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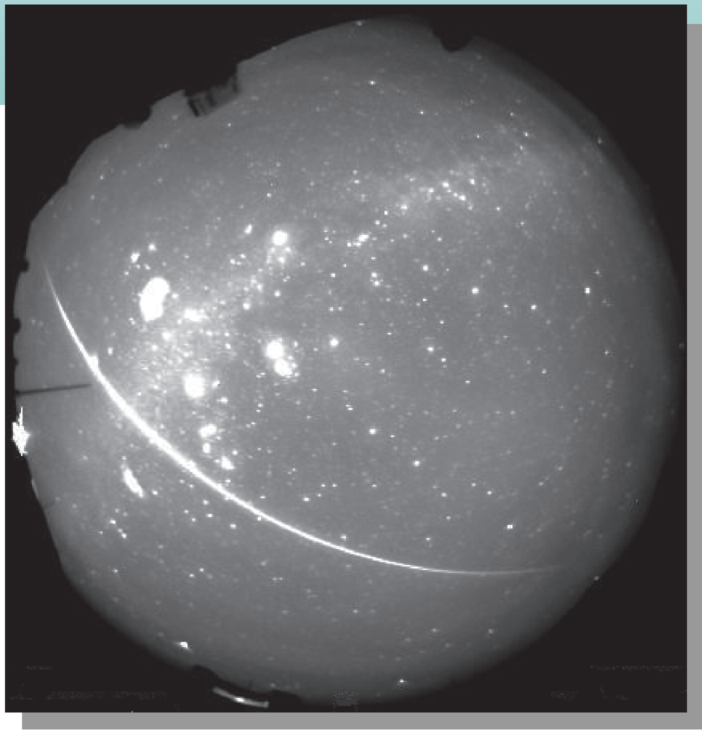

Halley shower analysis
History of meteor beliefs
Czech and Spanish bolides
Modeling meteoroid streams
Video observations from cities

ISSN 1016-3115

WGN Vol. 31, No. 2, April 2003, pp. 35–72

Administrative

Observing techniques

Meteor showers

Fireballs

History

Ongoing meteor work

Front cover photo

Impressive image of an atmosphere-grazing Leonid on 2001 November 18 at about $10^{h}15^{m}$ UT. North is up and east is to the left. Taken by the CONCAM camera on Mauna Kea, Hawaii, operated by Michigan Technological University in Houghton, Michigan, USA. See `http://concam.net` for details of this project.

Back over photo

This fireball of absolute magnitude −7 crossed the Czech Republic on 2003 February 25. Details can be found in Pavel Spurný's paper on page 53; the back cover is an enlargement of his Figure 1.

Cover design Rainer Arlt

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Editorial

Chris Trayner

This is the second issue of WGN in the new format, and response to the first one has been favourable. The letter below is typical. Everyone likes to get everything right first time, and the only place we slipped up was with the section numbering. Thanks are due to those readers who pointed this out.

Readers of a Journal are aware of the Editor but may not realise that, even with a small organization like the IMO, there is an entire editorial team. Credit for the new look goes to these as much as to myself: to Rainer Arlt, Marc Gyssens, Mihaela Triglav and Jürgen Rendtel. Ina Rendtel, although theoretically not part of the editorial team, has given a lot of help. The section numbering mistake was entirely mine, as it appeared only after they had finished their proof-reading.

The new format is more compact, resulting in each article needing less pages. Although the total page-count this year will probably be less than before, the amount of material published will not fall.

The change to higher quality paper for the covers means that photographs appear better. The intention is that the back cover will normally be used for extra photographs, and Pavel Spurný's superb fireball makes a fine start. If you have photographs which you would like to see on the front or back cover, please offer them to us. They do not need an article to go with them, though a caption is needed. Please contact the Editor with details; as usual, the contact details are inside the back cover.

Letters

from Arkadiusz Olech[1]

I have just received the newest issue of WGN and, as we say in Poland, my jaw fell to the floor. You did a great job! Congratulations! WGN looks now like a professional journal.

The only thing which looks strange to me is a common numbering scheme for all sections in all papers in the issue. It is funny to read articles starting from an introduction which is labeled as 33 or so.

Congratulations again!

IMC 2002 — Proceedings

The Proceedings from the International Meteor Conference last September are nearly complete and should be posted soon. Those who attend these conferences will be aware that much important material is presented there. Some of this is not available elsewhere.

Details of the papers in these Proceedings will be published in the next issue of WGN. It will be available for sale to those who were not at the Conference.

IMC 2003 — Announcement

This year's International Meteor Conference will be held in September in Germany. In the aftermath of the spectacular Leonid years, it promisses to have much of interest to meteor scientists. Details can be found on the next two pages.

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The 2003 International Meteor Conference in Bollmannsruh, Germany

Jürgen Rendtel

The IMC 2003

The International Meteor Organization (IMO) will hold its next International Meteor Conference (IMC) in Bollmannsruh, Germany, on 18–21 September 2003. The location is about 40 km west of Berlin, or about 20 km northeast of the city of Brandenburg. The IMC 2003 is organized by the German meteor observing society Arbeitskreis Meteore e.V. Part of the program is an excursion to the Berlin Museum of Natural History where Prof. Stöffler will give a lecture about meteorites and their identification and guide participants through the meteorite collection.

Several IMO members and long-term meteor enthusiasts remember that the IMO was founded in 1988 at an IMC in Oldenzaal, the Netherlands. The IMC 2003 marks our 15th anniversary — a good opportunity to look back (with lots of pictures) and to plan for the future. Furthermore, it is the first IMC after the series of spectacular Leonid returns — time for reviews and projects. Please announce your planned contributions as soon as you register. Not only does this make it easier for the organizers, but it may also attract more people who have not yet decided to attend. It could also let participants think about bringing extra (raw, unpublished or preliminary) data and material if a specific topic is announced. (This is always recommended, of course, as discussions may yield new aspects and views on results and data.)

Registration

If you wish to attend the conference, please fill out the registration form on the next page. You can also download it from the IMO website: http://www.imo.net. Send it to: Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, Germany. The registration fee includes lodging, meals and the Proceedings. We offer an early registration fee of 115 EUR if your registration reaches us by 11 July 2003. Participants registrating after that pay a late registration fee of 130 EUR. We are currently checking the possibility of a limited number of reduced registration fees. People interested in such a reduced fee should indicate this on the (pre-)registration. The details will be mentioned on our web page as soon as they are definite. Please note that the IMO also offers travel support (guidelines to be published in the IMO Journal WGN elsewhere).

If there are people interested, we can arrange a program for accompanying persons. Please let us know about people who intend to travel with you but do not wish to attend the IMC. We may organize a program for these guests, who may visit Potsdam with its world-famous castles and parks as well as sights of Berlin. The costs for such a program would depend on the number of participants and on the entrance fees of the places visited.

Administrative

Have a look at the web page of the German Foreign Office:

http://www.auswaertiges-amt.de/www/en/willkommen/einreisebestimmungen/visumangelegenheiten_html

Here you find all information about visa regulations including a visa application form etc. We also provide information on our web site http://aipsoe.aip.de/~rend/2003imc.html which will be updated regularly.

International Meteor Conference

Bollmansruh, Germany, September 18–21, 2003

Registration Form

Each individual participant should fill out a form and return it to *Ina Rendtel, Mehlbeerenweg 5, 14469 Potsdam, Germany*, as soon as possible. Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 50 EUR. If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: ______________________________ Birth date: __________

Address: ____

____

____

Phone: ____________ Fax: ____________ E-Mail: __________

- ○ wishes to register for the 2003 *IMC* from September 18 to 21;
- ○ intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by ________, together with ______________________

Additional requests:

- ○ I need travel information from ______________ to Bollmannsruh;
- ○ I wish to stay in Germany before or after the *IMC* and require additional information.

For participants wishing to contribute to the program:

Lecture: ____

Duration: ______min. Required equipment: ______________________

Workshop or discussion: ______________________________

Poster presentation: ______________________ Space: ______ m^2

Either the entire fee of 115 EUR or a pre-payment of 50 EUR should be sent to the Treasurer, *Ina Rendtel*. Follow the payment instructions below. Participants making a pre-payment only have to pay the remaining 65 EUR in cash upon arrival in Germany. The registration fee increases to 130 EUR for participants registering after July 11, 2003.

Date and signature: ______________________________

Please send your payment to the Treasurer or one of her assistants as indicated below:

- in Europe: pay in EUR to Ina Rendtel, account number 547234107 at Postbank Berlin, bank code 10010010. No bank checks, please! (Bank checks can only be sent to Robert Lunsford, see below).
- in the UK: proceed as above or pay to Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- in Japan: pay to Masahiro Koseki, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
- all others pay in USD to Robert Lunsford, 161 Vance Street, Chula Vista, California 91910, USA. In case you pay by bank check, make it payable to Robert Lunsford, *not* the *IMO*!

People wishing to pay in other currencies should contact the appropriate IMO *contact person for exchange rates.*

Observing techniques

What can an urban observer do? Video work from downtown

Felix Bettonvil[1]

This paper demonstrates that, even from light polluted areas, useful meteor work can be done. In the center of a medium sized city an intensified video system was set up and the goal, instead of activity monitoring, was to do some orbit analysis. In April 2001, around the Lyrid maximum, multi-station observations were conducted from two stations, and together 50 meteor trails containing five double-station meteors were collected. As an example, three Lyrids were analyzed and their orbits calculated. The results illustrate that it is quite possible to do this kind of work under less favorable circumstances, but also showed some general problems with video multi-station work: neither radiant nor velocity could be determined accurately enough to compute all orbital elements precisely. Possible improvements to this are discussed.

1 Introduction

Unfortunately not all meteor observers live in the countryside. In particular, in the crowded Netherlands, many observers live in relatively light-polluted areas.

As it is not practical to travel every clear night to a dark spot I tried to do some work from my house located in the center of Utrecht, the fourth biggest city of the Netherlands, with a population about 250 000 inhabitants.

Figure 1 – Video setup with right the intensified video camera FIFIE looking through an open window and left the computer with Matrox Meteor frame-grabber and MetRec software.

2 Setup

The idea was not to perform visual observations but to investigate whether a video camera could be used under less favorable circumstances. The idea arose after completion of three intensified video cameras in 1999 in the *NVWS Meteors Section* (NVWS-WGM) (Table 1). For the test, the FIFIE camera was used, a three-stage first-generation intensifier mounted on a Sony camcorder, and connected to a Meteor-I frame-grabber in a Pentium-II PC using the MetRec meteor recognition software package (MetRec, 2003). FIFIE was set up in front of a window and had its aiming point at an elevation of about 60° (Figure 1). During observations the window was opened in order to minimize image aberrations. An additional advantage of such setup is that it is relatively well protected against severe weather conditions; unexpected rain doesn't normally result in a soaked camera. The camera is equipped with a Nikkor 50 mm, $f/1.4$ lens, but will accept other Nikkor lenses too. With a 50 mm lens the field of view is about 30°.

Table 1 – Comparison of the two types of intensified video camera's in use by the NVWS Meteor Section (NVWS-WGM).

Name device	SUMO	FIFIE
number available	2	1
intensifier type	Gen. II MCP	3-stage Gen. I
gain	6 000×	45 000×
input diameter	17.5mm	25mm
lens	Nikkor 50 mm $f/1.4$	Nikkor 50 mm $f/1.8$
field of view	20°	28°
CCD coupling	tapered fiber	macro lens

3 First experiments

A first test image was made in 2000 April (Figure 2a) with the lens stopped down to $f/5.6$. The weakest stars recognizable on a grabbed image were of the magnitude +6. For comparison another image is shown (Figure 2b) taken with FIFIE too, but at a dark site (Oekajmeden, Morocco, 2000 November). The limiting magnitude for stars is now approximately +7, but instead of the 50 mm lens another was used (28 mm $f/4$, field of view about 50°). Assuming an equal background level for both systems, and correcting for the different appertures, the sensitivity for the 'city' setup is about 2 magnitudes less (for stars).

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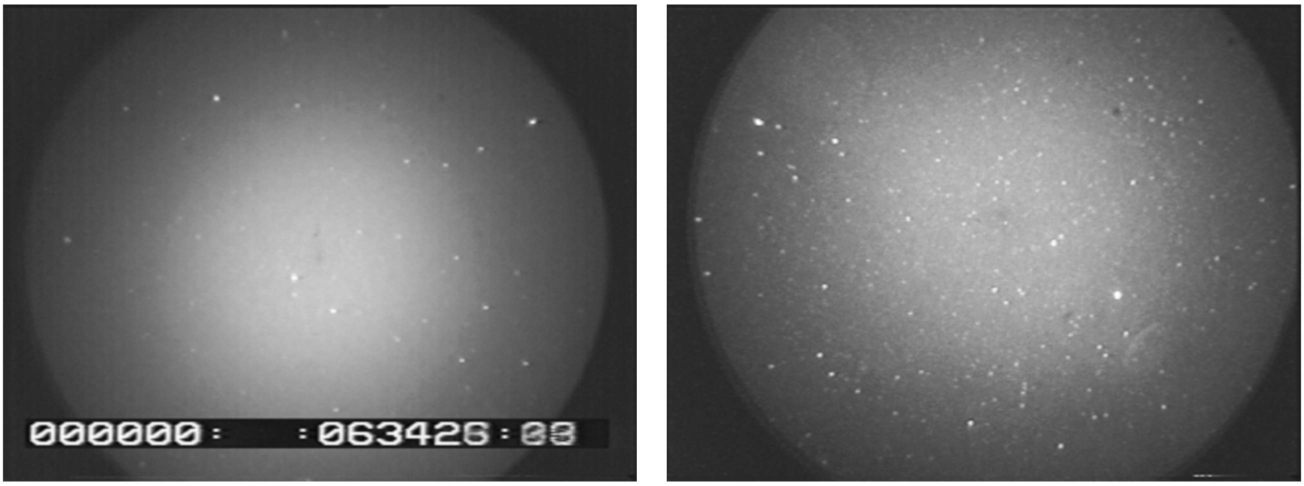

Figure 2 – Images taken with FIFIE from (left) a light polluted site (Utrecht center, the Netherlands) and (right) a dark site (Oekajmeden, Morocco).

4 What to observe?

Nowadays video systems are used intensively in meteor astronomy, both for obtaining activity profiles (Molau, 2001) and for radiant and orbit determination (de Lignie et al., 2001). As well as use for specific campaigns, there are examples of all-year-round patrols (Nitschke, 2001). With our setup it would also be possible to measure hourly rates of streams. However, because of the reduced sensitivity, the setup is more suited to doing positional analyses than population counts. One can think about radiant determination and the calculation of meteor orbits. The latter is what we intend to do.

Despite the limited sensitivity about 20 stars were visible in the image, and at first that seemed to be enough to do astrometric measurements. Position measurement of the meteor trail and calculation of the coordinates can be done directly by the MetRec software; when a meteor is detected, MetRec automatically calculates right ascension and declination from both start- and end-point, as well as duration. As an alternative Astrorecord can be used, written by Marc de Lignie and available from the IMO website (IMO, 2003), and Meteor written by members of the NVWS-WGM, to measure by hand AVI or BMP files containing meteors.

For computation of a heliocentric orbit at least two stations are needed, and for Utrecht there exist several alternatives, i.e. Rhenen (distance 30 km), Noordwijkerhout (60 km) and Uden (60 km).

5 Results

The first single station observations show that 0–5 meteors per night are recorded, not taking shower activity into account. Depending on the number of clear nights, monthly totals are about 20–30. A multi-station test under moderate circumstances was done during the 2001 Lyrids from two stations, Heesch and Meteren, with the last one simulating the city station at Utrecht. In total 50 meteors were captured, 5 of them simultaneous and 3 of these Lyrids (Bettonvil, 2001). Figure 3 shows the 3 multi-station Lyrids. From MetRec we know that the brightest one was of magnitude 0.

6 Data reduction

In this paper I will concentrate on the Lyrid observations to illustrate the concept. The images generated by MetRec were used as input and must therefore be measured first. This measurement of the six images was done with Meteor. The obtained positional accuracy was of the order of $3'$–$5'$, slightly more than one may expect from the pixel size.

The next step was to calculate the trajectory in the earth's atmosphere by calculating the intersection of the observations of both stations in 3-D space (triangulation); this could also be done with Meteor. The calculated velocity was determined from the video frame rate of 25 frames per second.

One of the three Lyrids was omitted for further processing because the meteor trail, the location of Station A and the location of Station B lay almost in a single plane, so the angle of convergence was nearly $0°$.

For the two others the angles of convergence were $13°$ and $22°$ respectively. That is not much and the reason for this small angle was the small baseline between the two stations of about 30 km.

The calculated radiant had an accuracy of $\pm 4°$ and differed by circa $6°$ from the literature (IMO, 2003; DMS, 2003) but variations of few degrees seem to be normal, as shown for example in the MSSWG database (IMO, 2003). The calculated velocities were respectively 55.8 ± 3.5 km/s and 48.7 ± 4.4 km/s, with errors in the range of 5% to 10%, with the latter one close to values (49 km/s) in the literature (Rendtel et al., 1996).

From the calculated radiant and velocity the orbital elements could finally be computed, again with Meteor. Lyrids have a highly eccentric orbit and slight variations in measurements, especially of velocity, can produce calculated orbits originating outside the solar system. Computation of the orbit with the radiant and velocity found did indeed demonstrate this problem. To get a mean elliptic orbit the velocity had to be decreased as shown in Table 2 (page 41). The radiant position also has some influence; changing it towards values quoted in the literature resulted in a higher maximum velocity for elliptical orbits. The conclusion was that the accu-

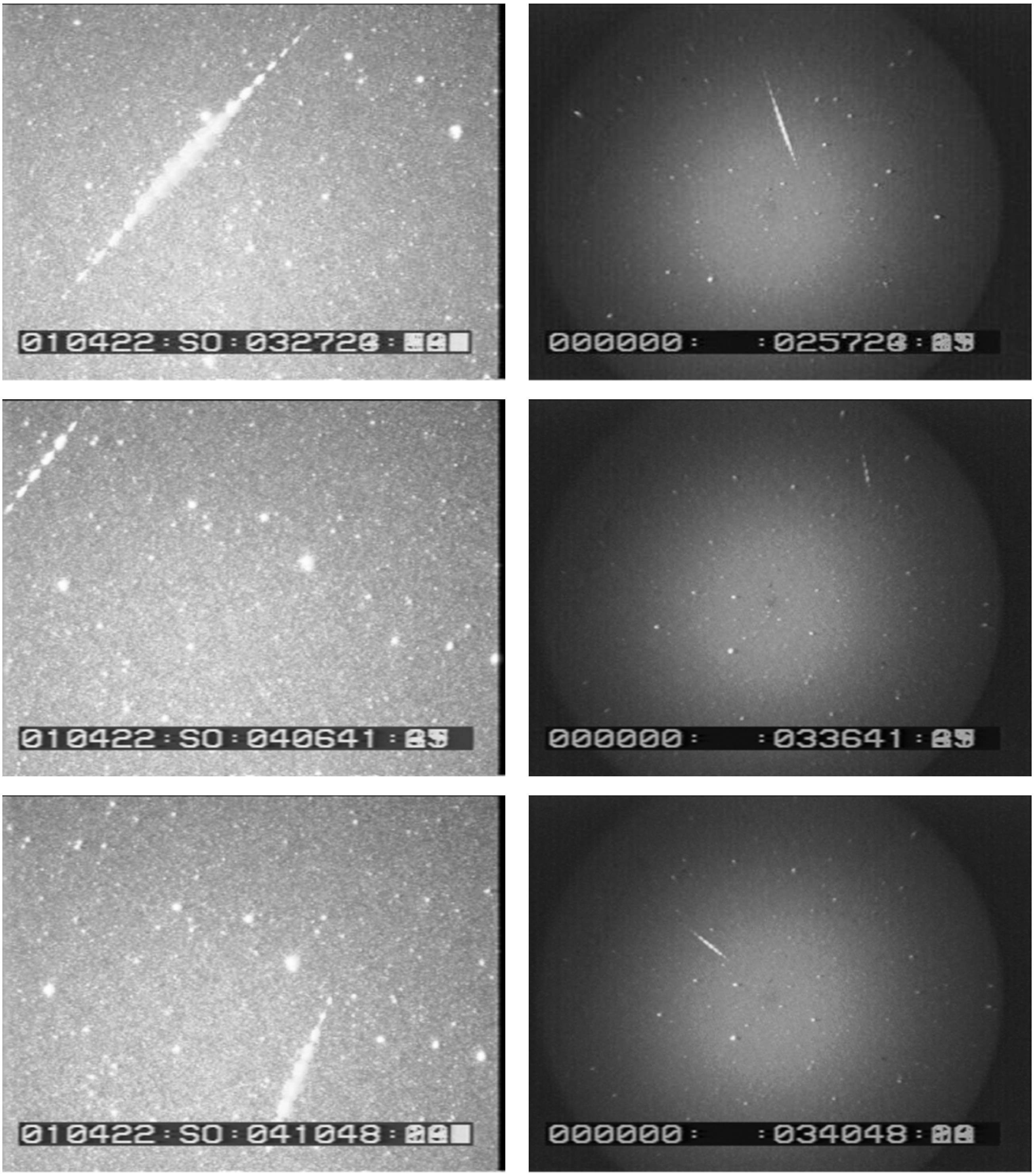

Figure 3 – The three double station Lyrids on April 21/22 from Heesch (left) and Meteren (right) at $01^{h}27^{m}23^{s}$ UT (upper), $02^{h}06^{m}41^{s}$(center) and $02^{h}10^{m}48^{s}$(bottom row). The images from Heesch are made with SUMO-I, equipped with a Gen-II image intensifier and tapered CCD and a field of view of 20°, the images from Meteren with FIFIE, a 3-stage Gen-I intensifier with camcorder. FIFIE has a circular field of 30° view and a lower sensitivity on the edge of the field, as well reasonable distortion. The images are a composition of single frames with every second one omitted.

racies obtained for both velocity and radiant position were inadequate to calculate a precise orbit, at least for the Lyrids.

