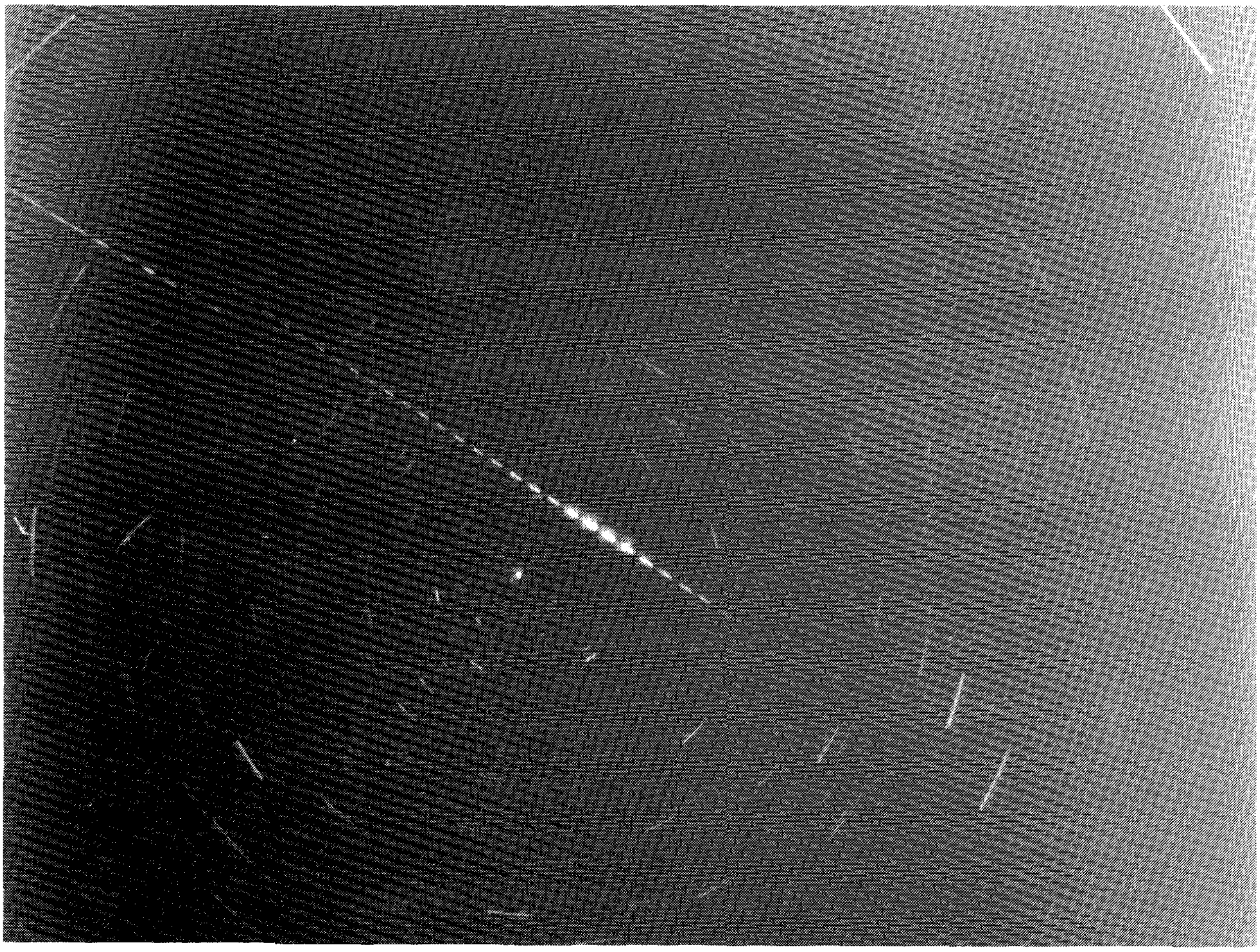
ISSN 1016-3115

wgn

21 - 3

june 1993

bimonthly journal of the international meteor organization



Two fireballs captured by Noel White on November 10, 1991, from Isham, Kettering, Northants., England ($\lambda = 52\overset{\circ}{.}356$ N, $\varphi = 0\overset{\circ}{.}708$ W, $h = 76$ m). The photograph was exposed from 3^h22^m to 3^h52^m UT on HP5 400 ASA film with a 28 mm $f/2.8$ lens and a rotating shutter yielding 20 1:1 breaks per second. The film was developed during 6 minutes in Microphen at 20° C. Probably, the brighter fireball was a −4 to −5 Northern Taurid (28 segments on the negative) while the other one was a Southern Taurid (11 segments).

In this issue:

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v.u.: Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium

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Contents

Useful Information

The August Issue *(WGN 21:4)*

Due to the printer's holidays, the *August issue* is expected to be mailed a little later than usual, around mid-August 1993. Because this issue will again become fairly thick, contributions are due early, on *July 2* at the latest. They should be sent to *Marc Gyssens* (address on inside back cover).

WGN Subscription/IMO Membership 1993

The subscription rate for volume 21 (1993) is 25 DEM for six issues. Additional gifts are of course welcome. It is anticipated that volume 21 will contain over 240 pages.

In Memoriam

Jan Štohl, 1932–1993

Iwan P. Williams, Acting President IAU Commission 22

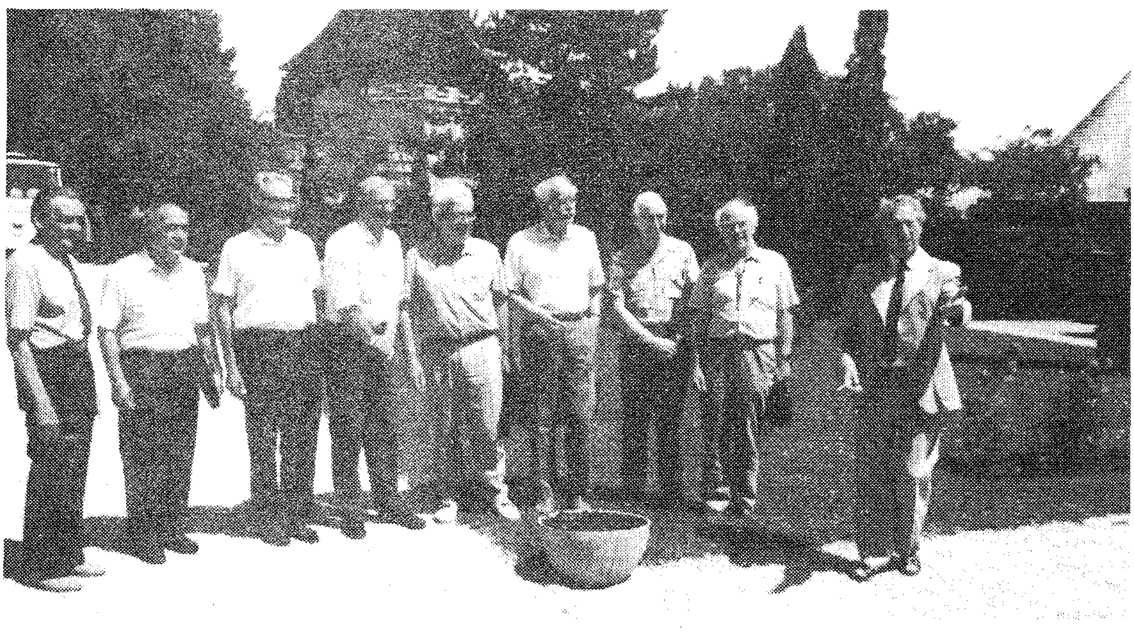
It is with deep regret that I record the sudden death at the age of 60 of Dr Jan Štohl, the President of *IAU Commission* 22, the Commission of the International Astronomical Union responsible for Meteors, on Sunday March 21, 1993.

Jan spent his last working day putting the final touches to the book "Meteors and their parent bodies," a volume based on the proceedings of the Smolenice Symposium last July. He spent the weekend with his family, and for most of Sunday they were walking in the Malé Karpaty mountains. On returning to his home in Pezinok, Jan felt unwell and died of a heart attack shortly thereafter. He leaves behind a widow, Marta, and two sons.

Jan was born in Pezinok, on July 26, 1932, the youngest in a family of four boys and two girls. After finishing his high school studies in Modra, he entered the Comenius University in Bratislava in 1951 where he studied mathematics and physics, transferring after the third year to the Charles University in Prague where he read astronomy.

In 1956 he obtained a post at the Astronomical Institute of the Slovak Academy of Sciences in Bratislava, in the Division of Interplanetary Matter headed by ubor Kresák. In 1966, he obtained the equivalent of a Ph.D. degree with a thesis entitled "Diurnal and annual variations of sporadic meteors." From 1966 to 1968 he held a postdoctoral fellowship awarded by the the National Research Council of Canada which allowed him to work with Dr. P.M. Millman in Ottawa.

His first son was born in Canada, but Jan decided to return to his native Slovakia to raise him, arriving in Czechoslovakia just two days before a large number of troops from the East. He remained in Slovakia for the remainder of his career, becoming head of the Division of Interplanetary Matter in 1981 and being appointed Director of the Institute in Tatranská Lomnica in 1989. He had been a member of Commission 22 of the International Astronomical Union since 1970, being elected Vice-President of the Commission at the General Assembly at Baltimore in 1988 and President at Buenos Aires in 1991. With the forming of a new country, Slovakia, Jan was elected Vice-President of the Slovak Academy of Sciences in 1992. This was a fitting tribute to both a great astronomer and a patriotic Slovak.



At the Smolenice Symposium in July 1992, Jan Štohl *(far right)* poses with *(from left to right)* Kresák, Babadzhanov, Ceplecha, Williams, Bel'kovich, Lindblad, Elford, and Keay.

Though he is best known for his work on meteors, Jan started his scientific research in stellar astronomy, with his first papers being on variable stars. However, he soon "saw the light" and devoted the remainder of his life to the study of small bodies in the solar system, mainly meteoroids and their generic relation to comets and asteroids. He was an active meteor observer (both visual and telescopic).

His first papers on meteors were devoted to the diurnal and seasonal variations of sporadic meteors, the distribution of radiants, and to the problem of hyperbolic meteors. He suggested the existence of a broad "sporadic stream" associated with Comet P/Encke, and is also well known for his work on the Taurid meteor complex and its origin. In the last years, he searched for a generic association between meteoroid streams and some Apollo asteroids. In all, Jan published more than one hundred scientific papers and attended more than 30 international conferences.

Jan was an enthusiastic popularizer of astronomy and science. He delivered hundreds of lectures for the public, wrote two popular books on astronomy and many popular articles for the newspapers and journals, and was a strong supporter of close cooperation between amateur and professional astronomers. Jan had also dreamt of organizing a Symposium in his homeland and this also came to fruition with the highly successful conference held in Smolenice in 1992. Without Jan's enthusiasm and drive, the conference would never have got off the ground, and without his charm, many of the minor difficulties encountered would never have been resolved so smoothly.

With the passing of Jan, Astronomy has lost one of its true gentlemen—we shall all miss him greatly.

From the Editor-in-Chief

Marc Gyssens

First, I also want to express my sorrow over the unexpected death of Jan Štohl. His death is an immense loss for the meteor community. On behalf of the IMO, *President Jürgen Rendtel sent condolences to Mrs. Štohlova.*

Members of the IMO *should find enclosed with this issue a Voting Bulletin for the Council elections and the 1994* IMO Meteor Shower Calendar *is enclosed. Finally, all subscribers will receive with this issue a text on the 1993 Perseids which they are free to use to attract the attention of the general public and the local media to this event.*

The 1993 Perseids are indeed the big event this summer, and everybody is anxious to know how the shower will perform. As this event is a unique opportunity for the IMO *to gain more visibility, it is very important that, should a major outburst occur, the Organization be notified as soon as possible, preferably when the event is still going on! Instructions for the observing and fast reporting of an outburst are included in this issue and repeated on the back cover. Your cooperation is greatly appreciated!*

The Perseids will no doubt be a major topic of discussion at the 1993 IMC *in Puimichel, which is almost fully booked. Do not hesitate to register at once if you did not yet do so and still want to participate!*

Finally, this issue is again a thick one, as you can see. So many articles and notes arrived in the last few months that it is impossible to accommodate all of them in this issue. Of course, we gave priority to articles related to the Perseids; we apologize to the authors whose articles have been delayed. We are hopeful, however, that the backlog will be eliminated in the August issue. The large influx of articles is a healthy sign for our Organization. Therefore we hope that the coming months will provide our members and subscribers with plenty of opportunities to observe and report their findings to our—your—Journal.

The 1993 Edition of "Who is Who?"

Paul Roggemans

The next edition of "Who is Who?" will be printed together with the next thick issue of *WGN*, presumably the August issue. Until then, it will still be possible to report changes concerning your entry. Members who failed to reply to the letter mailed with the February issue are urged to use the extra time to send in the required information to the Secretary-General (address on inside back cover).

If the August issue will indeed be a thick one, all information must be received by July 31, 1993.

Letters to WGN

compiled by Marc Gyssens

Radio reflection duration and visual magnitude

The letter from George Zay published in last year's December issue (WGN 20:6, p. 210), *pointing out that visually bright meteors do not always yield long radio reflections and vice-versa, still continues to trigger reactions:*

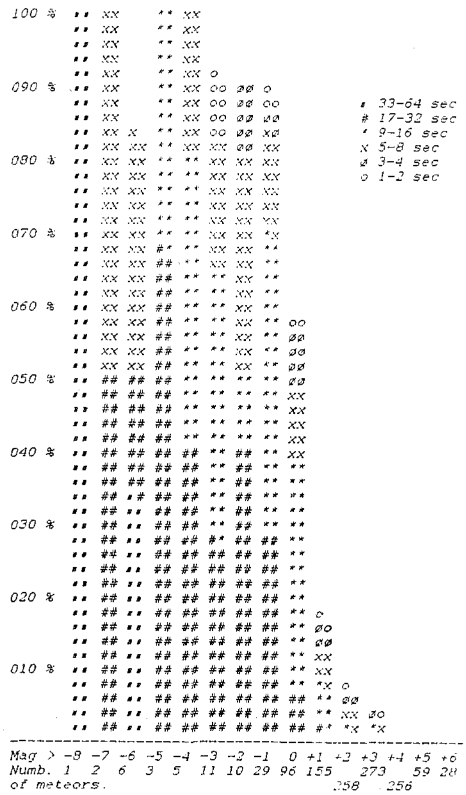


Figure 1 – Correlation between radio echo duration and visual magnitude.

