$;
TFC: $\alpha = 040°$, $\delta = -39°$ and $\alpha = 065°$, $\delta = -62°$ ($\beta < 10°$ N).

Only one impressive Phoenicid return has so far been reported, that of its discovery in 1956, when the ZHR was about 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 this year are reasonable for all southern hemisphere watchers, with the waning gibbous Moon not rising until around 23h-00h local time on December 6, while the radiant is well on view for most of the night, but culminates at dusk.

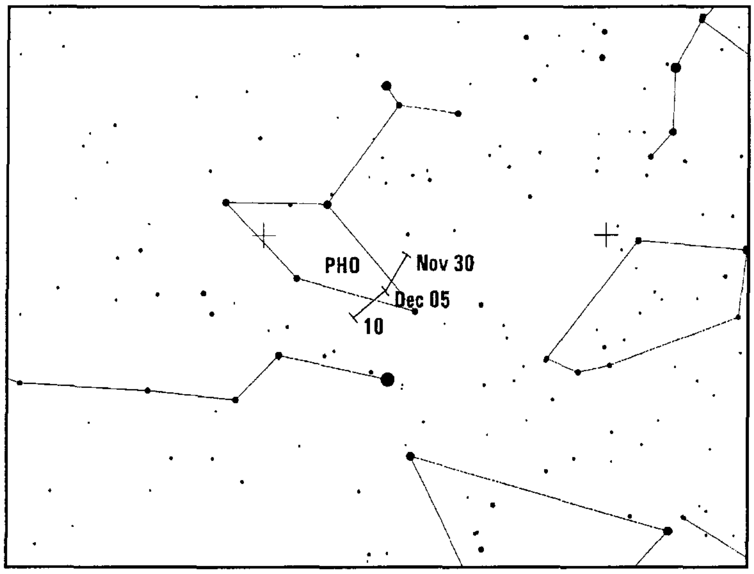

Figure 4 – Radiant position of the Phoenicids.

Monocerotids

Active: November 27–December 17; Maximum: December 9 ($\lambda = 257°$); ZHR = 3;
Radiant: $\alpha = 100°$, $\delta = +8°$; Radiant drift: see Table 6; $V_\infty = 42$ km/s; $r = 3.0$;
TFC: $\alpha = 88°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +48°$ ($\beta > 40°$ N); or
$\alpha = 120°$, $\delta = -3°$ and $\alpha = 84°$, $\delta = +10°$ ($\beta < 40°$ 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, including even its radiant position, are rather uncertain. Recent *IMO* data shows only weak signs of a maximum as indicated above. Telescopic data suggests a later maximum, around December 15 (λ around 264°) from a radiant at $\alpha = 117°$, $\delta = +20°$. This is a moderate year for making observations, as the Moon rises within about 20 minutes of 1^h local time (rising later south of the equator) on December 8-9. The radiant is on-show nearly all night, but culminates about moonrise.

σ-Hydrids

Active: December 3–15; Maximum: December 11 ($\lambda = 260°$); ZHR = 2;
Radiant: $\alpha = 127°$, $\delta = +02°$; Radiant drift: see Table 6; $V_\infty = 58$ km/s; $r = 3.0$;
TFC: $\alpha = 95°$, $\delta = 0°$ and $\alpha = 160°$, $\delta = 0°$ (all sites, after midnight only).

Although first detected in the 1960s by photography, σ-Hydrids are typically swift and faint, and rates are generally very low, close to the visual detection threshold. Since their radiant, a little over 10° east of the star Procyon (α Canis Minoris), is near the equator, all observers can cover this shower. The radiant rises in the late evening hours, but is best viewed after local midnight, so the waning crescent Moon will be little problem, as it rises about the start of morning twilight on December 11-12. Recent data indicates the peak may occur up to six days earlier than suggested above, which would be much less favorable for moon-free watching. The shower would benefit from visual plotting, telescopic or video work to pin it down more accurately.

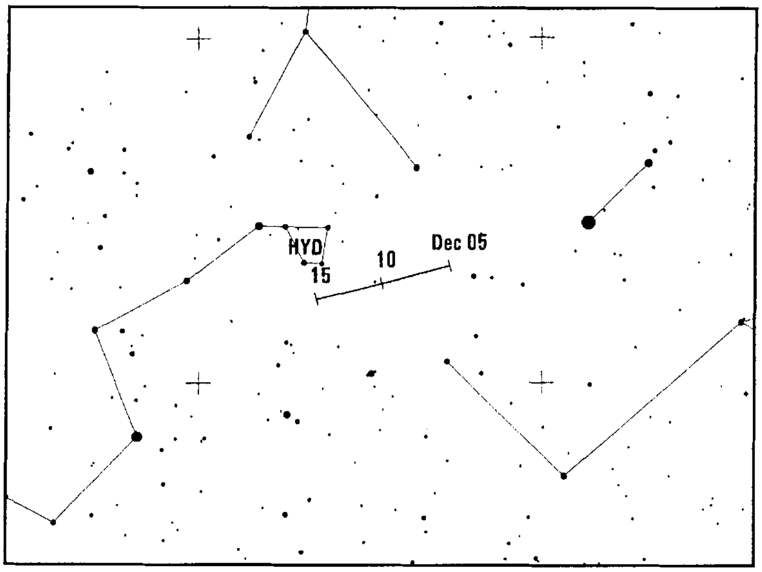

Figure 5 – Radiant position of the σ-Hydrids.

Geminids

Active: December 7–17; Maximum: December 14, 4^h UT ($\lambda = 262.^\circ 2$ or before); ZHR = 120;
Radiant: $\alpha = 112°$, $\delta = +33°$; Radiant drift: see Table 6; $V_\infty = 35$ km/s; $r = 2.6$;
TFC: $\alpha = 87°$, $\delta = +20°$ and $\alpha = 135°$, $\delta = +49°$;
before 23^h local time, $\alpha = 87°$, $\delta = +20°$ and $\alpha = 129°$, $\delta = +20°$ after 23^h local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = -3°$ and $\alpha = 84°$, $\delta = +10°$ ($\beta < 20°$ N);
PFC: $\alpha = 150°$, $\delta = +20°$ and $\alpha = 60°$, $\delta = +40°$ ($\beta > 20°$ N); and
$\alpha = 135°$, $\delta = -5°$ and $\alpha = 80°$, $\delta = 0°$ ($\beta < 20°$ N)

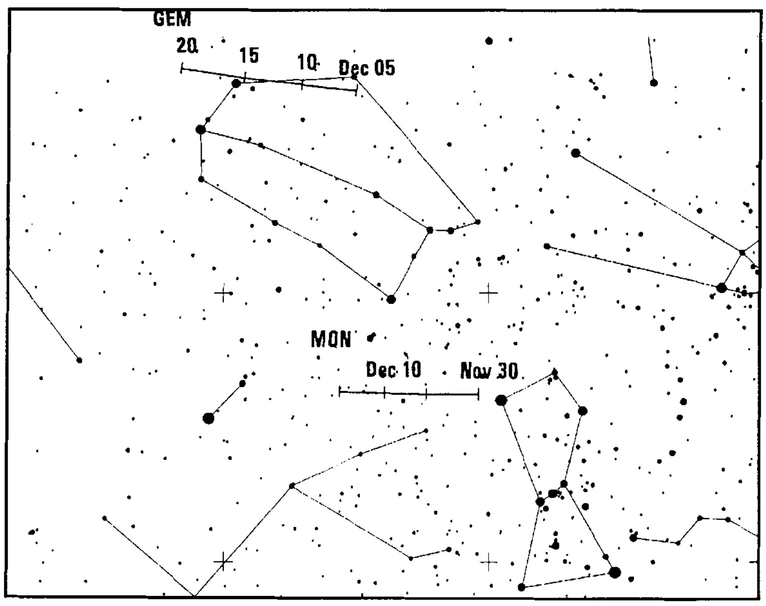

Figure 6 – Radiant positions of the Geminids and Monocerotids.

One of the finest annual showers presently observable, whose peak falls perfectly for new Moon this year. 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 the actual peak timing in recent years. The six most reliably observed maxima over the past twelve years have all occurred between $\lambda = 262.^{\circ}1$–$262.^{\circ}3$ (ZHRs 110–130), which timings equate to December 14, 2001, 1^h30^m to 6^h30^m UT. The peak time of 4^h UT above is the more probable, and especially favors sites from Europe west to eastern North America if correct. 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, but all observing methods can be employed to observe the shower.

Coma-Berenicids

Active: December 12–January 23; Maximum: December 19, ($\lambda = 268°$); ZHR = 5;
Radiant: $\alpha = 175°$, $\delta = +25°$; Radiant drift: see Table 6; $V_\infty = 65$ km/s; $r = 3.0$;
TFC: $\alpha = 180°$, $\delta = +50°$ and $\alpha = 165°$, $\delta = +20°$ before 3^h local time; or
$\alpha = 195°$, $\delta = +10°$ and $\alpha = 200°$, $\delta = +45°$ after 3^h local time ($\beta > 20°$ N).

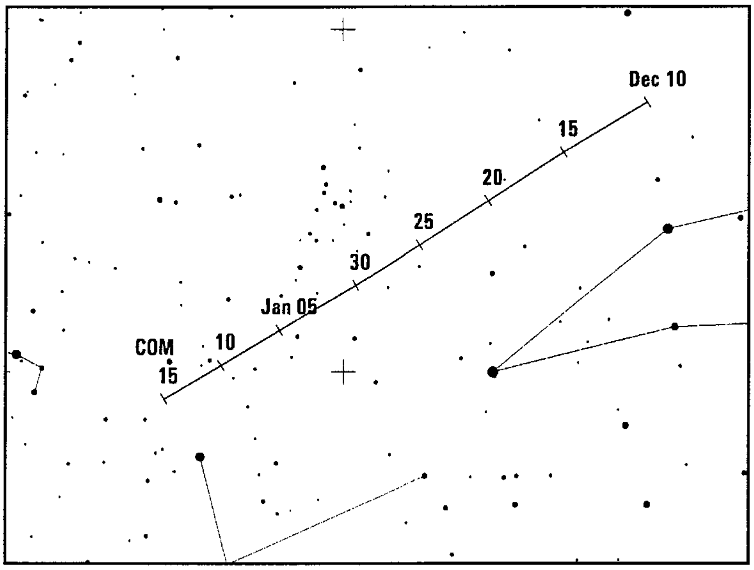

Figure 7 – Radiant position of the Coma Berenicids.

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, especially this year as its expected peak benefits from an early-setting waxing crescent Moon. The radiant is at a useful elevation from local midnight onwards.

Ursids

Active: December 17–26; Maximum: December 22, 12^h UT ($\lambda = 270.^{\circ}7$); ZHR = 10 (occ. var. up to 50);
Radiant: $\alpha = 217°$, $\delta = +76°$; Radiant drift: see Table 6; $V_\infty = 33$ km/s; $r = 3.0$;
TFC: $\alpha = 348°$, $\delta = +75°$ and $\alpha = 131°$, $\delta = +66°$ ($\beta > 40°$ N);
$\alpha = 63°$, $\delta = +84°$ and $\alpha = 156°$, $\delta = +64°$ (β 30° to 40° N);

A very poorly observed northern hemisphere shower, but one which has produced at least two major outbursts in the past 60 years, in 1945 and 1986. Several other rate enhancements, recently in 1988 and 1994, 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 $\lambda = 270.^{\circ}8$, for instance, which might suggest a slightly later maximum time in 2001 of December 22, 15^h UT. The Ursid radiant is circumpolar from most northern sites (thus fails to rise for most southern ones), though it culminates after daybreak, and is highest in the sky later in the night. The first quarter Moon will set around midnight on December 22, giving dark skies for observations after this, favoring sites from central North America to the north-central Pacific Ocean.

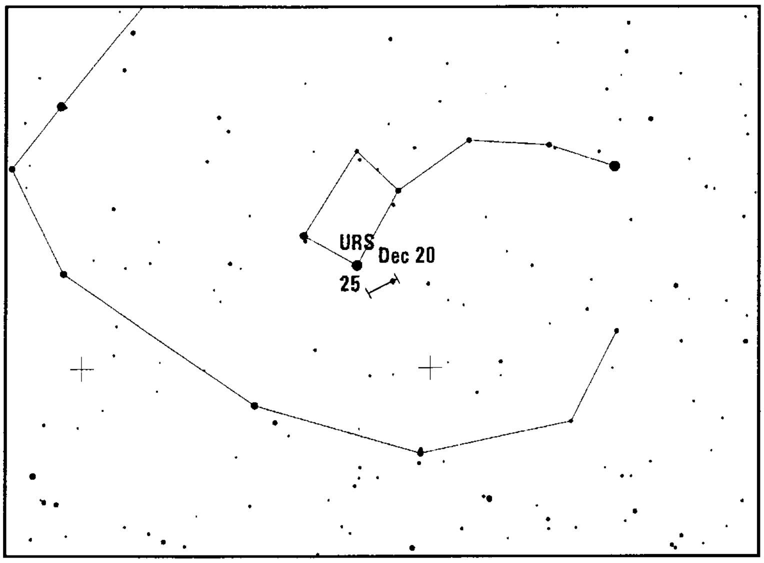

Figure 8 – Radiant position of the Ursids.

1. Working list of meteor showers

Table 1 is the *IMO* Working List of meteor showers. The coordinates of the radiant refer to the reference date (in most cases, the date of maximum). When observing the shower on other dates, one must take into account the radiant drift. This can be deduced from Table 3, where the radiant coordinates are listed with steps of five days for other dates within the activity period.

Table 1 – Working list of meteor showers for the period October–December 2001. Showers marked with an asterisk are periodically or occasionally active, and therefore no ZHR is cited. The "maximum" date cited for the Puppid/Velids should be seen as a reference date only.

