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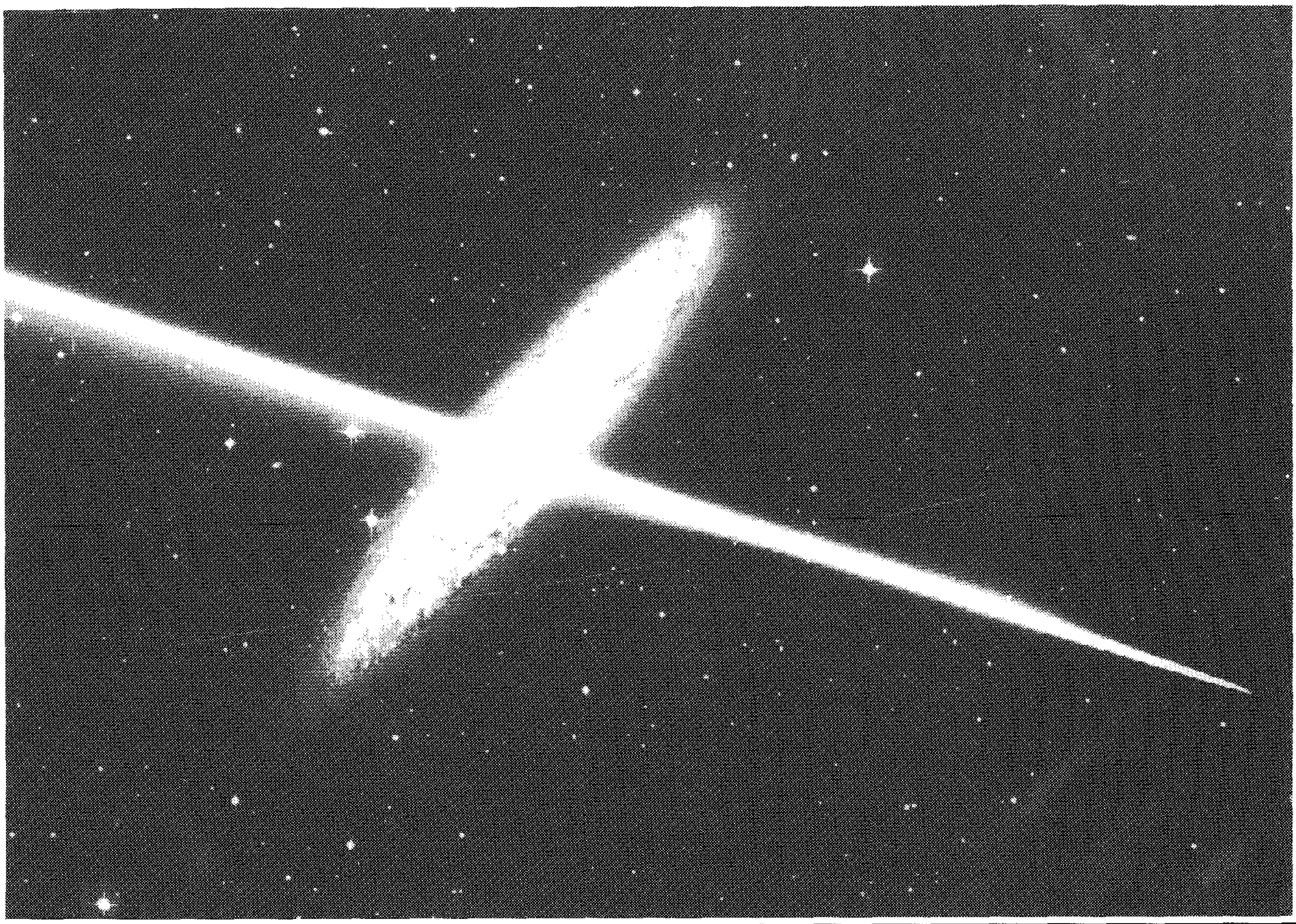

This photograph taken with the U.K. Schmidt Telescope in Australia shows an apparent collision between a fireball and the galaxy NGC 253. Only about one-ninth part of the fireball path, observed September 8, 1991, is shown in this view. This photograph is courtesy Dr. David Malin, and © the Anglo-Australian Telescope Board (1991).

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Useful Information

The June Issue *(WGN 20:3)*

The *June issue* is expected to be mailed during the first week of June 1992. Therefore, contributions are due *May 8*. They should be sent to *Marc Gyssens* or to any member of the editorial board (addresses: inside of back cover).

WGN Subscription/IMO Membership 1992

The subscription rate for volume 20 (1992) is 25 DEM for six issues. Additional gifts are of course welcome. It is anticipated that volume 20 will contain over 240 pages.

Administrative Correspondence

Ordering *IMO* publications is done in the same way as paying subscription/membership fees. Complaints about not receiving *WGN* or changes of address should be sent to Paul Roggemans. All addresses can be found on the inside of the back cover.

From the Editor-in-Chief

Marc Gyssens

Once more, your are reading a thick issue of your magazine. This is of course a good sign, because it means that many contributions are coming in and, hence, that IMO *is living! As the Letter Section proves, we got several reactions on items published in the February issue, or earlier. In particular, we received a reaction from Paul Roggemans on last year's November 5 meteor display seen in Hawaii in which he gives good arguments for a possible association with the Bielid Complex.*

In the spirit of my call in the last issue, I nevertheless still find that the Letter Section is under-used. Since opportunities to meet each other in person within IMO *remain limited, opinions—more in particular, scientific opinions—simply need to be exchanged in writing.*

This issue also contains an article about the program Radiant *designed within* IMO *by Rainer Arlt to determine radiants from collections of meteor trails, especially trails obtained from visual observations. While these words are being written, the program is applied to the data of the* Aquarid Project, *on which we will report in full most probably in the next issue. The efforts that have been spent in developing this software show again that* IMO*'s interests are not limited to the major showers as is often suggested. Regarding this matter, I cannot but repeat what many* IMO *officers including myself have said already so often: if you want your Organization to analyze these minor showers, then provide us with us with lots of observations of the highest possible quality!*

Finally, I wish to thank Dr. Duncan Steel and his colleagues at the Anglo-Australian Observatory for providing us with the spectacular photograph on the front cover on which you can read more in this issue's Fireballs-and-Meteorites Section.

Happy reading and happy observing!

Letters for WGN

compiled by Marc Gyssens

The strong meteor display of November 5, 1991

In WGN *20:1, February 1992, pp. 28–31, a strong meteor display over Hawaii on November 5, 1991, was reported. Gotfred Møbjerg Kristensen says he also recorded higher activity on that date by radio.*

If you take a look at my graph in *WGN* 20:1, p. 52, showing the Leonid activity of 1991, you will find a significant increase in bright radio meteor signals on November 5. I have checked hour-per-hour distributions of all signals and of the brightest signals around this date. This work pointed out that a meteor radiant may have passed the southern meridian between 0^h30^m and 1^h30^m UT. I think the Taurids are very probably responsible for the observed activity. An investigation of the bright reflections suggests, however, that another meteor radiant may have passed the southern meridian between 21^h30^m and 22^h30^m UT (or between 9^h30^m and 10^h30^m UT). A radiant somewhere in the vicinity of the Pegasus Square would pass the southern meridian around 21^h40^m UT.

Gotfred Møbjerg Kristensen, February 28, 1992

Comment by the editor: I do not want to elaborate on whether or not the increased radio activity reported by Gotfred Kristensen is related to the November 5 outburst. I just want to point out that both the Hawaiian data and the absence of visual activity over Europe indicate that the maximum of the outburst must have occurred during European daytime-hours.

Several ideas were proposed regarding the origin of this sudden outburst. Paul Roggemans thinks a fragment of the disintegrated comet P/Biela is the most likely explanation.

Reading the article on the 1991 November 5 meteor activity in the last issue of *WGN*, I was a little bit surprised to read that the authors considered a possible identification of the radiant with the Taurid Complex or P/Hartley 2, as this seems impossible to me. Personally, I would allow for the possibility that we are just dealing with a new, thus far unknown meteor stream. Unfortunately, no experienced visual observer was lucky enough to witness part of the display; for instance in Australia, Jeff Wood did not notice anything of the Hawaiian activity [1].

I can, however, go along with Dr. Watanabe's suggestion that the old and forgotten Bielid stream might be the source of last November's display, despite the discordances in radiant position and date of maximum.

Before I give my arguments, let me first recall the history of the Bielids.

When the comet returned in 1845, Herrick and Bradley (Yale) saw a small companion beside the main comet. A few months later, several cometary fragments were seen around the nucleus. At the next return in 1852, only two components were still noticed. The others either fell to pieces or were even more separated from the main comet and continued to exist unnoticed as asteroid-like objects. Nothing was seen any more with certainty after 1852, although there were unconfirmed "rediscoveries" of a few fragments of Biela at later returns. One thing however is sure beyond any doubt: P/Biela was destroyed by dramatic, violent, non-gravitational forces, leaving behind an enormous mass of dust and fragments.

After 1852, all the fragments were lost out of sight but some may have survived as "orphans" on an orbit of their own, undergoing slightly different perturbations than the main dust cloud. These fragments may have disintegrated further in the course of time and developed meteor streams off-set from the known stream. The catastrophic break-up of P/Biela and the subsequent unknown distribution of its mass is likely to have formed a scattered complex meteor stream, of which sooner or later members may start to encounter the Earth's orbit.

The 1991 November 5 display, radiating from $\alpha = 6°$, $\delta = +17°$, at first sight looks quite different from the lost stream of Biela that gave its best display in 1872 on November 27.8, from a radiant at $\alpha = 27°$, $\delta = +44°$. However, the Bielid meteor stream shows a very important nodal regression and also its inclination decreases. The following table is extracted from [2,3,4].

Table 1 – Historical data on the Bielids or Andromedids.

Year	Date	Ω	α	δ	i	Comments
1772		261°	19°	+58°	17.°1	No shower observed
1798	Dec 6.7–9		23°	+48°		Confused dating: various nights with high activity
1838	Dec 7		31°	+43°		42 meteors in 30 minutes
1867	Nov 30		17°	+48°		Only a few meteors
1872	Nov 27.8		27°	+44°		Strong meteor storm seen in Europe
1885	Nov 27.8	247°	21°	+44°	13°	Strong meteor storm in Europe and USA
1892	Nov 24.2		25°	+40°		80–100 meteors per hour in the USA
1899	Nov 24					90 meteors per hour
1904	Nov 21.8		26°	+44°		24 meteors per hour in strong moonlight
1940	Nov 16.1					30 meteors per hour in the USA; outburst of faint meteors
1953	Nov 14	228.°1	26°	+25°	7.°5	photographic data
1991	Nov 6		24°	+21°	6.°3	*Extrapolated data*

When no orbit is known, a stream must be identified with the data on its activity, radiant position and velocity. The Bielids or Andromedids are known to have appeared as real storms in 1872 and 1885, in both cases on November 27-28, about 22 days later as the 1991 stream. (In 1798, the Andromedid maximum was expected on December 7.)

The Bielid orbit suffers from severe planetary perturbations resulting in a strong nodal regression. The perturbations do not cause gradual changes but rather a sequence of quite abrupt changes. A rough estimate of $\Delta\Omega$ is $-0.°18 \pm 0.°02$ for the period 1772–1953. This agrees well with the shift in the date of maximum; taking 1872 as a reference, the assumed nodal regression would place the maximum in 1892 on November 24.2, in 1904 on November 22.0, in 1940 on November 15.6, in 1953 on November 13.2, and in 1991 on November 6.4, which is very close to the observed date of maximum in 1991. If $\Delta\Omega$ is assumed to be $-0.°19$ degrees, we would find November 5.4, or exactly the observed date! Small differences are normal since linear extrapolation is definitely not precise, but within a period of 100 years it may still be appropriate.

The radiant position may seem problematic, but also here we see that δ decreases over the years, mainly due to the decreasing inclination. Extrapolating this trend to 1991 a declination of $+21°$ would be possible. No systematic changes in α are noticeable in the course of the last two centuries.

The difference of 17° between the extrapolated radiant position and the position mentioned for the November 5 display is not a real problem, as P/Biela probably formed a complex of filaments that all follow a same general trend in orbital evolution, but with orbits that need not be completely the same. As a matter in fact, the spread on the orbits was already large from the very first appearance, and in 1872, the radiant area was remarkably wide with a diameter of over 20°! It should also be remembered that in the past, the Bielid structure already led people to suppose that the Bielids were composed out of two [5] or more streams [6]. Such streamlets may start to encounter the Earth orbit at some point in time giving rise to a "new' stream, that will not necessarily be recognized immediately as belonging to the Bielid family. In view of all this, the radiant positions match very well, and certainly better than with any other stream radiant active around the same time.

Finally, we have to consider the velocity, which unfortunately has not been measured. The telescope operator compares it with 1.25 to 1.5 times the angular velocity of a fast satellite. Fast satellites are still as slow as the slowest meteors visible (14 km/s); 1.25 or 1.5 times this amount yields 18 to 22 km/s, also very well in agreement with the 20 km/s of the Bielid meteor stream.

Given the nature of the Bielid meteor stream, the agreement in date, radiant position and velocity, it thus looks quite reasonable to associate the unexpected appearance of November 5, 1991, with the Bielid family.

Anyway, the November 5 display must definitely have been extremely faint since Japanese [7] and Australian [1] observers did not notice it. The extremely thin, transparent sky of the Hawaiian observatory must have favored the visibility a lot. This illustrates once more how easily a spectacular meteor display can be missed!

[1] Wood J., *personal communications*, 1992.

[2] Roggemans P. (ed.), "Handbook for Visual Meteor Observations", Sky Publishing Corporation, 1989.

[3] Kronk G., "Meteor Showers: A Descriptive Catalogue", Enslow Publishers, Hillside, N.J., 1988.

[4] Hawkins G.S., Southworth R.B., Stienon F., "Recovery of the Andromedids", *Astron. J.* 64, 1959, pp. 183–186.

[5] Prentice J.P.M., "Note on the return of a meteor stream connected with Biela's comet", *Journal of the BAA* 51, 1941, pp. 92–95.

[6] Cook A.F., Lindblad B.A., Marsden B.G., McCrosky R.E., Posen A., *Smithson. Contrib. Astrophys.* 15, 1973, pp. 1–5.

[7] Tomioka H., *personal communications*, 1991 reports from the Nippon Meteor Society.

Paul Roggemans, March 17, 1992

Daylight Fireball over Czechoslovakia

In WGN *20:1, February 1992, p. 27, a daylight fireball over Czechoslovakia on September 22, 1991,* 16^h48^m *UT, was reported. Gotfred Møbjerg Kristensen writes us that he actually registered this fireball with his radio equipment.*

When I checked my pen recorder paper for meteor signals, I sometimes think: "One day you will catch a big fireball or meteorite on its way through the atmosphere over Denmark, which will also have been observed by many people."

I have not experienced this yet, but for the second time, I have registered a radio signal from a bright fireball over Central Europe, described in *WGN* (the first one was the Earth-grazing fireball of October 1990 in Czechoslovakia-Poland). The second one is the fireball mentioned in the article referred to here. I have noted the following data in my radio meteor diary:

Signal: $16^h48^m51^s \pm 10^s$ UT
Duration: 22 s
Power: 2.0.

Verification of the pen-recorder paper yielded:

Signal: $16^h48^m44^s \pm 10^s$ UT
Duration: 25 s
Power: 2.2.

Interesting to note is the stronger oscillation in the background signal which began at $16^h47^m49^s \pm 10^s$ UT and lasted for 80 seconds. It had a power of 0.3. I am quite sure that this signal was caused by the daylight fireball.

Gotfred Møbjerg Kristensen, February 28, 1992

The reappearance of P/Swift-Tuttle

In last year's October issue (WGN 19:5, pp. 181–184) we mentioned Dr. Marsden's hypothesis that the Perseids' parent comet P/Swift-Tuttle might be identical to comet Kegler, yielding a return in 1992. Recently, we received a letter of our Crimean observer Andrey Grishchenyuk expressing scepticism towards Marsden's ideas.

In 1991, Perseid activity was grandiose! We know that observers in Japan and Siberia (Krasnoyarsk) registered peaks with ZHRs exceeding 300. A similar phenomenon was observed in 1980 by European observers. This leads us to the problem of the parent comet of the Perseid Meteor Stream. The comet was found neither in 1980 nor in 1981 and it is therefore often assumed that the comet will pass later, the more so since B. Marsden identified Comets 1862 III and 1737 III. He needed to assume though that the period of the comet increases with time. Regarding this idea, I want to make the following observations:

1. Comet 1862 III was very bright, and intense activity was observed: qualitative changes in the nucleus, rejected parts and strong magnitude variations [1]. Therefore, perhaps, the comet then rejected so much material that it passed barely active and therefore unnoticed several years ago.
2. By studying Chinese and Japanese chronicles, Denning discovered a possible period of 11.72 years in the Perseid shower. He showed that the maxima of the periodic activity had to occur in 1932.88, 1944.60, 1956.32, 1968.04 [2], and later in 1980.82 and 1992.52. We do not know about high activity in 1932, but Olivier [2,3] reports about high Perseid activity in 1931. Moreover, we do know about high activity in 1945 and 1968 [4], and the Perseid "rains" in 1980 and 1981. Finally, there was also high activity in 1921. Thus, we have the following years with high activity: 1921, 1931, 1945, 1968-69, 1980 and 1991. This is well-known. Therefore the period of this shower exists, but is not constant. The value of 11.72 years is probably too precise, but perhaps a period of 9 to 12 years is more real. Only the years between 1955 and 1957 did not show high activity, and the Perseid returns of 1911 and 1912 were even poor.

3. We should also recall the (in Western Europe unknown) Perseid rain in 1928 [5,6]. During one hour, six observers saw 2960 different Perseids. It is also known that a Perseid rain was observed in 830. If we suggest a period of 91 years then 1928 − 830 = 1098 fits exactly (1098/91 = 12.06 periods)! If we take the proper motion of the particles into account, then 5 years (0.06 periods) is realistic to get away far enough from the comet's nucleus. Therefore, the following questions arise:
   a) In 1928, Comet 1862 III was near aphelion, but a very strong meteor occurred. How was such a dense structure formed at the opposite part of the stream's orbit?
   b) Why do we not know about activity in other years, such as 1837 (1928 − 91) or 1808 (1928 − 120) or 1746? Was the rain of 1928 an exceptional phenomenon? Shall we observe similar phenomena in 2019 (1928 + 91) or 2048 (1928 + 120)?

What I want to point out is that a periodicity in the activity exists, independently from the return of Comet 1862 III, and that the Perseid Meteor Stream has an involved structure. I would be glad if the comet would return in 1992, but that does not answer the questions raised above. Personally, I believe that the comet has already returned in 1980-81 and that we saw secondary filaments in 1921, 1928, 1931, 1945, 1968, and 1991. Such filaments may be observed in any year! The last argument in favor of a 1980-81 return is that overall activity in 1980 was much higher than in 1991!

[1] Vsehsviatskyi, "Fizicheskie charakteristiky komet", Moscow, 1958.
[2] Lovell A.C., "Meteor Astronomy", Oxford, 1954.
[3] Olivier C.P., "Meteors", 1932.
[4] *Sky and Telescope* 39:4, 1969.
[5] Astapovich I.S., "Meteor phenomena in the Earth's atmosphere", Moscow, 1958.
[6] Subbotin A.F., "Meteor Calculation August 13, 1928", *Mirovedenie* 18:1, 1929 (in Russian).

A.I. Grishchenyuk, February 1992

Paul Roggemans wrote the following comments on the issues raised by Andrey Grishchenyuk.

I fully agree with the remark that an increased activity of the Perseid stream at maximum does not necessarily tell anything about the vicinity of the comet. Several years with an exceptionally high Perseid activity at maximum were reported which had nothing to do with the perihelion passage of the comet.

However, care should be taken with the relevance of reports of past years. Some examples: *830 A.D.: "Countless large and small meteors flew from evening till morning."* [1] What does it describe? A normal Perseid display at the maximum date seen under a perfectly dark transparent sky is already impressive and in ancient times 500 to 800 meteors in one night may have be "countless" to most people. Occurrences of ancient meteor displays are mostly presented as if really exceptional rates were seen; however, if one goes back to the original references, nothing guarantees that these historic records refer to meteor storms or exceptional activity. Other historical records for the Perseids are 833, 835, 841, 924, 926, 933, 989, 1007, 1042, 1451, 1581, 1590, 1625 and 1645 [1]. They might have been merely normal returns that were seen under very favorable circumstances. These old data simply do not provide any concrete information for calibrating rates of activity to our current standards. Selecting some years from such historical records may suite any given periodicity indeed.

Better-documented observations became only available in the 19th century. This way, we know about very rich Perseid displays in 1861, 1862, and 1863—the years before, around and after the perihelion passage of P/Swift-Tuttle 1862 III—reported by qualified astronomers (e.g., A.S. Herschel, [2,3]). Especially 1863 was very well covered in Europe. While the 1862 return of Swift-Tuttle was accompanied by a rich Perseid display, no account on good or remarkable Perseid rates exist for the 18th century, except for some vague descriptions referring to 1779, 1784 and 1789. Not a single note has been found so far on meteor activity around the passage of Comet Kegler in 1737.

As to W.F. Denning, he found several periodicities, but was misled by pure coincidences. How could he compare year after year Perseid maxima when:

a) no global data were available, and outbursts, not visible in England, were not known;

b) no method existed to compare rates with different sky conditions, as most of the attention went into producing radiant positions from visual plottings. Stream activity in different years was assessed by Denning based upon subjective impressions and descriptions, not on ZHRs.