7 Improvements

A plan to obtain a better accuracy would of course first be to improve the resolution of the image, so the velocity as well as the radiant position could be determined more accurately. A first step would be the improvement of METEOR, which relies partly on the 'Refstars' function (used in METREC for calibration). This is not necessarily the best choice because 'Refstars' is not intended for measuring meteor trails. Moreover, METREC only uses 376 × 291 pixels out of the 752 × 582 produced by the camera, thus using only half the resolution.

Table 2 – Heliocentric orbit for the two Lyrids on April 22, $01^h27^m23^s$ and $02^h06^m41^s$ compared with values from literature. These last are: [Bet]: (Bettonvil, 2001), [DMS]: (DMS, 2003), [IMO]: (IMO, 2003).

Date	2001 Apr 22	2001 Apr 22	
Time (UT)	$01^h27^m23^s$	$02^h06^m41^s$	
Julian date 00^h UT (calculated)	2452021.5	2452021.5	
Solar longitude $\lambda_\odot$	31.°990	32.°017	
Standard equinox	2000.0	2000.0	
Atmospheric trajectory			
Longitude	5.°499	5.°331	
Latitude	51.°811	51.°756	
Altitude [km]	117.496	91.863	
Radiant			
α (observed)	268.°167	264.°464	272° [Bet]
δ (observed)	37.°947	40.°225	34° [Bet]
α (geocentric)	268.°140	264.°221	
δ (geocentric)	37.°787	40.°070	
Astr. longitude helio	164.°810	157.°916	
Astr. latitude helio	65.°958	61.°178	
Velocity			
Observed [km/s]	45.000	42.000	49 [Bet,DMS]
Geocentric [km/s]	43.500	40.440	
Heliocentric [km/s]	41.740	41.240	
Orbit			
Ω	31.°991	32.°018	31.°7 [IMO]
i	71.°9	66.°0	79.°0 [IMO]
ω	212.°557	214.°054	214.°3 [IMO]
a [AU]	38 ± 43	14 ± 17	28 [IMO]
q [AU]	0.93	0.92	0.919 [IMO]
Q [AU]	77	26.7	
e	0.976	0.93	0.968 [IMO]

To improve the resolution even more, a test was performed with a 200 mm $f/4$ telephoto lens, instead of the 50 mm lens stopped down to $f/4$ normally used, increasing the resolution by a factor of four (as long as the whole meteor fits in the image). Figure 4 shows an example of a meteor taken with the 200 mm lens. For stars, the illumination in the focal plane depends on the lens area, which is 16 times that of the 50 mm; this amounts to an improvement of 3 magnitudes. For meteors the illumination varies as d^2/f (Rendtel, 1993), where d is the diameter, giving an improvement of 1.5 magnitudes.

The number of meteors seen per hour must be considered, and depends on the r value and sensitivity. The above-mentioned 1.5 magnitudes increase the observable meteor rate by $r^{1.5}$; with $r = 2.5$ for shower meteors, the ratio is about 4.

The field of view is smaller, however, varying as the inverse square of the focal length. For multi-station work, with both stations using 200 mm lenses, the volume of atmosphere observed by both cameras varies as the inverse cube of focal length. This reduces the number of meteors observed by a factor of $(200/50)^3 = 64$. Taken together with the above improvement factor of four, the number of observable meteors falls by a factor of sixteen.

The final result is a resolution four times better, but with only 1/16th (6%) the number of meteors collected compared with a 50 mm lens. Statistically speaking, the 200 mm doesn't help to get a more precise view on the meteor stream; it merely decreases the amount of analysis work.

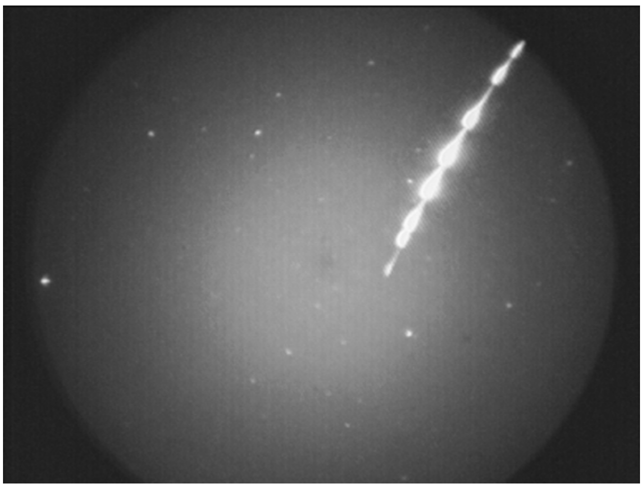

Figure 4 – Image taken with FIFIE form Utrecht, but equipped with a 200 mm, $f/4$ lens instead of the 50 mm lens. The brightest star left is χ Draconis of magnitude +4, the weakest stars are of magnitude +8.

In addition to obtaining better accuracy, it would be wise to create a larger baseline (of the order of 50–100 km) to get larger angles of convergence (de Lignie, 1996). The orientation of the baseline also plays an important role for the angle of convergence. In an ideal situation it would be oriented perpendicularly to the radiant. To operate such a network all year round with all kind of showers, and hence many different radiants, it is advisable to have at least three stations instead of two. This would give three different baselines with different orientations, ensuring there is always one with a favorable angle to every given radiant.

Last but not least, for this kind of work it is better to use Second Generation intensifiers which use microchannel plates and have a very small distortion compared to First Generation intensifiers used in FIFIE.

8 Further improvements

On a yearly base you may expect to get something on the order of 100 orbits (based on a 50 mm lens). At the moment computing one meteor orbit costs about 20 minutes of the operator's time. It would be interesting to speed this up; the ideal would be an almost automatic treatment. In our example a substantial gain would be to input the meteor co-ordinates generated by MetRec directly into the Meteor software, so the whole measuring could be skipped. This needs to be investigated further. In this perspective it is interesting to mention that probably a new version of MetRec will soon be available having orbit computation completely implemented, as communicated by MetRec's creator Sirko Molau (pers. comm), serving our goal perfectly.

9 Conclusion

In principle it does indeed seem possible to do meteor observations from polluted areas, with orbital analysis a successful application.

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Meteor showers

Long-term activity of meteor showers from Comet 1P/Halley

Audrius Dubietis[1]

Owing to the common origin of the Orionid and η-Aquarid meteor showers, these produce similar observational characteristics despite distinct intersection geometry. From the observational data of the Visual Meteor Data Base (VMDB), which represents a homogeneous dataset gathered by a standardized visual observing technique, long-term population index and activity profiles were derived. Typical ZHRs are in the range of 15–30 for the Orionids, and 40–80 for the η-Aquarids. It was found that there exists a $\sim$ 12-year periodicity of the Orionids and a certain correlation between the long-term activity profiles of both showers. The paper also gives some insight into the filamentary structure and variations of the population index of the Orionids recovered from visual observations, illustrating the complexity of the meteoroid stream.

1 Introduction

Comet 1P/Halley is one of the famous comets. The six last apparitions of the comet are well documented and the orbital motion of the comet is established rather precisely (Yeomans, 1977). Is is recognized that Comet 1P/Halley produces two meteor showers — the Orionids in October and the η-Aquarids in May. The latter are hardly observable from northern latitudes, but their activity is stronger since the Earth crosses a denser region of the meteoroid stream. The comet made two perihelion passages in the last century, namely in 1910 and 1986. There is no indication that the 1910 perihelion passage led to enhanced activity of the associated meteor showers. The 1986 perihelion passage of the comet boosted a world-wide interest of the scientific and amateur meteor community and promoted a rapid development of explicit models of the comet's meteoroid stream (McIntosh & Hajduk, 1983; McIntosh & Jones, 1988; Babadzhanov et al., 1987; Hughes, 1987). However, visual observations of the meteor showers associated with Comet 1P/Halley performed in the frame of the International Halley Watch (IHW) (Porubčan et al., 1991; Spalding, 1987) showed just normal levels of activity. Visual results were confirmed by radio observations indicating no extraordinary features (Hajduková et al., 1987). An explanation of the observational results followed thereafter pointing to the non-observability of freshly ejected particles because of the stream intersection geometry (Babadzhanov et al., 1987; McIntosh & Jones, 1988).

Despite disappointing meteor activity results during the Comet 1P/Halley return, Orionids and η-Aquarids are strong and interesting annual showers. A striking feature of both showers is the filamentary structure which is due to the orbital evolution of the meteoroid stream being strongly affected by major planets. McIntosh & Hajduk (1983) first suggested a shell model of the meteoroid stream explaining most of the observational features of the Orionid and η-Aquarid meteor showers rather well. Later, McIntosh & Jones (1988) presented a refined model based on numerical simulations, which is the most exhaustive study of the evolution of the Comet 1P/Halley meteoroid stream to date.

It has been recognized that the activity of the Orionid meteor shower varies from year to year, and these variations may reach a significant level (Lovell, 1954). Hajduk (1970) compiled various observational data of the Orionid activity backwards to 1900. Even though the available data was extrapolated from different observing techniques (not only visual), he made an attempt to align the data in terms of the ZHR and found that a certain periodicity in the long-term activity profile is clearly present. The period has not been explicitly mentioned, however. Jenniskens (1994) also noted variations in the Orionid activity from year to year which resemble a periodic behavior and discussed the possibility of an 11-year period being related to the solar cycle, which affects the upper atmosphere conditions.

2 Orionids. Individual profiles and filamentary structure

Individual profiles are of particular interest as the Orionids belong to a category of showers whose activity profiles possess short-lived temporary features (filaments) and could not be properly recovered by averaging data from subsequent years. In general, the typical activity profile of the Orionids is represented by a symmetric exponential rise and fall at the edges and a modulated 3–4-day maximum due to the superposition of several filaments. An example is the 1999 Orionid activity profile as shown in Figure 1. A two-sided exponential fit centers on $\lambda_\odot = 208\overset{\circ}{.}5$ and yields a slope value of $B = 0.22$. The filamentary structure is persistent form year to year, and for a long time it has been recognized from radio observations only (Štohl & Porubčan, 1981; Lindblad & Porubčan, 1999). As regards visual observations, the filamentary structure was usually lost either due to insufficient data coverage of the maximum period or just smeared out by averaging within long (1° or so) intervals. Examples could be

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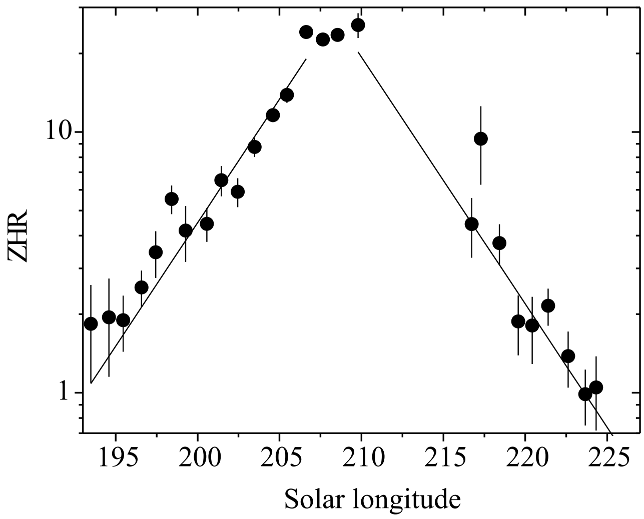

Figure 1 – Semi-log plot of the full profile of the 1999 Orionids. A double-sided exponential fit is shown by a solid curve.

the 1985 Orionid activity profile which represents a flat-topped curve (Spalding, 1987) and the combined profile of several years (Jenniskens, 1994).

As regards recent analyses, the filamentary structure of the Orionids in post-perihelion years of comet 1P/Halley was recovered from visual observations of 1990, showing that the typical duration of a single peak (associated with the filament) is $\sim$ 24 hours ($\sim 1°$ in solar longitude) (Koschack & Roggemans, 1991). VMDB data of 1993, 1995 and 1998 provide an almost continuous coverage of the period of the maximum and also allows the derivation of high-resolution (bin size $0\overset{\circ}{.}2$–$0\overset{\circ}{.}3$) ZHR profiles and profiles of the population index (Figures 2–4). The ZHR was computed using a standard procedure:

$$\overline{\mathrm{ZHR}} = \left(1 + \sum_i n_i\right) \Big/ \sum_i \frac{T_{\mathrm{eff},i}}{C_i} \,,$$

where n_i is the individual number of shower meteors observed during a time period of duration $T_{\mathrm{eff},i}$, and C_i is the total correction for the limiting magnitude LM, the field obstruction factor F, and the radiant elevation h_{R}:

$$C_i = r^{(6.5-\mathrm{LM})}\, F \Big/ \sin h_{\mathrm{R}}.$$

A standard data selection according to $C_i \leq 8$ was applied. The error margins were estimated as

$$\Delta\mathrm{ZHR} = \overline{\mathrm{ZHR}} \Big/ \sqrt{1 + \sum_i n_i}$$

In fact both, the ZHR and population index profiles illustrate the diversity of the nature of the meteoroid stream associated with Comet 1P/Halley. There is no fixed time of maximum, and no reproducible trend in the population index which could be considered typical. Although a large visual data set contributes to the analysis of the Orionids, it is difficult to determine whether or not the constant shift of the maximum time exists, as was suggested by several authors (Hajduk, 1973; McIntosh & Jones, 1983). From year to year, the Earth encounters different regions of the meteoroid stream, and continuous monitoring over years is necessary to reconstruct the changes in the fine structures of the stream.

3 Long-term activity profile

The population index has been derived for every single year, with the limitation of $LM \geq +5.0$. Table 1 lists the population index of the Orionids by year. The most typical value was found to be $r = 2.4$, and not $r = 2.9$ as listed in the IMO Working list of meteor showers. Probably the latter value came from the Comet's perihelion epoch, as the present analysis also finds high r-values in the period of 1984–1991. In general, different sources show quite a large scatter in the values of the population index; Hughes (1987) gives a mass index range for the Orionids of $s = 1.85$ to 2.51 as derived from visual observations by several authors from different years, which results in $r = 2.2$ to 4.0, using a relation of meteoroid mass and meteor magnitude indices, $s = 1 + 2.5 \lg r$.

Table 1 – Population index of the Orionids by years ($LM \geq +5.0$).

Year	Met.	r	Year	Met.	r
1984	608	3.06 ± 0.14	1993	2854	2.25 ± 0.03
1985	329	2.67 ± 0.18	1994	311	2.45 ± 0.13
1986	–	–	1995	5386	2.43 ± 0.03
1987	217	2.70 ± 0.20	1996	1469	2.42 ± 0.06
1988	294	2.52 ± 0.14	1997	798	2.61 ± 0.10
1989	206	2.74 ± 0.20	1998	4184	2.37 ± 0.03
1990	2584	2.64 ± 0.06	1999	2044	2.56 ± 0.05
1991	351	2.82 ± 0.17	2000	2464	2.37 ± 0.04
1992	800	2.41 ± 0.08	2001	1311	2.47 ± 0.06

Figure 5 depicts variations of the population index of the Orionids in 1984–2001. It is interesting to note that the population index reached the exceptionally low value of $r = 2.25$ in 1993, whereas in the years near the Comet's return, r-values were significantly higher. To be precise, the latter were derived from considerably smaller numbers of meteors, resulting in large error bars. It is not clear in the meantime how these variations in the population index are related to the overall activity of the shower. From telescopic observations (meteors up to magnitude +8), it was found that small particles are distributed continuously across the orbit (Znojil et al., 1987), whereas the flux of larger particles is considered to vary from year to year. The rate database consists of more than 30 000 Orionids observed in 1984–2001 with the major part of observations stored in the VMDB. Datasets of the years 1984–1988 were extended by the observational data of the German AKM team (kindly provided by J. Rendtel), the data published in 1985–1986 WGN issues (collected by R. Arlt) and a few observations of the author in 1987–1988. Orionid data from the solar longitude interval $\lambda_{\odot} = 190°$ to 225° (roughly October 3–November 11) are listed in Table 2. A constant 1° bin was used throughout the data analysis. Such an averaging step was applied in or-

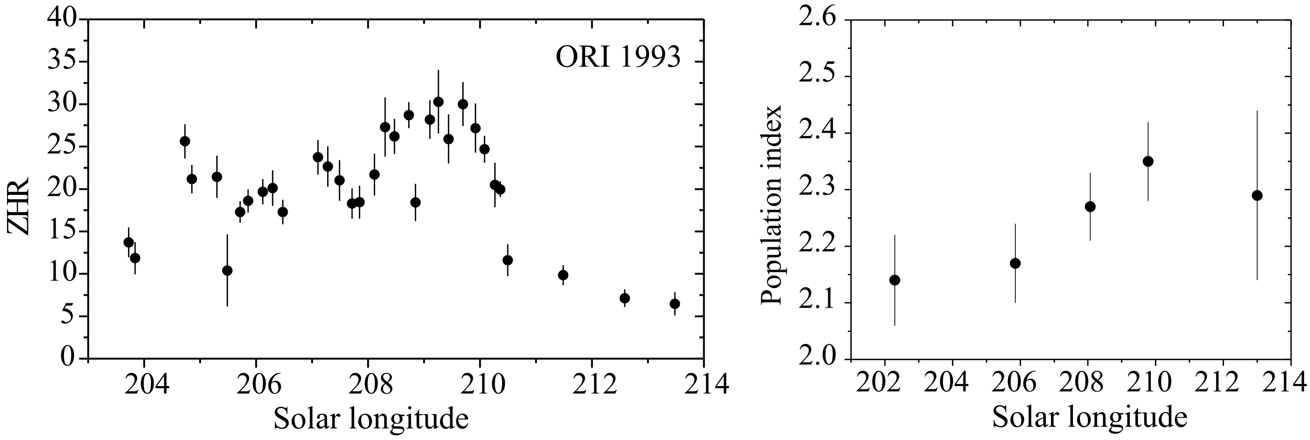

Figure 2 – Activity and population index profiles of the 1993 Orionids derived from 572 observations.

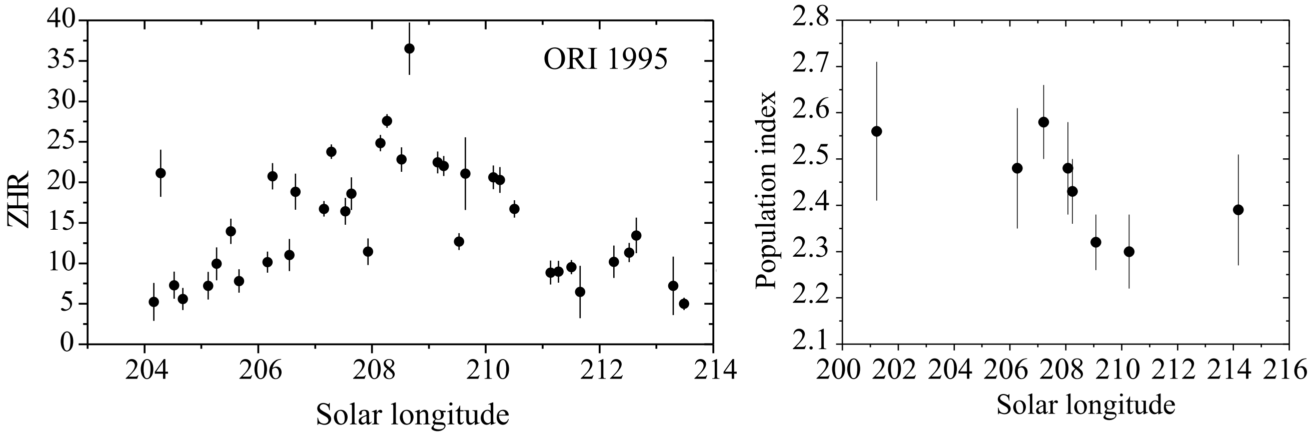

Figure 3 – Activity and population index profiles of the 1995 Orionids derived from 715 observations.

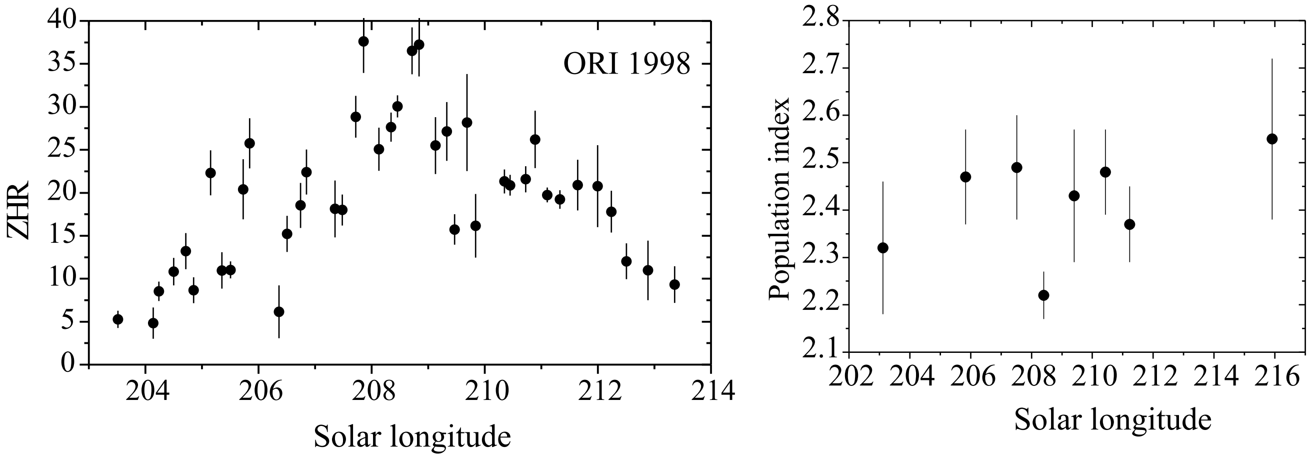

Figure 4 – Activity and population index profiles of the 1998 Orionids derived from 819 observations.

der to make the data comparable with that previously published and avoid the influence of rapid changes in the activity imposed by the filamentary structure. Of course, with such simple data processing, the observer-related factors (experience, perception, etc.) are not allowed for. On the other hand, these have only a small influence on the final result if the number of averaged observing periods is large, and hence are mainly ruled out by the statistics. This is indeed the case for the Orionid activity analysis, where 30 to 100 observing periods contribute to a single ZHR estimate.

