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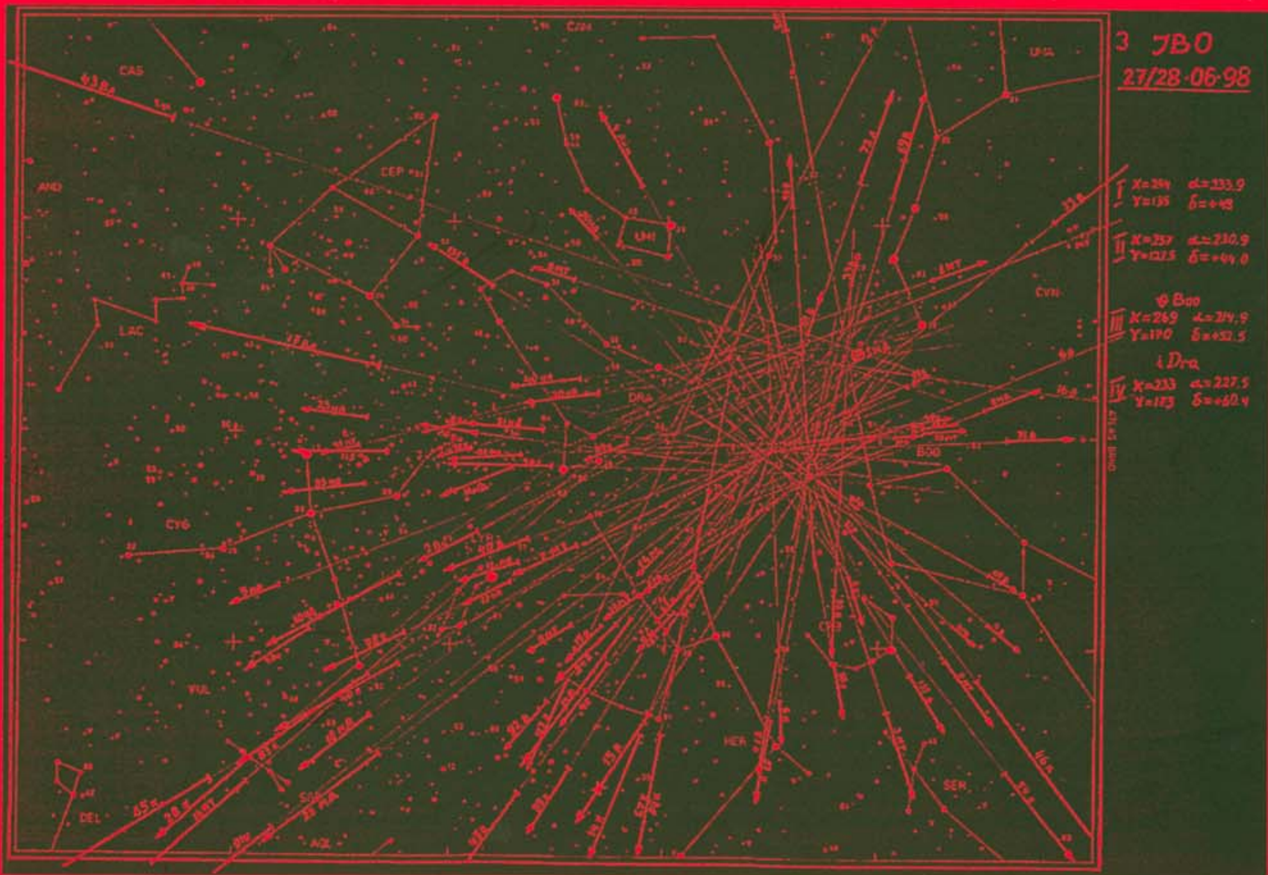

A composite chart of almost all June Bootid meteors plotted by members of the *Astroclub Canopus* in Varna, Bulgaria, during the night of June 27-28, 1998, seen from their observing site in Avren. Note that the meteors were originally plotted on several maps, whence the meteors at the border. The chart was created by Valentin Velkov.

In this issue:

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From the Editor-in-Chief

Marc Gyssens

These are exciting times for meteor observers... First of all, there are the June Bootids who showed an unexpected outburst of activity, on which we report extensively in this issue. As every year, there are the Perseids, and the evolution of the "new peak" that emerged for the first time about ten years ago keeps intriguing us. We hope to give a preliminary report in the next issue. And then, there is the anticipation of what the Draconids and Leonids might bring us this year—and on this, we provide you with all the relevant information, both in this and the next issue.

Especially the June Bootid event, during a period that short and often not completely dark summer nights make observing unattractive, illustrates again that it is important to have a continuous coverage of the meteor activity throughout the year, and that it does not suffice to observe only when major showers are active. Let me remind you that obtaining such coverage is one of the reasons why the IMO *was founded!*

Anyhow, there will be a lot to talk about at the IMC *later this month. Meanwhile, enjoy this issue!*

Meteor Shower Calendar: October 1998–March 1999

compiled by Alastair McBeath

1. October to December

Ecliptical minor shower activity reaches what might be regarded as a peak in early to mid November, with the Taurid streams in action (the Southern Taurid maximum will be lost to bright moonlight this year, but something of the Northern peak should still be seen). Before then come an important return of the Draconids, the Orionid, and the minor ε-Geminid maxima. This is also a key year for the Leonids in November, and a good one to check for a repeat of 1995's outburst for the α-Monocerotids. December's Full Moon claims the maxima of the χ-Orionids, Phoenicids (December 6, 13^h UT) and the early, better, part of the weak Puppid-Velid complex, as well as much of the Monocerotids and σ-Hydrids. This does mean the Geminids, Coma Berenicids, and Ursids are all much better-placed with regard to the Moon.

Draconids

Active: October 6–10; Maximum: October 8, 17^h–23^h UT ($\lambda_\odot = 195\fdg40$);
ZHR: periodic—up to storm levels;
Radiant: $\alpha = 262°$, $\delta = +54°$; radiant drift: negligible; radius: 5°; $V_\infty = 20$ km/s; $r = 2.6$
TFC: $\alpha = 290°$, $\delta = +65°$ and $\alpha = 288°$, $\delta = +39°$ ($\beta > 30°$ N).

Despite the presence of a waning gibbous Moon, which will rise within 2–3 hours of nightfall for the northern hemisphere sites this shower is visible from, 1998 is a very important year for observing the Draconids. This periodic shower has produced spectacular, brief, meteor storms twice already this century, in 1933 and 1946, and lower rates in several other years (ZHRs ranging from 20 to 200+), most recently in 1985. So far, detectable activity has only been seen in years when the stream's parent comet, 21P/Giacobini-Zinner, has returned to perihelion, which it is expected to do again in November 1998.

Perturbations of the stream, coupled with the fact that the 1946 event remains the best-observed return, mean predicting when activity might occur is very difficult. The spread in solar longitudes at which notable past activity has been detected is from $\lambda_\odot = 195\fdg26$ (1985) to $\lambda_\odot = 197\fdg0$ (1933), which equates to times between October 8, 17^h UT and October 10, 12^h UT in 1998. This is certainly a period that all observers should be alert to, using a full range of techniques, but with the Earth expected to pass the comet's node at $\lambda_\odot = 195\fdg398$ (October 8, 21^h UT), times earlier in this period may be more likely. The peak time given in the box above is a mean value of the previous returns, and should be viewed more as a general guide than an absolute value. The radiant, near Draco's "Head", is circumpolar from many locations, but is higher in the pre-midnight and near-dawn hours on October 8–10. Photographic and video data would be especially valuable in case high rates do take place.

ε-Geminids

Active: October 14–27; Maximum: October 18 ($\lambda_\odot = 205°$); ZHR = 2;
Radiant: $\alpha = 102°$, $\delta = +27°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 90°$, $\delta = +20°$ and $\alpha = 125°$, $\delta = +20°$ ($\beta > 20°$ S).

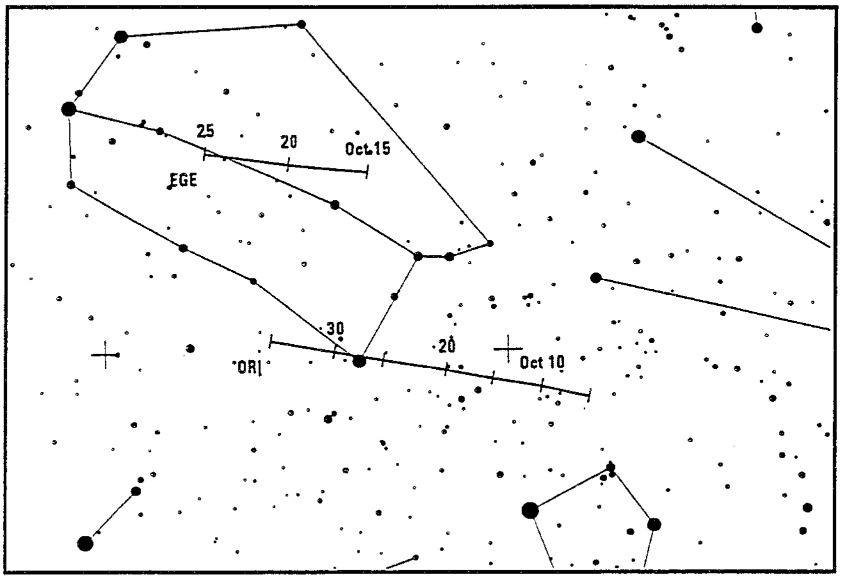

Figure 1 – Radiant positions and drift of the ε-Geminids (EGE) and the Orionids (ORI).

A weak minor shower, whose meteors are very like the Orionids, active, and at maximum, around the same time, 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 20 presents an excellent opportunity to obtain more data on them from either hemisphere, although northern observers have an advantage. The radiant is higher only after midnight.

Orionids

Active: October 2–November 7; Maximum: October 21 ($\lambda_\odot = 208.^\circ7$); ZHR = 20;
Radiant: $\alpha = 95°$, $\delta = +16°$; Radiant drift: see Table 2; radius: 10°; $V_\infty = 66$ km/s; $r = 2.9$;
TFC: $\alpha = 100°$, $\delta = +39°$ and $\alpha = 075°$, $\delta = +24°$ ($\beta > 40°$ N);
$\alpha = 80°$, $\delta = +01°$ and $\alpha = 117°$, $\delta = +01°$ ($30° \leq \beta \leq 40°$ N).

October's New Moon enhances the Orionids this year too. They are noted for having several maxima other than the main one detailed above, with activity sometimes remaining almost constant for several consecutive nights centered on this peak. In 1993, a sub-maximum 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 sub-radiants 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, 19^h UT ($\lambda_\odot = 235.^\circ25$);
ZHR: more than 50, expected to reach storm levels in 1998–99;
Radiant: $\alpha = 153°$, $\delta = +22°$, radiant drift: see Table 2; radius: 5°; $V_\infty = 71$ km/s; $r = 2.5$
TFC: $\alpha = 140°$, $\delta = +35°$ and $\alpha = 129°$, $\delta = +06°$ ($\beta > 35°$ N);
$\alpha = 156°$, $\delta = -03°$ and $\alpha = 129°$, $\delta = +06°$ ($\beta < 35°$ N).
PFC: $\alpha = 120°$, $\delta = +40°$ before 0^h local time ($\beta > 40°$ N);
$\alpha = 120°$, $\delta = +20°$ before 4^h local time;
$\alpha = 160°$, $\delta = 00°$ after 4^h local time ($\beta > 0°$ N);
$\alpha = 120°$, $\delta = +10°$ before 0^h local time;
$\alpha = 160°$, $\delta = -10°$ after 0^h local time ($\beta < 0°$ N).

The recovery of the Leonids' parent comet, 55P/Tempel-Tuttle, on March 4, 1997, has raised hopes further that a storm of Leonids might occur in 1998 or 1999. There are, of course, no guarantees that this will happen, but all observers must realize that even discovering the absence of any unusual Leonid activity would still be very valuable information—albeit not all that interesting to witness! Visual *IMO International Leonid Watch* and radio observations in 1996 indicated quite a broad Leonid maximum between $\lambda_\odot = 235^\circ\!.1$–$235^\circ\!.4$ (equivalent to November 17, 1998, 14^h–22^h UT), with one minor peak at $\lambda_\odot = 235^\circ\!.17$ (equivalent to November 17, 1998, 17^h UT). As the Earth should pass the node of the comet's orbit around November 17, 1998, 19^h UT ($\lambda_\odot = 235^\circ\!.25$), this may well be the most likely time for the very highest activity to occur.

As the radiant, in Leo's "Head" or "Sickle" asterism, rises only around local midnight (or indeed afterwards south of the equator), places in the Far East, including China, Eastern Siberia and Japan, south through the Western Pacific islands to Australia, should be the favored spots, if the maximum keeps to this time. Even a minor variation could mean places east or west of this zone may see something of the shower's best too, however. **More information on observing the Leonids can be found in this issue.**

The Moon is just two days from New Moon on November 17, so it will cause no problems this year, and all observing methods should be utilized to the full, especially photography and video if a storm manifests.

α-Monocerotids

Active: November 15–25; Maximum: November 21, 20^h UT ($\lambda_\odot = 239^\circ\!.32$);
variable ZHR, usually around 5, but may produce outbursts to 400+;
Radiant: $\alpha = 117^\circ$, $\delta = +01^\circ$; radiant drift: see Table 2; radius: 5°; $V_\infty = 65$ km/s; $r = 2.4$;
TFC: $\alpha = 115^\circ$, $\delta = +23^\circ$ and $\alpha = 129^\circ$, $\delta = +20^\circ$ ($\beta > 20^\circ$ N);
$\alpha = 110^\circ$, $\delta = -27^\circ$ and $\alpha = 98^\circ$, $\delta = +06^\circ$ ($30^\circ \leq \beta \leq 20^\circ$ N).

Another late-year shower capable of producing surprises, the α-Monocerotids gave their most recent brief outburst in 1995 (the top ZHR, 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, however, so all observers should continue to monitor this source closely. New Moon on November 19 makes this an excellent year for such scrutiny, with the radiant well on view in both hemispheres after about 23^h local time or so.

Geminids

Active: December 7–17; Maximum: December 13, 5^h UT ($\lambda_\odot = 262^\circ\!.0$); ZHR = 120;
Radiant: $\alpha = 112^\circ$, $\delta = +33^\circ$; radiant drift: see Table 2; radius: 5°; $V_\infty = 35$ km/s; $r = 2.6$
TFC: $\alpha = 87^\circ$, $\delta = +20^\circ$ and $\alpha = 135^\circ$, $\delta = +49^\circ$ before 23^h local time;
$\alpha = 87^\circ$, $\delta = +20^\circ$ and $\alpha = 129^\circ$, $\delta = +20^\circ$ after 23^h local time ($\beta > 40^\circ$ N);
$\alpha = 120^\circ$, $\delta = -03^\circ$ and $\alpha = 84^\circ$, $\delta = +10^\circ$ ($\beta \leq 40^\circ$ N).
PFC: $\alpha = 150^\circ$, $\delta = +20^\circ$ and $\alpha = 60^\circ$, $\delta = +40^\circ$ ($\beta > 20^\circ$ N);
$\alpha = 135^\circ$, $\delta = -05^\circ$ and $\alpha = 80^\circ$, $\delta = 00^\circ$ ($\beta \leq 40^\circ$ N).

One of the finest annual showers presently observable, their early stages will be lost to moonlight this year, but their peak occurs with a waning crescent Moon which should present few problems, and then only late in the night. Well north of the equator, the radiant rises around sunset, and can be usefully observed from the local evening hours onwards, but in the southern hemisphere, the radiant appears only around local midnight or so. Even here, this is a splendid stream 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 (ZHRs were about 110 around $\lambda_\odot = 262^\circ\!.2$–$262^\circ\!.4$ in 1996, for instance), so the best activity may occur a little before or after the suggested time above. Even so, European, African, Near-Eastern, and American sites are the most likely beneficiaries of the very best Geminid rates in 1998. Some mass-sorting within the stream means the fainter telescopic meteors should be most abundant almost 1° of solar longitude ahead of the visual maximum, with telescopic results indicating these meteors radiate from an elongated region, perhaps with three sub-centers. Further results on this topic would be useful, but all observing methods can be employed to observe the shower.

Coma Berenicids

Active: December 12–January 23; Maximum: December 20 ($\lambda_\odot = 268^\circ$); ZHR = 5;
Radiant: $\alpha = 175^\circ$, $\delta = +25^\circ$; radiant drift: see Table 2; radius: 5°; $V_\infty = 65$ km/s; $r = 3.0$;
TFC: $\alpha = 180^\circ$, $\delta = +50^\circ$ and $\alpha = 165^\circ$, $\delta = +20^\circ$ before 3^h local time;
$\alpha = 195^\circ$, $\delta = +10^\circ$ and $\alpha = 200^\circ$, $\delta = +45^\circ$ after 3^h local time.

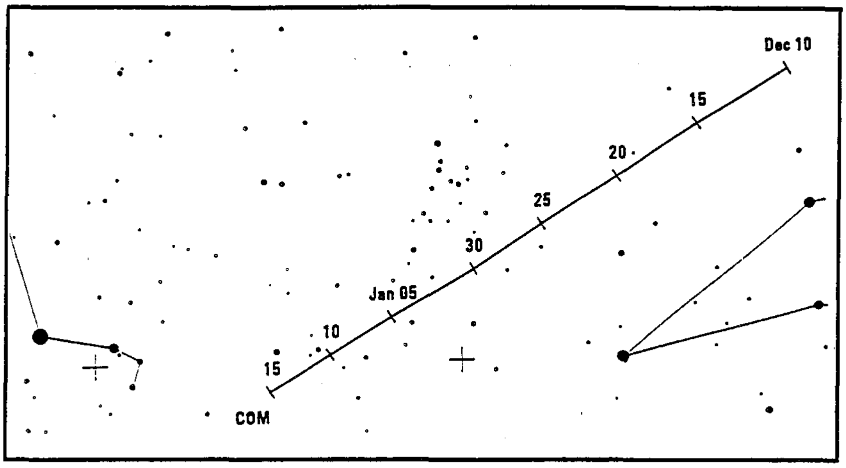

Figure 2 – Radiant positions and drift of the Coma Berenicids (COM).

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 is just two days after new Moon. The radiant is at a useful elevation from local midnight onwards.

Ursids

Active: December 17–26; Maximum: December 22, 18^h UT ($\lambda_\odot = 270.°7$);
ZHR = 10 (occasionally variable up to 50);
Radiant: $\alpha = 217°$, $\delta = +76°$; Radiant drift: see Table 2; radius: 5°;
$V_\infty = 33$ km/s; $r = 3.0$;
TFC: $\alpha = 348°$, $\delta = +75°$ and $\alpha = 131°$, $\delta = +66°$ ($\beta > 40°$ N);
$\alpha = 63°$, $\delta = +84°$ and $\alpha = 156°$, $\delta = +64°$ ($30° \leq \beta \leq 40°$ N).

A very poorly-observed northern hemisphere shower, but one which has produced at least two major outbursts in the past half-century or so, 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 $\lambda_\odot = 270.°8$, for instance, which might suggest a slightly later maximum time in 1998 of December 22, 20^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 waxing crescent Moon will give dark skies for observations almost all night on December 22.

2. January to March

The year's first quarter brings several low activity showers, including the diffuse ecliptical stream complex, the Virginids, active from late January to mid-April. Of the two major showers, the northern-hemisphere Quadrantids (visual peak around January 3, 23^h UT) are lost to bright moonlight. The southern-hemisphere α-Centaurids (maximum expected circa February 8, 10^h UT) are somewhat better-placed, but the Last-Quarter Moon rises around local midnight on February 8, a nuisance as the shower is most observable only after late evening. However, the minor δ-Cancrids benefit from New Moon in January, as do the γ-Normids in March. Daylight radio peaks are due from the Capricornids/Sagittarids around 20^h UT on February 1, and the χ-Capricornids on February 13, probably around 21^h UT. Neither radio shower has been well-observed in recent times, and as both have radiants under 10°–15° west of the Sun at maximum, they cannot be regarded as visual targets even from the southern hemisphere.

δ-Cancrids

Active: January 1–24; Maximum: January 17 ($\lambda_\odot = 297°$); ZHR = 4;
Radiant: $\alpha = 130°$, $\delta = +20°$; Radiant drift: see Table 2; size: $\alpha = 20° \times \delta = 10°$;
$V_\infty = 28$ km/s; $r = 3.0$
TFC: $\alpha = 115°$, $\delta = +24°$ and $\alpha = 140°$, $\delta = +35°$ ($\beta > 40°$ N;
$\alpha = 120°$, $\delta = -03°$ and $\alpha = 140°$, $\delta = -03°$ ($\beta \leq 40°$ N)

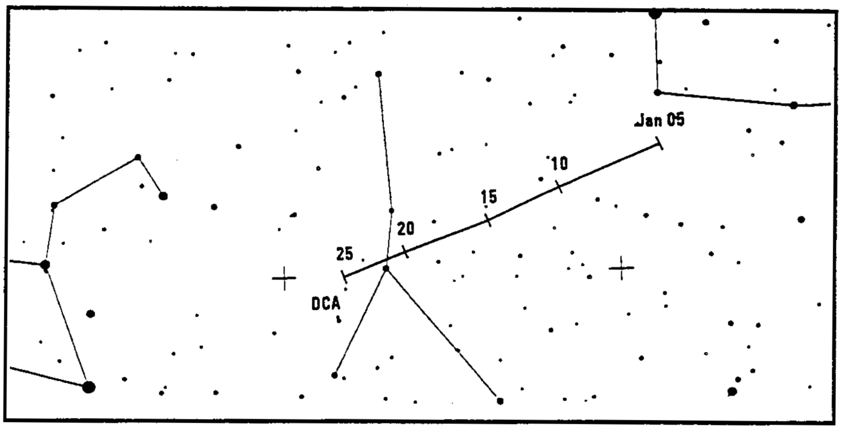

Figure 3 – Radiant positions and drift of the δ-Cancrids (DCA).