For some more recent years with high activity we should also be very cautious. To illustrate this, just consider the following few cases:

1920, 1921: Öpik's observers worked with a double-count method, under limiting magnitudes between +4.5 and +5.0. Hence ZHRs are most uncertain. Other reports speak about very good Perseid rates, but fail to report data that would allow a comparison with current observations. How much higher than normal was the activity?

1945: Only one observer (!) described these good rates, but what was his limiting magnitude? Someone with a high perception, with a limiting magnitude of +7.3 may see 200 meteors per hour during a normal display (ZHR = 85). Again, how can we compare this to standards?

1980: I was one of the observers who saw these good rates. The ZHR of 180 was for a few observers, for their best hours. I would not be surprised that the average of 50 observers would result in a more moderate value, still far above averages of other years, but less spectacular.

I conclude there are variations along the extent of the Perseid stream, but I claim that there is no ground to speak about periodicities. How would these be explained? A 12-year period reminds of planetary perturbations by Jupiter, but these are neglectable for highly-inclined highly-eccentric orbits such as for the Perseids. The solar activity cycle is assumed to favor the luminosity of meteors in the "swollen" Earth's atmosphere around solar maxima. This does not occur instantly, but is extended over a couple of years. The question is to which extent the solar influence and the resulting atmospheric state can favor the visibility of meteors (increase in luminosity) with no increase in real influx occurring.

Assuming that the particle density along the core of the stream is evenly distributed, so that the particle flux is guaranteed to be constant every year, would be more surprising than annual variations of up to one third around an average value. An almost-constant repeated activity profile year after year would indeed look too artificial, as a clock work. The build-up of a stream is just the result of a complex process with several processes acting randomly, such as collisions and break-ups. Therefore we should expect almost random variations in the maximum activity in which periodic variations along the the stream's orbit would be hard to detect, except for a dense cloud of sufficient extent to give the Earth a fair chance to encounter it regularly, as is the case with the Leonids.

Perseid particles traverse 1.2×10^9 km along their orbit between two successive years of Perseid activity. During 24 hours around a maximum, we can picture the density profile over only 3.4×10^6 km, covering only 0.27% of the segment that has passed the Earth's orbit in the preceding year! One should keep in mind that in these 24 hours, the Earth moves almost perpendicularly through the longitudinal tube of the core of the stream, like a space probe passing a celestial body. This implies that even during well-observed Perseid returns, still 99.7% of the particle population along the stream's orbit has remained unprobed!

Therefore, it would take many orbital revolutions before a reasonable sample is obtained to investigate real periodicities along the stream's orbit, especially when taking into account that a dynamic complex such as a meteor stream also changes and does not stay stable over several revolutions.

So far, it is known with certainty that periodicity occurs in meteoroid clouds, clustered near their parent comet, as is the case for the Leonids (every 33 years), Grigg-Skjellerupids (every 5 to 6 years), and Giacobinids (every 6 years). It is reasonable to expect a young meteoroid population near the comet as was observed in 1946 near P/Giacobini-Zinner. Comets do not necessarily produce dust, however, and many comets have past the Earth orbit apparently without any dust environment able to produce meteors in the Earth's atmosphere.

One argument in favor of the 1991 outburst being associated with P/Swift-Tuttle, is the sharpness and the reoccurrence of the first peak of the double maximum. Not being distinctly noticed before, it appears when the Earth encounters a particle concentration shortly before the "old", main core of the stream is met. This "new" concentration has an extension large enough to have allowed the Earth to cross it in 1988, 1989 and 1991 as was observed [4,5,6]. Such an extended, very dense belt must be of relatively recent origin since perturbing forces have not yet had the occasion to smear it out, away from the main mass. The first peaks in 1988 and 1989 are much wider but less intense, being more spread out and respectively 3 and 2 years ahead of the very compact 1991 first peak. It is the structure that can be expected when the first maximum is from a rather recent origin: the closer to the parent body, the less the particles got spread out. Moreover the 1991 outburst was more intense by an order of magnitude than any of the previously reported years with better-than-usual Perseid activity (including 1980-81), and thus much more significant than just-above-average maxima which may be due to solar activity or purely natural random variations in the particle density.

All in all, I am afraid we have to admit we know so little, that real long-term studies are not yet possible. Any conclusions using data from the past or based on too small samples should be regarded with scepticism and this area is indeed a playground for pure speculation.

[1] Roggemans P. (ed.), "Handbook for Visual Meteor Observations", Sky Publishing Corporation, 1989.

[2] Herschel A.S., *Mon. Not. Roy. Astron. Soc.* 32, 1872, pp. 355–359.

[3] Herschel A.S., *Mon. Not. Roy. Astron. Soc.* 34, 1874, pp. 211–215.

[4] Roggemans P., "The Perseid Meteor Stream in 1988: A Double Maximum!", *WGN* 17:4, August 1989, pp. 127–137.

[5] Roggemans P., Koschack R., "The 1989 Perseid Meteor Stream", *WGN* 19:3, June 1991, pp. 87–98.

[6] Roggemans P., Gyssens M., Rendtel J., "One-Hour Outburst of the 1991 Perseids Surprises Japanese Observers!", *WGN* 19:5, October 1991, pp. 181–184.

Paul Roggemans, March 14, 1992

Observers' Notes: May–June 1992

Jeff Wood

The months of May and June contrast greatly between the northern and the southern hemispheres. In the northern hemisphere there are few showers active and hence overall meteor rates tend to be low. In the southern hemisphere there are quite a few showers to be seen. This together with the ecliptic being high overhead ensures that good rates are seen. Table 1 lists some of the meteor showers to be seen in May and June 1992. Table 2 shows moonlight conditions. The dates of the phases of the Moon are given in UT. Note that the activity period data for the June Bootids and the o-Cetids are uncertain. The showers chosen for special investigation for the months of May and June are discussed below.

Table 1 – A list of some of the meteor showers to be seen in May–June 1992.

Shower	Activity	Max	Radiant			Drift		V_∞	r
			α	δ	D.	$\Delta\alpha$	$\Delta\delta$		
η-Aquarids	Apr 19–May 28	May 05	336°	−02°	4°	+0°.9	+0°.4	66	2.7
β-Corona Australids	Apr 23–May 30	May 18	284°	−40°	4°	+0°.9	+0°.1	45	3.1
Southern Ophiuchids	May 10–May 29	May 20	258°	−24°	5°	+0°.9	−0°.1	30	2.9
Northern Ophiuchids	Apr 25–May 31	May 13	249°	−14°	5°	+0°.9	−0°.1	30	2.9
κ-Scorpids	May 04–May 27	May 19	267°	−39°	4°	+0°.9	0°.0	45	2.8
θ-Ophiuchids	Jun 04–Jul 15	Jun 13	267°	−20°	5°	+0°.9	0°.0	27	2.8
γ-Sagittarids	May 23–Jun 13	Jun 06	272°	−28°	5°	+0°.9	0°.0	29	2.9
λ-Sagittarids	Jun 05–Jul 25	Jul 01	276°	−25°	5°	+0°.9	0°.0	23	2.6
Lyrids (June)	Jun 11–Jun 21	Jun 16	278°	+35°	5°	+0°.8	0°.0	31	3.0
Bootids (June)	Jun 26–Jun 30	Jun 28	219°	+496°	8°			14	3.0
o-Cetids	May 06–Jun 05	May 15	25°	−04°	5°			36	3.0
α-Scorpids	Mar 26–Jun 04	May 03	246°	−25°	5°	+0°.9	−0°.1	35	2.5

Table 2 – *Moonlight in May–June 1992.*

New Moon:	May 2, June 1, June 30
First Quarter:	May 9, June 7, July 7
Full Moon:	May 16, June 15, July 14
Last Quarter:	April 24, May 24, June 23

1. Scorpio-Sagittarids

The Scorpio-Sagittarids encompasses a number of streams that occur in the constellations of Scorpius and Sagittarius during the months of March, April, May, June and July. Named by Dr. C. Hoffmeister during the 1930s, these ecliptic streams are thought to have originated from Comet Lexell (1770 II). The Scorpio-Sagittarid showers are noted for greatly varying rates. At times, they are virtually not active while on other occasions, ZHRs of around 10 have been recorded. The Scorpio-Sagittarid showers are noted for bright colored fireballs and the occasional meteor that produces a persistent train.

As mentioned previously, the Scorpio-Sagittarids consists of a number of sub-streams. The major components whose details are described in Table 1 are the β-Corona Australids, Southern and Northern Ophiuchids, κ-Scorpids, θ-Ophiuchids, α-Scorpids, γ-Sagittarids and the λ-Sagittarids. Since Scorpio-Sagittarid meteors have velocities similar to those of the majority of sporadic meteors, great care needs to be taken in identifying them. Observers should be facing the radiant area and plot all meteors seen.

2. The η-Aquarids

The η-Aquarids which were produced by debris from Halley's Comet are a very spectacular stream especially for southern hemisphere observers. Unfortunately, because the radiant reaches culmination during daylight hours, the η-Aquarids cannot be viewed in all their glory. Although the radiant is equatorial with a declination of −1°, the seasons are such that it is daylight in much of the northern hemisphere before the radiant can rise more than 20° above the horizon. The southern hemisphere is more favorably placed and the radiant is able to rise above 50° before sunrise.

The η-Aquarids are best viewed the last couple of hours before sunrise approximately from 3^h45^m to 5^h45^m am local time. They are characteristically fast, yellow in color and have a train. It is not unusual for these trains to be very persistent lasting more than 30 seconds. Also, the η-Aquarids produce many brilliant fireballs. 1992 is a favorable year moon-wise to observe the η-Aquarids. The *IMO* encourages observers in both hemispheres to make this stream a special target for their attention.

3. Daytime showers

Since the southern hemisphere is approaching the winter solstice, the long nights mean that the radiants of several of the major daytime streams can rise substantially above the horizon before daylight. The two best candidates for viewing are the May *o-Cetids* and the June *Arietids*. Past observations of these streams indicate that during the last hour of darkness before dawn visual rates can rise up to 5 meteors per hour. Both the *o*-Cetids and the Arietids produce fast blue-white colored meteors which often have a train. Intending observers should look as close to the radiant area as possible and plot all meteors seen.

4. Theoretical radiant of Comet 1983 VII

The orbit of the long period Comet 1983 VII approaches the Earth at a minimum distance of 0.003 AU on May 12, yielding a theoretical radiant at $\alpha = 289°$ and $\delta = +44°$ with $V_\infty = 45.4$ km/s. This radiant is well situated for observers in the northern hemisphere. The geocentric velocity as well as the very close approach of the comet's orbit leave a chance that there will be a detectable shower.

The actual radiant position may differ somewhat from the predicted one. To determine it, plot all meteors possibly radiating from an area of about 15° radius around the predicted radiant, fill out a list as for the Aquarid Project and send it to the Visual Commission. Using *PosDat* and a radiant analyzing program it will be investigated whether there is a radiant and where.

For plotting, the *Gnomonic Atlas Brno 2000.0* is recommended. The field of view should be centered at a distance of about 10° to 30° from the predicted radiant. For observations the time from around May 5 until May 20 is recommended.

5. June Bootids

The June Bootids were produced by the debris of Comet Pons-Winnecke (1915 III) and appeared as a new shower in 1916. For several years they produced high ZHRs of up to 100 but in recent years the shower has mostly been absent, though on rare occasions low rates of 1–2 meteors per hour have been recorded. The last of these were in the late 1960s and early 1970s. The June Bootids are expected to be active around June 28. They have a visual radiant diameter of approximately 8° and are extremely slow-moving. Although there are some bright meteors, observations of the shower indicate that it is unusually rich in fainter members. In 1992 there is no interference from the Moon. Observers should begin the watch from June 24 and continue until July 1 or 2. All meteors seen should be plotted and great care taken to identify possible shower members.

6. Telescopic notes *(by Malcolm J. Currie)*

This time of year is dominated by ecliptic complexes stretching from Virgo to Sagittarius. Most produce a high proportion of faint meteors—rates over half the sporadic background are possible; and they all have moderate speed making them amenable to telescopic study. As ever, it's the accuracy of careful telescopic plotting that permits separation of the various components, even with low numbers of meteors.

The *Virginids* continue during May, though the center of activity is in Libra. During the dark time at the beginning of May I should like telescopic observers to concentrate on this shower complex until around 2h local time. At the same time it is possible to cover a few *Ophiuchids*, whose northern component lies about 30° east with a judicious choice of field centers. During 1990 *BAA* observers recorded a significant fraction of Ophiuchids—up to a third of the sporadic rate—from late April through May. I think that following the activity of the Ophiuchids could be a fun and novel project for Australasian and South-American watchers as the improved radiant elevation could lead to rates comparable with the background. There are few telescopic showers that offer such high rates.

There are few telescopic data on *Scorpio-Sagittarid* showers, principally because the telescopic observers historically have been situated at mid-northern latitudes, and have been prevented by twilight, the radiant elevation, and public examinations. Once again there is ample opportunity for rewarding observations for those fortunate to reside south of the equator.

1992 is a good year for the Halley showers regarding interference from moonlight. The *η-Aquarids* also favor those south of latitude +40°. Further north twilight prohibits effective watches. It is a continuing program of the Commission to probe the structure of the stream by plotting meteors and to determine the fascinating, complex structure of the radiants.

For those in the north who may feel left out of the party so far it will be interesting to look again for more evidence of Mark Vints's compact radiant around $\lambda_\odot = 67\overset{\circ}{.}5$, and to determine if it is an annual event, and if so what is its activity period. In early June there may be low activity from the *τ-Herculids.* In late June look out for residual *June Boötids* from the periphery of the Pons-Winnecke stream.

The Software "Radiant"

Rainer Arlt

The main algorithms underlying the program *Radiant* are described. Backward tracings and probability functions are used to determine radiants. First experiences and methods to estimate the reliability of the results obtained by the software are discussed.

1. Introduction

Rummaging in old literature, I found several attempts to determine radiants mostly from visual observations. In 1934, E. Öpik published the results of his Arizona Expedition. It was one of the first times that somebody compared the reliability of radiants with the accuracy of the plots. He found a so-called "probable error" of $\pm 8\overset{\circ}{.}4$, which might be a value like the standard deviation.

One of the radiant-finding procedures was applied to radar observations and uses the normal vector of the great circle the meteor moved on. These normals in turn lie on a great circle, provided the radiant is exactly a point. The normal vector of that circle then corresponds to the direction of the radiant or the anti-radiant respectively. Because of the underlying assumptions, this method is insensitive for the radiant structure.

Another frequently used method is determining all intersections of two different tracings (yielding up to $n(n-1)/2$ intersections for n meteors). The density of these intersections then gives an impression of the prominence of a radiant. This procedure is, however, too sensitive for poorly distributed paths. Indeed, imagine several parallel-moving meteors not producing any intersection. A single perpendicular meteor will generate a sharp radiant as its prolongation crosses those of all the other, parallel, meteors. Actually, this radiant is spurious. Moreover, the orientation of two non-parallel meteors must differ by a minimum value. If not, a slight orientation error of one of the paths will causes a strong displacement of the intersection, as a consequence of which the position of the radiant along the prolongation is of no significance.

Finally, meteors can be simply prolonged as it is often done by hand when verifying some suspicious paths. After dividing the sky into small squares, the number of incident backward tracings can be determined for each of these areas. We only applied this last method in the program.

Originally, the idea of a program that displays distributions of radiant densities grew with the Aquarid project. One of the simplest and basic advantages of computers is to process huge amounts of data. That was exactly what we needed for the Aquarids. The interface between data and program is the *PosDat* database format as well as the structure of *FIDAC*. Meteors stored in these files can directly be treated by *Radiant*. Selective criteria allow the user to specify, e.g., periods, observers, and sites. The program reads up to 65 534 meteors into a temporary, internal list.

The meteors are traced backward in a certain area of the sky, where the radiants are expected. This area is divided into small squares and the number of incident backward prolongations per square is counted. The sky is divided gnomonically, although equal gnomonic squares generally do not represent equal areas in the sky. However, since the center of the gnomonic projection can be chosen in the vicinity of the expected radiants, the resulting effect is fairly moderate. Moreover, there is also a special correction in the algorithm for the scale change.

Radiants always move over the sky with time. The displacement per day depends on the direction of the motion vector of the meteoroids, and the heliocentric velocity and the structure of the stream at the orbital node.

The revolution of the Earth through parallel orbits of meteoroids in the ecliptic would cause daily shifts of $0\overset{\circ}{.}4$–$1\overset{\circ}{.}0$, due to the angular motion of the Earth of about one degree per day and its addition to the meteoroids' motion vector. The value depends on the heliocentric velocity of the stream: higher velocities cause smaller shifts. Radiants at very high ecliptical latitudes can have quite low daily motions (e.g., the κ-Cygnids and the Ursids).

The effect is amplified by the structure of most streams. When passing the stream from inner to outer (or from outer to inner) parts, we observe meteoroids on slightly different orbits. The differences either in semi-major axis or in longitude of the node (mostly in ecliptical showers) also affect the displacement of the radiant. Generally, the geometric value caused by the Earth's motion is increased. If we meet the shower near its perihelion, the curvature of the orbits is near its maximum, whence the daily motion can be rather large despite the higher ecliptical latitude of the shower (e.g., the Perseids). We then get the typical motions between $0\overset{\circ}{.}6$ and $1\overset{\circ}{.}2$ of ecliptical longitude per day.

Since the radiant drift is nearly parallel to the ecliptic, *Radiant* only considers a displacement of the meteors in ecliptical longitude. With a given daily motion m_d and reference solar longitude λ_{ref} (generally coinciding with the date of maximum), the individual longitudinal shift Δl of the meteor in degrees is

$$\Delta l = 1.01456\, m_d(\lambda_{\text{ref}} - \lambda_{\text{met}}), \tag{1}$$

where λ_{met} is the solar longitude of the meteor's appearance. The constant is exactly 1/360 of the tropical year of 365.2422 days.

Applying this shift in ecliptical longitude allows for the use of meteors from different nights to determine one radiant.

For computing radiant positions, the program *Radiant* provides two variations on the principle outlined above, the first of which is "naive" backward tracing.

2. Backward tracings

The prolongation of a meteor does not cover the entire sky, but only a reasonable portion of that great circle taking into account the angular and geocentric velocities of the meteor and its path length.

The distance ξ of the individual radiant of the meteor from its starting point is a function of the observed angular velocity ω and the geocentric velocity v_∞. For simplicity's sake however, we prefer to compute ω as a function of ξ and v_∞. Thereto, consider the component $v_\perp$ of the entrance velocity v_∞ perpendicular to the observer's view line, i.e., the component of the velocity vector tangential to the celestial sphere: $v_\perp = v_\infty \sin\xi$ (Figure 1).

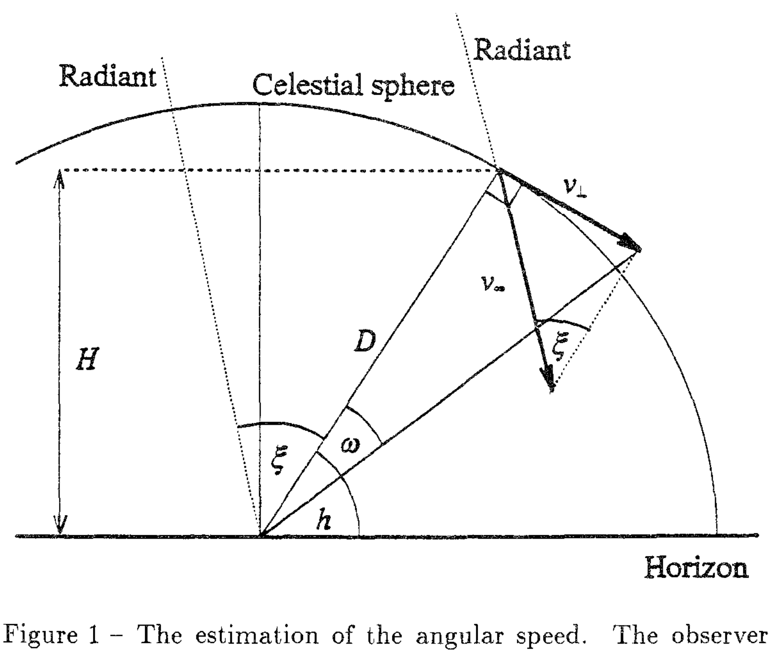

Figure 1 – The estimation of the angular speed. The observer sees the velocity projected onto his celestial sphere. See the text for details.

Furthermore, we need the distance of the meteor from the observer given by $D = H/\sin h$ with H the height of the atmospheric layer in which the meteor becomes visible and h the (angular) starting altitude of the meteor. Then the angular speed ω in radians per second is given by

$$\omega = \frac{v_\perp}{D} = \frac{v_\infty \sin\xi \sin h}{H} \tag{2}$$

As the angular velocity is an estimate only, the tracing is drawn in the interval corresponding to the range $[\omega - 2\sigma, \omega + 2\sigma]$. Koschack [1] determined the standard deviation σ of the speed as a function of the angular velocity itself. We thus find the interval of the backward tracing with

$$\sin\xi_{\mathrm{beg}} = \frac{(\omega - 2\sigma)H}{v_\infty \sin h}, \qquad \sin\xi_{\mathrm{end}} = \frac{(\omega + 2\sigma)H}{v_\infty \sin h} \tag{3}$$

H is automatically correlated to v_∞ by *Radiant* with $H \approx 0\overset{s}{.}625 \times v_\infty + 76$ km.