Another factor which may affect the overall content of the Orionid data is related to shower association. In particular, the ε-Geminids, which are very similar to the Orionids from the observer's point of view, have their maximum on October 18 with the radiant being in close vicinity of that of the Orionids. The overall activity of the ε-Geminids is low (ZHR ≈ 2), so there is a high probability that the rates of the ε-Geminids are overestimated at the expense of the Orionids.

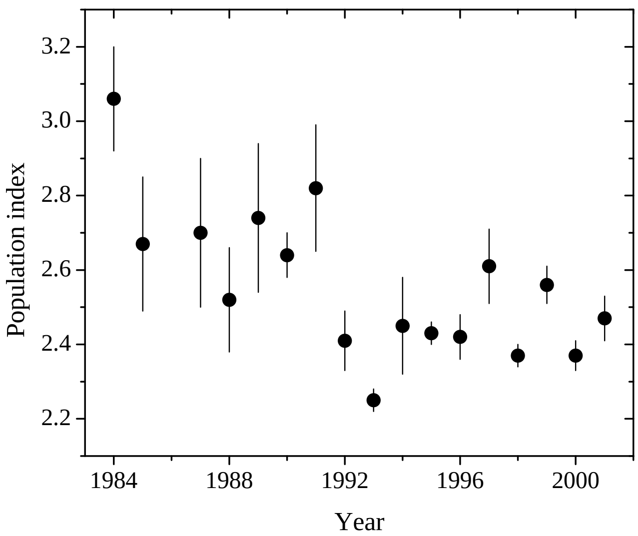

Figure 5 – Long-term population index profile of the Orionids.

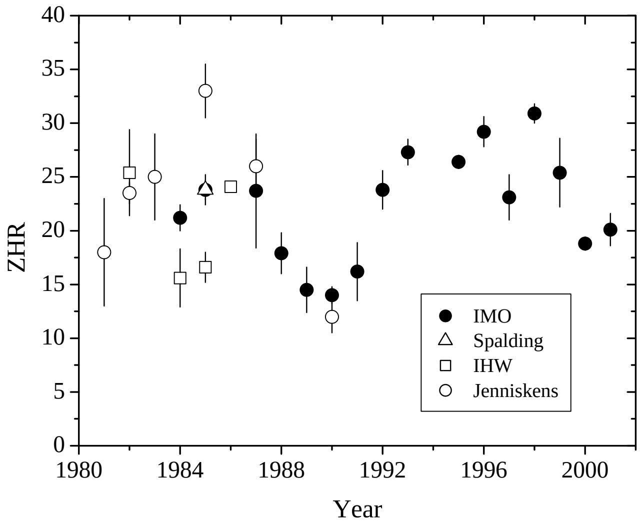

Figure 6 – Long-term activity profile of the Orionids.

Table 2 – Orionid data ($\lambda_\odot = 190°$ to $225°$) from visual observations in years 1984–2001. ZHR is calculated using 1° bins and represents the average activity level.

Year	Met.	ZHR	Year	Met.	ZHR
1984	866	21.2 ± 1.2	1993	3835	27.3 ± 1.2
1985	1791	23.8 ± 1.4	1994	351	–
1986	–	–	1995	5979	26.4 ± 0.6
1987	542	23.7 ± 5.3	1996	2186	29.2 ± 1.4
1988	504	17.9 ± 1.9	1997	1076	23.1 ± 2.1
1989	482	14.5 ± 2.1	1998	4648	30.9 ± 0.9
1990	3052	14.0 ± 0.8	1999	2571	25.4 ± 3.2
1991	523	16.2 ± 2.7	2000	2378	18.8 ± 0.6
1992	1167	23.8 ± 1.8	2001	1317	20.1 ± 1.5

An average ZHR versus year is plotted in Figure 6. Data of the IHW (Porubčan et al., 1991), Spalding (1987) and Jenniskens (1994) are added as well. Although the results of the IHW are scattered, there is a satisfactory agreement between all the data. An outstanding feature of the long-term profile is a gradual change in the ZHR with maxima in 1984–1985 (although the scatter in ZHR values is large) and 1993–1998 (ZHR ≈ 30). An exceptional activity of 1993 has been noted by Rendtel & Betlem (1993) to date. A clear minimum in 1989–1991 with ZHR ≈ 15 is also well detectable. From the compilation of 1900–1970 data by Hajduk (1970), the most prominent activity peaks were found in 1924, 1936 and 1948 pointing to $\sim$ 12-year periodicity. Indeed, visual observations of 1947 pointed to high Orionid activity with ZHR ~ 30 (Porubčan & Zvolanková, 1984). If the $\sim$ 12-year period is true, maxima in 1984 and 1996 could be projected forward. Indeed, the long-term profile of 1984–2001 provides a good extension for Hajduk's compilation with a well-pronounced maximum in 1996 and a less obvious one in 1984. In contrast, the 11-year period — if starting with 1936 as the middle — gives maxima in 1991 and 2002, which are completely out of phase with data shown in Figure 6.

A correlation between the minima of Orionid activity and the 12-year period of Jupiter has been noted by McIntosh and Hajduk. They related changes in the meteor activity to a combined effect of a rapid motion of the longitude of the nodes of the cometary orbit and a variation of the period of the Comet at each return, which evolve from the perturbations by major planets (Jupiter in particular). Although the above considerations explain the origin of the filaments within the meteoroid stream well, there is only slight understanding of the evolution of fine structures, which may be responsible for the periodicity. Interestingly, the periodic behavior seen in the activity profile is not obviously followed by the changes in the population index. Of course, the time window of the r-profile is too narrow to make extensive conclusions. There is also no clear indication that filaments are populated by larger-mass/size particles, which would in turn result in a lower population index, as would be seen from individual profiles of the population index.

4 η-Aquarids

Another encounter of the Comet Halley meteoroid stream produces the η-Aquarid meteor shower in May. In general, the η-Aquarids exhibit similar structural features (filaments) to the Orionids. The existence of a filamentary structure has been justified from radio (Hajduková et al., 1987) and, to some extent, from visual observations too (Cooper, 1996). Because of much closer geometry of the encounter, the activity of the η-Aquarids is higher by a factor of 2–3 than compared that of the Orionids. Despite this, there is not much observational data on the η-Aquarids since the radiant of the shower is badly disposed for observers in the Northern hemisphere. Recent analyses of visual data cover the periods of 1984–1987 (Porubčan et al., 1991), 1986–1995 (Cooper, 1996) and a single year of 1997 (Rendtel, 1997). Satisfactory data on the η-Aquarids, cov-

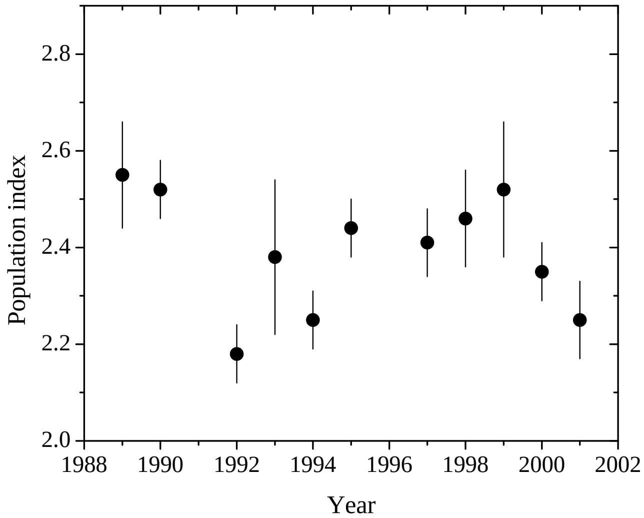

Figure 7 – Long-term population index profile of the η-Aquarids.

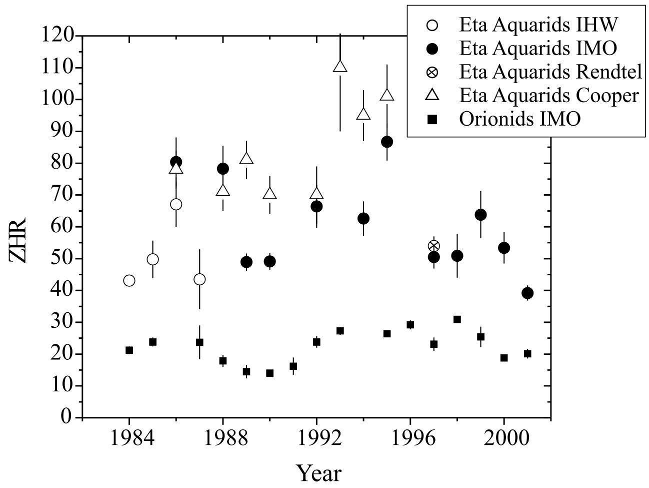

Figure 8 – Comparison of Orionid and η-Aquarid activity in 1984–2001.

ering the interval of April 25–May 16 and the time of maximum (May 5–7) in particular, can be found in the VMDB from 1986 up to the present, with the exceptions of 1987, 1991, 1993 and 1996 (see Table 3).

Figure 7 depicts the population index profile of the η-Aquarids. It is interesting to note that the population index of the η-Aquarids had a minimum in 1992–1994, while an extremely low population index of the Orionids was found in 1993. Without going into much detail with individual activity profiles of the η-Aquarids, an average activity level has been derived in the same manner as in the case of the Orionids, i.e. using 1° bins and $C_i \leq 8$. In addition, a limitation of $h_R \geq 20°$ was found worthwhile here. For the sake of clarity, the latter limitation does not change the trend greatly but rather alters the ZHR values by some 5%. No magnitude data were available for 1986 and 1988, so $r = 2.5$ (which is supported by the trend in Figure 7) was used in the ZHR calculation.

A comparison of the long-term activity profiles of the η-Aquarids and Orionids is given in Figure 8. Interestingly, there is a certain correlation between these two. This finding looks rather surprising as the conditions of encounter of the meteoroid stream with Earth differ greatly (0.065 AU for the η-Aquarids and 0.154 AU for the Orionids). Beside the physical factors which may result in similar activity behavior of both meteor showers, observer-related factors may play a significant role in the derivation of the average activity profile of the η-Aquarids, because fewer observational data are available. Additionally, ZHRs estimated from the observations in the Southern hemisphere are larger almost by factor of 2 than those estimated from the Northern hemisphere on several occasions (Cooper, 1996). Nevertheless, there is a good indication of a rise of η-Aquarid activity towards 1996. All these features require deeper insight and have not yet been tested, being a matters for further concern.

Table 3 – η-Aquarid data ($\lambda_\odot = 35°$ to $55°$) from visual observations in the years 1986–2001. The ZHR is calculated using 1° bins and represents an average activity level. Meteors are the numbers of observations on which the corresponding Values are based.

Year	r-value		ZHR	
	Meteors	Value	Meteors	Value
1986	–	–	487	80.4 ± 7.7
1988	–	–	664	78.3 ± 7.2
1989	507	2.55 ± 0.11	2803	48.9 ± 2.7
1990	1320	2.52 ± 0.06	1384	49.1 ± 2.7
1992	957	2.18 ± 0.06	1051	66.4 ± 6.8
1993	212	2.38 ± 0.16	293	–
1994	960	2.25 ± 0.06	1053	62.6 ± 5.4
1995	1239	2.44 ± 0.06	1258	86.7 ± 5.9
1997	962	2.41 ± 0.07	1117	50.5 ± 3.6
1998	571	2.46 ± 0.10	650	50.9 ± 6.9
1999	359	2.52 ± 0.14	365	63.9 ± 7.4
2000	1396	2.35 ± 0.06	1733	53.4 ± 4.9
2001	495	2.25 ± 0.08	617	39.2 ± 2.4

5 Concluding remarks

It was found that both the Comet-1P/Halley-related meteor showers, the Orionids and the η-Aquarids, exhibit periodic changes in their activity levels. These variations may reach a factor of 2 with typical ZHRs of Orionids and η-Aquarids varying from 15 and 40 in the minimum to 30 and 80 in the maximum, respectively. Moreover, there is a definite correlation of the long-term activity profiles of both showers, suggesting an $\approx$ 12-year period, which follows from comparison with the compilation of the long-term activity profile of the Orionids by Hajduk (1973). Most probably, such a period is imposed by the perturbations by the major planets (Jupiter in particular) of the meteoroid stream, which has a low inclination to the ecliptical plane. Although the population indices of both showers possess variations from year to year too, they do not resemble the changes in the activity level. Nevertheless, again a certain connection between the population indices of the Orionids and the η-Aquarids exists. Probably there were clear minima of $r = 2.18$ and $r = 2.25$ for the Orionids in 1993 and the η-Aquarids in 1992. An average population index is similar for both showers with $r = 2.4$ being a characteristic value.

In the meantime, it follows from this analysis that we are facing a local activity minimum of the Comet 1P/Halley meteor showers. If the considerations presented in this paper are correct, the forthcoming maximum is due in 2008.

Acknowledgment

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Fireballs

A superbolide recorded by the Spanish Fireball Network

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An impressive −17 absolute magnitude fireball recorded by CCD cameras of the Spanish Fireball Network is described. An initial analysis is presented including first information about the probable fall of meteorites on Morocco. Observations of two other fireballs on similar dates but from different radiant sources are also presented. Future plans and the prospects for meteorite recovery in Spain are discussed.

1 Introduction

We reported in a previous paper the build up of our network (SPMN, Spanish Photographic Meteor Network), a project that began its activities in 1997 through a joint effort between professional and amateur astronomers (Trigo-Rodriguez et al., 2001). We are currently developing a monitoring system aimed at recording the sky using CCD cameras. With this type of device we are able to record fireballs appearing over Spain and bordering countries, a zone where no information about fireballs has previously been available. The first all-sky CCD camera has been operative since 2002 December at the El Arenosillo Observatory as a part of the BOOTES project (Castro-Tirado et al., 1999). This observatory is at CEDEA-INTA in Huelva (Spain). We plan to install two additional all-sky stations in Castellón and Valencia provinces in the near future. Our purpose is to perform continuous fireball monitoring in Spain, obtaining orbital as well as chemical information on meteoroids. We also hope in the future improve our detection systems and continue our close collaboration with the European Fireball Network (Spurný, 1997).

Different types of studies are being performed, such as the calculation of meteoroid orbits from conventional photography, video and CCD techniques, stream spatial fluxes, elucidation of meteor parent bodies, meteor spectroscopy, meteor atmospheric modeling, identification of meteorites, meteorite recovery and meteorite analysis, and development of meteor software.

2 The 2003 January 27/28 fireball

On Monday, 2003 January 27/28, a slow-moving fireball of −17 maximum absolute magnitude was observed entering the atmosphere from the Southeast of Spain. The event was really impressive although it appeared low in the horizon, being observed from different Spanish provinces, in particular from Andalucía, Castilla-La Mancha and Murcia regions. Our first steps were to consider the possibility that such an impressive event was produced by a rocket or satellite re-entry, as our previous reported Shenzhou artificial fireball (Trigo-Rodríguez et al., 2000). However, taking into account the available information on re-entries and the fireball trajectory, apparent velocity and flares produced along the path, this possibility was completely ruled out.

The fireball, cataloged as SPMN030101, was really extraordinary. It appeared at $19^{\mathrm{h}}50^{\mathrm{m}}36^{\mathrm{s}} \pm 1\mathrm{s}$ UT, being observed by hundreds of people who usually leave work and return home at this hour. The head of the fireball was blue/green according to eyewitness reports, leaving a short but bright orange train of short persistence. Many people reported that the fireball train lasted more than one second. The eyewitnesses reported an angular velocity of 5–10°/s, which gives a geocentric velocity in the approximate range 20–30 km/s. We are waiting for information from satellite detectors and searching for additional images to improve the quality of the trajectory and the geocentric velocity.

At the same moment of fireball apparition, Instituto Astrofísica de Andalucía (IAA) researchers Eloy Rodríguez and Pedro Amado were coincidentally making photometry on star Y Camelopardalis. The photometer registered an extraordinary increase in the background luminosity of the sky when the fireball reached its maximum luminosity, due to several flares in the ending part of its trajectory. The increase was detected in the four Strömgren bands (filters ubvy centered at 350.5, 411.0, 468.5 and 548.8 nm respectively) with a photometer able to estimate the background luminosity with precision. The diaphragm used to make these measurements was only 45″ in diameter. The increases in luminosity of these bands obtained during one second of integration are given in Table 1.

This photometric data demonstrates that the background sky brightness increased despite the large angular separation between the area collected by the photometer (directed towards Y Camelopardalis at $\alpha =$

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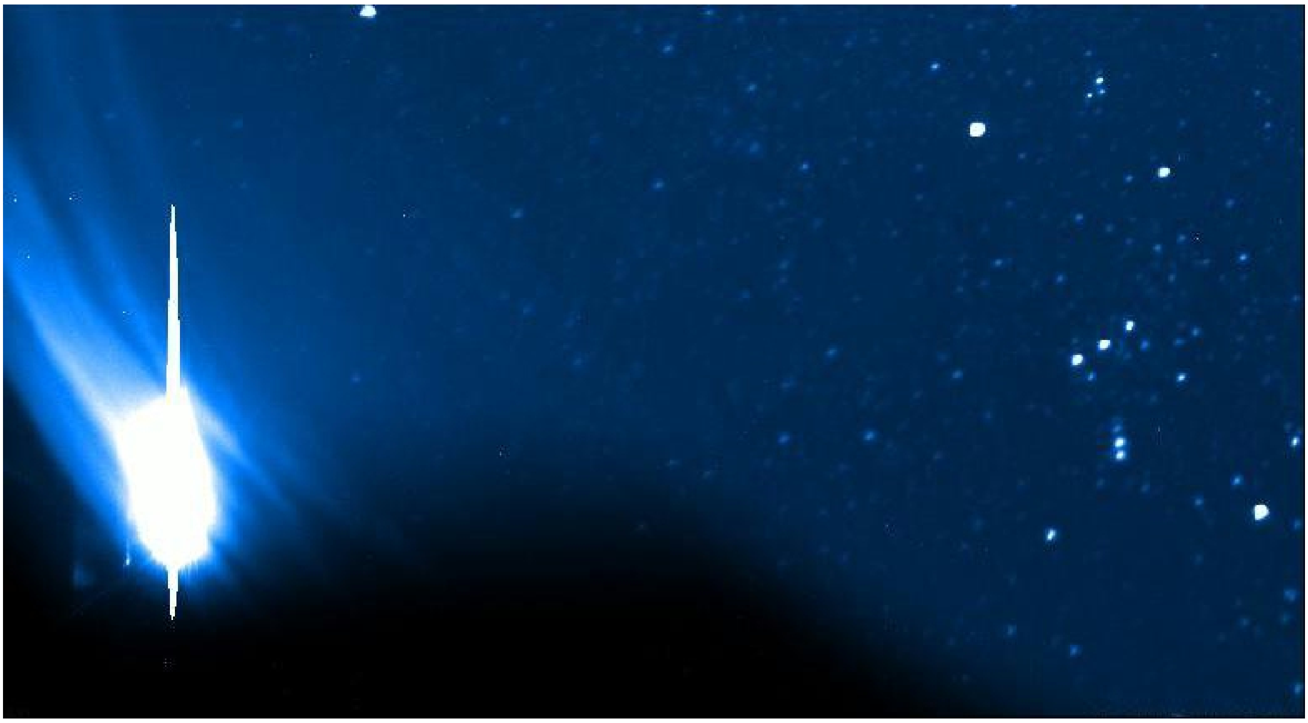

Figure 1 – A part of the CCD all-sky image of the 2003 January 27/28 fireball SPMN030101 registered from the El Arenosillo station in Huelva (INTA-LAEFF). It is important to note that the vertical brightest line is produced by CCD saturation and that the fireball trajectory deviates slightly from this.

105.29°, $\delta = 76.1°$) and the region where the fireball appeared. In order to estimate the fireball magnitude we have analyzed the increase in background luminosity due to the Full Moon on February 16 when it was at a similar distance (65°) from the photometric field and the altitude in the horizon was similar (30°). Such data, and the evidence that the fireball path on the image during the flares is clearly saturated, suggest that during the flares the fireball reached apparent magnitude −13. Taking into account the distance to our observing stations, we derived that the fireball absolute magnitude was −17. It is probably one of the brightest fireball events ever recorded from our country. A fireball of such magnitude really is capable of illuminating the whole sky as eyewitnesses reported. Our simulation software assuming a geocentric velocity of 25 km/s, a zenith angle of 65° and a density of 3 g/cm^3, giving an initial mass of 1500±700 kg and a fireball lifetime around 6 seconds, in full accord with observations. We have deduced that some small fragments probably survived, totaling a few kilograms in mass. This is probably confirmed by people who contacted us from a specific region of Morocco, giving serious evidences of meteorite recovery in the form of small fragments. We are studying the truth of such reports and trying to obtain some of these pieces.