This minor stream is well-suited to telescopic observations, with its large, complex radiant area, that probably consists of several sub-centers. Many of its meteors are faint. It is probably an early part of the Virginid activity. Recent observations show the δ-Cancrid ZHR is unlikely to rise much above 3–4, and the visual maximum may fall around $\lambda_\odot = 291°$ (January 11, 1999).

January's New Moon on January 17 provides an excellent opportunity for checking what happens this year. The long winter nights in the northern hemisphere provide a further incentive, though the radiant is above the horizon almost all night, whether your site is north or south of the equator. Even on January 11, the first half of the night is moon-free for all observers.

γ-Normids

Active: February 25–March 22; Maximum: March 14 ($\lambda_\odot = 353°$); ZHR = 8;
Radiant: $\alpha = 249°$, $\delta = -51°$; radiant drift; see Table 2; radius: 5°;
$V_\infty = 56$ km/s; $r = 2.4$
TFC: $\alpha = 225°$, $\delta = -26°$ and $\alpha = 215°$, $\delta = -45°$ ($\beta < 15°$ S)

The γ-Normid meteors are similar to the sporadics in appearance, and for most of their activity period, their ZHR is virtually undetectable above this background rate. The peak itself is normally quite sharp, with ZHRs of 3+ noted for only a day or two to either side of the maximum. Activity may vary somewhat at times, with occasional broader, or less obvious, maximá having been reported in the past. Post-midnight watching yields best results, when the radiant is rising to a reasonable elevation from southern-hemisphere sites.

The waning crescent Moon on March 14 rises around or after 2^h local time south of the equator, and should cause only minor problems. All forms of observation can be carried out for the shower, although most northern observers will see nothing from it.

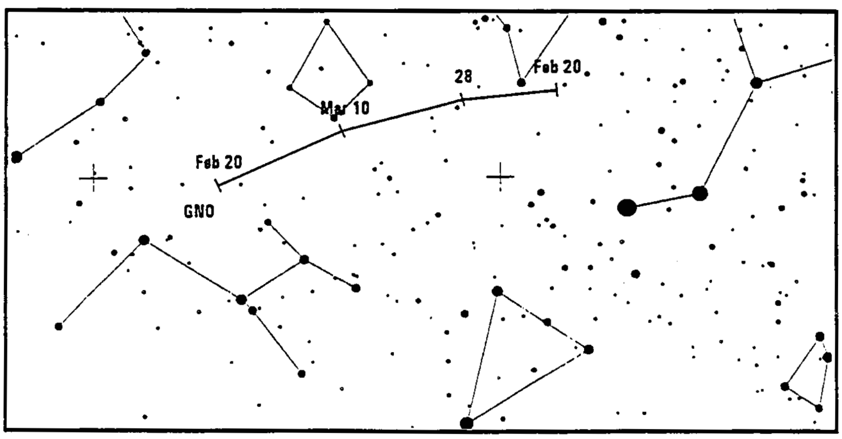

Figure 4 – Radiant positions and drift of the γ-Normids (GNO).

3. Working list of meteor showers

Table 1 – Working list of meteor showers for the period October 1998–March 1999. The "maximum" dates cited for the Virginids and the Puppid/Velids should be seen as reference dates only.

Shower	Activity	Maximum		Radiant			V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	Radius	(km/s)		
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 08	166°	60°	+47°	5°	64	3.0	6
Piscids (SPI)	Sep 01–Sep 30	Sep 20	177°	5°	−01°	5°	26	3.0	3
Draconids (GIA)	Oct 06–Oct 10	Oct 08	195°4	262°	+54°	2°	20	2.6	var
ε-Geminids (EGE)	Oct 14–Oct 27	Oct 18	205°	102°	+27°	5°	70	3.0	2
Orionids (ORI)	Oct 02–Nov 07	Oct 21	208°	95°	+16°	10°	66	2.9	20
Southern Taurids (STA)	Oct 01–Nov 25	Nov 05	223°	52°	+13°	10°/5°	27	2.3	5
Northern Taurids (NTA)	Oct 01–Nov 25	Nov 12	230°	58°	+22°	10°/5°	29	2.3	5
Leonids (LEO)	Nov 14–Nov 21	Nov 17	235°2	153°	+22°	5°	71	2.5	var
α-Monocerotids (AMO)	Nov 15–Nov 25	Nov 21	239°3	117°	+01°	5°	65	2.4	var
χ-Orionids (XOR)	Nov 26–Dec 15	Dec 02	250°	82°	+23°	8°	28	3.0	3
Dec Phoenicids (PHO)	Nov 28–Dec 09	Dec 06	254°3	18°	−53°	5°	22	2.8	var
Puppid/Velids (PUP)	Dec 01–Dec 15	Dec 07	255°	123°	−45°	10°	40	2.9	10
Dec Monocerotids (MON)	Nov 27–Dec 17	Dec 09	257°	100°	+08°	5°	42	3.0	3
σ-Hydrids (HYD)	Dec 03–Dec 15	Dec 12	260°	127°	+02°	5°	58	3.0	2
Geminids (GEM)	Dec 07–Dec 17	Dec 14	262°0	112°	+33°	5°	35	2.6	120
Coma Berenicids (COM)	Dec 12–Jan 23	Dec 20	268°	175°	+25°	5°	65	3.0	5
Ursids (URS)	Dec 17–Dec 26	Dec 22	270°7	217°	+76°	5°	33	3.0	10
Quadrantids (QUA)	Jan 01–Jan 05	Jan 03	283°2	230°	+49°	5°	41	2.1	120
δ-Cancrids (DCA)	Jan 01–Jan 24	Jan 17	297°	130°	+20°	10°/5°	28	3.0	4
α-Centaurids (ACE)	Jan 28–Feb 21	Feb 08	319°2	210°	−59°	4°	56	2.0	6
δ-Leonids (DLE)	Feb 15–Mar 10	Feb 25	336°	168°	+16°	5°	23	3.0	2
γ-Normids (GNO)	Feb 25–Mar 22	Mar 14	353°	249°	−51°	5°	56	2.4	8
Virginids (VIR)	Jan 25–Apr 15	Mar 25	4°	195°	−04°	15°/10°	30	3.0	5

Table 2 – Radiant positions in α and δ.

	NTA	**STA**	**ORI**	**DAU**				
Oct 5	25o +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°	**DCA**		217° +75°			
Jan 0	186° +20°	**QUA**	112° +22°					
Jan 5	190° +18°	231° +49°	116° +22°					
Jan 10	194° +17°		121° +21°					
Jan 20	202° +13°		130° +19°	**ACE**	**VIR**			
Jan 30				200° −57°	157° +16°	**DLE**		
Feb 10				214° −60°	165° +10°	155° +20°	**GNO**	
Feb 20				225° −63°	172° +06°	164° +18°	225° −53°	
Feb 28					178° +03°	171° +15°	234° −52°	
Mar 10					186° 00°	180° +12°	245° −51°	
Mar 20					192° −03°		256° −50°	
Mar 30					198° −05°			

Table 3 – Working list of daytime radio meteor streams. The "Best Observed" columns give the approximate local mean times between which a four-element antenna at an elevation of 45° receiving a signal from a 30-kW transmitter 1000 km away should record at least 85% of any suitably positioned radio-reflecting meteor trails for the appropriate latitudes. Note that this is often heavily dependent on the compass direction in which the antenna is pointing, however, and applies only to dates near the shower's maximum.

Shower	Activity	Max Date	$\lambda_\odot$ 2000.0	Radiant α	Radiant δ	Best Observed 50° N	Best Observed 35° S	Rate
Sextantids	Sep 09–Oct 09	Sep 27	184°3	152°	00°	06^h–12^h	06^h–13^h	medium
Cap/Sagittarids	Jan 13–Feb 04	Feb 01	312°5	299°	−15°	11^h–14^h	09^h–14^h	medium
χ-Capricornids	Jan 29–Feb 28	Feb 13	324°7	315°	−24°	10^h–13^h	08^h–15^h	low

4. Lunar phases

Table 4 – Lunar phases for October 1998–March 1999.

New Moon		Oct 20	Nov 19	Dec 18	Jan 17	Feb 16	Mar 17	Apr 16
First Quarter	Sep 28	Oct 28	Nov 27	Dec 26	Jan 24	Feb 23	Mar 24	
Full Moon	Oct 05	Nov 04	Dec 03	Jan 02	Jan 31	Mar 02	Mar 31	
Last Quarter	Oct 12	Nov 11	Dec 10	Jan 09	Feb 08	Mar 10	Apr 09	

Observing Hints for the 1998 Leonid Return

Rainer Arlt, Sirko Molau, Malcolm Currie

A guide to observing the 1998 Leonid activity is given. Expectations of peak time and activity profile are presented, and hints on visual, telescopic, video and photographic observations are given with the intention to derive scientifically useful data about the whole activity range of the 1998 Leonids.

1. What is to be expected

The return of the Leonid meteor shower is without any doubt the major astronomical event of 1998. The observing network which has been established within the *International Meteor Organization* in the last 15 years, provides us with all means for getting a complete picture of the Leonid meteor shower. This guide covers the whole range of activity we are expecting, not just the moment of highest rates, since we should not forget about deriving accurate results for off-peak rates as well.

The Leonid meteoroid stream is linked to the periodic comet 55P/Tempel-Tuttle. The comet has an orbital period of 33.2 years and was rediscovered on March 4, 1997 [1]. For a prediction of the peak time of meteor activity, the time of nodal crossing of the comet is important. The node lies at $\Omega = 235\overset{\circ}{.}258$, and the Earth will pass the node at $\lambda_\odot = 235\overset{\circ}{.}29$, which corresponds to November 17, 20^h UT.

Comparing the 1998/1999 Leonid return with past events, we find that the encounter conditions are similar to those of 1866. If we use the 1866 ZHR profile of [2] for a prediction in 1998, we find ZHRs above 1000 between November 17, 19^h and 21^h UT. The ZHR will have returned to a level of 100 at 23^h UT. The background component is fairly broad and lasts for about 12 hours with ZHRs above 50 according to the 1996 results [3] and for about 10h according to the decay exponent of 1866 given in [2].

Figure 1 shows a sort of visibility function of the Leonids. It will be interesting to know how many hours before the peak time the radiant will be sufficiently high above the horizon. The later limit will be dawn, and the period before the Sun approaches the horizon will be interesting too. We coupled both times by multiplication, since this operation gives only one maximum where both times are equal. Best observability with a minimum radiant elevation of 40° and a minimum depression of the Sun of 12° is in the north-east of China.

We may construct a scenario with a peak equivalent ZHR of 10 000 meteors per hour. Given this maximum rate, Figure 2 shows an overview of expected activity at different geographical locations. All positions refer to the same local time—3^h30^m, when the peak is expected in eastern Mongolia and north-eastern China. The activity profile was defined by the exponential-decay constants derived for 1866 in [2]. You can read the geographical longitude as a time axis: positions east of Mongolia represent times before the peak, positions west of Mongolia represent times after the peak. The radiant elevation at that local time is included as well, giving the visible meteor rate at a limiting magnitude of +6.5. Observers in Japan will see about 1000 meteors per hour in the night November 17-18, shortly before the peak will take place. As it is dark until more than an hour later in Japan, they will observe strongly increasing activity. European observers will see a rate of 100 at best in the same night, that is, after the maximum. American observers will face a low activity of 10–20 on November 17-18. They may have seen, however, higher rates before the peak as shown in the lower part of Figure 2. Visible rates are between 20 and 50 in the night November 16-17. Hawaiian observers are closest to the peak on the western hemisphere with rates of 100. Note that the date now switches to November 17-18 when you consider Japan as above. Again, note that this graph of visible rates is only one of the scenarios possible, the predicted peak activity of 10 000 may well be wrong by a factor of 10 towards both lower or higher rates.

Although these predictions look quite accurate, we should definitely not rely on them and be prepared for the full range of activity at any location. It is indeed most unlikely that the peak will be shifted by more than 2 hours or that the background activity is much higher than anticipated. However, if something very unusual happens and we are not properly prepared, we will lose the chance of the first global, scientific monitoring of a Leonid meteor storm.

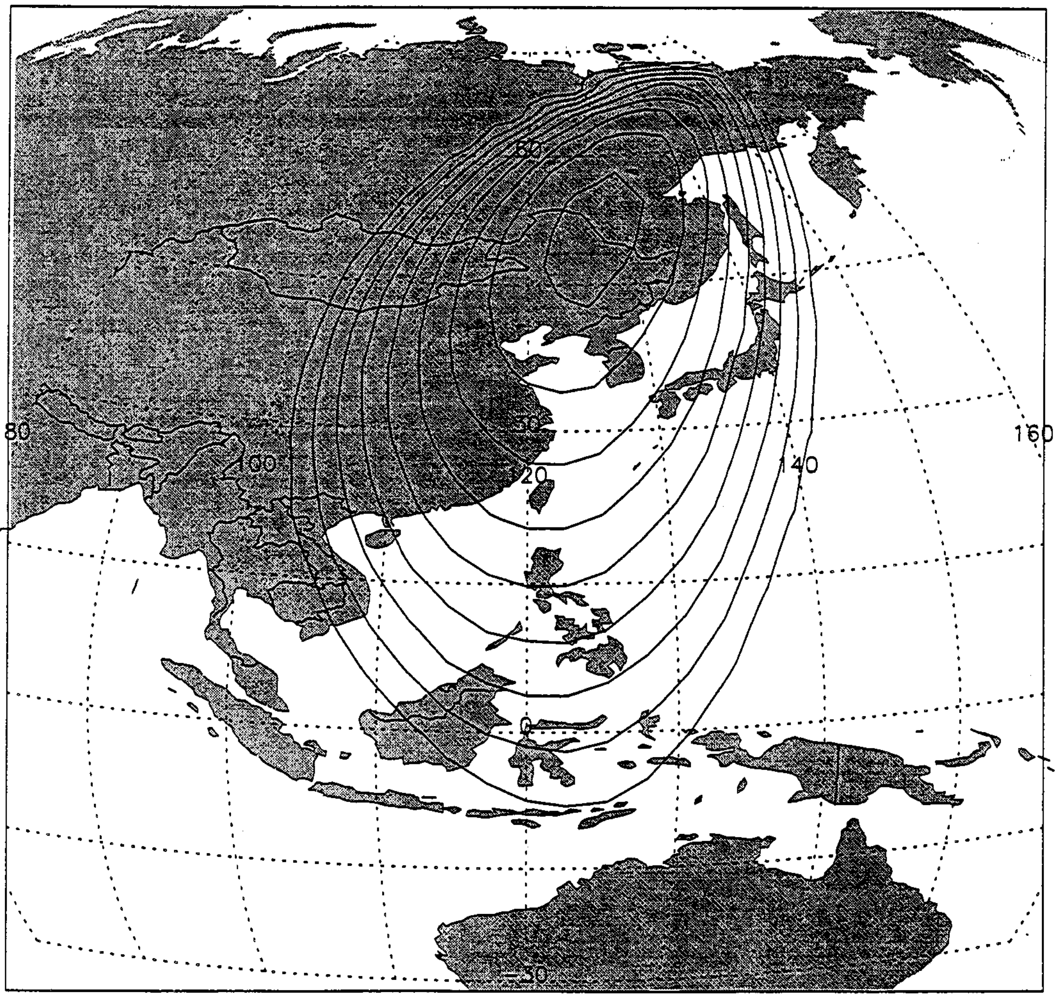

Figure 1 – Visibility function of the Leonid peak on November 17, 20^h UT. The number of hours with the radiant above 40° elevation and the number of hours with the Sun more than 12° below the horizon are multiplied. The contour lines are not radiant elevation lines; they indicate where the best combination of dark hours and high-radiant hours can be found. The area in the north-east of China has the best conditions, provided the peak-time prediction is correct.

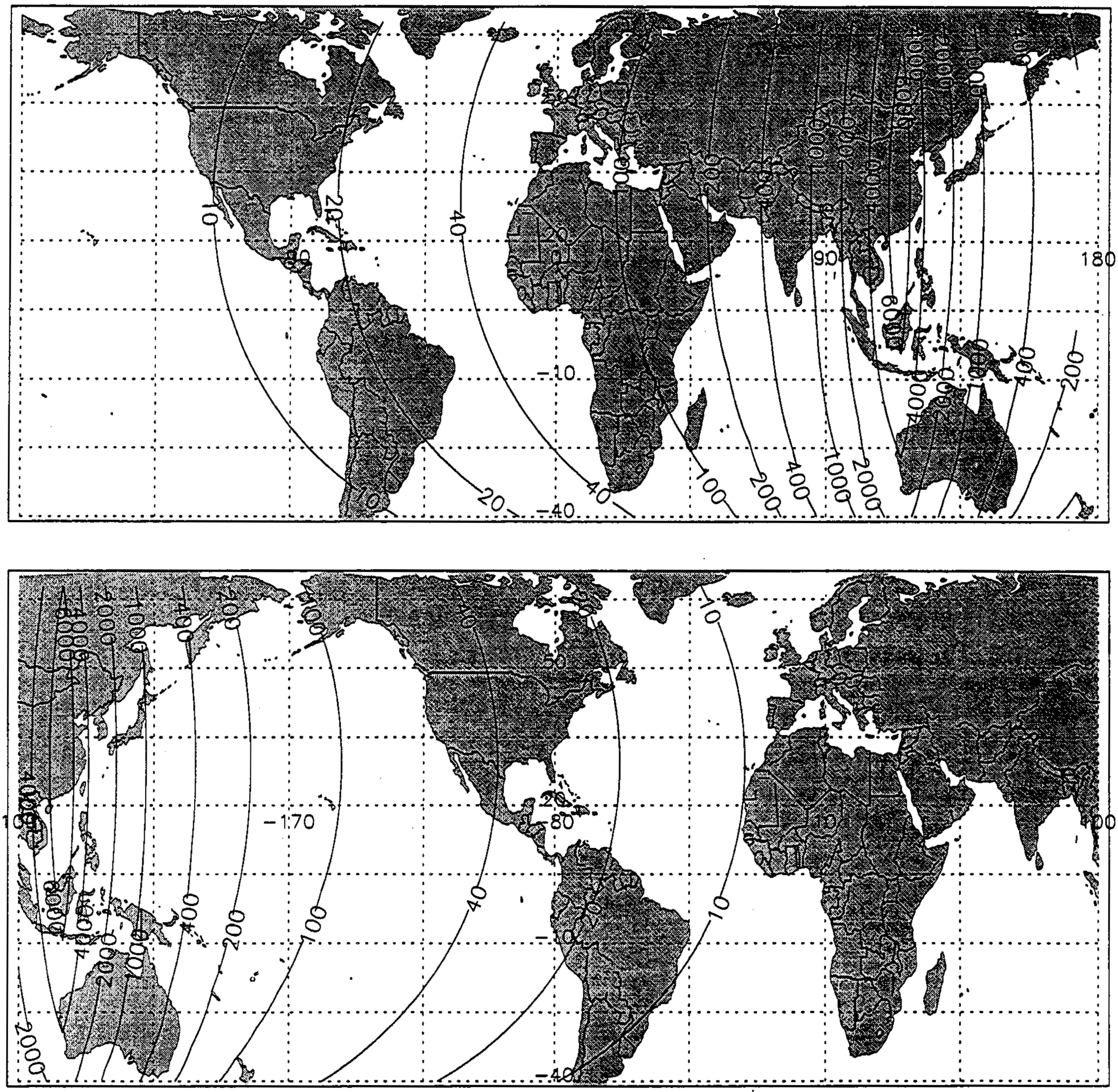

Figure 2 – Expectation of visible rates for all geographical positions. The predicted visible rate at lm = +6.5 is given for a local time of 3^h30^m local time at each position. The upper graph refers to the night November 17-18, the lower graph shows the night November 16-17 for America, Europe, and Africa.

For everyone who intends to travel to central or eastern Asia, the hints for using astronomical equipment on cold climates [4] are warmly recommended. Night temperatures below −20° C (below −4° F) are very common in Asian desert and prairie areas in November.

2. Hints for visual observers

The Leonids will cover the whole range of activity from usual major-shower rates up to perhaps several meteors per second within a few hours. It will be very difficult for visual observers to cope with these conditions. We will describe the techniques for which a visual observer should be prepared, depending on the visible rate of meteors which would be recorded if continued for one hour (HR).

In this article, you will find a modified form for the observing report. The "Observed shower" will be LEO, and you can fill in up to 30 observing periods in the form. One period should contain between 10 and 30 meteors. You should, therefore, not forget to give enough time marks on your recording device. If you were not able to discriminate Leonids from sporadics due to high activity, just write TOT in the blank shower field in the header of the table and leave the number of sporadics empty.

Magnitude distributions should be given with 40 to 80 meteors. Please select some of those time marks for the boundaries of magnitude distributions which were already used in the upper table for observing periods.

Major-shower activity (HR = 50–500)

A tape recorder or the somewhat awkward looking paper-roll technique have proven capable of recording up to 500 meteors per hour. This rate corresponds to 8 meteors a minute. Since meteors are assumed to be randomly distributed, rates may be 15 meteors per minute occasionally. The average rate is thus misleading. Even a usual major shower like the Quadrantids, Perseids, or Geminids can keep you talking or writing continuously for a minute or two which are followed by periods of quiescence.

You should not stop your tape but just speak a magnitude into the microphone whenever you see a meteor. Note that the shower information is not very important for hourly rates beyond 200, since the error caused by the very few sporadic meteors is small. A rate of 200 meteors per hour corresponds to 3 to 4 meteors per minute.

You should not stop reporting magnitudes of the meteors even if you feel uncertain about the quality of your estimates. If all your fellow observers are doing so, meteor quantities will yet be large enough to obtain a good average population index.