Shower	Activity	Maximum		Radiant		V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	(km/s)		
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 08	166°	60°	+47°	64	3.0	6
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	2.9	20
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	storm?
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°	22	2.8	var
Puppid/Velids (PUP)	Dec 01–Dec 15	Dec 07	255°	123°	−45°	40	2.9	10
Dec Monocerotids (MON)	Nov 27–Dec 17	Dec 09	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 14	262°0	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

Below are the lunar phases for the period October–December 2001.

Table 2 – Lunar phases for October–December 2001.

New Moon	Oct 16	Nov 15	Dec 14
First Quarter	Oct 24	Nov 23	Dec 22
Full Moon	Oct 02	Nov 30	Dec 30
Last Quarter	Oct 10	Nov 08	Dec 07

Table 3 – Radiant positions in α and δ.

	NTA	**STA**	**ORI**	**DAU**				
Oct 5	25° +12°	27° +7°	85° +14°	89° +49°		**GIA**		
Oct 10	29° +14°	31° +8°	88° +15°	95° +49°		262° +54°		
Oct 15	34° +16°	35° +9°	91° +15°		**EGE**			
Oct 20	38° +17°	39° +11°	94° +16°		99° +27°			
Oct 25	43° +18°	43° +12°	98° +16°		104° +27°			
Oct 30	47° +20°	47° +13°	101° +16°		109° +27°			
Nov 5	53° +21°	52° +14°	105° +17°					
Nov 10	58° +22°	56° +15°		**LEO**	**AMO**			
Nov 15	62° +23°	60° +16°		150° +23°	112° +02°			
Nov 20	67° +24°	64° +16°	**XOR**	153° +21°	116° +01°			
Nov 25	72° +24°	69° +17°	75° +23°		120° 00°	**MON**	**PUP**	**PHO**
Nov 30			80° +23°	**HYD**		91° +8°	120° −45°	14° −52°
Dec 5	**COM**	**GEM**	85° +23°	122° +03°		96° +8°	122° −45°	18° −53°
Dec 10	169° +27°	108° +33°	90° +23°	126° +02°		100° +8°	125° −45°	22° −53°
Dec 15	173° +26°	113° +33°	94° +23°	130° +01°	**URS**	104° +8°	128° −45°	
Dec 20	177° +24°	118° +32°			217° +75°			

2. Radiant sizes and meteor plotting

If you are not observing during a major-shower maximum, it is much more essential to associate meteors with their radiants correctly, since the total numbers will be small. Meteor plotting allows the shower association by more objective criteria than the prolongation of paths under the sky.

As you plotted the meteors on gnomonic maps, you can trace the radiant by straight lines. If the radiant lies on another chart, you should find common stars on an adjacent chart in order to extend the backward prolongation there.

How large should the radiant be assumed for shower association? The physical radiant size is very small; visual plotting errors cause many true shower meteors to pass the radiant outside this area. We have to assume a larger radiant. The opposite behavior is caused by sporadic meteors—more and more sporadics line up accidentally upon enlarging the radiant. Hence, we have to apply an optimum radiant diameter compensating the loss due to plotting errors, and the sporadic meteor pollution.

Table 4 below gives the optimum radiant diameter as a function of the angular distance of the meteor from the radiant involved.

Table 4 – 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 direction of the path is not the only criterion for shower association. The angular velocity of the meteor should match the expected speed of the shower meteors according to the geocentric velocity of the meteoroids. Angular velocity estimates should be made in degrees per second (°/s). In your imagination, you make the meteors move for one second. The path length of this imaginary meteor is the angular velocity in °/s. Note that typical speeds are in the range 3°/s–25°/s.

Typical errors of such estimates are given in Table 5. Table 6 gives the angular speeds for a few pre-atmospheric velocities, which can be looked up in Table 1 for each shower.

Table 5 – Error limits for the angular velocity.

Angular velocity (°/s)	5	10	15	20	30
Permitted error (°/s)	3	5	6	7	8

Table 6 – Angular velocities as a function of the radiant distance and the elevation of a meteor for three different pre-atmospheric velocities. All velocities are in °/s. The tables are symmetric: you can read radiant distance horizontally and elevation vertically, or vice-versa.

$h \backslash D$	$v_\infty = 25$ 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

3. Daytime radio meter showers

Table 7 – Working list of daytime radio meteor showers. 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	J2000	α	δ	50° N	35° S	
Sextantids	Sep 09–Oct 09	Sep 27	184°3	152°	00°	06^h–12^h	06^h–13^h	medium

Leonids

Leonid Storm Flux from Efficient Visual Scanning of 1999 Leonid Storm Video Tapes

David Holman and Peter Jenniskens (SETI, NASA Ames)

A small fragment of Leonid storm video data from the 1999 Leonid Multi-Instrument Aircraft Campaign is analyzed visually at exhaustion to measure the detection efficiency of visual scanning techniques and calibrate the meteor flux at the peak of the storm. The high meteor rate makes it possible to obtain statistically meaningful results over short time intervals. We arrive here at a flux estimate for the peak of the 1999 Leonid storm of 2.8 ± 0.4 km^2/hr ($m < +6.5$), a factor of two higher than reported elsewhere.

1. Introduction

Visual scans of meteor video tapes tend to produce more meteor detections than found by automatic meteor detection software. This is especially true for video records obtained during the Leonid Multi-Instrument Aircraft Campaign [1], when up to 70 meteors a minute were detected by a real-time video counting technique [2], including many short tracks near the horizon, on a gradually changing star background because of aircraft motion. Earlier, Gural and Jenniskens [3] used visual scanning to detect meteor in a 12-minute interval of one of the Leonid MAC video tapes. Each detected meteor was then measured from digitized images and the distribution of meteors on the sky was determined. From fitting the observed distribution with elevation to a model, they found a magnitude distribution index of $r = 1.8 \pm 0.1$, lower than the $r = 2.2$–2.4 reported elsewhere [2]. From the rate of detected meteors, they found a factor of two lower peak storm flux than reported from visual meteor observations by Arlt et al. [4]. However, in earlier studies of 1998 Leonid MAC video data, we found that subsequent scans reveal more meteors [5]. Here, we examine the possibility that this lower flux rate is the result of an incomplete sample down to a given limiting magnitude. For that, we carefully examined a short fragment of the storm footage in great detail. For the first time, we assigned magnitudes to all meteors. We find large numbers of faint meteors, surmising that these tapes may contain up to 170 faint Leonids per minute at the peak of the storm.

2. Methods

The camera in question is called "AR50F" (ARIA, Right, 50mm, Forward), deployed onboard the ARIA aircraft [2]. The period of $1^h10^m00^s$–$1^h20^m00^s$ UT was chosen for the exhaustive analysis. The field of view of the camera was $29\overset{\circ}{.}5 \times 23\overset{\circ}{.}6$, pointed at a low ($19\overset{\circ}{.}5$) elevation, and was centered near β Cephei during the test period. The video data shows large numbers of meteors because of the high airplane altitude and low extinction near the horizon [3].

All visual scans were made by one of us (DH—who participated in Leonid MAC as an amateur observer in the "flux measurement team") using a 19-inch (41.3 cm × 30.5 cm) color TV viewed slightly above axis from a distance of 1.5 to 1.8 meters. This setup results in an average apparent screen size of $14\overset{\circ}{.}2 \times 10\overset{\circ}{.}5$. Given the field of view size above, the resulting apparent image scale is about 46%. All meteors were plotted on Brno Atlas map #3. In order to study the distribution across the video field, all Leonid meteors were assigned to a segment of the monitor screen according to the end-point position.

Figure 1 shows a drawing of the screen. Near the edges of the screen, optical vignetting is observed, which lowers the sensitivity for a 3° strip. The inner circle marks the beginning of field vignetting (0%), the outer circle marks where vignetting is 100% (black beyond), and the dashed line marks where vignetting is approximately 50%. The dashed line was used to determine segment area. The center of all three circles is marked with a circled cross. The time marker is outlined by the rectangle in the lower right.

The initial scan was made by concentrating on the center of this field, while allowing the eyes to roam constantly around the center. Visual roaming is necessary to prevent the reviewer's vision from losing sharpness while staring at a noisy video image. Many meteors are apparent all over the field using this method, but many are also found when attention is drawn to a brighter meteor and the rewind function is used. No attempt was made to formally divide the frame into segments and attention was concentrated on the center of the field when hunting for new meteors on previously unseen video footage. This type of scan will be referred to as a "center" scan.

The second scan divided the field into 6–8 loosely defined pie shaped segments, which were examined separately with almost all attention paid to the outside edges of the field. This was done to compliment the initial attention focused on the center of the image in the first scan. This method proved to be inadequate.

The third scan accurately divided the entire field into 16 rectangular segments, which were reviewed one at a time. This segmented scanning technique was intended to find as many faint meteors as possible that are usually only recognized when seen in the center of the field of view. This scan was made under normal room-lit TV conditions. Care was taken to eliminate any direct glare from light sources.

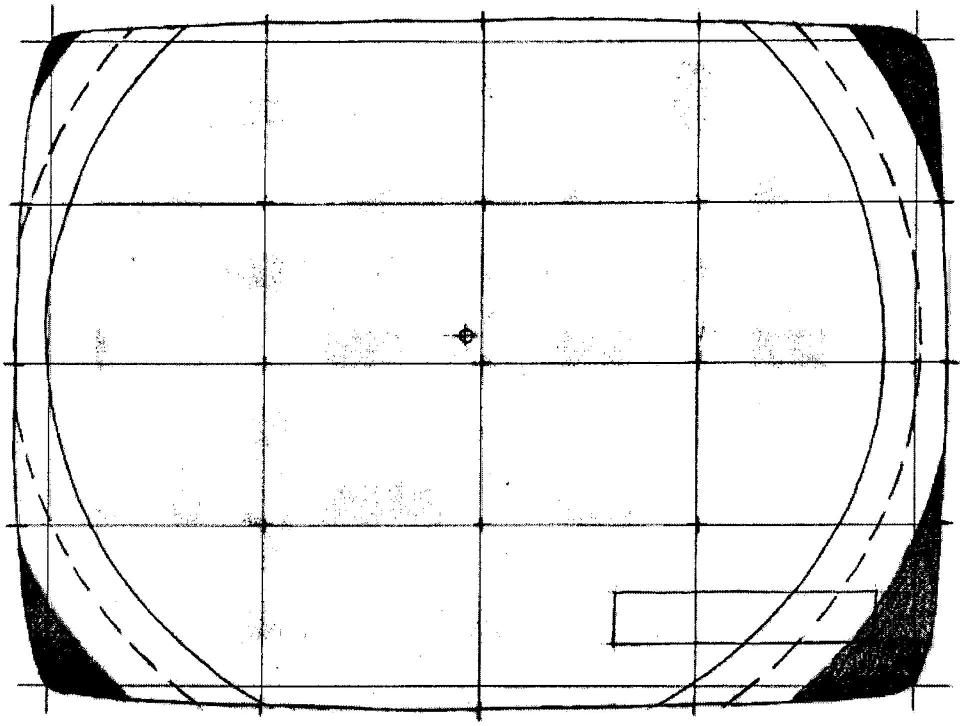

Figure 1 – A diagram of the TV screen layout. The lines defining the border of each segment were not drawn on the TV screen. Only crosses at each intersection were drawn.

Finally, a fourth 16-segment scan was made with all lights in the room turned off, which prevents distraction from other light sources in the peripheral vision. Light was allowed to enter the room only through openings to other rooms or through draped windows. This method brings the signal-to-noise ratio of the reviewing setup closer to the signal-to-noise ratio of the video data itself. To boost the detection of faint meteors further, a special protocol was used. If after 15 seconds of scanning no true or false detection had triggered a closer study, the tape was rewound and reviewed again. Each segment was scanned twice in this manner.

The 16-segment scans were made by first dividing each side of the full TV screen into four equal lengths, thereby dividing the entire screen into 16 rectangles of nearly equal area. Although each segment is of near equal size, the corner segments contain less usable field of view than the center segments due to optical vignetting. The average apparent size of the central segments is $3.6^\circ \times 2.6^\circ$. Curved edges on the TV screen result in the edge segments being slightly larger than the center segments. Small tick marks were made screen with a white china-marking pencil on the TV around the edges and at the corner of each segment to help keep them well defined. These marks are thin enough that they do not obscure meteors. The layout of the TV screen is shown in Figure 1 and is discussed in detail in Section 3.

For each minute of the period, each segment was scanned in turn (always left to right, top to bottom) with concentration limited to some point within the segment. The individual scan of each segment was done like a miniature center scan, and rewind was used liberally. All bright meteors outside the segment currently being scanned were ignored, but fainter meteors in or near the segment were checked against the list established during the initial center scan. Any new meteor in or outside the current segment was plotted on a separate map from the first scan.

When concentrating on a typical segment, it is still possible to overlook many meteors occurring in the segment. These "Elusive" meteors, discovered during the fourth scan, are typically faint (+5 and +6 magnitude, i.e., $\geq$ lm $-$ 2) with a short, thin track of short duration. Because of these characteristics, they are near the limit of resolution set by the intensifier noise and so near the limits of reviewer perception, and therefore easy to overlook. We think that Elusive meteors are largely undetectable by existing automated scanning systems.

Elusive meteors can only be found using a segmented scan in a darkened room, and after all bright meteors have been counted and logged so they can be ignored. The reviewer must be rested, relaxed, physically and mentally undistracted, and able to concentrate intently for scanning efforts to be productive. The reviewer must also check every flicker of light or movement spotted or few Elusive meteors will be found. Candidates were spotted clearly at least twice before plotting, and at least once after plotting to keep the plot as a data point in order to prevent false counts of noise as meteors. The method used to find Elusive meteors necessarily includes many false detections. About 5 to 10 negative events are examined for every positive Elusive meteor recovery, but once a positive event is located it is much easier to find again.