Astrometric measurements from the all-sky image are not easy due to the luminosity of the fireball, the saturation of the image and the presence of clouds (see Figures 1 and 2). Fortunately we obtained one additional image (not included in this paper) from another CCD camera automatic system. This other high res-

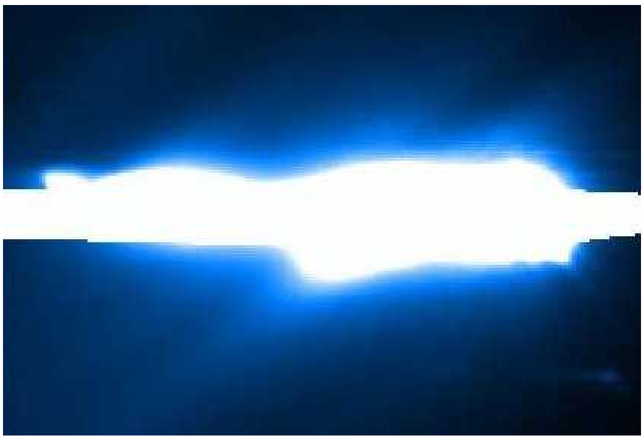

Figure 2 – Enlarged image of the SPMN030101 fireball showing the beginning of the path on the left. We can note on this image that the fireball was recorded through high clouds (cirrus).

Table 1 – Luminosity in the different bands of Strömgren photometric bands. The field altitude (F.A) and angular distance (A.D) to the photometric center are also given.

Object	F.A. (°)	A.D (°)	u	b	v	y
Fireball	30	65	−4.6	−3.9	−3.8	−3.0
Full Moon (95% illuminated)	45	100	−4.4	−4.4	−4.7	−3.6

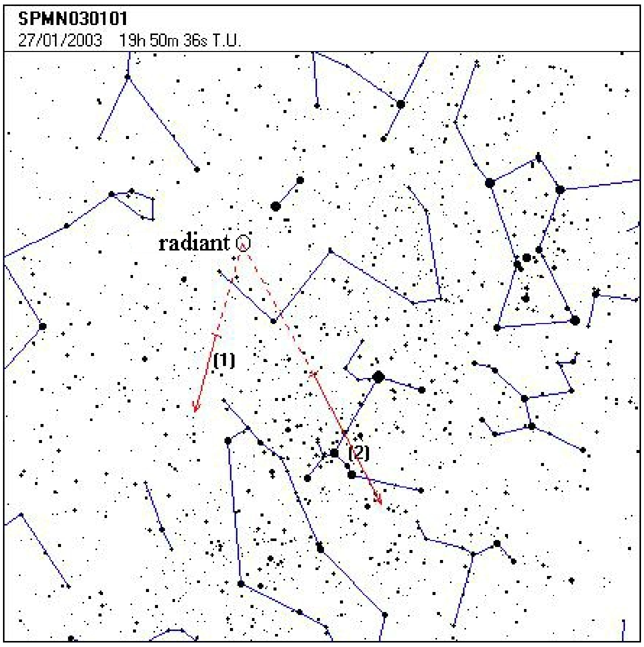

Figure 3 – Determination of the SPMN030101 fireball radiant from the apparent trajectories derived from CCD imaging by El Arenosillo Observatory in Huelva (1) and visual data from Málaga (2) obtained by experienced meteor observers. Another good visual trajectory obtained from Alhama (Murcia) also matches the derived radiant well, but it is outside this sky field because from Murcia region the fireball appeared below the constellation of Cetus.

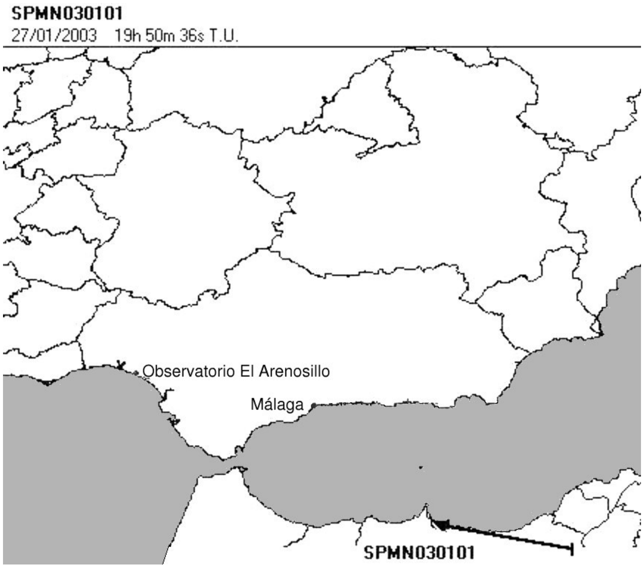

Figure 4 – Preliminary trajectory of the SPMN030101 fireball projected on the North of Africa, as deduced from CCD and visual observations.

olution image, covering a field of 40° × 28° in size, showed the first part of the fireball path and allowed us to improve astrometric measurements. The apparent trajectories of the fireball from the different stations are plotted on the celestial sphere in Figure 3.

From these trajectories we have derived its apparent radiant located at $\alpha = 119° \pm 1°$ and $\delta = +1° \pm 1°$. Taking into account the observational geometry from the different stations, our software (Trigo-Rodríguez et al., 2002) derived the trajectory of the fireball in the atmosphere. Figure 4 gives this preliminary trajectory projected on the terrestrial surface. We hope to obtain additional data to improve the quality of the fireball path in the near future.

3 Other fireballs in late January

At the end of January there were other fireballs which attracted our attention. We decided to analyze in detail the reports available in order to unravel if such activity originated from the same radiant. Several people filled in the Spanish Fireball Network fireball report form online, allowing us to obtain interesting data on two other bright fireballs. One of them also appeared on January 27/28 around 05^h30^m UT, but its radiant was located in the Virgo-Leo region, being in this epoch considered sporadic. The second one occurred the following night of January 28/29 around 18^h UT being cataloged as SPMN030102. Unfortunately our cameras did not register these two additional fireballs, but they were reported by several eyewitnesses from the Barcelona and Girona areas. The fireball of January 28/29 was so bright that it was clearly visible from the same city of Barcelona under a sky illuminated by severe light pollution. The eyewitnesses' reports suggest a tentative fireball magnitude around −7 to −10. The approximate trajectory from Viladrau (Girona) was $\alpha_{\rm beg} = 307°$, $\delta_{\rm beg} = +9°$ and $\alpha_{\rm end} = 266°$, $\delta_{\rm end} = +52°$. The fireball duration was around 4 or 5 seconds, with a green head that fragmented into three pieces along the final part of the trajectory. The slow angular velocity and its apparent trajectory reveal a probable association to the ε Columbae–ζ Canis Majoris radiant, according to the Terentjeva list of fireball sources (Terentjeva, 1990). Unfortunately, single-station visual data are not sufficient to reach any conclusion about either additional fireball.

4 Meteorite recovery in Spain

We plan to establish two new stations in Castellón and Valencia, adding precise rotating shutters to the all-sky CCD cameras in order to derive the velocity of the fireballs. At the moment we have several photographic camera batteries capable of providing velocity data with an accuracy of 0.1–0.2 km/s but we use them only in periods of predicted high meteoric activity (Trigo-Rodriguez, 2001; Trigo-Rodríguez et al., 2002).

We believe that the actual development of this Fireball Network is a key step to obtaining valuable information on the fall of meteorites in Spain and neighboring countries currently outside the European Fireball Network cameras' coverage. Multiple station imaging of eventual big fireballs, such as those reported here, provide excellent information about the exact fall areas of the associated meteorites enabling relatively easy recovery (Spurný et al., 2002). Photometric magnitude and fragmentation processes along the fireball path recorded by video, photography or CCD imaging techniques provide valuable information on the density and the survival mass of the meteorites arriving at the Earth's surface. This information is required in order to plan meteorite recovery. During the last decades, meteorite recovery in Spain has been very rare; before the development of our network, fireball information was not considered or was scarce, except in one recent fortunate case (Docobo & Ceplecha, 1999). A possible explanation is that during the last decades a significant part of the rural population in Spain has settled down in the big cities and, in consequence, casual reports on meteorite falls on rural zones are now difficult. Otherwise, meteorite recovery in nearly desert regions of our country would be very favorable, being a clear incentive for our organizing effort. More information on our project is available at `http://www.spmn.uji.es/`.

Acknowledgments

We thank to both Dr. Eloy Rodríguez and Dr. Pedro Amado (IAA). We are also grateful also for the additional information on fireball activity in January received from Dr. Pavel Spurný (Ondrejov Observatory) and from Dr. Peter Brown (University of Western Ontario). Francisco Ocaña of the Agrupación Astronómica de Madrid collaborated actively in collecting fireball reports from many people. Finally our sincere thanks to casual eyewitnesses who reported the events registered at the end of January: Fernando Acedo del Olmo, Marta Ardiaca i Falguera, Christian Castillo, Jesús Chinchilla, Antonio E. López Blanco, María Dolores López Morales, José J. López Moreno, Francisco J. Montalbán Rodríguez, Isidro Rodríguez Sarmiento and Carles Valentí.

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Bright fireball recorded from the EN photographic network

Pavel Spurný [1]

A very slow moving fireball of absolute magnitude −7 was recorded at six Czech stations of the European Fireball Network (EN). The eight all-sky records were taken by fish eye cameras with Zeiss Distagon $f/3.5, f =$ 30mm lenses at the stations 20 Ondřejov (4 records), 9 Svratouch, 15 Telč, 11 Přimda and 14 Červená hora. Another record was taken by a long focus horizontal camera ($f/4.5, f =$ 360mm Tessar lens) located at station 12 Veselínad Moravou. In addition to these direct photographic records, the fireball was also recorded by two spectral cameras from the Ondřejov Observatory. These very detailed photographic spectra cover the entire luminous trajectory of the fireball and contain hundreds of emission lines. A radiometric system also located in Ondřejov provided us with a very detailed light curve (1200 samples/s) and the exact time of the event — $03^h53^m25.0^s$ UT for the beginning. The fireball travelled a 86.2 km luminous trajectory in 7.0 seconds and terminated at an altitude of 33.9 km. The beginning of the fireball was photographed at a height of 74.1 km eastward from the Czech town Mladá Boleslav and terminated near the small Czech town Kácov in central Bohemia. The meteoroid with an initial mass of about 5 kg entered the atmosphere at a velocity of almost 14 km/s. During its flight it was decelerated to a terminal velocity of 6.2 km/s. In the last third of its luminous flight, the body gradually fragmented and small meteorites with a total mass of several hundreds of grams could have landed in the vicinity of the Czech town of Cechtice. The calculated impact point for the possible 100 g meteorites is $\lambda = 15\overset{\circ}{.}0796$ E, $\varphi = 49\overset{\circ}{.}6144$ N.

The fireball stations, especially the closest one at Ondřejov, were very favourably situated to the fireball trajectory so that all parameters describing this fireball were determined with very high precision. Due to the very good photographic records, very detailed velocity information and radiometric light curve, and very rich photographic spectra, this fireball is the best ever recorded within the European fireball network.

All important values describing the atmospheric trajectory and the heliocentric orbit are summarized in the Table.

Table 1 – Observed and reduced data for the "Kácov" fireball EN250203 on 2003 February 25, $3^h53^m25.0^s \pm 0.3^s$ UT (time refers to the beginning of the fireball).

Atmospheric trajectory data			
	Beginning	Max. light	Terminal
Velocity (km/s)	13.950 ±0.002	12.70	6.13 ±0.12
Height (km)	74.08 ±0.01	46.3	33.92 ±0.02
Longitude E (°)	15.0791±0.0002	15.094	15.0919±0.0002
Latitude N (°)	50.4604±0.0001	49.992	49.7802±0.0001
Dynamic mass (kg)	5	2.5	≈ 0.1
Absolute magnitude	−2.8	−7.1	−2.3
Slope (°)	28.096 ±0.005	–	27.416 ±0.005
Total length (km)		86.2	
Duration (s)		7.0	
Ablation coefficient (s^2km^{-2})		0.013±0.003	
PE coefficient/fireball type		4.41 / I	
EN stations no.	20 Ondřejov, 9 Svratouch, 15 Telč, 11 Přimda 12 Veselínad Moravou, 14 Červená hora		
Radiant data (J2000.0)			
	Observed	Geocentric	Heliocentric
Right ascension (°)	47.342±0.014	49.784±0.009	–
Declination (°)	67.619±0.005	50.499±0.009	–
Ecliptical longitude (°)	–	–	64.549±0.001
Ecliptical latitude (°)	–	–	6.617±0.003
Initial velocity (km/s)	13.954±0.002	8.404±0.003	37.536±0.002

Orbital data (J2000.0)			
a (AU)	2.3126 ± 0.0010	ω (°)	175.801 ± 0.004
e	0.5724 ± 0.0002	Ω (°)	336.08674 ± 0.00001
q (AU)	0.98883 ± 0.00001	i (°)	6.619 ± 0.003
Q (AU)	3.636 ± 0.002	Shower	–

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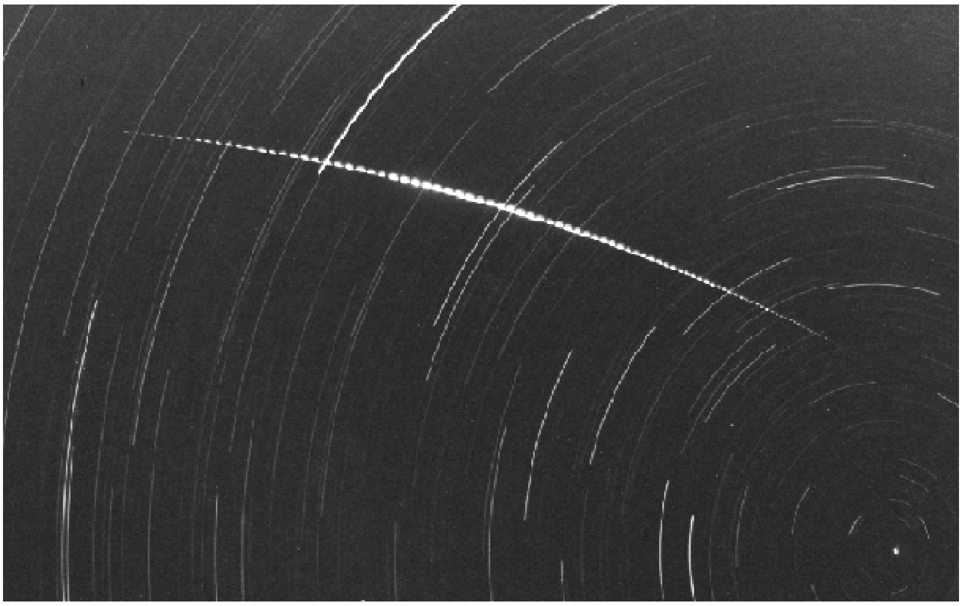
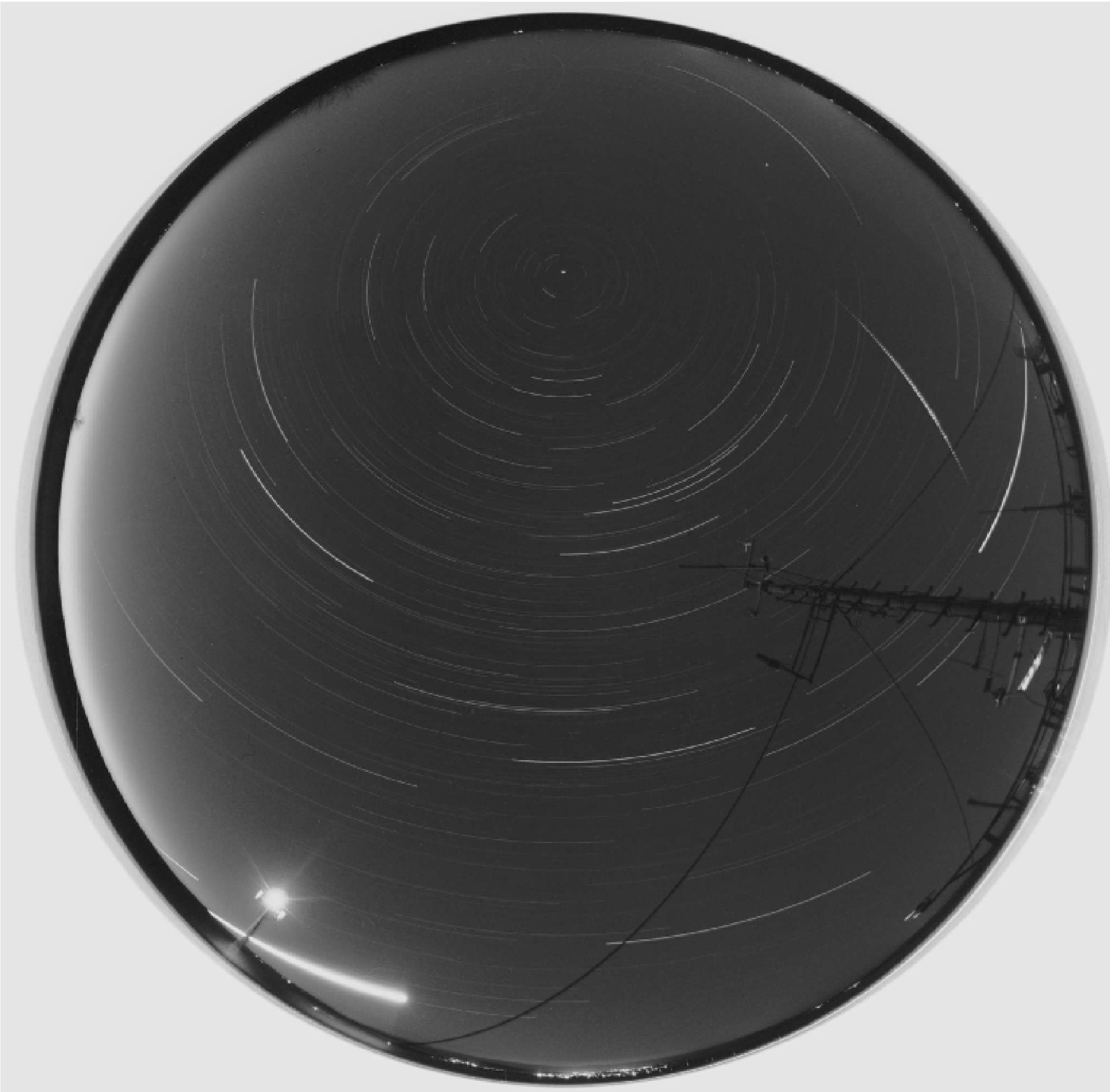


Figure 1 (left) – Detailed view of the EN250203 fireball from the automated all-sky camera located at the Ondřejov Observatory, equipped with a Zeiss Distagon fish eye lens of $f/3.5$, $f = 30$mm. Interruptions of the luminous path of the fireball are caused by three arms of a rotating shutter placed near the focal plane (21 breaks/s).
A larger copy of this appears on the back cover.

Figure 2 (below) – All-sky image of the EN250203 Kácov taken by fixed fish-eye camera at the Czech fireball station Svratouch. The luminous path of the fireball is interrupted by rotating shutter with 15 breaks/s.



History

Meteor Beliefs Project: Introduction

Alastair McBeath[1] *and Andrei Dorian Gheorghe*[2]

A new project to investigate beliefs in meteors and meteoric phenomena in past and present times using chiefly folklore, mythology, prose and poetic literature, is described. Some initial examples are given, along with a bibliography of relevant items already in print in IMO publications.

1 Introduction

Among the many and varied articles published in *WGN* and the *IMC Proceedings* volumes in recent years, a proportion have included aspects of beliefs in meteors in past and current times. The Romanians in particular have employed artistic methods, as well as scientific ones, to help interest and enthuse new meteor astronomers, often drawing on such beliefs, or reinterpreting them in fresh ways. These activities have always formed part of their annual *Perseide* meteor festivals each summer. At IMCs too, the Romanian displays of photos and other artwork, along with poetry and prose collections, sketches and short plays have led the way in encouraging others to produce similar materials, so that this has become a regular part of the IMCs. It is clear from personal contacts at IMCs and through correspondence we have had during the last decade and more that a good many people also find such things entertaining and of interest. What we propose now is a distinct project to encourage more people to share such matters among the IMO's membership as a whole, and indeed beyond.

2 The Meteor Beliefs Project

Our proposal is quite simple in essence, but potentially far-reaching and open-ended in practice. What we would like is that anyone with information to share should write to us with their favourite literary, poetic, mythological or folkloric references to meteors. We will then either re-edit short items into articles for *WGN*, or present longer pieces in a suitable format for this journal under the authorship of the originator, and under the general Meteor Beliefs Project banner. Of course, we will happily acknowledge all contributors in whichever case.

When you are sending us your material, we need to know exactly where the reference comes from, giving as much detail as possible, and including things such as specific line numbers for poems and plays, or dates, places and people for oral tales you have collected, for example. The information should be sufficient to allow any future investigator to easily find and confirm your report for written items. As all IMO publications are in English, we will need an English translation of whatever you send, but in some cases, you may also feel that an original-language version should also be presented (perhaps where poetic scansion cannot be properly represented in English). If there are particular problems with words or concepts that cannot be translated into English, please make this clear. If you are unsure, do contact us to discuss such things in advance. If you need to send material using characters which are not in the standard American/English ASCII computer character set, please send a hard copy by ordinary mail and not by e-mail, as this will only cause problems and delays in publishing anything sent.