I do not understand how someone could say that correlating radio durations and visual magnitudes is a useless task. Of course, there is a close connection, but it is not so simple that one can establish a sharp cutoff duration such that all meteors with a longer-lasting echo are surely fireballs. I think, however, that statistically, long-duration meteors are caused by bright visual meteors.

Figure 1 shows that there is a significant correlation between long-duration radio meteors and bright visual meteors. Short radio echo durations are related to faint visual meteors. For instance, no meteors fainter than magnitude +4, and only a few meteors of magnitude +2 and +3, produce radio signals over 1 second. Furthermore, can someone tell me why there is an obvious increase in long-duration radio meteors coinciding with the increase in bright meteors during the Perseid, Geminid, and other meteor showers if there is no correlation between echo duration and visual magnitude?

Moreover, radio meteors of very long duration are extremely infrequent, just like visual fireballs. It is also easy to explain certain 30+-second signals by meteors we do not see. No one can watch the entire sky, and I have caught signals from fireballs as far away as over Germany or Poland. During 1992, I observed 695 154 radio meteors by pen recorder, having covered 97.7% of the entire year. Among these were 1225 signals of 30 seconds or more. I believe the 30-second limit on my equipment corresponds more or less to the limit for a visual fireball. The 1225 signals mentioned above represent 0.2% of all radio meteors recorded. In 1992, I also observed visually a total of $243^{h}16$ of effective observing time and saw 1229 meteors. Among these were 10 fireballs of magnitude −4 or brighter, or 0.8%. Both percentages agree very well. I am of the opinion, therefore, that we can still make useful notes about long-duration meteors.

Gotfred Møbjerg Kristensen, May 2, 1993

Comment by the Editor: *Once again, nobody argues the existence of a correlation between echo duration and visual magnitude. The point that needs to be made is that the correlation is fairly complex and that the simple formula used earlier in certain* IMO *publications is not generally applicable.*

Following on from the examination of radio meteor and visual magnitude in the letter columns of *WGN* in recent issues, I should like to broaden the discussion to examine the practical use of the forward-scatter technique itself, since it has increasingly seemed to me in recent times that we are assuming a level of accuracy in the results produced which simply does not exist in practice.

My recent researches have involved me in work concerning the possible correlation of noctilucent clouds, meteor shower activity, and Sporadic-E during the northern hemisphere summer, and I hope to be able to publish some findings from this endeavor in *WGN* shortly. Of interest from that now, however, is the apparent problem encountered by a number of amateurs using short wave radios in establishing whether the propagation mode used for transmitting a signal was Sporadic-E, meteor scatter, or Auroral-E, as while all are usually treated as being separate and quite distinct in the literature, in terms of practical observing, this is often not the case. The problems created by Sporadic-E for radio amateurs trying to observe the June daylight showers, for instance, have been commented on in a number of places.

In his contribution to the 1994 *IMO Meteor Shower Calendar*, Jeroen Van Wassenhove indicated to me that he sees the Radio Commission as concentrating primarily on the major showers, since observing minor showers with the forward-scatter method is simply not reliable enough to get real data. Forward scatter, for example, cannot derive important parameters such as the velocity and the radiant of the meteors, and is moreover heavily dependent on the type and orientation of the aerial and set employed, so much so that a radiant zenith angle which would be highly favorable for visual observations may produce absolutely no trace of shower radio activity.

Jeroen has also very helpfully forwarded some data to me concerning my latest work, consisting of the whole-year raw forward-scatter count graphs, made with a variety of equipment using different frequencies in different years. He made the comment that even when the equipment and frequency remained the same, it was best not to compare the graphs directly between years. The problem could be cleared up by using correction factors, such as commonly used to compute ZHRs visually, but since there are so many different variables involved with each individual radio set-up, this is unfortunately impractical.

The above thoughts, plus discussion with a number of people, some of whom have been involved in the use of short wave radios for many years, have led me to wonder how viable forward-scatter observing actually is. I think it would be a mistake for us to assume it will ever produce the kind of accuracy we are used to seeing with visual data, despite the possibilities of its use throughout the day with no problems from clouds or moonlight. There are in fact a great many more problems instead, due to the vagaries of the phenomenon involved, the radios and the aerials used, the occasional difficulty in separating one radio propagation mode from another, plus the fact that it is far from easy to compare results made by individual observers, even when using similar set-ups.

Despite this, it does seem to me there is some value in obtaining forward-scatter results, since they do provide a guide to what occurs in terms of major meteoric events, and have provided essential confirmation of otherwise poorly-observed or unobserved unusually high shower peaks in the past, especially as radio amateurs (not meteor workers) rarely give informative details from their use of meteor scatter, other than who they contacted and when. In order to calibrate the results *IMO* observers obtain, of course, the same equipment must be used regularly, and the data scanned routinely. smallnewpar I have no wish to dissuade the splendid efforts of all forward-scatter observers past and present, nor to belittle their work, but I do feel a more realistic approach to the technique as a whole would not go amiss. The recent discussion of the problems of deriving magnitudes from radio signal strengths is simply the first of what I think may be many such, unless we adopt a fresh attitude to radio meteor observing.

Alastair McBeath, April 30, 1993

Changes in ionospherical radio emission caused by meteors

In the previous issue (WGN 21:2, pp. 69-71), *Andreić, Beg, and Korlević reported on a negative attempt to determine changes in ionospheric radio emission caused by meteors. Following the article was a comment by Peter Brown in which he suggested that the evidence presented by the authors might not be conclusive. Below is a comment on Peter Brown's statement by Dr. Colin Keay.*

I feel it is necessary to comment on Peter Brown's remarks following the paper "No evidence of change in ionospherical radio emission at 1.25–10.6 kHz during and after meteor flight." Peter Brown stated that *the mechanism which might lead to VLF emission in meteors is not at all understood—it is possible that only a small number of meteors are involved.*

The mechanism that *does* lead to ELF/VLF emission from very large meteor fireballs has been known since 1980, when I first published the "magnetic spaghetti" model (inspired by Fred Hoyle's theory of sunspots). Within two years it was supported by further calculations performed by Vitalij Bronshten, who showed that it could generate megawatts of radiated power. I did not push my explanation strongly until it was verified by the first direct observational evidence of radio emissions obtained by Watanabe et al. (published in Japanese in 1988, but I did not know about it until I visited Japan in 1990).

My explanation of the generation of the required radio energy relies on the presence of a turbulent plasma, either in the fireball trail or in the ball of plasma resulting from an explosion of the meteoroid. My 1992 *Meteoritics* paper shows that for continuous radio emission (up to several seconds) the fireball must be brighter than -9 absolute magnitude, a value found empirically many decades ago by Astapovich. In the case of a short (under 1 second) burst of radio energy generated by an exploding meteoroid (not dealt with in the *Meteoritics* paper) the peak magnitude may be less, perhaps as low as -6. The example observed by the Japanese was a magnitude -7 Perseid fireball, which produced a burst of radio energy lasting only 0.15 seconds.

The paper presented by Andreić et al., and many other attempts to record radio signals from meteor fireballs, have simply not observed fireballs that are bright enough to generate the sought-after signals. Peter Brown was perfectly correct in stating that only a small number of meteors are involved. Many months of continuous observation will be needed to gather a brief burst of radio noise from an exploding meteor of at least magnitude -6, and many years (or even decades) of observations will be necessary to record a radio signal lasting a second or so. We do not often have the luck to witness fireballs brighter than -9 which reach low heights.

Despite the odds, I hope attempts to record fireball electromagnetic signals will continue, and it would be even better to have at the same time a tape-recording of the electrophonic sounds, but that will require a suitable transducer close to the tape-recorder microphone. Some plastic Christmas-tree material that produces a loud rustling sound is about as good as I can suggest at this time. There must be something present to transduce the audio-frequency radio energy into audible sound energy.

Colin Keay, University of Newcastle, April 8, 1993

We also received a reaction from the authors of the paper "No evidence of change in ionospherical radio emission at 1.25–10.6 kHz during and after meteor flight" to Peter Brown's comments in which additional information on the experiment is provided and certain criticisms are countered.

The project described in our article was proposed and conducted by Željko Andreić, plasma physicist at the Ruder Bošković Institute in Zagreb. Every single component of the equipment was tested separately. After that, the complete configuration was tested. Lučano Beg, engineer in the telecommunications workshop, is very aware of the problems inherent to working at such low frequencies.

We tested our antenna sensitivity (gain), both in emission and receiving mode, at a frequency of 5 kHz. The instruments we used were a Marconi Radio Communication Test Set 2955 R, a standard universal instrument Matex 3650 CR, and instruments built for the occasion. The measurements resulted in the antenna diagram shown in our article.

Our antenna was most sensitive to the regions in the sky corresponding to a 60° cone centered at the zenith, a small one at 60° zenith distance, and near the horizon. We were also quite aware that the strength of the signals from near the horizon would be lower because of the increased distance.

I suppose that Peter Brown did not have the figures at hand when he wrote his comment *(this was indeed the case, Ed.)* and that he was speaking about one theoretical antenna sensitivity diagram, while we were using another, which might have caused confusion to some readers. In light of this, we strongly recommend that people involved in similar experiments measure the sensitivity for *every single* antenna they wish to use on the frequencies under consideration.

Korado Korlević, April 14, 1993

Fragmenting dusty meteoroids observed?

Dr. Duncan Steel, of the Anglo-Australian observatory, wonders whether certain phenomena sometimes observed during meteor watches can be attributed to fragmenting dusty meteoroids.

Over the past few decades there has been some evidence accumulated, in particular from spacecraft dust impact sensors, for large meteoroids breaking apart into clouds of dust particles when the larger object was close to the Earth but well above the atmosphere (see, for example, [1] and [2]). A similar phenomenon appears to have been witnessed by a meteor observer in the USA (John Gallagher [3]), who has reported as follows:

> Diffuse luminous objects moving at angular velocities similar to those of meteors were observed during over 200 hours of meteor watching in 1991. They fell in three broad categories: arcs, patches, and "meteors" similar in appearance to comet comas. Though I at first dismissed the possibility of their being related to meteors, I reconsidered this relation after eliminating other possible causes such as reflections from aircraft lights and tricks of vision. Their meteor-like behavior suggested that perhaps these events might be caused by clouds of exceedingly small meteoroids, visible only because of their numbers and compact grouping. Because such a formation would be unlikely to be maintained long in space, it appeared necessary that the particles involved must have maintained some weak physical contact until just prior to becoming visible. Perhaps some type of "cosmic dust bunny," disrupted by air resistance, might be the cause of these events.

Have any *IMO* members witnessed similar things? If so, I would encourage all observational groups to maintain a look-out for such unusual meteors.

[1] Singer S.F. and Stanley J.E., in *IAU Symp. 90: Solid Particles in the Solar System*, I. Halliday and B.A. McIntosh, eds., Reidel, Dordrecht, 1980, p. 329.

[2] Fechtig H., in *Comets*, L. Wilkening, ed., University of Arizona Press, 1982.

[3] Gallagher J.S., *The Strolling Astronomer* 36, 1992, p. 115.

Duncan Steel, Anglo-Australian Observatory, May 19, 1993

As a matter of fact, Dr. Steel's note reached me at approximately the same time as a note from Mr. Zay who, also referring to Gallagher, describes phenomena of the kind that Dr. Steel is asking for.

I would like to bring attention to something I have seen on occasions during my meteor observing. I have been seeing for the past year and a half what I have always referred to as "Dark Broad Fuzzy Objects." After discussing this with Peter Brown, I guess the proper terminology is "Dark Meteors." So that is how I will refer to them from now on. During all of 1992, I have seen perhaps a dozen. They appeared to be very dark objects of a roughly broad rectangular shape moving at a very fast velocity (on a 1–5 scale, a 5). I found no real apparent pattern for the best time to see them. At first I thought they favored the spring months, but I think this is not a real property. That dozen I have seen always seemed to occur on the edges of my vision going from left to right or right to left. I have discussed this with Robert Lunsford and I personally concluded that since I did not notice any going up or down, that they most likely were an optical illusion. Possibly due to fatigue or whatever? Robert informs me of another meteor observer in New Jersey by the name of John Gallagher who has been writing him about these things. Mr. Gallagher thinks they are "mini-comets" or chunks of ice based on an idea by Dr. L.A. Frank. I do not know if I agree with this idea. I am still trying to determine if what I have "seen" is real or not. I wrote Gallagher and informed him that my opinion of these "dark meteors" was that I believed them to be optical illusions. This was about five months ago. I have seen a couple more since then and passed them all off as illusions.