Sometimes it happens that the speed estimate plus twice the standard deviation determining the far end of the backward tracing is too large for the given geocentric velocity. The result of the right term of (3) then is greater than 1. In that case, we put $\xi_{\mathrm{end}} = 2\pi - \xi_{\mathrm{beg}}$. On the other hand, geometrical reasons prohibit the prolongation to begin before the distance ξ has reached a certain ratio to the length of the path. The start-up value for this ratio in *Radiant* equals 1.0., i.e., ξ_{beg} must be larger than the length of the meteor.

Taking into account the limiting conditions above, the meteor is now traced backward between ξ_{beg} and ξ_{end}. The number associated to every square intersected by the prolongation is incremented by 1; if the correction for scale change is enabled, it is incremented by some value c.

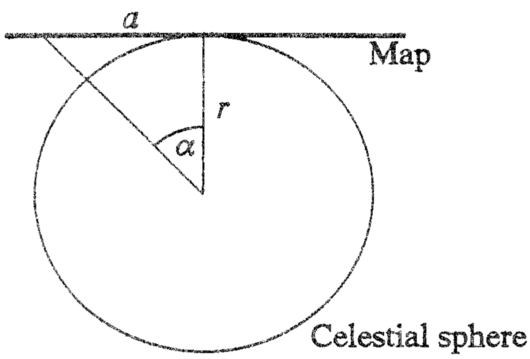

Figure 2 – The gnomonic projection as used by *Radiant*. The point where the map touches the sphere is the center of the chart.

To compute this value c, we first observe that the distance a of a point on the gnomonic chart from the center of projection depends on the angular distance α on the sky:

$$a = r\tan\alpha \tag{4}$$

with r the radius of the projecting sphere[1], which may also be considered as the scale in the center of the map (Figure 2). The scale in any other point is then given by

$$\frac{\mathrm{d}a}{\mathrm{d}\alpha} = \frac{r}{\cos^2\alpha} = \frac{r^2 + a^2}{r} \tag{5}$$

We are only interested in the *scale change*, i.e. the ratio of the scale to the scale in the center. As the distance a can be expressed in gnomonic coordinates (x, y) by $a^2 = x^2 + y^2$, we get:

$$c = \frac{\frac{\mathrm{d}a}{\mathrm{d}\alpha}}{r} = 1 + \left(\frac{a}{r}\right)^2 = 1 + \left(\frac{x}{r}\right)^2 + \left(\frac{y}{r}\right)^2 \tag{6}.$$

At a distance of 20°, the correction c equals 1.13. The correcting effect is obvious when we consider three meteors meeting in one pixel near the border of the "chart" and three other prolongations meeting near the center. Since the outer square represents a smaller angular area than the inner one, it is a more distinct radiant, and, indeed, it gets a higher correction.

[1] Atlas Brno charts have $r = 160.43$ mm.

3. Applying probability distribution functions

Unfortunately, the very simple method of tracing the meteors backward requires large amounts of data. As all plots have certain errors associated to them, a large number indeed are needed to fill the (approximately Gaussian) error distribution in order to obtain a reliable, most probable radiant.

Alternatively, if the plotting errors are known, then the corresponding Gaussian probability functions can be explicitly applied to single meteors. The same also holds for the angular velocity.[2]

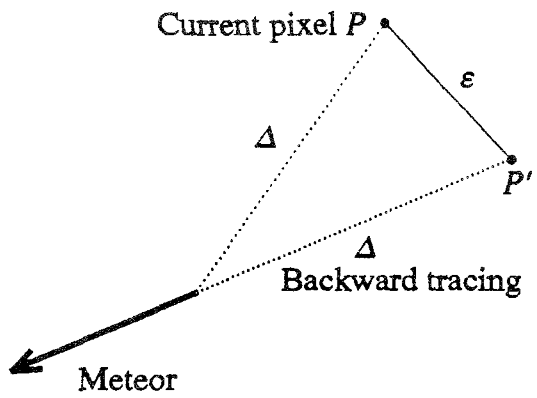

Figure 3 – The distance ε is the angle used by *Radiant* to determine the probability of P being the meteor's radiant.

In this approach, an area of display squares is created behind each meteor, the values of which represent their probability to be the radiant of that meteor. Given a meteor and a square P, the distance Δ between the starting point of the meteor and the current pixel P is computed. Let P' be the point on the backward prolongation of the observed meteor trail at distance Δ from its starting point. De distance ε between P and P' (see Figure 3) is then used to compute the geometric probability p_ε of P to be on the backward prolongation of the real meteor. The probability p for P to be the radiant then is the product of this geometric probability p_ε and the probability p_ω with respect to the angular velocity, i.e.,

$$p = p_\omega \times p_\varepsilon \tag{7}$$

where

$$p_\omega = \frac{1}{\sigma(\omega)\,\sqrt{2\pi}}\; \mathrm{e}^{-\frac{(\omega-\omega_{\mathrm{exp}})^2}{2\sigma(\omega)^2}}\,, \tag{8}$$

with ω_{exp} the expected speed at the distance Δ of the computed pixel, and $\sigma(\omega)$ the standard deviation depending on the angular velocity of the meteor, and

$$p_\varepsilon = \frac{1}{\sigma(\Delta)\,\sqrt{2\pi}}\; \mathrm{e}^{-\frac{\varepsilon^2}{2\sigma(\Delta)^2}}\,, \tag{9}$$

with $\sigma(\Delta)$ the standard deviation of the plot at distance Δ from the meteor's starting point. While the role of the geometry in the probability function is intuitively obvious, the influence of the angular velocity should not be underestimated either. As an illustration, Figure 4 shows probability distributions for two meteors, the upper one moving at 5°/s and the lower one at 10°/s.

These calculations are applied to every square behind the meteor. The floating point operations make the algorithm seem rather slow. Therefore, some concessions were made in the implementation in order to reduce the calculating time to some extent (e.g., cutting away areas of too low probabilities, and searching for the next zero instead of a complete scanning). The probability distributions of the individual meteors overlap each other yielding a smoothed display of the radiant structure. Each meteor gets the same total weight, as $\int_{-\infty}^{+\infty} p = 1$, independent of σ.

[2] Surprisingly, the error distribution of speed estimates resembles a Gaussian distribution even better than that of plotting deviations [1].

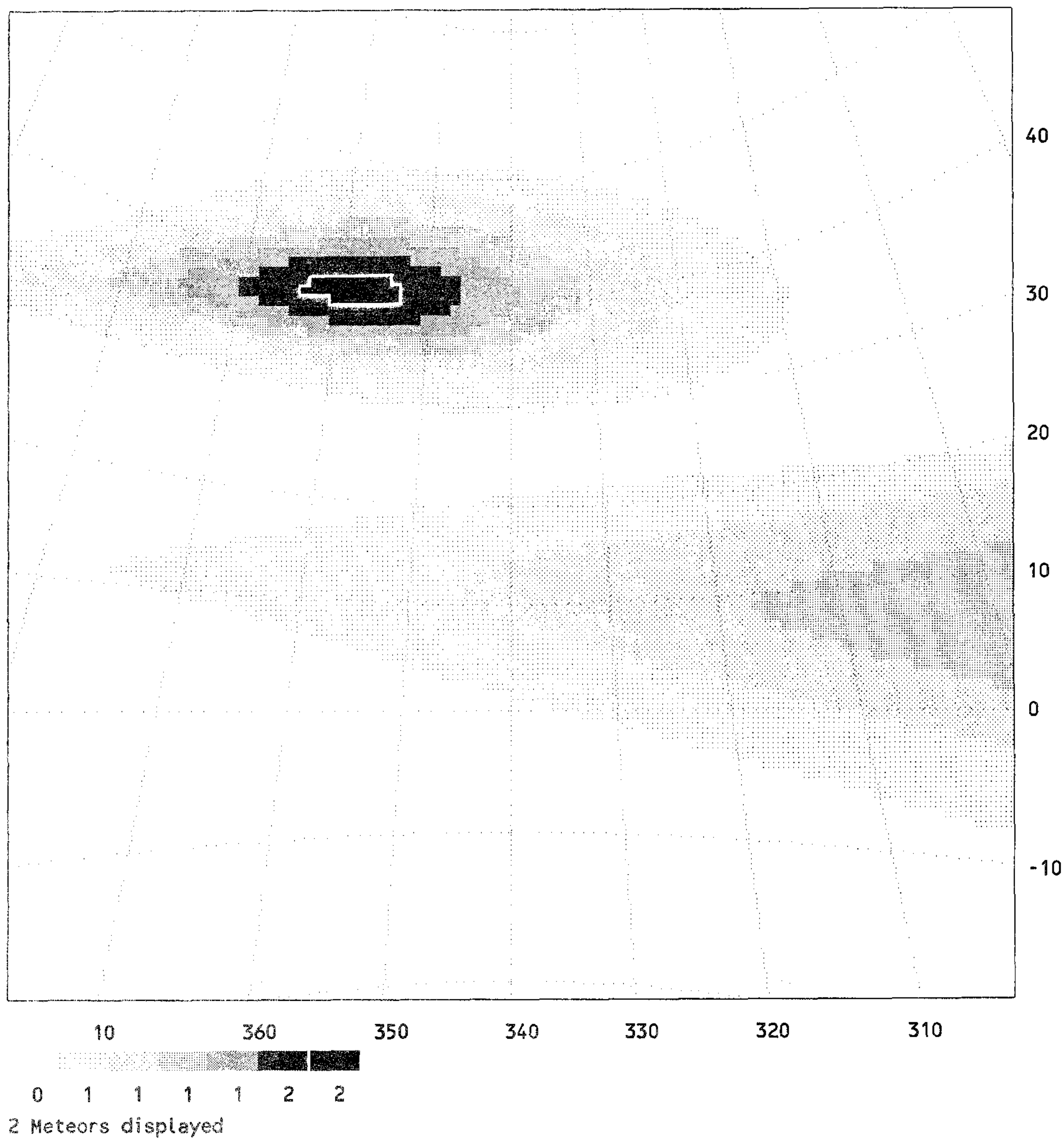

Figure 4 – Two meteors traced with probability functions. The upper one has $\omega = 5°/s$, the lower one $\omega = 10°/s$. Both meteors start at about 10 mm outside the left edge.

Obviously, the probability value corresponding to a square is directly proportionate to the area of the square. In turn, this area is inversely proportionate to the square of the scale correction. With enabled scale correction, we thus get $p = p_\omega \times p_\varepsilon / c^2$.

4. First experiences

Obviously, the simple backward tracing method requires lots of meteors. No square around the investigated area should be left empty. Even one hundred visual plottings do not give any reliable result, since the procedure may be described as "filling Gaussian distributions" and finding their maxima.

Of course, the required number of meteors depends on the chosen resolution of the sky. The smaller the size of the squares (i.e., the pixel size), the larger the number of meteors becomes needed to obtain "well-filled" radiant distributions, but also the better the quality of the display. For searches with visual meteors, a typical size of 1° is appropriate. For this resolution you need some 500 meteors.

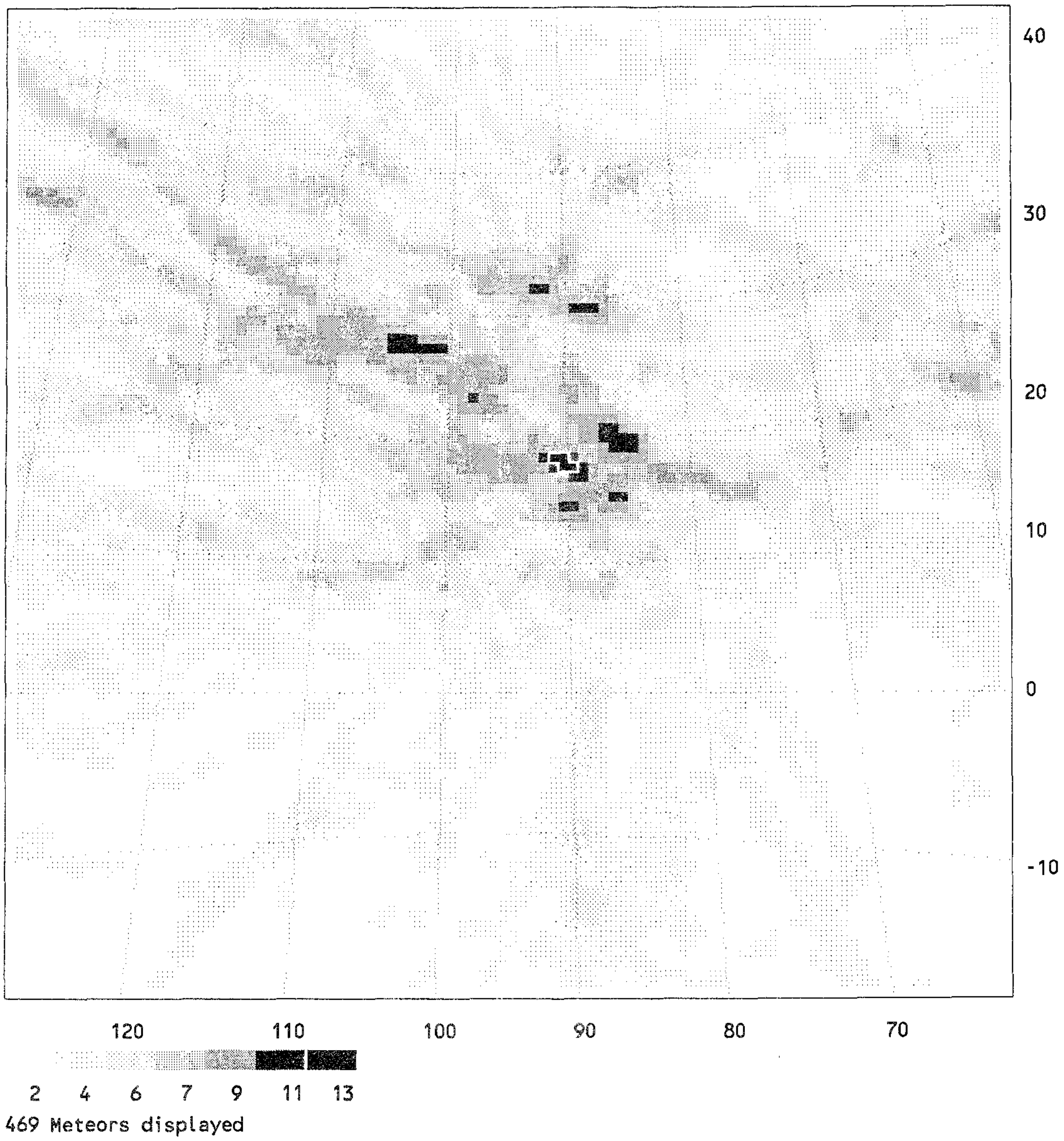

Figure 5 – The result of the simple backward tracing of 469 meteors around the maximum of the Orionids. Additionally, the display was smoothed (each pixel with its eight neighbors).

Figure 5 shows a nice result obtained by simple backward prolongation of 469 meteors seen between October 18 and 25. It has been computed with $v_\infty = 66$ km/s. The distribution array consists of 100×100 elements of size 1° in the center of the map. Notice that the radiant of the Orionids is striking.

To illustrate the importance of the velocity once again, Figure 6 shows the same meteors displayed with the same parameters, but with v_∞ set to 30 km/s. The Orionid radiant has clearly vanished; on most of the meteors' backward prolongations, the relevant interval even lies completely outside the chart.

Compared to the first method, the probability method is better suited for visual naked-eye plots, as fewer meteors are needed. With the mentioned resolution of 1° you get good results with 100 to 200 meteors already. This is however the lower limit for any investigation using visual observations.

Figure 7 shows a probability distribution of 363 meteors from the southern showers of early August. It is a 50×50-elements distribution grid.

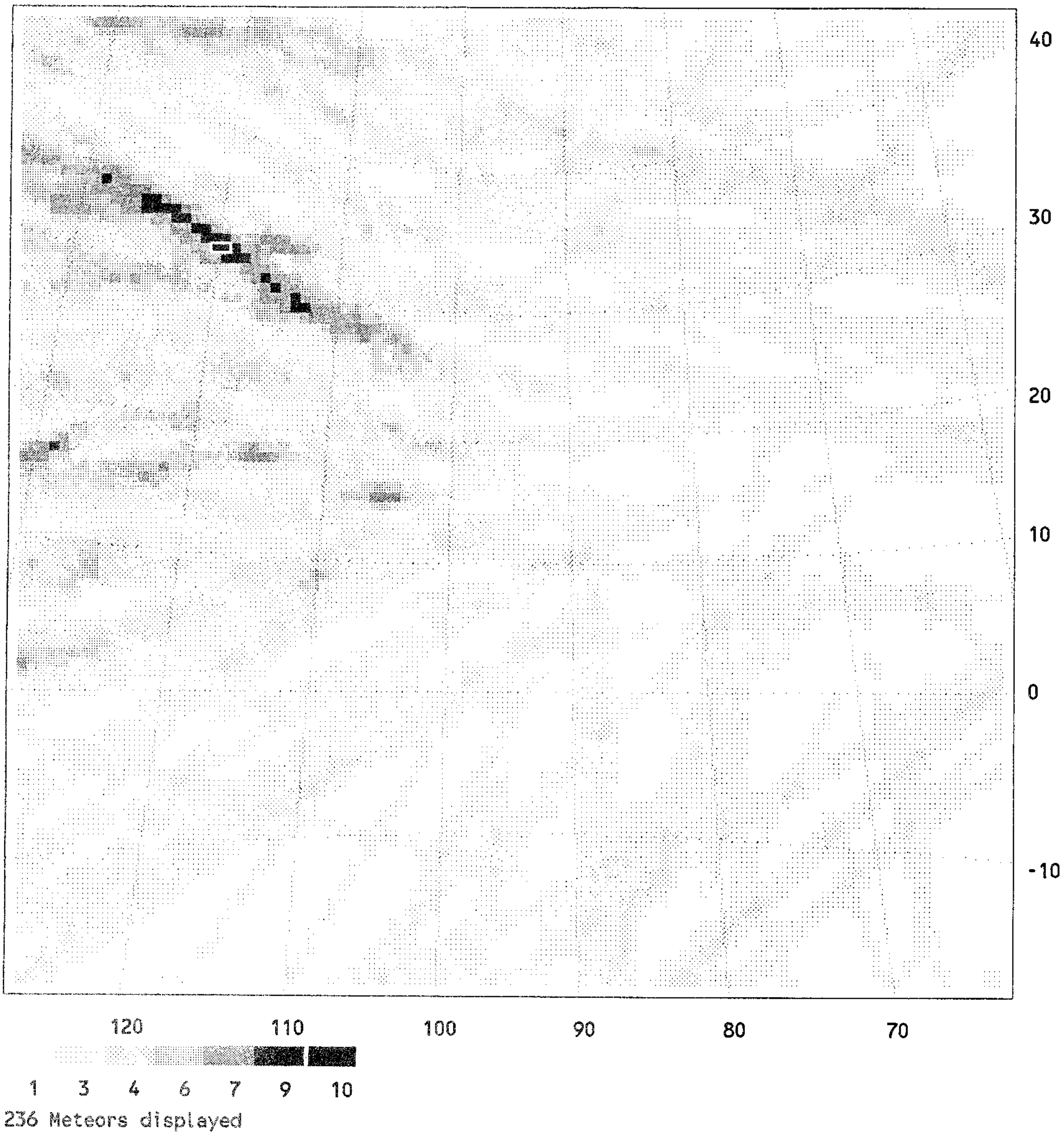

Figure 6 – The same meteors as in Figure 5, but computed with the incorrect entrance velocity of $v_\infty = 30$ km/s. The Orionid radiant vanished completely.

In the tracing mode, the calculation speed is quite favorable. At the AT standard clock speed of 8 MHz, an 80286 computer calculates 3 to 4 meteors in a second. At 16 MHz, the number increases up to 6 or 7. An 80386 computer working at 33 MHz clock speed manages to finish 12 meteors per second. The probability mode on the other hand does not get any meteor ready in a second; an AT at 16 MHz computes between 70 and 95 meteors per hour. In that time, the 386 board produces the result of 200 to 300 meteors.

It is rather hard to define criteria for the reliability of the radiants found. A background-noise function of *Radiant* delivers the mean distribution value as well as the standard deviation of the calculated display. The prominence z can then be estimated by

$$z = \frac{x_{\max} - \overline{x}}{\sigma} \tag{10}$$

with $x_{\max}$ the maximum value of the radiant, $\overline{x}$ the average value, and σ the standard deviation. The estimate z is fairly useful when comparing several displays with the same parameters. As it is not an absolute value, it is however not applicable to computations with different resolutions, pixel sizes, or calculation methods.