We have several items almost ready for publication, and plans for some things we would like to do if there is sufficient response from you, but we welcome constructive comments and ideas for anything connected with this Project, as well as individual items as already outlined. If you think we've missed something, or if you've found a variant translation you think is interesting, let us know! We are far from infallible!

So far, we have articles in preparation on meteoric aspects of ancient Greek and Roman mythology; in some of Shakespeare's plays; what 'meteor' means and has meant in English; and meteoric imagery in the works of William Blake. Among future plans, we would like to examine beliefs in meteoric dragon myths beyond Britain and Romania (we have some notes on Bulgarian and Serbian meteor-dragons, but would welcome more on these too), and we are interested in collecting meteor folklore and myths from other European and, especially, non-European countries and cultures. What is 'meteor' in your native language? Where does it derive from? Does it have any other meanings? Does it have some special meaning in some localities and not others within your country? Were you told tales or beliefs about meteors as a child? What were they? Did you pass them on to your children or other relations?

We do not want to be too restrictive on what material we wish to collect and present, and we would enjoy seeing contemporary or past material. However, we are less interested in minor mentions of meteors which give little other information, such as may be found in some medieval chronicles, for example. So a simple reference to a meteor being seen with no other information or description is less useful to us than one which

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perhaps embellishes the event with some other connection or some interesting commentary on how the event was perceived. Remember, we are looking at what people believed and believe about meteors, not necessarily what may be scientifically relevant. We would also like to strike at least a general balance between material from different times, and not end up concentrating too closely on any one particular time interval.

If you are not sure, send us the material anyway, and please do not be concerned that your report may duplicate someone else's. We would rather get some material we cannot use, or several repetitions of the same thing, than miss the chance to bring to light some long-forgotten or potentially important item. In all cases, we are relying on you to help us move the Project forwards!

The following sections provide some short examples of what we have collected so far. These are not definitive, nor do they cover the full range of what we would like to cover. They are simply to start the Project off. In future, we intend both short articles with examples that may bring in additional material and comments, and occasional longer items where more discussion or detail is felt desirable.

3 Snippets from some English poets

JOHN MILTON (1608–74), 'Paradise Lost', 1667; Book I, lines 536–537: *The imperial ensign; which, full high advanc'd,/ Shone like a meteor streaming to the wind./* Here taken from (Milton 1833, p. 19).

THOMAS GRAY (1716–71), 'The Bard', 1754–57; lines 19–20: *Loose his beard, and hoary hair/ Stream'd like a meteor, to the troubled air.* From (Starr & Hendrickson 1966, p. 19). Gray attributed his inspiration for the 'meteor' line directly to Milton's line 537, just above here.

ALFRED, LORD TENNYSON (1809–92), 'The Princess', 1847–50; Part VII, lines 117–118: *Now slides the silent meteor on, and leaves/ A shining furrow, all thy thoughts in me./* Quote from (Tennyson 1994, p. 276).

4 Edgar Allan Poe

Poe lived from 1809–49, surviving his young wife Virginia by just two years (she was 25 when she died of tuberculosis). His life in America was lived in often extreme poverty and he appears to have been at times a deeply troubled and melancholic man. He was able to enjoy only an incredibly brief period of success after the publication of his 'The Raven and Other Poems' in 1845, prior to his death. The magnificence of many of his Gothic tales and poems continues to provide fascination and inspiration modernly, and in that way he and his works live on. The extract we give here is from Part II of an astronomical poem he wrote as a youth, 'Al Aaraaf', a name he gave it after Tycho Brahe's supernova in Cassiopeia in 1572. We wondered if the following quotation might have been influenced by his witnessing of the Leonid storm in 1833. It is taken from (Poe 1938, pp. 997–998). It is led up to by a descriptive twin image of the Moon and the 'fair stranger light' of the supernova in the heavens shining above mountains and water:

Uprear'd upon such height arose a pile
Of gorgeous columns on th' unburthen'd air,
Flashing from Parrian marble that twin smile
Far down upon the wave that sparkled there,
And nursled the young mountain in its lair.
Of molten stars their pavement, such as fall
Thro' the ebon air, besilvering the pall
Of their own dissolution, while they die—
Adorning then the dwellings of the sky.
A dome, by linked light from Heaven let down,
Sat gently on these columns a crown—
A window of one circular diamond, there,
Look'd out above into the purple air,
And rays from God shot down that meteor chain
And hallow'd all the beauty twice again,
Save when, between th' Empyrean and that ring,
Some eager spirit flapp'd his dusky wing.

Poe attributes the 'Of molten stars' line to Milton's inspiration of him by the couplet: *Some star which, from the ruin'd roof/ Of shak'd Olympus, by mischance, did fall./* (footnote 1 on p. 998 of (Poe 1938)). Typical for his time, Poe does not elaborate on where this quote comes from, but it derives from lines 43–44 of Milton's poem 'On the Death of a Fair Infant Dying of a Cough', something we shall return to later when we consider other meteoric imagery in the works of John Milton.

5 Piers Anthony

Moving forward in time, we thought to end this first selection of quotes with something more lighthearted. Beginning in the late 1970s, Piers Anthony wrote a series of fantasy novels set in his invented, imaginary land of Xanth (derived from his own name, not the Greek for 'yellow'). The basic premise for his stories centred around using word-play, especially puns, to create a fantastic landscape for his heroes to interact with. So in Xanth a dogwood tree is a tree which barks and behaves like a dog. All his characters from Xanth have some magical ability, each having a single talent, but every one is different, while the geography of Xanth is very loosely based on the state of Florida in the USA. The tales are very entertaining, especially the earlier novels, and as with all our quoted material here, are well worth reading in their entirety. The meteoric details we have extracted come from Chapter 8 'Mad Constellations' in his second Xanth novel (Anthony 1979).

To set the scene, a group of heroes, including a gnome magician, a human and a centaur, all with assorted strengths and weaknesses, are travelling across a dangerous area of untamed wilderness. During the night, they are affected by the curious magical nature of the landscape, and begin hallucinating that the constellations are coming alive. As time goes on, it becomes impossible to be sure whether this is really the case or not, as sky and earth inhabitants begin to interact with one another.

Pages 160–161: *Now the constellation centaur shot his arrow. The missile blazed as it flew, forming a brilliant streak across the sky, growing brighter and yet brighter as it drew near. Suddenly it loomed frighteningly large and close, as if flying right out of the sky—and cracked into a nearby tree. ... That constellation arrow, no more than a shooting star, had struck a real tree close by!*

The real centaur on earth shoots an arrow back into the sky, hitting the sky-centaur's flank (p. 161): *The creature leaped with pain. From his mouth issued two comets and a shooting star: a powerful exclamation!*

The sky-centaur seizes a handful of soft, downy feathers from the sky-swan, and swabs his injury with them (p. 161): *Now it was the defeathered swan who cussed a bright streak of shooting stars, but the bird did not dare attack the centaur.*

Later, the adventurers battle other sky creatures, a serpent, a hydra and a dragon. The group's magician blocks the dragon's throat as it tries to breath a jet of flame and (p. 171): *The dragon exploded. Stars shot out in every direction, scorching the jungle foliage below ... They watched the upward-flying stars rise to their heights, then explode in multicolored displays of sparks. The whole night sky became briefly brighter.*

Eventually, the adventurers realise the magical activity in the sky is mostly illusion, and they retreat from battling the creatures there, to the illuminated cries of derision of the sky-dwellers (pp. 174–175): *The giant swung his huge club, bashing stars out of their sockets and sending them flying down. The centaur fired glowing arrows. ... One of the giant's batted stars whizzed over ... and ignited a rubber tree. ... The smell was horrible.* Remember, in Xanth, the rubber tree is a tree made of rubber!

6 Meteor beliefs: an IMO bibliography

This final section contains a listing of what we consider to be the main references regarding meteor beliefs which have appeared in *WGN* and the *IMC Proceedings* volumes since 1988. Other articles may have touched upon relevant aspects too, but not in the same detail. Further references to non-IMO material can be found in many of these items too.

Darley G. (1988) "The Fallen Star", *WGN*, **16:3**, 76. (A poem by George Darley (1795–1864).)

Beech M. (1992) "The Makings of Meteor Astronomy: Part I", *WGN*, **20:6**, 218–219. (Introductory notes.)

Beech M. (1993) "The Makings of Meteor Astronomy: Part II", *WGN*, **21:1**, 36–38. (Brief notes on "meteor" in English; ancient Greek and Roman meteor explanations.)

Beech M. (1993) "The Makings of Meteor Astronomy: Part III", *WGN*, **21:2**, 67–68. (Work of Aristotle, Seneca and Ibn Hayyan considered.)

Beech M. (1993) "The Makings of Meteor Astronomy: Part IV", *WGN*, **21:4**, 100–202. (Includes poetic quotations from Donne, Caxton and Cowley, and discusses the folklore connecting meteors with mushrooms and "star jelly" fungi. Additional meteor-mushroom comments followed in letters by AM *WGN*, **21:5** (1993) 225 and MB *WGN*, **22:2** (1994) 28.)

Beech M. (1993) "The Makings of Meteor Astronomy: Part V", *WGN*, **21:6**, 259–261. (Work of Newton, Wallis and Halley discussed.)

Beech M. (1994) "The Makings of Meteor Astronomy: Part VI", *WGN*, **22:2**, 52–54. (More discussion of Halley and the people who followed after.)

Beech M. (1994) "The Makings of Meteor Astronomy: Part VII", *WGN*, **22:4**, 132–134. (Blagden, and meteors as electrical phenomena.)

Beech M. (1994) "The Makings of Meteor Astronomy: Part VIII", *WGN*, **22:6**, 214–217. (The work of Chladni.)

Knöfel A. and Rendtel J. (1994) "Chladni and the Cosmic Origin of Fireballs and Meteorites, Two Hundred Years of Meteor Astronomy and Meteorite Science", *WGN*, **22:6**, 217–219.

Beech M. (1995) "The Makings of Meteor Astronomy: Part IX", *WGN*, **23:2**, 48–50. (More on Chladni and other concurrent beliefs about meteors.)

Beech M. (1995) "The Makings of Meteor Astronomy: Part X", *WGN*, **23:4**, 135–140. (Work by Brandes and Benzenberg, and Lichtenberg.)

Beech M. (1995) "The Makings of Meteor Astronomy: Part XI", *WGN*, **23:6**, 210–212. (Lubbock's meteors-as-reflections theory.)

Beech M. (1996) "The Makings of Meteor Astronomy: Part XII", *WGN*, **24:3**, 89–91 (On Kirkwood, confirming he did not make an association between comets and meteor streams.)

Beech M. (1996) "The Makings of Meteor Astronomy: Part XIII", *WGN*, **24:5**, 154–157. (More on Lubbock's reflection theory and its aftermath.)

Sauval J. (1997) "Quetelet and the Discovery of the First Meteor Showers", *WGN*, **25:1**, 21–33.

McBeath A. (1997) "Meteoric Dragons", *WGN*, **25:1**, 34–36.

Beech M. (1997) "Public Perception, Meteor Astronomy, and Leonid Storms", *WGN*, **25:3**, 124–128.

McBeath A. (1997) "Stones from Heaven: Some Meteoric Fossil Folklore", *WGN*, **25:3**, 128–130. (Additional information followed as letters by Martin Beech on native North American star stone folklore in *WGN*, **25:4** (1997) 147, and by AM on star shapes in *WGN*, **25:5** (1997) 204–205.)

Beech M. (1997) "The Makings of Meteor Astronomy: Part XIV", *WGN*, **25:4**, 157–160. (The Perseids and the Tears of St Lawrence folklore.)

Gritzner C. (1997) "Human Casualties in Impact Events", *WGN*, **25:5**, 222–226.

Gheorghe A. D. and McBeath A. (1998) "Romanian Meteor Mythology", In: Knöfel A. and McBeath A. (eds.), Proceedings IMC 1997, Petnica, Yugoslavia, IMO, 82–88.

Beech M. (1998) "The Makings of Meteor Astronomy: Part XV", *WGN*, **26:1**, 19–34. (Denning, part one.)

Beech M. (1998) "The Makings of Meteor Astronomy: Part XVI", *WGN*, **26:2**, 85–92. (Denning, part two.)

Beech M. (1998) "The Makings of Meteor Astronomy: Part XVII", *WGN*, **26:6**, 268–272. (Denning, part three.)

Beech M. (1999) "The Makings of Meteor Astronomy: Part XVIII", *WGN*, **27:1**, 45–51. (Balloon-borne meteor observations.)

McBeath A. and Gheorghe A. D. (1999) "Luceafărul: A Romanian Meteor-Inspired Poem", *WGN*, **27:5**, 255–258.

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Ongoing meteor work

An investigation into the 1998 and 1999 Giacobinids by meteoroid trajectory modeling

Mikiya Sato [1,2]

Calculation of the trajectories of meteoroids ejected from a comet close to Jupiter is very difficult, since the Jovian perturbations are very large. A technique for calculating the trajectories of meteoroids from Comet 21P/Giacobini-Zinner by a two-stage method is presented. The trajectories leading to the Giacobinid showers of 1998 and 1999 are calculated using the method.

1 Introduction

In recent years, the trajectory followed by dust ejected from the comet 55P/Tempel-Tuttle has been calculated, and observations of Leonids meteors match these predictions, making clear the details of the meteor shower from this comet. However, considering meteor showers from shorter period comets including 21P/Giacobini-Zinner, trajectory calculation is complicated by large Jovian perturbations. This paper presents a solution to these problems involving a two-stage calculation. In the first stage a fast outline calculation is performed, and trails which approach the earth near enough to suggest the possibility of meteors are identified. In the second stage, a calculation including planetary perturbations is performed in detail, based on the trajectories found in the first stage. In this paper, this method is applied to the comet 21P/Giacobini-Zinner, and the trajectories leading to the observed major Giacobinid shower in 1998 and their middle-scale shower in 1999 are deduced.

2 Method

The basis of this method is the same as the dust trail theory applied to Leonids in recent years. That is, as a comet passes perihelion, the method assumes the meteoroid stream to be formed by dust ejected in a direction opposite to the movement to that of the parent comet, and calculates the distribution of this dust.

2.1 First stage: outline calculation

In the first stage, the perturbations due to Jupiter were calculated only approximately, and the distribution of the whole dust trail from comet 21P/Giacobini-Zinner was investigated. Microsoft Excel(TM) was used for calculation, because it can calculate rapidly by referring to a table of positions of Jupiter through one revolution.

In the model, dust was ejected from the comet at intervals at every perihelion passage, and these particles were followed by numerical integration with the simplest Euler method at intervals of 0.5 days. The ejection velocities (positive in the direction of the comet's travel) ranged from -30 m/s to $+30$ m/s in steps of 5 m/s. Thus ejections in the same direction as that of the comet were considered along with ejections in the conventional, opposite direction. This method was repeated and an outline distribution of the whole dust trail was obtained. This ejection of dust was modeled for every perihelion passage of Giacobini-Zinner from the 1894 perihelion passage onwards, namely 16 occasions. The error per revolution in this calculation was about 0.01 AU or less in perihelion distance and about 10 days or less in the time of perihelion passage, when the known orbital elements of the parent comet were applied. It is assumed that these errors accumulate with the number of passages.

The dust trails presumed to approach the earth were identified by this method. In addition, the difference between the calculated and observed results was noted. The calculated longitude of the ascending node Ω should equal the solar longitude $\lambda_\odot$ at the time of the shower. (Note that the shower occurs at the descending node of the meteoroid stream, which is 180° different from the ascending node; but that Solar Longitude $\lambda_\odot$ is defined in geocentric co-ordinates, thus differing by 180° from the position of the Earth in heliocentric co-ordinates.)

2.2 Second stage: precise calculation

The more precise calculations including planetary perturbations were performed along those dust trajectories estimated by the first stage to approach the earth.

They were calculated using NIPE (v3.21 for MS-DOS, programmed by Mr. Naito) which is software that calculates planetary positions based on DE200. This software calculates perturbations due to nine planets and the moon. The program author quotes a calculation error of less than 1.0×10^{-14} AU per 8000 days] about the position of each planet to DE200. This amounts to 4.6×10^{-16} AU per year, or less than 5×10^{-14} AU for the entire integration for the worst case. The numerical integration proceeds in intervals of 0.125 days using the Adams-Bashforth-Moulton method. In order to calculate perturbations as accurately as possible, this method was used to calculate the position of the dust. The error per revolution of this calculation was

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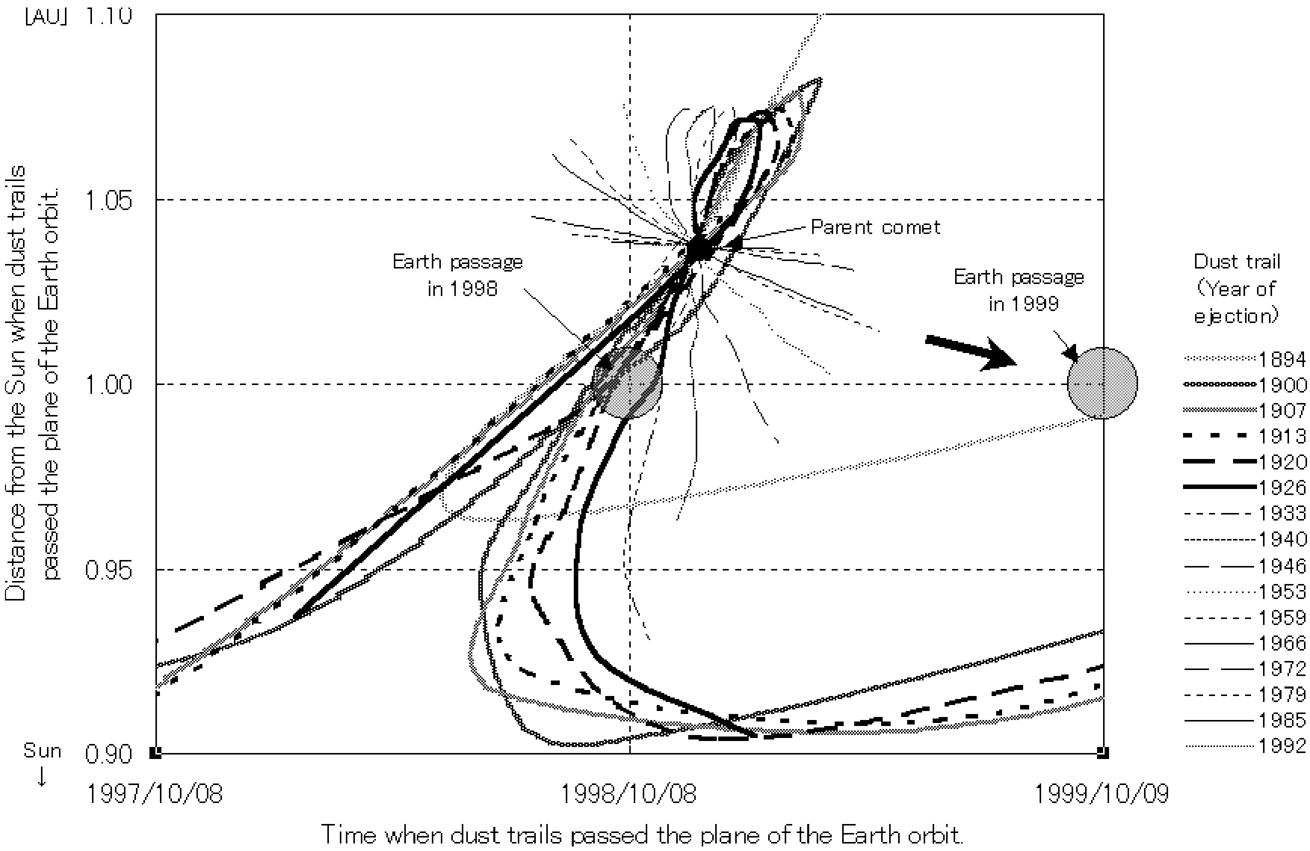

Figure 1 – Distribution of dust trails from the results of the First Step. (Shaded circles represent the Earth; their diameters are arbitrary.)