But then on the mornings of March 22 and March 23, I saw three directly in my field of vision while feeling very refreshed and alert. I have no doubt that I saw something. The question is which side of my eyeballs did they originate from? What I did see is as follows: the first event occurred at 10^h19^m UT (2^h19^m a.m. local time) on March 22, 1993. The limiting magnitude was near 5.7. It moved with the fastest velocity I have seen for meteors and it was extremely dark and very broad. Its dimensions were roughly rectangular. If I stretched my arm out full length, it would seem to be about the size of my thumbnail. Then later at 11^h19^m UT I saw my second event. It too was in my full vision and again I felt clear-headed and alert. It had the same characteristics as the first but was slightly smaller. The following night, things got more disturbing. At 8^h55^m UT, I saw another very dark object traveling at an apparent slower velocity. On a 1–5 scale, it was a 4. The odd thing about this one was that it had a rope-like shape and was moving in a direction perpendicular to the "rope." With my arm outstretched, it would be about as long as two thirds the length of my standard-sized pointer finger. All three objects had to be as dark or darker than magnitude 5.8. No trail of any kind was noticed. What appears to make them visible is not how "bright" they were, but rather how dark they seemed in reference to the background sky. They seem to momentarily blot out the background sky glow. I am pretty certain that they were not owls or bats, although I have frequently seen both. All three events traversed a distance shorter than the length of Bootes with one object making a path slightly longer than the longest dimension of Corona Borealis. I have seen them begin and I have seen them end. I also had my radio on for meteor reflections (92.9 MHz) and the antenna was aligned in the general direction of where I had seen these "dark meteors." No sound was heard directly or over the radio. I was able to plot all 3 events. The coordinates are in Table 1.

Table 1 – Trajectories of dark meteors.

Nr.	Begin		End	
	α	δ	α	δ
1	15^h58^m	$+27°$	17^h08^m	$+25.^\circ5$
2	15^h36^m	$+34.^\circ5$	15^h45^m	$+25°$
3	15^h58^m	$+47°$	14^h20^m	$+46°$

Then on one of those two mornings (I forgot which now. I thought I wrote it down in my notes, but apparently I did not.) I saw a broad-shaped meteor of third magnitude and very fast velocity. It seemed to have a thumbnail-size look to it with an outstretched arm also. It seemed similar to the broad "dark meteors." The only difference was that it produced light. This meteor appeared very, very fragile. It kind of gave me the impression that it could be a "fuzz-ball" under my children's bed with respect to its delicate appearance. The whole structure briefly sparkled in several places as it zipped by.

The most disturbing thing about these "dark meteors" is that I do not have any co-observers to confirm what I see. I frequently view with Robert Lunsford, but we usually look in slightly different directions. Whenever I do see one, it seems that Robert is looking somewhere else or has just rubbed his eyes or something for a moment. That part is frustrating, as Robert has excellent eyesight. In fact I feel that he has two fish-eye lenses for eyeballs and I would very much like for him to see one of these when I do. I feel confident that I did see something unusual in March, but I am not confident enough to say that they were not some kind of optical illusion. It would be very reassuring to hear about others having similar sightings.

George J. Zay, May 8, 1993

On documenting our photographs

We received the following interesting suggestion from a senior member, Mr. Noel White. We will try to accommodate his suggestions in the future. Observers sending us data are therefore kindly asked to supply us with all relevant data.

I would like to make the suggestion that the scientific value of photographs of meteors and fireballs for inclusion in *WGN* would increase if all possible data were included. It would also, I feel, assist other meteor photographers to assess their own work and perhaps to improve their techniques. The following details would be helpful: start and end of the exposure, date and time of the meteor (if known), "F" number and focal length of the lens, film type, speed, and processing, for the rotating shutter, breaks per second and open-to-closed ratio, a description of the object, if identified, and the number of breaks on the negative, and the location of the camera by town and country, as well as by latitude and longitude.

Noel White, March 17, 1993

The 1993 IMO International Meteor Conference

Puimichel, France, September 23–26

Paul Roggemans

1. Update

So far, over 50 people from Belgium, Bulgaria, Croatia, the Czech Republic, France, Germany, Hungary, Italy, Ireland, the Netherlands, Portugal, Rumania, Russia, Slovakia, Slovenia, Spain, Tadjikistan, and the United Kingdom have made arrangements to participate in the Conference.

We still have some places available, so we invite you to consider participating if you have not yet registered. Therefore, you can use the registration form printed in the February issue of *WGN*.

Because we had to arrange for additional more expensive accommodation, the registration fee for people having registered or registering after March 31 had to be raised to 850 FRF. Of this sum, 100 DEM (which is 350 FRF) must be pre-paid as a reservation fee. The form should be sent to Paul Roggemans, the money to our Treasurer, Ina Rendtel (all addresses on inside back cover). If you have difficulties with international currency transfers, please ask for special arrangements.

Of course, people who registered *no later than* March 31 and did not require special accommodation still benefit from the lower rate of 650 FRF (180 DEM).

2. Conference program

As is usual at *IMC*s the official language at the Conference is English. Facilities for other languages are *not* provided; every participant is expected to use the English language to the best of his or her abilities in order to communicate. The program of the Conference is as follows:

- *Thursday, September 23:* arrival and welcoming of participants, opening, and introduction program;
- *Friday, September 24:* lectures, poster session, General Assembly of the *IMO*, workshops;
- *Saturday, September 25:* lectures, afternoon excursion by bus to the Verdon Canyon, open-air dinner, informal evening with cheese and wine;
- *Sunday, September 26:* lectures, evaluation and closing, departure of participants.

About 25 lectures and 12 posters have been scheduled so far. Presentation of a lecture or poster is still possible: mention title and duration. Please note that a written version of your contribution must be delivered at the Conference for inclusion in the *Proceedings*, which will be published by the *IMO*.

3. Practical information

Participants from certain countries may need a visa to enter France. For this purpose, the organizer will gladly provide a personal invitation. As visa procedures may take several weeks, participants needing a visa should contact the French Embassy or a French Consulate in their country promptly.

The organizer will also provide assistance with travel arrangements. In particular, car-pooling among European participants is encouraged. Assistance can also be provided in the form of time tables for local public transport. Furthermore, a shuttle service between Puimichel and the local train and bus stations will be organized.

Additional information on the *International Meteor Conference* can be obtained from the organizer, Paul Roggemans (address on inside back cover). Additional information on the *Puimichel Observatory* can be obtained from Arlette Steenmans, La Remise, Puimichel, F-04700 Oraison, France, tel. +33-92 79 94 28.

Update on the Meteor Train Observing Project

Mark Vints

1. Status report of the observing project

As of April 18, 1993, the following people have submitted reports for the meteor train observing project. Included between brackets is the number of reports received. I wish to thank all observers for their efforts:

> Luc Bastiaens (5), Marc Bastiaens (5), Koen Clement (2), Eric Crauwels (2), Mark Davis (15), Albert De Clerck (1), Carl De Pooter (1), Werner Depoorter (2), J. Kenneth Eakins (6), Phyllis Eide (6), George W. Gliba (12), Erwin Guetens (3), Robert H. Hays Jr. (10), Inge Leyssens (1), Robert Lunsford (18), Michael J. Morrow (4), Daniel L. Rhone (2), Tom Roelandts (4), Karl Simmons (1), Wanda Simmons (1), Doug Smith (2), Siegfried Stapf (3), Mireille Vanheerentals (2), Cis Verbeeck (3), Jean-François Viens (1), Linda C. Wilson (2), Jean-Marc Wislez (2), George Zay (75).

Most of these reports include complete magnitude and train duration distributions as requested, with the exception of those submitted by Siegfried Stapf and Robert Lunsford. The latter's reports cover almost 7000 meteors from 53 nights of major shower activity between 1983 and 1991. Despite the fact that only train percentages are reported, and this only for shower meteors, these may serve as a valuable reference set. I am particularly grateful to George Zay, who has not only filled out the most reports, but has also collected all other North-American reports and is working to further expand the network.

The table gives an overview of all complete magnitude and train duration distribution reports received thus far. The number of different nights covered each month is indicated, as well as how many reports were filled out by how many observers. The final three columns give the total observing time and the number of meteors and trains seen.

Table 1 – Overview of magnitude and train distribution reports.

Year	Month	Days	Rep.	Obs.	T_{eff}	Met.	Trains
1991	May	3	3	1	5.65	41	4
	Jun	2	2	2	2.83	29	6
	Jul	2	3	2	3.80	24	1
	Aug	9	19	8	37.30	688	149
	Sep	1	1	1	2.72	3	1
	Oct	2	2	2	2.36	23	4
	Nov	3	3	2	10.04	72	5
	Dec	1	2	2	2.43	181	8
1992	Jan	2	2	2	7.72	29	1
	Feb	4	7	3	19.90	110	9
	Mar	3	3	2	5.49	17	1
	Apr	8	8	2	34.49	149	11
	May	11	12	4	35.15	188	23
	Jun	7	9	3	27.99	148	8
	Jul	9	22	11	57.12	597	59
	Aug	11	32	17	54.86	655	92
	Sep	3	3	1	15.04	109	13
	Oct	5	5	1	18.95	168	24
	Nov	4	5	2	25.38	157	17
	Dec	4	4	1	19.23	234	27
1993	Jan	3	3	1	22.40	120	15
	Feb	4	4	1	19.98	59	4
	Mar	14	14	1	60.99	177	10
Tot	23	110	158	26	491.82	3978	492

Since the major aim of this project is to study meteor trains in a statistical manner covering a large number of meteors over a small interval of time (1 day), a great amount of information is still needed. Therefore I wish to call upon all active observers to include meteor trains in their observing program and to report the results to me (address on the inside back cover).

2. The visual meteor train report form

The improved version of the report form accompanying this article should be used to report the observed train activity. Most of the information requested is straightforward, but let me point out the following:

- One page per night per observer is needed;
- For every meteor stream and for the sporadic meteors, a magnitude distribution must be supplied as well as a train duration distribution for each magnitude class;
- The fact that no meteor trains were seen for a given shower or even for the entire observation, is useful information too;
- The most active meteor showers (or the sporadics) may occupy the table, all others are referred to the lines at the bottom of the page. In case a very large number of meteors and trains was seen, the information may be spread over different tables on separate report forms, which must be stapled together;
- Very bright meteors or long-lasting train events which do not fit into the table, must be specified separately just below the table. Four different magnitudes brighter than -6 can each hold 8 different train events. In case any of the trains was seen to be drifting, circle its duration number. In case any problems or doubts remain with correctly filling out the report form, do not hesitate to write me about it (especially if you make an effort to fill out more than just a few).

International Meteor Organization

VISUAL METEOR TRAIN OBSERVING FORM

Date : ___/___ (day) __ (month) ____ (year). Begin : ___^{h} ___^{m}. End : ___^{h} ___^{m} (UT)
Location : λ = ___° ___' ___" E/W, ϕ = ___° ___' ___" N/S, h = ____ m. IMO Code : ______
Place : ________________________________ Country : ______________
Observer : ____________________________________ IMO Code : ________
Net observed time T eff = ____ ^{m} = ____ ^{h}. Average Lm = ____ , spread = ____ - ____
Total number of meteors : _____ . Remarks ______________________________

magnitude & train duration distribution table. Shower IMO Code : ________

magnitude	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	Tot
meteors														
train 0.5 s														
1 s														
2 s														
3 s														
4 s														
5 s														
>5 s														
Total														
%														

specify events brighter than -6^m and/or exceeding 5 seconds duration :
magnitude : ___ duration ___ ___ ___ ___ ___ ___ ___ ___ circle those events
___ ___ ___ ___ ___ ___ ___ ___ ___ that were drifting
___ ___ ___ ___ ___ ___ ___ ___ ___
___ ___ ___ ___ ___ ___ ___ ___ ___

Are any drawings of drifting trains included ? : Yes / No (circle appropriate).

Other showers : first line : magnitude distribution : (mag) nr, (mag) nr, (mag) nr, ... + total
second line : trains in format nr x n^m of n^s (number, mag, duration)

shower : _____ ______________________________________
____
_____ ______________________________________
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_____ ______________________________________
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_____ ______________________________________
____
_____ ______________________________________
____

The Ripple Effect—An Alternative Method for Daylight Meteor Observations?

Alastair McBeath

All meteor observers in the northern hemisphere are undoubtedly now looking forward to the forthcoming Perseid return in August in the hopes that the third outburst from the shower in consecutive years will indeed occur, following in the wake of the reappearance of the shower's parent comet, P/Swift-Tuttle, towards the end of last year.

Predictions based on the last two outbursts, in 1991 and 1992, suggest that European and North African sites, and perhaps also the North-American East Coast, may well be especially favored in 1993 if another unusually high Perseid rate does take place this year, but naturally, all observers need to be alert in case the Perseids prove as unpredictable as they have in the past. Observers at other locations may have the chance to spot the results of high Perseid activity visually, however, even in daylight, if the theory behind the phenomenon described below is correct.

The phenomenon itself, the ripple effect, is a very rare one, and to the knowledge of the authors has been observed on only four reported occasions so far. The ripple effect consists of light and dark bands moving through solar halo effects, either singly or in irregularly-spaced groups. In all the reports, the halos in question appeared in aircraft contrails, suggesting that only very thin clouds of this type are capable of sustaining the effect, although this has not been definitely proven to date. Halos themselves result from the reflection or refraction of sunlight by minute, aligned ice-crystals in high altitude clouds, most commonly of stratus type, and come in a variety of forms (cfr. [1]).

The idea that these moving ripples could be produced by sound waves from meteors was suggested only in 1984 [2], and unfortunately, the phenomenon has not been observed since that date to allow further research in this matter.

Evidence for a meteoric origin for the ripples includes the near coincidence with reported sightings to meteor shower maxima (the four recorded instances occurred on August 9, 1944, July 20, 1949, July 20, 1971, and June 17, 1979) and the fact that the time intervals between ripples was in line with moderate to high meteor activity. Further information on how the sound waves could be propagated and why the ripples are seen only in aircraft contrails can be found in [2].

One reason for the paucity of observations is undoubtedly the lack of suitably-placed contrails with respect to the Sun at the appropriate times. Contrails can also dissipate in a matter of minutes too, which further reduces the possibility of sightings. An additional problem is a lack of knowledgeable observers, but hopefully, that difficulty has now been partially eliminated by this present article.

Clearly, if this phenomenon is due to meteoric sound waves, observations become more likely if meteor activity is high, as we believe may occur for the Perseids on August 11 or 12, 1993. Therefore, I would urge all northern hemisphere observers to keep watch, particularly during the daylight morning hours when the Perseid radiant is at its highest in the sky, on these dates, looking for any sign of moving ripples crossing any halo effects which may be apparent.