The estimation of limiting magnitudes will often be interrupted by meteor sightings. It is suggested to *stop the observations for limiting magnitude counts*. It's hard to stop recording when many meteors are falling, but it will only be for a short interval of one or two minutes, and remember that the accuracy of the final ZHR highly depends on a reasonable estimate of the limiting magnitude. Don't forget to regularly count two limiting-magnitude fields during your observation.

Strong activity (HR = 500–4000)

This range of meteor rates covers 8 to 67 meteors per minute on average. In other words: it will be between "sometimes" and "always" that you are not able to report reasonable magnitudes of the meteors anymore. An activity of 4000 meteors per hour is roughly 1 meteor per second. Again, due to the random temporal distribution of meteors, seconds with three or four meteors will occur as well as quiet seconds.

Try to record magnitudes of the meteors as long as possible. Do not worry if you start feeling less confident in your estimates—the large number of meteors recorded will give your results sufficient statistical significance. You should not stop your tape recorder after each meteor; just speak onto the running tape. Times can be derived afterwards from playing time. Nevertheless, for calibration purposes, it will be useful to record the times of start and end onto the tape. So your recordings will contain an exact start time, then (hopefully) plenty of magnitudes or beeps, and an exact end time when the tape was stopped.

Storm level (HR > 4000)

A rate of one or two meteors per second on average should be recordable by simple "beeps" which you speak onto the tape; higher rates will soon become impossible to record because of the uneven temporal distribution of meteors. You may switch to 10-meteor countings, that is, you "beep" onto your tape when you have *the impression* that 10 meteors have appeared. The same method of recording the time as for "strong activity" should be applied here.

Another method was used by observers in 1966, who were completely taken by surprise when they saw many meteors a second. Observers swept their gaze across the sky for one second and estimated how many meteors they saw. A maximum value of 40 was reported. This method bears uncertainties in both the estimation of the number of meteors and the estimation of how long one second is. This year, we have the chance to check visual estimates by video technique (see below), and if we try the same visual method as in 1966, we can calibrate the old activity estimates by comparing our 1998 visual and video results. A powerful software to check your capabilities of monitoring meteors at storm conditions can be found on the Internet at `ftp://www.imo.net/pub/software/metsim/`. Investigations on the reliability of visual observations based on that program were published in [5].

3. Hints for video and photographic observers

Whereas the observation of very high meteor activity will be most exciting for visual observers, it is the ultimate domain for video systems. A video camera is an emotionless piece of electronics that supplies accurate figures no matter if there is one meteor per hour or one per second. In fact, if a meteor storm establishes this or next year, it will be for the first time that we get reliable quantitative measurements of meteor storms at all.

Activity profiles

The main goal for video observers will be the determination of meteor activity followed by meteoroid flux computations. For this purpose, all types of video system (see [6] for a detailed discussion of the different camera types) may be used.

Similar to visual observers, wide angle cameras combine a large field of view with moderate limiting magnitudes. They are able to record a vast number of bright meteors. From the ratio of bright and fainter shooting stars we can derive the mixture of different particle sizes found in the meteoroid stream. Because of their similarity to visual observers, wide angle video systems are the first choice for the calibration of 1966 visual data as explained in Section 2.

Normal and tele video systems have successive smaller fields of view, but are also able to record fainter meteors. Thus, they extend the flux profile obtained with wide angle systems to smaller meteoroids causing fainter meteors. With their help we will be able to find out, whether the Leonid activity cuts off at a certain magnitude, or if the number of meteors is continues to increase exponentially towards those which cannot be detected by the naked eye anymore.

Finally, a battery of video systems with different lenses gives us the unique chance to study meteor activity over a range of about 15 magnitudes—from fireballs of −7 down to the faintest meteors of +7! We suggest that video observers at the same place arrange their activities to gain a large coverage of particle sizes and a maximum of information.

At locations where no video cameras are in operation, photographic equipment can also be supportive in meteoroid flux estimates given very high Leonid activity. When you are lucky enough to experience such rates, try to make five-minute exposures. Away from the times of highest activity, you can increase the exposure time to 10 or 20 minutes to cover the entire night with a single film.

Meteoroid orbits

Another observing goal may be the determination of Leonid orbits from the storm filament. For this purpose, we suggest the use of photographic equipment. Though video systems will record orders of magnitudes more meteors, the accuracy of meteor photographs is clearly superior. This is caused by the up to 10 times higher spatial resolution of film material compared to the phosphorous screen of an image intensifier. The expected high activity will result in a sufficient number of meteor photographs, which will give the best meteoroid orbits. A problem, however, may be the identification of meteors on the pairs of images. Exposures should be short and precisely timed.

Other aims

Given the large quantities of bright meteors expected, certain special studies may be carried out by means of video and photographic equipment.

High-resolution meteor spectra are rare, because the chance of capturing a meteor being bright enough is extremely small. Using a high precision grating, the limiting magnitude of the detector is about 3^{m} lower for meteor spectra than for meteors. Cheap holographic plastic grating cause another loss of 1 to 2 magnitudes. That is, in the absence of large meteor showers, you will have to operate your camera on average in the order of several (video systems) to several thousand hours (photographic equipment) until you have secured a spectrum. Even during the Perseid maximum, average exposure times between several tens of minutes and hours are to be expected. As the activity during a meteor storm surpasses major meteor showers by some magnitudes, you have a fair chance of recording several high quality photographic spectra in one night. Even more, with the help of video systems it will be possible to assess differences in meteor spectra of one meteoroid stream from a large statistical sample.

Another special target for video and photographic observers may be persistent trains. The Leonids are caused by fast meteoroids of cometary origin. They are known to produce a large number of persistent trains, sometimes visible for several tens of minutes [7]. The larger the meteor number, the higher the chance to record bright persistent trains and their deformation by winds in the high atmosphere. Here, video systems have the advantage to minutely track all changes. On the other hand, you can use longer exposure times with photographic equipment and thereby follow the train development even after it has become invisible to visual or video observers. If you possess a grating or prims, but no video equipment, you should definitely consider having a camera with your spectral equipment at hand when a very bright fireball appears leaving a train persisting for many tens of seconds. Meteor train spectra are extremely rare, and the Leonid maximum offers a unique chance to capture train spectra.

Last but not least, both video and photographic equipment can present you an unique souvenir from a unique event. Every video observer knows about the excitement of the audience when some recordings of the Perseids are presented. A photograph of the 1966 Leonids showing more than 70 meteors has become famous not only among meteor observers, but among the whole community of astronomy enthusiasts. So, use the chance to produce your own memorable video and photograph! Who will be able to present "stars falling like rain" on a video screen in real time? Who will be the first having a hundred shooting stars on a single photograph? We wish you much luck with your experiments!

4. Hints for telescopic observers

In these days of video, you would be forgiven for thinking that telescopic observations of the Leonids have minor import. Video systems are still uncommon; many of those will be trained on the maximum in China or Japan, or concentrate on visual meteors. To garner a comprehensive picture of a Leonid outburst, it is imperative to observe meteors across the full spectrum of brightness (mass). Remember that telescopic meteors vastly outnumber their visual counterparts. Telescopic data provide information about the meteors fainter than visual, and is the only means open to amateurs of gathering information for meteors fainter than magnitude +9.

The main goals are to determine the meteor flux of faint Leonids throughout the period of activity, not just at the maximum; and to determine the time of peak activity.

If you are fortunate to have a selection of telescopes and binoculars, (*i*) choose a wider apparent field of view (up to about 70°) to maximize the number of meteors seen, and (*ii*) select the largest suitable instrument to detect the faintest Leonids.

Normal activity (HR < 30)

Plotting is feasible up to around HR = 25–30 based upon experience at a dark site during the Geminid peak. Thus, for rates below about 30 meteors per hour, adopt the standard plotting technique, alternating between two fields of view approximately every 30 minutes. Suitable pairs of *IMO* charts are 123 and 147, 80 and 146, 81 and 145, and 103 and 146. Measurement of the dead-time while recording the meteor details and plotting its path is especially important so these data may also be used for flux measurements. Do not forget to record the decay time and distortion of persistent trains if the meteor frequency permits.

Be prepared to switch to the following technique should rates become too high. Observers are expected to use their judgment as to what is unmanageable.

Enhanced activity (HR = 30–500)

These rates are too high to plot. At a given time, the smaller field of view compared with that of the visual observer will make scientific observations somewhat easier, not least because the observed rate is expected to be lower. However, the onset of higher telescopic rates may occur before the visual rate accelerates.

Select *one* field. This need not be an *IMO* chart region, though these are strongly preferred as they will enable limiting magnitude estimates within the field. The important thing is to have a wide range of star brightnesses, be situated 10°–20° from and be at a higher elevation than the Leonid radiant. Proceed as if observing with the naked eye, as described in Section 2. Note that this requires equipment not normally used for telescopic watches. So, if you are not familiar with the paper-roll technique or using a tape recorder, practise with them prior to the Leonids so they become second nature. Note that accurate limiting magnitude estimates using several stars in the field are vital, and will need to be estimated regularly. For those using their own fields lacking a magnitude sequence within the field should estimate the naked-eye limiting magnitude. In the case use the standard counting method in two regions in the vicinity of the telescopic field.

Record the magnitude of the meteors seen, and in addition the shower association for non-Leonid meteors; all such meteors are deemed to be sporadic. This will save time if there is a short flurry of activity. It will be obvious which meteors are Leonids as they will dominate the sporadic meteors. As you will need to estimate magnitudes quickly and "on-the-fly," become familiar with the integral magnitudes of selected field stars spanning the range of brightnesses expected. Again, it is best to do this before the Leonid activity commences.

Strong activity (HR = 500–4000)

Again, see the corresponding visual tips in Section 2. If the rate goes to one every few seconds to one per second, dispense with the shower discrimination, and just note magnitudes. You can also omit the "plus" before the magnitude; a negative magnitude meteor will be a stupendous, but rare sight. In exceptional cases, you may wish to pause to allow your eye(s) to recover.

Storm level (HR $\geq$ 4000)

At this point, it is going to be very difficult to stay glued to the eyepiece even though you can see meteors continuously. The visual sky will be stunning. If observers can make some measurements at the eyepiece during storm activity, these data will be most valuable, but it would be understandable if you wanted to witness the spectacle of a lifetime across the whole sky. Again, adopt the visual technique of beeping as meteors appear in the field (Section 2). There should not be any need to sweep, however. It should be easier to estimate the telescopic count than visually because of the narrower apparent field of view.

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International Meteor Organization

VISUAL OBSERVING FORM – Leonid Report

Date: ____ (day), ____ (month), ____ (year). Begin: ____^{h}____^{m}. End: ____^{h}____^{m}. (UT)

Location: $\lambda =$ ___°___′___″ E/W, $\varphi =$ ___°___′___″ N/S, $h =$ ___ m. IMO Code: ________

Place: ______________________________ Country: ____________

Observer: ______________________________ IMO Code: ________

Observed shower (*please use IMO three-letter code*): ______ : $\alpha =$ ______° $\delta =$ ______°

Observed numbers of meteors per period and per shower:

N: number of meteors observed; distinguish between "0" (no meteors seen) and "/" (shower not analyzed)

Period (UT)	Field		T_{eff}	F	Lm	___	Spo	Period (UT)	Field		T_{eff}	F	Lm	___	Spo
($^{h\,m}$–$^{h\,m}$)	α (°)	δ (°)	(^{h})			N	N	($^{h\,m}$–$^{h\,m}$)	α (°)	δ (°)	(^{h})			N	N

Magnitude distributions (combine several periods from above to about 50 meteors):

Shw, from/to	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7	Tot
Spo (all night)															

International Meteor Organization

TELESCOPIC OBSERVING FORM – Leonid Report

Date: ____ (year), ____ (month), ____ (day). Begin: ___^{h}___^{m}. End: ___^{h}___^{m}. (UT)

Location: λ = ___° ___′ ___″ E/W, φ = ___° ___′ ___″ N/S, h = ___ m. IMO Code: ________

Place: ______________________________ Country: ____________

Observer: ______________________________ IMO Code: ________

Telescope: __________ Magnification: __________× True field of view: __________°

Observed shower (*please use IMO three-letter code*): _____ : α = _____° δ = _____°

Observed numbers of meteors per period and per shower:

N: number of meteors observed; distinguish between "0" (no meteors seen) and "/" (shower not analyzed)

Period (UT) ($^{h\,m}$–$^{h\,m}$)	Field α (°)	Field δ (°)	T_{eff} (^{h})	F	Lm	___ N	Spo N	Period (UT) ($^{h\,m}$–$^{h\,m}$)	Field α (°)	Field δ (°)	T_{eff} (^{h})	F	Lm	___ N	Spo N
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Magnitude distributions (combine several periods from above to about 50 meteors):

Shw, from/to	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	Tot
Spo (all night)															

The Leonids
Bulletin 12 of the International Leonid Watch: Final Results of the 1997 Leonids and Prospects for 1998

Rainer Arlt and Peter Brown

Visual reports of the 1997 Leonid shower are used to calculate an activity profile for the Leonid stream's 1997 return. Despite the Full-Moon conditions, it was possible to derive a fairly consistent ZHR profile; the flux profile is much more noisy, as it strongly depends on the population index profile which is less reliable due to the limited number of meteor magnitude estimates available. Increased activity began near $\lambda_\odot = 235\overset{\circ}{.}0$ (all solar longitudes refer to equinox 2000.0) and persisted until at least $\lambda_\odot = 236\overset{\circ}{.}0$. The peak ZHR value is near 100 ± 15 at circa $\lambda_\odot = 235\overset{\circ}{.}22 \pm 0\overset{\circ}{.}04$, corresponding to November 17, 1997, $12^{\rm h}15^{\rm m}$ UT. High activity of ZHR ≥ 80 persisted until $\lambda_\odot = 235\overset{\circ}{.}5$, but it is argued that this continued activity is an artifact due to underestimated limiting magnitudes as judged from sporadic rates. The population index shows an increase from 2.0 to 2.5 at $\lambda_\odot = 235\overset{\circ}{.}15 \pm 0.02$ (November 17, $10^{\rm h}30^{\rm m}$ UT), as occurred in 1996, but the statistical significance of the increase is marginal in 1997. Strong lunar interference precludes any definitive statement concerning the visual activity of the shower in 1997. The outlook for the 1998 return based on available information is summarized.

1. Introduction

As discussed in the previous *International Leonid Watch* (*ILW*) Bulletin [1], the 1997 return was well covered by observers, but the nearly Full Moon severely hampered most observations for the nights around the peak. Nevertheless, as so many observers did attempt observations, enough data are available to attempt some cautious analysis. In 1997, a total of 73 observers observing 2623 Leonids in 237.30 hours reported their observations. They were from 14 countries: Belgium, Canada, Croatia, Finland, Germany, India, Italy, Japan, Jordan, the Netherlands, Spain, the United States, Venezuela, and Yugoslavia. We thank the many observers listed below who contributed to the 1997 analysis:

Sana'a Abdo (ABDSA, $2\overset{\rm h}{.}02$), Mohammad Al-Alwanew (ALAMO, $4\overset{\rm h}{.}50$), Ramez Al-Mualla (ALMRA, $3\overset{\rm h}{.}20$), Ahmad Al-Niamat (ALNAH, $4\overset{\rm h}{.}67$), Joseph D. Assmus (ASSJO, $2\overset{\rm h}{.}42$), Lance Benner (BENLA, $4\overset{\rm h}{.}17$), Orlando Benítez Sánchez (BENOR, $2\overset{\rm h}{.}10$), Nikola Biliskov (BILNI, $1\overset{\rm h}{.}67$), Matthew Collier (COLMA, $0\overset{\rm h}{.}96$), Hani Dalee (DALHA, $4\overset{\rm h}{.}27$), Mark Davis (DAVMA, $4\overset{\rm h}{.}00$), Peter Detterline (DETPE, $1\overset{\rm h}{.}08$), German Dominguez Delmas (DOMGE, $1\overset{\rm h}{.}42$), Yosinori Fuyube (FUYYO, $0\overset{\rm h}{.}50$), Slaven Garaj (GARSL, $0\overset{\rm h}{.}67$), George W. Gliba (GLIGE, $2\overset{\rm h}{.}00$), Roberto Gorelli (GORRO, $2\overset{\rm h}{.}67$), Lew Gramer (GRALE, $7\overset{\rm h}{.}94$), Robin Gray (GRARO, $0\overset{\rm h}{.}75$), Wayne T. Hally (HALWA, $2\overset{\rm h}{.}55$), Joost Hartman (HARJS, $4\overset{\rm h}{.}75$), Takema Hashimoto (HASTA, $10\overset{\rm h}{.}55$), Roberto Haver (HAVRO, $2\overset{\rm h}{.}59$), Robert Hays (HAYRO, $1\overset{\rm h}{.}00$), David Hernandez (HERDA, $3\overset{\rm h}{.}15$), Dave Hostetter (HOSDA, $1\overset{\rm h}{.}54$), Oomi Iiyama (IIYOO, $3\overset{\rm h}{.}99$), Daiyu Ito (ITODA, $4\overset{\rm h}{.}71$), Kiyoshi Izumi (IZUKI, $1\overset{\rm h}{.}00$), Carl Johannink (JOHCA, $2\overset{\rm h}{.}08$), Niladri Kar (KARNI, $7\overset{\rm h}{.}41$), Kevin Kilkenny (KILKE, $2\overset{\rm h}{.}03$), Marco Langbroek (LANMA, $6\overset{\rm h}{.}14$), Vladimir Lukić (LUKVL, $1\overset{\rm h}{.}00$), Robert Lunsford (LUNRO, $9\overset{\rm h}{.}49$), Katuhiko Mameta (MAMKA, $13\overset{\rm h}{.}00$), Pierre Martin (MARPI, $0\overset{\rm h}{.}58$), Takuya Maruyama (MARTA, $3\overset{\rm h}{.}43$), Antonio Martinez (MARTI, $2\overset{\rm h}{.}34$), Koen Miskotte (MISKO, $8\overset{\rm h}{.}51$), Hidekatu Mizoguchi (MIZHI, $0\overset{\rm h}{.}73$), Sirko Molau (MOLSI, $4\overset{\rm h}{.}03$), Koji Naniwada (NANKO, $1\overset{\rm h}{.}33$), Jos Nijland (NIJJO, $5\overset{\rm h}{.}40$), Markku Nissinen (NISMA, $1\overset{\rm h}{.}04$), Mohammad Odeh (ODEMO, $4\overset{\rm h}{.}89$), Ibrahim Odwan (ODWIB, $4\overset{\rm h}{.}09$), Masayuki Oka (OKAMA, $5\overset{\rm h}{.}84$), Kazuhiro Osada (OSAKA, $10\overset{\rm h}{.}00$), Toru Sagayama (SAGTO, $1\overset{\rm h}{.}72$), Mitsue Sakaguchi (SAKMI, $3\overset{\rm h}{.}64$), Javier Sanchez (SANJA, $2\overset{\rm h}{.}22$), Koetu Sato (SATKO, $1\overset{\rm h}{.}83$), Tomoko Sato (SATTM, $0\overset{\rm h}{.}50$), René Scurbecq (SCURE, $1\overset{\rm h}{.}23$), Miguel Serra Martin (SERMI, $2\overset{\rm h}{.}93$), Hiroyuki Sioi (SIOHI, $4\overset{\rm h}{.}00$), James N. Smith (SMIJN, $3\overset{\rm h}{.}92$), Enrico Stomeo (STOEN, $0\overset{\rm h}{.}46$), Máximo Svárez Tejera (SVAMX, $2\overset{\rm h}{.}03$), Richard Taibi (TAIRI, $3\overset{\rm h}{.}55$), Kazumi Terakubo (TERKA, $0\overset{\rm h}{.}50$), Masayuki Toda (TODMA, $3\overset{\rm h}{.}00$), Robert Togni (TOGRO, $2\overset{\rm h}{.}41$), Michael Toomey (TOOMI, $2\overset{\rm h}{.}96$), Josep M. Trigo Rodriguez (TRIJO, $5\overset{\rm h}{.}09$), Anne van Weerden (VANAE, $2\overset{\rm h}{.}43$), Frans van Loo (VANFA, $1\overset{\rm h}{.}50$), Maarten Vanleenhove (VANMT, $1\overset{\rm h}{.}75$), Ilkka Yrjölä (YRJIL, $1\overset{\rm h}{.}05$), George Zay (ZAYGE, $5\overset{\rm h}{.}48$), Goran Zgrablic (ZGRGO, $2\overset{\rm h}{.}40$)

2. Population index profile

The average reported limiting magnitudes near the time of the Leonid peak in 1997 were between 4.5 and 5.5, typically resulting in large correction factors due to the limiting magnitude alone (between 2 and 5). This underscores the necessarily large uncertainties which follow in every quantity discussed (and further emphasized by the large error margins present in the figures).