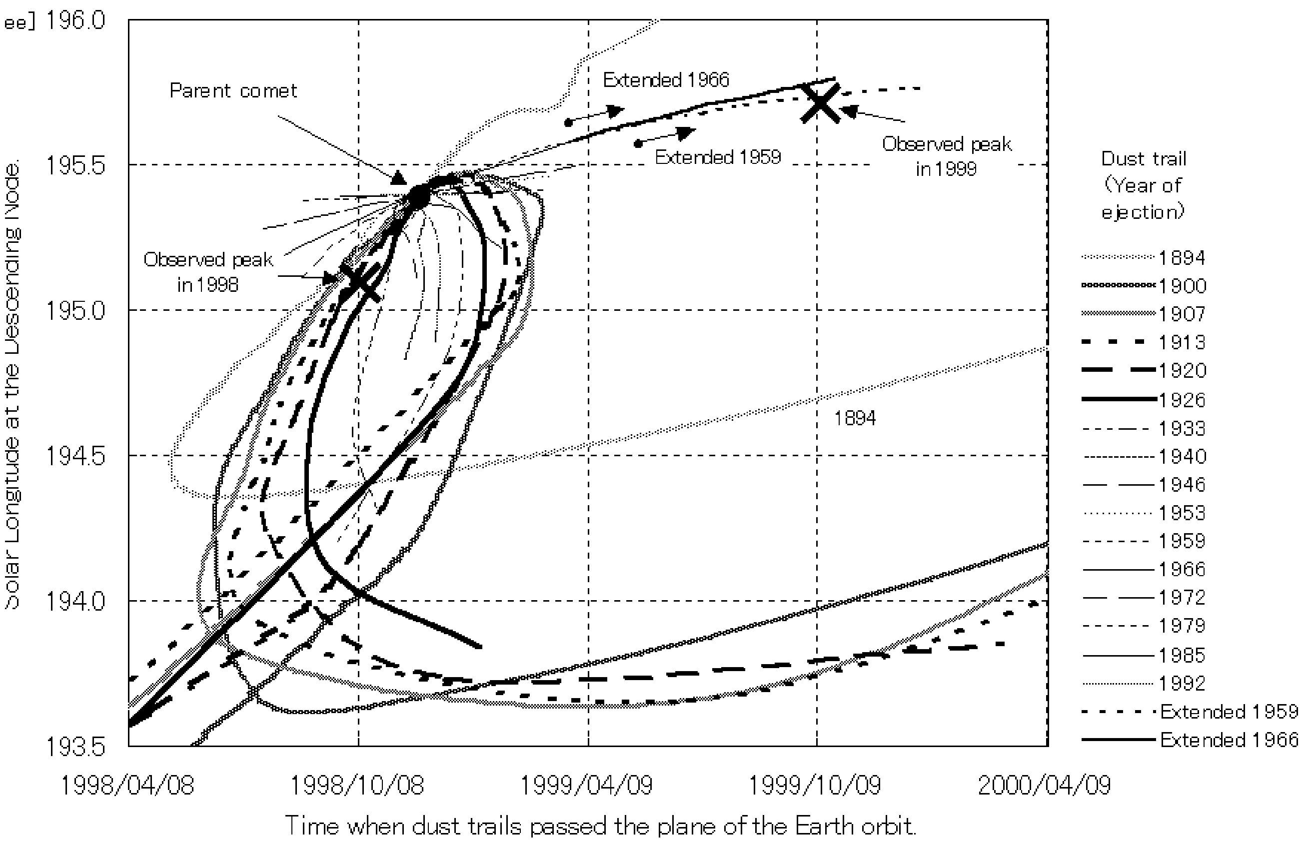

Figure 2 – Relation of the ascending node to the time of perihelion.

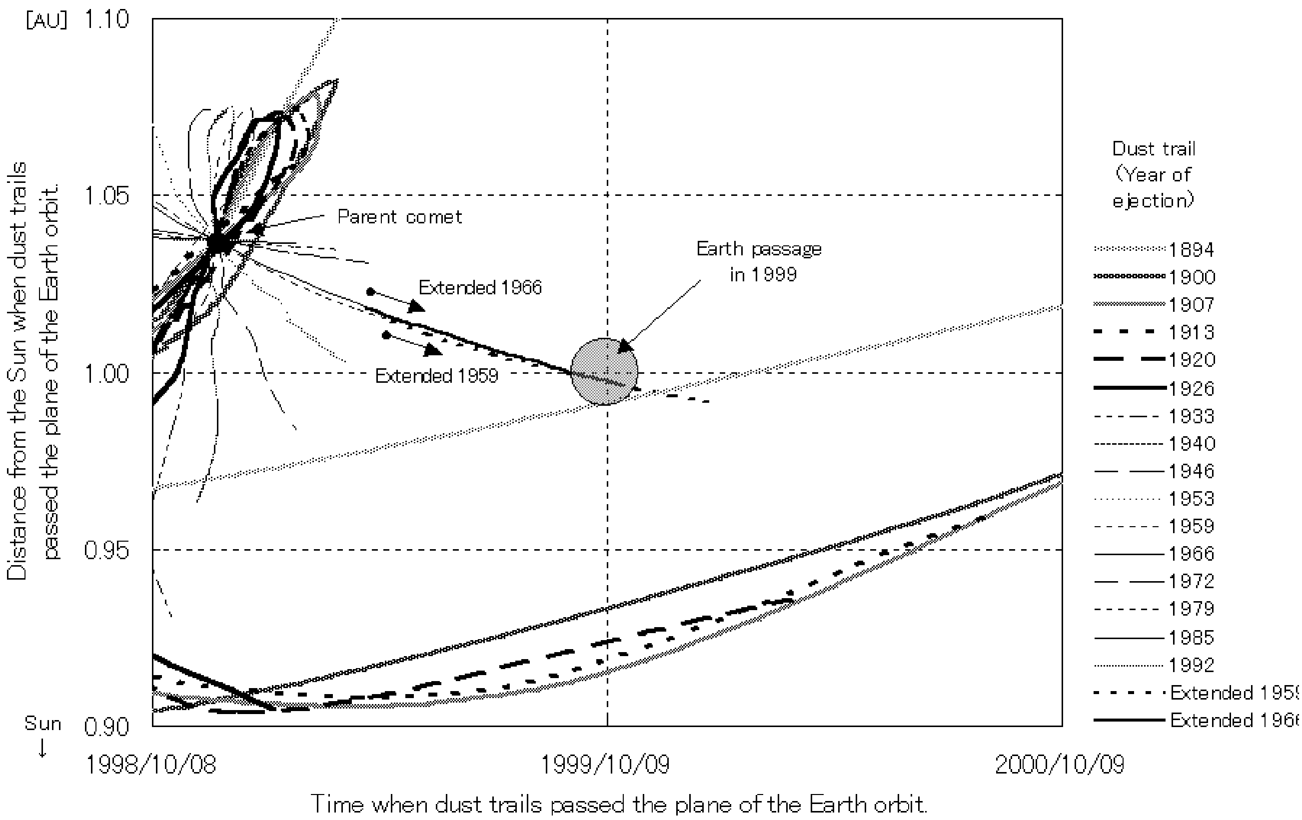

Figure 3 – Distribution of dust trails from the results of the First Step when the ejection velocity is extended to 70 m/s for the 1959 and 1966 trails. (Shaded circles represent the Earth; their diameters are arbitrary.)

about 0.001 AU or less in perihelion distance and about one day or less in the time of perihelion passage, when the known orbital elements of the parent comet were applied. These results were regarded as of sufficient accuracy.

3 Results

3.1 First stage: outline calculation

The distribution of the calculated dust trail is shown in Figure 1.

It can be seen that the trails are intricately distributed due to the large Jovian perturbations. It also turns out that several trails were likely to approach the earth in 1998. These results are summarized in Table 1.

In Table 1, material ejected with negative velocity produced large differences between the calculated and observed longitudes. This material was excluded from the second stage of the calculation. The observed peak was at $\lambda_{\odot \mathrm{OBS}} \simeq 195.08°$ in 1998 (Iiyama, 1999).

The trails not shown in Table 1 are those which tended not to approach the Earth on Figure 1, and were therefore judged not to approach it in reality.

The only trail which approached the earth closely in 1999 was that ejected in 1894. However, this trail had been excluded from the second stage calculation due to its distance from the Earth in 1998. The observed peak was at $\lambda_{\odot \mathrm{OBS}} \simeq 195.72°$ in 1999 (Iiyama, 2000). When dust with ejection velocity out of the chosen range was considered, however, it seemed likely that dust ejected in 1959 and 1966 would also approach the earth in 1999.

Table 1 – Outline calculation results of trail positions in 1998, showing ejection velocity and solar longitude $\lambda_{\odot \mathrm{SIM}}$ at the descending node. Data marked with an asterisk were excluded from the second-stage calculations.

Year of ejection	Ejection velocity (m/s)	$\lambda_{\odot \mathrm{SIM}}$ (°)	
1894	+0 – +5	195.1	
1900	+5	195.2	
1907	+5	195.2	
1913	+5 – +10	195.2	
1920	+5 – +10	195.1	
1926	+10 – +15	195.0	
1933	+15 – +25	194.7 – 195.1	
1900	−20	194.0	*
1907	−25	194.4	*
1913	−25	194.5	*
1920	−25	194.2	*
1926	−25	194.4	*
1933	−30	194.3	*

It also appeared that the calculated longitude of the ascending node matched well with observation, as shown in Figure 2.

The allowed range of ejection velocities was therefore extended for these two trails and the calculation was applied. The distribution of these two dust trails is shown in Figure 3.

It turned out that these trails approached the earth in 1999. These results are summarized in Table 2.

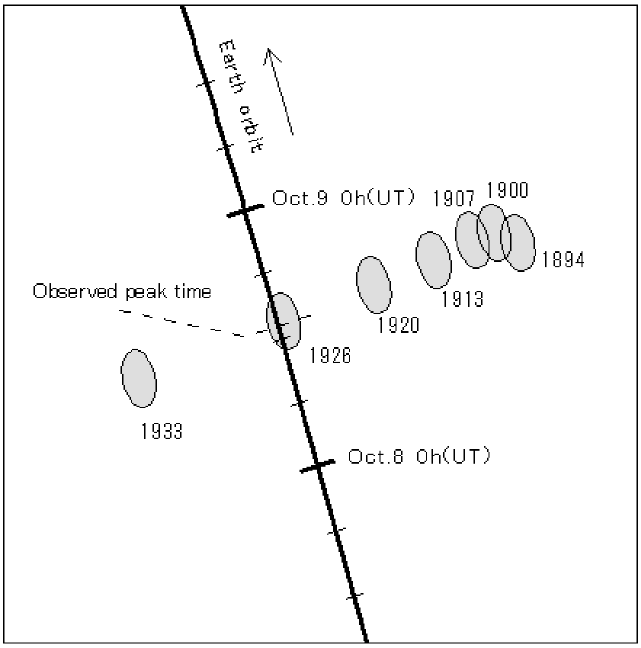

Figure 4 – Position of the trails in 1998. The radius of a trail was assumed to be 0.001 AU. The distance between the 6-hour marks is 0.0043 AU.

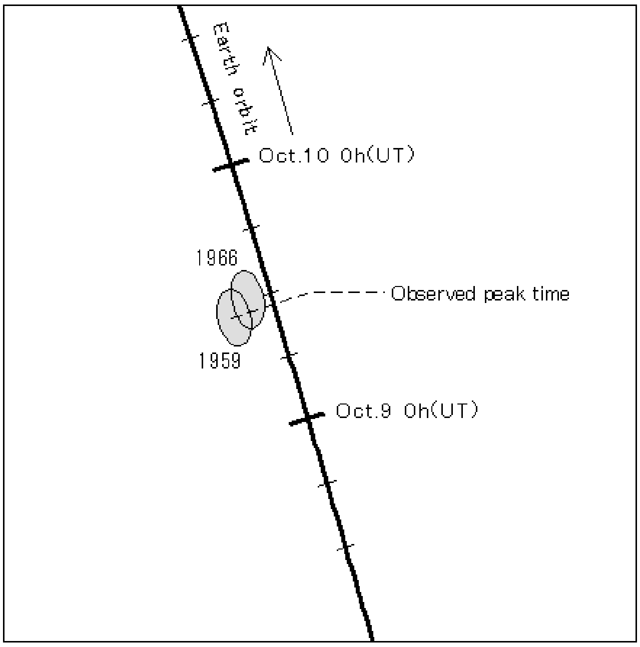

Figure 5 – Position of the trails in 1999. The radius of a trail was assumed to be 0.001 AU. The distance between the 6-hour marks is 0.0043 AU.

Table 2 – Outline calculation results of trail positions in 1999, showing ejection velocity and solar longitude $\lambda_{\odot\mathrm{SIM}}$ at the descending node. Data marked with an asterisk were excluded from the second-stage calculations.

Year of ejection	Ejection velocity (m/s)	$\lambda_{\odot\mathrm{SIM}}$ (°)	
1894	+5 – +10	194.7	*
1959	+60	195.7	
1966	+70	195.8	

3.2 Second stage: precise calculation

The trails shown in the first stage to approach the Earth closely were calculated more precisely. The results are summarized in Table 3 for the trails which approached the earth in 1998, and the situation is illustrated in Figure 4.

Consequently, it became clear that the trail which was ejected in 1926 intersected the earth in 1998. The ejection velocity was +10.8 m/s. The earth passed the descending node of this dust trail at $13^{\mathrm{h}}33^{\mathrm{m}} \pm 1^{\mathrm{m}}$ UT on October 8, and the time of minimum approach was $13^{\mathrm{h}}25^{\mathrm{m}} \pm 5^{\mathrm{m}}$, at a distance of +0.0004 AU. (For reference, the diameter of the Earth is about 0.000085 AU.) The observed peak was around 1998 October 8, $13^{\mathrm{h}}10^{\mathrm{m}}$ UT (Iiyama, 1999), and the result was generally in agreement to within a few dozen minutes.

The results are summarized in Table 4 for the trail which approached the earth in 1999, and the situation is illustrated in Figure 5.

It turns out that the dust trail from 1959 approached to a distance of 0.0026 AU and the one from 1966 to 0.0015 AU. The earth passed the descending node of the dust trail from 1959 at $10^{\mathrm{h}}48^{\mathrm{m}} \pm 1^{\mathrm{m}}$ UT, and the one from 1966 at October 9, $11^{\mathrm{h}}54^{\mathrm{m}} \pm 1$ UT. The time of minimum approach of the 1959 dust trail was $11^{\mathrm{h}}25^{\mathrm{m}} \pm 5$ UT, and of the 1966 one $12^{\mathrm{h}}25^{\mathrm{m}} \pm 5^{\mathrm{m}}$ UT on the same day. The observed peak was around 1999 October 9, $11^{\mathrm{h}}00^{\mathrm{m}}$ UT (Iiyama, 2000), and the time of dust trail from 1959 was generally in agreement to within a few dozen minutes.

4 Conclusion

The results of the calculations proved that the trail which caused the major Giacobinids shower in 1998 was the trail ejected in 1926. The calculated time of the peak was in agreement with observation to within a few dozen minutes. The meteor showers in 1998 often produced hourly rates of 50–100 in moonlight (Iiyama, 1999). This high rate was brought about by the trail only 0.0004 AU away.

In 1999, the observed peak time was close to that calculated from the trail ejected in 1959. But the appearance in 1999 showed a broad peak from $10^{\mathrm{h}}00^{\mathrm{m}}$ to $13^{\mathrm{h}}00^{\mathrm{m}}$ UT on October 9, so the trail ejected in 1966 might also have participated.

The ejection velocities of these two dust trails are high, +60.0 m/s and +69.5 m/s. It is important for future research that the possibility of such high ejection velocities has been demonstrated. The question of which return produced the dust ejection can also be considered, since the perihelion distance in 1959 and 1966 was smaller than the other returns, namely 0.93–0.94 AU. The meteor rates in 1999 were small (ZHR = 20–30) compared with those in 1998. This reason could be greater trail distance, or higher ejection velocity, or

Table 3 – Precise calculation results of trail positions in 1998. Distance is positive away from the Sun. In the Position column, D. Node indicates the Descending Node and Min. the minimum distance of the Earth from the trail.

Year of ejection	Ejection velocity (m/s)	Position	Date (UT)	Time (UT)	$\lambda_{\odot}$° (J2000.0)	Distance (AU)
1894	+1.5	D. Node	Oct. 8	15^h00^m	195.151	+0.0161
		Min.	Oct. 8	10^h25^m	194.966	+0.0160
1900	+5.3	D. Node	Oct. 8	16^h25^m	195.209	+0.0148
		Min.	Oct. 8	12^h15^m	195.042	+0.0147
1907	+6.0	D. Node	Oct. 8	16^h15^m	195.202	+0.0135
		Min.	Oct. 8	12^h20^m	195.045	+0.0134
1913	+6.7	D. Node	Oct. 8	15^h22^m	195.166	+0.0108
		Min.	Oct. 8	12^h20^m	195.045	+0.0107
1920	+8.2	D. Node	Oct. 8	14^h34^m	195.133	+0.0066
		Min.	Oct. 8	12^h25^m	195.049	+0.0066
1926	+10.8	D. Node	Oct. 8	13^h33^m	195.091	+0.0004
		Min.	Oct. 8	13^h25^m	195.090	+0.0004
1933	+15.4	D. Node	Oct. 8	11^h56^m	195.025	−0.0094
		Min.	Oct. 8	14^h35^m	195.138	−0.0094

Table 4 – Precise calculation results of trail positions in 1999. Distance is positive away from the Sun. In the Position column, D. Node indicates the Descending Node and Min. the minimum distance of the Earth from the trail.

Year of ejection	Ejection velocity (m/s)	Position	Date (UT)	Time (UT)	$\lambda_{\odot}$° (J2000.0)	Distance (AU)
1959	+60.0	D. Node	Oct. 9	10^h48^m	195.712	−0.0027
		Min.	Oct. 9	11^h25^m	195.740	−0.0026
1966	+69.5	D. Node	Oct. 9	11^h57^m	195.760	−0.0015
		Min.	Oct. 9	12^h25^m	195.782	−0.0015

both.

This method showed that dust trail calculations can be performed for a comet greatly perturbed by Jupiter. The accurate prediction of meteor showers from such a comet demonstrates the viability of this method. Finally, the influence of radiation pressure is not included in these calculations. This is because there is no function which calculates radiation pressure in NIPE. If the method is improved to include this influence, still better conclusions can be drawn.

References

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Iiyama, O. (2000), “The Report of Visual Observation in October 1999”, *Astronomical Circular (Bulletin of the Nippon Meteor Society, ISSN-0388-5852)* **690**, 4–12.

SPA Meteor Section Results: Preliminary 2003 Quadrantid Report

Alastair McBeath [1]

A preliminary review of observations presented to the SPA Meteor Section during the 2003 Quadrantid epoch is given and discussed. Two possible visual peaks were identified on January 4 at roughly $01^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 283\overset{\circ}{.}22$; ZHR $= 90 \pm 16$) and about $09^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 283\overset{\circ}{.}56$; ZHR $= 80 \pm 17$; eq. 2000.0). Four potential mean radio maxima were found too, centred at approximately January 3, $12^{\rm h} \pm 1$h (in only 33% of results, and relatively minor) and $21^{\rm h} \pm 2$h, January 4, $3^{\rm h} \pm 1$h and $10^{\rm h} \pm 2$h UT, $\lambda_\odot = 282\overset{\circ}{.}65 \pm 0\overset{\circ}{.}042$, $283\overset{\circ}{.}03 \pm 0\overset{\circ}{.}085$, $283\overset{\circ}{.}29 \pm 0\overset{\circ}{.}042$, and $283.585 \pm 0\overset{\circ}{.}085$ respectively. The strongest maximum occurred in about 70% of datasets during the interval between January 3–4, $19^{\rm h}$–$05^{\rm h}$ UT and, reinterpreting the radio data, trying to allow for numerous reception problems in this period, could imply the main Quadrantid maximum happened at a mean time of January 3, $23^{\rm h}15^{\rm m} \pm 4$h UT ($\lambda_\odot = 283\overset{\circ}{.}128 \pm 0\overset{\circ}{.}17$).

1 Introduction

While the moon-free Quadrantid maximum was eagerly anticipated by SPA Meteor Section observers at the start of the Society's 50th anniversary year, January 3/4 was not especially clear across the UK judging by reports received by late February. Positive results then or on January 2/3 were obtained only from parts of western and southern England, south Wales, southern East Anglia and south-west to central Scotland. A few continental European watchers also provided results, along with two regular correspondents in the USA.

The observers reporting directly were:

Dirk Artoos (radio; Belgium), Jay Brausch (North Dakota, USA), Russell Cockman and several members of Falkirk Astronomical Society (visual and photo data; Scotland), David Entwistle (radio; England), Steve Evans (video; England), Kim Gowney (Wales), Valentin Grigore (Romania), Robin Leadbeater (video; England), Bob Lunsford (California, USA), Edward Mallett (England), Tony Markham (England), Tom McEwan (Scotland), George Spalding (England), Enrico Stomeo (Italy), Roy Watson (Scotland).

In addition, many more radio reports came in as Radio Meteor Observation Bulletin 114 (January 2003; RMOB; website: `http://www.rmob.org`), provided by Chris Steyaert. These observers covering the Quadrantid epoch included:

Enric Fraile Algeciras (Spain), Mike Boschat (Nova Scotia, Canada), Walter Boschin et al. (Italy), Jeff Brower (Colorado, USA), Maurice de Meyere (Belgium), Minoru Ehara (Japan), Kenji Fujito (Japan), Valter Gennaro (Italy), Ghent University (Belgium), Patrice Guérin (France), Steve Hansen (Massachusetts, USA), Michael Krocil (Czech Republic), Toshihide Miyake (Japan), Stan Nelson (New Mexico, USA), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Robert Savard (Quebec, Canada), Dave Swan (England), Pierre Terrier (France), Bruce Young (Queensland, Australia), Ilkka Yrjölä (Finland).

The raw radio data were treated and analysed as usual in these reports (McBeath, 2001a), with Figures 1 to 6 presented as illustrative of what this work found. Unfortunately, there were a number of problems with radio reception and interpreting the radio data during the Quadrantid epoch, most of which will be discussed shortly. However some, due to the lack of suitable transmitters (an ever-increasing difficulty for European observers especially), interference, equipment malfunctions or other unidentified non-meteoric events, meant that too little — or even nothing — of the Quadrantids could be found in 38% of the RMOB datasets, and these had to be discounted before beginning the analysis.

2 Shower review

Table 1 gives global magnitude distributions for the better-sky Quadrantids and early January sporadics. There were a few casual reports from the UK of several bright to fireball-class meteors, some identified as probable Quadrantids, during the UT evening hours of January 3/4, while the radiant was very low in the northern sky, which are not represented in Table 1.