Observations should include details on the halos seen, the cloud formations they occurred in, the date, time, and location of the sighting, what the ripples looked like, how frequent they were, and how fast they were moving—this latter preferably as an angular measurement in degrees per second. A photographic record would be immensely valuable, as there is no such record known at the present time, while a video recording would be even more important. Please send any positive sightings of the ripple effect to me (address on the inside back cover) as soon as possible after they have been made. This applies whether the effect was observed during this year's Perseid shower or not.

With a phenomenon so poorly known and under-observed, it is vital we should lose no opportunity to increase our understanding of it.

Meanwhile, we wish you success with your Perseid observations, whether during night-time or daylight!

References

[1] Greenler R.H., "Rainbows, Halos, Glories", Cambridge University Press, 1989.

[2] Archenhold G.H., *Quarterly Journal of the Royal Astronomical Society* 25, 1984, pp. 122–125.

Visual Observers' Notes: July–August 1993

Jeff Wood

1. Introduction

The period July–August is the most consistently rich period for meteor rates of the whole year. On a dark night an observer can expect to see over 20 meteors per hour for much of this time. During the last few days of July and around August 12 with the maxima of the major showers the δ-Aquarids and the Perseids, respectively, the total number of meteors exceeds 50 per hour and rates much higher than this are not uncommon at these times. The rediscovery of P/Swift-Tuttle last fall combined with the Perseid outburst recorded the last two years adds to the excitement surrounding this year's Perseid return. With all this activity around then, meteor workers are encouraged to get out and observe the many showers that occur. Table 1 lists the more important showers that occur during July and August.

Table 1 below lists some of the more important showers that occur during July and August. Table 2 as usual shows the observing conditions moon-wise.

Table 1 – A list of some of the meteor showers to be seen in July–August 1993.

Shower	Activity	Maximum		Radiant			Drift		V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	D.	$\Delta\alpha$	$\Delta\delta$			
Pegasids	Jul 07–Jul 11	Jul 09	107°7	340°	+15°	5°	+0°8	+0°2	70	3.0	8
Phoenicids (Jul)	Jun 24–Jul 18	Jul 15	112°7	21°	−43°	7°	+1°0	+0°2	47	3.0	
Piscis Austrinids	Jul 09–Aug 17	Jul 28	125°7	341°	−30°	5°	+1°0	+0°2	35	3.2	8
δ-Aquarids S	Jul 08–Aug 19	Jul 28	125°7	339°	−16°	5°	Table 3		41	3.2	20
α-Capricornids	Jul 03–Aug 25	Jul 29	126°7	307°	−10°	8°	Table 3		23	2.5	8
ι-Aquarids S	Jul 15–Aug 25	Aug 03	131°7	333°	−15°	5°	Table 3		34	2.9	3
δ-Aquarids N	Jul 15–Aug 25	Aug 12	139°7	337°	−05°	5°	Table 3		42	3.4	5
Perseids	Jul 17–Aug 24	Aug 12	139°9	46°	+58°	5°	Table 3		59	2.6	95
κ-Cygnids	Aug 03–Aug 31	Aug 18	145°7	286°	+59°	6°			25	3.0	5
ι-Aquarids N	Aug 11–Sep 20	Aug 20	147°7	327°	−06°	5°	Table 3		31	3.2	3
π-Eridanids	Aug 20–Sep 05	Aug 29	155°7	52°	−15°	6°	+0°8	+0°2	59	2.8	
α-Aurigids	Aug 24–Sep 05	Sep 01	158°6	84°	+42°	5°	+1°1	0°0	66	2.5	15
Piscids S	Aug 15–Oct 14	Sep 20	177°7	8°	00°	8°	+0°9	+0°2	26	3.0	3

Table 2 – Moonlight and observing conditions in July–August 1993.

Date	k	Date	k
Friday July 02	0.96+	Friday August 06	0.89−
Friday July 09	0.77−	Friday August 13	0.27−
Friday July 16	0.14−	Friday August 20	0.07+
Friday July 23	0.17+	Friday August 27	0.76+
Friday July 30	0.88+	Friday September 03	0.97−

New Moon:	June 20, July 19, August 17
First Quarter:	June 26, July 26, August 24
Full Moon:	July 3, August 2, September 1
Last Quarter:	July 11, August 10, September 9

2. Perseids

This shower is active from July 17 to August 24 and traditionally reaches a maximum ZHR of about 95 on August 12 or 13. Due to the Full Moon on August 2, observing conditions are not that favorable during the early part of August. However, by the time of the maximum, the Moon will have waned sufficiently so that dark-sky observations can be made during late evening and early morning hours. As the radiant has a high declination, the Perseids are best studied from the northern hemisphere.

In 1992, the Perseids had an outburst with several hundreds of meteors per hour witnessed in Asia and Eastern Europe. Shortly thereafter, Comet P/Swift-Tuttle was finally rediscovered. The year 1992 was the second of two consecutive years in which an outburst was seen. (The double maximum was first registered in 1988 after which it became ever more obvious.) A detailed account of the 1992 outburst can be found in [1].

The prospects for a third consecutive outburst are good, to say the least [2]. In many respects, the Perseid events in the period 1991–1993 are more or less a repetition of what happened in 1861–1863 at the previous return of P/Swift-Tuttle. However, the circumstances are better now: the orbital distance between P/Swift-Tuttle and the Earth is now merely 0.001 AU (compared to 0.005 AU in 1863) and at the maximum we will be 8 months after the comet's perihelion passage (compared to 12 months in 1863). So, if the Perseids are ever to show something spectacular, it has to be now!

The article by Joe Rao in this issue offers a very comprehensive outlook on what can be expected from the 1993 Perseids.

Needless to say, the 1993 Perseids provide a unique opportunity to gather valuable information on the best known meteor shower as well as a rare occasion for our Organization to reach the general public. Therefore, please mind the following guidelines:

1 Of course, the usual *IMO* observing method ceases to be applicable when an outburst with several hundreds of meteors per hour occurs. Following the observers' notes is an article by Ralf Koschack and Robert Hawkes precisely describing what to do under these exceptional circumstances. Please read this article attentively!

2 After the 1992 Perseid outburst, it took the *IMO* a considerable time to compile a general picture of the shower's activity. If we do not want to miss this year's unique opportunity to gain visibility among the general public as well as the meteor community, it is important that the *IMO* staff is informed *immediately* about a possible outburst, as soon as such an event becomes imminent. In this way, it is possible to focus the attention of the international media on the event. During the morning after, we intend to prepare and distribute a first report on what happened.

   Following the article by Ralf Koschack and Robert Hawkes is a note by Paul Roggemans containing precise guidelines for the fast reporting of a possible outburst. Please also read this note attentively!

3 Finally, this issue has a leaflet enclosed with general information on the Perseids, their recent behavior, and the prospects for a 1993 outburst which you are free to use in raising awareness of the event for the general public and the press in your region of the world. Please help our—your—Organization by making publicity for this unique event and the *IMO*'s role in it!

3. Aquarids/Capricornids

This rather complex group of showers were subject to intense scrutiny during 1989 to 1991. Several thousand meteors were recorded. Nevertheless, more data on this still too poorly covered complex are still required. The visual observing program requires good observational experience and an observing site south of 45° N. Looking at Table 3, it is obvious that the observer has to look at a point between the radiants of the δ-Aquarids N and the ι-Aquarids S in order to distinguish between meteors of these southern showers. This will be quite impossible for observers situated north of 45° N. Observations of this program should start only when the radiants have reached a sufficient altitude. If possible, two observers should look at the same field simultaneously. This may allow estimates of the accuracy of the data. Only meteors possibly radiating from the Aquarius/Capricornus-region should be plotted. It is necessary to consider the direction, trail length and angular velocity. All other meteors are counted only. Any Aquarids or Capricornids appearing outside the map's field are also counted after they are associated with the radiants given in Table 3.

Table 3 – Radiant drifts for the α-Capricornids, the δ-Aquarids South and North, the ι-Aquarids South and North, and the Perseids.

Date	α-Cap		δ-Aqr S		δ-Aqr N		ι-Aqr S		ι-Aqr N		Per	
	α	δ	α	δ	α	δ	α	δ	α	δ	α	δ
Jul 05	290°	−14°	321°	−21°								
15	296°	−13°	329°	−19°	316°	−10°	311°	−18°			12°	+51°
25	303°	−11°	337°	−17°	323°	−09°	322°	−17°			23°	+54°
Aug 05	312°	−09°	345°	−14°	332°	−06°	334°	−15°			37°	+57°
15	318°	−06°	352°	−12°	339°	−04°	345°	−13°	322°	−07°	50°	+59°
25	324°	−04°			347°	−02°	355°	−11°	332°	−05°	65°	+60°
Sep 05									343°	−03°		
15									353°	−02°		

In doing so, we are able to calculate ZHRs based on the tabulated radiant positions, and to analyze the radiant position using the plotted meteor trails only. We want to draw attention to the relationship between the angular velocity of shower meteors, the altitude of their beginning point h_b and the distance D between their end point and their radiant. This criterion is as important as the alignment and the trail length and has to be used carefully when using the counting method. For your convenience, the relationship between these quantities is repeated in Table 6.

Your reports must include the following for each date:

1. copies of your *Atlas Brno* maps with the meteors plotted on them (X and Y coordinates should be measured with respect to the frame of the map), and
2. a report using the *IMO* Visual Observing Forms.

The shower association should be done at a desk using all criteria, including path length, position with respect to the radiant and angular velocity. For more details, we refer the reader to [3].

4. κ-Cygnids

This shower is active from August 3 through to August 31 and reaches a maximum ZHR of 5 on August 18. The radiant position of $\alpha = 286°$ and $\delta = +59°$ is virtually constant throughout the activity period due to its proximity to the North Ecliptic Pole. Its diameter is 6°. For the period August 15 to 25 observers north of latitude 45° N should concentrate on the κ-Cygnids. The κ-Cygnids are noted for their slow-moving often bright meteors. All possible shower members should be plotted. Observers should ensure that the center of their observing field is located at a distance less than 40° from the radiant.

5. July Phoenicids

The July Phoenicids are fairly fast, faint meteors which is probably the reason why they were first detected by radio techniques. Since this stream can only be observed from the southern hemisphere where it is winter, it has not been very well monitored to date. As the July Phoenicids are well placed for viewing moon-wise in 1993, southern hemisphere observers are therefore encouraged to make this a special project.

6. Piscis Austrinids

The Piscis Austrinids are active from July 9 to August 17 and reach a maximum ZHR of 5 to 10 meteors per hour on July 28. With the Full Moon occurring on August 2, observers can only obtain dark skies up until the maximum. Thus the *IMO* recommends that the period July 12-28 be monitored during 1993. Observers are encouraged to observe this shower as part of the Aquarid/Capricornids observations. They should plot all Piscis Austrinids occurring in the part of the sky covered by the map and count those appearing outside the map's field after careful consideration of path length and angular velocities.

Table 4 – Radiant positions of the Piscis Austrinids.

Date	α	δ	Date	α	δ	Date	α	δ
Jul 13	326°	−33°	Jul 28	341°	−30°	Aug 12	356°	−27°
Jul 18	331°	−32°	Aug 02	346°	−29°	Aug 17	1°	−26°
Jul 23	336°	−31°	Aug 07	351°	−28°			

7. π-Eridanids

The π-Eridanids radiate out from the "Loop of Eridanus" during the latter part of August and early September. They reach maximum on August 29. Observations to date indicate that activity varies from year to year. At best they produce ZHRs of around 10, at worst they are almost non-existent. The π-Eridanids are fast meteors and they frequently produce trains. Observers should watch for these meteors in the pre-dawn hours when the radiant is high in the sky and the gibbous Moon has set. They are best seen in the southern hemisphere. All π-Eridanids should be plotted.

Table 5 – Radiant positions of the π-Eridanids.

Date	α	δ
Aug 20	46°	−17°
Aug 28	52°	−15°
Sep 05	60°	−13°

References

[1] P. Brown, M. Gyssens, J. Rendtel, "New Outburst Announces Return of P/Swift-Tuttle", *WGN* 20:5, October 1992, pp. 192–197.

[2] P. Roggemans, "The Perseids: Prospects for the 1993 Return", *WGN* 20:5, October 1992, pp. 205–206.

[3] R. Koschack, J. Rendtel, "Aquarid Project 1989", *WGN* 17:3, June 1989, pp. 90–92.

Table 6 – Angular velocity (°/s) as a function of the altitude of the meteor's beginning point h_b and the distance D between the end point and the radiant for various values of a stream's geocentric velocity V_∞. H_b is the altitude of the meteor's beginning point above the Earth's surface.