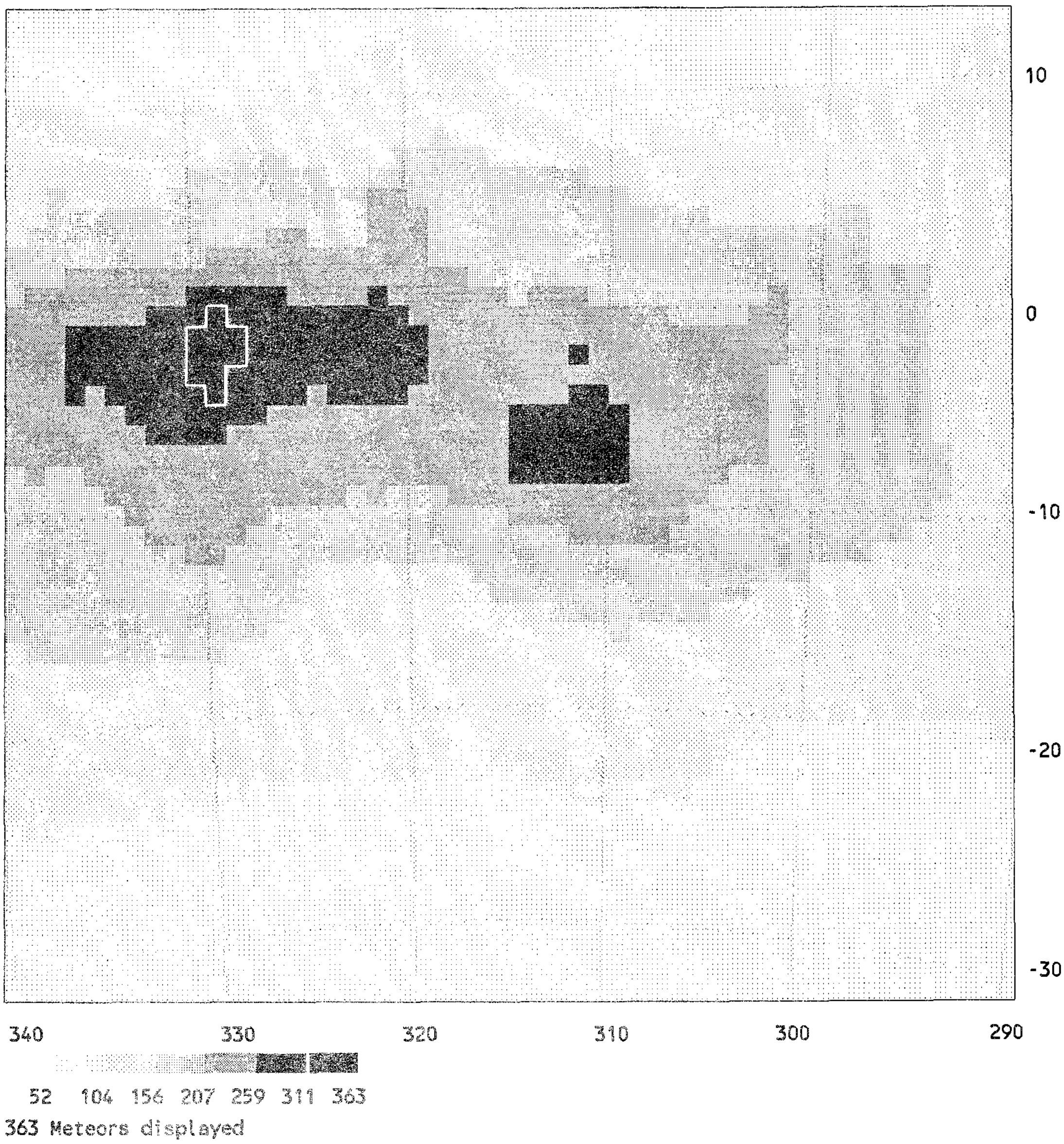

Figure 7 – The result of probability functions of 363 meteors of early August showing more realistically the capabilities of visual plots. Probability distributions are scaled to the total number of meteors displayed, as the probability values are extremely small.

Furthermore, it is possible to slightly decrease or increase the daily motion of the investigated radiant, provided the exact value is known. If the radiant becomes more distinct with smaller or larger shifts, it is very likely that a significant number of meteors does not belong to the shower, whence the radiant is not that distinct as it seems to be. Analogously, the paths of the meteors can also be randomly "perturbed" to simulate plotting errors. The more distinct the radiant remains, the less likely it is to be spurious. However, this procedure cannot be executed with *Radiant*. The user has to create *PosDat* files with these "dirty" paths.

At present, the data of the Aquarid project are treated with *Radiant*. The results will be published in one of the forthcoming issues of *WGN*.

The software is free and can be obtained from the author.

Reference

[1] Koschack R., "Analysis of Visual Plotting Accuracy and Sporadic Pollution and Consequences for Shower Association", *WGN* 19:6, December 1991, pp. 225–241.

Precision of Telescopic Meteor Recordings

Plotting Errors and Recording Probability

Petr Pravec and Jaroslav Boček, Ondřejov Observatory

Forty meteors of magnitudes between 4 and 8.5 were observed both telescopically and by means of a TV-camera during the 1991 Perseid campaign at the Ondřejov Observatory. Using standard telescopes for telescopic observations of meteors (7 binoculars db 10×80 and 1 binocular mb 12×60), 152 individual telescopic recordings of those 40 meteors were obtained. An analysis of the precision of these 152 telescopic recordings is presented. No systematic deviations were found; the standard deviation on the position angle (SDPA) equals 11°, and the standard deviation on the position of the recorded trajectory w.r.t. the stars (transversal deviation) equals 0°5. Important improvements of the accuracy were found during several nights of the observing campaign. During the first night (after a long period of non-activity) the SDPA was equal to 13°, while after three observing nights it seemed to stabilize around 9°. No significant relationships were found between the accuracy of the telescopic recording and the magnitude of the meteor, its velocity, position in the field of view, recorded length, the presence of a train, or the observer's opinion about the quality of the recording.

The probability of recording a meteor was determined for the particular set of observers, equipment, and observing conditions. It was found to be constant for meteors of magnitude +6 or brighter, equaling about 80–85% (not 100% due to the relatively high rate of "dead-time"). The recording probability gradually decreases towards fainter meteors and amounts to less than 50% for magnitude-+8 meteors. Five out of the eight participating observers were found to be "good observers," their probabilities of recording meteors brighter than +8 being similar and about 5–10% higher than the above-mentioned values (obtained from averaging over all observers).

1. Introduction

Among various techniques of observing meteors, telescopic meteor observations play a key role in studying a range of the meteor magnitude distribution not or poorly covered by means of other techniques. Telescopic meteor observations enable us to study meteor activity in the range between +4 and +9, complementing visual and photographic methods, applicable to meteors of magnitude +4 or brighter, and covering almost the same magnitude range as a TV-camera. (Radar and radio methods cover a similar interval of the magnitude distribution, but they detect different phenomena than telescopic and TV-camera observations.) Hence a very promising interaction between the various methods is possible. In particular, telescopic meteor work can take care of extensive monitoring of meteor activity in the magnitude range between +4 and +9 (these meteors are called telescopic meteors) while TV-camera methods can be used for more detailed studies of particular problems and to solve them with much better accuracy.

Already since about 1950, telescopic meteor observations were performed by Czechoslovak observers on a relatively large scale. Many tens of thousands of telescopic records of meteors were obtained [1]. While only a small part of this large amount of data has already been analyzed, they form a very valuable database. Analyses can be found in, e.g., [2,3,4].

The efforts of Czechoslovak telescopic observers are continued in recent times and were concentrated on the Perseid Meteor Shower, in order to watch for possible changes of activity due to the possible return in 1992 of the parent comet P/Swift-Tuttle 1862 III [5]. In the context of the Czechoslovakian 1988–1992 Perseid Project, more than 5000 telescopic recordings were obtained between 1988 and 1991 [6,7].

There are only a few telescopic meteor observers in other countries, but they are able to obtain valuable data, too. It seems to be useful to join their and our efforts by establishing a common observing program. The first step in this direction was recently set: common observations were made of the 1992 Quadrantids in order to obtain a better picture of its telescopic activity and the structure of the radiant (see, e.g., [8,9]).

In scientific work, it is necessary to be thoroughly aware of the method used. Amateurs sometimes have a tendency to neglect this aspect as a consequence of which their data cannot be reliably analyzed. Fortunately, this does not apply to the Czechoslovakian telescopic meteor observations from about 1960 till the present time. Big efforts have been spent in describing characteristics and inaccuracies of telescopic meteor observing, and achieving the best possible methods for observation and analysis (e.g., [10]).

The analyses are based on statistical comparison of simultaneously observed meteor recordings. That is why some systematical deviations and distortions in telescopic recordings may not show up. Therefore we organized parallel telescopic and TV-camera observations at the Ondřejov Observatory during August 1991 to reveal these phenomena [6,7].

2. Brief description of the telescopic method

In the 60s, the Czechoslovak standard method of telescopic meteor observations was established. Apart from some minor modifications, this method is still being used.

In principle, a certain area of the sky is watched during a telescopic meteor observation by means of a wide-field binocular. All meteors seen are recorded (i.e., their positions among the stars are plotted, and time, magnitude, velocity, train and other parameters are noted). Several types of binoculars are used, from 7 × 50 to 25 × 100. Most frequently, binoculars of 10 × 80 and 12 × 60 are used, the former (called "db") having been established as the standard instrument for telescopic meteor observations in Czechoslovakia. The field of view varies from 3°5 to 7°4, the latter being the diameter of the field of view of the db 10 × 80.

Hence a part of the sky of a few tens of square degrees is watched, corresponding to an area in the atmosphere on the meteor level at about 100 km of several hundreds of square kilometers. When several fields around the radiant of a meteor shower are observed by several observers at the same time, then by analyzing the telescopic recordings statistically, activity and magnitude distribution of the shower (and subsequently spatial density and mass distribution of the stream) may be determined. However, great care must be taken in accounting for different systematic deviations, distortions and errors.

In this particular event of parallel telescopic and TV-camera observations at the Ondřejov Observatory, a group of eight observers used seven db 10 × 80 and one 12 × 60 binoculars. Four fields were watched, centered at 12°5 from the Perseid radiant at the time of maximum. The field diameters were 7°4 and 5°0 respectively. The limiting telescope star magnitude varied between 10.5 and 11.0 (average conditions). At each moment during the observation, at least two, but usually 4 to 7 observers watched the same area in the sky. The times of the meteors seen were recorded as accurately as possible (up to about 1 s) by an assistant. The observers plotted the meteor trail on star maps with a scale of 2 cm per degree (based on the SAO-catalogue), and recorded magnitude, velocity and several other parameters.

3. The TV-system: methods of parallel observations and reduction

The Ondřejov TV-camera meteor observation system was used in parallel telescopic and TV-camera observations. This system is in operation at the Department of Interplanetary Matter at the Ondřejov Observatory and its main device is a night-vision camera, model HT 11-22/SIT (Hiradash Technika, Budapest), containing an RCA 4804/H SIT-vidicon tube with an S 20 photo-cathode. The system operates with a 625-lines scan at a frame rate of 25 per second. The camera lens is a Leitz-Noctilux 1/50 mm. The field of view is 14°7 horizontally by 11°0 vertically.

The observation data were recorded on a video tape by a VHS Tesla-Philips VM 6465 tape recorder with a bandwith of 3.1 MHz. On a monitor, the video tapes were checked visually for meteors. Each time a meteor was found, it could be analyzed by means of an image processor Tesla Vúst (255 levels of gray, memory for four images of 512 × 512 pixels or sixteen images of 256 × 256 pixels), in conjunction with a PC.

As to the magnitude range covered by the camera: the faintest recorded star had a magnitude of +10 while the faintest recorded meteor was of +8 (when the naked-eye limiting star-magnitude was 6.0).

We watched the same area in the sky by means of the TV-camera and the group of telescopic observers, separated by distances of about 100 m. (No telescopically detectable shift of the meteor position on the sky can have been caused by this separation.) The area in the sky was situated at about 12° from the Perseid radiant and was observed by 2 to 7 observers at any time.

Several important differences between both techniques of meteor observing have to be noted:

1. The effective area watched by the TV-camera is 2 to 4 times larger than in telescopic observations, depending on the length of meteor;
2. The probability of perceiving a meteor brighter than +4 (respectively a meteor fainter than +8) with the TV-camera is close to 100% (respectively 0%), whereas the same probability for the telescopic method is about 85% (respectively less than 50%, but not equal to 0%!)[1];
3. The spectral sensitivity of the TV-camera differs from that of the eye. (Hence, differences in brightness of TV-camera recordings of different meteors may not correspond to differences in telescopic recordings);
4. The accuracy of TV-camera meteor trails is much better (about 1′ versus about half a degree for telescopic recordings);
5. The length of the telescopic recording may be longer than the length of TV-camera recording of the same meteor, which is caused by the greater sensitivity of the eye-telescope combination;

In contrast to these differences, time-recordings are of similar accuracy in both cases (about 1 second, TV-time being a little more accurate).

During a few weeks after the observations, TV-camera and telescopic recordings were searched for simultaneous meteors. TV-camera recordings were checked by watching a video screen several times and all meteors detected (i.e., their times and trails among the stars) were noted. Comparing these notes with the telescopic recordings, possible simultaneous events were identified and afterwards confirmed or rejected during a more detailed search of the TV-camera recordings. During that search, the differences between the telescopic and the TV-camera methods described above were taken into account.

We were able to effectively discriminate between simultaneous meteors and accidental coincidences in all cases and we have no doubts about the simultaneous meteors found. The trails of the simultaneous meteors were measured and all data were entered into a computer for analysis. Two typical cases of TV-camera and corresponding telescopic recordings of the same meteor can be seen in [7].

4. The group of telescopic observers

The telescopic group consisted of eight observers. Four of them were "experienced", meaning they were observing meteors telescopically for at least five years (observers nrs. 3, 4, 5 and 6). The remaining four observers were "less-experienced"; they started telescopic meteor observing only one year ago. However, all observers were seasonal, i.e., they observe meteors only a few months each year (almost all during summer). So, this Perseid campaign was their first observing session after about one year of non-activity.

Their names were:

1. Petr Halaxa, 2. Ján Mušinský, 3. Kamil Hornoch, 4. Filip Hroch, 5. Petr Pravec, 6. David Konečný, 7. Denisa Dvořáková, and 8. Karel Trutnovský.

Observers nrs. 1 to 7 used a db 10 × 80, observer nr. 8 used an mb 12 × 60.

[1] Of course, the presented probabilities were found after analyzing these parallel observations. Previously, we had only a qualitative idea of these values.

5. Basic characteristics of the data-set obtained

The parallel observations of meteors, telescopically and by means of the TV-camera, were performed at the Ondřejov Observatory from August 7 to 16, 1991. The total number of telescopic meteor recordings was 815, obtained during 117.8 hours. Of these, 152 concerned 40 meteors observed simultaneously by the TV-camera during 11.5 hours of simultaneous observations (of those 40 common meteors, 15 were Perseids). These observations were performed under the following average sky conditions: naked-eye limiting star-magnitude of about 6.0 (between 10.5 and 11.0 in the binoculars), and moderate interference of clouds.

A summary of the observing nights and the individual observers' activity is presented in Tables 1 and 2, below.

Table 1 – Summary of observing nights. Durations are in minutes.

Night	Tot. eff. dur.	Nr. tel. rec.	Dur. TV-tel. obs.	Nr. sim. met.
Aug 07–08	881	80	124	5
08–09	266	13	38	0
09–10	539	52	49	2
10–11	892	112	93	7
11–12	1478	211	96	8
12–13	1608	226	123	12
15–16	1403	121	166	6
Total	7067	815	689	40

Table 2 – Individual telescopic observers' activities. Durations are in minutes.

Obs	Tot. dur.	Nr. tel. rec.	Tel. HR all rec.	Tel. HR brighter than +8	Dur. TV-tel. obs.	Nr. rec. sim. met.	HR sim. met
1	1034	92	5.3	2.3	586	11	1.1
2	900	123	8.2	3.6	500	26	3.1
3	991	105	6.4	2.9	570	26	2.7
4	598	55	5.5	2.1	384	10	1.6
5	849	120	8.5	3.3	517	22	2.6
6	750	159	12.7	3.4	436	17	2.3
7	926	71	4.6	3.1	505	28	3.3
8	1019	90	5.3	1.3	560	12	1.3
Tot	7067	815				152	

The obtained data-set covers the magnitude range between +4 and +8. Most meteors had magnitudes between +5.5 and +7.5. This data-set of telescopic and TV-camera recordings of simultaneous meteors was analyzed. The results of this analysis with respect to recording probability and plotting errors of telescopic meteor observations are presented in the following sections.

6. Probability of recording a meteor telescopically

The probability of recording meteor telescopically is a function of meteor magnitude, angular velocity and position in the field of view. The influence of velocity may formally be considered as a change in observed brightness. Hence both the magnitude m_{real} and the angular velocity v

result in an apparent magnitude m_{obs}:

$$m_{\text{obs}}(v) = m_{\text{real}} + \Delta m(v), \tag{1}$$

where $\Delta m(v)$ is a term expressing the fact that faster meteors look fainter. One has:

$$\Delta m(v) = -0.64 + 0.10 \log v + 0.30 (\log v)^2, \tag{2}$$

where v is in degrees per second (apparent angular velocity, magnified by the telescope). This expression is valid in the range $20°/\text{s} \leq v \leq 300°/\text{s}$ with an accuracy of 0.2 magnitudes.

After having performed these transformations one can express the probability of recording a meteor as

$$p(d, m) = p_c(m) \times (1 - d^2)^{q(m)}, \tag{3}$$

where $m \equiv m_{\text{obs}}$ is the apparent magnitude, $p_c(m)$ the probability of recording a meteor of apparent magnitude m at the center of the field of view, d the minimal distance of the meteor from the center as a fraction of the radius of the field of view, and $q(m)$ an exponent expressing that the recording probability decreases with increasing d.

Formulae (1) to (3) resulted from previous research, see, e.g., [4,11].

In this analysis of parallel TV-camera and telescopic observations we were not able to collect a sufficient amount of data to prove the validity of (3). We could only determine a mean probability $\langle p(m) \rangle$, averaged over all positions of meteors of magnitude m in the field of view.

In the case of bright meteors, $q(m)$ is close to 0 (the recording probability does not depend on the distance of the bright meteor from the center of the field of view) and the obtained recording probability $\langle p(m) \rangle = p_c(m) = p(m)$ does not depend on d for m smaller than some limiting magnitude. Towards fainter meteors, the recording probability $\langle p(m) \rangle$ is lower than $p_c(m)$ (significantly when $q(m) > 0.5$, which is usually the case for meteors fainter than +6 when a db 10×80 is used). In the remainder of this section, recording probability always refers to $\langle p(m) \rangle$; the probable influence of $p_c(m)$ and $q(m)$ on $\langle p(m) \rangle$ is discussed.

The probabilities of recording meteors of different magnitudes by the group of observers having used a db 10×80 binocular (i.e., excluding observer nr. 8, who used a different type) under the particular conditions are shown in Figure 1. Only smoothed curves are shown. Error margins are about 5% for meteors brighter than +6, but larger than 10% for meteors of +8. Nevertheless, the general profile is evident.

The recording probability of a meteor brighter than about +6 is constant and equals 80–85% (90%) for an average observer (for a "good observer"[2]). Such meteors are so bright that observers cannot miss them providing they really watch the field in binocular. A telescopic observer however *cannot* watch uninterruptedly. There are several causes for a decrease in attention or a short interruption while observing meteors telescopically, e.g., the necessity to record observed meteors or operating the telescope. As a consequence, the probability of recording a bright meteor does not equal 100%.

Towards fainter meteors the recording probability gradually decreases, equaling approximately 50% for meteors of +8. This decrease of $\langle p(m) \rangle$ is probably due to an increase of $q(m)$, while $p_c(m)$ decreases only slowly with increasing m (in the range of $m < +8$).

[2] The term "good observer" will be explained later in this section

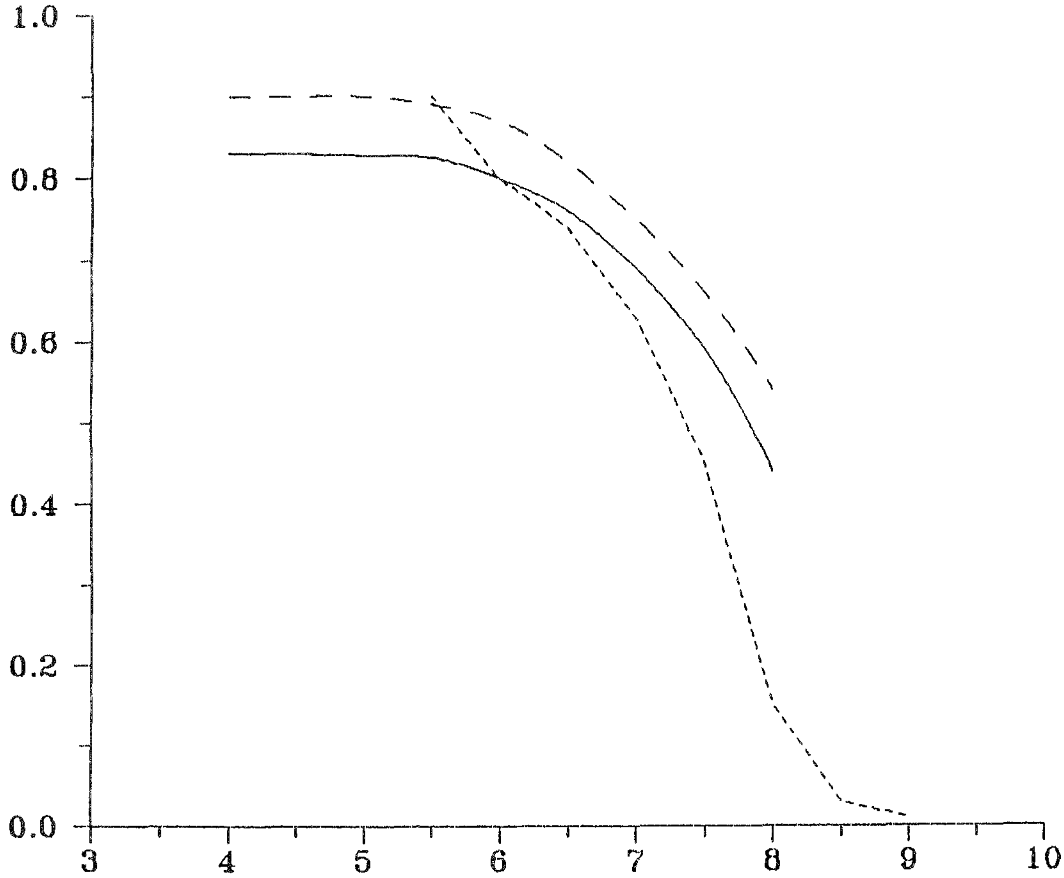

Figure 1 – The recording probability $\langle p(m) \rangle$ as a function of the meteor magnitude m. The solid line refers to all observers having used a db 10×80, while the dashed line refers to the "good observers" only (nrs. 2, 3, 5, 6, and 7). Both curves are smoothed. The short-dashed line is the result of Kvíz's analysis [12] of Czechoslovakian observations made during September 1964 with the same type of binocular. (See Sections 6 and 8.)