Figure 7 gives an impression of how visual Quadrantid activity behaved on January 2/3 and 3/4. The relative paucity of observers meant a few data points were based on less than ideal observations (LM $= +5.4$ to $+5.0$, radiant elevation $< 20°$), or the results of just one watcher. Consequently, the exact timings and strengths of the ZHRs must be treated with due caution at this stage, though the general trends shown are likely to give a reasonable guide to what the shower maximum produced.

Within these provisos, two peaks are apparent on January 3/4, one over Europe at about $01^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 283\overset{\circ}{.}22$; ZHR $= 90 \pm 16$), the other over the USA around $09^{\rm h}30^{\rm m}$ UT ($\lambda_\odot = 283\overset{\circ}{.}56$; ZHR $= 80 \pm 17$). The anticipated visual maximum (McBeath, 2003, pp. 2–3) was due at $00^{\rm h}$ UT, $\lambda_\odot = 283\overset{\circ}{.}16$, or so, thus the main visual peak may have been a little later in 2003. Observations in 2000 and 2001 (McBeath, 2000, 2001b) suggested a second, chiefly radio, maximum may have happened some 9 to 12 hours after the usual main one. The $\sim 09^{\rm h}30^{\rm m}$ UT peak fell within that window certainly.

Checking the radio data proved a particularly com-

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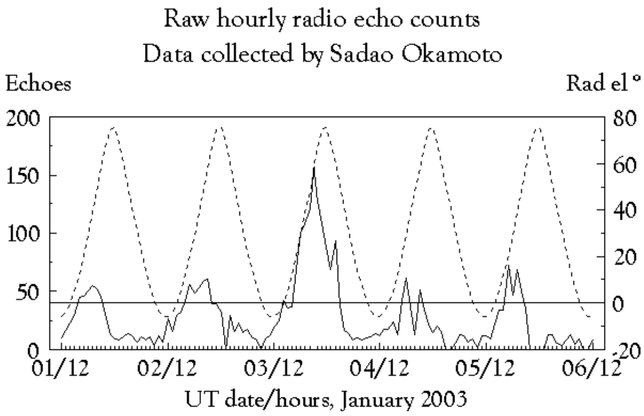

Figure 1 – Raw hourly radio meteor echo counts across the 2003 Quadrantid maximum, in data collected by Sadao Okamoto. In all the radio graphs given here, the thicker, irregular line, keyed to the left-hand y-axis, shows the raw hourly radio echo count values, while the thinner, daily-symmetrical, curve (keyed to the right-hand y-axis) gives the Quadrantid radiant elevation for each observer's site. Sadao's system, in common with all the radio data shown, was in continuous operation, and drops in the echo trace to zero in general indicate times when accurate recording was negated by interference problems.

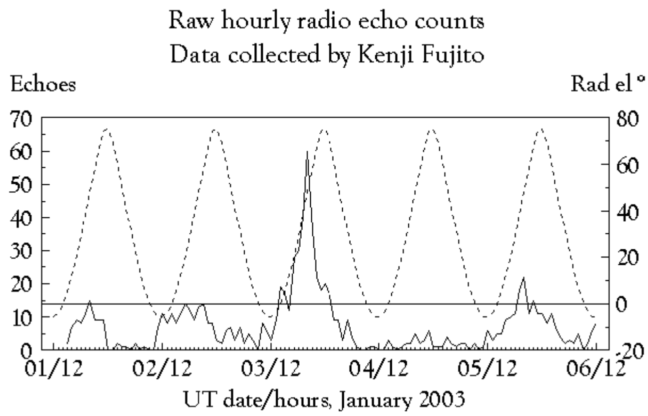

Figure 2 – As Figure 1, but for radio meteor data collected by Kenji Fujito. Kenji's system was affected by interference in only one hour after 15^h UT on January 1, from 00^h–01^h UT on January 2. Other drops to zero counts are thus genuine 'no meteor echo' hours. Although this system recorded typically lower daily echo counts than some of the other Japanese set-ups, the counts on January 4 were unusually poor, but were apparent in some of the other Japanese results.

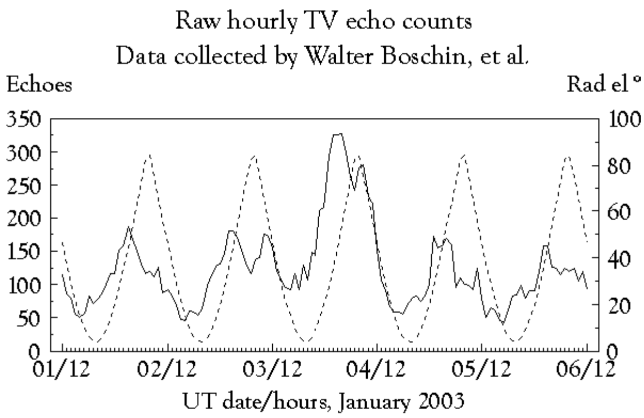

Figure 3 – As Figure 1, but for TV results collected by Walter Boschin, Diego Ganzini, Alessandro Candolini and Giuseppe Candolini.

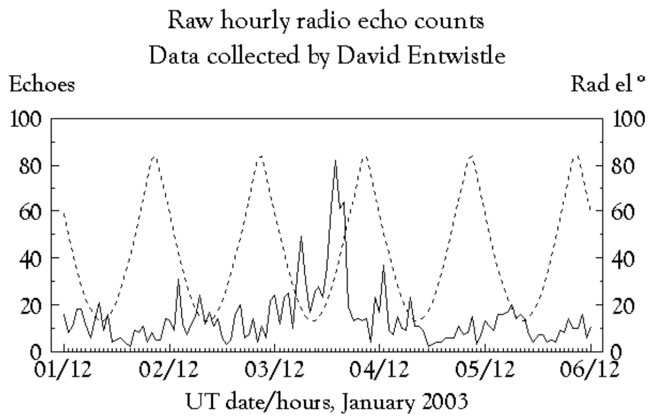

Figure 4 – As Figure 1, but showing longer-duration radio echo details collected by David Entwistle.

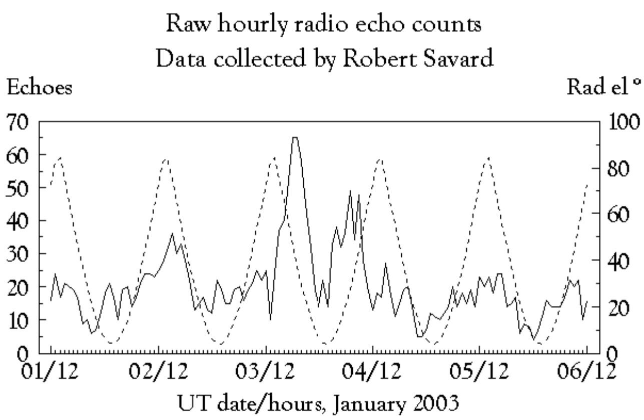

Figure 5 – As Figure 1, but for radio data collected by Robert Savard.

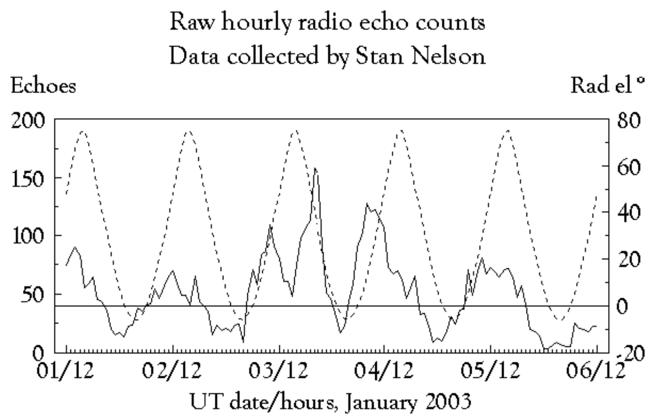

Figure 6 – As Figure 1, but illustrating radio observations collected by Stan Nelson (his Receiver 4 data, which seem to show the Quadrantids more clearly than his other systems).

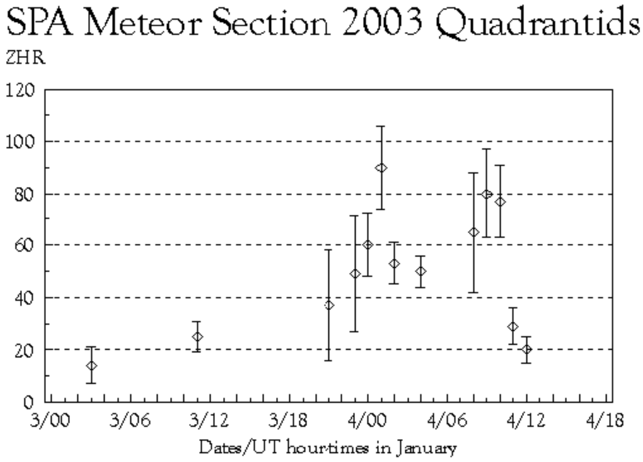

Figure 7 – Mean Quadrantid ZHRs on 2003 January 3 and 4, computed using an assumed $r = 2.1$, for observations made where the LM was +5.0 or better (most no worse than +5.5), cloud cover was less than 20%, and the radiant elevation was at least 10° (most having a minimum radiant elevation of 20°), with standard error bars appended.

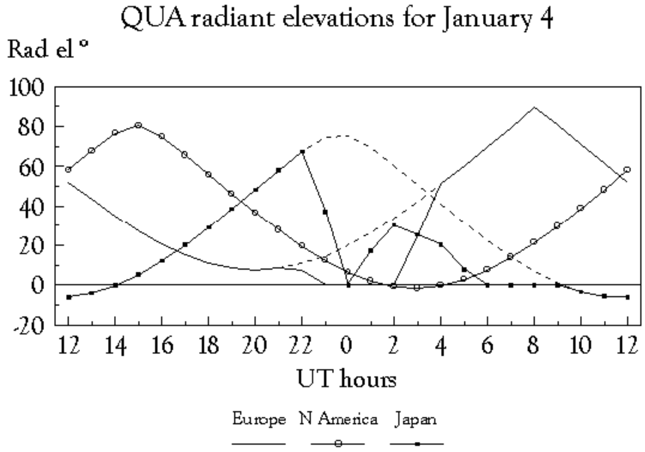

Figure 8 – An attempt to show graphically, and somewhat crudely, the effects of the various radio problems during the Quadrantid near-peak period in 2003. The three traces show 'effective' (solid lines) and true (in part dashed lines) Quadrantid radiant elevations for typical sites in the three radio observing regions, using average site location values of $\phi = 48\overset{\circ}{.}6$ N, $\lambda = 8°$ E (Europe), $\phi = 39\overset{\circ}{.}5$ N, $\lambda = 94°$ W (North America) and $\phi = 34\overset{\circ}{.}9$ N, $\lambda = 134°$ E (Japan). The 'effective' elevation lines are reduced during the most problematic times for the majority of observers in each area, showing that at times there was almost no radio meteor coverage of the Quadrantids between roughly 23^h–02^h UT on January 4.

plex task this time. Elements of this can be seen in Figures 1–6, which give two graphs each for observers in Japan, Europe and North America, in an attempt to give a useful overview of the way different places were able to view the 2003 Quadrantids.

In Japan, for some unidentified reason, observers failed to record as strong a response after the Quadrantid radiant had culminated on January 3/4 UT as before, though as the European and North American data revealed, this should not have been the case. In some instances, the Japanese data shows an almost total drop-out in echo counts from around 23^h–13^h UT on this date (note that Quadrantid radiant-set from Japan is between 09^h–10^h UT however). A few show a possible partial recovery around 02^h–$04^h \pm 1$h UT. Whether this was an atmospheric problem, a transmitter fault, some systematic antenna fault, or due to another cause is unknown. As local solar time for Japan is nine hours ahead of UT, the hours preceding 09^h UT would have brought the usual declining diurnal sporadic rates towards this time (equivalent to 18^h local solar time). This should not have influenced Quadrantid activity of course, which should have remained readily detectable in theory until at least 06^h UT, if not later. An auroral display was reported visually by the Falkirk observers in Scotland after 20^h30^m and before midnight UT on January 3/4, and by radio between 15^h–21^h UT by Ilkka Yrjölä in Finland, but no other radio observers indicated any auroral propagation interference was present then.

In Europe, the problem was the on-going one mentioned several times in these results' articles in recent years, of numbers of transmitters shutting down for several hours over midnight UT, aside from that of fewer suitable transmitters generally. This meant that, in many European datasets, echo count numbers which should have been improving as the Quadrantid radiant pulled away from the horizon, actually fell, in some cases to virtually negligible levels, from approximately 22^h–$03^h \pm 1$h UT. The overlap with the timing of the mysterious lack of Quadrantid echoes over Japan, simultaneously with the expected shower peak, was extremely unfortunate, further compounded when one realizes this period coincided with the lower radiant elevations for North America! I have endeavoured to give a crude graphical impression of this overall effect in Figure 8. The 'effective' radiant elevations in that should not be seen as definite numerical values, but are merely intended to highlight the overlap in problematic periods between the three main geographic regions.

A first analysis of the raw radio data under the usual strictures (McBeath, 2001a) revealed four potential Quadrantid maxima, with mean values for their UT timings centred at approximately January 3, $12^h \pm 1$h (in only 33% of the results, and of relatively minor strength;

Table 1 – Global magnitude distributions for the 2003 Quadrantids and January sporadics seen under better sky conditions (cloud cover < 20%, $LM = +5.5$ or better), including mean LMs and corrected mean magnitudes.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	LM	$\overline{m}_{6.5}$
QUA	2	6.5	16.5	21	49.5	68.5	54	30	9	257	+6.39	+1.97
SPO	0	0	0	3	9.5	19.5	27.5	22	12.5	94	+6.39	+3.14

$\lambda_\odot = 282^{\circ}\!.65 \pm 0^{\circ}\!.042$) and $21^{h} \pm 2h$ ($\lambda_\odot = 283^{\circ}\!.03 \pm 0^{\circ}\!.085$), January 4, $03^{h} \pm 1h$ ($\lambda_\odot = 283^{\circ}\!.29 \pm 0^{\circ}\!.042$) and $10^{h} \pm 2h$ ($\lambda_\odot = 283^{\circ}\!.585 \pm 0^{\circ}\!.085$). The strongest maximum occurred in some 70% of the datasets in the interval between January 3–4, 19^{h}–05^{h} UT. The longer-duration echo counts ($D > 1s$) sometimes give additional guidance to major shower maxima especially, but very few suitable datasets were available. The Japanese observers gave details only on echo durations in excess of 20s in this category and, as very few of these events occur on any given day, interpreting the results is extremely difficult. Some of these results could support a longer-duration echo peak around January 3 at $22^{h} \pm 1h$ UT, though this is close to the time of best radio-visibility during the rising part of the Quadrantid radiant's diurnal curve for Japan, so this may not be very significant. Only two European longer-duration datasets were available for examination, and these favoured a mean peak time of $01^{h}30^{m} \pm 1^{h}\!.5$ UT on January 4, while the radiant was still relatively low for the observers in question ($\sim 30^{\circ} \pm 10^{\circ}$), and during the time of greatest transmitter problems. This could indicate this was the more likely longer-duration radio peak which, while conveniently coincident with the preliminary visual findings, is not especially soundly based.

Reinterpreting the radio data in trying to allow for the reception difficulties outlined when discussing Figure 8 above, and giving somewhat more weight to times when the Quadrantid radiant was less well-placed for observations, what the longer-duration echo findings showed, and when various observers found their strongest echo counts generally, all within the 17^{h}–06^{h} UT period on January 3/4, could imply the main Quadrantid maximum happened at a mean time of January 3, $23^{h}15^{m} \pm 4h$ UT ($\lambda_\odot = 283^{\circ}\!.128 \pm 0^{\circ}\!.17$). There are however considerable uncertainties in doing so. The problems around the midnight UT interval on January 3/4 certainly suggest strongly that the two 'central' radio peaks of the four found should be treated as parts of a single, reception-affected, period, rather than two separate ones at least, even if the main maximum cannot be better defined than this.

The other two radio peaks (January 3, $\sim 12^{h}$ and January 4, $\sim 10^{h}$ UT) also need further discussion. The first, though relatively poorly reported, may be a rare retrieval of the radio-telescopic Quadrantid maximum known from previous results as happening up to 14 hours before the visual peak, as mentioned in (McBeath, 2003, p. 3). If we take the main radio-visual peak in 2003 as falling sometime between roughly 23^{h}–02^{h} UT on January 3/4, this earlier peak preceded the main one by some 11 to 14 hours or so, exactly what would be expected. If correct, this is quite an achievement, as this earlier peak was not found in radio reports from most of the recent Quadrantid returns. The second peak was found in all the available datasets where the Quadrantid radiant was above the horizon and, again assuming the same main peak times as above, trailed that maximum by about 8 to 11 hours, very similar to the 9 to 12 hour gap seen previously, as noted above, and very close to the probable 'USA' visual maximum as discussed earlier. It is too early to say if other visual results may confirm this timing, or even find it at all, but it may be another confirmation that two such peaks are indeed currently happening within the Quadrantids if so.

3 The observers' view

From the observers' perspective, the 2003 Quadrantids were not as successful as had been hoped for overall. In the UK, several people reported seeing a few Quadrantids casually during the evening hours of January 3/4, including the bright meteors and fireballs referred to earlier, but the near and post-midnight periods seem to have had generally poorer skies, typically timed for the increasingly favourable radiant elevations! Despite this, some observers had a reasonably good night, including Steve Evans, who managed almost 6.25 hours of video observing on January 3/4, picking up 24 QUA, 1 COM, 2 DCA and 12 sporadics. One of Steve's composite video-still images is given here as Figure 9.

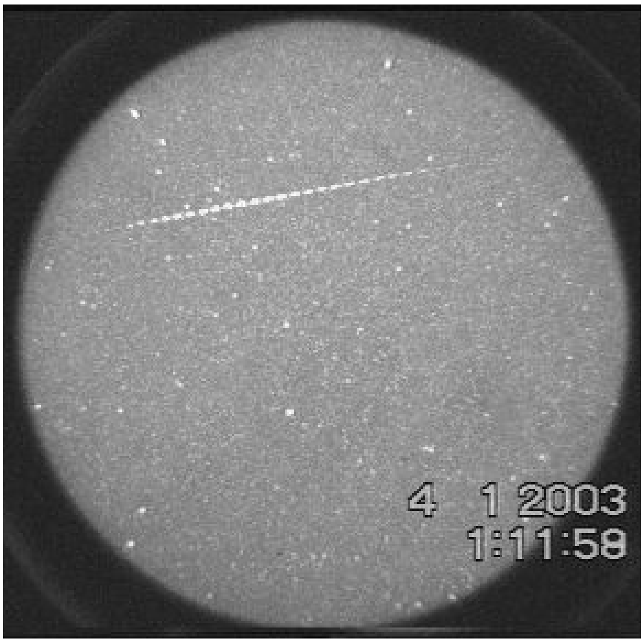

Figure 9 – A composite video-still Quadrantid image from January 4 at $01^{h}11^{m}$ UT. The meteor passed through Cepheus. The brighter star just below-left of centre is γ Cephei, with π a little way above it, β near the top left edge and ι towards the top centre-right. Compiled by Steve Evans, using his CCD video system 'Emily', fitted with an 18mm second-generation MCP image intensifier and a 50mm, $f/1.4$ lens, giving a 21° field of view and a video-stellar LM of +6.5. Every other frame has been stacked to construct the image, giving breaks in the trail to allow the measurement of the apparent velocity of the meteor, which along with the path length and direction enables confirmation that this was a Quadrantid.

In continental Europe, very few observers to report so far had any luck on Quadrantid maximum night. Valentin Grigore in Romania reported most positively, with almost entirely clear skies from midnight UT onwards, but in Italy and Belgium (information from Hendrik Vandenbruaene of the VVS meteor group), conditions were useless. Bob Lunsford in California had the best skies from the preliminary North American reporters, a mostly clear night on January 3/4, with clouds coming up only towards the end of the night to spoil the view.

4 Conclusions

Despite visual and radio difficulties, two visual-radio maxima are suggested, between $\sim 23^{\mathrm{h}}$ and $\sim 01^{\mathrm{h}}30^{\mathrm{m}}$ UT on January 3/4, and near $09^{\mathrm{h}}30^{\mathrm{m}}$–$10^{\mathrm{h}}$ UT on January 4. A further, lesser, radio peak may have occurred around 12^{h} UT on January 3. These preliminary findings will need further data to confirm them of course, when these become available.

Acknowledgements

Grateful thanks are extended to everyone who sent in data and comments so soon after the event, allowing such an early preliminary report (a version of this report was posted on the SPA website, `http://www.popastro.com`, in early March).

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SPA Meteor Section Results: 2002 Perseids

Alastair McBeath[1]

Details of observations collected by the SPA Meteor Section during the Perseid shower in 2002 August are presented, with some discussion. A relatively flat maximum was found on August 12/13 in the visual results, with a somewhat stronger mean ZHR = 74 ± 7 found between 22^{h}–04^{h} UT, perhaps implying a peak at $01^{h} \pm 3$h UT ($\lambda_{\odot}$ (eq. 2000.0) = $140\overset{\circ}{.}101 \pm 0\overset{\circ}{.}12$). Unfortunately the radio reports were affected by a series of atmospheric problems and equipment failures near the Perseids' best but, in general, they support a lower and longer Perseid peak than has been seen for some time. Some notes based on comments by observers are given too.