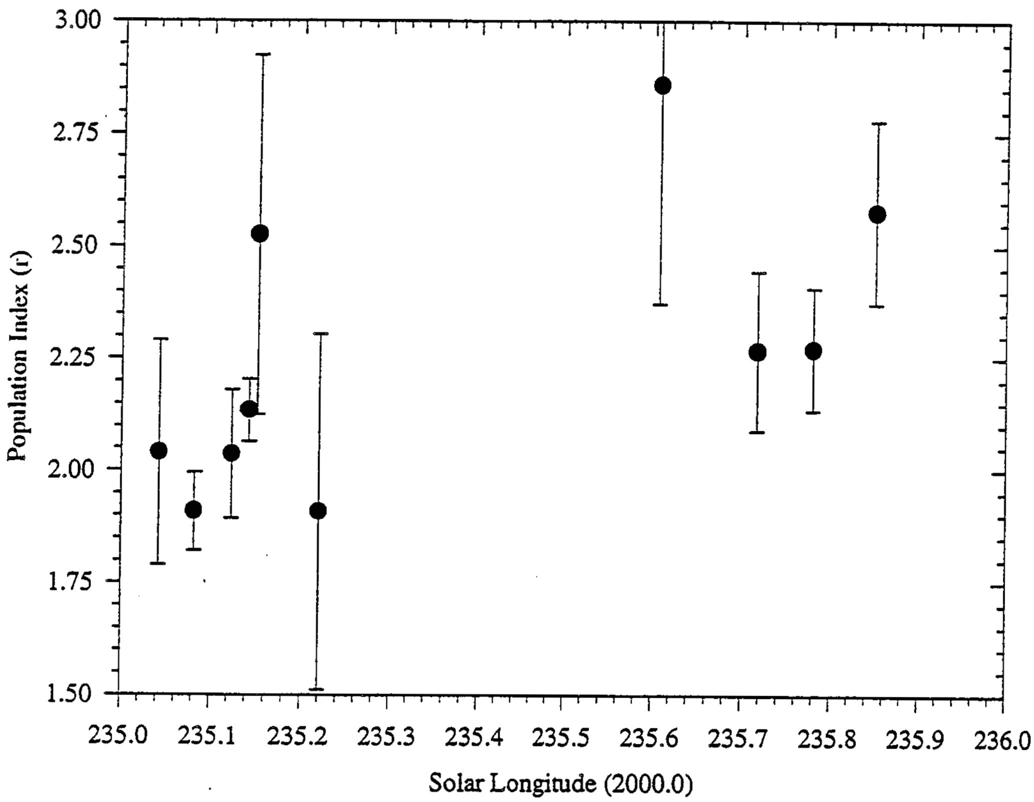

Figure 1 – Population index r versus solar longitude for the 1997 Leonid return. From 235°0 – 235°3 the magnitude data were binned in intervals of 0°06 and shifted in steps of 0°03. From 235°3 onwards, the binning windows were 0°2 wide and shifted by 0°1.

Since sufficient magnitude estimates were made in 1997, a complete r-profile can be constructed during the principle activity period of the shower; the graph is shown in Figure 1.

The initial values for r are consistent with the longer-term average for the shower near 2.0. The values between $\lambda_\odot = 235°0$ and $\lambda_\odot = 235°15$ (equinox 2000.0 throughout this paper) are in the range 1.8–2.1, and are very similar to the profile from 1996. The large increase at $\lambda_\odot = 235°17$ is at precisely the same location as a similar (though smaller) increase recorded in 1996 [2]. However, the large error margin associated with this particular datum implies that this is only a probable concordance with the 1996 profile. Within error, however, the value of r does clearly increase between $\lambda_\odot = 235°08$ and $\lambda_\odot = 235°17$ as in 1996; it is the magnitude of the increase which is most uncertain.

Unfortunately, the remainder of the Leonid interval is only modestly covered by magnitude estimates, particularly as no magnitudes are reported from eastern Asian longitudes, and the most consistent value for r from $\lambda_\odot = 235°3$ onward is near 2.3. Curiously, these are higher (within error) as compared to the same intervals in 1996 and the longer-term average. It might be argued that, on the one hand, observers were able to estimate a reasonable limiting magnitude under the Full-Moon conditions (as can be seen from the reasonable ZHRs), but systematically underestimated meteor magnitudes on the other hand (i.e., making them fainter). This may occur since observers do not always compare a meteors appearance with a star of similar brightness. Instead, judgments like "relatively faint" might have been converted into a magnitude estimate as if under better sky conditions, making a magnitude +3 or +4 meteor a full magnitude fainter.

3. ZHR profile

The ZHR activity profile is shown in Figure 2. The build-up in activity beginning near 235°0 is apparent, and, between $\lambda_\odot = 235°1$ and $\lambda_\odot = 235°3$ (November 17, 9^h30^m–10^h UT), a clear peak with a maximum ZHR of 96 ± 13 is reached. The peak at $\lambda_\odot = 235°22\pm0.04$ (November 17, 12^h15^m UT) is based on reports from a dozen observers and is quite reliable (excepting the ever-present large error margins due to the Moon). Additionally, it comes after the large peak in the population index at a point where this is a large drop in r and is thus not a simple artifact of the sudden jump in r. The activity seems to decline after the peak with about the same steepness as the increase, yet is soon followed by another maximum at $\lambda_\odot = 235.^\circ45 \pm 0.05$ (November 17, 17^h30^m UT) with ZHR $= 85 \pm 13$. It should be noted that the error margins do overlap during large parts of the Leonid maximum. We cannot exclude that the maximum furnished a plateau activity between solar longitudes $\lambda_\odot = 235.^\circ15$ and $\lambda_\odot = 235.^\circ5$.

However, the sporadic HR during the second, less prominent enhancement of activity is very high, the values being definitely too high (compared to normal sporadic rates for this time of the year) by factor of about 3. We assume that the few observers contributing to these ZHR values underestimated their limiting magnitudes significantly—a typical effect under moonlit sky conditions. Upon changing the limiting magnitude by +1 to reduce the sporadic HRs by a factor of 3, Leonid ZHRs decrease by a factor of roughly 2, i.e., the ZHR graph turns into a gradually declining curve matching the reliable value of about 35 after a solar longitude of $\lambda_\odot = 235.^\circ8$.

When comparing the ZHR-graph with that of the preliminary analysis in [1], one finds the most striking difference in the high value of about 150. This value was based on very few individual counts and is now smoothed out by additional data.

We do not present values for flux, as the large errors in r and ZHR make flux values virtually indeterminate. We can only say that near the time of the early peak ($\lambda_\odot \approx 235.^\circ2$), the shower flux was somewhere in the interval 0.01–0.05 meteoroids/km^{-2} hour^{-1} to a limiting absolute magnitude of +6.5.

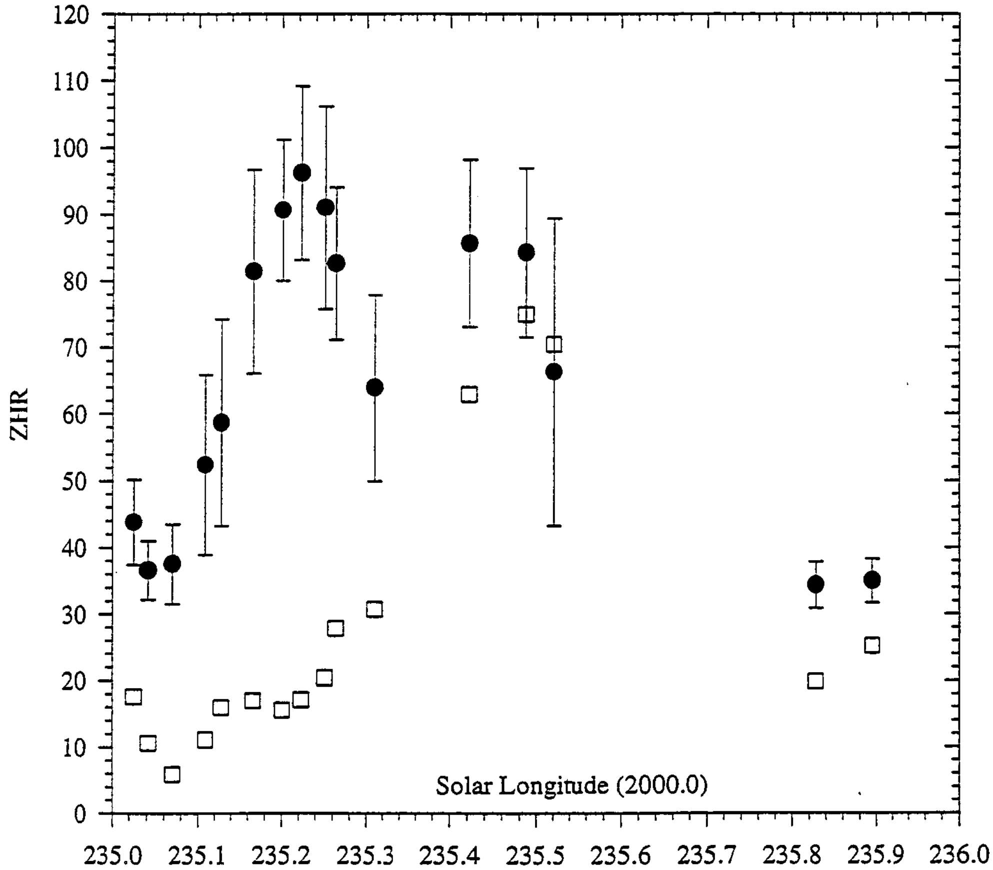

Figure 2 – The ZHR versus solar longitude for the 1997 Leonid return. Observations were binned in windows of $0.^\circ06$ size from $\lambda_\odot = 235.^\circ0$ to $\lambda_\odot = 235.^\circ3$ and smoothed in steps of $0.^\circ03$, while from $\lambda_\odot = 235.^\circ3$ to $\lambda_\odot = 235.^\circ6$, the binning intervals were $0.^\circ2$ wide and the steps used were $0.^\circ1$. For all intervals after $\lambda_\odot = 235.^\circ6$, the bins were $1.^\circ0$ wide and stepped at $0.^\circ5$ intervals.

4. Prospects for 1998

As all visual data have now been analyzed in the lead-up to 1998, we may attempt to use the features from the last few years, plus model and other general considerations to estimate the time of the peak of the shower in 1998. The magnitude of the peak ZHR in 1998 is much more difficult to divine, but we present some of the most recent predictions in Table 1.

Table 1 – Recent predictions for the Leonid meteor storm expected for 1998. The ZHRs are estimates for the anticipated activity.

Author	Peak	Time (UT)	Peak ZHR
Jenniskens, 1996 [7]	235°34	21^h30^m	10 000
Yeomans, 1998 [8]	235°26	19^h40^m	200–5000
Brown et al., 1998 [6]	235°24	18^h50^m	1000–10 000
Kresak, 1993 [9]	234°8	08^h30^m	10 000

From the analysis of each of the returns in 1995, 1996, and 1997 [2,3], a period of transient activity has been noted in each of these years. The peak ZHR values and location in 1995 are most uncertain (ZHR $\approx$ 50 and peak near $\lambda_\odot = 235°0$), while a clear outburst feature was noted in 1996 near $\lambda_\odot = 235°16$ with a peak ZHR of 90. The present analysis suggests another "early" peak near $\lambda_\odot = 235°22$ with a peak ZHR approaching 100. In all cases, the trend appears to be for the peaks to be shifting closer to the nodal longitude of 55P/Tempel-Tuttle ($\Omega = 235°26$) in the few years immediately before the comet reaches perihelion. The most reliably determined of these peaks (that from 1996) is also at the same longitude as the 1966 meteor storm.

On general dynamical grounds, it is expected that any meteor storm in 1998 will occur near the time of the comet's nodal passage [4]. From the recorded Leonid meteor storms over the last 200 years, there is a clear trend whereby the strongest storms occur closest to the cometary node. Curiously, the 6 largest storms all peaked 0.5–2 hours after the nodal longitude of the comet [5].

The most recent numerical modeling results suggest that, if a storm occurs in 1998, it will likely do so within 0.5 hours of the nodal passage (specifically somewhat before the time of the passage) [6]. The most recent predictions for 1998 are summarized in Table 1, along with estimates of the peak ZHR where these have been given.

5. The eighth ILW period: November 5–25, 1998

Summarizing all of the above, it appears most probable that any significant enhancement in Leonid activity in 1998 will occur in the interval $\lambda_\odot = 235°15$–$235°3$. This implies the best location is likely to be in the Western Pacific or Eastern Asia. Noting the possible plateau in activity observed in 1997 and similar behavior observed in past Leonid returns near the time of the comet's passage (such as in 1965 [5]), it is quite probable that much higher than normal activity from the extended component of the shower may be visible for as much as 24 hours centered about the cometary node.

As a result, observers are encouraged to exercise special vigilance during their local 0^h–6^h times on the mornings of November 17 and 18 in particular. The days around the time of the peak will be completely free of lunar interference and ideal for observations. As 1998 has some prospect for producing a meteor storm, observers are reminded that fixed cameras may be most useful during the storm, though disciplined observers should be able to make successful counts should rates reach even as many as several Leonids per second [6]. A detailed description of various observing methods during the Leonid maximum is given earlier in this issue.

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[7] P. Jenniskens, "Meteor Stream Activity. III. Measurement of the First in a New Series of Leonid Outburst", *Meteoritics and Planetary Science* 31, 1996, pp. 177.

[8] D.K. Yeomans, "Comet 55P/Tempel-Tuttle and the Leonid Meteors", *AIAA Leonid Storm Hazard Conference*, Manhattan Beach, CA., April 27, 1998.

[9] L. Kresák, "Meteor Storms", in *Meteoroids and their Parent Bodies*, J. Štohl, I.P. Williams, eds., 1993, pp. 147–157.

The June Bootids

Surprising Activity of the 1998 June Bootids

Jürgen Rendtel, Rainer Arlt, and Valentin Velkov

After a quiescent period of several decades, the June Bootid meteor shower (sometimes referred to as June Draconids) surprised a number of regular and casual observers by an outburst with maximum ZHRs near 100. A total number of 619 meteors was recorded during regular meteor observations. An average population index of $r = 2.22 \pm 0.07$ was derived from 511 magnitude estimates. The broad activity profile with high rates for more than 10 hours and the large radiation area in 1998 resemble the appearance of the 1916 and 1927 outbursts. The peak time is found to be between $\lambda_\odot = 95\overset{\circ}{.}7$ and $\lambda_\odot = 96\overset{\circ}{.}0$ (eq. 2000.0); the average radiant is $\alpha = 230°$ and $\delta = +47°$.

1. Introduction

Considerable activity of the June Bootids was observed at two occasions in 1916 and 1927. Some sources also list the year 1921, but the activity reported from this return is rather low (see Table 1). Additionally, there are some reports of possible activity before and after these returns, but the association to the June Bootids is not certain. Nevertheless, Hoffmeister [1] considered the shower (listed as June Draconids on p. 88) as a "real shower," which was excluded from his final catalogue only because of insufficient observation. When the current *IMO* working list of meteor showers was established by Arlt [2], the shower was rejected because its regular activity was practically below the detection limits for many years. However, June is a period of the year which is poorly covered by meteor observations generally, and in particular from the northern hemisphere.

Observers were surprised by a high meteor activity in the night June 27-28, 1998. The display attracted the attention of casual witnesses, because there were numerous bright meteors visible.

Due to the short duration of northern summer nights, there were not many reports of regular observers.

In total, we received reports or notes from 42 observers from 13 countries:

E. Bojurova (Bulgaria), P. Brown (Canada, radar), G. Carstairs (Australia), S. Crivello (Italy), M. Dionisi (Italy), B. Ewen-Smith (Portugal), D. Girling (Australia), R. Gorelli (Italy), V. Grigore (Romania), R. Haver (Italy), W.K. Hocking (Canada, radar), T. Hashimoto (Japan), T. Holmes (UK), D. Ito (Japan), K. Izumi (Japan), P. Jenniskens (USA), J. Kac (Slovenia), K. Kerr (Australia), A. Knöfel (Germany), H.G. König (Germany), K. Kretsch (Ireland), R. Maňák (Czech Republic), A. Marsh (Australia), A. McBeath (UK), S. Näther (Germany), A. Negoescu (Romania), K. Nose (Japan, video), K. Osada (Japan), D. Penn (Portugal), L. Rashkova (Bulgaria), J. Rendtel (Germany), K. Sato (Japan), L.R. Sobkoviak (USA), E. Stomeo (Italy), P. Sütterlin (Germany), K. Suzuki (Japan, forward scatter), M. Taylor (USA), J.M. Trigo (Spain), M. Ueda (Japan, forward scatter), B. Vanderwark (USA), V. Velkov (Bulgaria, visual, photographic), R. Vodicka (Australia).

The activity of the June Bootids was also evident in forward-scatter and radar data. The first note about increased activity came from Japan (Koseki 1998, *IMO* News), reporting counts that were three to five times higher after 9^h UT, continuing to at least 14^h UT, on June 27. One witness gave a number of 50 meteors per hour seen from inside an observatory dome.

Table 1 – Historical records of the June Bootid activity during the 1916, 1921, and 1927 returns of the shower. Rates do not refer to the term ZHR which is in use nowadays, but give only numbers per hour independent of the observing conditions. Other papers just give numbers of shower meteors noted by the observer.

Time (UT)	Activity	Observer, remarks	Source
1860, 1861 Jun 30	"many"	Lowe	Denning [7]
1916 Jun 28 22^h25^m–00^h10^m	55 met.	Denning	Denning [7]
1916 Jun 29 00^h45^m–01^h15^m	14 met.	partly cloudy	Denning [7]
1921 Jun 24	2.9/h	summary	Hoffmeister [8]
1921 Jun 25	2.5/h	summary	Hoffmeister [8]
1921 Jun 26	0.6/h	summary	Hoffmeister [8]
1921 Jun 28	7 met.	Denning	Kronk [9]
1921 Jun 28	1.7/h	summary	Hoffmeister [8]
1921 Jun 28 21^h45^m–22^h50^m	5 met.	3 observers, Prague; hazy and cirrus	Prey [10]
1921 Jun 28 21^h50^m–24^h00^m	5.5/h	Štepanek, Ondřejov	Svoboda [11]
1921 Jun 28 23^h00^m–01^h10^m	≈ 20 JBO	Jadot	Jadot [12]
1921 Jun 29.17	7 met.	Dole, USA	Kronk [9]
1921 Jun 29	1.1/h	summary	Hoffmeister [8]
1921 Jun 29 21^h35^m–23^h10^m	2 met.	Mrazek, Prague; very hazy	Prey [10]
1921 Jun 30.10	8 met.	Dole, USA	Kronk [9]
1921 Jun 30 21^h10^m–00^h50^m	≈ 20 JBO	Jadot	Jadot [12]
1921 Jul 01 22^h00^m–23^h00^m	6 met.	Heybrock, Frankfurt hazy, clouds	Heybrock [13]
1921 Jul 03	153 met.	Nakamura	Yamamoto [14], questioned by Denning [15]
1927 Jun 24.8	54/h	236 met., 2 obs., Tashkent	Sytinsky [3]
1927 Jun 25.8	96/h	316 met., 2 obs., Tashkent	Sytinsky [3]
1927 Jun 26.8	213/h	1054 met., 2 obs., Tashkent	Sytinsky [3]
1927 Jun 27.8	357/h	1213 met., 2 obs., Tashkent	Sytinsky [3]
1927 Jun 26–30	145 met.	Dole, USA	King [16]

2. Previous observations of the June Bootids

In this section, we give a summary of old observations of the June Bootids regarding their activity. We restrict to those returns where a considerable rate was reported from several locations. Most observers made plots, even when high rates were present. For the 1927 return, plots and counts were made by different observers of the Tashkent group (Sytinsky [3]; detailed report by Sytinskaya [4]). Please note that there are no data for the further reduction, such as the limiting magnitude. The data are also difficult to compare with one another.

The June Bootid activities of 1916, 1921, and 1927 are quite well-documented in the literature. The meteors were often described as faint, but at the same time there were reports of bright meteors and fireballs. A magnitude −14 June Bootid fireball was photographed on June 29, 1927 (Yamamoto [5]). Denning [6] immediately associated the shower with comet 7P/Pons-Winnecke, a comet of the Jupiter family. Relatively close encounters with Jupiter caused quite rapid changes of the comet's orbit. These changes shifted the perihelion from inside the Earth's orbit (until 1916) to outside the Earth's orbit (from 1921). The minimum distance between the orbits increased continuously after the 1921 perihelion passage and reached 0.24 AU in 1998 (Figure 1). So, it is quite unlikely that recently released meteoroids approached the Earth in 1998. The event, which is described next, must be linked to meteoroids ejected from the parent comet 7P/Pons-Winnecke earlier in this century.

Contrary to most known outbursts of meteor showers, the June Bootid activity lasted for more than 12 hours. This was also reported from the observations in 1916 and 1927. Obviously, there was no relation to the actual comet position: the 1916 activity happened almost 300 days after the last perihelion passage (with $q = 0.970605$ AU). The 1927 event occurred just 7 days after the comet passed its perihelion (then $q = 1.039235$ AU). When 7P/Pons-Winnecke passed the perihelion (now $q > 1.25$ AU) last on January 2, 1996, the entire orbit was distant from the Earth's orbit (Figure 1). The orbital data of the comet were taken from [17]. Given the current distance between the orbits of the comet and the Earth, such an enhanced activity was not to be expected. Furthermore, the encounter conditions of the 1998 June Bootid outburst are of a different type compared to the earlier events of this shower and also compared to the peaks of the Draconids, Leonids, and Perseids, for example.