The reduced image scale (46%) and random motions of video/intensifier noise severely reduces the apparent area in which 100% of the Elusive meteors are detected compared to natural sky visual observations. Separate observations of the same data indicate that this is a circular area of not more than one square degree. Bright meteor activity in the segment is also a distraction. Physical distractions of short duration include itches, coughs, floaters in the aqueous humor of the eye, and tensing the eye muscles when anticipating the appearance of an Elusive meteor during a playback. All of these short duration distractions contribute to the difficulty of finding Elusive meteors. Considering that a 16-segment scan of one minute of tape takes two hours or more to complete, it is not practical to reduce the size of the segments.

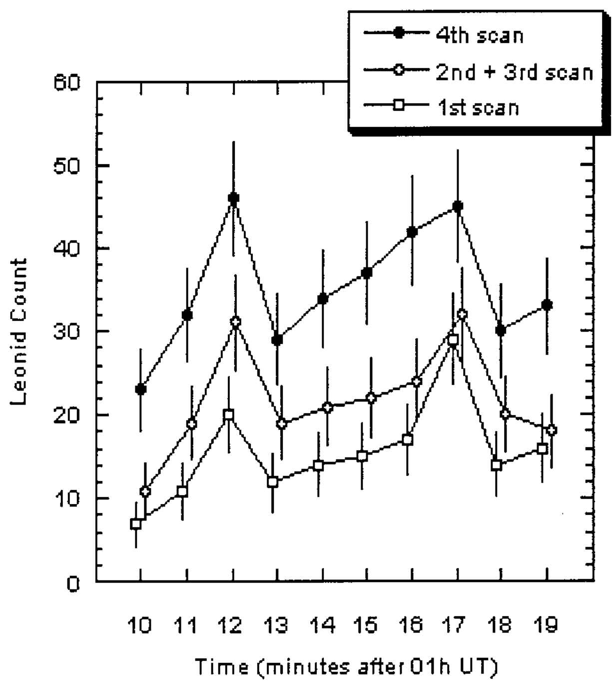

Figure 2 – Accumulated Leonid counts of the test period in one-minute intervals, corrected for dead time.

3. Results

Figure 2 shows the increase in detected Leonids with each scan. The segmented scanning method greatly increases the detection efficiency when working under dark ambient light conditions. The initial center scan of the period 1^h10^m–1^h20^m UT finds 151 Leonids and 7 sporadics. Segmented scanning increases that count by a factor of 2.3 for the Leonids and six for sporadics (343 and 42, respectively). Clearly, small variations in the detection efficiency of faint meteors in the first scan can lead to large variations in the count, which could account for some of the flux variations reported by Molau et al. [10] and Rendtel et al. [11]. However, we note that statistically (barely) significant variations during the time interval are not fully removed in subsequent scans.

Table 1 shows the distribution of all Leonids found across the field of view, corrected for the amount of area that is not obstructed. The original half scale drawing of Figure 1 was used to measure the amount of unobstructed field in each segment. To account for the semi-transparency of the time marker, the area of this rectangle was multiplied by 0.75 before being subtracted from the surrounding segments. It is useful to compare Table 1 to Figure 1. The camera was tilted to the horizon such that the lower left segment was at the lowest elevation as in [3]. The apparent rate does not depend much on azimuth, but the rate does increase toward the horizon. The latter is an effect of the low extinction and large effective surface area near the horizon and has a similar distribution to that shown in the results of [3]. The high counts in the upper corners are due entirely to large numbers of Elusive meteors found during the fourth scan. Such enhancement is not apparent in the initial scan (e.g. [3]).

Table 1 – Distribution of all meteors $1^h10^m00^s$–$1^h20^m00^s$ UT across the field. Total Leonid count is the upper number, and the correction factor for unobstructed area is in parenthesis. Shading is keyed to the number of meteors in each segment.

20 (0.90)	11 (1.16)	14 (1.16)	21 (0.81)
12 (1.14)	18 (1.00)	25 (1.00)	31 (0.98)
27 (1.12)	19 (1.00)	26 (1.00)	16 (0.94)
32 (0.79)	29 (1.16)	32 (1.07)	26 (0.39)

Magnitudes were assigned to all meteors by making comparisons to selected stars in the same field of view. Only stars of spectral classes B7 through A3 were used for magnitude comparisons. These stars were identified using [6] and [7]. Comparison stars of magnitudes +4.2 to +7.2 were available in the field of view of the test period. In addition, a magnitude +2.4 A7 star was available in the same field, and two stars of magnitudes +2.1 and +3.0 in the accepted spectral range were available in an adjacent field of view. All magnitude estimates were made to a ± 1-magnitude tolerance, and systematic errors appear at +1 (undercount) and -2 (overcount). The faintest stars that are constantly visible against the noisy background are of magnitude 6.5 ± 0.1. This is expected to be the limiting magnitude for meteors as well. No variation is detectable across the field of view, a result of low extinction at altitude. Dimmer stars can be recognized in the noise. Using the count area #7 in Cepheus [8], both lit and dark room scanning has a limiting star magnitude of 7.1 ± 0.1.

These are V magnitudes. The camera has a different spectral response than the dark-adapted naked eye, which affects the relative brightness of meteors and star background. Based on a typical Leonid spectrum [9], this amounts to meteors being systematically brighter in the video record relative to stars of spectral type B7–A3 by +0.34 magnitudes compared to what a visual observer would notice. Most of the difference is due to the meteor's emission in the near-IR. Hence, we extrapolated counts to +6.16 (absolute) video magnitude, rather than +6.5.

The magnitude distribution is expected to be an exponential curve. Indeed, the distribution is exponential until an apparent magnitude of about +3. We find a best slope $r = 1.8 \pm 0.1$

(−1 to +4) for the apparent magnitude distribution and $r = 1.9 \pm 0.1$ (−5 to +0) for the absolute magnitude distribution. In contrast, the sporadic meteors have $r = 3.6$. This result is in surprisingly good agreement with Gural and Jenniskens [3], who found $r = 1.8 \pm 0.1$ without estimating meteor magnitudes. Instead, they used a Monte Carlo simulation based on the apparent distribution of Leonids with elevation.

If we extrapolate from an exponential curve fitted to brighter apparent magnitudes, 98 Leonids are missing, 34 from the +5 class and 64 from the +6 class. Similarly, from the absolute magnitude distribution, 118 Leonids are missing from the faintest magnitude class. From Figures 3 and 4, it follows that the first scan was 100% efficient only down to +2 magnitude ($\Delta m \geq 4.0$). Figure 3 shows how the detection efficiency increased with subsequent scans. For the expected rate of fainter meteors, we extrapolate the exponential distribution of bright meteors. Even after four scans (three segmented), the detection efficiency of faint meteors does not approach 100%.

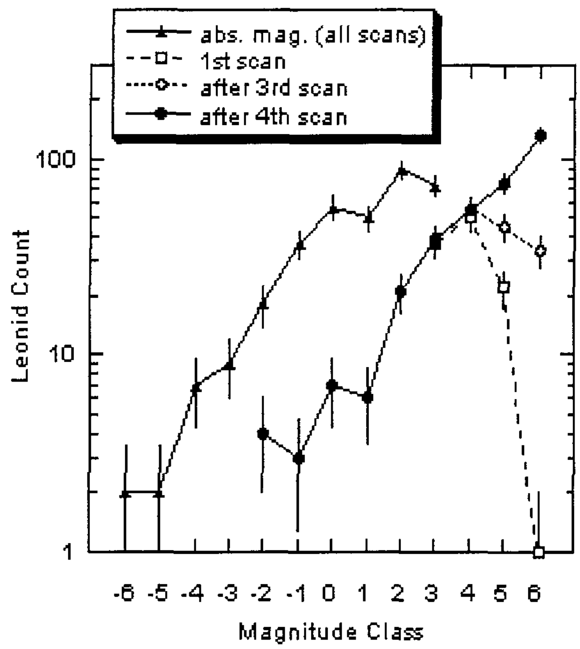

Figure 3 – Magnitude distributions for $1^h10^m00^s$ to $1^h20^m00^s$ UT. Apparent magnitudes are shown by bullets and absolute magnitudes (at distance 100 km) are shown by triangles.

4. Application to flux measurements

These detection efficiencies for the test period are thought to be typical of the complete observing interval. They apply as well to the neighboring camera AR50F, studied by Gural and Jenniskens. Figure 5 compares our observed counts with those of Gural and Jenniskens, showing that the latter represent essentially a single scan observation. Gural and Jenniskens found a meteor count density of 0.82 ± 0.19 km^2/hr. Now, we find that the fraction of meteors detected after one scan is only (numbers from Figure 4): $F = (0.95 \times 1.8 + 0.9 \times 1.8^2 + 0.2 \times 1.8^3 + 0.0 \times 1.8^{3.66})/(1.8 + 1.8^2 + 1.8^3 + 1.8^{3.66}) = 0.30$. Therefore, the Leonid flux is rather $0.82/0.30 = 2.7 \pm 0.6$ particles per km^2 and per hour ($< +6.5$, $D = 100$ km).

In order to measure the flux independently, we continued to calculate the effective detection area of our camera and calculate the absolute flux at the peak of the shower. Three flux estimates were made for zones that describe the absolute magnitude corrections $\Delta M = -3$, -4, and -5 (Table 2). The effective field of view of the intensified camera was derived by plotting each segment corner onto the same map used for plotting so that elevations and distances to each point could be determined. The truncations by the top and bottom monitor edges on the circular camera field were defined by linear equations, and computer integration was preformed on this apparent field of view (see Figure 1) to determine the associated meteor surface area. We calculate an effective surface area of 60 073 km^2 for the entire field of view, an adopted end height of 97 km, and a slightly tilted field of view relative to the horizon as in [4]. For a radiant altitude of 47°2 (ARIA) at the peak of the shower, the effective cross-section of the shower is 44 077 km^2.

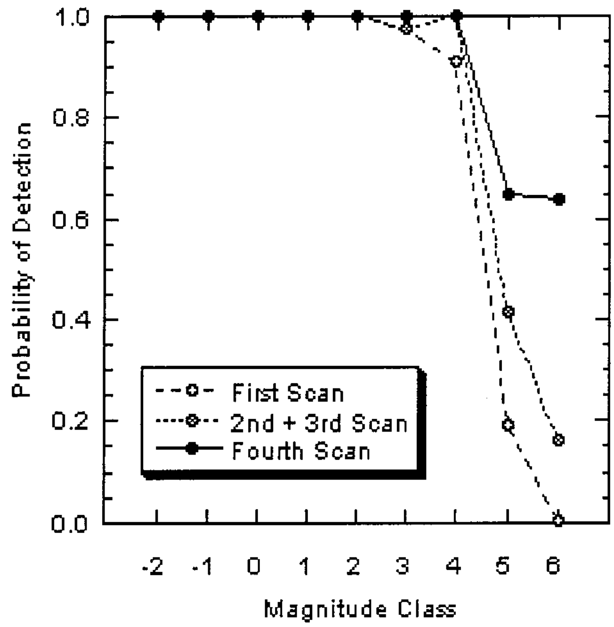

Figure 4 – Probability of detection.

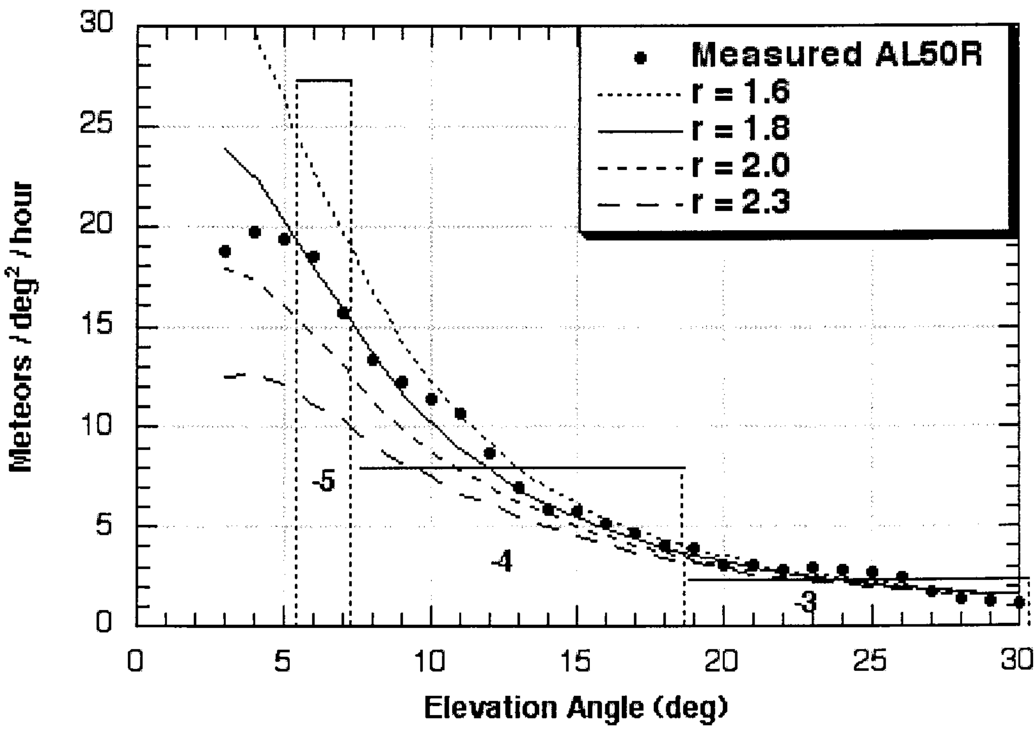

Figure 5 – Comparison of a single scan detection rate at the peak of the shower with the rate of meteors detected by Gural and Jenniskens (2000).

Table 2 – Results from each limiting magnitude zone in the field of view, where $\Delta M = \mathrm{lm}_{abs} - \mathrm{lm}_{app}$. *) 2.7 if same trend as Gural and Jenniskens (Figure 5).