1 Introduction

The Perseids of course are always an eagerly anticipated highlight of the meteor watcher's year, and the New Moon on 2002 August 8, just a few days before the expected peak on August 12/13, raised hopes still more. The maximum was due around $22^{h}30^{m}$ UT on August 12 (McBeath & Arlt 2001, pp. 9–11), just as the radiant would be reaching a usable elevation for British sites, so it was a little disappointing that even the clearer parts of the UK had haze and patchy clouds at times all night on August 12/13. Luckily, observers were generally happy with what they saw despite the conditions, thanks to a pleasing number of bright to fireball-class Perseids, and for once the UK did much better than many places elsewhere in Europe on the critical night!

A combined list of all observers active in August from data presented to the SPA Meteor Section follows. It includes those who reported successful watches, and those whose efforts were thwarted by clouds but who still troubled to send in details of their attempts. Visual observers in England have no additional notes given. Those elsewhere are listed with the country they observed from. Non-visual observers are denoted by the letters 'R' = radio, 'RM' = radio data from Radio Meteor Observation Bulletin 109 (August 2002; website: `http://www.rmob.org`) kindly provided by editor Chris Steyaert, or 'V' = video. A '+' sign before the letter indicates the observer also carried out visual watching. The German Arbeitskreis Meteore (AKM) data were chiefly taken from their journal Meteoros **5:9** and **5:10** (2002) submitted by Ina Rendtel (website: `http://www.meteoros.de`), while the American Meteor Society (AMS) results came primarily from their journal Meteor Trails 17 (December 2002), presented by Bob Lunsford (website: `http://www.amsmeteors.org`). I am especially grateful to the named societies above, who have been willing to share their data with us. The observers included:

AKM watchers (all in Germany, except where noted): Rainer Arlt, Pierre Bader, Orlando Benitez-Sanchez (Canary Isles; V), Lukas Bolz, Frank Enzlein, Darja Golikowa, Daniel Grün, Ralf Koschack, Detlef Koschny (Netherlands; V), Hartwig Lüthen, Sirko Molau (+V), Selina Müller, Sven Näther, Mirko Nitschke (V), Steve Quirk (Australia; V), Jürgen Rendtel (+V), Ulrich Sperberg (V), Rosta Štork (Czech Republic; V), Jörg Strunk (V), Heinrich Wiechell (Greece), Roland Winkler, Oliver Wusk, Ilkka Yrjölä (Finland; V, RM); AMS observers (with their observing States in the USA or countries outside the USA): Ardalan Alizadeh (Iran), Jure Atanackov (Slovenia), Javad Azizi (Iran), Malcolm Currie, Thomas Davis (Texas), Vincent Desmarais (Quebec, Canada), Vincent Giovannone (New York), George Gliba (West Virginia), Jonathan Gore (North Carolina), Cathy Hall (Ontario, Canada), Amir Hasanzadeh (Iran), Robert Hays (Indiana), Carl Johannink (Netherlands), Edwin Jones (Arizona), Javor Kac (Slovenia), Soheil Khoshbinfar (Iran), Gene Kispert (Minnesota), Marco Langbroek (Netherlands), Pierre Martin (Ontario, Canada), Paul Martsching (Iowa & South Dakota), Ashley Matous (Kansas), Bert Matous (Kansas), Jim McGraw (Iowa), Norman McLeod (Florida), Alan McRobert (Massachusetts), Ali Moosazadeh (Iran), Michael Morrow (Hawaii), Dennis O'Day (Florida), Mazyar Seyyednezhad (Iran), David Swann (Oklahoma), Richard Taibi (Virginia), Rocky Togni (Arizona), Kim Youmans (Georgia); Enric Fraile Algeciras (Spain; RM), Dirk Artoos (Belgium; R), Mike Boschat (Nova Scotia, Canada; RM), Walter Boschin (Italy; RM), Jay Brausch (North Dakota, USA), Michael Brooke, Jeff Brower (Colorado, USA; RM), Dave Campbell, Chris Chambers (Bulgaria), John Chapman-Smith, Terry Churms, Maurice de Meyere (Belgium; RM), Minoru Ehara (Japan; RM), David Entwistle (R), Steve Evans (V; data also listed in the AKM journal), Valter Gennaro (Italy; RM), Ghent University (Belgium; RM), Shelagh Godwin, Patrice Guérin (France; RM), Alan Heath, Philip Heppenstall, Tomislav Jurkić & Petra Korlević (Croatia; RM), Michael Krocil (Czech Republic; RM), John Lambert, Bob Lunsford (California, USA; part of data tabulated with AMS results), Edward Mallett, Tony Markham, Alastair McBeath, Simon McBeath, Tom McEwan (Scotland), Jane Mills, Toshihide Miyake (Japan; RM), Stan Nelson (New Mexico, USA; RM), Robert Obraz (Croatia; RM), Hiroshi Ogawa (Japan; RM), Robert Savard (Quebec, Canada; RM), Jonathan Shanklin, George Spalding, Enrico Stomeo (Italy), Dave Swan (RM), Pierre Terrier (France; RM), Stanley Toyn, Shinji Toyomasu (Japan; RM), Yung Cheich Tsao (Taiwan; RM),

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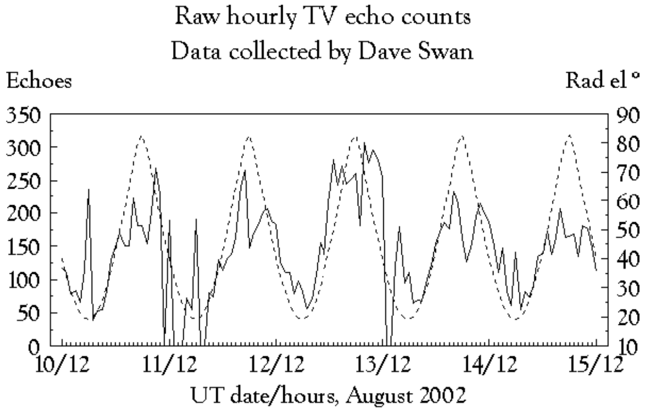

Figure 1 – Raw hourly TV meteor echo counts across the 2002 Perseid maximum, in data collected by Dave Swan (thicker, irregular line, keyed to the left-hand y-axis). The system was in continuous operation, and drops in the echo trace to zero indicate times when accurate recording was negated by interference problems. The thinner, daily-symmetrical, curve (keyed to the right-hand y-axis) gives the Perseid radiant elevation for Dave's site.

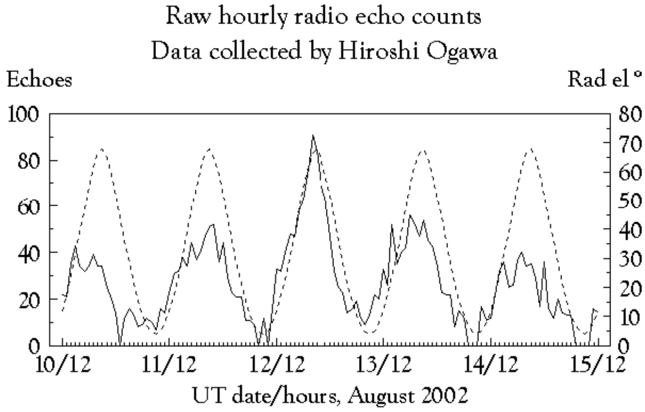

Figure 2 – Raw radio meteor echo counts collected by Hiroshi Ogawa, using the same format as Fig. 1. Zero counts in the echo trace again show times when interference intervened.

Takashi Usui (Japan; RM), Jan Verbert (Belgium), Julie Yellowley, Bruce Young (Queensland, Australia; RM).

The raw radio data were examined as normal in the SPAMS reports (McBeath 2001b), and Figures 1 and 2 were chosen as representative illustrations of these analyses.

2 Shower overview

Table 1 gives a global magnitude distribution for the Perseids and sporadics, using observations made under $LM = +5.3$ or better skies, a value relaxed from the more normal value of +5.5 in these reports due to the generally unhelpful sky conditions experienced, in Europe especially, near the shower's maximum. Table 2 has persistent train details only for the Perseids, as insufficient sporadics had train data submitted this year. Even the number of Perseid trains was low enough to leave some uncertainty in the analyzed results. The usual steady decline in mean train durations with fainter magnitude classes is not particularly well illustrated, and the enforced use of small-number statistics has also created an oddly low train percentage value in the magnitude −2 bin, for instance.

Figures 3 and 4 give two mean ZHR graphs for the Perseid activity. As Figure 3 shows, Perseid coverage was possible on every night between August 1/2 to 17/18 inclusive, one of the very best runs across the Perseid maximum the Section has ever enjoyed. The next best return from recent times was in 2000 (McBeath 2001a), when moonlight truncated the overall ZHR graph after August 13/14. Figure 3's data points show the typical Perseid pattern, with activity becoming quite obvious to dedicated watchers (ZHRs $\simeq$ 10) by August 3/4, picking up to a casually-detectable level (ZHRs $\simeq$ 25) by August 9/10, before shooting up to strikingly obvious numbers between August 11/12 to 13/14. The decline after the peak is generally always rapid, and was back below ZHRs of 10 by August 17/18.

The near-peak ZHRs of August 12 over the USA (ZHR = 73 ± 10 at $08^{h}30^{m} \pm 1$h UT, $\lambda_{\odot} = 139\overset{\circ}{.}44 \pm 0\overset{\circ}{.}04$) give a slightly false impression of two maxima, because of the gap in data coverage between $\simeq 10^{h}$ and $\simeq 22^{h}$ UT. In all probability, rates continued at about similar levels between these times, although as indicated in the IMO global analysis (Arlt & Buchmann 2002), there is the suggestion of a slight sub-peak in activity near $\lambda_{\odot} = 139\overset{\circ}{.}417$, $07^{h}54^{m}$ UT (ZHR = 84.7 ± 3.9).

Table 1 – Global magnitude distributions for the 2002 Perseids and August sporadics seen under better sky conditions (cloud cover < 20%, $LM = +5.3$ or better), including mean LM and corrected mean magnitudes.

Shower	-3^{-}	−2	−1	0	+1	+2	+3	+4	$+5^{+}$	Tot	LM	$\overline{m}_{6.5}$
PER	25.5	40.5	53.5	141.5	180	313.5	295.5	212.5	68	1330.5	+6.03	+2.46
SPO	1	3	1	10	28.5	38.5	92	80.5	42	296.5	+6.03	+3.54

Table 2 – Global persistent train percentages and mean durations in seconds per magnitude class for the Perseids, based on 412.5 meteors from the magnitude distribution. Too few August sporadics had train details recorded (88.5 meteors) to allow an analysis of them, but 5.7% left trains.

Magnitude	-3^{-}	−2	−1	0	+1	+2	$+3^{+}$	Tot	%
PER train %	100	57	90	74	54	44	18	130	31.5
PER train duration (s)	4.5	2.3	3.4	1.0	1.15	0.81	0.54	–	–

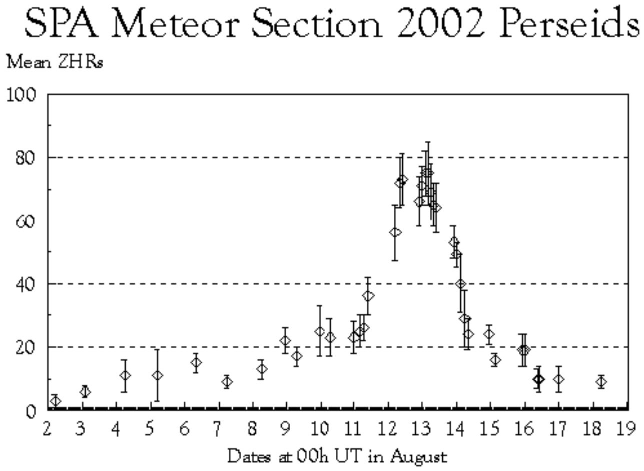

Figure 3 – Mean Perseid ZHRs during 2002 August, calculated using an assumed $r = 2.6$, for observations made where the LM was +5.3 or better, cloud cover was less than 20%, and the radiant elevation was at least 20°, with standard error bars appended. Each data point is based on hour-long observing intervals.

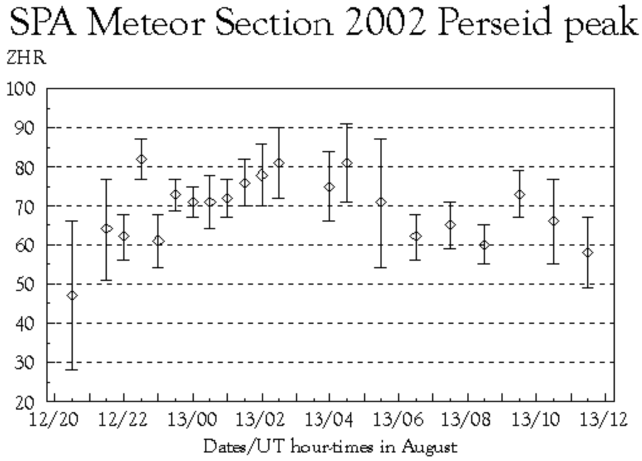

Figure 4 – Detail in the Perseid mean ZHRs from Fig. 3 closest to the shower's maximum, now using observing intervals of 30m duration.

Figure 4 uses 30^{m} intervals where possible to compute the mean ZHRs from, in an attempt to show more fine detail in the highest rates on August 12/13. ZHRs seem to have settled into pretty much of a plateau for most of this time, without producing any very clearly defined maxima. Aside from the main predicted maximum near $22^{h}30^{m}$ UT, two other UT maxima were possible on the same date (McBeath & Arlt 2001, pp. 9–11), the 'primary' peak at about $20^{h}15^{m}$, not seen since 1999, and the 'tertiary' one around $08^{h}30^{m}$ (found only in 1997–1999). There is no sign that these were found here, nor in the IMO results, which latter gave the marginally highest ZHRs of 106.1 ± 2.9 at $\lambda_{\odot} = 140.^{\circ}109$ (August 13, $01^{h}12^{m}$ UT).

Three slightly higher mean ZHRs are apparent in SPAMS data on August 12/13, at $22^{h}30^{m}$ ($\lambda_{\odot} = 140.^{\circ}0$; ZHR $= 82 \pm 5$), $02^{h}30^{m}$ ($\lambda_{\odot} = 140.^{\circ}16$; ZHR $= 81 \pm 9$), and $04^{h}30^{m}$ UT ($\lambda_{\odot} = 140.^{\circ}24$; ZHR $= 81 \pm 10$), but the significance of these is unclear, given the general scatter in rates during the near-maximum 'plateau'. The mean overall ZHR between 22^{h} and 04^{h} UT was 74 ± 7, while that between 04^{h} and 10^{h} UT was slightly lower at 69 ± 9. This implies a peak at $\simeq 01^{h} \pm 3$h UT ($\lambda_{\odot} = 140.^{\circ}10 \pm 0.^{\circ}12$), although the gently rising trend seen between 00^{h} and $02^{h}30^{m}$ UT is more suggestive of a peak towards $02^{h}30^{m}$. The gap in data points between $02^{h}30^{m}$ and 04^{h} UT is most unhelpful in this respect!

Hopes that some of these features might be further examined using the radio data could not be carried through with much success regrettably, as the radio observers did not enjoy the best of times in August. Apart from the traditional northern hemisphere summertime problems with interference due to Sporadic-E propagation, several European radio workers suffered equipment failures or power cuts at the least helpful times near the Perseid maximum. Allowing for these difficulties, a clear peak was apparent in surprisingly few European results (as Figure 1 indicates), while even the Japanese observers, who generally recorded the Perseid maximum more obviously (Figure 2), often found the radio meteor counts for several days to either side of August 12/13 made the Perseids stand out relatively poorly. Overall, the best the radio information could do was provide support for the general visual findings, suggesting a somewhat lower, but more protracted, Perseid peak than has been seen for some time.

3 Observers' impressions near the Perseid peak

Details from British locations on August 12/13, including a selection of newsgroup messages thoughtfully forwarded by other observers, indicated south-east England came off best for clearer skies. Positive reports arrived from places near the south-east coasts of England north-westwards across and near London into the English Midlands, and East Anglia. Parts of northern and north-east England up to the Scottish border saw several observers active too, but south-west England, Wales, western England, Northern Ireland and south-west Scotland were stuck beneath clouds.

Many of the clearer sites still had problems with clouds at times, and few UK reports with limiting magnitudes better than +5.0 to +5.3 were received, hence the relaxation in this parameter already commented on. Most people, though not all, seemed satisfied by what they saw however, as observed Perseid rates sometimes reached one or two meteors a minute briefly, making it a good display, but well below the strength of some seen in the past decade. There were several pleasing Perseid fireballs about too, including a notable one around $22^{h}01^{m}$ UT which was spotted from nine sites across south-east England. While Perseid fireballs may be commoner close to the maximum, it is certainly unusual to get so many reports on any one of them (from my experience during the last two decades at least!), and indications are this was an especially bright event to be so noteworthy, perhaps magnitude $-6/-8$ or more at best. Unfortunately, most watchers were rightly concentrating on getting accurate Perseid rate counts that

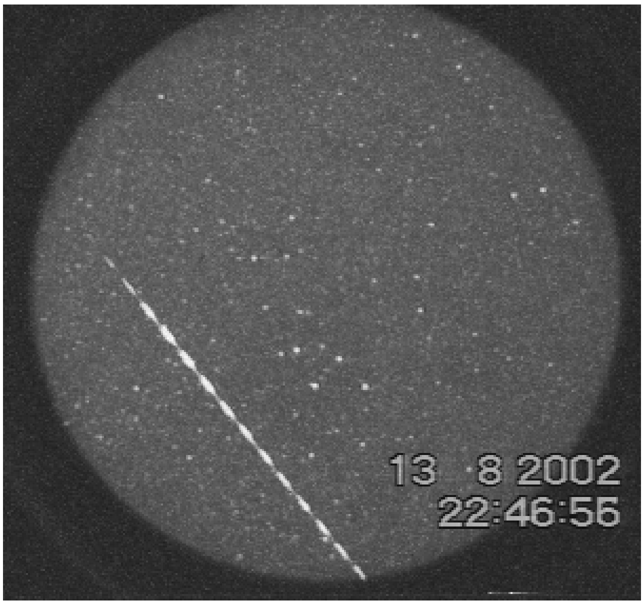

Figure 5 – A composite video-still Perseid image from August 13/14 at 22^h46^m UT. The meteor passed very close to Delphinus, seen inverted near the centre of the field, with south to the top of the image. Compiled by Steve Evans, using his CCD video system 'Emily', fitted with an 18mm second-generation MCP image intensifier and a 50 mm $f/1.4$ lens, giving a 21° field of view and a video-stellar LM of +6.5. Every other frame has been stacked to construct the image, giving breaks in the trail to allow the measurement of the apparent velocity of the meteor, which along with the path length and direction enables confirmation that this was a Perseid.

night, and too few of the lucky witnesses were able to give details on the fireball's sky-position (no photographs or video images were secured on the fireball either), insufficient to even estimate a possible surface track. Some useful video results were secured by Steve Evans at other times, and two of his more impressive composite images after the Perseid peak are shown here as Figures 5 and 6.

Mainland Europe had dismal conditions, with clouds and heavy rain across much of the continent during the Perseids' best. Indeed, there were some serious flooding problems in places. On maximum night, the most positive news came from Bulgaria, Greece and southern Italy. A few observers managed to snatch at most a couple of hours of better skies further north, in north and north-west Germany, parts of the Netherlands and Belgium (here only some notes from Jan Verbert, who enjoyed just one seven-minute clearer spell all night!). By contrast to this, UK observers had by far the better luck.

Among the reporters further afield on August 12/13, the Iranian group who provided data via the AMS had some moderate conditions, but only short watches were possible under at times poor limiting magnitude

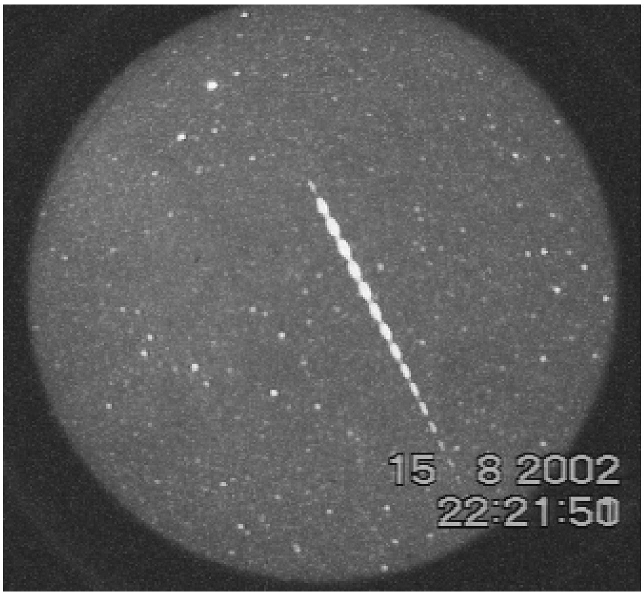

Figure 6 – A second bright Perseid caught by Steve Evans, on August 15/16 at 22^h21^m UT. The meteor is between Sagitta (left), Delphinus (right), and Aquila (top). The brightest star to the top left is Altair, α Aquilae. Other details are as captioned under Fig. 5.

skies. In eastern North America, Ontario and Quebec in south-east Canada, and Virginia in the eastern USA had the clearer skies, even so typically with quite inferior limiting magnitudes. Elsewhere in the USA, only observations from North and South Dakota and California appeared but, here at least, skies were much more transparent. As Figures 3 and 4 show though, Perseid ZHRs were already below their best by the time night had fallen over much of North America.

Acknowledgements

Very many thanks go to all the observers and correspondents who have provided the details included in this report. Good luck and clear skies for your next watching!

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