	$V_\infty = 20$ km/s, $H_b = 100$ km					$V_\infty = 25$ km/s, $H_b = 100$ km				
	$h_b = 10°$	20°	40°	60°	90°	10°	20°	40°	60°	90°
$D = 5°$	0.2	0.3	0.6	0.9	1.0	0.2	0.4	0.8	1.1	1.3
10°	0.3	0.7	1.3	1.7	2.0	0.4	0.9	1.6	2.2	2.5
20°	0.7	1.3	2.5	3.4	3.9	0.9	1.7	3.2	4.3	4.9
40°	1.3	2.5	4.7	6.3	7.3	1.6	3.2	5.9	8.0	9.3
60°	1.7	3.4	6.3	8.5	9.8	2.2	4.3	8.0	11	13
90°	2.0	3.9	7.3	9.8	11	2.5	4.9	9.3	13	14
	$V_\infty = 30$ km/s, $H_b = 100$ km					$V_\infty = 35$ km/s, $H_b = 100$ km				
	$h_b = 10°$	20°	40°	60°	90°	10°	20°	40°	60°	90°
$D = 5°$	0.3	0.5	1.0	1.4	1.6	0.3	0.6	1.1	1.5	1.7
10°	0.5	1.1	2.0	2.7	3.1	0.6	1.2	2.2	3.0	3.4
20°	1.1	2.1	4.0	5.3	6.2	1.2	2.3	4.3	5.8	6.7
40°	2.0	4.0	7.4	10	12	2.2	4.3	8.2	11	13
60°	2.7	5.3	10	14	16	3.0	5.8	11	15	17
90°	3.1	6.2	12	16	18	3.4	6.7	13	17	20
	$V_\infty = 40$ km/s, $H_b = 100$ km					$V_\infty = 50$ km/s, $H_b = 110$ km				
	$h_b = 10°$	20°	40°	60°	90°	10°	20°	40°	60°	90°
$D = 5°$	0.3	0.7	1.3	1.7	2.0	0.4	0.8	1.5	2.0	2.3
10°	0.7	1.4	2.6	3.5	4.0	0.8	1.6	2.9	3.9	4.6
20°	1.4	2.7	5.0	6.8	7.9	1.6	3.1	5.8	7.8	9.0
40°	2.6	5.0	9.5	13	15	2.9	5.8	11	15	17
60°	3.5	6.8	13	17	20	3.9	7.8	15	20	23
90°	4.0	7.9	15	20	23	4.6	9.0	17	23	26
	$V_\infty = 60$ km/s, $H_b = 115$ km					$V_\infty = 66$ km/s, $H_b = 115$ km				
	$h_b = 10°$	20°	40°	60°	90°	10°	20°	40°	60°	90°
$D = 5°$	0.5	0.9	1.7	2.3	2.6	0.5	1.0	1.9	2.5	2.9
10°	0.9	1.8	3.4	4.5	5.2	1.0	2.0	3.7	5.0	5.8
20°	1.8	3.5	6.7	9.0	10	2.0	3.9	7.3	10	11
40°	3.7	6.7	13	17	20	3.7	7.3	14	18	21
60°	4.6	9.0	17	23	26	5.0	10	18	25	29
90°	5.3	10	20	26	30	5.8	11	21	29	33

	$V_\infty = 70$ km/s, $H_b = 126$ km				
	$h_b = 10°$	20°	40°	60°	90°
$D = 5°$	0.5	0.9	1.8	2.4	2.8
10°	1.0	1.9	3.6	4.8	5.5
20°	1.9	3.7	7.0	9.4	11
40°	3.6	7.0	13	18	21
60°	4.8	9.4	18	24	28
90°	5.5	11	21	28	32

Telescopic Observers' Notes, July–August 1993

Malcolm J. Currie

1. Perseids

The long-awaited return of P/Swift-Tuttle last year and the recent bursts of high activity has fueled considerable interest in this year's *Perseid* shower. The hope is that the comet has laid down sufficient fresh meteoroids that will cause greatly enhanced rates. In the past we have been disappointed by such predictions, but certainly the omens are good. The "new" maximum seen in recent years, and which coincides with the burst seen in 1992, is timed to suit Europe, where the greatest density of observers lies. A crescent moon—four days before the new phase—rises around midnight on the night of maximum, but will cause minimal interference.

If remarkable rates do occur the spectacle will prove a compelling attraction to observe with the naked eye, but I hope there will be at least a few telescopic observers active. If we observe only the bright meteors we shall not know the effect the return of the comet has had on the numbers of low-mass particles. Telescopic coupled with video techniques can give an estimate of the flux of meteors below the naked-eye limit.

These techniques also give a chance to look at the radiant structure. Although visually there appears to be a simple symmetric radiant [1] these data exclude observations around the shower's maxima because rates are too high to plot paths. This is not the case for the telescopic method because the Perseids are not abundant in faint meteors. (The fact that we can see significant numbers of telescopic Perseids at all is due the overall strength of the shower.) Indications of secondary radiants have been claimed around the time of peak activity, and include telescopic data [2]. It would be fascinating to see if these claims are justified, or even if a new sub-radiant is located. If any are detected we could look for any correlation with maxima in the visual rates.

Observations should begin from August 10 and made until August 16. For this project, small binoculars are best. Choose field centers about 10°–15° from the Perseid radiant, to reduce the angular speed of the meteors, and therefore making them more visible, but so close as to encroach on the moving radiant. Orient the fields to delineate the radiant, for example arranged in an equilateral triangle around the radiant. Alternatively, charts can be obtained from me, as can the new report sheets. Please state your typical field limiting magnitude and the instrument you intend to use so I can select the charts most suitable.

Whatever the outcome of the 1993 Perseids I am sure we shall learn more of this popular showers.

2. Other showers

Moving back to July the *α-Lyrid* shower is something of an enigma. At its discovery in 1958 and twenty-odd years ago this was easily the most prolific shower of the year—some two to three times the best telescopic showers of today. On a visual scale it would have been the equivalent of a ZHR around 150. In 1989 and 1990 it was more like a weak minor shower. As to whether this change is a permanent decline or is due to a concentration of particles in the stream, only regular monitoring can tell. The meteors are fast, so again select centers 10°–15° from the radiant at $\alpha = 281°$ and $\delta = +44\overset{\circ}{.}5$. The activity period is approximately July 12–20. At the same time it is possible to record *o-Draconid* meteors.

Every year there is always a chance to record activity from the dense area of radiants that is the *Aquarid-Capricornid complex*. Most favored this year is the third week of July—a time when we do not have many observations. Observers should take especial care to plot the meteor paths as carefully as possible, and to use at least three field centers separated by 25°–30°, around $\alpha = 230°–20°$ and $\delta = +10°$. The southerly declinations favors those in Australia and South America. For northern observers you should be south of 45° N, though *BAA* data show that it is possible to collect useful data even as far north as England.

After the Perseids come the *κ-Cygnids*. Famed for their slow, bright fireballs, this shower does have moderate telescopic activity. It is one of several possible weak centers in Cygnus and neighboring constellations during July and August that are apparent in recent telescopic analyses. Only if we see them during more than one year can we be confident of their reality. You can use the same field centers as for the Aquarids.

References

[1] R. Arlt, R. Koschack, J. Rendtel, "Results of the IMO Aquarid Project", *WGN* 20:3, June 1992, pp. 118–119.

[2] M. Vints, "A New Telescopic Perseid Subradiant?", *WGN* 16:5, October 1988, p. 171.

Observations During Exceptionally High Activity

Ralf Koschack, and Robert Hawkes, Mt. Allison University

1. Introduction

During the analysis of the reports on the Perseid outbursts in 1991 and 1992, it has become obvious that the *IMO* standard observing method is not adequate if the activity (i.e., the visible meteor rate) is extraordinarily high. Instructions for observing under such exceptional circumstances have hitherto not been published. The instructions below are the result of a discussion conducted by correspondence and at the 1992 *IMC* in Slovakia. The experiences gained with the analysis of the 1991 and 1992 Perseid outbursts were taken into account.

As the prospects for an outburst during the 1993 Perseid maximum during the night of August 11–12 are good, all observers are urged to read the instructions below very carefully and to carry out their observations accordingly in order to obtain results that will allow a meaningful analysis. (Ed.)

2. Visual observations

With increasing meteor frequency, the general problem which arises is that the time available for recording the data of a meteor is reduced. Therefore, the more meteors that appear the more you should restrict yourself to recording the most important data only. The most important information about a meteor is its brightness. For very high activity, shower association is not that important as only a very small fraction of the meteors will not belong to the shower. To keep recording time to an absolute minimum you should just record the magnitudes (estimated only to the whole magnitude) on tape. If a meteor is obviously sporadic, then add this information; all other magnitudes are assumed to belong to shower meteors. Do not forget to put sufficient time stamps in your recording. With very high activity, record the time every 5 to 10 minutes.

It is extremely important to have the magnitude for each meteor recorded. Plain counting without estimating the magnitudes is almost completely useless for analysis purposes [1].

As activity becomes unusually high, first start the photographic program as outlined in the next section. Since visual observations become uncertain for very high activity, the photographic program has priority.

If you feel that it is becoming impossible to record all meteors seen along with their magnitude, record only those of +4 and brighter with their magnitude. The fainter meteors should simply be left out. If even this becomes impossible restrict yourself to +2 or brighter or even to magnitude 0 or brighter. When activity decreases again, proceed in the opposite direction. Whenever you switch to another magnitude threshold, you must insert a time stamp in your recording with a remark such as "brighter than +4."

If the limiting magnitude is better than approximately +5.0, and if you are also carrying out photographic observations as outlined in the following section, you can stop your visual observation at the point when it becomes impossible to record all meteors of magnitude +4 or brighter along with their magnitude. You should fully concentrate on the photographic program and enjoy the show. Just record the appearance of bright fireballs and try to estimate the time of maximum activity. For limiting magnitudes worse than approximately +5.0, this change in procedure is recommended as soon as you have to switch to only recording meteors of magnitude 0 or brighter.

Soon after the event you should report the complete record of the observation (i.e., the meteor list with time stamps, begin, end, breaks, and information about clouds and limiting magnitude) to the *VMDB* responsible. Also enclose a short report including the estimated time of the maximum, remarkable events such as bright fireballs, special circumstances, remarkable properties of the meteors (e.g., persistent trains). This procedure of reporting the complete record of the observation should be used whenever the activity gets extraordinarily high (ZHR greater than about 200).

3. Photographic observations

The visual observing technique has the advantage of allowing the analysis of meteors down to magnitude +5 or +6. Thanks to the size of the sample obtained, i.e., the rather large number of meteors on which an analysis can be based, visual observing yields accurate results despite its subjective character. Photography is a more objective technique, but suffers from its poor limiting magnitude for meteors, which is +1–+2, and its restricted field of view. Even during a "normal" maximum of a major shower only 1–2 meteors per hour can be caught by one camera. Such a sample is far too small to analyze rates and magnitude distributions.

For very high activity, however, this restriction no longer holds. On a 3-minute exposure taken during the great Leonid storm in 1966, for instance, some 40 meteors appear! Moreover, visual results become increasingly uncertain with increasing activity. Hence photography is clearly favored for the monitoring of very high activity. An analyzing procedure for photographic observations is under preparation and will be published in *WGN*.

Generally, you can use any camera with any film and point the camera in any direction feasible from your observing site. In the following paragraphs the most favorable parameters are given. The closer you follow the instructions below the more accurate the results obtained from your observation will become. Therefore, you should prepare your observation in accordance with these instructions if very high activity is predicted. For unexpected meteor storms, however, you have to use the equipment you have at hand even if it is not the optimum. In order to be prepared for unexpected outbursts you should carry a camera with you whenever you go outside for observing.

Camera

For our purpose, 35-mm cameras or medium-format cameras (6×6 cm, 6×9 cm) are the best. If you can use only one camera the standard lens of $f \approx 50$ mm for 35-mm cameras or of $f \approx 80$ mm for medium-format cameras is optimal. In order to improve the quality of the image the speed of the lens should be restricted to $f/2$–$f/2.8$.

If two cameras are available, the second one should be used in connection with a wide-angle lens, preferably a fish-eye lens.

The photographs taken with the first camera are used to determine hourly rates and magnitude distribution, for which a relatively small field and a good limiting magnitude for meteors are desirable. This is the most important information. The second camera provides information about the appearance of fireballs. Here the field of the second camera needs to be as large as possible.

Since the short exposure times must be recorded exactly, and you want to have enough time to enjoy the show or to carry out visual observations, it is suggested that only two cameras be used as mentioned above. Four cameras operated with long exposure times cannot provide information as valuable as the information obtained from two cameras operated with short exposure times.

Film

Clearly, black-and-white negative films of 400–3200 ASA are appropriate. Color films are nearly useless for scientific analysis.

Exposure times

Begin and end of each exposure have to be recorded with an accuracy of ± 1 s. The optimum exposure time depends on the activity and should range between 10 minutes when the activity is not that high to about 2 minutes for an extraordinary meteor storm. Try to avoid having to change the film while at the same time keeping the exposure times as short as possible.

Direction of the camera field

In azimuth, the wide-angle camera should be pointed in a direction opposite the direction of the radiant. The lower edge of the field should be $10°$–$20°$ above the horizon. A fish-eye camera should be pointed to the zenith, of course.

The camera with a standard lens is pointed towards the same azimuth. The optimal elevation of the field center depends on the radiant elevation and is given in Table 1.

Table 1 – Optimum elevation of the field center (camera with standard lens) depending on the radiant elevation.

Radiant elevation	Field center elevation
0°	90°
20°	80°
40°	70°
60°	60°
90°	45°

The analyzing procedure requires the photographic limiting magnitude for the shower meteors to be constant over the camera field. Since the photographic limiting magnitude depends on the angular speed of the shower meteors, the latter must vary as little as possible across the camera field. This requirement yields the optimal elevations listed in Table 1.

Reporting the results

The analysis of the photographs will be carried out by an *IMO* responsible who is specialized in this field since the procedure is difficult to deal with. As it is not practicable to mail the negatives, you are asked to make high-quality paper prints of the format 13×18 cm or larger. Ensure that the whole area of the negative is on the print.

For each photograph, you should report the following:

- date;
- start and end of the exposure in UT;
- approximate field center in right ascension and declination;
- observing site (geographic coordinates as accurately as possible);
- observer;
- focal length and effective speed of the lens;
- format of the negative; and
- film, process, effective sensitivity.

Send the paper prints to the *VMDB* responsible as soon as possible.

Use of a video camera

If you have access to a video camera, you are encouraged to use it. Although normal color camcorders are limited to about magnitude +2, the precise timing and the possibility for frame-by-frame analyses compensate for sensitivity limitations. Better sensitivities can be obtained with special high sensitivity monochrome video cameras, or with image-intensified video cameras.

Use the largest aperture possible with your video camera lens. If it is a zoom lens, you will want to adjust for a fairly wide angle. Once you have selected a "zoom" setting, do not change it during the course of the observations. Set the focus to "manual" at infinity, as some types of automatic focus mechanisms will not operate properly when aimed at an almost black sky. For most purposes you will not want to use the electronic shutter available on CCD video cameras since the sensitivity will be further decreased. Some observers may, however, want to use this feature to specifically look for wake—in this case be sure to note the electronic shutter speed used (e.g., 1/1000 s).