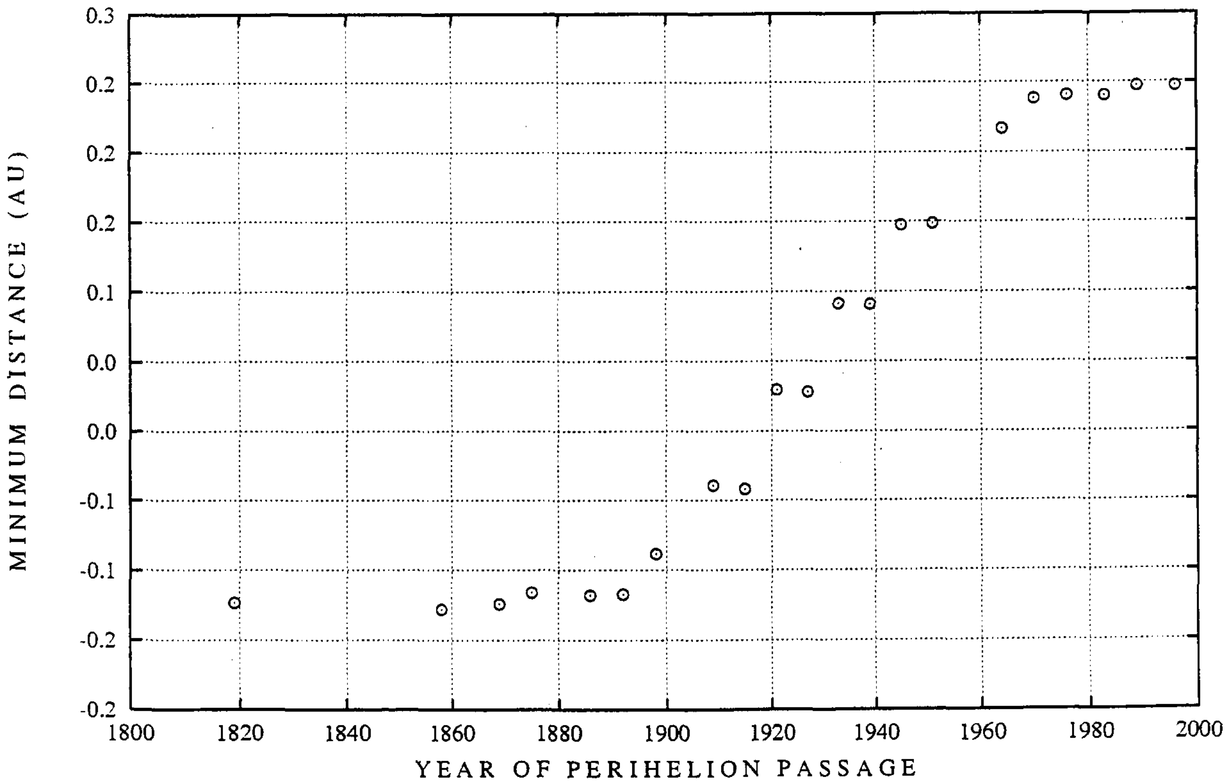

Figure 1 – Evolution of the minimum distance of the orbit of 7P/Pons-Winnecke from the Earth's orbit.

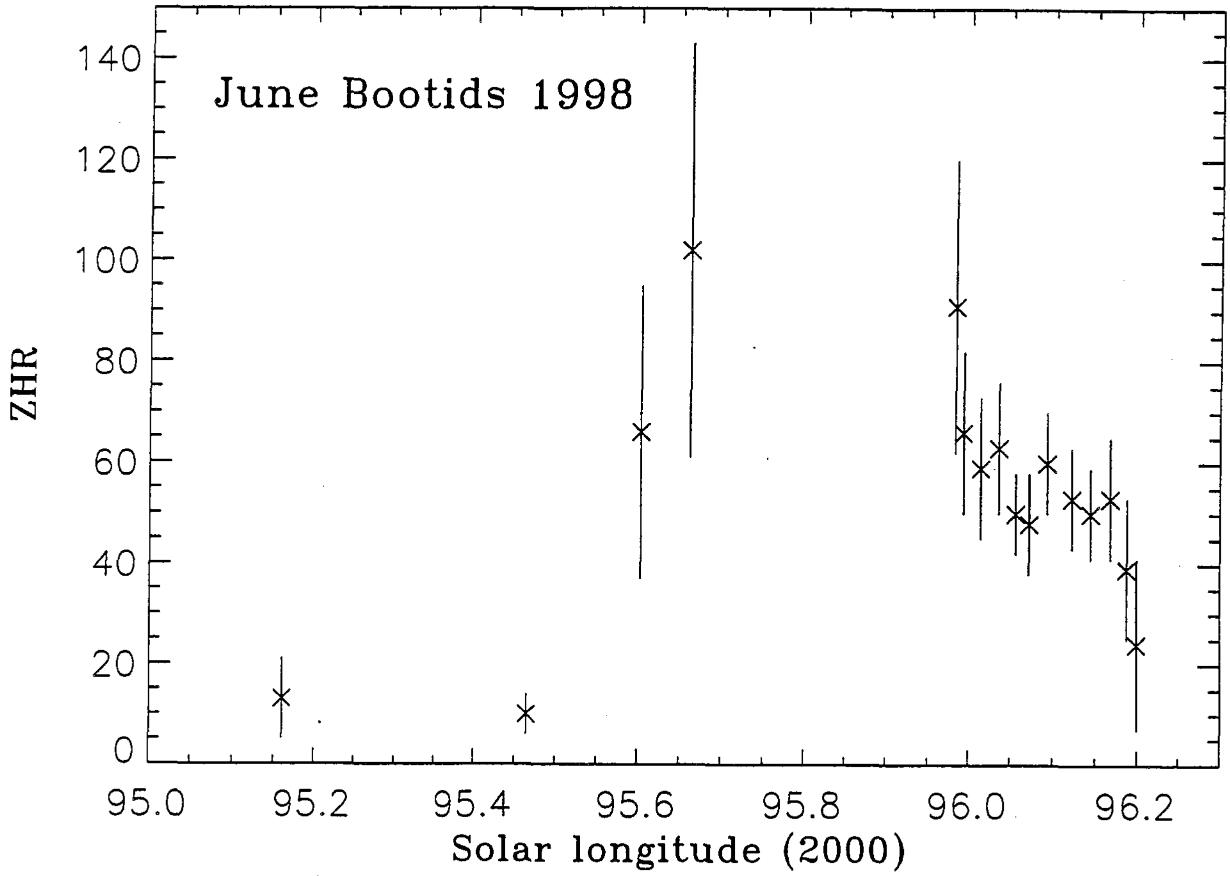

Figure 2 – ZHR profile of the 1998 June Bootids. The values are based on a population index of $r = 2.22$ and a radiant position at $\alpha = 230°$ and $\delta = +47°$.

Table 2 – Profile of the average ZHR values for the 1998 June Bootids. "Obs." is the number of individual rates involved in the average and JBO is the number June Bootid meteors; solar longitudes refer to eq. 2000.0.

Date	Time (UT)	$\lambda_\odot$	Obs.	JBO	ZHR
June 26	23^h10^m	95°16	3	13	13 ± 8
June 27	07^h30^m	95°464	1	28	10 ± 4
June 27	10^h20^m	95°603	1	21	66 ± 29
June 27	11^h50^m	95°662	1	25	102 ± 41
June 27	19^h30^m	95°983	3	40	91 ± 29
June 27	20^h10^m	95°993	6	68	66 ± 16
June 27	20^h40^m	96°014	6	69	59 ± 14
June 27	21^h20^m	96°036	8	97	63 ± 13
June 27	21^h50^m	96°056	14	150	50 ± 8
June 27	22^h10^m	96°072	11	102	48 ± 10
June 27	22^h40^m	96°093	14	155	60 ± 10
June 27	23^h20^m	96°122	14	113	53 ± 10
June 28	00^h00^m	96°144	14	114	50 ± 9
June 28	00^h40^m	96°167	10	81	53 ± 12
June 28	01^h00^m	96°187	6	33	39 ± 14
June 28	01^h20^m	96°199	2	8	24 ± 17
June 28	12^h20^m	96°64	1	0	0
June 29	11^h00^m	97°53	6	6	2 ± 2
June 29	21^h00^m	97°93	1	0	0

3. The 1998 event

A considerable amount of 511 magnitude estimates allowed the determination of a population index of the June Bootid meteor shower. We derived $r = 2.22 \pm 0.07$ from observations of the period June 27, 19^h30^m to June 28, 01^h30^m UT. This population index as well as the average radiant position of $\alpha = 230°$ and $\delta = +47°$ (see below) were used to obtain a profile of the ZHR (Figure 2). Highest rates of roughly 100 occurred between June 27, 12^h and 20^h UT. Whereas these rates are based on very few observations, the ZHRs of the period June 27, 20^h to June 28, 1^h30^m UT constitute a reliable picture of the activity.

Another surprising fact is the large apparent size of the radiant area. This was reported in the early activity events as well as during the 1998 display. Other meteor showers producing high rates show a well-defined radiant. The analysis of 139 meteor plots by Bojurova, Rashkova and Velkov with the RADIANT software [18] yields a distinct radiant at $\alpha = 230° \pm 2°$ and $\delta = +47° \pm 2°$ (eq. 2000.0), which corresponds very well to the average radiant position reported by all other observers. The software corrects each individual meteor for zenithal attraction by assuming a most probable radiant for each meteor according to its direction and speed. The resulting radiant is fairly compact, in contrast to the reports of other observers.

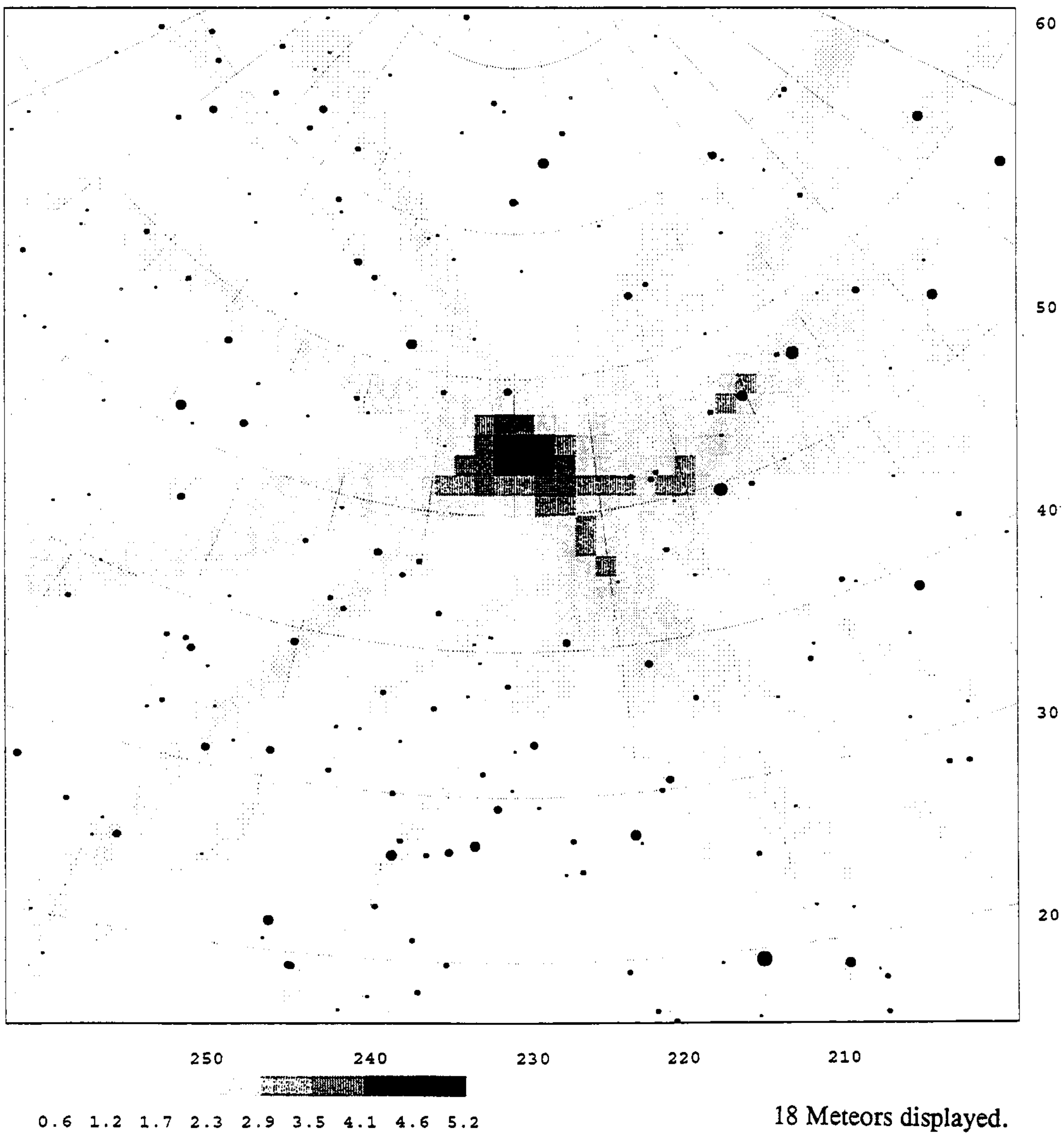

Figure 3 – Analysis of the meteor plots of Denning of the 1916 June Bootid return. Since no meteor velocities are available, simple backward tracings of the paths are drawn and accumulated.

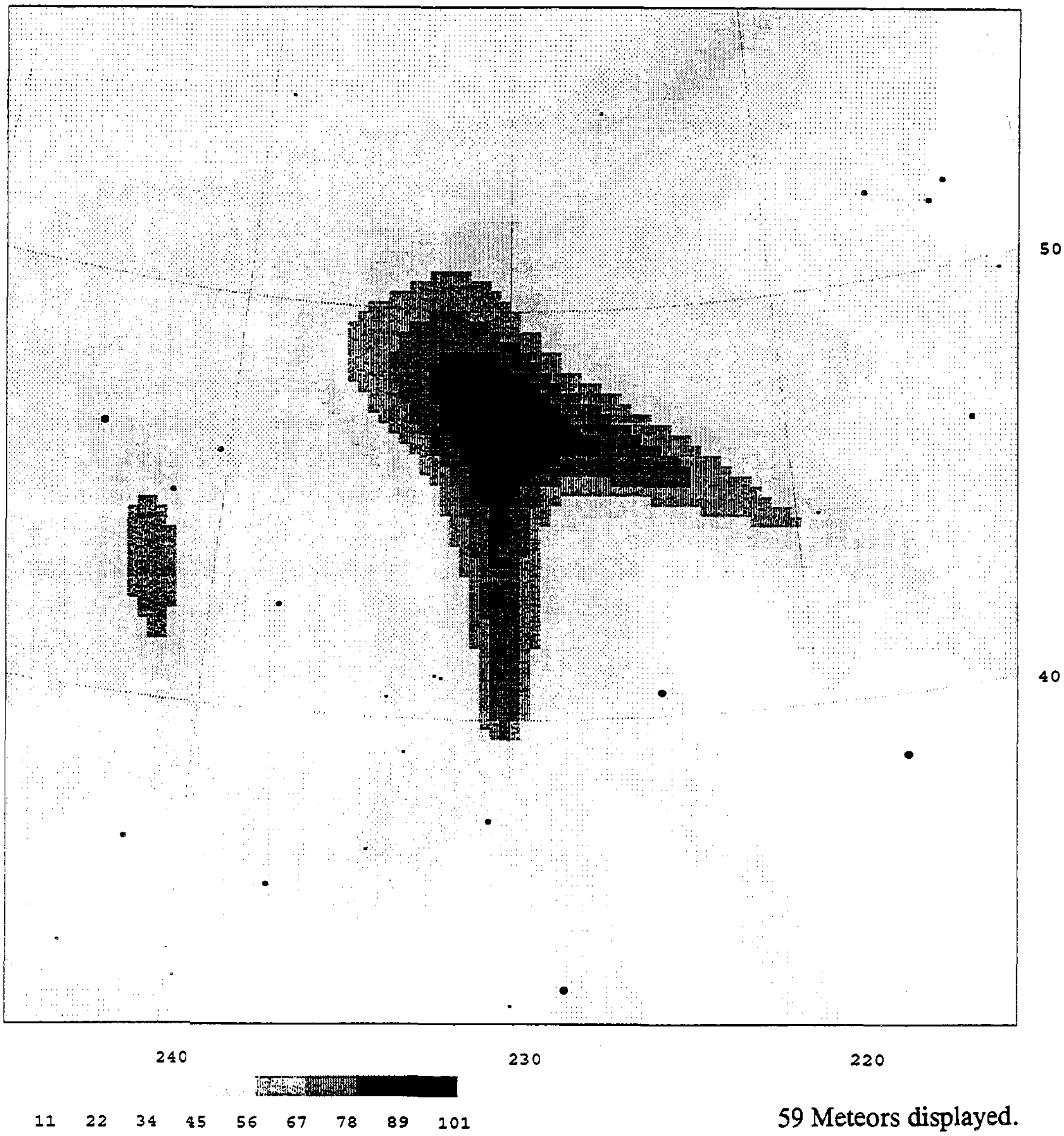

Figure 4 – Analysis of 139 meteor plots recorded by Bojurova and Velkov on June 27-28, 1998. The graph was obtained by the application of the probability method (see [18] for details), which determines an area of radiant probabilities behind every meteor. A pre-atmospheric velocity of 18 km/s was assumed.

It is argued that the large scatter in radiant positions results from the strong zenithal attraction of slow-velocity showers, which varies between 0° (radiant at the zenith) and 12° (radiant elevation 10°). The radiant height decreases from 80° to 40° during the night on mid-northern latitudes, inflating the apparent radiant by 7° automatically.

Upon processing the films, one of the authors (Valentin Velkov) found five photographs of June Bootids. Four of them, situated in a fan-shape within an angle of almost 180°, formed a radiant with coordinates $\alpha = 229\overset{\circ}{.}6$ and $\delta = 48\overset{\circ}{.}1$. They appeared in the interval between 20^h35^m and 22^h10^m UT, when the zenith attraction is not very large. Given a pre-atmospheric velocity of 18 km/s, this apparent radiant position corresponds to a geocentric radiant at $\alpha = 225\overset{\circ}{.}2$ and $\delta = +48\overset{\circ}{.}4$. This is very close to the radiant position derived from a double-station photograph of a June Bootid at $\alpha = 222\overset{\circ}{.}9$ and $\delta = +47\overset{\circ}{.}6$ reported in [19].

4. Discussion

When the Earth crossed the meteoroids of comet 7P/Pons-Winnecke in 1916, the particles were far behind the comet—298 days. Meteors released from the comet during the perihelion passage in 1915 were substantially disturbed by Jupiter between 1917 and 1919. The closest approach to Jupiter occurred in mid-May 1918 (0.719 AU).

Table 3 – Radiants given for the June Bootids as given in historical records as well as in 1998 reports. If the column "Z" is tagged, the radiant was corrected for zenithal attraction. Note the large scatter in the positional data.

Date	α	δ	Source	Equinox	Z
1916 Jun 28	203°	+53°	observer at Birmingham; [20] Olivier (1916)	1900.0?	
1916 Jun 28	221°	+56°	Denning [21], no. 183	1900.0?	
1916 Jun 28	231°	+54°	Denning [21], no. 184	1900.0?	
1916 Jun 28	213°	+53°	Denning [21], no. 185a	1900.0?	
1916 Jun 28	223°	+41°	Denning [21], no. 185	1900.0?	
1916 Jun 28	213°	+49°	Nakamura (in Kronk [9])	1950.0?	
1921 Jun 28	228°	+58°	Denning [21], no. 186	1900.0?	
1921 Jun 28/29	208°	+61°	Hoffmeister [8]; 12 meteors	1910.0	
1927 Jun 26.8	198°	+53°	3 observers Tashkent (Sytinskaya [4])	1927.0	√
1927 Jun 27	213°	+55°	Dole (King [16])	1900.0?	
1927 Jun 27.8	198°	+54°	4 observers Tashkent (Sytinskaya [4]	1927.0	√
1927 Jun 28.8	198°	+54°	2 observers Tashkent (Sytinskaya [4])	1927.0	√
1927 Jun 29.7	200°	+54°	2 observers Tashkent (Sytinskaya [4])	1927.0	√
1927 Jun 30	218°	+60°	Dole (King [16])	1900.0?	
1927 Jun 30.7	204°	+55°	1 observer Tashkent (Sytinskaya [4])	1927.0	√
— Jun 27–30	212°	+58°	Bakulin [22], no. 18 (visual)	1950.0	
— Jun 13–Jul 02	229°	+48°	Bakulin [22], no. 90 (photographic)	1950.0?	
— Jul 01	209°	+56°	Bakulin [22], no. 52	1950.0?	
1942 Jul 06	206°	+54°	Bakulin [22], no. 29 (telescopic)	1942.0	
1944 Jun 24	208°	+55°	Bakulin [22], no. 30 (telescopic)	1900.0	
1987 Jun 27	229°	+44°	Velkov	1950.0	√
1998 Jun 27.6	218°	+53°	report Vodicka and Marsh, radiant position corrected by McNaught (1998, meteorobs)	2000.0	√
1998 Jun 27.60	228°	+54°	Brown and Hocking [23]; radar	2000.0	
1998 Jun 27.60	219°	+61°	Brown and Hocking [23]; radar, second rad.	2000.0	
1998 Jun 27.89	222°.9	+47°.6	Spurný and Borovička [19]; 2-station photograph	2000.0	√
1998 Jun 27.9	225°	+48°	Velkov, 5 photographic meteors	2000.0	√
1998 Jun 27.9	230°	+47°	Bojurova, Rashkova, Velkov	2000.0	√
1998 Jun 27.9	237°	+46°	Crivello (1998, pers. comm.)	2000.0	√
1998 Jun 27.9	240°	+50°	Gorelli (1998, IMO News)	2000.0	
1998 Jun 27.9	224°	+50°	Haver (1998, IMO News)	2000.0	
1998 Jun 27.9	220°	+59°	Stomeo (1998, IMO News)	2000.0	

The comet and the particles of each ejection phase are disturbed by Jupiter in a different way. The question whether this effect is the reason for the large scatter of the radiants reported at all occasions, can only be answered after the fully attraction-corrected radiant analysis of original data plus an evolution study of orbital elements of June Bootid meteoroids.

It is certainly a typical feature of short-period cometary meteoroid streams to show an activity behavior which is decoupled from the orbital motion of the parent body. Perturbations from Jupiter are assumed to be the key mechanism which directs filaments of the stream closer to Earth at certain times. Since it is not the comet's perihelion passage but the encounter conditions with Jupiter which trigger an outburst, filaments ejected at different perihelion passages (being evolved quite differently) will be directed towards the Earth resulting in broad activity profiles and possibly different radiants at each return.

In 1916, the enhanced rates were observed when the comet was far away from the perihelion (298 days). Comet 7P/Pons-Winnecke reached its perihelion on June 21.1, 1927, and high rates were observed for more than two nights. The situation was quite similar in 1921, when the perihelion was passed on June 13.4, but the rates remained low.