We must point out that *the probability of recording meteors telescopically depends on a variety of conditions*, e.g, the telescope, the quality of the observer, sky conditions, the observer's physical and psychological conditions, whence it is practically impossible to find any general formula for this probability. Thus the presented probabilities (valid for the particular group, telescopes and conditions) may serve only as a rough reference in case of other observations. Of interest is a comparison between our recording probabilities and the results obtained by Kvíz [12], which are also shown in Figure 1. While this will be discussed in Section 8, it is nevertheless apparent that modulo a shift of half a magnitude in the magnitude scale, Kvíz's results fit rather well with ours. This shift can probably be accounted for by different observing conditions.

It should nevertheless be understood that *every method of analyzing telescopic meteor observations must take into account that the real probability of recording meteors telescopically ($\langle p(m) \rangle$, and the less so $p(m,d)$) during the particular observation is unknown, and thus has to eliminate this problem.*

There were significant differences between individual observers. In the case of observations under common sky and meteor-activity conditions, well-satisfied for observations during the same intervals at the same site, observers' individual probabilities of recording meteors may be represented by their hourly rates. In Figure 2, the hourly rate of common TV-telescopic meteors (the eighth column in Table 2, called `HRCOM`) is shown versus the hourly rate of all telescopic recordings (the fourth column in Table 2, called `HRALL`) for each observer. In Figure 3, `HRCOM` is shown versus the hourly rate of meteors brighter than +8 (the fifth column in Table 2, called `HRBRIGHT`).

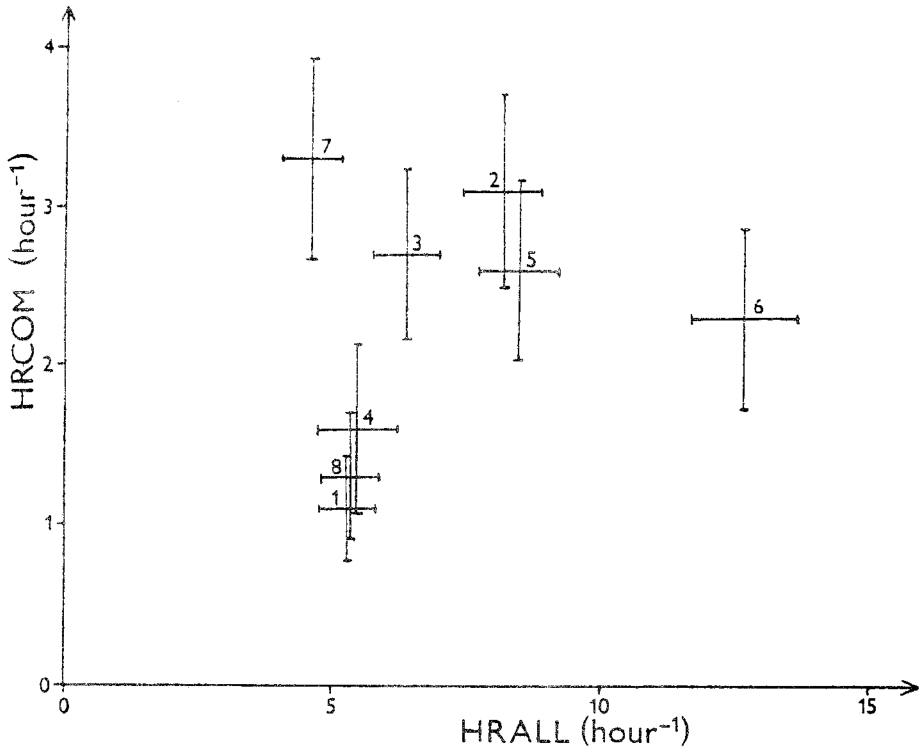

Figure 2 – Individual HRs of simultaneous TV-telescopic meteors (HRCOM) versus individual HRs of all meteors (HRALL). 68%-confidence intervals are indicated.

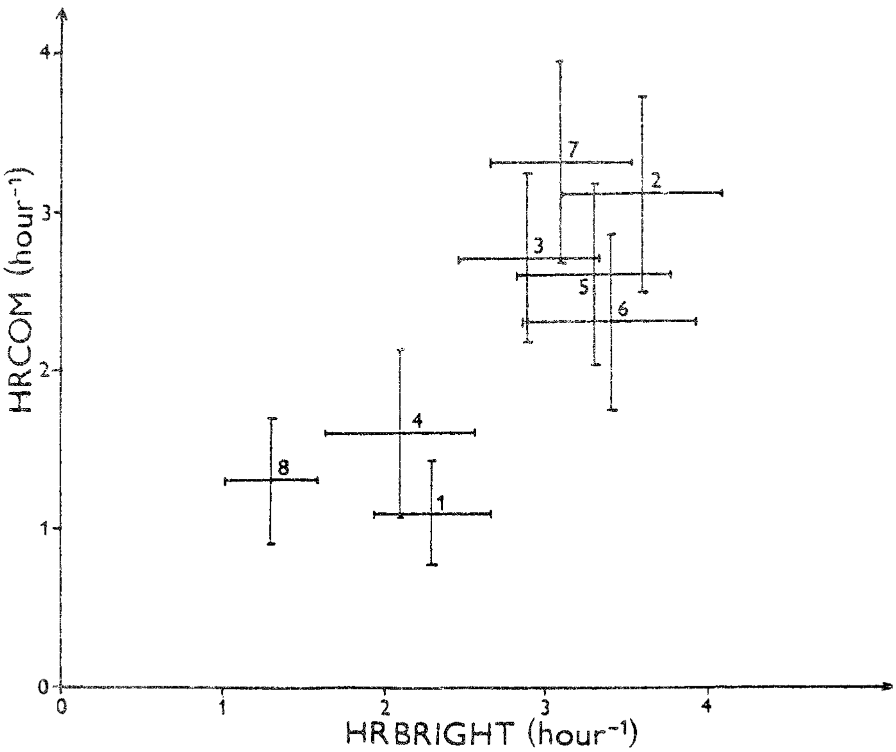

Figure 3 – Individual HRs of simultaneous TV-telescopic meteors (HRCOM) versus individual HRs of bright meteors (HRBRIGHT). 68%-confidence intervals are indicated.

Two groups of observers can be distinguished.

The first group consisting of observers nrs. 2, 3, 5, 6, and 7 has HRCOM values of about twice those of the other group. That first group will be called the *good observers*. As can be seen on the figures, all "good observers" had similar probabilities of recording meteor brighter than +8, since their HRBRIGHTs as well as their HRCOMs were almost the same. (There was a strong correlation between HRBRIGHT and HRCOM due to the fact that most of the meteors brighter than +8 were recorded by the TV-camera too.) Individual dependences of recording probability on meteor magnitude differed significantly from one another only in the range of fainter meteors, which shows up in differences between individual HRALLs (hourly rates of all records), in which usually fainter meteors dominate.

For these reasons the set of data points corresponding to "good observers" is stretched along the horizontal axis in Figure 2, while in Figure 3 it is very compact. From Figure 2 it is also apparent that HRCOM tends to decrease when HRALL increases. This is probably connected with a larger amount of "dead-time" for a larger HRALL.

While the group of "good observers" seems to be homogeneous at least in the sense of having almost the same recording probability for bright meteors, the other group (consisting of observers nrs. 1, 4 and 8) seems more inhomogeneous. Observer nr. 8 used a different binocular and after evaluating this difference it seems probable that if he were using a db 10 × 80, his values for HRBRIGHT would be similar to those of observer nr. 1. Furthermore, the adherence of observer nr. 4 to the group seems accidental. Indeed, his simultaneous TV-telescopic data represent a statistically very small sample and were obtained outside the interval of high Perseid activity (when this observer served as a time-recorder for the others). Hence his lower values for HRBRIGHT and HRCOM were really caused by lower meteor activity, not by a lower recording probability. Most likely, this observer would have belonged to the "good observers" if he had observed around the Perseid maximum.

7. Plotting errors in telescopic meteor recordings

A sufficiently large amount of data obtained during the parallel TV-camera and telescopic observations enabled us to perform an analysis of the accuracy of telescopic recordings of meteor trails. Some preliminary results were presented at the *1991 IMC* in Potsdam [13]; a more detailed analysis is presented below.

Deviations in telescopic meteor recordings may be described using several parameters:

1. deviation in position angle;
2. transversal shift: the shift of a point defined on the meteor trajectory perpendicular to the real trajectory; and
3. shifts in the recorded start and end points in the direction of the recorded trajectory. (These shifts may be described as a deviation of the recorded length and a sliding error.)

All these errors were discussed in, e.g., [10,14].

In this analysis, we only considered deviations in position angle and transversal shifts. An exact analysis of the errors mentioned under item 3 above was impossible, because of the lower sensitivity of the TV-system (cfr. item 5 in Section 3). Only a qualitative assessment of these kinds of errors was possible. In almost all instances, telescopic recordings of meteors were longer and covered the TV-recordings at both ends (i.e., when the limited field of view allowed the telescopic detection of the real beginning respectively ending). This is in agreement with the lower sensitivity of the TV-system (see above). The standard deviation of telescopic recordings of start as well as end points is certainly below 1°, probably between 0°5 and 1°0. As will be seen later, this estimate agrees well with the standard deviation of the transversal shift.

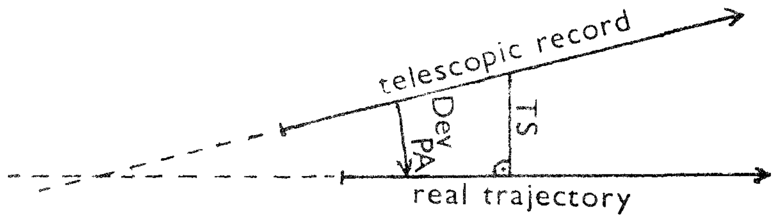

Figure 4 – The errors investigated. Both the deviation in position angle (DevPA) and transversal shift (TS) have positive signs in the figure shown.

Below are the exact definitions of the types of errors analyzed as well as some related terms (see also Figure 4).

- *Position angle* (PA) of a meteor trajectory: the angle between the meteor velocity projected on the celestial sphere (i.e., the direction of the apparent meteor trail) and the north. PA is oriented clockwise.
- *Deviation of* PA (DevPA): the difference between the PA of the telescopic trajectory recording and the PA of the real meteor trajectory (as shown by a TV-camera recording).
- *Transversal shift* (TS): the angular distance between the center of the telescopic trajectory recording and the real meteor trajectory perpendicular to the real trajectory. In other words, the TS is the oriented angular distance of the direction of the center of the recorded trajectory from the plane of the real trajectory. This distance is positive if the cross-product of the TS vector and the projected meteor velocity vector is oriented towards the observer (i.e., towards the center of the celestial sphere).

A thorough statistical analysis of the errors (DevPA and TS) of 152 telescopic recordings of the 40 simultaneous TV-telescopic meteors was performed. Below are the main results. It should be noted though that *all statements are valid for meteors of magnitude* +8 *or brighter only!*

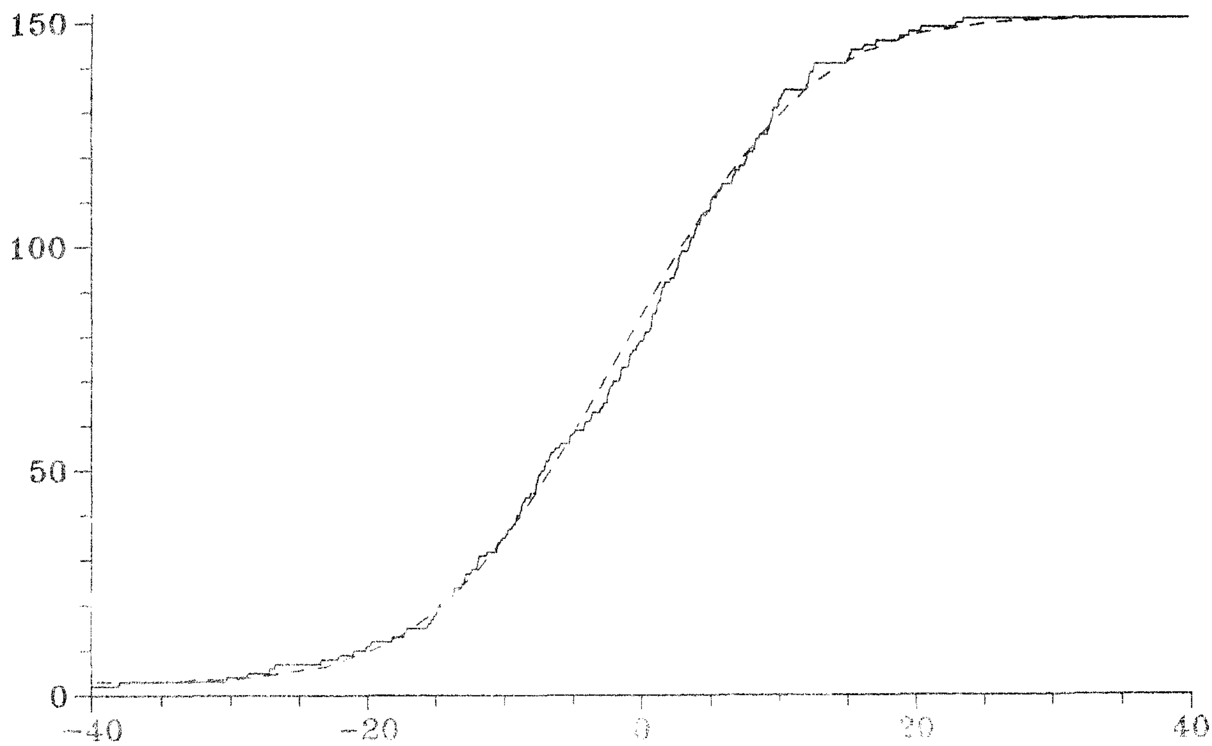

Figure 5 – Cumulative numbers of 152 telescopic recordings of 40 simultaneous TV-telescopic meteors versus DevPA. After excluding outlyers, a normal distribution with an SDPA of 10°9 fits rather well.

1. The *distribution of* DevPA *is rather normal*, with a small share of large errors (outlyers). See Figure 5. Out of 152 records, four have DevPAs greater than 3 times the standard deviation of the remaining 148 recordings. Those deviations were −179°, −76°, −38° and +42°, respectively. The other 148 recordings have a rather normal distribution with a standard deviation (SDPA) of 10°9 and a mean deviation of −1°4. (This value is due to the first night of the observing campaign only, which was characterized by a poor recording accuracy—see also item 5 below and Table 3.) On other nights the mean deviation of PA was quite close to 0°.

Table 3 – Analysis of the accuracy of telescopic records of meteor trajectories (significant dependences only).

Selection criteria	⟨DevPA⟩	SDPA	⟨TS⟩	SDTS	Nr. rec.
All records exc. outlyers	−1°4	10°9	+0°05	0°51	148
Individual nights					
"Night 1" (Aug 07–08 to 09–10)	−5°7	12°9	+0°16	0°75	35
"Night 2" (Aug 10–11)	−0°2	11°3	+0°05	0°34	33
"Night 3" (Aug 11–12)	+1°6	10°2	+0°07	0°44	24
"Night 4" (Aug 12–13)	−1°0	8°3	+0°01	0°40	40
"Night 5" (Aug 15–16)	+0°1	8°9	−0°06	0°46	16
"Good observers"					
"Nights 1 to 2"	−2°3	12°0	+0°15	0°57	51
"Nights 3 to 5"	+0°1	9°2	−0°03	0°44	66
Other observers					
"Nights 1 to 2"	−5°2	13°4	−0°04	0°63	17
"Nights 3 to 5"	−0°5	8°8	+0°19	0°32	14
Individual observers					
Observer nr. 1	−3°0	11°4	−0°08	0°34	11
Observer nr. 2	+0°5	8°8	+0°12	0°54	25
Observer nr. 3	−1°1	11°2	+0°07	0°51	26
Observer nr. 4	−2°6	12°3	+0°20	0°74	10
Observer nr. 5	+2°1	10°5	+0°06	0°54	22
Observer nr. 6	−5°4	9°6	+0°02	0°63	17
Observer nr. 7	−1°8	10°9	−0°02	0°33	27
Observer nr. 8	−3°6	11°8	+0°08	0°38	10
"Good observers"	−0°9	10°6	+0°05	0°51	117
Other observers	−3°1	11°8	+0°06	0°53	31

2. *Transversal shifts are quite small* due to the magnification of 10×: their standard deviation equals 0°51. Thus deviations in PA are much more important for radiant determination from telescopic recordings than transversal shifts.

3. There is *no significant dependence of the accuracy (i.e.,* SDPA*) on any of the following parameters*: meteor magnitude, observed length, angular velocity, distance from the center of the field of view, orientation of the meteor trajectory with respect to the center of the field of view, presence of a train and the observer's opinion about quality. All weak dependences mentioned in [13] were found to be statistically non-significant or biased by an incomplete elimination of outlyers.

4. *Differences in accuracy between telescopic recordings of individual observers were rather small, but significant.* Standard deviations of PA of different observers varied from 8°8 to 12°3 (see Table 3). There was a small difference between the "good observers" (cfr. previous section) and the others: the SDPAs for both groups were 10°6 and 11°8, respectively.

5. *An important improvement in the accuracy of the recorded PA during the campaign* was found (see Figure 6). In the first night, the SDPA was about 13° (the other accuracy parameters being also very poor). During the following nights, it gradually decreased and after three observing nights it became stable around 8°–9° (see Table 3). This tendency was evident for both "good" and other observers.

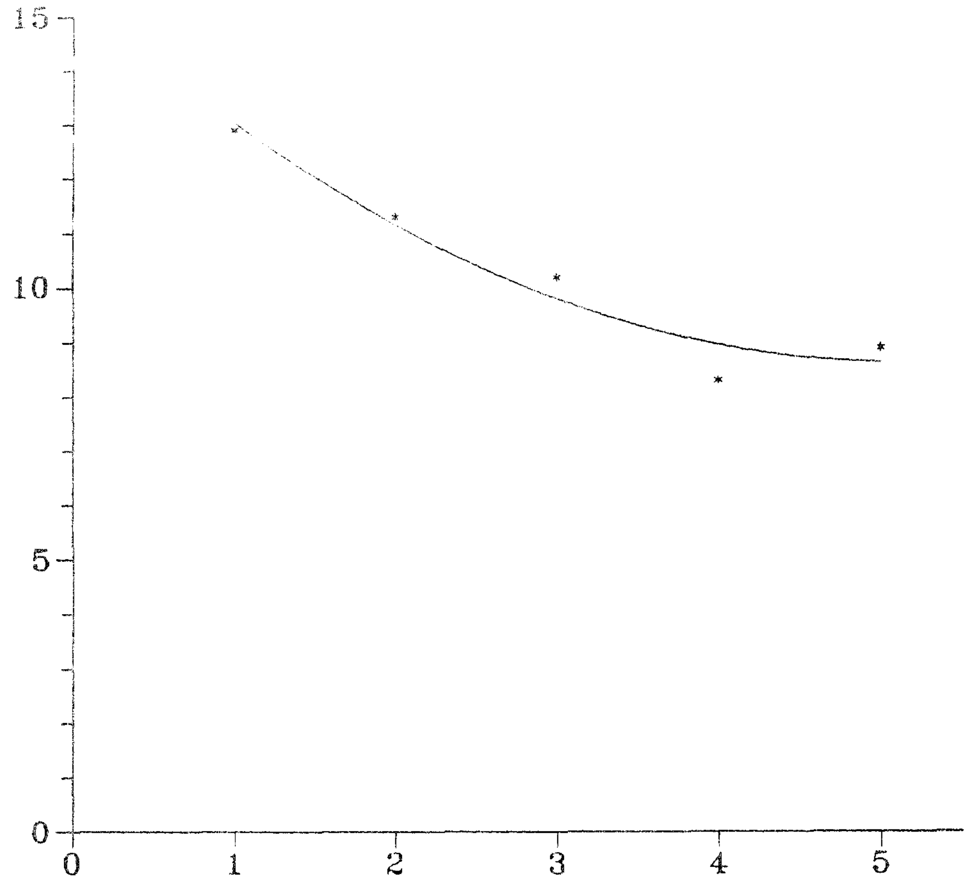

Figure 6 – Gradual improvement of accuracy of telescopic meteor recordings (expressed as SDPA in degrees) during the campaign.

It should be noted that "Night 1" in Table 3 and Figure 5 really includes three nights (August 07–08 to 09–10), during which relatively little time was spent on parallel observations, due to clouds. This formal merging of three poor nights does not affect significantly the result of the analysis mentioned in item 5 above, as those three night are approximately equivalent with one good observing night.

8. Discussion

Recording probability

The probability of recording meteors brighter than magnitude +8 was already discussed in Section 6. Here we would like to compare our results with those of Kvíz's analysis [12].

Kvíz analyzed telescopic records of simultaneously observed meteors during the Czechoslovak meteor expedition in September 1964, during which also db 10 × 80 binoculars were used. He obtained recording probabilities that are in good agreement with ours, provided his magnitude scale is shifted over half a magnitude to the larger values (which may be due to different observing conditions).