ΔM	r	App. Area (square degress)	Actual Area (km^2)	Elevation Range	Flux ($km^{-2}hr^{-1}$)
−3	1.83	288.6 (48.0%)	8 816 (14.7%)	$30.^\circ5 \geq E \geq 18.^\circ6$	2.4
−4	1.92	296.2 (49.3%)	43 594 (72.6%)	$18.^\circ6 > E \geq 7.^\circ2$	2.6
−5	2.28	16.4 (2.7%)	7 664 (12.7%)	$7.^\circ2 > E \geq 5.^\circ3$	3.8*

The resulting mean flux value at the peak of the shower (using the Lorentz profile of [2] to extrapolate to the peak) is 2.8 ± 0.4 particles per km^2 and per hour larger than absolute magnitude $V = +6.5$. This value agrees with the corrected single-scan results by Gural and Jenniskens [3]. Hence, we now confirm the low r and find good agreement in the peak flux measurement after correcting for missed meteors. Our estimates, however, are a factor of two higher than the 1.4 ± 0.1 km^2/hr derived from visual data [4] and the 1.6 ± 0.1 km^2/hr from video data reported in [10].

Acknowledgments

Peter Gural provided the computer code used to make the absolute magnitude corrections. The deployment of ARIA in the 1999 Leonid Multi-Instrument Aircraft Campaign was supported by the US Air Force and NASA's Planetary Astronomy program.

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Observational Results

The Forward Scatter Meteor Year: 2001 Update

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A table of forward scatter radio meteor echo count peaks detected by various systems throughout the year is given and discussed, which updates the information on this topic first presented at the 1997 *IMC* [1]. Some notes on the analysis methods employed are also given, with brief comments on the problems and future of radio meteor observing at the present time.

1. Introduction

The increasing use of automated radio meteor detection systems since 1993, and the publication of reliably regular results using such equipment in the *Radio Meteor Observation Bulletins* (*RMOB*s) produced by Chris Steyaert since August of that year, led to the construction of a working list of radio meteor activity peaks, the Forward Scatter Meteor Year (FSMY), in 1997 [1]. This listing was based on a careful statistical and comparative analysis of the raw radio data, using methods, and for reasons, outlined in that paper (these were briefly tackled earlier in [2], and are summarized below for clarity, updated as the methods have been refined with time). It was presented at the 1997 *IMC*, and some useful discussions followed both at the Conference and afterwards.

By the next *IMC*, it was possible to present evidence from mid-1997 to mid-1998 to support the vast majority of echo-count peaks defined by the FSMY table, and an attempt was also made then to derive a numerical proportion of daily echoes due to the sporadic background. These details were published in [3], and as in 1997, further useful discussions followed.

In the 30 months since this last update, radio data have continued to be produced, enabling additional checks, changes and corrections to the FSMY listing, many of which have been notified in the on-going *SPA Meteor Section* series of results articles in this journal, though some have been too minor to warrant specific mention. Here, all of the new information has been employed to completely revise the FSMY list, and a fresh table is presented as part of this current work. It is very encouraging to find that no wholesale changes have proven necessary to the original version, but as we have found increasingly with visual meteor work in the last decade and more, meteor shower activities are not fixed things (even if some non-*IMO* meteor shower listings continue to try to give a contrary impression!), and some adjustments must be expected from time to time.

Since all of the contributing observers and correspondents have been named already in the *SPA Meteor Section* articles, these are not repeated again here, but all are once more gratefully thanked. However, I should like to pay particular tribute to Chris Steyaert for his efforts in operating the *RMOB*s, and most especially to the observer Maurice de Meyere of Belgium for his continuous provision of monthly radio data throughout the entire life of the *RMOB*s to date, and indeed whose efforts were a major catalyst to my original production of the first FSMY analysis in 1997.

2. Nature of the observations and analysis methods

As was pointed out in [3], the raw radio echo numbers and activity patterns through the year are remarkably similar to the same parameters obtained from visual observations, providing allowance is made for the fact that a radio system enjoys a larger and more objective view of the meteor layer for any given site than a visual watcher. Generally speaking, the radio meteor echo numbers are of the order of tens of events per hour, not the hundreds we would expect from radar observations, for example. This is an important consideration, because it suggests the vast majority of radio systems are detecting chiefly overdense meteor trails (those where the meteoric ionization is above a certain critical level, usually taken as equivalent to visual meteors of about magnitude +5 or brighter). If this is true, then because the various computational methods established since the 1950s, which attempt to reduce raw radio meteor data much as ZHR computations reduce raw visual meteor counts, require all the considered trails to be underdense (that is, produced by meteors fainter than magnitude +5 or so), then these will not work satisfactorily, if at all, in modern forward scatter radio meteor analyses.

There are other problems with using these radio Observability Functions in practice as well. The formulae for all the variants are complex, and mistakes can very easily occur through even a minor error in data-entry, so thorough and repeated checking is essential. With modern PCs, this is not a particular problem, but the fact that a significant proportion of the required numerical data for both receiver, and especially the transmitter(s), may be unknown, potentially even unmeasurable, is. In addition, other factors have to be estimated, assumed, or perhaps more accurately, if less elegantly, guessed-at. The more "assumed" elements in the formula, the less reliable it becomes. Complex as these formulae may be, they are usually incapable of accuracy unless only a single shower radiant is active above the horizon at any given time, which from observations we know is almost never the case in reality. Finally in this non-exhaustive summary of problem areas, the fraction of echoes due to the sporadic meteors must be removed before the computation. Although in [3] I attempted to derive this sporadic flux, in practice the method involved a number of further assumptions, because we cannot presently determine the origin of every radio meteor. Such knowledge would be essential to say with conviction exactly what was being detected.

Not unnaturally, these difficulties have put off most people from using these cumbersome computations, usually after a period of hopeful dabbling in them, as they realize the end results are no more reliable than what a careful examination of the raw rates would show. It was this realization after my own struggles with the Observability Functions that led to my concentration on working entirely with the raw rates during the past 5-6 years.

I am the first to admit that using the raw results alone is not an ideal solution, and that at times the analysis can seem more of an arcane art than a science, but apparently it does work (something which never fails to surprise me!), as has been shown by the independent radio confirmation of elements of the major meteor shower maxima, even at quite short timescales on occasion (e.g. during the 1999 Leonid storm peak), and the highlighting of unusual events, including the 1995 α-Monocerotid outburst, the 1998 Draconids, and the heightened Taurid activity in late October 1998, as a few examples.

What is done is to create raw activity graphs and compare the shape and character of those graphs from day to day, and with others made at different locations within the same region, and between regions globally, where such information is available. In doing this, the greatest weight is given to those reports that were collected for at least 10 continuous hours daily on at least half the days in each calendar month, and where the observer identified specific times when interference or some other problem occurred. In the best cases, continuous monitoring on almost every day is available, and every potential problem area is flagged for attention. All times when any interference was registered are removed as a matter of course before beginning the analysis now. Observations which fail to meet these basic criteria are treated with progressively less weight the further from the ideal they are, though observations concentrated around particularly interesting periods for even shorter parts of a day can be very useful too, providing any difficulties have been noted. Reports which do not flag problem periods at all are treated with the least weight, and at times when (particularly Sporadic-E) interference has been very strong, such as May–August 2000, this may mean entire months of data are effectively lost from some observers.

The comparison is achieved by examination of the graphs for each separate system, and determining dates where clearly heightened activity was present. Note that this does not necessarily equate with a single high echo-count spike during the daily observations, since lower but sustained levels of activity are also picked out as of potential interest. Once a listing has been compiled for each system, these are all compared with one another, and generally speaking a reasonably clear pattern of radio activity normally begins to emerge. Naturally, there are occasional anomalies, including unidentified interference (which is not always readily recognisable even by experienced radio observers), and it is this comparison between datasets which helps identify many of these oddities, in exactly the same way that drawing on visual watches from many people enables us to get a clearer picture of visual meteor activity. As with visual work, individual radio datasets are useful, but far from infallible, tools to discovering what activity has been present. Pooled datasets are far more reliable in both instances.

After amending the dates to rounded-off whole degrees of solar longitude, these compiled all-system notes are then compared with the FSMY listing. If there are significant differences, the radio data for that solar longitude are checked again for errors, and individual datasets are often examined as well, looking for interference problems or correlating UT and local solar high-count times where a potential new source may have been encountered. Typically, the pattern revealed will fit closely with previous FSMY findings.

For the normal, fairly minor, echo count peaks, at present the analysis usually ends there, because of time constraints. While it would be interesting to try to identify each possible meteoric peak source, the numbers of these small peaks make it impractical to do so. For each major shower peak or unusual event though, further details are sought, and a comparison between the observed diurnal radio activities and the probable source-shower's radiant elevation in the sky for the various sites is made. The daily pattern shown by the sporadic rates is allowed for during this, as are also the antenna directions of the operating systems with regard not only to the shower radiant, but also to where the transmitting stations are located.

Commonly, and with care, it is usually possible to derive an estimated peak time to the nearest hour for most major showers which produce well-defined single maxima. For showers with several maxima, or where the highest rates may persist for some hours, this can be more difficult, and a particular problem exists for the Arietid and ζ-Perseid maxima, which fall just two days apart in June. Overall, the success rate in finding maximum times which match well with those independently found from visual analyses, or with the theoretical peak times where visual reports were not made, is reasonably good, though the uncertainty in analysing the raw radio data always makes me treat the results with more caution than is perhaps sometimes warranted. A good example of this success is the higher Taurid rates in late October 1998 [4,5], where it was the correlation of the radio observations which first showed something anomalous after the Orionid maximum had faded away. It was only later checking of the visual data compared with the timings of the radio results which showed the source was the Taurids. Curiously, no individual radio or visual observers had realised this increased activity was present from their own data alone, which is a clear demonstration of the value of pooling visual and radio data.

Some of this analysis is carried out by computer, notably the graph-generation, but the variables involved in correlating between sites, radiants and radiant elevations, and individual radio set-ups, make it easier to carry much of it out by eye, brain and hand. The procedure for examining the raw radio results is thus quite arduous and time-consuming, and requires a degree of patience to successfully accomplish, but the experience gained along the way is also invaluable in helping to save time and being able to recognise the difference between, say, an unnoticed interference problem and a genuinely interesting new event.

3. The Forward Scatter Meteor Year

The revised FSMY listing follows below as Table 1. In comparing it with Table 1 of [1], most of the changes will be seen to be quite small, but all are based on the analyses carried out since the original list was derived, in conjunction with that earlier work. The "Notes" column highlights particular amendments where some comment was felt desirable, or other points worthy of attention, and is the major addition to the list as a whole. The "Possible associated showers" column should not be taken as definitive of the sources of activity, except for the major showers, for reasons already outlined. Further discussion of individual showers as possible radio meteor sources can be found in [1].

4. The future

I have already commented above that the FSMY listing is not carved in stone, but is a flexible tool, just as the working list of visual meteor showers is for visual observers, and like the visual list, it will hopefully continue to be updated based on the best-available results in future. One element that could be improved on would be to better-define which of the showers might be associated with which radio peaks, and indeed to identify those without known visual shower sources. This would be an extensive project however, and may not prove possible in the short to medium term. The detailed analysis of major shower and outburst maxima, along with unusual or unexpected events, should continue though, since this is more manageable.

Unfortunately, it is less clear how long a future radio meteor observing may have. Several of the European observers have found increasing problems in recent years with transmitters changing frequencies, particularly those in eastern Europe which were always a mainstay of western European radio meteor efforts, for instance. At the same time, a significant number of European transmitters which formerly operated 24 hours a day have reduced their operating times, most commonly shutting down for several hours overnight. This has created some apparently strange diurnal radio activity patterns, where just as the sporadic rates are apparently recovering from their daily trough (which occurs at about 18^{h} local solar time), they then dip again to a similar trough for a few hours over local midnight, before rising sharply towards the "dawn peak" near 6^{h} local time. This too has to be allowed for in the affected datasets. Problems have already been generated for the radio analysis of showers that have peaked overnight from Europe, and it is improbable these are liable to lessen as time goes on.

Table 1 – Forward-scatter radio meteor echo peaks found from 1993 August–1997 June, as amended by observations from 1997 July–2000 December.

Column one gives the solar longitude ($\lambda_\odot$; for equinox J2000.0) an echo-count enhancement was recorded during. Longitudes given in square parentheses, "[ ]", indicate peaks found only since 1997 July. These parentheses' are similarly employed in columns two and three.

Column two ($\pm$ to $\lambda_\odot$) shows the spread in degrees of solar longitude sometimes noted by observers before and after the period in column one, but not necessarily in every year. A single number indicates both the start and end solar longitudes may be so modified in some years (e.g. interval $\lambda_\odot = 314°$ to 318°, plus-minus 2°; greatest extent of enhancement thus $\lambda_\odot = 312°$ to 320°), while two numbers indicate different amounts should be allowed for at the start (first number) and end (second number) of the period. Thus the interval 309°–310° has been found to extend from 307°–311° at times.

Column three indicates the relative strengths of the solar longitude peaks on a simple three-point scale (weak-medium-strong). This scale has been simplified from the original five-point one used in the 1993–1997 analysis, and is no longer as numerically based as that earlier scale. Some comments on poorly confirmed peaks or unusual events are noted too.

Column four gives possible associated meteor showers (most minor ones associated by date only), and their peak solar longitudes. The three-letter *IMO* shower code is used for night-time shower data extracted from [6]; daylight shower information from the same source is indicated by unreferenced shower names consisting of the standard *IAU* constellation abbreviation, amended by adding the appropriate Bayer letter or month name in full, in brackets, where necessary (e.g. the daytime β-Taurids become "β-Tau"; the April Piscids become "Psc (April)"). Other sources include: "Artoos I" and "II" [7]; "HV" [8]; "K" [9]; and "*" [10]. The use of set parentheses here ("{ }") indicates a shower whose radiant has a high southerly declination, which may never rise from some of the radio observing sites employed.

Column five gives relevant notes on each specific echo-count enhancement.

Table 1 – The forward scatter meteor year.