Radiant searches among photographic and radar orbits give only weak hints on the existence of a shower. Sekanina [24] associated 4 streams found from radar data with the orbit of 7P/Pons-Winnecke. The most prominent are the "July Draconids" (54 orbits) between June 2 and July 19, with an average radiant at $\alpha = 209\overset{\circ}{.}8$ and $\delta = +70\overset{\circ}{.}7$. Much closer to what we call the June Bootids are the "Bootid-Draconids" in Sekanina's list, with a nodal passage on July 2, 1969, and a radiant at $\alpha = 233\overset{\circ}{.}7 \pm 3\overset{\circ}{.}1$ and $\delta = +52\overset{\circ}{.}2 \pm 1\overset{\circ}{.}8$. The geocentric velocity is 14.7 km/s, which is accelerated by the Earth's gravity to a pre-atmospheric velocity of 18.3 km/s.

The available literature and archives do not include hints on significant rates of the June Bootids until 1998. It may well be that a short time activity event of a radiant so far in the northern sky was missed due to the short nights at mid-northern latitudes. However, the analyzed returns of the June Bootids show a remarkably long duration, definitely exceeding one night. Nevertheless, it remains most difficult to say whether the few meteors reported over the years are real members of a meteoroid stream associated with 7P/Pons-Winnecke or sporadic meteors which are aligned with the large apparent radiant area by chance.

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SPA Meteor Section Preliminary Radio Results: 1998 June Bootid Outburst

Alastair McBeath

A review of radio data submitted to the *SPA Meteor Section* from the June Bootid outburst of June 27-28, 1998, is presented and discussed. Despite problems because of the β-Taurid maximum around June 28, the June Bootid signature is clear in all datasets covering the radiant's best visibility from Japan and Europe. The approximate maximum time and lengthy peak activity found in visual data [1] is generally supported by the radio results.

1. Introduction

The June Bootid outburst of June 27-28, 1998, was completely unexpected, for reasons that are well explained elsewhere [1]. Unfortunately, this meant that many potential visual and radio observers were unable to cover the event, thus the amount of available data is not nearly so complete as for the 1995 α-Monocerotid outburst, for example (cf. various articles in *WGN* 23:6 (1995), 24:1/2, and 24:3 (1996)). Here we examine some of the forward-scatter radio data.

Most of the radio results used were taken from *Radio Meteor Observation Bulletin* (*RMOB*) 59 (July 1998), kindly provided by Christian Steyaert, although a substantial number of e-mail and Internet messages featuring initial impressions of radio meteor activity on June 27-28 were also forwarded by numerous *SPAMS* correspondents. In addition, Kimio Maegawa thoughtfully sent in a preliminary version of a paper [2] with some of the clearest continuous Japanese radio data on the outburst.

The contributing radio observers active during the June Bootid outburst were Maurice de Meyere (Belgium, *RMOB*), Ghent University (Belgium, *RMOB*), Will Kelsey (California, USA, *RMOB*), Werfried Kuneth (Austria, *RMOB*), Chikara Shimoda (Japan, *RMOB*), and Masayoshi Ueda and Kimio Maegawa (Hamband Radio Observation, HRO, Japan).

The raw radio data analysis was carried out using the usual procedures as outlined in [3]. The graphs used are generally representative of the detected overall radio meteor activity. Note that all the discussions here concern raw radio meteor echo rates only. No corrected rates were used, since these are not currently felt to produce substantially more accurate final results, due to uncertainties in the calculation factors and assumptions that must be made about possible sporadic and other shower activities.

2. Results and discussion

Sporadic-E and other atmospheric disturbances were quite prevalent throughout June, as in most recent years. Fortunately, during the critical spell on June 27-28, these problems were at a minimum, and only minor breaks in recording were necessitated because of them for a few observers.

Only two observers to report data to us—Ghent University and the HRO set-up operated by Ueda and Maegawa—ran their systems continuously during the outburst period. Will Kelsey was generally active sampling the radio meteor activity for one hour on most days in June (usually at some point between 10^h and 15^h UT). He was operating between 12^h and 13^h UT on June 27, unfortunately after June Bootid radiant-set for his site. Werfried Kuneth changed his recording level from 17^h UT on June 26 after almost a one-day break in recording from 19^h UT on June 26. This was unlucky timing, because there is thus too little comparison data to judge how significant the rates he recorded on June 27 and 28 were, apart from being probably enhanced between 11^h and 15^h UT on June 27 and from 22^h UT on June 27 to 3^h UT on June 28. Data from the two remaining observers for the whole of June are shown in Figures 1 and 2. Other aspects of the June radio data will be discussed in a later *SPAMS* results article.

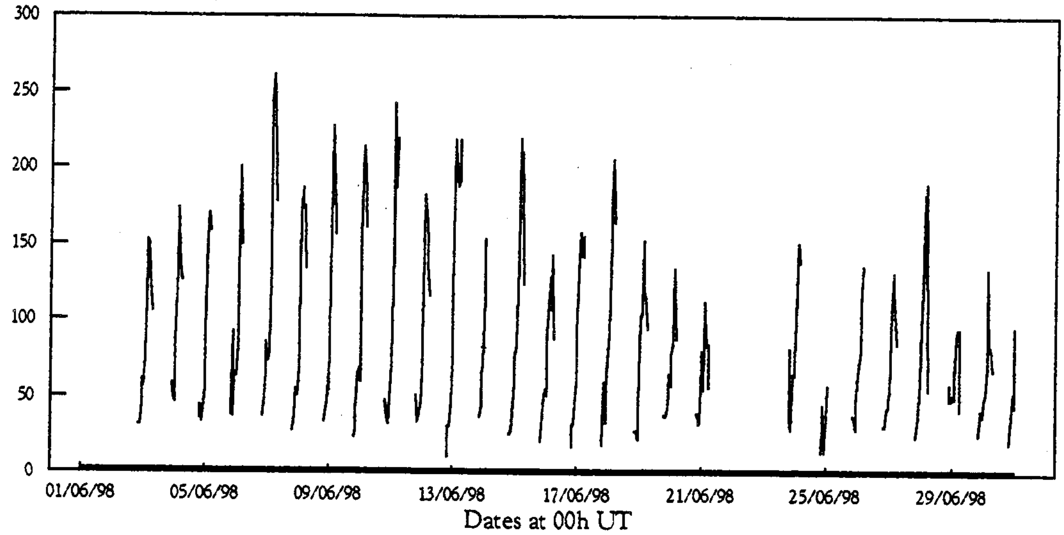

Figure 1 – Raw hourly radio meteor echo counts of minimum 0.027s duration between June 2 and July 1, 1998, from data collected by Maurice de Meyere. Maurice usually operated his set-up for 11 hours daily, between 20^h and 7^h UT. Data from a one-day experimental test on June 1-2 using a different antenna elevation have been omitted here, as the rates detected were not directly comparable to those recorded during the rest of the month. Note the different y-axis scales in Figures 1 and 2.

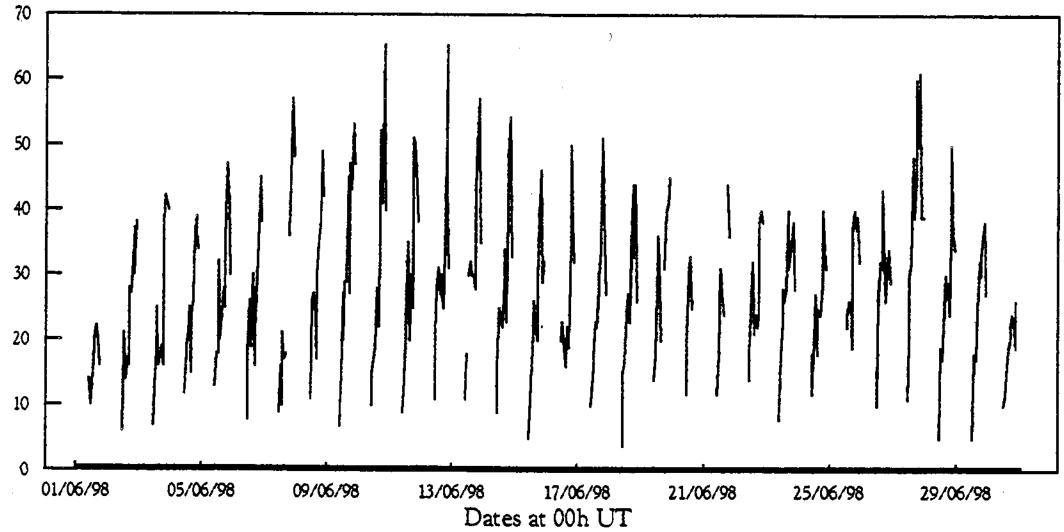

Figure 2 – Raw hourly radio meteor echo counts during June, 1998, from data produced by Chikara Shimoda. With a few occasional gaps, Chikara operated his set up for usually 12 hours daily, between 11^h and 23^h UT. The "bulge" in both Figures 1 and 2 during the first half of June is chiefly due to the daytime Arietids and ζ-Perseids.

All the datasets covering the June Bootid outburst epoch as well as most of June show a distinct peak around $\lambda_\odot = 95°–96°$ (eq. 2000.0). However, this is not especially surprising, since the expected maximum of the daytime β-Taurids is expected at $\lambda_\odot = 96°–97°$, and a weak echo count maximum was consistently found around this time ($\lambda_\odot = 95°–97°$) from 1993–1997 [4]. Whether this peak was due to the β-Taurids during that period can only be suspected, but echo counts were regularly enhanced from $\lambda_\odot = 89°–97°$, most especially around $\lambda_\odot = 91°–93°$. The peak detected in 1998 was significantly stronger than would normally be expected at this time, however.

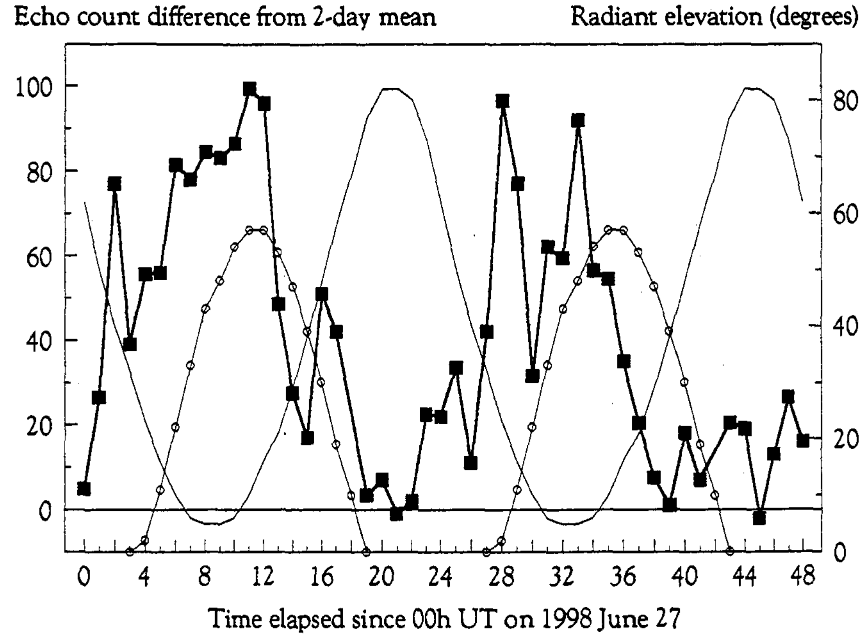

Figure 3 – The (usually positive) difference in echo counts for each hour on June 27-28, compared with the mean echo count for the same time on June 25-26, from Ghent University radio meteor data (thick line with filled-square data points, scaled using the left-hand y-axis). One-hour breaks in the data collection at 18^h UT on both June 27 and 28 have been filled by simply extending the line to the next available data point. Superimposed are curves showing the radiant elevation for the β-Taurids (line with open circles) and June Bootids (unmarked curve) for the Ghent site (scaled using the right-hand y-axis; note the different zero point for the two y-axes). For other details, see text.

To test for β-Taurid and June Bootid activities (the other late June showers are probably too weak to be important, e.g., the Sagittarids, waning Arietid and ζ-Perseid rates), Figure 3 was prepared. This shows data from Ghent University covering the whole of June 27 and 28, plotted as a positive or (very occasionally slightly) negative echo count difference, as compared to the mean counts for the same times on June 25 and 26, both days which showed no unusual features in the Ghent results. Thus the overall enhancement in echo counts on June 27-28 above normal can be viewed directly. Superimposed on this graph are two curves showing the approximate radiant elevations for the β-Taurids and the June Bootids for the same time intervals for the Ghent site (latitude about 51° N). The elevations are approximate, as the size of the β-Taurid and June Bootid radiants are not known with any accuracy, and may be several tens of degrees in diameter, plus the June Bootids seem to have been active from several radiants, or perhaps a very diffuse series of radiants as [1] and [5], for instance, demonstrate. In addition, Green [5] suggests a second June Bootid radiant some distance from the main one ($\alpha = 219°$ and $\delta = +54°$) was detected by the Skynet radar. Based on Ghent data, Steyaert suggested a possible radiant position around $\alpha = 205°$ and $\delta \geq +45°$ in *RMOB* 59, p.6. Consequently, radiant positions at approximately $\alpha = 85°$, $\delta = +20°$ (β-Taurids) and $\alpha = 230°$, $\delta = +50°$ (June Bootids) were assumed in making these plots. For the June Bootids, a radiant further west as suggested by Steyaert or Green will alter the characteristics of this curve only very slightly, at most moving the entire curve one hour to the left (peak and trough about 1^h earlier).

Although different radio set-ups do not always react well to a high radiant elevation, there is a general correlation with visual activity that requires the radiant to be above the horizon for readily detectable meteor rates to be found under normal circumstances, and higher echo counts are likely when the radiant is clear of the horizon. From other shower analyses in the ongoing *SPAMS* results series by the present author, it seems likely that few or no shower meteor echoes can be expected when the radiant elevation is less than 15°–20°, unless meteor rates are particularly enhanced from that source. In addition, all radio meteor systems detect a diurnal rate variation which approximately follows the visual sporadic trend, with a peak around 6^h local time, and a trough roughly twelve hours later, regardless of any shower activity (at Ghent, UT is approximately local time). Here, much of this sporadic trend will have been removed by subtracting the mean activity from the two previous days, however. Even so, this, and the other noted aspects need to be borne in mind when considering Figure 3.

From this simplified, though viable, view, part of the meteor activity on June 27-28 detected over Europe appears to be due to the β-Taurids, but a significant proportion was undoubtedly due to the June Bootids, which shower seems to suffer especially from its maximally small radiant zenith distance, at least with the Ghent set-up. Indeed, the June Bootid proportion is so high that it probably accounts for roughly half the total difference in echo populations between June 25-26 and 27-28, with a surprisingly large number of June Bootids present even with a very low radiant elevation. This facet appears to be borne out by the Japanese data, as around latitude 35° N, the June Bootid radiant sets around 6^h local time, rising again around 13^h. Echo count increases appear perhaps around 12^h–13^h in [2] on June 27, dipping back to normal levels around 7^h on June 28, before rising again around 12^h–13^h, finally dropping back to normality circa 17^h–18^h. Shimoda's data in *RMOB* 59 also suggest a cut-off around 6^h–7^h on June 28, though his system was not operating beyond 8^h local time. For Japan, the β-Taurid radiant overlaps with the June Bootid radiant's visibility for only a few hours, between June Bootid radiant-rise and β-Taurid radiant-set at about 18^h local time. Consequently, the early part of the supposed June Bootid enhancement noted here may be mildly boosted by the β-Taurids, but even so, the best rates occur with the β-Taurid radiant well below the horizon.

The maximum time itself is difficult to estimate in the European data, partly because of the overlap in June Bootid and β-Taurid visibilities, but June Bootid activity seems clearly present for the best part of 36 hours from midnight UT on June 27, certainly from 2^h UT onwards. The Bootid radiant culminates at about 21^h local time, but the Japanese data shows non-culmination peaks around 23^h–1^h local time on June 27-28 [2], and 3^h–6^h (Shimoda), which times are perfectly coincident with the peak suggested by visual data in [1], 13^h–21^h UT.

Comparing the overall echo peak shape and character with the much more minor peak found around June 28 in past years, shows the 1998 event to have been distinctively unusual. As Figures 1 and 2 demonstrate, the June Bootid peak echo count numbers were not far below the levels of the Arietids and ζ-Perseids earlier in June. This is quite exceptional, and once again shows the value of having active radio observers operating their systems as often as possible, reporting throughout the year, regardless of expected meteor activity.

Acknowledgments

I am most grateful to all Section correspondents and observers for providing so much data on the June Bootid outburst so soon after the event, but I would also like to particularly thank Jürgen Rendtel and Kimio Maegawa for sending copies of their pre-publication papers, and for their willingness to share their findings.

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Photographic Observation of a June Bootid Fireball

Czech Republic, June 27, 1998, $21^h23^m04^s \pm 2^s$ UT

Pavel Spurný and Jiří Borovička, Ondřejov Observatory

On the night of June 27, 1998, a bright fireball (EN270698) was photographed by two Czech stations of the European Fireball Network from which reliable data were obtained. The fireball was of the cometary type IIIB, and also its light curve confirms its cometary origin. There is little doubt that this fireball was produced by the June Bootid meteor shower. The data confirm the connection between this fireball and Comet P7/Pons-Winnecke.

Thanks to only about one hour of clear sky over a small part of the Czech fireball network, we were able to photograph two bright meteors, which were undoubtedly connected with the enhanced activity of the June Bootids.

One of them was only single station, i.e., without possibility to determine atmospheric and heliocentric data.

The second one was photographed from two stations, and gave very reliable data. This relatively short, slow-moving fireball (initial velocity was only 17.9 km/s) was photographed by two (fixed and guided) fish-eye cameras (fish-eye objectives Zeiss Distagon $f/3.5$, $f = 30$ mm) and one long-focus spectral camera (objective Tessar $f/6.3$, $f = 360$ mm) at the Ondřejov Observatory (station no. 20) and one fixed fish-eye camera at the Telč station (no. 15).

The EN270698 fireball was recorded shortly after the regular beginning of the exposure on June 27, 1998, at $21^h23^m04^s$ UT. The meteoroid of initial photometric mass of 0.15 kg traveled on a relatively short 18.15-km luminous trajectory in 1.1 seconds, terminating its light at a height of 72.2 km.

According to its behavior in the atmosphere, this meteoroid belongs to the most fragile, typically cometary type IIIB, strongly resembling the October Draconid material. Also its light curve is typical for cometary fireballs with a great terminal flare (−7.9 absolute magnitude) close to the end of the luminous trajectory (see also Figure 1). From the radiant position and the heliocentric orbit (see also Figure 2), it is evident that this meteoroid belonged to the June Bootids meteor stream. All important data are presented in Tables 1–3.

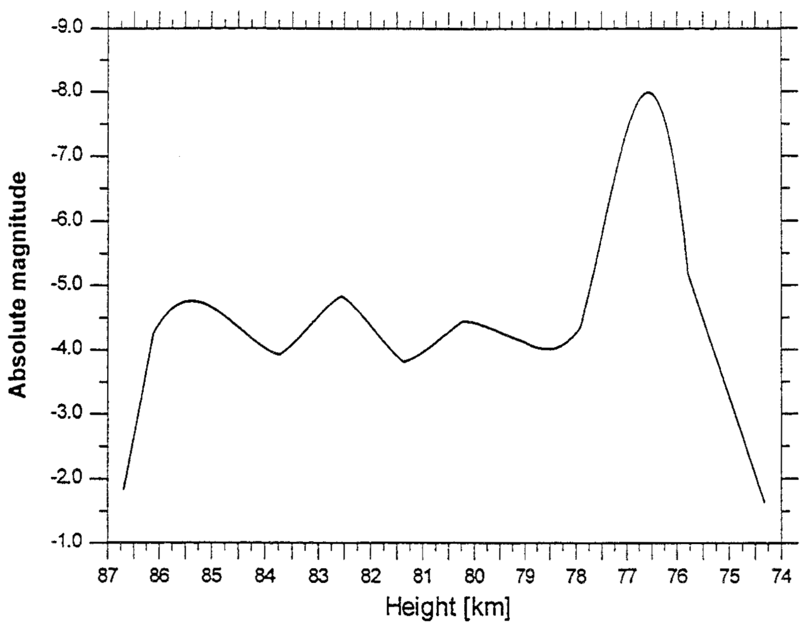

Figure 1 – The light curve of EN270698.