The necessity for such a shift is also supported by the fact that the probability of recording meteor of +9 obtained by Kvíz is only about 1%, while in our case it must be approximately an order of magnitude larger, as is evident from the not-so-small portion of magnitude-+9 meteors in our full data-set.

However, we must repeat that the dependence of the probability $\langle p(m)\rangle$ on m presented in Figure 1 provides but a rough reference for telescopic meteor observations. The real dependence will vary with the particular conditions (telescope, quality of observer, sky conditions), but the general tendency (constant recording probability for bright meteors and its gradual decrease towards fainter ones) is evidently a general feature of each telescopic meteor observer. Nevertheless, every analysis of telescopic meteor observations must take into account that the real dependence of the probability $p(m, d)$ on m and d is unknown, and thus must effectively eliminate this problem. Suitable methods are described in, e.g., [4,11].

Plotting errors

The analysis of plotting errors on recordings of meteors of magnitude +8 or brighter, presented in Section 7, has several important consequences.

1. *Systematical deviations in telescopically recorded* `PA`*s do not occur. The distribution of* `DevPA` *is rather normal* (not taking into account a few outlyers). Finally, this analysis indicates *no significant dependence of* `DevPA` *on any telescopically recorded meteor parameter* (such as meteor magnitude, velocity, position in the field of view, etc.). However, this last statement needs confirmation from a larger sample of data.

   All these findings are satisfactory, as they are necessary conditions for the good applicability of the analyzing methods in, e.g., [4,11].

2. Differences between different observers are small. *All individual* `SDPA`*s are in the range of only a few degrees around* 10°. This justifies the use of similar criteria for analyzing plottings of different observers.

3. *Regular observations are needed to obtain very high accuracies.* In the case of seasonal observers, the recordings obtained during the first observing night after a long period of non-activity are very poor (here, the `SDPA` was about 13° for the first night). After several more nights, an important improvement is evident (here, the `SDPA` becomes 8°–9°). It is probable however that for very active observers spending some ten hours on telescopic observing each month, the `SDPA` would still be lower (perhaps around 5°). This value would be consistent with `SDPA`s of very experienced visual observers [15].

5. Even in the case of seasonal observers, the accuracy of radiant position and structure determination by the telescopic method is better, but the difference is not so large as is usually assumed. The difference is caused mainly by the very small transversal shift, due to magnification. In telescopic work, almost the entire error on the radiant position is caused by the error on `PA`, while in the case of visual work, the errors on both `PA` and `TS` are significant.

   A second reason why telescopically-determined radiants are more accurate is the fact that visual meteors are usually seen at greater distances from the radiant.

It is of interest to compute errors on telescopically-determined radiant positions and compare them with the results of Koschack's analysis [15]. The standard deviation of the recorded meteor line from the true position of the radiant (`SDRP`) results from the standard deviation on the position angle (`SDPA`) and transversal shifht (`SDTS`).[2]

[2] More precisely, the deviation of the recorded meteor line from the radiant position is the angular distance between this line and the true radiant position on the celestial sphere.

It is easy to show that

$$\mathtt{SDRP} \approx \sqrt{\mathtt{SDPA}^2 \sin^2 D + \mathtt{SDTS}^2 \cos^2 D}. \tag{4}$$

where D is the distance between radiant and meteor (see, e.g., [15]). Of course, TS here is not the same as d in Koschack's analysis [15], but differences are small.

Using the values of SDPA and SDTS that resulted from this and Koschack's analysis (several estimated values are marked by "?"), SDRP-values for various cases were calculated (Table 4). It must be emphasized that the values for "very-experienced observers" are most probably limit values. It seems likely that no other improvement of accuracy of neither telescopic nor visual plottings is possible.

Table 4 – Standard deviations of recorded meteor line from radiant position (SDRP) in various cases.

Distance field-radiant	Observer (SDPA,SDTS)		
	Telescopic		Visual
	seasonal (10°, 0°.5)	very-experienced (5°?, 0°.3?)	very-experienced (5°, 3°?)
12° (suitable for very fast meteors)	2°.1	1°.1	
20° (very slow meteors)	3°.4	1°.7	
30° (typical for visual observations)			3°.6

It is also useful to compare our results with those of previous statistical analyses of simultaneously observed meteors. Two such analyses are of major importance.

Grygar and Kohoutek [14] analyzed 515 meteors observed simultaneously during the Czechoslovak meteor expedition in July 1958. (Binoculars db 10×80 and 25×100 were used.) They found that the dependence of SDPA on magnitude had two distinct ranges, in each of which the SDPA was independent of the magnitude. The SDPA was about $8° \pm 1°$ for meteors of magnitude +8 and brighter (this range accidentally coincides with the range we investigated) and about $13°.0 \pm 1°.5$ for meteors of +8.5 and fainter.

The value of 8° of the SDPA for brighter meteors agrees well with our results, providing the 1958 observers were somewhat more regular than ours, or the 1958 expedition lasted significantly longer than the 1991 observations in Ondřejov. Contrary to our result, Grygar and Kohoutek found a weak relationship between the SDPA and the meteor length: shorter meteors were recorded somewhat less accurate than longer ones.

Another important analysis of plotting errors was made by Znojil et al. [10]. They analyzed plotting errors on telescopic recordings of meteors observed simultaneously at the Ondřejov expeditions in August 1972 (12 nights, 22 observers) and July–August 1973 (8 nights, 23 observers). They found a median value of the SDPA of individual observers of 10°.1 (varying from 6°.3 to 13°.2 for different observers.) and a median value of SDTP of 0°.48 (varying from 0°.25 to 0°.93). Their results are in excellent agreement with our results. Although they did not differentiate between meteors of various magnitudes, their results are valid mostly for meteors brighter than about

+8.5, as only such meteors were often observed simultaneously [16]. The somewhat better accuracy of the 1972–73 records was very probably due to the longer duration of these meteor expeditions and partially also to the presence of more regular observers in the 1973 expedition.

Acknowledgments

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- if you intend to go the *IMC* in Smolenice and you have not yet send in your registration form, you should do so at once;
- the *Potsdam IMC Proceedings* will appear shortly. Ordering information is on the outside back cover;
- we can only put spectacular photographs on the front cover if we receive then. So, do not forget to send prints of your best meteor photographs to *WGN*!

Fireballs and Meteorites

Fireball

Czechoslovakia, December 13, 1991, $3^h55^m22^s$ UT

Pavel Spurný and Zdenek Ceplecha, Ondřejov Observatory

In the early morning of December 13, 1991, a −10 maximum absolute magnitude Geminid fireball was photographed over Czechoslovakia.

A very bright Geminid fireball of −10 maximum absolute magnitude was photographed by four Czech stations of the European Network. The fireball traversed a 64 km luminous trajectory in 2.0 seconds and terminated its light at a height of 41 km.

The following results are based on all available photographs measured by J. Keclíková.

Table 1 – Trajectory data.

	Beginning	Maximum light	Terminal
Velocity (km/s)	35.29	28.5	17.3
Height (km)	93.73	45.8	41.20
Latitude (° N)	49.0642	49.126	49.1321
Longitude (° E)	15.1744	15.623	15.6663
Abs. magnitude	− 1.85	−10.03	− 1.69
Photom. mass (kg)	1.8	0.5	none
Z R (°)	35.07		35.40

Fireball type: I

Ablation coefficient: 0.0126 s^2/km^2

Table 2 – Radiant data.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
α (°)	112.81	111.51	
δ (°)	+ 32.75	+ 31.94	
λ (°)			53.80
β (°)			+ 9.98
Initial velocity (km/s)	35.29	33.67	33.28

Table 3 – Orbital data.

Orbit (1950.0)	
a	1.277 AU
e	0.8898
q	0.1407 AU
Q	2.413 AU
ω	325°14
Ω	260°0338
i	21°70

Fireball

Czechoslovakia, January 2, 1992, $20^h10^m01^s$ UT

Pavel Spurný, Ondřejov Observatory

In the evening of January 2, 1992, a slow-moving −11 maximum absolute magnitude fireball was photographed over Czechoslovakia.

A slow-moving fireball of −11 maximum absolute magnitude was photographed by four Czech stations of the European Network. The fireball traversed a 65 km luminous trajectory in 3.7 seconds and terminated its light at a height of 33 km.

The following results are based on all available records measured by J. Keclíková.

Table 1 – Trajectory data.

	Beginning	Maximum light	Terminal
Velocity (km/s)	19.938	16.28	8.0
Height (km)	84.79	40.6	32.67
Latitude (° N)	49.7602	49.991	50.0327
Longitude (° E)	16.4287	16.157	16.1069
Abs. magnitude	− 2.8	−11.3	− 2.1
Photom. mass (kg)	41.3	14.8	few grams
Z R (°)	36.26		36.61

Fireball type: I or II

Ablation coefficient: 0.0171 s^2/km^2

Table 2 – Radiant data.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
α (°)	82.14	82.75	
δ (°)	+18.10	+15.00	
λ (°)			34.68
β (°)			− 3.50
Initial velocity (km/s)	19.942	16.412	38.658

Table 3 – Orbital data.

Orbit (1950.0)	
a	2.863 AU
e	0.7223
q	0.7950 AU
Q	4.931 AU
ω	57°.02
Ω	101°.1812
i	3°.82

Fireball

Czechoslovakia, February 2, 1992, $19^h18^m04^s$ UT

P. Spurný, Ondřejov Obs., and V. Porubčan, Astron. Inst., Bratislava

In the evening of February 2, 1992, a fast-moving −13 maximum absolute magnitude fireball was photographed over Czechoslovakia.

A fast-moving fireball of −13 maximum absolute magnitude was photographed by one Czech and one Slovak station of the European Network. The fireball traversed a 130 km luminous trajectory in 3.7 seconds and terminated its light at a height of 44 km.

The following results are based on all available records measured by J. Keclíková.

Table 1 – Trajectory data.

	Beginning	Maximum light	Terminal
Velocity (km/s)	37.76	36.55	11
Height (km)	96.9	58.6	44.2
Latitude (° N)	48.162	48.012	47.951
Longitude (° E)	18.644	17.528	17.099
Abs. magnitude	− 3	−13	− 4
Photom. mass (kg)	50	30	none
Z R (°)	65.7		66.6

Fireball type: I or II

Ablation coefficient: 0.0190 s^2/km^2

Table 2 – Radiant data.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
α (°)	160.5	161.8	
δ (°)	+ 25.3	+ 24.3	
λ (°)			103.5
β (°)			+ 14.5
Initial velocity (km/s)	37.76	35.79	37.73

Table 3 – Orbital data.

Orbit (1950.0)	
a	2.36 AU
e	0.9012
q	0.233 AU
Q	4.48 AU
ω	307°7
Ω	312°6088
i	28°1

A Galaxy Bisected by a Fireball?

Duncan Steel, Anglo-Australian Observatory

A fireball is reported, apparently intersecting the galaxy NGC 253 on a photograph with the U.K. Schmidt Telescope in Australia on September 8, 1991, between 15^h47^m and 16^h47^m UT.

The photograph on the cover of this issue apparently shows a galaxy (NGC 253) being zapped by an extremely bright fireball; however, their widely different ranges mean that this was not really a celestial near-miss. This galaxy is at $\alpha = 00^h45^m$, $\delta = -25°34'$. Since there were no other reported observations a radiant for the fireball could not be determined. The observer who exposed this plate was Dr. Shaun Hughes. The photograph was taken on September 8, 1991. The 60-minutes exposure started at 15^h47^m UT.

The print covers a field of about 0°5 by 0°7, only a small part of the whole 6°4 square frame taken with the U.K. Schmidt Telescope (for another example of a photograph taken with that instrument see the cover of *WGN* 19:3, June 1991). This fireball covered almost the whole of the frame from top to bottom, only the beginning being seen here in an expanded view. This is by far the brightest fireball recorded amongst the 15 000 plates exposed with this telescope since it began operating in 1973.

The full photo will most likely appear in a future issue of *Sky and Telescope*; high-quality photographic reproduction beyond the scope of *WGN* is required to see all of the details so that there is no point in printing it here.

However, there is something of interest in the photo for both meteoriticists and meteorologists. A notable feature of the complete fireball is that since it produced a persistent train, wind-driven distortion of that train was clearly seen, the wind direction changing with altitude; distinct inhomogeneities in the train are also evident. Even in this short portion of the trail (about one-ninth of the total length, and the dimmest part) the action of the upper atmospheric winds—of order 100–200 km/h at meteor heights—in dispersing the train can clearly be seen.

One other thing recorded in the photograph, which may be just glimpsed, is a faint satellite trail which also cuts across the galaxy, and indeed the path of the fireball too.

Meteors are not very often seen on Schmidt plates for a number of reasons. The U.K. Schmidt Telescope is a younger twin in size (1.2 m aperture) to the Oschin Schmidt at Palomar Mountain in California. That telescope entered operation in the late 1940s, when meteor science was in its infancy, and apparently Dr. Fred Whipple used some of the early plates in his meteor studies: since meteors are relatively close their heights could be estimated from the amount that the trains were out of focus.

A Meteorite in Central Africa

Noel White

Reports are brought to attention concerning a meteorite fall on the evening of March 11, 1929, in Belgian Congo (now Zaire).

A relative, Dr. J.F. Carrington, lived and worked in Zaire as a teacher and missionary for most of his life and was an authority on the Lokele river peoples and their drum language. While conducting research into early church records of this area, he found the following account.

1929 March.

"We the people of Yakusu saw a large meteorite going down-river in the evening of March 11 and then we heard it explode down-river. We would be grateful if a village teacher or anyone who saw it come down to Earth would tell us where that was and what happened then."

Letter from Botemalikolo, April.

"The star we call a meteorite, I saw that star in the north as it looked a bit like lightning though smaller, and as it was moving at great speed I, Botemalikolo, nearly drowned because I was in my small canoe so as to go more quickly on my journey, and I jumped hard like a man who has an epileptic fit. I saw a big light over the river, it shone over all the people there and over their nets, it shone over the whole countryside. It came from the north and passed over to the south and there it fell like a great fire. After it had fallen I saw lights in my eyes and then I was able to see the stars again. After it fell to Earth we all heard tremendous thundering: Kwu-U-U and everybody around shouted Ho-o-o. We have never seen a thing like this before and I am 26 or 27 years old, though there was a small one on the 24th of December 1928, I marveled that such a miracle could take place."

Letter from Lyalano Isaiah.

"To my friends at B.M.S. Yakusu. You asked us teachers in the villages to let you know where the meteorite fell. We, Liyalano Isaiah and Kalokola Samuel, teachers at Ilambi, saw the place where the meteorite fell. It was between Lieke and Yafela. Friends in very truth, that place looked as though someone had cut down trees with a big axe. The grass had been burned with fire. We marveled indeed at the affair."

Note: Lieke's position is approximately $\lambda = 24°06'$ E, $\varphi = 0°40'$ N, on the East bank of the river Lomami, a tributary of the River Zaire, with Yafela some distance west of the river in the Upper Zaire (then Belgian Congo).

Dr. Carrington has told me that before the white-man came to that part of Africa, the native people were using tools made from meteoric iron and that they were magnetic.

Noctilucent Clouds:

Call for Observations from North-Western Europe

Alastair McBeath

Amateur observations of noctilucent-cloud phenomena during the summer season are requested.

Noctilucent clouds can be seen at night in summer when the Sun lies between 6° and 12° below the horizon, from about 50°–65° latitude in either hemisphere. They are thin ice-crystal clouds which form at around 80–90 km altitude. This means that they are still able to reflect sunlight and remain visible while the "ordinary" tropospheric cloud (which normally does not exceed 12 km altitude or so) is in darkness, hence the name which literally means "shines-at-night".

The clouds do not occur on every summer night, and their formation may be associated with higher than normal levels of meteoric dust in the upper atmosphere. They may also be indicators of the presence of high-altitude methane concentrations, and thus may possibly be important in our understanding of the behavior of the global atmospheric ecosystem as a whole. There is some evidence to suggest the clouds are less frequently noted during periods of increased solar/auroral activity, perhaps as a result of aurorae heating up the lower thermosphere, the layer just above the region where noctilucent clouds form.

Observations of the presence or absence of noctilucent clouds on every clear night during the summer are needed to ensure we build up as complete a pattern of cloud occurrence as possible. If noctilucent clouds are present, detailed measurements of their angular extent, brightness and appearance every fifteen minutes are needed (made on the hour, half-hour and quarter-hours), either visually or photographically. If auroral activity is present simultaneously or on the same night, it is important to record this too.

Professional scientists presently rely almost solely on amateur data in this field, especially for long-term noctilucent cloud studies, so all contributions are very welcome.

Observers in North-Western Europe only can obtain more detailed instructions from:

Dr. D. Gavine, 29 Coillesdene Crescent, Edinburgh, EH15 2JJ, Scotland, U.K.

to whom all observations of the phenomenon made from this region should be sent. Interested observers in other parts of the world should contact their nearest major amateur astronomical organization, either regional or national, for details on where the noctilucent cloud coordinator is located for their area. Please try to enclose return postage (stamps for the same country, an IRC for all others) when writing to any of the above.

Good luck to all noctilucent cloud watchers, particularly those in the northern hemisphere, where the 1992 May-August noctilucent cloud "season" will shortly be starting.

Visual Observational Results

1991-92 Fall and Winter U.K. Visual Results

Alastair McBeath

Activity detected by *JAS Meteor Section* observers from the U.K. between September 1991 and January 1992 is briefly reviewed. Notable events included a possible "burst" of Taurids fireballs on November 8-9, 1991, confirmation that fainter Geminids reach a maximum in advance of the main visual peak, and a higher than normal Quadrantid return.

1. Introduction

British *JAS Meteor Section* visual observers enjoyed some further success after the 1991 Perseids, with conditions particularly good in September and December. Ten watchers spotted 2199 meteors in $273^{h}48$ from September 1991 to January 1992, inclusive. The observers were:

Neil Bone, Shelagh Godwin, David Jenkins, Craig Johnson, Richard Livingstone, Tony Markham, Alastair McBeath, Steve Phipps, Graham Pointer, Ian Rigney.

2. Magnitudes and trains

Global magnitude distributions for the δ-Aurigids, Taurids, Geminids and Quadrantids are given in Table 1, along with combined sporadic figures from September to November (S–N) and December to January (D–J) for comparison. Table 2 contains train details for each shower and the two sporadic groups. The often small number of trained meteors made a more thorough analysis, as suggested in [1], impractical. No meteor fainter than magnitude +3 left a persistent train.

Table 1 – Global magnitude distributions for the indicated showers and sporadics, 1991-91 Fall-Winter.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	$\overline{\text{Lm}}$	$\overline{m}_{6.5}$
δ-Aur	1	2	2	11	11	10	14	12	4	67	6.12	2.35
Tau	1	0	1	7	6	12	9	4	2	42	5.87	2.39
Spor (S–N)	5	4	15	50	101	164	211	121	57	728	5.77	3.05
Gem	1	5	11	30	59	90	123	73	7	399	5.60	3.18
Qua	6	7	17	27	40	55	80	37	20	289	5.90	2.62
Spor (D–J)	2	4	5	25	62	93	128	68	22	409	5.82	3.10

Table 2 – Global trained meteor numbers (N), percentages (%) and mean durations ($\overline{D}$) in seconds, per magnitude class for the named showers and sporadic groups, 1991-92 Fall-Winter.

Shower	δ-Aurigids			Taurids			Sporadics (S–N)		
Magnitude	N	%	$\overline{D}$	N	%	$\overline{D}$	N	%	$\overline{D}$
-3^-	1	100	3.0	0			4	80.0	3.3
-2	2	100	3.0	0			3	75.0	1.5
-1	2	100	1.8	0			10	66.7	2.5
0	6	54.5	1.8	0			20	40.0	1.6
+1	6	54.5	1.0	1	16.7	0.5	17	16.8	1.5
+2	3	30.0	0.7	0			16	9.8	1.3
$+3^+$	2	14.3	0.4	0			3	1.4	0.6
Total	22	32.8		1	2.4		73	10.0	

Table 2 – continued.

Shower	Geminids			Quadrantids			Sporadics (D–J)		
Magnitude	N	%	$\overline{D}$	N	%	$\overline{D}$	N	%	$\overline{D}$
-3^-	0			5	83.3	6.6	1	50.0	5.0
-2	3	60.0	0.5	4	57.1	20	2	50.0	1.5
-1	2	18.2	0.5	4	23.5	0.8	3	60.0	1.0
0	1	3.3	0.5	2	7.4	0.5	5	20.0	1.1
+1	0			3	7.5	1.0	8	12.9	1.8
+2	1	1.5	0.5	0			7	7.5	1.4
$+3^+$	0			0			2	1.6	0.8
Total	7	1.8		18	6.2		28	6.9	

3. δ-Aurigids

This shower was observed as an individual stream for the first time by the *JASMS* in 1991. Before this, these meteors would have been classed as "α-Aurigids" (see [2]). Only low activity was detected in September–October, never more than 6 meteors per hour, and no obvious maxima were seen. The relatively small amount reliably witnessed seemed to be generally brighter than *IMO* suggests (as in [3] for instance), and about one in three left trains.

4. Taurids

Poor weather made for patchy Taurid observations, and while the magnitude and train data seem reasonable enough from past returns, they cannot be seen as particularly enlightening in view of the low meteor numbers.