$\lambda_\odot$ interval	± to $\lambda_\odot$	Strength	Possible associated showers	Notes
281°–287°	none	281° medium; 282°–283° strong;	283° QUA; 287° ρ-Geminids (K 11-12).	Main peak generally at 283°.
		284°–287° weak		
289°	1°–0° in 2000 only	weak	287° ρ-Geminids (K 11-12); 290°–291° δ-Cancrids (HV 143).	Poorly confirmed in 1999 and 2000.
290°–294°	none	weak	290°–291° δ-Cancrids (HV 143); 292°–296° δ-Cancrids (K 5-7).	No clear single peak.
295°	none	weak; clear only in 1997 and 2000	292°–296° δ-Cancrids (K 5-7).	Hardly noticeable in 1998–1999.
298°	1°	weak	297° DCA.	Only seen since 1997.
300°–302°	1°	weak	300° δ-Cancrids (K 5-7); 300° α-Hydrids (K 12-14);	Usually best at 299°,
			304° Canes Venaticids (K 19-20).	and may blend over 298°–300°+.
[304°–305°]	[none]	[weak]	304° Canes Venaticids (K 19-20);	First found 1998; weakly recovered in 1999–
			304°–305° January Coma Berenicids [11]	2000; notably in long duration echoes.
309°–310°	2°–1°	weak	309°–313° Capricornids-Sagittarids (K 25-26); 312°–313° Cap/Sgr.	Continued to 311° in 1999 and 2000.
314°–318°	2°	314° weak; 315° medium;	309°–313° Capricornids-Sagittarids (K 25-26);	Main peak time seems variable,
		316°–318° weak	312°–313° Cap/Sgr; 316°–321° Aurigids (K 23-25); {319° ACE}.	314° (1999), 313° (2000).
320°–322°	none	weak	316°–321° Aurigids (K 23-25); {319° ACE}; 325° χ-Cap.	Confirmed 1998–2000
[326°]	[1°(?)–0°]	[weak]	325° χ-Cap.	325° in 1998, but 326° only since.
328°	1°–2°	weak	325° χ-Cap; 330°–336° δ-Leonids (HV 148).	Confirmed 1998–2000.
[331°]	[none]	[weak]	330°–336° δ-Leonids (HV 148).	Seen since 1998, but poorly found in 1999.
333°–342°	none	333°–335° weak; 336°–337°	330°–336° δ-Leonids (HV 148); 336° DLE;	Generally confirmed 1998–2000.
		medium; 338°–342° weak	340°–355° Virginids (HV 155); 342° ρ-Leonids (K 48).	
344°	0°–1°	weak	340°–355° Virginids (HV 155).	Confirmed 1998–2000.
346°–347°	none	weak	340°–355° Virginids (HV 155).	Typically found on both dates.
350°	none?	weak	340°–355° Virginids (HV 155).	Poorly confirmed, ≈ 349°–352° (?).
352°–355°	none	weak	340°–355° Virginids (HV 155); {353° GNO}.	Typically best at 352° or 354°.
357°–358°	1°–0°	weak	340°–355° Virginids (HV 155)?; 359°–0° ϑ-Virginids (K 44-46).	Confirmed 1998–2000.
359°–4°	none	359° medium (?); 0°–3° weak;	359°–0° ϑ-Virginids (K 44-46); 0° β-Leonids (K 35-37).	359° good in 1998–1999, 4° in 1999–2000;
		4° medium (?).		2° was weak-medium in 1999 too.
				May blend with 357°–358° and 7°–8°.
7°–8°	1°–3°	weak	7°–9° η-Draconids (K 33-35).	Commonly ill-defined.
14°–19°	1°–0°	14°–16° weak; 17° medium (?);	17°–28° α-Virginids (K 60-64).	Commonly ill-defined.
		18°–19° weak		
21°	1°–0°	weak	17°–28° α-Virginids (K 60-64).	21° since 1999.
22°–24°	none	weak	17°–28° α-Virginids (K 60-64); 24°–25° γ-Virginids (K 64-65).	First found 1997;
				very weak/poorly confirmed in 1999–2000.
25°–27°	0°–1°	weak	17°–28° α-Virginids (K 60-64); 24°–25° γ-Virginids (K 64-65).	Sometimes blends with previous peak.
30°–33°	none	32° medium; others weak	30° Psc (April); 32° LYR.	Better-defined than in original FSMY.
34°–39°	0°–2°	weak	{33°–34° PPU}; 34° δ-Psc.	Commonly ill-defined.
40°	1°	weak	45°–46° ETA.	May blend with previous peaks.
42°–50°	none	42°–45° weak; 46° strong;	45°–46° ETA; 49° ε-Ari.	Variable peak strengths and timings.
		47°–50° medium		
52°–53°	none	52° weak; 53° medium	45°–46° ETA; 55°–56° Ari (May).	Confirmed 1998–2000.
54°–58°	none	weak	55°–56° Ari (May); 59° o-Cet.	Generally confirmed 1998–2000.
[60°–61°]	[none]	[weak]	59° o-Cet.	First found 1998.

Table 1 – The forward scatter meteor year (continued).

$\lambda_\odot$ interval	± to $\lambda_\odot$	Strength	Possible associated showers	Notes
62°–66°	none	weak	66°–70° Sagittarids (HV 168).	Poorly confirmed 1998–2000.
69°	1°	weak	66°–70° Sagittarids (HV 168).	Revised activity using 1998–2000 data.
71°	none	weak-medium (?)	66°–70° Sagittarids (HV 168).	Stronger activity not confirmed 1998-2000.
73°	none	weak	66°–70° Sagittarids (HV 168).	Confirmed 1998–1999.
75°–82°	2°–0°	75° medium; 76° weak; 77° medium; 78° weak; 79° medium; 80°–82° weak.	77° Ari; 79° ζ-Per.	Stronger peaks at 75°–76°, 78°–79° and 81°–82°/83°, 1998–1999. 1996, one dataset showed activity from 71°–96°.
84°	1°–2°	weak	85° June Lyrids (K 99-103); 90°-Sagittarids (HV 168).	Confirmed 1998-2000. May blend with previous peaks.
89°–97°	none	89°–90° weak; 91°–93° medium; 94°–97° weak	90° Sagittarids (HV 168); 96° JBO; 97° β-Tau.	Strong June Boötid peak at 95°–96° in 1998 only. Other peak timings variable.
99°	1°	weak	97° β Tau.	Generally confirmed 1997–2000.
107°	4°(?)–2°	weak	107°–108° JPE.	Typically poorly confirmed 1997–2000.
111°–114°	none	weak	{111° PHE}	Possible peak at 112°?
[115°]	[none]	[weak]	Aquarid-Capricornid complex (late July)?	1998 only; poorly confirmed since.
116°	none	weak	Aquarid-Capricornid complex (late July)?	Only found in 1996 and 1999 (long duration echoes).
120°	1°–3°	weak	Aquarid-Capricornid complex (late July).	Confirmed 1997–2000.
122°–128°	2°–3°	122°–123° weak; 124°–125° medium to strong; 126°–128° weak	125° PAU; 125° SDA (124°–126° HV 179); 127° CAP (124°–130° HV 183); Aquarid-Capricornid complex (early August).	Sometimes blended with previous peak. Peak at 128° now considered linked. Highest counts usually 124°–126°.
129°	0°–1°	weak	Aquarid-Capricornid complex (early August); 132° SIA (133°–137° HV 187).	Previously set at 130°, but not well confirmed there.
[131°–133°]	[none]	[weak]	Aquarid-Capricornid complex (early August); 132° SIA (133°–137° HV 187).	First found 1999. Clearest in long duration echoes at 131° 1999–2000.
135°	none	weak	132° SIA (133°–137° HV 187); 136° NDA (133°–139° HV 178).	Very poorly confirmed 1997–2000.
137°–142°	4°–0°	137° medium; 138° weak; 139°–140° medium to strong; 141°–142° weak	136° NDA (133°–139° HV 178); 139°–140° PER.	Well-confirmed main peak between 139°–141°.
144°	1°–2°	weak	145° KCG; 147° NIA (146°–153° HV 187).	Generally confirmed 1997–2000.
[148°–149°]	[none]	[weak]	147° NIA (146°–153° HV 187).	First found 1998; ill-confirmed since.
155°	5°–1°	weak	147° NIA (146°–153° HV 187); 152° γ-Leo.	Confirmed 1997–2000, but no clear peak.
[158°–159°]	[none]	[weak]	159° AUR.	First found 1998. Generally confirmed since.
160°–163°	none	160°–161° weak; 162°–163° medium	159° AUR.	Generally confirmed 1997–2000.
165°	none	weak	166° DAU.	Confirmed present 1997, 1999, and 2000.
169°	3°–0°	weak	169° η-Draconids (K 180-181).	Confirmed 1997–2000.
170°	0°–1°	weak	169° η-Draconids (K 180-181).	First found 1996; confirmed 1997–1999.
172°–173°	0°–1°	weak	174° (Artoos I).	Confirmed 1997–1999.
[174°]	[none]	[weak]	174° (Artoos I).	Found in 1999, possibly extending to 175° for European observers only; stronger in southern hemisphere results in 2000.
176°–177°	0°–2°(?)	176° medium; 177° weak	177° SPI.	Confirmed 1997–2000.
180°–181°	none	weak (1996, one dataset showed weak activity from 178°–182°)	179° κ-Aquarids*; 181° γ-Piscids (K 181-182); 182° October Cetids (K 208-209).	Sometimes from 179°, but confirmed 1997–2000.

Table 1 – The forward scatter meteor year (continued).

$\lambda_\odot$ interval	$\pm$ to $\lambda_\odot$	Strength	Possible associated showers	Notes
183°	1°–0°	strong	182° October Cetids (K 208-209); 183°–187° (Artoos II); 184° Sex; 185°–190° Sextantids (K 205-207).	Well-confirmed in 1998–1999, less well detected in 1997 and 2000.
185°–187°	none	usually weak, but strong at 186° in 1999	183°–187° (Artoos II); 184° Sex; 185°–190° Sextantids (K 205-207).	Found 1996; confirmed 1997–2000.
190°–192°	1°–3°	190° weak; 191° medium; 192° weak	185°–190° Sextantids (K 205-207); 190° Capricornids (October)*; 192° October Cetids (K 208-209); 192° σ-Orionids*.	Confirmed 1997–2000. Up to three peaks between 189°–195° in some years.
195°	0°–1°	weak to strong (1998 only)	194° October Arietids (K 183-185); 195°–196° GIA.	Most likely due to Draconids, but 190°–192° peak often extends to 195° as in 1999–2000.
198°–199°	0°–1°	weak	–	Confirmed 1997–1999, poorly found 2000.
201°–212°	none	201° weak; 202° medium; 203°–206° weak; 207°–208° strong; 209°–212° weak.	203°, 214° October Cetids (K 208-209); 205° EGE; 208° ORI (205°–212° HV 222).	Confirmed 1997–2000. Strongest peak usually at 208°.
[216°–217°]	[none]	[weak]	Taurid “swarm” [4,5].	Only found in 1998, coincident with higher visual Taurid rates. Very weak, less clear peaks found in 1999–2000.
219°	1°(?)	weak	Taurid fireballs?	Weak confirmation 1997–1998, better confirmed 1999–2000.
224°	2°–3°	weak	223° STA (220°–230°, especially 224°–225° HV 232).	Confirmed 1998–2000 particularly.
227°	1°–4°	weak	230° NTA (220°–230°, especially 227°–230° HV 232).	Generally confirmed 1997–2000, especially around 227°–228°. May blend into 230°.
230°	0°–1°	weak	230° NTA (220°–230°, especially 227°–230° HV 232).	Formerly found at 229°, but noted at 230°–231° since 1997.
233°–237°	none	233° medium; 234°–236° medium to strong; 237° weak	235° LEO.	Confirmation of visual high activity since 1998. Main peak times variable.
238°–239°	none	weak, except 1995	239° AMO.	Confirmed weak activity 1997–2000.
240°–248°	none	weak	250° XOR (248°–250° HV 248).	Several peaks, but timings inconsistent.
249°–250°	none	weak	250° XOR (248°–250° HV 248).	Confirmed 1997–2000.
[252°]	[1°–0°]	[weak]	–	First found 1998, confirmed each year since.
254°	0°–3°	weak	{254° PHO}; 257° MON.	Generally confirmed 1997–2000.
257°	1°–0°	weak	257° MON.	Formerly at 256°, but at 257° in 1997–2000.
258°–264°	1°–0°	258° weak; 259°–260° medium; 261°–263° medium to strong; 264° weak	257° MON; 260° HYD (254°–256° HV 260); 262° GEM.	Generally confirmed 1997–2000, but parameters amended from observations of slightly later peak than original FSMY.
265°–267°	none	weak	265°(?) σ-Hydrids (HV 260); 268° COM (265°–278° HV 271).	Confirmed 1997–2000; peak generally 265°–266°.
269°–270°	0°–1°	weak to medium	268° COM (265°–278° HV 271); 271° URS (269°–271° HV 274).	Confirmed 1997–2000.
272°–275°	0°–1°	weak	268° COM (265°–278° HV 271); 271° URS (269°–271° HV 274).	Possible peak at 273° in 1997 and 1999.
278°–279°	none	weak	268° COM (265°–278° HV 271).	Usually at 278° mainly.

The increasing use of satellite systems to transmit radio signals, as well as the Internet, the shift towards digital broadcasting from analog (most likely to have an impact on how many transmitters use which frequencies), and mobile phones eating into the available terrestrial transmission bands, may well become important in determining the future for radio observing too. With the ingenuity and tenacity shown by radio meteor observers though, it seems probable that in some fashion, radio work will survive. How many visual meteor observers would have continued struggling to make reports, knowing that their data could not be properly analyzed, and was being largely ignored, for years, I wonder? The Japanese example of setting up a dedicated transmitter beacon specifically for radio meteor work [12] might be one way forward for other groups too, where suitable permission and funding can be obtained to run it.