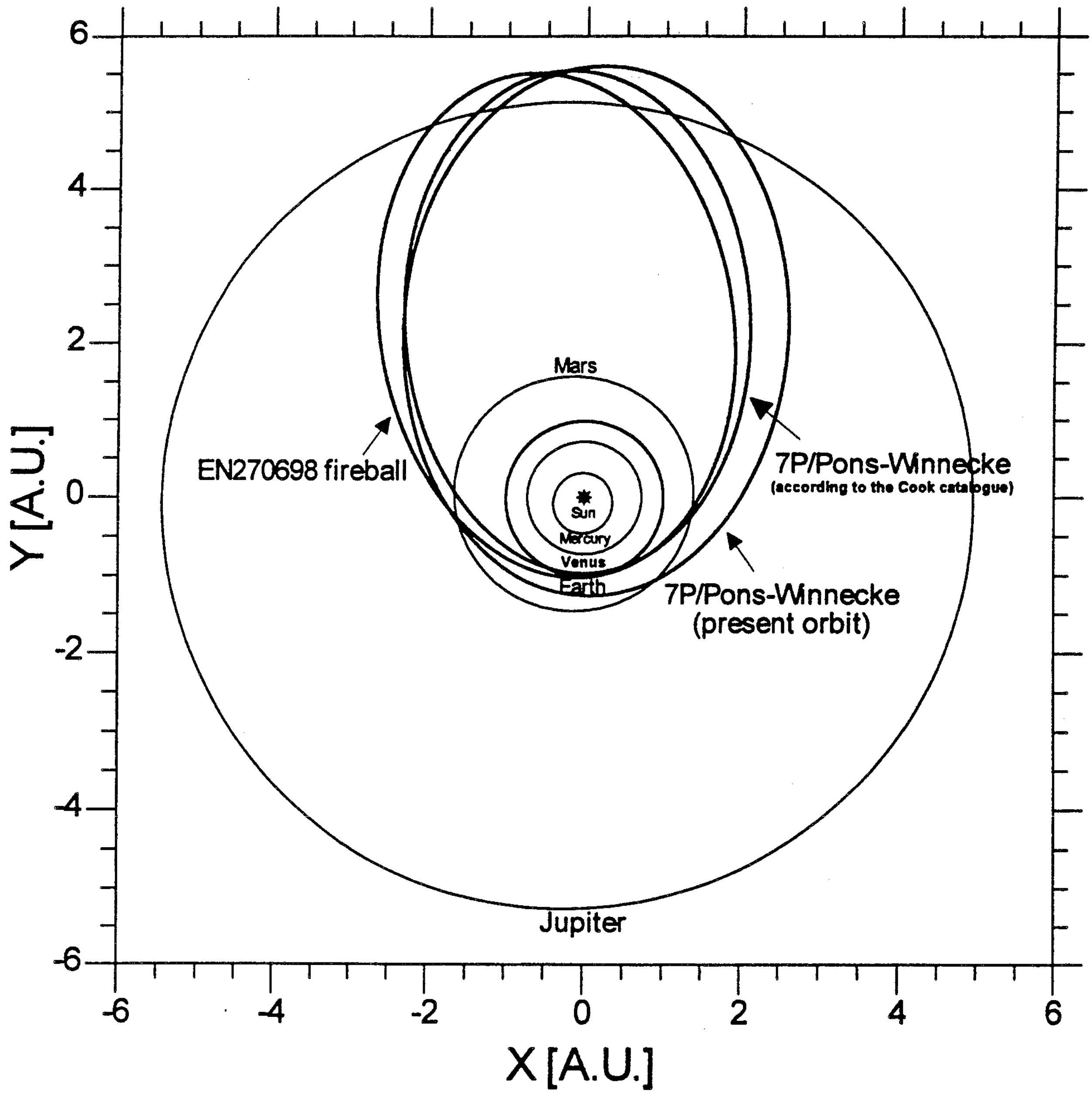

Figure 2 – Heliocentric orbits of the EN270698 June Bootid fireball and Comet 7P/Pons-Winnecke.

Very probably, the EN270698 fireball is the only June Bootid meteor photographed at all[1], and results presented above and in the table below undoubtedly confirm the connection of this meteor with Comet 7P/Pons-Winnecke.

Table 1 – Trajectory data.

	Beginning	Maximum light	Terminal
Velocity (km/s)	17.9 ± 0.3	16.5	11 ± 2
Height (km)	89.67 ± 0.02	76.9	72.22 ± 0.02
Latitude (° N)	49.7334 ± 0.0001	49.731	49.7296 ± 0.0001
Longitude (° E)	14.9763 ± 0.0002	15.026	15.0444 ± 0.0002
Abs. magnitude	− 1.9	− 7.9	− 1.6
Photomet. mass (kg)	0.15	0.9	none
Slope (°)	74.05 ± 0.03		74.02 ± 0.03

[1] *However, see also the next article about a possible June Bootid fireball photographed in Japan in 1995* (ed.)

Table 2 – Radiant data (J2000.0).

Radiant (2000.0)	Observed	Geocentric	Heliocentric
α (°)	227.16 ± 0.08	222.88 ± 0.16	
δ (°)	+ 48.46 ± 0.05	+ 47.60 ± 0.06	
λ (°)			187.62 ± 0.06
β (°)			+ 18.4 ± 0.4
Initial velocity (km/s)	17.9 ± 0.3	14.1 ± 0.4	38.4 ± 0.3

Table 3 – Orbital data (J2000.0).

Orbit	
a	3.3 ± 0.3 AU
e	0.69 ± 0.03
q	1.01577 ± 0.00005 AU
Q	5.6 ± 0.5 AU
ω	183.°65 ± 0.°07
Ω	96.°04559 ± 0.°00003
i	18.°4 ± 0.°4

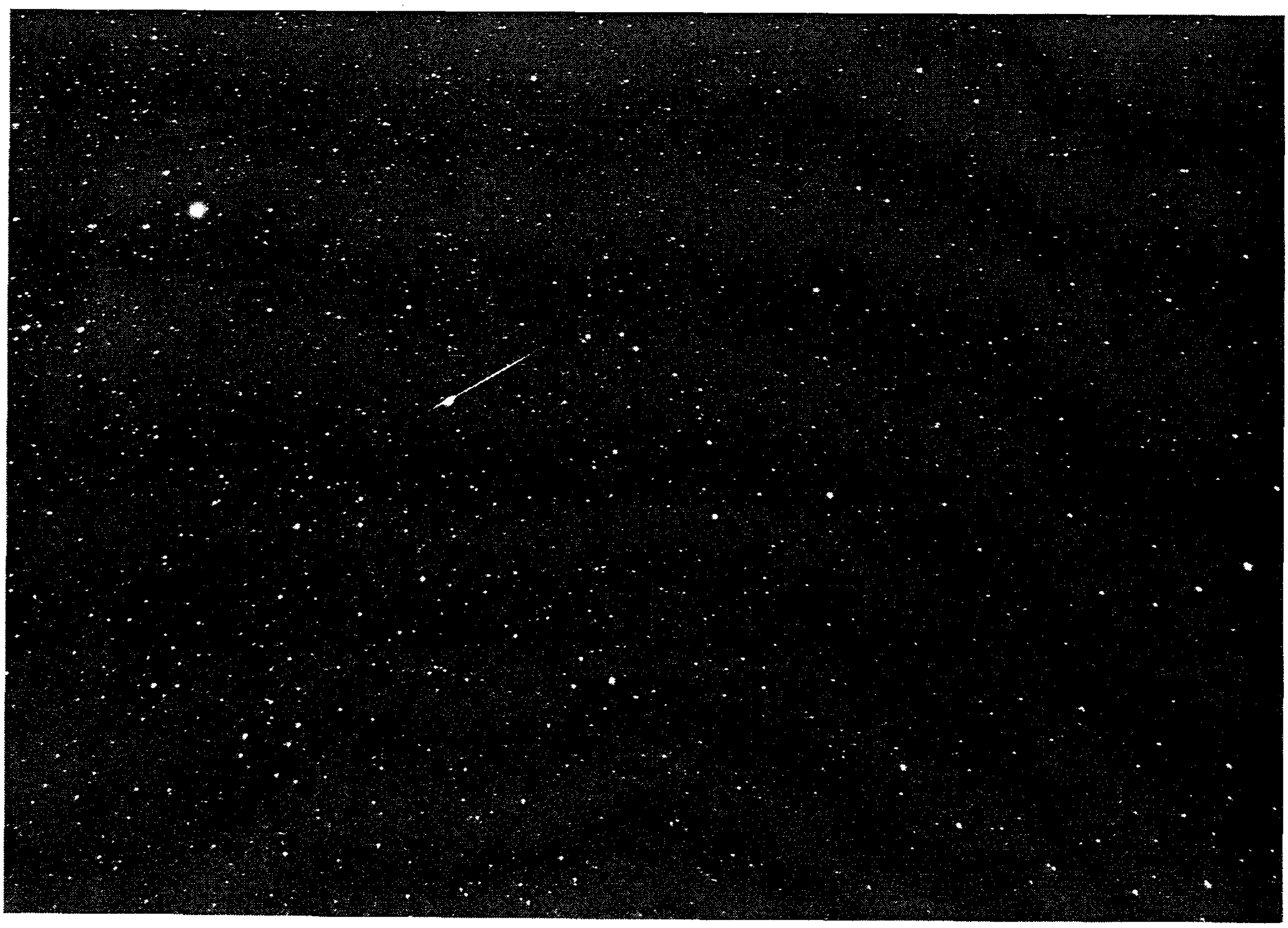

Figure 3 – The detailed view of the EN270698 June Bootid fireball photographed in the constellation of Hercules by the guided fish-eye camera ($f/3.5$, $f = 30$ mm) at the Ondřejov Observatory on June 27, 1998, at $21^{h}23^{m}04^{s}$ UT.

A Pons-Winneckid Fireball?

Japan, June 24, 1995, $13^h04^m39^s$ UT

M. Tomita, K. Ohtsuka, T. Maruyama, and Y. Shiba

The results of orbital computations of a June-Bootid fireball of magnitude −5 photographed in the *Japanese Fireball Network* on June 24, 1995 are presented. The orbital elements are very similar to those of Comet 7P/Pons-Winnecke.

The recent most impressive meteor shower event, on June 27, 1998, is a recurrence of a strong June-Bootid return on June 27, after 70 years of silence [1–3]. It has been accepted that Comet 7P/Pons-Winnecke (with a period of about 6 years) is the most likely candidate for the parent comet of this meteor shower [3]. Unfortunately, none of the *Japanese Fireball Network* (*JN*) stations was operated that night, because of cloudy weather.

However, we could retrieve a June-Bootid fireball, photographed three years ago, among past *JN* orbit records. This fireball (JN950624), whose visual magnitude reached up to −5 in the terminal flare (see Figure 1), was simultaneously photographed by three *JN* stations, including the Kiso all-sky camera [4], on June 24, 1995, at $13^h04^m39^s$ UT. The results of orbital computation are shown in Table 1, along with the orbital data of Comet 7P/Pons-Winnecke as a comparison. The position of the apparent radiant is well-determined for our optical system using fish-eye and/or wide-angle lenses. However, the observed velocity may be less precise due to the large shutter flutter.

Table 1 – Trajectory and orbital data (J2000.0).

JN950624	
Time of appearance	June 24, 1995, $13^h04^m39^s$ UT
Apparent radiant	$\alpha = 240\overset{\circ}{.}43 \pm 0\overset{\circ}{.}05$ $\delta = +57\overset{\circ}{.}88 \pm 0\overset{\circ}{.}03$
Corrected radiant	$\alpha = 237\overset{\circ}{.}6 \pm 0\overset{\circ}{.}3$ $\delta = +59\overset{\circ}{.}6 \pm 0\overset{\circ}{.}2$
Begin	$\lambda = 137\overset{\circ}{.}3539$ E $\varphi = 36\overset{\circ}{.}0863$ N $h = 93.8$ km
End	$\lambda = 137\overset{\circ}{.}3676$ E $\varphi = 36\overset{\circ}{.}0020$ N $h = 70.3$ km
Trail-length	25.36 km
Velocity	$v_\infty = (21.0 \pm 1.2)$ km/s $v_{geo} = (17.9 \pm 1.4)$ km/s $v_{hel} = (38.2 \pm 0.9)$ km/s
Angular elements	$\omega = 182\overset{\circ}{.}1 \pm 0\overset{\circ}{.}3$ $\Omega = 92\overset{\circ}{.}6334 \pm 0\overset{\circ}{.}0003$ $i = 26\overset{\circ}{.}7 \pm 1\overset{\circ}{.}5$
Other elements	$e = 0.68 \pm 0.08$ $q = (1.0162 \pm 0.0001)$ AU $a^{-1} = (0.317 \pm 0.080)$ AU^{-1}
7P/Pons-Winnecke	
(Epoch June 9, 1927) [5]	
Angular elements	$\omega = 170\overset{\circ}{.}3974$ $\Omega = 99\overset{\circ}{.}1422$ $i = 18\overset{\circ}{.}9397$
Other elements	$e = 0.685685$ $q = 1.039235$ AU $a^{-1} = 0.302448$ AU^{-1}

As seen from the results in Table 1, we can find at least two remarkable features in the fireball data.

The first is that the orbital elements are very similar to those of 7P/Pons-Winnecke [5], especially in the linear elements and the perihelion longitude π, i.e., $\pi = \omega + \Omega$ (see also Figure 2).

The other is that the fireball has a greater beginning height (93.8 km) than the average beginning height (about 80 km) of usual *JN* fireballs with almost the same velocity in the same optical system.

This means that the fireball body should be apparently of cometary origin and may be as fragile as the Draconid meteors [6,7]. This fireball should return to the perihelion about half a year before the comet, whose perihelion time was January 2.453 (TT), 1996 [5], a shorter time lag than that of the 7P/Pons-Winnecke-1998 shower, i.e., about 2.5 years. Therefore, we can conclude that this fireball is possibly associated with Comet 7P/Pons-Winnecke.

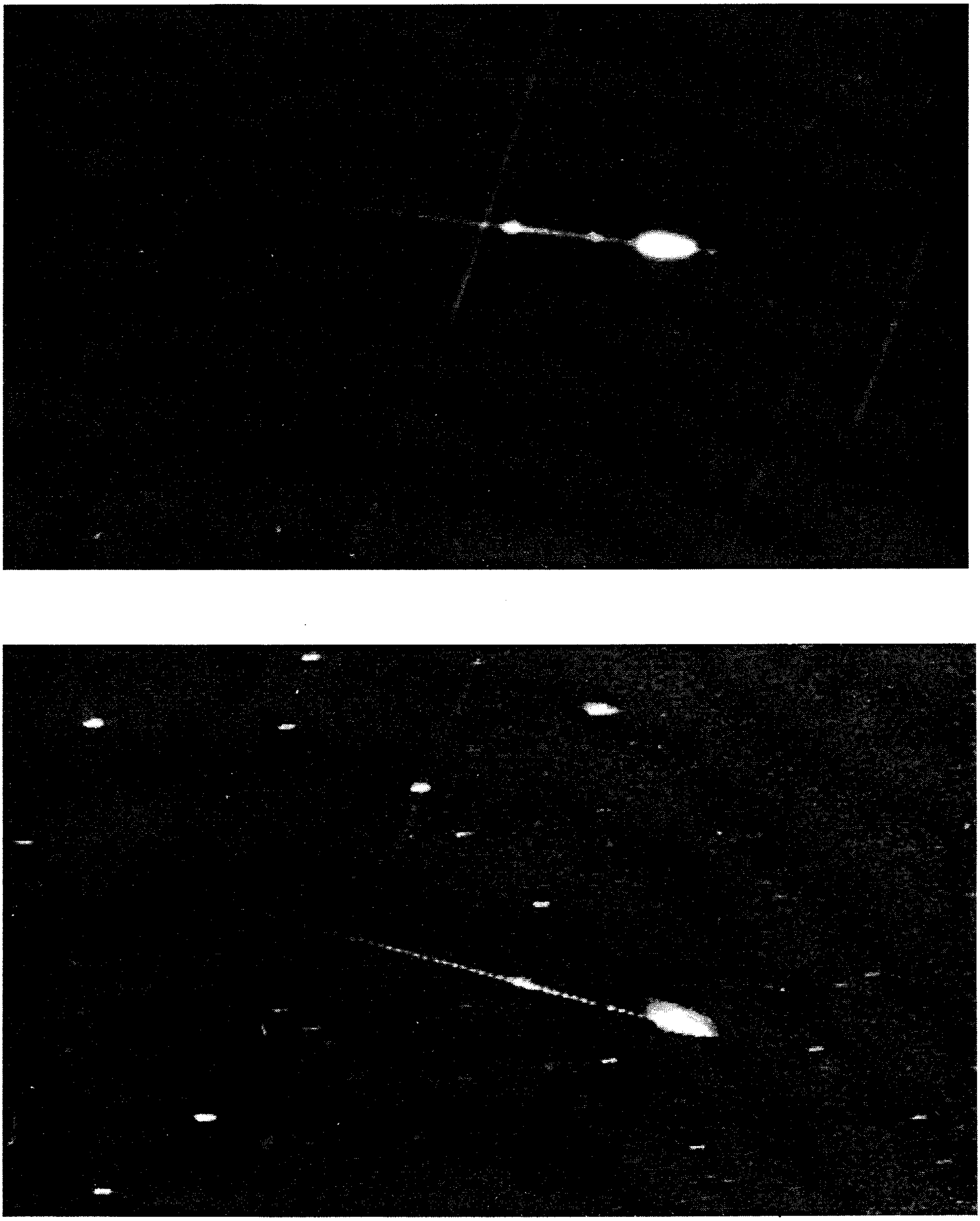

Figure 1 – Photographs of the June Bootid fireball JN950624 by T. Maruyama, JN Nakahara (*top*), and by M. Tomita, JN Chiji (*bottom*).

Acknowledgments

We wish to thank Prof. Y. Kiyama, Niigata University, for permission to use the Kiso all-sky image data. The trail images shown in Figure 1 were reduced by C. Shimoda, JN Hario.

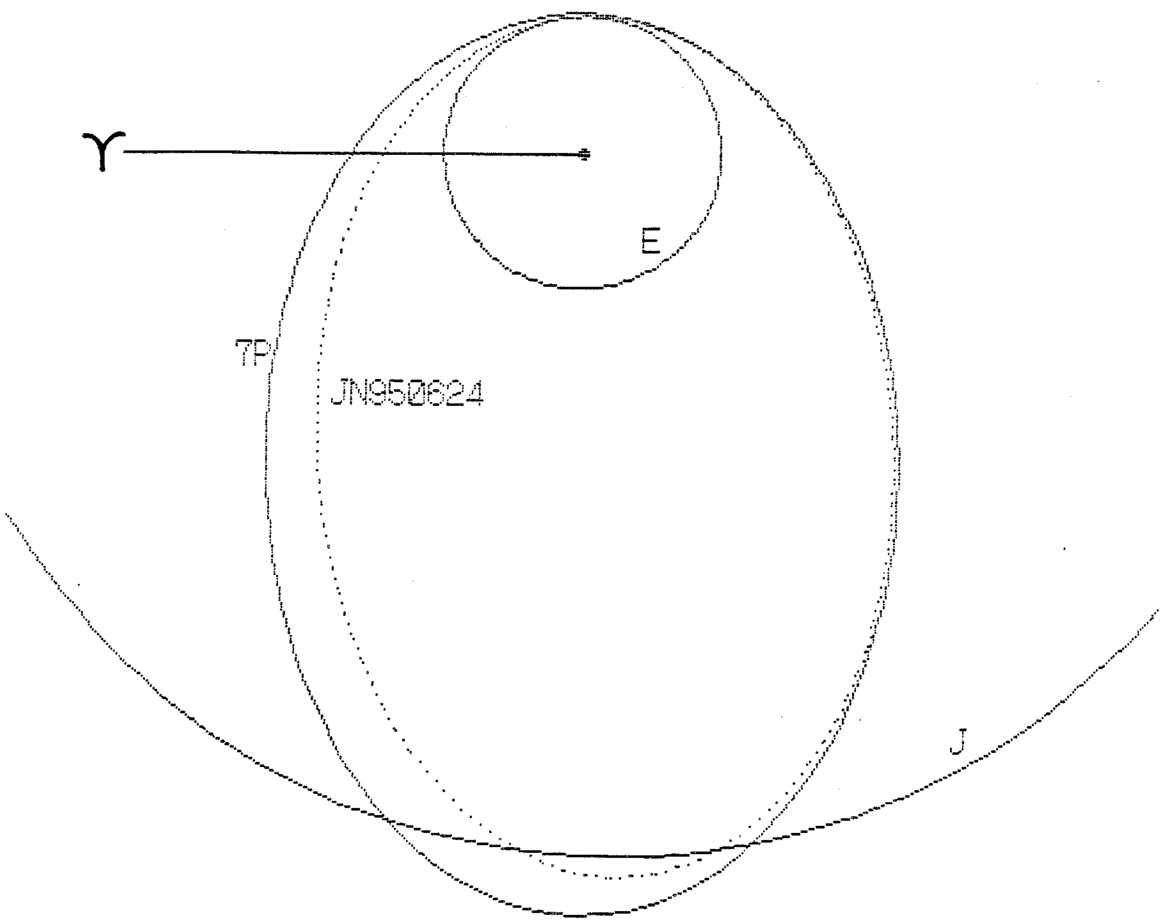

Figure 2 – Orbits of Comet 7P/Pons Winnecke and JN950624, relative to the orbits of the Earth and Jupiter, projected on the ecliptic plane.

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Call for more June Bootid observational reports

Some groups who happened to observe (part of) the June Bootids may still be in the stage of processing a report for WGN. We strongly encourage them to do so.

However, we wish to point their attention to the fact that we intend to send out the October issue exceptionally early, around mid-September, because it will contain important information not only on the Leonids but also on the October Draconids, and we wish to bring this information timely to our reader and potential observers.

So, please send us your report as soon as possible after having received this issue, if you still want to see it published in the October issue! (Ed.)

Observational Results

The 1998 Quadrantids from Romania

Valentin Grigore and Ştefan Berinde

An overview is given of *SARM* observations of the 1998 Quadrantids.

The maximum of the 1998 Quadrantids was not very favorable for Romania, because around 17^h UT the radiant was too low in the sky.

The National Meteor Network of the *Romanian Society for Meteors and Astronomy* (*SARM*) was active between January 2 and 5 at 6 sites, covering over 100 000 km^2 of the Romanian territory to watch the 1998 Quadrantid activity. Unfortunately, the sky was clear at 4 sites, with good all-night covering of the maximum at only 1 site.

On a hill near Târgovişte ($\lambda = 25°29'00''$ E, $\varphi = 44°57'18''$ N), a team was active composed of Valentin Grigore, Adrian Negoescu, Zoltan Deak, and Adrian Sima, who made visual and photographic observations. At this site, the sky was clear all the time. This team was very lucky, because a dense fog covered the region, including the town of Târgovişte, but left an area of about 200 to 300 m around the observing site clear. Although it is known that the Quadrantid peak is very sharp, activity was good the entire night of January 3-4. The majority of Quadrantids were very long: 20°–30°, or sometimes over 50° long.