One point not illustrated in the tables above is of interest, however. The night of November 8-9, 1991, brought a major auroral storm which was very widely seen over much of the world. Clear skies in the U.K. meant many observers were alerted and were outdoors observing, and subsequently a number of casual reports of good meteor rates were received, in spite of the greatly reduced limiting magnitude due to the all-sky auroral "light pollution"

Experienced meteor/auroral observers commented that meteor numbers were higher than they had expected from previous auroral events, and many were pleasantly surprised to record one or more fireballs. A large amount of the meteors from this night were attributed to the Taurid streams, though the casual nature of the reports precludes their inclusion in the normal analysis. One period especially seemed very fireball-productive, the hour around 23^{h} UT. From that time, no fewer than 15 separate fireball reports were received. Unfortunately, few reports gave any useful details, since most watchers were clearly far more intent on the aurora than meteors, but a minimum of four actual events—probably all Taurids—seem to have occurred between approximately $22^{h}40^{m}$ and $23^{h}15^{m}$ UT, the brightest of which was estimated at magnitude -10. If correct, this may provide further evidence of "clumps" of fireball-producing material within the Taurid streams, much as the various Taurid papers and references in *WGN* 20:1 suggest.

It is perhaps worth noting that reliable observers active once the aurora had lessened in intensity (after 0^{h}–2^{h} UT, depending on location) recorded normal Taurid rates, but no further fireballs.

5. Geminids

Conditions allowed several observers a useful view of the Geminid maximum on December 13-14, when a mean ZHR of about 100 was recorded. This had dropped to about 80 by the next night, and fell away after this much as usual. The pre-maximum period suffered from hazy or cloudy skies generally, though some reports showed the humble beginnings of activity earlier in December.

One curious feature was the much fainter nature of the Geminids in 1991, a fact which almost certainly reduced their train proportions too. However, as the bulk of Geminids were recorded on the maximum night only, when the latest watches concluded some eight hours in advance of the predicted peak (due December 14, 12^{h} UT [3]), this is not too surprising, as it has been known for some time that fainter Geminids peak in advance of the main visual maximum. This is a useful apparent confirmation of earlier data, though Spalding's formula [4] implies $\lambda_{\odot} = 262.^{\circ}0 \pm 0.^{\circ}05$ for the $\overline{m}_{6.5}$ of $+3.2$ obtained for December 13-14 only (allowing $+0.^{\circ}7$ for precession from epoch 1950.0 to 1992.0), rather than the mean value for the watch times here (about 2^{h} UT), which was $\lambda_{\odot} = 261.^{\circ}7$. If true, this may suggest a small change in the Earth's passage through the Geminids since the data in [4] was collected.

6. Quadrantids

Only one observer, the author, was able to cover the Quadrantid maximum in 1992, hence the Quadrantid data in Tables 1 and 2 need to be viewed with some caution. A single observer's work is never enough to base reliable judgements on, no matter how experienced the individual. However, the data seem to fit into the overall pattern of previous years, and the mean magnitude was noted to brighten as the night of January 3-4, 1992, progressed. Rates were about 120–130 meteors per hour at best, though the higher peak reported elsewhere at about $4^{h}30^{m}$ UT could not be confirmed owing to clouds. A variable limiting magnitude, thanks to haze, was also a problem, but from a personal point of view, the night was very interesting indeed!

Acknowledgments

My thanks as ever go to the *JASMS* observers, whose contributions and support continue to make these reports possible.

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Spanish Visual Observations in the Winter 1991-92

José M. Trigo

Observations of the 1992 Quadrantids in Spain are presented.

During the Geminid maximum the sky was clouded in the Valencia region, so we were not able to perform observations. Other groups of the *Spanish Meteor Society (SMS)* detected normal activity during the night of the maximum with ZHRs of about 100. The study of the large-scale structure of this stream is very difficult with few data but we hope to collect enough data to prepare a thorough analysis in the next years.

During the last week of December, two observations were carried out to study the sporadic activity. No radiant activity from showers recognized by *IMO* was apparent on December 28 or 29 (from nightfall to midnight). We totaled 2 nights, 5.13 hours of effective observing time and 59 meteors in December 1991.

Several members of the *SMS* in Valencia, Barcelona and the Canary Islands observed during the night of January 3-4 and noted a very continuous flux of Quadrantids. The activity seen by the author (with a tape recorder, using the counting method) was very strong and persisted through the entire night, but with a maximum between 2^h30^m and 5^h30^m UT. I worked with five-minute intervals and noted data on twins and bundles detected during this night.

Table 1 – Magnitude distributions of the Quadrantids and Coma Berenicids on January 3-4, 1992, as obtained by the author.

Sh	$\overline{Lm}$	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$	Tr
QUA	6.50	2	4	14	30	31	36	91.5	151	116.5	58	3	537	2.55	85
COM	6.50							1.5	1	3.5	3.5	0.5	10	4.05	0
SPO	6.50		1	1	2	3	5	10.5	15.5	22	14.5		75	3.01	8

During the night, the *SMS* campaign on the large-scale structure of the Quadrantid meteor shower was successful. Two other observers also participated: Oscar Cervera (CEROS) and Sebastià Torrell (TORSE) from Valencia and Barcelona. The limiting magnitude was very high: respectively 6.6 and 6.3 in both sites. The author's ZHRs are in the range 150–200 at several intervals. From $4^h18^m33^s$ till $4^h19^m25^s$ UT I saw 10 Quadrantids! Our group worked from several sites to study the internal structure of the Quadrantids.

A complete study of the Quadrantids with interesting results on the ZHRs photographically obtained by the Barcelona and Valencia groups is being prepared. The ZHRs were obtained in situations fairly similar to visual observations, so the method we applied is very interesting for moments of very high activity.

1992 Quadrantid and Coma Berenicid Activity in Spain

Luis Ramon Bellot Rubio

The 1992 Quadrantid and Coma Berenicid activity in Granada, Spain, from January 1 to 4 is discussed. The position of the Quadrantid radiant was photographically determined. A possible increase of Coma Berenicid activity is commented upon.

1. Introduction

Good weather in the first week of January 1992 allowed a very successful Quadrantid campaign from January 1 to 4. Some other showers were monitored as well, such as the Coma Berenicids, the α-Leonids and the ω-Canis Majorids. Observations were made simultaneously by Antonio Roman and the author from Granada, Spain, during $23^{\mathrm{h}}.22$ of effective time. Table 1 summarizes magnitude distributions and train data for the 991 meteors seen.

Table 1 – Magnitude distributions and trained meteors per shower

Sh	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	Tr	$\overline{\mathrm{Lm}}$	$\overline{m}_{6.5}$
QUA	2	2	17	49	201	194.5	77	3.5		546	49	6.35	2.63
COM				8.5	22.5	41.5	22.5	4		102	6	6.32	3.11
ALE					2	5	1.5	0.5		9	0	6.32	3.24
OCM		1	0	0	0.5	0.5	1			3	0	6.20	
SPO		2	3.5	22	70	126.5	86.5	8	0.5	319	29	6.33	3.08

In the following paragraphs we will comment on some interesting features of these showers.

2. Quadrantids

The 1992 Quadrantid return was normal, reaching a ZHR of 105 ± 10 between $5^{\mathrm{h}}00^{\mathrm{m}}$ and $6^{\mathrm{h}}20^{\mathrm{m}}$ UT on January 4. There were some cases of simultaneity, most of them with two meteors and seldomly with three. From $3^{\mathrm{h}}00^{\mathrm{m}}$ till $6^{\mathrm{h}}20^{\mathrm{m}}$ UT we could detect 9 such appearances. Counts were carried out in five-minutes intervals. The maximum five-minutes' rate was 13 Quadrantids. However, between maximum intervals there were some deep gaps, the most important of them between $5^{\mathrm{h}}45^{\mathrm{m}}$ and $5^{\mathrm{h}}50^{\mathrm{m}}$ UT.

Pre-maximum nights showed 16% of the Quadrantids with a train, while during the maximum, only 8.6% had a train. As the number of meteors used to compute the first rate is low (32), this fact could be explained by selection effects. However, more data are needed to find out whether this feature is real or not.

On the night of January 3-4, also photographic work was carried out. We were able to catch 7 meteors, 5 of which were Quadrantids. They allowed us to compute the Quadrantid radiant position with fairly high accuracy. Four of these meteors came exactly from a point-like radiant, while the other one deviated a little bit probably due to different orbital elements. The apparent radiant based on the four meteors, was located at $\alpha = 227^{\circ}.6$ and $\delta = 50^{\circ}.7$ (1950.0). Correcting for zenithal attraction results in $\alpha = 228^{\circ}.7$ and $\delta = 50^{\circ}.7$.

These values should be compared with the photographic radiant of the Quadrantids obtained by J.M. Trigo during the 1987 return [1], not corrected for zenithal attraction: $\alpha = 230^{\circ} \pm 1^{\circ}$, $\delta = 48^{\circ} \pm 1^{\circ}$, and the *IMO* Quadrantid radiant position at maximum at $\alpha = 230^{\circ}.1$, $\delta = 48^{\circ}.5$. Clearly, the differences are explained by different orbits within the stream. Although almost all meteors come from a radiant of 3° of diameter, larger deviations remain possible.

3. Coma Berenicids

Maybe this shower was the most interesting of the whole campaign. From January 2 onwards we detected a high activity of Coma Berenicids. That night we had a recorder failure, but the author remembers that in an effective observing time of $1^{h}\!.48$, at least 7 Coma Berenicids were spotted, yielding ZHR around 5. As this value equals the maximum ZHR reached on December 17, activity was above normal. This behavior continued during the following nights: on January 3, we detected 16 Coma Berenicids in $2^{h}\!.50$, from $4^{h}15^{m}$ till $5^{h}30^{m}$ UT.

Maximum activity took place between $1^{h}50^{m}$ and $3^{h}00^{m}$ UT on January 4, with a ZHR of 18 ± 5. Using 98 meteors, we obtained a population index $r = 3.38 \pm 0.32$. Perhaps the high activity was due to a poor determination of r, although the computations were consistent. The uncertainty on r is high because of the low number of meteors.

Nevertheless, a lower population index would still yield more or less the same ZHR, as the limiting magnitude was 6.35. Hence, the high activity seems real as only perception could decrease the zenithal rate obtained.

The mean magnitude of the Coma Berenicids was $m_{6.5} = 3.11$ with only 6 meteors showing a train, which is about 6%. Although $m_{6.5}$ is similar to that of the sporadics, train rates were lower (for sporadics, we got 9% from 319 meteors). On the other hand, the sporadic population index was $r = 3.87 \pm 0.25$ (for 310 meteors), about 0.5 higher than for the Coma Berenicids.

4. Other showers

We also observed some α-Leonids and ω-Canis Majorids. None of them left a train, but then the number of shower members was also very low. The apparent angular velocity of the ω-Canis Majorids was set to medium, so that the geocentric velocity would be around 35–40 km/s [2]. Activity from both showers seemed to be very irregular, even with nights with no meteors seen.

References

[1] Trigo J.M., "El enjambre meteorico Quadrantidas", *Jornadas Nacionales de Astronomia* 13, Madrid, 1989.

[2] Trigo, Marin, "Guia del observador", *Meteors* 2, March-April 1988, p 5.

Comments from the editor

As weather conditions are often unfavorable around the Quadrantid maximum, I think it is difficult to say whether or not the Coma Berenicid activity was unusual. Comparing ZHR values to catalogue values for a "maximum" is certainly not a good criterion, as these minor showers often do not have a well-defined maximum, and, moreover, these standard values are merely estimates based on scarce information.

On the other hand, there can be no doubt that the Coma Berenicids were distinctively present during the Quadrantid maximum as completely independent sources reported this (see the previous issue). Also observers generally sceptical towards minor showers confirmed the presence of the Coma Berenicids at the beginning of this year.

These 1992 Coma Berenicid observations show how minor showers should be detected: independently by various observers and not by starting from someone's favorite list of hundreds of radiants of which one tries to detect activity at any cost. Moreover, I take this occasion to repeat my plea to observers interested in minor showers to produce high-quality data through very regular observing and respecting Ralf Koschack's guidelines in last year's December issue.

The 1992 Quadrantids in Crimea

A.I. Grishchenyuk

Observations of the 1992 Quadrantids in Simferopol, Crimea, are presented.

The maximum of the Quadrantid shower in 1992 occurred in the morning of January 4 at 6^h UT [1]. We observed between January 2 and 6, but the night of January 2-3 was clouded. The conditions were better in the night of January 3-4, and even good during the following night. We had an open sky for about one hour in the night of January 3-4, but the limiting magnitude was low (5.0–5.2). Then the sky closed with haze. The following observers participated: A. Petrenko (PA), D. Suchov (SD), D. Karkach (KD), and A. Levina (LA). Table 1 shows the rates recorded during the maximum night.

Table 1 – Quadrantid and corresponding sporadic rates registered in Simferopol, Crimea, on January 3-4 between 2^h50^m and 3^h45^m UT.

Obs	Time (UT)	$T_{\rm eff}$	Lm	QUA	SPO
PA	3^h15^m	$0\overset{h}{.}83$	5.1	31	3
SD	3^h20^m	$0\overset{h}{.}68$	5.0	54	3
KD	3^h15^m	$0\overset{h}{.}83$	5.0	29	2
KD	3^h35^m	$0\overset{h}{.}68$	5.2	39	3

We had a low limiting magnitude and very high correction coefficients (4.2–4.5). As a consequence, our ZHRs range from 280 to 320! This is very high. In [1] it is stated that the activity is around ZHR 100–120. Alternatively, we used the method of Belkovich [2] which yielded values around 110–130 for the same observers, consistent with [1]. The method of Belkovich gives reasonable results under poor observing conditions, contrary to the *IMO* method.

In the follow nights, we did not see many Quadrantids: one in the period 17^h–18^h UT on January 4-5 and two in the period 1^h–3^h UT on January 5-6.

[1] J. Wood, R. Koschack, D. Artoos, "Observers' Notes: January–February 1992", *WGN* 19:6, December 1991, p. 222.

[2] O.I. Belkovich, A.I. Grishchenyuk, A.S. Levina, V.V. Martynenko, "The Activity and Structure of the Perseids", *WGN* 19:2, April 1991, pp. 53–57.

Radio Observational Results

Radio Observations of the 1990 Quadrantids

Jeroen Van Wassenhove

An analysis of radio observations of the 1990 Quadrantids is presented.

1. Introduction

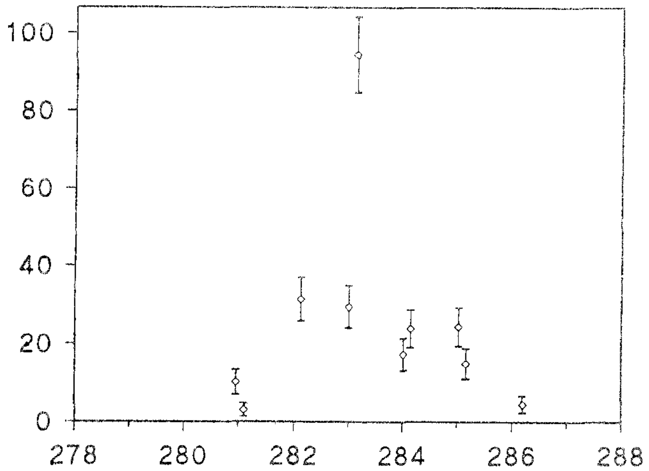
Every year, the Quadrantids, are the first meteor shower a radio observer can detect. It is known for its short activity period and its narrow maximum which can be easily missed. This and the usual New Year's activities make this shower easily neglected. In 1990 however, several observers managed to monitor the Quadrantids and sent in their observations:

> Edward Haemers (the Netherlands), Ingo Reimann (Germany), G.M. Kristensen (Denmark), Public Observatory Urania (Belgium), and Dirk Artoos (Belgium).

Together, they heard 4191 meteor reflections. All the observations were entered into the *RMDB*.

2. Reduction and results

As usual, observations were checked on errors and observations lasting less than 30 minutes are not used in this analysis. Still some observers listen during 30 minute-intervals. However, such an observing period is statistically rather critical. We strongly recommend these people to lengthen their observing interval to one hour.



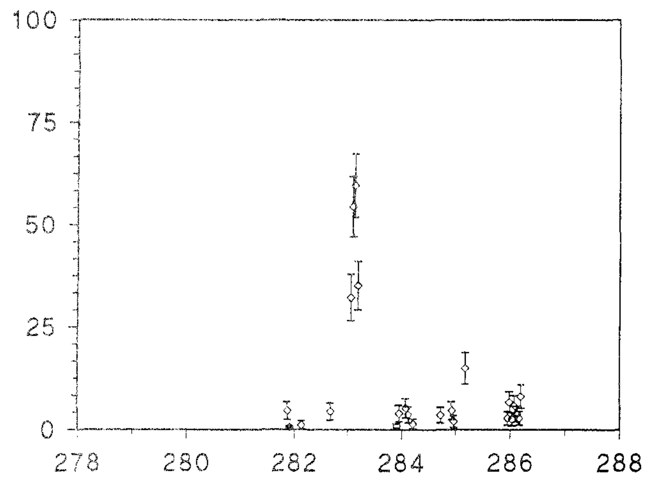


Figure 1 – *Left:* Corrected numbers for the 1990 Quadrantids observations by Dirk Artoos at 66.45 MHz.*Right:* Corrected numbers for the 1990 Quadrantid observations by Gotfred Møbjerg Kristensen at 100.50 MHz. (Epoch 2000.0)

Also, several observers listened on one or more days during irregular intervals, which made their observations incomplete. This gave no decent results. The method of reduction which was applied is described in [1], which corrects the observations for the sporadic activity and the radiant motion. The results obtained after reductions are presented in Figure 1. The Y-scale is not an absolute scale but a relative one.

Both results show a high increase around $\lambda_\odot = 283°$. From those two results, the maximum of the Quadrantids was calculated, yielding $\lambda_\odot = 283\overset{\circ}{.}1 \pm 0\overset{\circ}{.}1$ (Epoch 2000.0), Note that as this result is based on a small amount of data, it might differ from other results. For the future, more observations are *urgently* needed so that a detailed shower analysis can be carried out.

Reference

[1] J. Van Wassenhove, "The 1989 Geminids", *WGN* 19:2, April 1991, pp. 65–66.

Radio Observations Regarding Earth-Grazing Asteroids

Dirk Artoos

The author presents his observations aimed at detecting activity from Earth-grazing asteroids and comets.

The previous two or three years, several Earth-grazing asteroids were discovered some of which may be meteor producers while others produce nothing at all. In March and April 1991, 1981 Midas (March 20, 0.001 AU) and 1863 Antinous (0.178 AU) could have caused meteor activity. As can be seen in Figure 1 showing my personal observations, 1981 Midas can claim a part of the meteor activity, but only during the second observing campaign around November 20. An additional argument in favor of this hypothesis is that during this second period, there were more reflections with long duration (at least 1 s), more specifically around the date of the theoretical maximum.

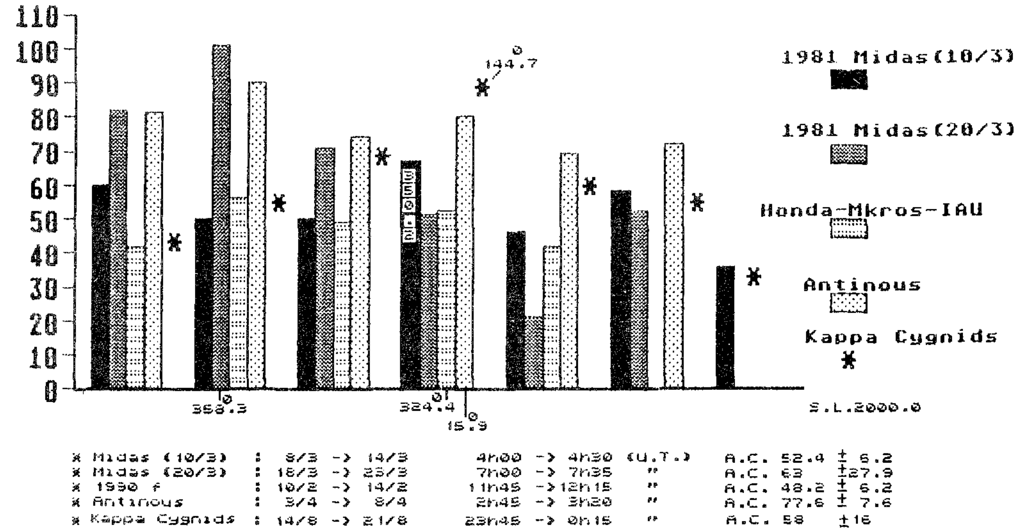


Figure 1 – Radio observations to detect possible activity from Midas, Antinous and Comet 1990 f.

For the first encounter ($\lambda_\odot = 350\overset{\circ}{.}2$) we definitely have a negative result. The same holds for 1863 Antinous ($\lambda_\odot = 15\overset{\circ}{.}9$) and for Comet 1990 f which could have produced activity in mid-February. This last fact was also confirmed by radio observer Norihito Kawamura who worked around the clock during that period (February 10 to 15) . Unfortunately, the second encounter for 1990 f (mid-August) was overshadowed by the κ-Cygnids which had their maximum around August 18 ($\lambda_\odot = 144\overset{\circ}{.}7$). It is perhaps a good idea to search for visual meteors in records of the Perseid observations. The radiant was located at $\alpha = 325\overset{\circ}{.}5$ and $\delta = -14\overset{\circ}{.}5$ near δ Capricorni.