We can but hope that having finally achieved some recognition and success in helping to determine what the meteor activity the Earth encounters has been doing in recent times, radio work may continue to provide us with additional fascinating insights into this topic well into the new century at least!

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Call for photographs

As is often the case, we are short of photographs for the front cover. When you think you have such a photograph, please send it to us! The details that matter of a suitable photo should not be too fine to accommodate for the uninevitable information loss in the printing process. Remember that other subjects than meteors such as observer groups, equipment, meteorite craters, etc. are also acceptable.

Marc Gyssens, Editor-in-Chief

Results of the Schwassmann-Wachmann-3 Meteors

Rainer Arlt

The relatively far encounter with a dust trail of Comet 73P/Schwassmann-Wachmann 3 was monitored by visual, video, and radio observers. The activity from a probable geocentric radiant at $\alpha = 212°$, $\delta = +28°$ was marginal to entirely zero during the period May 24–June 1. Observing problems with zenithal attraction are discussed.

1. The dust trail encounter

For the prediction of Leonid outbursts, the numerical integration of dust trail particles ejected at various perihelion passages of the parent Comet, has shown very satisfying accuracy. The same method was used to study the trails of the fragmented Comet 73P/Schwassmann-Wachmann 3, and indeed a dust trail encounter with material from the Comet was predicted for 2001 [1]. The miss distance was too large for an outburst alert, but still, observational monitoring of such a near-miss-event is of importance to obtain a quantitative basis for activity preditictions from dust trail computations.

2. The 2001 observational data

The data set is not nearly as comprehensive as that of any major meteor shower, but we do appreciate the reports of the following 19 observers who watched visually or operated their video equipment (marked as such) from nine countries:

> Rainer Arlt (`ARLRA`, Germany), Felix Bettonvil (`BETFE`, the Netherlands, *video*), Andreas Buchmann (`BUCAN`, Switzerland), Goedele Deconinck (`DECGO`, Belgium), David Holman (`HOLDA`, USA), Peter Jenniskens (`JENPE`, USA), Carl Johannink (`JOHCA`, the Netherlands), Takema Hashimoto (`HASTA`, Japan), Mike Koop (`KOOMI`, USA), Marco Langbroek (`LANMA`, the Netherlands), Robert Lunsford (`LUNRO`, USA), Robert McNaught (`MCNRO`, Australia, *video*), Sirko Molau (`MOLSI`, Germany, *video*), Marc Neijts (`NEIMA`, the Netherlands, *video*), Jürgen Rendtel (`RENJU`, Germany), Rosta Štork (`STORO`, Czech Republic, *video*), Josep M. Trigo-Rodriguez (`TRIJO`, Spain), Arnold Tukkers (`TUKAR`, the Netherlands), Cis Verbeeck (`VERCI`, Belgium).

Many of the reports were taken from the `meteorobs`-mailing list, thus do not represent the final full report.

The main problem of scrutinizing data of possible SW3 meteors arises from the uncertainty in the radiant position. The model gives fairly precise coordinates, but they turned out to be far from the "historical" position in Hercules, and we have to be careful about the actual radiant used by the individual observers. Sometimes additional correspondence helped clarify if the correct position was used or whether, at least, the classified SW3-ids also line up with the model position.

Japanese observers anually report numbers for the shower of May α-Bootids which lies very close to the predicted SW3 position as listed in their shower catalog. Since observers in Japan reported low, but probably significant meteor numbers from that radiant in previous years—in 2000 in particular—, we faced a possible precursor for 2001 activity. The only report coming from Takema Hashimoto this year was entirely negative for the UT-afternoons of May 31 and June 1, though off the dust trail encounter time. He also informed the author that he stayed at the MU-radar of Kyoto University on May 30, but did not note an increase of meteor echo numbers due to SW3-ids. On May 31, the radar was not in an operation mode suitable for meteor observations.

Even more problematic is the effect of the Earth's gravity which is strongest for slow meteoroids. The actual geocentric motion suffers a bending towards the center of the Earth giving rise to a radiant displacement towards the local zenith. This zenithal attraction also varies with the elevation of the geocentric radiant; typical values are 3° for a radiant height of 65° and

9° for 30° elevation. Both apparent and geocentric radiant elevations are given in Table 1 with the observational data. In practice the observer needs to be aware of this shift, which varies drastically during the night. Generally it is not taken into account though. No meteor coordinates are available at this stage of analysis, and the activity overview given here is thus an approximate graph only. Table 1 shows the list of all individual reports during the probable activity period of meteors from Schwassmann-Wachmann 3.

The video data cannot be converted into ZHRs easily. The significance of their negative results are evaluated by the number of sporadics recorded. The video observations by Felix Bettonvil suffered from cloud and only one sporadic meteor was recorded in two nights. The video thus gives a rough upper limit which SW3 activity has not exceeded, say about $ZHR_{max} = 20$. The video system oprated by Sirko Molau recorded 14 sporadics in the night of May 29-30 yielding an upper limit of $ZHR_{max} = 2$ for SW3 activity. His observation of May 30-31 shows 5 sporadics, whence $ZHR_{max} = 5$. These numbers at least exclude an outburst during the corresponding periods.

Table 1 – Individual observing periods during the nights of possible Schwassmann-Wachmann-3 activity. The observing periods are given in UT. The total correction factors $C = 3^{(6.5-\mathrm{lm})} F / \sin h_R$ represent the significance of the individual resultis. The radiant elevation h_R is given for the apparent (only zenithally attracted though) and the geocentric (no gravity of the Earth) position.

Date	Observer	$\lambda_\odot$ (J2000)	Period	N_{SW3}	C	h_R (app./geoc.)
May 24	JOHCA	63.°77	21^h54^m–22^h16^m	0	0.210	68°/65°
May 25	LANMA	64.°74	21^h45^m–22^h45^m	1	0.647	68°/64°
May 25	TUKAR	64.°74	21^h45^m–22^h45^m	0	0.461	68°/64°
May 25	JOHCA	64.°75	21^h45^m–23^h05^m	1	0.862	67°/63°
May 25	TUKAR	64.°78	22^h45^m–23^h45^m	0	0.398	63°/59°
May 25	LANMA	64.°78	22^h46^m–00^h00^m	0	0.628	62°/58°
May 25	JOHCA	64.°79	23^h05^m–00^h05^m	0	0.394	61°/56°
May 25	TUKAR	64.°82	23^h45^m–00^h45^m	1	0.368	57°/51°
May 26	JOHCA	64.°83	00^h05^m–01^h05^m	0	0.629	54°/48°
May 26	LANMA	64.°83	00^h00^m–01^h12^m	0	0.779	54°/48°
May 26	TUKAR	64.°85	00^h45^m–01^h15^m	0	0.178	52°/45°
May 29	STORO	68.°62	21^h00^m–01^h30^m	1	(video)	
May 29	VERCI	68.°63	22^h58^m–00^h20^m	0	0.113	60°/55°
May 29	DECGO	68.°63	22^h50^m–00^h20^m	0	0.148	60°/55°
May 29	MOLSI	68.°63	21^h03^m–02^h15^m	0	(video)	
May 29	RENJU	68.°64	23^h00^m–00^h36^m	0	0.914	55°/49°
May 29	BETFE	68.°66	21^h55^m–02^h30^m	0	(video, lm = +5, $F \approx 2$)	
May 30	ARLRA	68.°67	00^h17^m–01^h00^m	0	0.194	49°/41°
May 30	TRIJO	68.°75	02^h03^m–03^h05^m	0	0.308	39°/30°
May 30	LUNRO	69.°01	08^h30^m–09^h33^m	0	0.930	54°/44°
May 30	LUNRO	69.°05	09^h33^m–10^h35^m	0	0.844	40°/31°
May 30	LUNRO	69.°09	10^h35^m–11^h38^m	0	0.488	30°/18°
May 30	HOLDA	≈ 69.°1	casual	0	–	
May 30	JENPE	≈ 69.°1	casual	0	–	
May 30	KOOMI	≈ 69.°1	casual	0	–	
May 30	MOLSI	69.°62	22^h56^m–01^h29^m	0	(video)	
May 31	HASTA	70.°21	14^h45^m–15^h20^m	0	0.122	62°/57°
May 31	HASTA	70.°32	17^h15^m–18^h15^m	0	0.189	34°/24°
May 31	BEFTE	70.°56	21^h45^m–02^h00^m	0	(video, lm = +5, $F \approx 1.1$)	
Jun 01	HASTA	71.°28	17^h25^m–18^h25^m	0	0.160	32°/21°

The professional video system at Ondřejov observatory, Czech Republic, recorded one possible SW3-id among 19 meteors in total according to the personal report from Rosta Štork. The meteor passed in 6°9 distances from the zenithally attracted, theoretical radiant; the angular velocity was 5.1°/s—in good agreement with the theoretical 6.6°/s.

Table 2 shows a rough profile of the "activity". We used the averaging equation

$$\overline{\mathrm{ZHR}} = \frac{1 + \sum\limits_i n_i}{\sum\limits_i T_{\mathrm{eff},i}/C_i},$$

where n_i are the shower meteor numbers of each observing period, $T_{\mathrm{eff},i}$ their effective durations, and C_i the combined correction factors for each period, consisting of the limiting magnitude (lm) correction, field obstruction correction F, and apparent-radiant elevation (h_R) correction: $C_i = r^{(6.5-\mathrm{lm})} F / \sin h_\mathrm{R}$. Because the meteor numbers are extremely small, we get into the skew regime of Poissonian statistics meaning that the expectation value for the ZHR can never be exactly zero. Instead, the ZHR plus error margin represents a probable upper limit for the activity oberserved, particularly for the case that no meteors were seen. This is why the "1+" appears in the averaging.

Table 2 – Tentative averages of the ZHR of possible meteors from Schwassmann-Wachmann 3. Note that the last row is based on zero meteors; the ZHR plus error margin thus gives an upper limit of the ZHR if no meteors are seen under given conditions.

$\lambda_\odot$ (J2000)	Intervals	N_{SW3}	$\overline{\mathrm{ZHR}}$
65°75	10	3	0.7 ± 0.3
68°65	5	1	1.2 ± 0.8
69°05	3	0	0.4 ± 0.4

We should note also the gaps in the observational data, the most prominent being that between European and American nights, on May 30 from $3^\mathrm{h}05^\mathrm{m}$ to $8^\mathrm{h}30^\mathrm{m}$ UT. This 5.4-hour lapse is well capable of comprising a meteor activity peak of a young dust trail. Here we are looking for material from a 11-revolution dust trail which should exhibit a more extended structure noticable for several hours.

In a conclusive paragraph we may state that there was no activity from Comet Schwassmann-Wachmann 3 in 2001, neither from the close encounter with the 1941 dust trail nor from another source connected with that Comet. Again, the miss distance to the trail was large, and a failure of activity from that trail is not surprising. Since the 2000 activity was possibly more pronounced, it will certainly be interesting to model the dynamics of those cometary ejecta in more detail.

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SPA Meteor Section Results: November–December 2000

Alastair McBeath

Details from observations and correspondence in the *SPA Meteor Section* files from 2000 November and December are presented and discussed. A brilliant, possible Taurid, fireball lit up British skies around 19^h05^m–19^h10^m UT on November 3-4, as reported from 19 locations, including one in the Netherlands. The Leonid near-maximum epoch was well covered by visual and radio observers, the latter in particular providing some interesting comparisons with the preliminary *IMO* visual results in [1]. A review of British visual Leonid reports is given, along with some brief recollections of the event from observers. In December, good Geminid radio-visual rates were found on both December 12-13 and 13-14, despite bright moonlight deterring many visual watchers. The results favour a peak on the latter date, much as predicted. Some confirmation of the possibly extended Ursid maximum discussed in [2] was found in the radio and visual data from December 22, with perhaps two radio peaks around 5^h–7^h and 8^h–11^h UT (visual peaks at $\approx 6^h$ and $\approx 8^h$–9^h UT). Visual ZHRs at best were of the order of 20 ± 5 (6^h UT) and 30 ± 5 (8^h–9^h UT), moderately enhanced above normal. No evidence supporting the strong outburst around 7^h30^m UT on December 22 proposed in [2] was detected however.

1. Introduction

Moonlight deterred or hampered observations around almost all the major shower peaks in November–December 2000, and as often happens, the early northern winter weather provided scant assistance for outdoor watchers generally. Even so, parts of the near-peak Leonid, Geminid and Ursid epochs were covered by our observers. Table 1 gives the observing tallies.

All the photographic and much of the video results came from cameras operated by *Arbeitskreis Meteore* (*AKM*) observers. All the *AKM* data used here was taken from their journal *Meteoros* 3:12 (2000), 4:1 and 4:2 (both 2001), sent to us by Ina Rendtel. The photographers were Jürgen Rendtel and Jörg Strunk (who both operated video cameras too). A first overview of his Leonid video observations from Spain was sent to us by Steve Evans, but the bulk of the video data here was secured by *AKM* members J. Höffner, Detlef Koschny (Netherlands), Sirko Molau, Mirko Nitschke, and Ilkka Yrjölä (Finland), all in Germany where not noted.

Of the radio reports, all the data except that from Dirk Artoos were sent to us by Chris Steyaert as *Radio Meteor Observation Bulletins* 88–90, December 2000 to February 2001 inclusive. The observers were:

> Jean-Louis Aillaud (Réunion Island, Indian Ocean), Enric Fraile Algeciras (Spain), Dirk Artoos (Belgium), Mike Boschat (Canada), Patrick Decomble (France), Maurice de Meyere (Belgium), Ghent University (Belgium), Rafael Haag (Brazil), Will Kelsey (Arkansas, USA), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Ingo Reimann (Germany), Ton Schoenmaker (Netherlands), Dave Swan (England), Ervin Szlanicska (Slovakia), Istvan Tepliczky (Hungary), Pierre Terrier (France), Garfield Tsao (Taiwan), Bruce Young (Australia), Ilkka Yrjölä (Finland).