Turn the time display to "on" and set it to the finest time increment possible. Synchronize your clock time to a standard time signal. If no video time signal is possible with your camera, briefly blank the picture (by covering the lens) at several recorded times. Recording a short wave radio time signal on the audio track of the video recording offers another timing option (or more simply, using a microphone to place time markers on the audio track according to the time indicated on an accurate and calibrated clock).

Use high quality video tape, and in most cases it is preferable to use the highest recording tape speed possible (e.g., SP in VHS, Beta I or II).

Unless a clock-driven equatorial mount is available, use a firm tripod with a fixed direction. Select an observing direction in the same way as suggested above for photographic work, but adjust it as necessary to make sure that a minimum of 3 stars are visible in your field of view.

It will assist with photometric corrections if, at the beginning or ending of your observing period, you record several minutes with the same camera settings but with the camera skewed at angular rates roughly corresponding to that of the expected shower. Note the identification of the stars used in the test.

Immediately after the observations, make a copy of the video tape. It is acceptable (perhaps even preferable) to make this copy on a slow tape speed (e.g., SLP in VHS or Beta III), since frame-by-frame advance is better on most machines with slow tape speeds. In making the copy of your tape use the "video in" and "video out" connectors, rather than the RF modulated signal. Be sure to use shielded cables intended for video work in making the copy.

Carefully review the tape at least once (preferably twice) to make a listing of all meteor occurrences. This will make it easy for others to complete the analysis of your observations. For each meteor note the following:

- date and time (UT) to the nearest second;
- position of the meteor on the screen;
- apparent direction of motion;
- approximate apparent angular speed; and
- approximate apparent luminosity, in magnitudes.

Send this information and a copy of the tape to the *VMDB* responsible as soon as possible.

The current VMDB responsible is Rainer Arlt. His address is on the inside back cover. Notice the change in postal codes in Germany! (Ed.)

Reference

[1] Koschack R., "Determination of the Flux Density for High Activity up to Meteor Storms Basing on Visual Observations", in *Proceedings of the 1992 International Meteor Conference*, to appear.

The IMO on Alert for the 1993 Perseids!

Paul Roggemans

1. General information

It is impossible to predict a meteor storm and it is very rare to observe one in a human lifespan. Notwithstanding, our current knowledge of the Perseids and their parent comet indicates that something spectacular might happen on the night of August 11-12, visible mainly over Europe. The possibility of a meteor storm poses a major dilemma. On the one hand one can take a "wait and see" attitude, risking that a major storm occurs with millions of potential watchers asleep. On the other hand, one can make a lot of fuss and involve the media at the risk of making a fool of oneself if nothing happens. For instance, astronomers were blamed for announcing a Leonid storm in 1899 which did not occur. This blame might have been avoided if the orbital configuration of the Earth and comet had been known better. After examining the literature to figure out the probability of a very remarkable Perseid return materializing in 1993, I have concluded that it seems almost certain we are going to cross a dense belt of fresh cometary particles. In view of what we know, it would actually be more surprising if just normal rates occurred than if we become witness to rates of several hundreds of meteors per hour or even storm conditions: the Earth will indeed almost intersect P/Swift-Tuttle's orbit, closely behind the comet.

With the "wait and see" option we have nothing to lose, but also nothing to gain. If on the other hand we take the initiative and involve the media we may be able to generate much positive publicity for meteor work; if moreover we carefully point out that we cannot fully guarantee a burst of Perseid activity, nobody can blame us later for having predicted with absolute certainty that a "rain of shooting stars" will occur. Taking into account this consideration, the *IMO* will undertake the following steps:

A press release will be sent to the main press agencies and international TV networks, to direct their attention to the possibility of exceptional Perseid activity. We cannot write to all local press agencies, observatories, or societies, however. You can play a vital part in this by informing your local media. If you as an *IMO* member do inform your local press, we urge you to be careful in your wording: please emphasize that nobody can predict a meteor storm with certainty in advance, but that there are nevertheless fairly good indications something special may happen this time. Also be careful when converting UT to your local time. You may refer to the *IMO*, but then use only information endorsed by the *IMO*. For your convenience, we enclose in this issue a document you are welcome to use as the basis for a press release. Below, we list the relevant articles in *WGN* that you can use to document your articles or statements:

- *WGN* 19:5: pp. 181–184;
- *WGN* 20:2: pp. 57–59;
- *WGN* 20:5: pp. 192–197, p. 198, pp. 199–200, pp. 200–202, pp. 203–204, pp. 204–205, pp. 205–206;
- *WGN* 20:6: p. 238, pp. 238–240;
- *WGN* 21:1: pp. 13–18;
- *WGN* 21:3: pp. 110–120.

We even hope to obtain live coverage from one or two TV stations at one of our observing stations. Perhaps you will be able to follow the Perseid shower in progress on your TV!

A fast communication network has been set up with coordinating centers in France at Puimichel and Hove near Antwerp in Belgium. Most *IMO* officers will be out in the observing fields, and some will be on the move to escape from bad weather. Therefore we selected Puimichel, from where most observing projects in Southern France are coordinated, as a headquarters to collect observational reports at the very start of any unusual activity. We therefore ask all observing teams to phone Puimichel (+33-92 79 94 28) immediately when you see that activity is significantly above normal. Report briefly the following essential data:

- your name and location, and number of observers;
- activity level (e.g., 50 Perseids/10 minutes) and time in UT;
- tendency of the activity: increasing or decreasing;
- sky conditions: cloud percentage and limiting magnitude; and
- characteristics: abundance of bright or faint meteors, train phenomena, etc.

Each reporting should be kept short (1 to 2 minutes) in order to keep the lines free. As a back-up reporting site, in case you fail to reach Puimichel, call the Public Observatory Urania in Hove near Antwerp in Belgium at +32-3-455 07 32, where Marc Gyssens will set up a secondary data center. Based upon our own results in Southern France and the incoming phone calls in Puimichel, the *IMO* observing team in France (Peter Brown, Martin Beech, Marc de Lignie, Klaas Jobse, Paul Roggemans, and Yasuo Yabu) will decide whether or not to send out a warning to alert international news agencies. If the decision is positive, Puimichel will then contact Hove, where messages prepared for different scenarios will be ready. From there, the appropriate message will be sent to the international press and BBSs. We hope to arrange all this in a time lapse of 15 minutes or less after the first sign of special activity. *Therefore, it is important to communicate your first report as soon as significantly increased activity is apparent, and not to wait for a full-grown meteor storm!*

After these first minutes of intense communication on the verge of a possible meteor storm, we expect communication to calm down as everybody wants to watch the show! *Notice that you should* not *call Puimichel or Antwerp just to get an update on the latest situation!* If you cannot observe yourself, watch your TV news or listen to the radio. For the *IMO* it is very important to keep the lines in Puimichel and Hove available for important news on changes in activity and to be able to take proper action. *In particular, it goes without saying that under* no *circumstances should the phone numbers above be passed on to the general public!*

At the end of the observing night, our last task is to immediately compile a more complete report for the international media and astronomical institutes. *Therefore we ask you to report your preliminary results on the entire night* to one of the data centers. For this purpose, you can call to Antwerp all night and to Puimichel between 3^h30^m and 5^h UT. You can also send this report by e-mail to gyssens@wins.uia.ac.be. Be mindful, however, that e-mail messages will not be read before approximately 5^h30^m UT! At 5^h UT, communications will be collected and summarized by both data centers after which a first preliminary overview of August 11-12 will be prepared in Antwerp. *Therefore, make sure your report reaches us before* 5^h *UT!* After that time, there might be nobody present to answer the phone! Without complications, everybody will finally get to sleep at 7^h UT, after one of the longest and most exciting nights meteor-wise in history!

2. Call to all observing teams in Europe

Many observers and observing teams will anxiously count down to the evening of August 11-12. Clouds no doubt will make observers tense, so in case of overcast skies it may be appropriate to escape to a better site. Driving to an unknown observing area, however, can create problems, and therefore it would be very helpful if the groups who must escape from clouds could join neighboring teams. We would like to know where teams plan to observe, how they can be contacted, and if they can help teams on the run to escape from bad weather in their area. Especially for the big multiple-station project in Southern France, a scenario for emergency action on August 11-12 has been considered. Therefore, we need to know where we can put different groups of observers and equipment in special drop areas in France, Italy, Spain, or Switzerland in advance. Please do not wait until maximum, but provide Paul Roggemans with the necessary information immediately!

3. Call to observers in Southern France

On August 10, 1993, at 12^h UT, a meeting with all observing teams in Southern France will take place in Puimichel. You are welcome to attend this meeting to help facilitate coordination procedures and to fine-tune preparations for the night of August 11-12, and also to arrange any possible observer drop-offs in case of poor weather. Please inform us at least two days in advance if you also wish to take a lunch in Puimichel.

Figure 1 – At the 1990 *IMC* in Violau, from left to right: Paul Roggemans, José Trigo, Raúl Fernández, Miguel Camarasa, Mirjam Galičič, Korado Korlević, and Alan Pevec.

Progress in Meteor Science

Articles in this section have been formally refereed by at least one professional and one experienced, knowledgeable amateur meteor worker, and deal with global analyses of meteor data, methods for meteor observing and data reduction, observations with professional equipment, or theoretical studies.

The 1992 Quadrantid Meteor Shower

Jürgen Rendtel, Ralf Koschack and Rainer Arlt

For the first time, a complete activity profile of this meteor shower was obtained from visual observations during the 1992 *IMO* Quadrantid project. In total, 18 434 shower meteors were reported by 106 observers. The ZHR-peak (ZHR=145) occurred at $\lambda_\odot = 283^\circ.15$ (eq. 2000.0) and is very narrow. Its full width at half maximum is $\Delta\lambda_\odot = 0^\circ.6$, or 14 hours. The rate profile is slightly skewed toward its pre-maximum region. The population index r is low around the peak with $r \approx 2.1$ being the lowest value calculated. A systematic increase of r found during the maximum night is discussed. The highest number density of particles causing meteors of at least $+6.5$ was encountered at $\lambda_\odot = 283^\circ.15$ and was 380 particles per 10^9 km^3, which is higher than in the average Perseid shower, but about 30% lower than in a Geminid shower. Comparisons with observations in previous years are presented. No particular features are found for these returns of the shower. An activity profile for the period 1986–1992 is presented. There is some indication that higher than average peaks occurred during this period. This result could be related to the average orbital period of the Quadrantid meteoroids.

1. Introduction

The Quadrantid shower is generally difficult to observe. The activity shows a high but very narrow peak and although the northern winter nights are long, only the second half of the night can be used for effective observations as the radiant reaches its lowest point around 20^h local time. Both the narrow peak and the short period for which the shower can be watched from one site make it probable that one observer will miss the maximum. The often bad weather in early January adds to these unfavorable circumstances. For these reasons it is almost impossible to perform an analysis of this stream based on observational data from only one site or country and hence global cooperation is necessary. The 1992 return brought together several fortunate circumstances. The maximum occurred during the European morning hours and the weather conditions were atypically good for the Old Continent where most observers were active at that time. Japanese and North American observers completed the coverage. This resulted in the most successful Quadrantid watch ever analyzed by the *IMO*. In total, 106 observers reported 18 434 shower meteors seen in 739.36 man hours of effective observing time. The individual data will be published, as usual, in the respective volume of the *WGN* Report Series. We are grateful to the following observers who made this analysis possible with their observational efforts. We list the observer's name, *IMO*-code, number of Quadrantids and the effective observing time:

Rainer Arlt (**ARLRA**, 485, $39^h.94$), Kremena Baltova (**BALKR**, 6, $3^h.65$), David Batten (**BATDA**, 0, $2^h.70$), Luis R. Bellot (**BELLU**, 286, $12^h.74$), Ragnar Bödefeld (**BODRA**, 177, $2^h.16$), Grant Bonnel (**BONGR**, 91, $3^h.00$), Peter Brown (**BROPE**, 94, $5^h.35$), Óscar Cervera García (**CEROS**, 289, $5^h.04$), Jiang Chang-gui (**CHAJI**, 101, $2^h.62$), Yang Chunping (**CHUYA**, 80, $2^h.50$), Peter Dalakov (**DALPE**, 167, $10^h.97$), Vincent Devore (**DEVVI**, 55, $3^h.06$), José V. Díaz Martinez (**DIAJO**, 190, $3^h.54$), Aaron Doherty (**DOHAA**, 40, $2^h.97$), Kathrin Düber (**DUBKA**, 91, $2^h.48$), Krisztián Édes (**EDEKR**, 392, $8^h.45$), Roland Egger (**EGGRO**, 15, $7^h.87$), Ján Fabricius (**FABJA**, 152, $4^h.61$), Andrea Friebel (**FRIAN**, 180, $8^h.61$), Keiiti Fukui (**FUKKE**, 41, $4^h.92$), Michael Funke (**FUNMI**, 40, $1^h.24$), Kai Gaarder (**GAAKA**, 90, $2^h.61$), John Gallagher (**GALJO**, 1, $7^h.00$), Ivanka Getsova (**GETIV**, 127, $9^h.40$), Valentin Grigore (**GRIVA**, 10, $3^h.00$), Gabi Koschny (**HADGA**, 284, $9^h.68$), Jung Han-Sub (**HANJU**, 23, $3^h.32$), Werner Hasubick (**HASWE**, 63, $1^h.11$), Dóra Havassy (**HAVDO**, 360, $6^h.00$), Roberto Haver (**HAVRO**, 49, $2^h.00$), Lars T. Heen (**HEELA**, 53, $1^h.57$), Trond E. Hillestad (**HILTR**, 1025, $11^h.52$), Heinrich P. Himmelbauer (**HIMHE**, 64, $3^h.17$), Daiyu Ito (**ITODA**, 57, $2^h.55$), Klaus Jandl (**JANKL**, 133, $3^h.00$), Anne Jokinen (**JOKAN**, 88, $4^h.25$), Stanislav Kaniansky (**KANST**, 148, $4^h.61$), Junji Kawamura (**KAWJU**, 51, $4^h.31$), Ákos Kereszturi (**KERAK**, 532, $8^h.45$), Timo Kinnunen

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WGN, the Journal of the International Meteor Organization, Vol. 21, No. 3, June 1993, pp. 97–109.