Some fireballs were seen (see Table 1). The most impressive one was an over 55° long magnitude −7 light-purple Quadrantid (see the cover of *WGN* 26:2, April 1998). It appeared at $23^h14^m50^s$ UT in Cepheus, crossed Cassiopeia and Andromeda, and ended in Aries. It showed a lot of small flashes and a persistent train visible for 15 seconds with the naked eye. The persistent train of 4 Quadrantids lasted over 10 seconds, and a magnitude −2 Quadrantid had a 20-second persistent train.

Coma Berenicids were active, too, with 3–5 meteors per hour.

At 80 km south-east of Târgovişte, near Bucharest, Gabriel Ivănescu and Silviu Matei endured a very dense fog throughout the night of the maximum, and saw no meteors or a clear patch of sky. Also, at Roman, 250 km north-east of Târgovişte, the observers had overcast skies all the time.

At 200 km north-east of Târgovişte, at Palanca, Dan Mitruţ had clear skies during all the nights, except the maximum night! Gelu Radu, Şerban Săvulescu, and Loredana Făt were active visually and photographically 300 km north-west of Târgovişte, near Cluj Napoca, with clear skies on January 2-3 and 3-4. In Bunila, 200 km north-west of Târgovişte, Vasile Micu, Ştefan Berinde, and Iuliana Moldovan had variable skies, also on January 3-4. They made visual and photographic observations.

The observations were analyzed in the standard way, with a zenith exponent of 1. In view of the small radiant height, only observations with a radiant height of at least 15°, a cloud correction factor of at most 1.02, and a total correction factor of at most 5 were selected. The results are shown in Figure 1. Apparently, we observed the descending branch of the activity profile.

Table 1 – Magnitude distributions of Valentin Grigore's observations between January 2 and 5, 1998.

Shower	−7	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot
Quadrantids	1	1	0.5	2.5	2.5	7	16	24	31.5	19.5	6.5	4.5	1.5	118
Sporadics					0.5	1	6	18	22.5	11.5	12.5	10	2	84

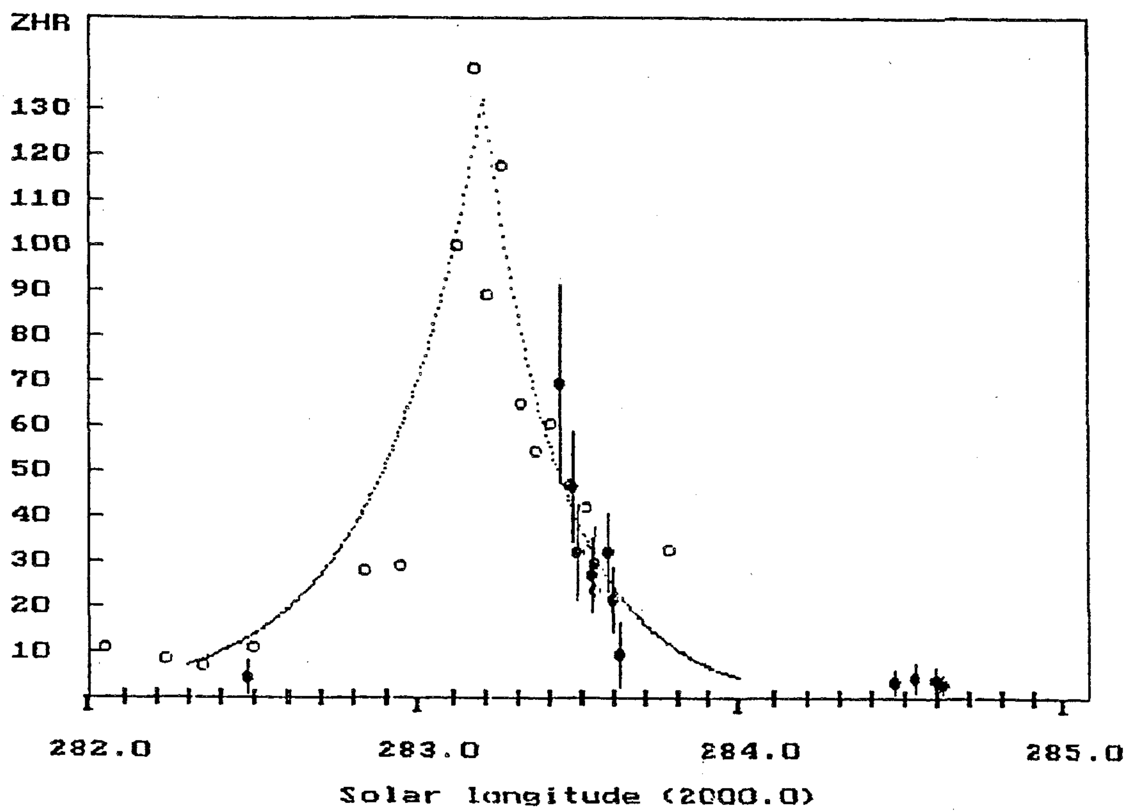

Figure 1 – The filled disks represent our selected observations. The empty disks represent the ZHRs from the *IMO* Circular published by Rainer Arlt after the Quadrantids campaign (`http://www.imo.net/news/news.html`). The curve represents the theoretical profile of the Quadrantid meteor shower according to [1]

Reference

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SPA Meteor Section Results: January–February 1998

Alastair McBeath

A compilation of results and news collected by the *SPA Meteor Section* from January and February, 1998, is presented. Good, if patchy, early January weather resulted in some useful visual Quadrantid data, although the maximum (around $\lambda_\odot = 283.^\circ17$ (eq. 2000.0), January 3, 17^h30^m UT [1]) was missed by our observers. Radio data did not show a particularly clear Quadrantid maximum. An unusual number of moderate (magnitudes −3 to −8) fireballs was recorded on January 24-25, a timing that coincided with a minor peak in radio rates not previously found around $\lambda_\odot = 304°–305°$. One possible meteoritic fireball was photographed from Germany on January 25. February produced no particular meteoric surprises, but some further photographic zodiacal light observations were received from both months.

1. Introduction

Weather conditions for the almost-moonless Quadrantid epoch were not outstanding, with parts of Europe and North America registering only unbroken clouds for them; skies were certainly unhelpful across much of the UK, for instance. Conditions were again patchy in February, but although the month is usually a poor one visually, several observers made more effort than normal, as the details in Table 1 demonstrate.

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

Month	Visual	QUA	COM	VIR	Meteors	Photo	Trails	Radio
January	$162^{h}.63$	1124	179	14	2712	$166^{h}.51$	3	2382^{h}
February	$54^{h}.73$			20	340	$131^{h}.28$	1	2578^{h}

Photographic observations came from the *Arbeitskreis Meteore* (*AKM*) all-sky fireball patrollers in Germany (all *AKM* details extracted from their journal *Meteoros* 1:2 and 1:3 (1998), kindly provided by Ina Rendtel): André Knöfel, Jürgen Rendtel, H. Ringk, and Roland Winkler; and Ştefan Berinde, Valentin Grigore, and Vasile Micu in Romania. Two of the January trails were Quadrantids on January 3-4 over Romania, while the third belonged to the fireball on January 25 over Germany. The February trail was secured by Vasile Micu during his photographic observations of the zodiacal light on February 26-27.

The majority of the radio results were taken from *Radio Meteor Observation Bulletins* (*RMOB*) 54 and 55 (1998 February and March respectively) thoughtfully submitted by Christian Steyaert, who also sent in graphs covering the Quadrantid epoch produced by Kimio Maegawa and Yoshifumi Minagawa in Japan. The radio observers were as follows:

Enric Fraile Algeciras (Spain, *RMOB*), Eisse Peter Bus (the Netherlands, *RMOB*), Maurice de Meyere (Belgium, *RMOB*), Ghent University (Belgium, *RMOB*), Ou Yang Tian Jing (China, *RMOB*), Will Kelsey (California, USA, *RMOB*), Sadao Okamoto (Japan, *RMOB*), Chikara Shimoda (Japan, *RMOB*), Robert S. White (England), Ilkka Yrjölä (Finland, *RMOB*), and Wim T. Zanstra (the Netherlands, *RMOB*).

Analysis of the radio data was carried out using what have become standard procedures for handling unprocessed radio results by the Section since 1996 [2]. The radio graphs which accompany this article are chosen as representative of the overall radio results from January and February.

Our visual observers were as follows:

AKM members Rainer Arlt, Frank Enzlein, Matthias Growe, André Knöfel, Sylvio Lachmann, Hartwig Lüthen, Sirko Molau, Sven Näther, Jürgen Rendtel, Petra Rendtel, Janko Richter, Thomas Schreyer, Harald Seifert, Ulrich Sperberg, Manuela Trenn, Björn Voß, Roland Winkler, Nikolai Wünsche, Oliver Wusk (all in Germany); *Astroclub Canopus* members Eva Bojurova, Elena Sarbinska, Lyna Rashkova, Valentin Velkov (all in Bulgaria); Shelagh Godwin (England), Bob Lunsford (California, USA), Alastair McBeath (England), *SARM* members Valentin Grigore, Florin Leu, Vasile Micu, Dan Mitruţ, Adrian Negoescu, Gelu-Caludiu Radu (all in Romania).

2. January

Opening the year was a reasonably well-seen Quadrantid return, with even a few lucky UK observers spotting some Quadrantids. Reports from other correspondents indicated January 3-4 was often a night of frustration, however, with clouds refusing to move, or only a brief clearance appearing. From European data, ZHRs were around 50–60 towards midnight UT on January 4, dropping only marginally towards dawn. Around twelve hours earlier, rates had been similar, around 40–50, over the western USA. All of this suggested a possibly slightly more prolonged maximum than we often see from this shower, which to some extent was borne out in the radio data, where observers across Europe and in Japan both registered good echo count numbers on January 3. Figures 1 and 2 illustrate this point.

The majority of European raw radio counts were highest from about 12^{h} and 14^{h} UT on January 3, while in Japan, a less well-defined peak at some stage between 18^{h} and 23^{h} UT was registered. Since the maximum was expected around 17^{h} UT [3], it is strange that the Japanese observers at least did not detect a clearer maximum, since the radiant would be high in the sky then. Preliminary visual data [1] showed a fairly flat maximum, with ZHRs of 110–130 in the period $\lambda_{\odot} = 283.^{\circ}1$–$283.^{\circ}2$, which is perhaps a further suggestion of a broader maximum than normal. The European radio data would then have shown part of the rising branch, and caught the declining post-maximum phase too, as Figure 1 implies.

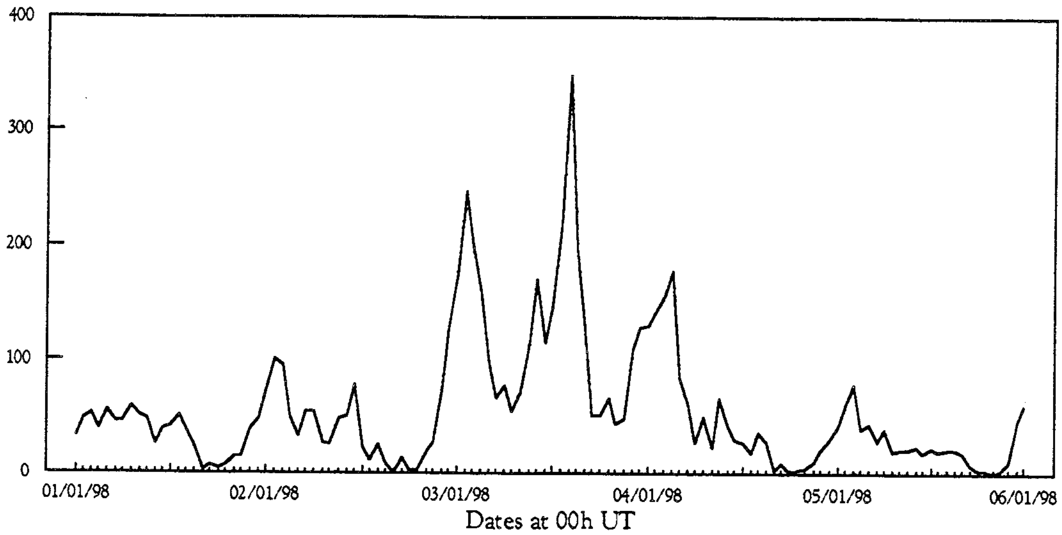

Figure 1 – Raw hourly radio meteor echo counts between January 1 and 6, 1998, from data collected by Robert S. White. Robert's radio set-up was operated continuously throughout this period. The Quadrantids are very obvious especially on January 3 and 4, but the peak soon after 0^h UT on January 3 was not confirmed as clearly in other European data. Note that the x- and y-axis scales vary from graph to graph in the radio results here.

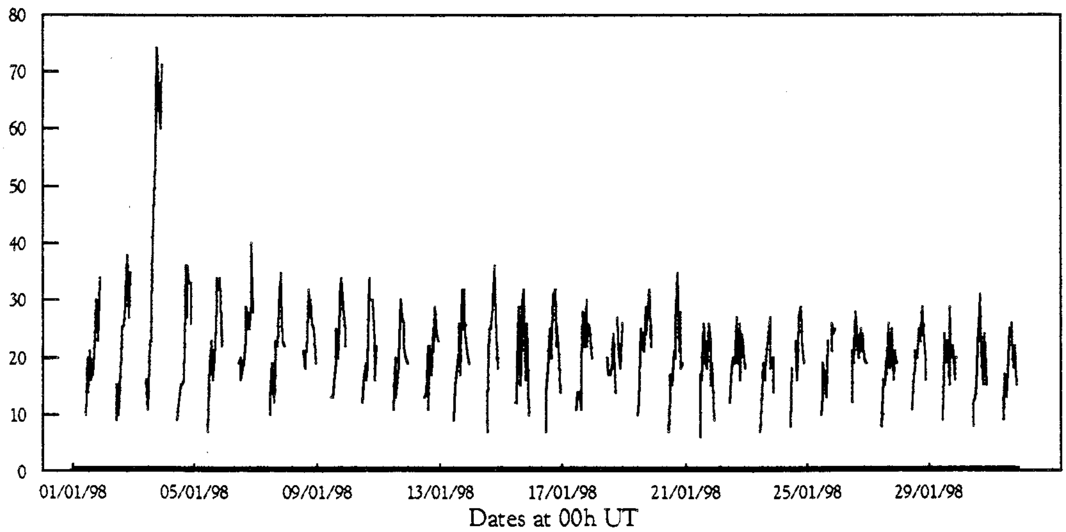

Figure 2 – Raw hourly radio meteor echo counts during January, 1998, from data produced by Chikara Shimoda. With a small number of minor gaps, Chikara operated his set up for usually 12 hours daily, between 11^h and 22^h UT. The Quadrantids produced a clear maximum on January 3.

The amount of visual data enabled a magnitude and train analysis to be carried out for the Quadrantids, and also for the Coma Berenicids, although the relatively small number of meteors from this latter shower is likely to have unbalanced the train details particularly. Tables 2 and 3 give details.

Much of January's visual data collection was unsurprisingly concentrated in the first week. Without the distraction of the Quadrantids, Ştefan Berinde in Romania was able to secure some photographs of the morning zodiacal light on January 5, a reflection of the excellent sky quality enjoyed over parts of south-east Europe in January—notably in Bulgaria and Romania. This was not the case everywhere, though. Having planned a special observing camp by the sea in Yugoslavia, January 3-4 proved very disappointing for the Serbian watchers, when only one short cloud-break manifested all night, barely allowing time to get to their observing site before the clouds returned. Similar problems were found in Britain, Croatia and parts of the USA, but in Germany, most watchers enjoyed several hours of cloud-free skies to see some Quadrantids.

Table 2 – Global magnitude distributions, including mean limiting magnitudes and corrected mean magnitudes for the Orionids and October sporadics seen in good sky conditions (limiting magnitude of +5.5 or better; cloud cover less then 20%).

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
QUA	21	12.5	29	75	115.5	136	121.5	63	36.5	610	6.12	2.13
COM		0.5	3.5	7.5	13.5	25	31.5	28	8.5	118	6.39	2.73
SPO		4.5	8	28.5	58.5	91	130.5	147	182	650	6.10	4.09

Table 3 – Global train percentages per magnitude class for the Quadrantids, Coma Berenicids, and January sporadics. Train details were only available for 310 Quadrantids, 46 Coma Berenicids, and 210 sporadics of the reported totals.

Magnitude	-3^-	-2	-1	0	+1	+2	+3	$+4^+$	%
Quadrantids	100	75	41	47	28	11	3	1	17
Coma Berenicids			100	86	38	21	4		15
Sporadics			20	47	27	11	4		7

A few observers were able to continue their efforts into late January. By then, only low sporadic rates and occasional Virginids were apparent. However, January 24-25 provided more interest. Between 19^h45^m UT on January 24 and 2^h35^m UT on January 25, at least five minor fireballs (magnitudes -3 to -8) were reported to the Section, most of those from the UK, and all by only single observers. This is an unusual cluster of fireballs away from a major meteor shower maximum, on what appears to have been an otherwise unremarkable night; there were no meteor watches recorded by any of our contributors then (though there are on the following nights), for example, suggesting skies were probably quite poor. The fireball details received were too scanty to determine if they might all have had the same source. Examining the radio data showed a minor peak around this time, $\lambda_\odot = 304°–305°$, which had not been found previously [4]. It is most obvious in the European data, but can be weakly seen in Figure 2 from Japan as well. The raw counts suggest a somewhat unusual number of echoes were detected around 4^h–6^h local time on January 24 and 25. If this was the source of perhaps an unexpected shower outburst, a radiant in the Dra-Her-Oph to UMa-Leo-Hya region of sky might be indicated, possibly the α-Hydrids [5, pp. 12–14], or the α-Leonids [5, p. 21], of the previously detected showers. There are too many unknowns to be sure, and naturally if anyone has any other data which might help resolve this matter, please contact the author with all speed!

On January 25, another fireball occurred at $19^h13^m50^s$ UT over Germany, but with a radiant in Camelopardalis. This was thought to have been a potential meteorite-dropping event, but no meteorites were recovered, regrettably, despite its having been captured on film by several European Network all-sky cameras. See [6] and [7] for preliminary analyses.

Concerning the lesser radio meteor peaks as compared to [4], all those seen earlier were detected again, at least within their spread parameters if not at the exact same solar longitudes. The $\lambda_\odot \approx 295°$ peak was again extremely weak, and not confirmed in all datasets, although the $\lambda_\odot \approx 298$ maximum seemed better than in 1997, but occurred closer to $\lambda_\odot = 297°$.

3. February

Most of February's visual results were collected during the second half, especially in the final week. Rates were low, with sporadics, Virginids and other minor sources only apparent. Several fireballs were reported at different times, however, confirming that sporadic fireballs are indeed more prevalent during this month, as previously found (e.g., [8,9]).

Vasile Micu made a series of photographic observations of the evening and morning zodiacal light on February 26-27 from Bunila, Romania, and was extremely fortunate in photographing a meteor accidentally during the evening observation as well. He also managed another photographic observation of the evening light earlier in the month, on February 22-23.

Radio rates were relatively flat all month (see Figure 3), and all the previously noted minor echo count enhancements from [4] were again detected. The $\lambda_\odot = 320°–322°$ interval was slightly stronger than usual around $\lambda_\odot = 321°–322°$, while another possible minor increase was found around $\lambda_\odot = 325°$ not seen before. Solar longitude $\lambda_\odot \approx 331°$ also showed up as a small spike in several data sets, although again, this was not found earlier. Of the February section of the $\lambda_\odot = 333°–342°$ enhancement, the main part at $\lambda_\odot = 336°–337°$ was definitely confirmed by most observations.

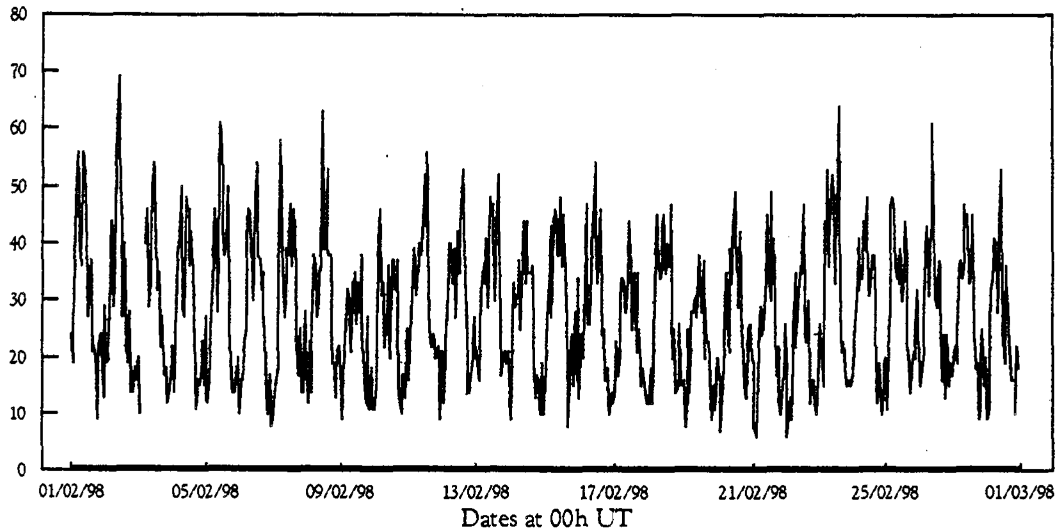

Figure 3 – Raw hourly TV meteor echo counts during February, 1998, in results from Enric Fraile Algeciras. With one minor gap from 1^h to 4^h UT on February 3 due to system problems, Enric operated his receiver throughout the whole month. Although February is generally meteorically quiet some minor peaks—most previously detected—can be seen.

Acknowledgments

I am delighted to gratefully thank all our contributors for their observations and correspondence.

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