Figures 1 and 2 give graphs showing the general behaviour of radio meteor activity during November and December, following the usual procedures for examining raw radio meteor data in these *SPA* reports. Figure 2 picks up some of the fine detail missed because of the large Leonid spike in echo counts in Figure 1.

Our visual observers (in England unless stated otherwise, and including those who reported unsuccessful attempts to cover the major shower maxima through to full watch data) were:

> *AKM* members Rainer Arlt, Pierre Bader, Lukas Bolz, Frank Enzlein, Christoph Gerber, Matthias Growe, Ralf Kuschnik, Hartwig Lüthen, Sirko Molau, Sven Näther, Jürgen Rendtel, Roland Winkler, and Oliver Wusk (all in Germany); Mark Bailey (Northern Ireland), K. Bergen, Jay Brausch (North Dakota, USA), Dave Bray, Michael Brooke, Dave Campbell, Chris Chambers, Maggie Daly, Peter Dean, Steve Evans (Spain), Shelagh Godwin (England and Singapore), Roberto Gorelli (Italy), David Gosnell, "Graeme", Lew Gramer (New England, USA), Valentin Grigore (Romania), Philip Heppenstall, Carl Johannink (Portugal), Mohammad Ali Khodayari (Iran), "Kieran", Marco Langbroek (Netherlands and Portugal), Jeff Lashley (Scotland), Trevor Law (Egypt), Bob Lunsford (California, USA), Tony Markham, Alastair McBeath, Tom McEwan (Scotland), Steve Milburn, Koen

Miskotte (Portugal), Charles Munton, Ben Notarini, Mohammad Odeh and other *Jordan Astronomical Society* members (Jordan), Terry Owen, Peter Phillips (Northern Ireland), Ian Ridpath, Paul Saunders (Wales), Robin Scagell, Jonathan Shanklin (airborne over the North Atlantic, and Falkland Islands), Nigel Smith, George Spalding, Roger Stapleton (Scotland), Darren Swindells, Alistair Thomson, Mihaela Triglav (Italy and Slovenia), Fiona Vincent (Scotland).

2. November

Bright moonlight and poor weather accounted for the first half of November for visual watchers, so little of the Taurid maxima could be seen. Radio results showed a recovery of all the minor peaks previously detected during this time [3], most notably around $\lambda_\odot \approx 227°$–$229°$ (November 9–11) as normal. A typical Taurid return can probably be inferred.

Around 19^h05^m–19^h10^m UT on November 3-4, a fireball of about magnitude -8 to -10 was witnessed from 19 sites across southern England and the Isle of Wight northwards to the South Wales-England border and eastwards to South Yorkshire and Humberside, as well as at one site in the Netherlands. Unfortunately, there are too few accurate reports to pin down the exact track of this object. From the data available, it is likely the fireball passed on an ESE to WNW track descending from around 90 km to 50 km altitude during its flight, which probably started over the southern North Sea, crossed the English coast heading inland north of London, passing high above Essex, northern Hertfordshire and Bedfordshire, and ending some way east of Northampton. The object was fragmenting along much of its trail, and produced a very late disintegration into a number of discrete, small, pieces before fading out. Assuming the above estimates to be broadly correct, the visible-flight atmospheric trajectory may have been $\approx$ 180–220 km long, and lasted $\approx$ 5–10 s according to the better estimates, implying a probably slow atmospheric velocity of between 20–35 km/s. The path direction and the meteor's speed indicate it is quite likely to have been a Taurid, but this could not be definitely confirmed. Most observers mentioned seeing a blue-green colour at the fireball's brightest, with yellow a popular description for other parts of the event's trail.

Two other bright fireballs were reported during the month, but only by single witnesses. One was at $\approx 21^h$ UT on November 19-20 (south-east Scotland, bright enough to cast shadows), the other at $\approx 22^h53^m$ UT on November 23-24 (south-west England, magnitude $-5/-6$).

Of course, the main interest in November was always going to be the Leonids in their first post-storm return of the current epoch, despite the presence of the last quarter Moon close to the radiant near the predicted maxima. In the *IMO* data [1] Leonid ZHRs on November 16-17 were generally between 30 and 50, plus-minus 6–10, for most of the night over Europe and North America. A short-lived slight increase to 50 to 60 ± 7 occurred around 4^h–5^h UT, with a further small peak detected from about 6^h–7^h UT (ZHRs $\approx 80 \pm 20$). The radio data used here suggested an increase in meteor echo rates between $\approx 6^h$–7^h UT, perhaps beginning near 5^h UT. This was eclipsed by a stronger radio peak around 8^h UT, a time when the visual ZHRs reached 130 ± 20. This timing was virtually coincident with both the Earth's closest approach to the 1932 Leonid dust trail, and the time of the nodal crossing in 2000.

November 17-18 was the more active night for the Leonids, with good radio counts and visual ZHRs throughout. *IMO* ZHRs were 100+ between 0^h15^m–9^h30^m UT on November 18, and the radio results gave a clear confirmation of distinctly enhanced rates exactly during the 0^h–10^h UT interval. Between $\approx 1^h50^m$–8^h25^m UT, when *IMO* ZHRs were 200+, the two strongest maxima were found, the first very ill-defined, building and declining slowly during a roughly one-hour long interval centred on 3^h24^m UT, (ZHR $\approx 290 \pm 20$). The radio results confirm an unsharp peak around this time, with increased echo counts between 2^h–5^h UT. The second, and most active, visual maximum near 7^h12^m UT (ZHR $\approx 480 \pm 20$) could also be quite well-defined in the radio results, with the strongest echo counts during the 2000 Leonids found from 7^h–8^h UT in virtually all the available datasets where the Leonid radiant was well above the horizon. Again though, this maximum was not sharply delineated in the radio observations. Overall, radio rates were at least somewhat enhanced, when the Leonid radiant was available, for the whole $\lambda_\odot = 233°–235°$ (November 15–17) interval, as noted before. This year, this period extended to $\lambda_\odot = 237°$ (November 19) in many reports, not for the first time in recent years. It is worth commenting that in the *IMO* report, ZHRs of 30+ persisted between November 15-16 to 18-19, coincident with this radio enhancement. The strength of the radio peak at $\lambda_\odot = 236°$ (November 18) also overtopped all the other detected major shower maxima in 2000 by a large margin in most datasets.

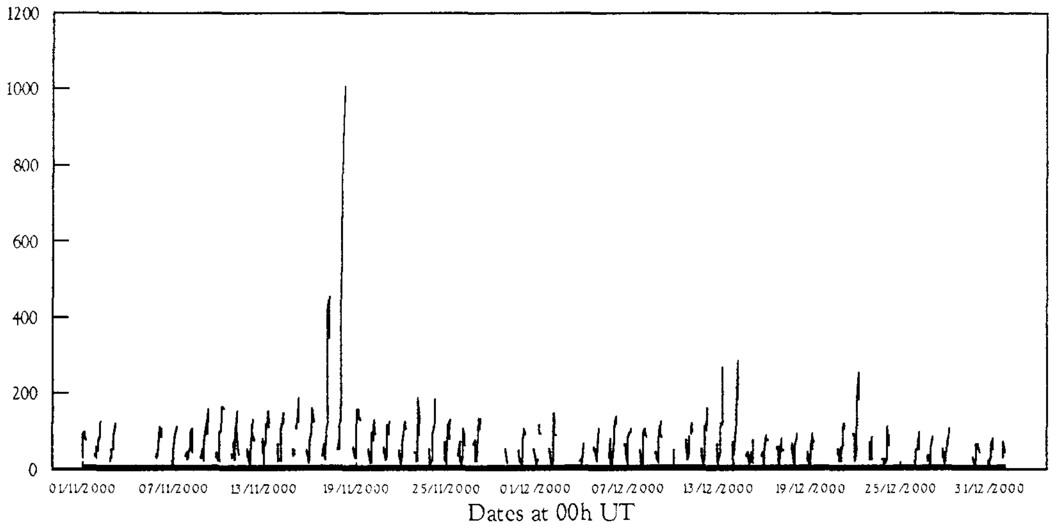

Figure 1 – Raw hourly radio meteor echo counts from 2000 November and December, in data collected by Maurice de Meyere (in *RMOB*s 88 and 89, December 2000 and January 2001 respectively). Maurice's equipment was in general active for 11h daily, between $21^h–7^h$ UT, with breaks for interference. Dates not observed on included November 3-4, 4-5, and 27-28, December 2-3, 19-20, 24-25, and 28-29. This graph has been scaled to show the dominant relative strength of the Leonid peak on November 17-18, compared to the Geminids and Ursids in December. Note that although the European radio observers generally recorded the Ursid peak more clearly than their colleagues elsewhere in the world, Maurice's data are unusual in showing the relative Ursid strength as being so similar to the Geminids.

Table 1 – Visual, photographic, video and radio hours' totals, plus visual and video meteor numbers, recorded in each month, with a partial breakdown of visual meteor types.

Month	Visual	STA	NTA	LEO	Meteors	Photo	Video	Trails	Radio
November	$93^h.8$	41	36	1885	2401	$40^h.9$	$259^h.9$	1354	$5738^h.6$

Month	Visual	GEM	URS	COM	Meteors	Photo	Video	Trails	Radio
December	$67^h.4$	284	216	18	1002	–	$420^h.5$	1425	7130^h

In Britain, observations on November 16-17 were possible from parts of south Wales and most of central to eastern England, while much of western England, Scotland and Northern Ireland seem to have been caught beneath overcast skies. From the UK-only data, something of the November 17, $\approx 6^h$ UT minor peak looks to have been visible as dawn twilight was strengthening, when Leonid ZHRs rose from a steady overnight $\approx 60 \pm 25$ between at least $2^h–5^h30^m$ UT, to around 100 ± 30 soon after 6^h UT. A few minor fireballs (magnitude -3) were spotted, with a hint of slightly more of these towards 6^h UT, but this was not convincing of an increased fireball rate. A couple of observers commented on the rather strange observing circumstances the Moon enforced, where Leonids were coming from "over their shoulder", as they faced towards the northern skies to keep the Moon as far from their line of sight as possible on this night and the next!

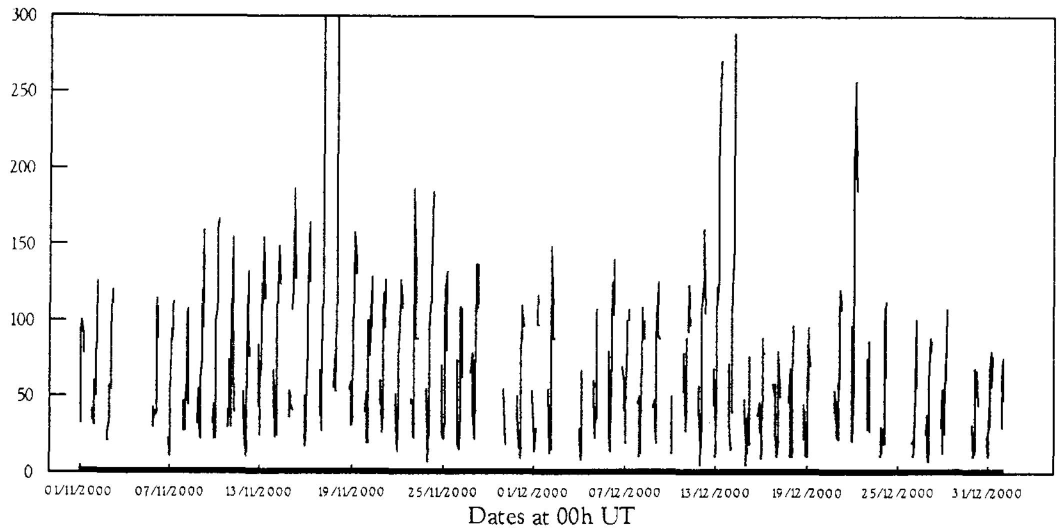

Figure 2 – Identical data to that in Figure 1, but now with the y-axis re-scaled to a cutoff of 300 echoes per hour, in order to more clearly show details in the lower radio meteor activity observed in 2000 November–December away from the Leonid peak.

Unlike in 1999, southeastern England seems to have been the place to be in Britain on November 17-18, as chiefly positive reports have arrived from this area, plus two with details of clearer skies for a short time around 3^h UT further north in Yorkshire. Even so, observers often struggled with clouds, though many reported seeing a superb 22° halo around the Moon, thanks to a high-altitude cirriform cloud-sheet ahead of an advancing frontal weather system. Healthy Leonid rates of up to minor fireball-class meteors (magnitudes −3 to −8) were viewed by most in spite of this.

By contrast, the frontal system produced generally overcast skies, and sometimes rain, across other parts of Britain. Clouds, rarely punctuated by occasional sightings of a meteor or meteoric flash brightening the overcast, were more typically observed from most places with active watchers in northern England, Northern Ireland, Scotland and Wales on November 17-18. Even so, most people greeted the lack of clear skies philosophically, as November is traditionally one of the worst months for clear weather in the UK, and those who had seen something the night before were glad not to have wasted that opportunity.

Under good skies overseas, several Section correspondents commented that the November 17-18 display seemed similar in strength and persistence to the 1998 Leonid fireball night, but that 2000's Leonid meteors were significantly fainter, with very few notable fireballs. Rainer Arlt in Germany and Mihaela Triglav in Slovenia chased holes in the clouds and fog, driving hundreds of kilometres overnight on November 17-18, to confirm this view. However in Romania, Valentin Grigore commented on how Leonid rates were strengthening to about 3–4 a minute until fog descended at 1^h26^m UT, which then lasted for the next nine hours! The clearest skies were found in Spain, Portugal, Egypt and some parts of the USA in our results. The Jordanian watchers at their Al-Azraq observing camp out in the desert were unlucky to be clouded-out throughout the shower, as skies were clear, though heavily streetlit, only 120 km away in the capital Amman! So much for the myth of clear desert skies!