(KINTI, 146, $4^h.73$), André Knöfel (KNOAN, 178, $6^h.11$), Bernhard Koch (KOCBE, 505, $39^h.45$), Bernd Koch (KOCBR, 72, $1^h.28$), Detlef Koschny (KOSDE, 436, $12^h.15$), Kazimierz Kosz (KOSKA, 33, $1^h.87$), Ralf Koschack (KOSRA, 1287, $44^h.70$), Norbert Kremminger (KRENO, 90, $3^h.75$), Gotfred M. Kristensen (KRIGO, 17, $2^h.08$), Gyöngyvér Kudor (KUDGY, 379, $8^h.45$), Robert Lunsford (LUNRO, 59, $3^h.25$), Jörgen Mad (MADJO, 126, $4^h.58$), Veikko Mäkelä (MAKVE, 58, $3^h.68$), Katuhiko Mameta (MAMKA, 56, $3^h.19$), Krasimir Manov (MANKR, 163, $9^h.44$), Antonio F. Marin (MARAT, 79, $2^h.44$), Manel Marin (MARMN, 222, $3^h.20$), Alastair McBeath (MCBAL, 289, $9^h.50$), Sirko Molau (MOLSI, 130, $2^h.27$), Sandra Niedermair (NIESA, 219, $10^h.50$), Atanas Nikolov (NIKAT, 192, $7^h.79$), Markku Nissinen (NISMA, 1, $1^h.07$), Seiko Nishioka (NISSE, 40, $2^h.17$), Mirko Nitschke (NITMI, 104, $2^h.27$), Kazuhiro Osada (OSAKA, 14, $1^h.93$), Leo Rajala (RAJLE, 189, $7^h.62$), Pia Rämä (RAMPI, 107, $3^h.29$), Thomas Rattei (RATTH, 132, $2^h.82$), Ina Rendtel (RENIN, 787, $51^h.19$), Jürgen Rendtel (RENJU, 592, $53^h.83$), Paul Roggemans (ROGPA, 506, $47^h.59$), Tuomo Roine (ROITU, 82, $2^h.42$), Antonio Román (ROMAN, 263, $5^h.52$), Holger Sack (SACHO, 50, $1^h.63$), Toru Sagayama (SAGTO, 9, $5^h.63$), Kotaro Sakuma (SAKKO, 26, $2^h.58$), Krisztián Sárneczky (SARKR, 494, $8^h.45$), Hiromi Sato (SATHI, 29, $1^h.03$), Koetu Sato (SATKO, 1, $1^h.98$), Tatuo Sato (SATTA, 18, $7^h.29$), Johannes Schnöller (SCHJH, 143, $3^h.45$), Takashi Sekiguchi (SEKTA, 206, $8^h.91$), Yasuo Shiba (SIBYA, 43, $1^h.33$), Tikara Simoda (SIMTI, 44, $1^h.67$), Hiroyuki Sioi (SIOHI, 109, $3^h.62$), Juraj Škvarka (SKVJU, 140, $4^h.66$), J.N. Smith (SMIJN, 101, $3^h.63$), Ulrich Sperberg (SPEUL, 103, $1^h.15$), Detlef Spötter (SPODE, 398, $14^h.44$), Siegfried Stapf (STASI, 434, $41^h.16$), Stefan Ströbele (STRST, 472, $22^h.89$), David Swann (SWADA, 5, $1^h.98$), Ouyang Tianjing (TIAOU, 12, $1^h.95$), Hiroyuki Tomioka (TOMHI, 61, $8^h.94$), Sebastia Torrell (TORSE, 270, $3^h.22$), Tuomas Törrönen (TORTU, 87, $3^h.00$), Josep M. Trigo Rodriguez (TRIJO, 537, $6^h.90$), Satosi Uehara (UEHSA, 66, $4^h.86$), Tadasi Usui (USUTA, 33, $2^h.83$), Yoshiaki Uyama (UYAYO, 64, $2^h.38$), Roger Venable (VENRO, 115, $3^h.28$), Roland Winkler (WINRO, 105, $7^h.83$), Nikolai Wünsche (WUNNI, 164, $5^h.18$), Yasuo Yabu (YABYA, 3, $1^h.53$), Liu Yunxing (YUNLI, 44, $3^h.94$), Peter Zimnikoval (ZIMPE, 142, $3^h.33$), Miroslav Znášik (ZNAMI, 223, $4^h.61$).

2. The population index profile

As shown in [1] and recent shower analyses [2,3] the population index r is the fundamental quantity required for detailed analyses. The method of determination of the r-profile has been described in [1] and very recently in [3]. First, all individual r-values have been computed from the magnitude distributions and finally the sliding average procedure including outlier rejection [3] has been applied to obtain a profile. The large quantity of data permitted the determination of the population index profile for the whole activity period of the shower. From $\lambda_\odot = 278°.0$ to $\lambda_\odot = 282°.7$ a sampling period of $3°.0$ width shifted by $1°.5$ was chosen. For the maximum period $282°.7 \leq \lambda_\odot \leq 283°.5$ a sampling period of $0°.06$ width shifted by $0°.03$ was possible, and for the post maximum period $283°.5 \leq \lambda_\odot \leq 287°.0$ the sampling period was $2°.0$ shifted by $1°.0$. The resulting profiles are shown in Figures 1 and 2 and in Table 1. The error bars correspond to the 68% confidence interval of the average.

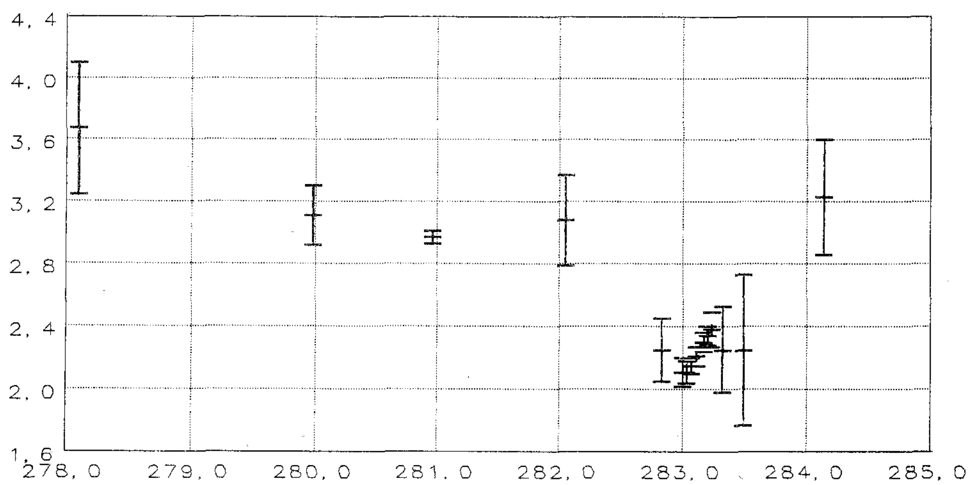

Figure 1 – Profile of the population index r for the 1992 Quadrantids. Solar longitudes are with respect to eq. 2000.0. Details for the night of the maximum are shown in Figure 2. Before and after the maximum the value of r does not differ from that of the sporadic background.

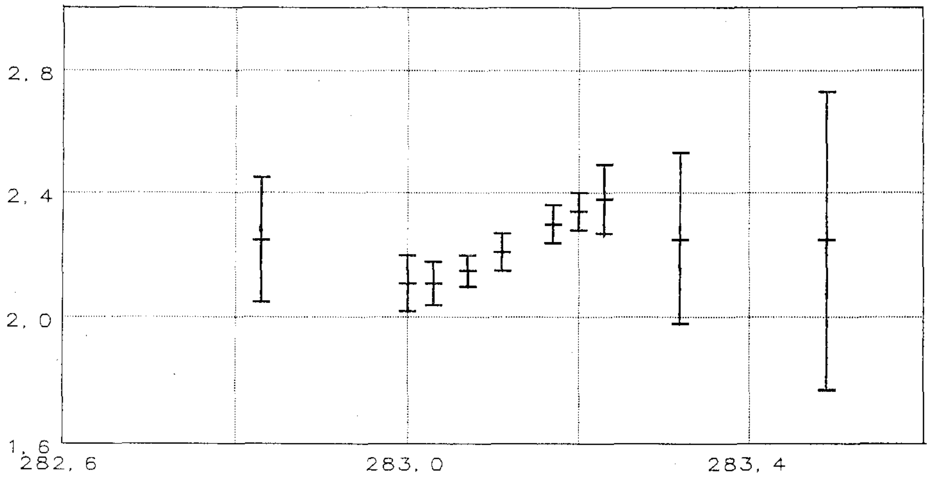

Figure 2 – Profile of the population index r around the activity maximum, showing a steady increase in activity within about 6 hours. This feature is discussed in the text.

Before and after maximum, the population index of the Quadrantids is comparable to that of the sporadic meteors. In the central part of the stream r drops to about 2.1. The population index values for the interval $283°0 \le \lambda_{\odot} \le 283°25$ are the most reliable as they are based on a very large quantity of data. During this period of only 6 hours, the value of r increases steadily from $r = 2.1$ to $r = 2.4$.

According to the r-profile shown in Figure 2 the minimum of r occurs around $\lambda_{\odot} = 283°0$, i.e., about 0°15 before the ZHR peak. Interpreting this feature, one has to bear in mind that the data in the interval $\lambda_{\odot} = 283°00$ to $\lambda_{\odot} = 283°25$ are based on European observations during the latter half of the night, in which the radiant rises from some 20° elevation to about 60°. It is possible that the observed increase in r is not caused by a real increase in the proportion of smaller particles, but is due instead to a dependence on entry angle of the transformation process of the particle's kinetic energy into radiation.

Table 1 – Profile of the population index r for the 1992 Quadrantids. It is derived from the magnitude distributions of the 75 observers who also sent magnitude data. Note the very small steps around the peak.

$\lambda_{\odot}$ (2000.0)	Date	r	Qua	$\overline{\mathrm{lm}}$
278°10	Dec 30	3.67 ± 0.43	44	7.33
279°98	Jan 01	3.11 ± 0.19	284	7.14
280°96	Jan 02	2.97 ± 0.04	389	7.18
282°05	Jan 04	3.08 ± 0.29	149	7.46
282°83	Jan 04	2.25 ± 0.20	110	6.20
283°00	Jan 04	2.11 ± 0.09	321	6.56
283°03	Jan 04	2.11 ± 0.07	1502	6.17
283°07	Jan 04	2.15 ± 0.05	4657	5.91
283°11	Jan 04	2.21 ± 0.06	4938	6.14
283°17	Jan 04	2.30 ± 0.06	3035	6.62
283°20	Jan 04	2.34 ± 0.06	2315	6.59
283°23	Jan 04	2.38 ± 0.11	927	6.53
283°32	Jan 04	2.25 ± 0.28	127	5.97
283°49	Jan 04	2.25 ± 0.48	99	5.96
284°14	Jan 05	3.23 ± 0.37	486	6.67

3. The ZHR profile

To begin, all individual ZHRs were computed for which the radiant elevation was greater than 20° and the total correction factor was less than 5. This correction factor is given by

$$C_{\mathrm{lm}} \times F \times C_z,$$

with C_{lm} the correction factor for limiting magnitude, F the correction factor for field obstruction, and C_z the zenith correction factor.

As explained in [3], the determination of perception coefficients for individual observers [4,1] requires intervals of relatively constant and high shower activity. For the Quadrantids such periods cannot be found. As long as the activity is constant, the rate is too low for a reliable determination of the perception coefficients. Approaching the maximum, the activity dramatically changes within very short time scales.

Experience from recent analyses show that the perception differences between individual observers are sometimes considerable and cannot be neglected. Therefore, we proceeded on the assumption that the perception characteristics of an observer do not change over a period of a few months. We applied the average limiting magnitude offsets Δlm for the observers determined from the analyses of the 1991 Geminids [3] and the 1991 Perseids (under preparation) for perception correction of the Quadrantid ZHRs.

Next, the ZHR profile was determined from the perception corrected individual ZHRs by application of the sliding average procedure including outlier rejection described in [3]. According to the available data and the variations of the ZHR the following sampling periods and shifts were chosen (Table 2).

Table 2 – Intervals chosen for the calculation of the ZHR-profile. The smallest resolvable structures are of the order of 0°05.

$\lambda_\odot$ (2000.0)	Width	Shift
277°5–282°5	1°0	1°0
282°5–283°4	0°1	0°05
283°4–285°0	0°5	0°25

The resulting ZHR profile is shown in Figures 3 and 4 and the values are listed in Table 3. The given error bars correspond to the 68% confidence interval of the average.