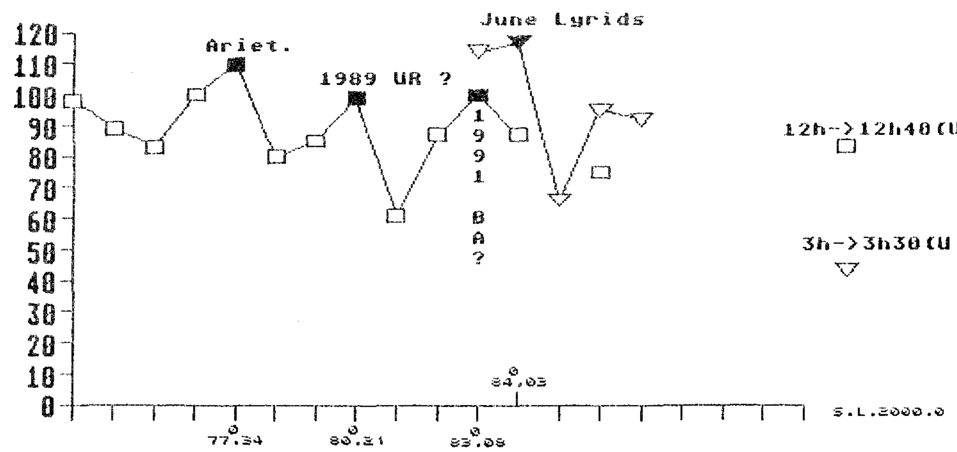


Figure 2 – Radio observations to detect possible activity from 1989 UR and 1991 BA.

A few months later I had more luck. Not only the Arietids and ζ-Perseids were active, but two asteroids (1989 UR and 1991 BA) were also likely responsible for some meteor activity (Figure 2). Comparing the activity profile with 1990 [1,2], the high peak possibly caused by 1989 UR ($\lambda_\odot = 79\overset{\circ}{.}50$) reappears in 1991 at $\lambda_\odot = 80\overset{\circ}{.}21$. After a two-day depression, a third peak was found at $\lambda_\odot = 83\overset{\circ}{.}08$ maybe caused by an injection of asteroid material from 1991 BA. After this, the number of echoes went down to normal background levels. In Figure 2 you can also notice a few triangular dots indicating the June Lyrids activity observed during five days (June 14 to 18). There was an increase at $\lambda_\odot = 84\overset{\circ}{.}03$. In 1990, a peak occurred at $\lambda_\odot = 82\overset{\circ}{.}96$.

These results are of course personal. Are there perhaps amateurs with other results?

References

[1] D. Artoos, "Call for Radio Observations: 1989 UR Again!", *WGN* 18:5, 1990, pp. 184–185.

[2] D. Artoos, "Meteor activity from asteroids (letter)", *WGN* 19:1, February 1991, pp. 4–7.

Bright Radio Signals from Geminids and Quadrantids

Gotfred Møbjerg Kristensen

An overview is given of the author's radio observations from Havdrup, Denmark, of the Geminids and the Quadrantids in the winters of 1989-90, 1990-91, and 1991-92. Rates for all radio signals respectively bright signals are compared.

If their is some doubt as to the genuine character of radio activity throughout the year, all doubts vanish when the Geminids arrive. A few weeks later, also the Quadrantids confirm that radio observations represent real meteor activity. The maximum hourly rates for all radio meteors (both bright and faint) during the previous three winters was as shown in Table 1.

Table 1 – Maximum hourly rates for all radio meteor signals (both bright and faint) for the Geminids and Quadrantids in the winters of 1989-90, 1990-91, and 1991-92, as recorded by the author from Havdrup, Denmark.

Shower	Year	Nr. signals per hour	Period (UT)
Geminids	1989	379	Dec 13, 04^h–05^h
	1990	521	Dec 13, 04^h–05^h
	1991	396	Dec 14, 04^h–05^h
Quadrantids	1990	179	Jan 03, 12^h–13^h
	1991	349	Jan 03, 11^h–12^h
	1992	382	Jan 04, 03^h–04^h

The graphs covering the bright and very bright meteors of both streams (Figure 1) indicate that Geminids and Quadrantids produce several fireballs, or at least many bright meteors. This is not surprising, of course. Visual observations show the presence of bright meteors and fireballs, especially Geminids.

For instance, on the night of December 14-15, I saw several Geminid fireballs, one of which was of magnitude at least −8. It exploded at $23^h46^m52^s$ UT. A faint thunder arrived at $23^h51^m42^s$ UT. This thunder and the fireball's direction indicate that it may have reached an altitude of 40 km or less. It was followed by a bright radio signal.

Figure 2 *(right)* shows the distribution of the bright Geminids per hour around the maximum. If you compare it with Figure 2 *(left)*, showing all radio meteors in the same period, you will see that the percentage of bright Geminids is much higher on the morning of December 14 than on the morning of December 13.

Figure 3 indicates that the Quadrantids were very active in 1992, as was already mentioned in *WGN* 20:1 (February 1992). The weather here in Denmark was almost cloudy, but late in the morning of January 4, many Quadrantids could be seen through the openings in between drifting clouds. In the night of January 4-5, I saw almost no Quadrantids, and also radio rates had dropped to almost nothing.

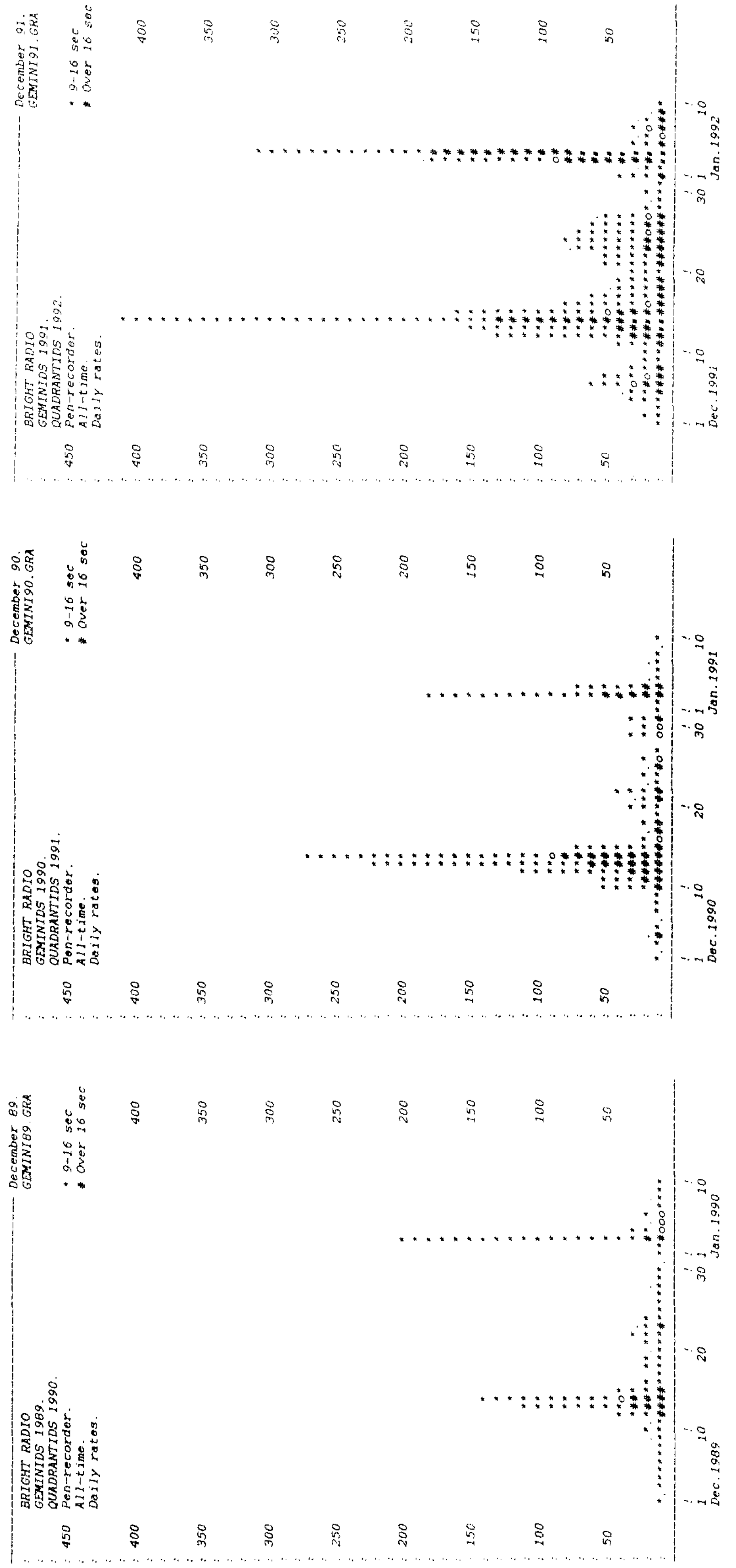


Figure 1 – Bright and very bright radio meteor signal rates for the Geminids and Quadrantids in the winters of 1989-90 *(left)*, 1990-91 *(middle)*, and 1991-92 *(right)*.

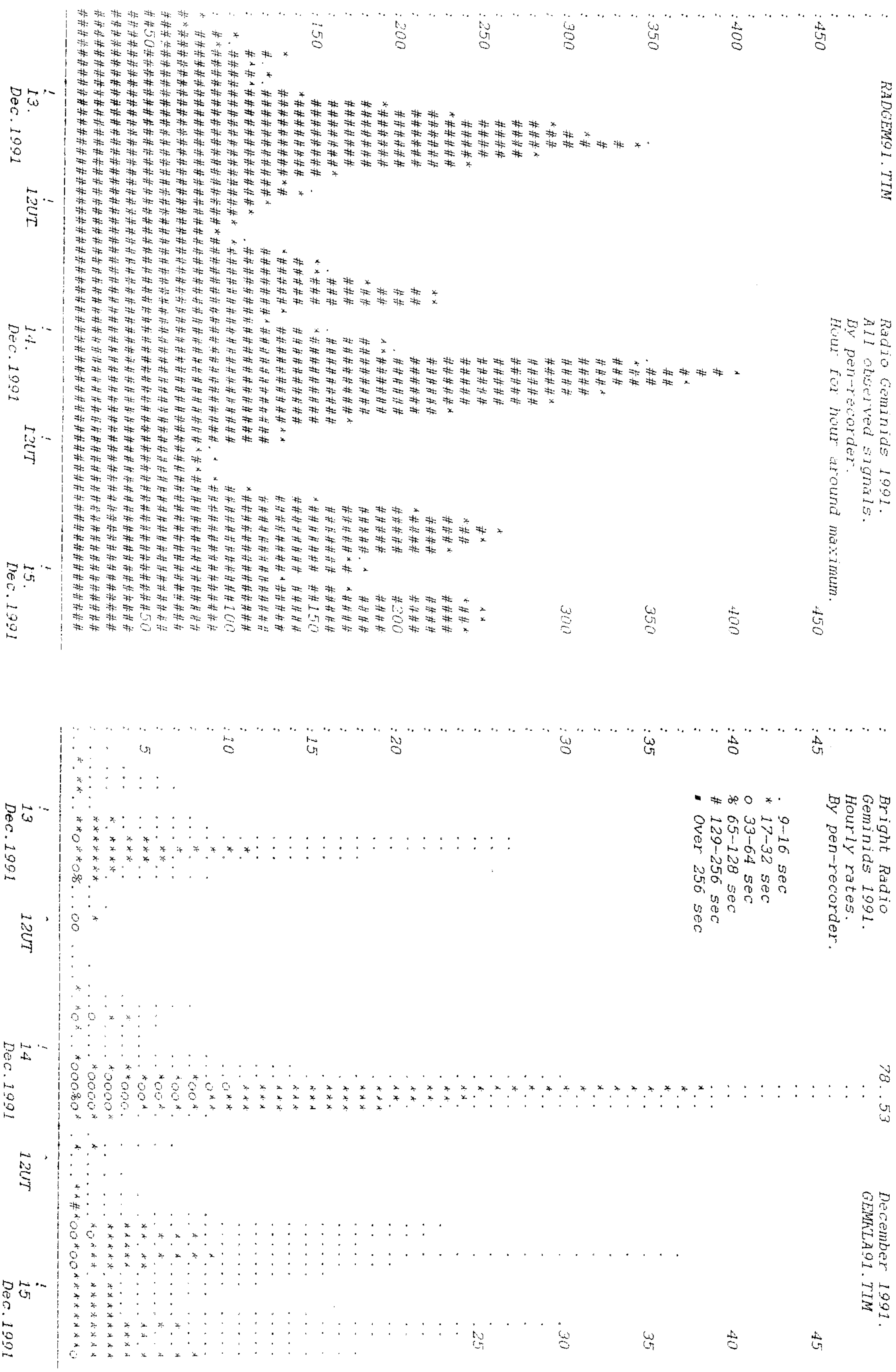


Figure 2 – The 1991 Geminids: comparison between rates for all signals *(left)* and for bright signals only *(right)*.

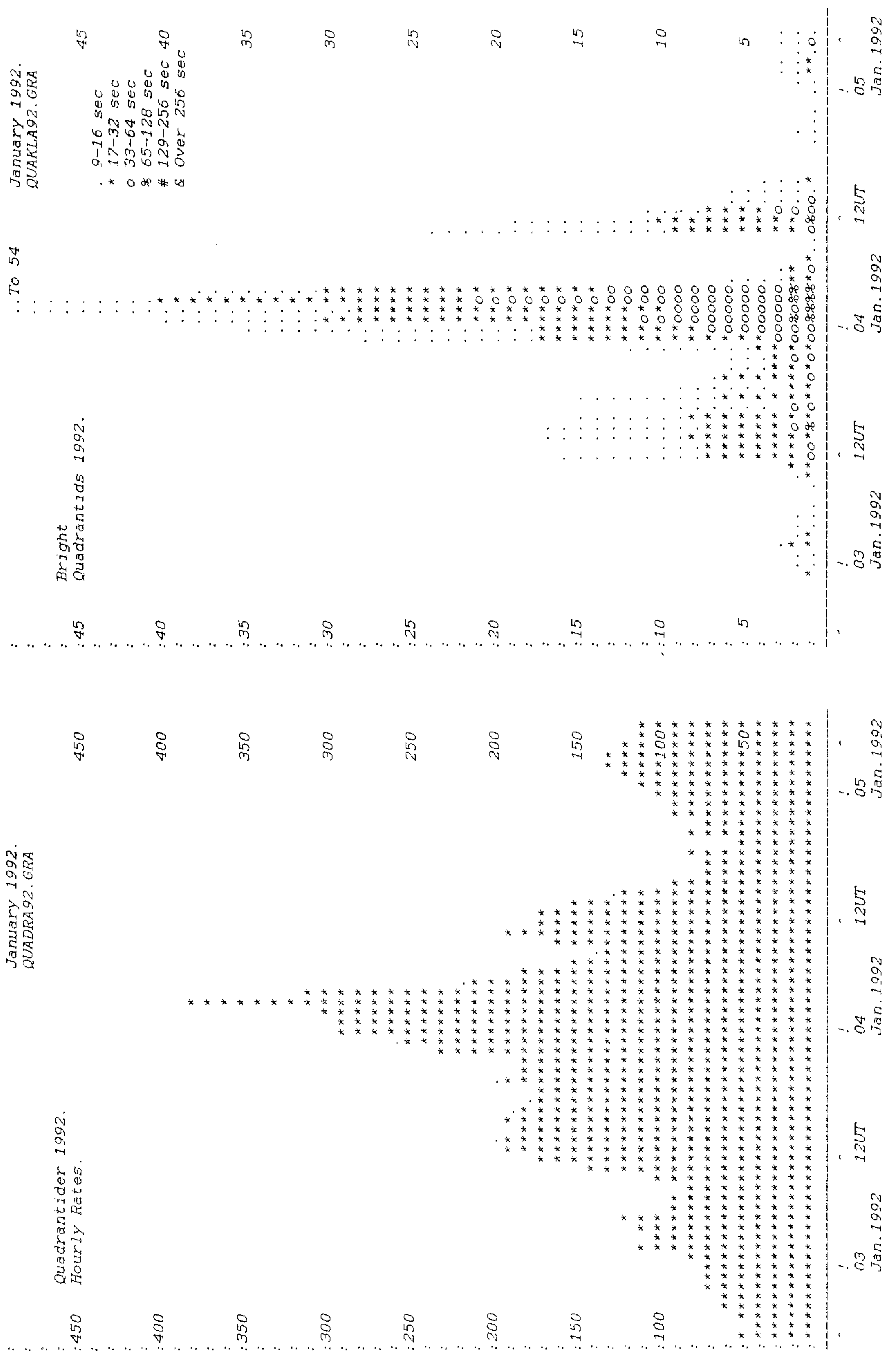


Figure 3 – The 1992 Quadrantids: comparison between rates for all signals *(left)* and for bright signals only *(right)*.

Meeting of the Radio Commission

Ghent, Belgium, February 1, 1992

Christian Steyaert

The visit of Knud Bach Kristensen (Denmark) was the opportunity to meet with the Belgian radio observers at the Observatory of the University of Ghent. Were also present: Maurice Demeyere, Knud's wife and son, Dirk Laurent, Christian Steyaert, Paul Vauthier, and Jeroen Van Wassenhove.

Paul Vauthier gave a demonstration of the automated meteor recording equipment, which won an international science prize. The set-up consists of a four-elements Yagi on the roof of the building, connected by means of 17 meter coax cable to a commercial receiver in the 66–72 MHz band. The signal strength is modulated and fed via a short optic fiber cable into an analog-digital converter, which is in turn connected to a C-64 microcomputer. The program on the C-64 is partly written in Basic, partly in Assembler. Some logic is built in to analyze only signals above a certain threshold. The details of the meteor reflections are stored on a diskette. Further off-line analysis is done on a PC with a program written in Pascal.

Maurice is in the process of duplicating the set-up, with the difference that the signal will be directly fed into a PC. A severe problem so far has been the interference of the PC, notwithstanding the use of net filters, shielding, and a large distance between the receiver and the computer.

Knud's experience lies mainly in the 2-meter band, where meteor reflections are much shorter but also more distinctive. Knud stressed the fact that non-meteor scatter (tropo, Es, aurora) can largely influence the counts and identification of meteors.

Christian showed the latest version of the *FORWARD* program, which gives a prediction of the effectiveness of the reception of a certain stream with given equipment. The calculation for the set-up of Knud for the 1992 Quadrantids seemed to agree quite well with the observed numbers. He suggested to add also the frequency as an input parameter to the program, in order to be able to compare results between various observers.

Christian and Jeroen had been working lately on defining reference values for radio equipment. A backscatter (radar) configuration, tracking the radiant at 90°, is the simplest case. A flat maximum is reached for radiant heights of 50° to 60°. Contrary to what might be expected, the most effective antenna is a four-elements Yagi. More elements will increase the maximum gain, but the decrease in opening angle causes a net loss in efficiency.

As a further statistical study of radio meteors, the duration distribution (in logarithmic classes) was discussed. Amongst others, this topic is handled in the *Radio Handbook*, planned for this year.

There was also a question about the effect of polarization. A second Yagi antenna perpendicular to the first one increases the signal strength with 40% on average.

All in all an interesting—otherwise gray and foggy—afternoon, with interesting new contacts and more questions to be answered. We wish to thank Paul Vauthier of the *Werkgroep Sterrenkunde* and the *University of Ghent* for providing us with the opportunity to use their facilities.

International Workshop on Radio-Meteor Science and Engineering

Lowell, Massachusetts, USA, August 17–21, 1992

D. Meisel, SUNY-Geneseo

The *American Meteor Society* is sponsoring an International Workshop on Radio-Meteor Science and Engineering to be held August 17–21, 1992 at the University of Lowell, Lowell, Massachusetts, USA. A registration fee of 250 USD per person is being charged to help defray the expenses of participants from the *CIS* invited to the workshop. The meeting is open to all who want to come and it is hoped that persons returning home from the *IAU* symposium may be able to attend this meeting also.

For further information contact *D. Meisel*, Dept. Physics/Astron., SUNY-Geneseo, Geneseo, NY 14454, USA, phone: +1-716-245-5282, fax: +1-716-243-1901, e-mail: meisel@geneseo.bitnet, or *Robert I. Desourdis, Jr.*, Science Applications International Corporation (SAIC), 300 Nickerson Rd., Marlborough, MA 01752, USA, phone: +1-508-460-9500, fax: +1-508-460-8100, e-mail: bobd@ubar.saic.com. We are sorry at present we cannot offer travel grants to others, but we have not yet found any US funding agency willing to help ...

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Do not miss it!

International Meteor Conference 1992

Smolenice, Slovakia, CSFR, July 2–5, 1992

The 1992 International Meteor Conference will take place in the Smolenice Castle, in most beautiful surroundings. Already now it is clear it will become the most international *IMO* event ever. Participants from the former USSR, Canada and various European countries have already registered.

Immediately after the conference, a professional symposium is taking place in the same building, providing amateurs and professionals with a unique opportunity to meet each other!

Do not be late! In the previous issue, you found more information about the 1992 *IMC* as well as a registration form. If you intend to participate and have not yet returned it to the local organizers, then do so at once!

As usual, the *IMO* will publish proceedings of this *IMC*.

Available very soon: Proceedings

International Meteor Conference 1991

Potsdam, Germany, September 19–22, 1991

The proceedings of this International Meteor Conference will be available soon. The book will contain articles about various fields of meteor astronomy—almost entirely covering the conference.

Included are: visual and photographic observations, radio meteor work, telescopic and video observations, new techniques in meteor observation, data processing, investigations on meteorite events in the past, meteor physics and the International Meteor Organization itself.

These proceedings are published by the *International Meteor Organization* and can be ordered at only 10 DEM per copy (surface mail delivery). Note that the proceedings were included in the registration fee for the participants of the 1991 *IMC*. Non-participants can order these proceedings already now in the same way as paying for *WGN*!