From quite a few of the British reports especially, something of a party atmosphere was apparent on both November 16-17 and 17-18. Several people made a real night of it, determined to have a splendid time, for example by observing all five naked-eye planets with the unaided eye in one night (although Mercury was extremely easy from the UK by mid-November, Venus was still setting very early then, especially for sites further north), the Moon, the lunar halo, and managing some Leonid watching as well. Peter Dean with a group in Surrey mentioned good Leonid rates could be counted just within the lunar halo!

Computed ZHRs based on the British results alone from November 17-18 showed a large scatter because of the often poor skies, but were generally $\approx$ 200+ by 2^h UT. There were indications of two clearer submaxima after then, most noticeably around 3^h30^m–4^h15^m UT when ZHRs were $\approx 330 \pm 100$, perhaps with two stronger phases towards 3^h40^m–3^h45^m and 4^h10^m–4^h15^m UT. The radio observations provided some support for the first of these two phases, but not especially the second. Interestingly, the *IMO* ZHRs showed a brief dip to $\approx 190 \pm 8$ near 4^h30^m UT, which may have helped give the impression of higher rates just before that in the cloud-affected British results. Drawing on overseas data as well, another possible submaximum may have happened close to $2^h50^m \pm 10$ min UT (ZHR $\approx 300 \pm 130$) in the *SPAMS* data, which coincided with a slight ZHR peak of $\approx 270 \pm 10$ around 2^h53^m UT in the *IMO* results. This also looked to have been weakly detected in the radio data.

Details on the Leonids' magnitude and train distributions can be found in Tables 2 and 3. Looking separately at the Leonid data from November 17-18 showed a corrected mean magnitude of +2.58 (711 meteors), somewhat brighter than the overall mean, but all these values, together with those for the British ZHRs given above, should be treated with caution because of the poor observing conditions, including moonlight, this year. The train details look to have suffered particularly because of this, with fewer Leonids recorded as leaving trains, and those that did apparently lasting for shorter durations than expected.

Table 2 – Global magnitude distributions, including mean LM and corrected mean magnitudes for the Leonids and November sporadics seen in good sky conditions (LM +5.0 or better—relaxed only from the usual level of +5.5 to allow use of moonlit data near the Leonid maximum—and cloud cover < 20%).

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	LM	$\overline{m_{6.5}}$
LEO	8.5	16	50.5	87	120	176.5	197	163.5	56	875	5.70	2.95
SPO	0	0	0	1	9	15	48	42	13	128	5.71	4.04

By November 18-19, skies were overcast above much of southern and western Britain, and very few positive reports have arrived from then. Those that did indicated Leonid ZHRs had fallen back to $\approx 35 \pm 20$. Even that level is two or three times better than the Leonids achieve in their more typical non-outburst years, however. Steve Evans in southern Spain commented that despite concentrating on his video and photographic equipment then, he was still spotting around 10 Leonids an hour quite easily in casual sky-checks, helped by being at a good, dark-sky, rural site.

Some of the early European radio results and comments from radio hams suggested system-saturation had occurred near the three main Leonid peaks. This may have been due to increased atmospheric ionization produced by the Leonids, possibly a type of Sporadic-E, last detected as strongly from the shower in 1996 [4]. However, subsequent enquiries have shown this to be much less widespread in 2000 than was first supposed, with only one radio meteor observer, Ton Schoenmaker, reporting very severe problems due to this, while no radio hams have come forward with actual evidence to support the few initial claims. Indeed [5] commented that the radio amateurs generally found the 2000 Leonids did not quite live up to their expectations, and also noted that at times there was so much noise from amateurs failing to observe the correct procedures on some radio frequencies, that making contact using meteor scatter propagation was impossible. It may be this noise which gave the early impression of system saturation for the radio hams, and might even have helped cause part of the difficulties Ton Schoenmaker reported.

Few visual observations were made during the α-Monocerotid epoch after the Leonids, but the radio data indicated only the normal minor meteor enhancements were found as before during late November, including $\lambda_\odot \approx 238°$–$239°$ (November 20–21) and in the $\lambda_\odot = 240°$–$248°$ (November 22–30) spell. No α-Monocerotid outburst seems probable from these at least.

Table 3 – Global train percentages and mean durations in seconds per magnitude class for the Leonids. Train details were available for only 218 Leonids from the magnitude distribution. Too few trained November sporadics were seen (1/56 meteors = 1.8%) for a sensible analysis of them to be made.

Magnitude	-3^-	-2	-1	0	+1	+2	3^+	Tot	%
LEO train percentage	33	83	61	44	20	4	0	54	24.8
LEO train duration	4.5 s	1.6 s	1.6 s	1.0 s	1.2 s	1.0 s	–	–	–

3. December

The month commenced with a pair of fireballs over Britain on December 1-2, each seen just by one observer unfortunately. The first was around 20^h UT (eastern Scotland; bright), the second at 0^h50^m UT (north-central England; magnitude -5, but very low to the north). Indeed, four other non-shower fireballs were seen by single witnesses during the first half of December from the UK, on December 5-6 ($\approx 17^h45^m$ UT), 9-10 ($\approx 17^h55^m$ UT), and 13-14 ($\approx 19^h24^m$ and 19^h41^m UT), all in the magnitude range -3 to -6. The two sporadic fireballs on December 13-14 were seen by observers less than 5 km apart in Northumberland, but annoyingly, neither observer saw both events (I was one of the observers)! Other than this, few visual watches were made during the first half of the month, until December 12-13.

Comparing the early December minor radio peaks with those seen before [3] revealed no especial surprises. The $\lambda_\odot = 252°$ peak first noted in 1998 was recovered only weakly around $\lambda_\odot \approx 251°$–$252°$ (December 3–4) in half the datasets, but this fits the pattern seen with this peak since 1998. No $\lambda_\odot = 256°$ (December 8) maximum was found, but it seems likely this peak now occurs the following day, since a minor echo count spike has happened around $\lambda_\odot = 257°$ in each year since 1998, and it would probably be more accurate to reset this peak's timing to the later date.

The Geminid peak was the main radio highlight of the month for most observers, as normal, although there is little close agreement as to an exact maximum time for the shower. A majority of the datasets indicated echo counts were very good on both $\lambda_\odot = 261°$ and $262°$ (December 13 and 14), though $\lambda_\odot = 262°$ usually provided the stronger activity. Long-duration echoes ($D >$ 5 s) in the Japanese data favour the latter date, though Sadao Okamoto's all-echo count numbers were marginally higher the day before, perhaps suggesting more brighter meteors from the Geminids on December 13-14, if longer duration echoes are produced by brighter events. The lack of consensus regarding a specific maximum time is not unexpected from recent Geminid returns, with the preliminary *IMO* visual analysis [6] suggesting ZHRs of $\approx 125 \pm 20$ were seen between about 20^h–3^h UT at least on December 13-14. Visual observations in the *SPAMS* files concur, with identical ZHRs to the *IMO* ones seen from Europe on December 13-14 through until $\approx 4^h$–5^h UT. Unfortunately, the bright waning gibbous Moon seems to have deterred far more people than the marginally less bright Leonid Moon in November, and many fewer visual reports were received for the Geminids. However, it has been possible to construct the magnitude analysis, which is of somewhat reduced reliability due to the conditions the data was obtained under, and this is given in Table 4.

Table 4 – Global magnitude distributions, including mean LM and corrected mean magnitudes for the Geminids, Ursids, and December sporadics seen in good sky conditions (LM +5.0 or better—relaxed only from the usual level of +5.5 to allow use of moonlit data near the Geminid maximum—and cloud cover < 20%).

Shower	-3^-	−2	−1	0	+1	+2	+3	+4	$+5^+$	Tot	LM	$\overline{m_{6.5}}$
GEM	4	10	14	28	34	58	59	30	2	239	5.26	2.96
URS	0	4	2	5	12	20	28	16	1	88	6.29	2.43
SPO	2	0	3	5	5	26	34	31	1	107	5.77	3.32

The post-Geminid minor radio peaks from [3] were detected much as usual, though the $\lambda_\odot = 278°–279°$ one (December 29–30) was found only weakly around $\lambda_\odot \approx 278°$ and 280°. A fuller investigation was carried out for the Ursids.

From comments in some correspondence it was clear the warnings about a possible Ursid outburst in 2000, even on e-mail, failed to reach all the potential observers, though quite why was not always clear (some people cited an e-mail server fault, however). This and poor weather (the UK was overcast across much of the Ursid epoch, for example) seems to have meant much less visual data was secured, even by the *IMO*, than we would ideally have preferred. Drawing on the initial *IMO* report [7], the revised *Nippon Meteor Society* details [8] and visual observations submitted to the *SPAMS*, there is the suggestion of a double peak, with a first maximum on December 22 around $5^h–6^h$ UT producing ZHR $\approx 20 \pm 5$ (the annual peak prediction, issued before any outburst warnings were made, was expected around 6^h UT then, $\lambda_\odot = 270\overset{\circ}{.}7$ [9]), followed by a second maximum between $8^h–9^h$ UT when ZHRs were $\approx 30 \pm 5$. Interestingly, the radio Ursid maximum in 1996 [10] was found at $\lambda_\odot = 270\overset{\circ}{.}8$, equivalent to December 22, 2000, 8^h30^m UT, as also noted in [9]. A global magnitude distribution for the Ursids reported on December 22 from $\approx 3^h20^m–11^h30^m$ UT is given in Table 4, although the sample is very limited, and should be treated with caution.

The 2000 radio Ursid picture is not especially clear-cut, with no ready consensus on a single maximum time. There are also problems in interpreting the European data in particular, as the Ursid radiant culminates between $8^h–9^h$ local (solar) time daily near the shower's maximum, while the diurnal sporadic peak occurs around $6^h \pm \approx 2$ h local time. For the active European radio operators, local solar time equates with UT to within an hour or two. Looking at all the available data considered reliable (primarily those with comparison results available for at least several hours near or over the expected Ursid maxima, and at the same time on days to either side), a peak at some time between $2^h–13^h$ UT on December 22 can be inferred, which is not especially helpful. A more careful examination gave an indication of a stronger peak away from the radiant's culmination time between $5^h–7^h$ UT (mean $\approx 5^h53^m$ UT). There was also the possibility of a slightly weaker peak between $\approx 8^h–11^h$ UT, which from the very limited sample available seemed more obvious in longer-duration echo counts ($D > 5$ s). Pushing the small visual magnitude distribution perhaps beyond its viable limits, hinted at more relatively brighter events after 7^h UT, but this is inconclusive.

Evidence for a strong peak between $7^h–8^h$ UT, which was the main prediction in [2], is lacking in the radio reports, with only one of nine datasets giving its unequivocally highest echo count between those times, and this observer reported another significant, but much less active, peak at exactly the same time on December 23. However, a majority of the available reports could suggest a main peak between $5^h–7^h$ UT followed by a loose "plateau" of generally enhanced rates, perhaps with some short-term fluctuations, after then until $\approx 11^h$ UT, within which the longer-duration echo count peak after 8^h UT took place. Such a view would be consistent with the further discussion in [2], where the possibility of a continuous peak profile some 4–5 hours long was briefly mentioned, but whether this confirms the theoretical work behind the predictions in [2] is much less clear, because of the previously detected Ursid maxima at $\lambda_\odot = 270\overset{\circ}{.}7$ and $270\overset{\circ}{.}8$.

There is no evidence to support a very high Ursid return in the radio data, with overall little to distinguish the 2000 Ursid radio signature from that seen by similar systems in 1997–1999. Three of the nine datasets, all three in Europe, recorded a relatively strong echo peak on December 22 (Figures 1 and 2 show this most obviously), while the remaining six, including three more in Europe, showed a weak to moderate peak profile, exactly what most previous observations since 1993 have found at non-outburst returns. A slight to moderate enhancement of the 2000 Ursids can be suggested, but nothing more substantial. This, with the most likely radio maximum times, is consistent with the visual activity noted above, though again caution needs to be expressed because of the limited nature of the visual reports.

One final note should be made concerning a possible meteorite fall at Biggleswade in Bedfordshire, England around 22^h30^m UT on December 25. There were some discrepancies in the sketchy reports received by the Section, not least the fact that a bright flash of light accompanying the supposed fall was observed only by residents of a single street in the town. The material sent for analysis has turned out not to be meteoritic, and a firework seems the most likely explanation for this event.

Acknowledgments

Naturally, I am as always indebted to the contributors who have made this report possible, and along with the observers and correspondents named earlier, I would like to add my thanks to John Lambert for his help in tracing details of the supposed Biggleswade meteorite. Some of the information here, particularly concerning the November 3-4 fireball and much of the Leonid report, were earlier featured on the *SPA* Website at: `http://www.popastro.com`.

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IMO Dark Meteor Survey Report Form

As a supplement to the article by Alastair McBeath in WGN *29:1/2 (February/April 2001), we give his Survey Form for dark meteors in this issue. We would like to apologize for not having published the Form in time.—Eds.*

Once completed, please return this form to:
Alastair McBeath,
12A Prior's Walk, Morpeth, Northumberland, NE61 2RF, England, U.K.
or e-mail the data to: <vice_president@imo.net>

Date (yy/mm/dd):________ Name:________
Correspondence address:________
Site location (town, country): ________
Longitude:________ Latitude:________ Altitude:________
LM:______ Other sky conditions: ________

Please circle as appropriate to answer:
Observed during meteor watch? Yes No - if "Yes", please give watch start and end times:________
Your fatigue condition: very alert alert normal tired very tired
Were you observing in: glasses contact lenses neither

If you have never reported a dark meteor to this project before, please state:
Your age: ______
Any known eye defects:________
How many years have you been observing meteors for:________
Do you consider yourself a regular occasional casual novice observer?
(Please circle one answer only)

If you did not make this sighting visually, please state equipment used:

____

For each dark meteor, give its appearance time in UT, and describe what you saw:

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