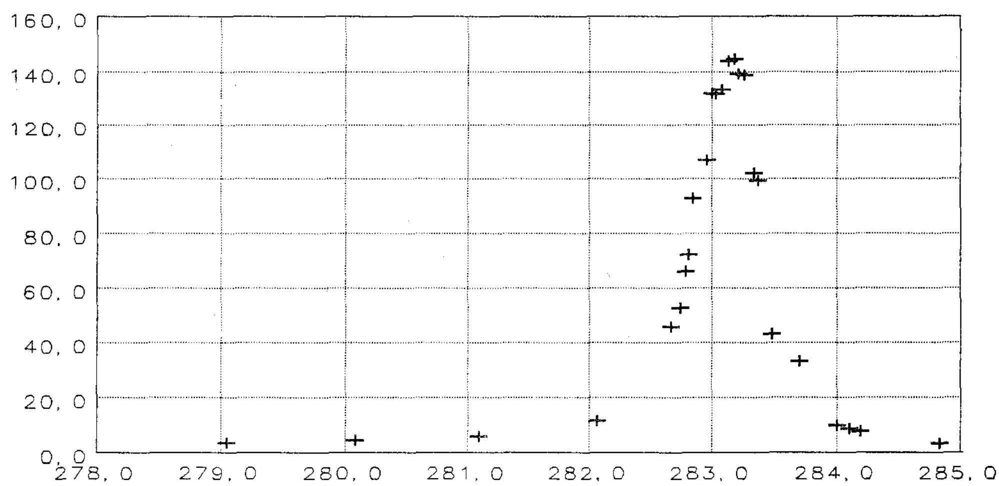

Figure 3 – ZHR profile of the 1992 Quadrantids derived from all selected observations for the entire activity period (eq. 2000.0).

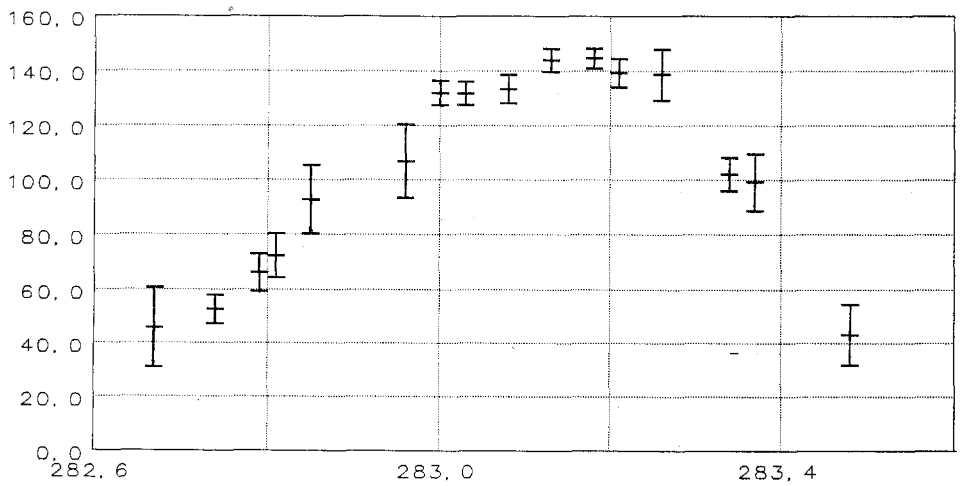

Figure 4 – ZHR profile of the 1992 Quadrantids around the activity maximum on January 4 UT. The peak period coincided with the European morning hours, and most observers were active from midnight to dawn. The observational material is therefore relatively homogeneous.

The maximum of ZHR=145 occurred at $\lambda_\odot = 283.°15$. This corresponds to 4^h UT on 4 January 1992. From $\lambda_\odot = 283.°0$ to $\lambda_\odot = 283.°25$ the ZHR varies little and exceeds a value of 130. The decrease after the maximum is steeper than the increase before the maximum. A similar feature was also recently described for the Geminid shower [3]. The peak is very narrow; its full width at half maximum (FWHM) is just $\Delta\lambda_\odot = 0.°6$, or 14 hours. As seen from Figure 3, the ZHR is of the order of the background activity roughly 14 hours before and after the peak (full width of the peak $\Delta\lambda_\odot = 1.°2$, or 28 hours). From radar data a FWHM of $\Delta\lambda_\odot = 0.°52 \pm 0.°07$ has been found [5].

4. Spatial number density profile

In [1], [2], and [3], it was explained in detail that the ZHR profile neither represents the profile of the spatial number density nor the flux density along the cross-section of the stream as it is affected by human perception properties. First, the spatial number density of particles causing meteors of magnitude at least +6.5 absolute magnitude was calculated according to the method described in [1]. The result is shown in Figures 5 and 6.

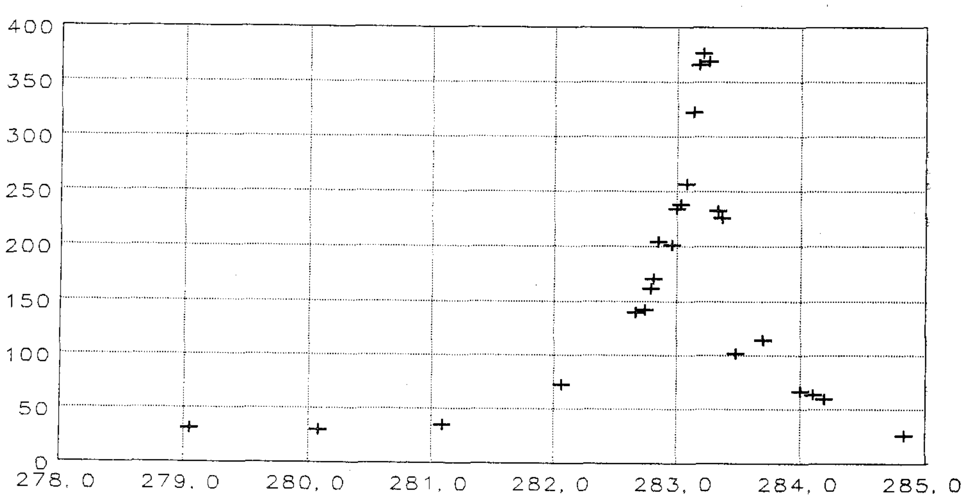

Figure 5 – Spatial number density of particles causing meteors of at least +6.5 absolute magnitude per 10^9 km^3 (eq. 2000.0). Since the population index r varies smoothly, the shape of the number density profile resembles the ZHR-profile very closely.

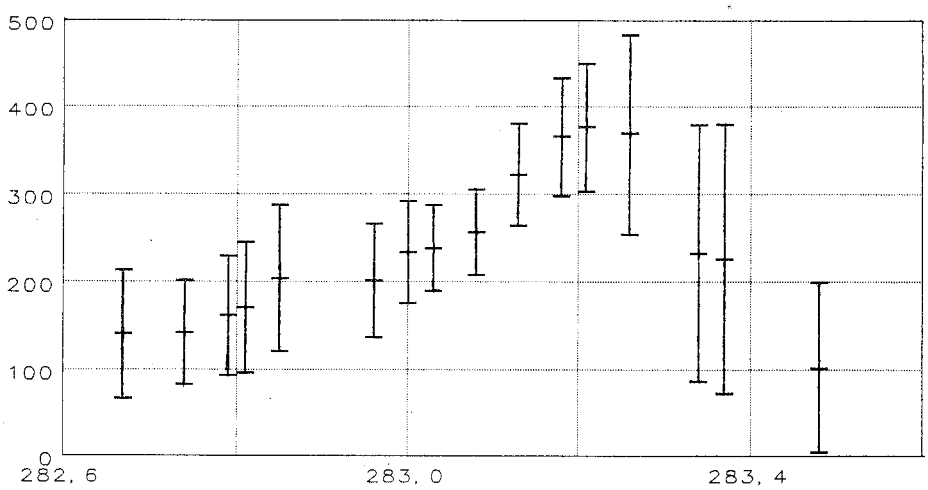

Figure 6 – Details of Figure 5 near maximum activity. This figure must be seen in connection with the respective r-profile and the detailed ZHR-curve for the same period.

The peak density of these particles was observed about 0°05 or 1^{h}2 *after* the ZHR maximum. However, this conclusion depends on the reality of the increase of r towards the morning (highest radiant position in Europe), which was discussed above. The peak density of smaller particles registered by radio techniques is reputed to occur several hours *before* the visual peak [6]. According to the relationship

$$m = 40 - 2.5 \log (2.732 \times 10^{10} M^{0.92} v^{3.91})$$

given in [7], the absolute magnitude $m = +6.5$ corresponds to a particle mass $M = 0.22$ mg for the Quadrantid meteoroids entering the Earth's atmosphere at $v = 41$ km/s.

To show the profile for larger particles, the spatial number density for particles causing meteors of at least $+0^m4$ absolute magnitude was computed (Figure 7). According to the equation given above, a meteor of +0.4 corresponds to a particle of mass 100 mg. Instead of a peak there is a plateau of nearly constant density from $\lambda_\odot = 283°0$ to $\lambda_\odot = 283°14$, showing that during the entire period the number density of this particle population was roughly constant. This is also consistent with radio observations of echoes longer than 8 s during the Quadrantids 1992, presented in graphical form by Šimek [8] at the 1992 *IMC* in Smolenice.

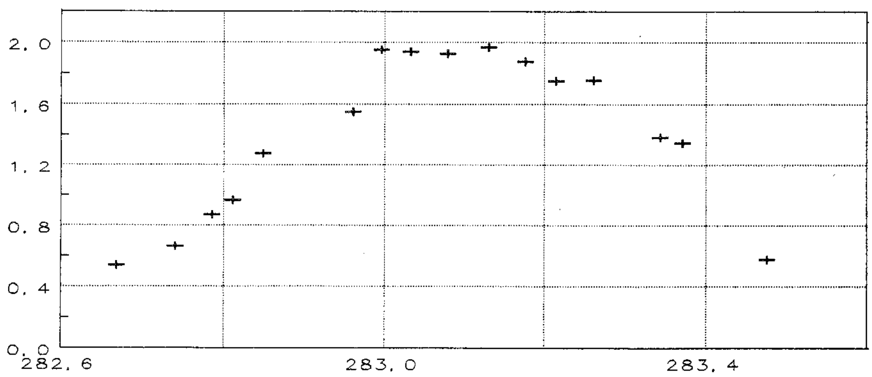

Figure 7 – Spatial number density of particles causing meteors of at least +0.4 absolute magnitude per 10^9 km^3 (eq. 2000.0). According to the equation cited in the text, the magnitude +0.4 for the Quadrantids corresponds to a particle mass of 100 mg.

Table 3 – Data calculated from the 1992 Quadrantid return: ZHR, population index r, mass index s, and number density of particles causing meteors of at least +6.5 ($\rho_{6.5}$) and at least +0.4 corresponding to about 100 mg ($\rho_{0.4}$). The figures $\rho_{6.5}$ and $\rho_{0.4}$ give the number of particles per 10^9 km^3.

$\lambda_\odot$ (2000.0)	r	s	Interv.	Qua	$\overline{\mathrm{lm}}$	ZHR	$\rho_{6.5}$	$\rho_{0.4}$
277.99	3.67 ± 0.43	2.30	8	29	6.68	4.0 ± 0.6	44.1 ± 16.4	6.1
279.05	3.39 ± 0.30	2.22	17	78	6.72	3.5 ± 0.8	31.0 ± 11.3	4.8
280.08	3.09 ± 0.17	2.13	19	108	6.77	4.4 ± 0.7	29.8 ± 8.1	5.4
281.09	2.98 ± 0.08	2.09	16	138	6.85	5.7 ± 0.7	34.6 ± 7.4	6.6
282.06	3.01 ± 0.28	2.10	31	385	6.69	11.5 ± 1.0	72.0 ± 23.1	13.5
282.67	2.43 ± 0.22	1.89	2	32	5.92	45.6 ± 14.9	139.8 ± 73.4	36.2
282.74	2.35 ± 0.21	1.85	6	87	6.07	52.5 ± 5.3	141.9 ± 59.2	38.7
282.79	2.29 ± 0.20	1.83	22	468	6.04	66.0 ± 6.9	161.3 ± 68.0	45.7
282.81	2.27 ± 0.20	1.82	23	568	5.97	72.2 ± 8.0	170.4 ± 74.2	49.0
282.85	2.23 ± 0.18	1.80	8	307	6.08	92.7 ± 12.6	203.6 ± 83.7	60.1
282.96	2.15 ± 0.12	1.76	10	313	6.07	106.8 ± 13.5	201.2 ± 64.6	62.8
283.00	2.12 ± 0.09	1.75	34	1133	5.97	131.9 ± 4.5	233.7 ± 58.2	74.5
283.03	2.13 ± 0.07	1.76	63	2736	6.11	131.7 ± 4.2	238.2 ± 49.2	75.4
283.08	2.16 ± 0.06	1.77	80	3978	6.14	133.3 ± 5.1	256.2 ± 48.3	79.4
283.13	2.24 ± 0.06	1.81	96	5893	6.23	143.9 ± 4.3	321.9 ± 58.2	94.4
283.18	2.31 ± 0.07	1.84	82	5921	6.43	144.5 ± 3.7	365.4 ± 67.6	102.2
283.21	2.35 ± 0.08	1.85	41	2788	6.45	139.2 ± 5.1	376.2 ± 73.5	102.5
283.26	2.34 ± 0.15	1.85	10	449	6.10	138.6 ± 9.4	368.5 ± 115.3	101.1
283.34	2.25 ± 0.31	1.81	4	149	6.11	102.0 ± 6.1	232.3 ± 145.8	67.6
283.37	2.25 ± 0.34	1.81	2	91	6.18	99.1 ± 10.4	225.7 ± 153.5	65.7
283.48	2.27 ± 0.46	1.82	6	110	6.00	43.0 ± 11.4	101.5 ± 97.1	29.2
283.70	2.51 ± 0.44	1.92	12	140	5.84	33.1 ± 5.9	114.1 ± 88.3	28.1
284.00	3.08 ± 0.39	2.12	21	137	6.40	9.9 ± 1.8	66.4 ± 30.5	12.0
284.10	3.18 ± 0.37	2.16	20	206	6.72	8.6 ± 1.4	63.4 ± 24.7	10.9
284.19	3.23 ± 0.37	2.17	5	87	6.95	7.7 ± 0.9	59.4 ± 20.5	10
284.83	3.23 ± 0.37	2.17	1	1	5.70	3.3 ± 0.0	25.5 ± 11.6	4.3

The different shapes and maximum times of the ZHR profile relative to the spatial number density profiles for different masses result from the variation of the population index r. As already discussed, the spatial number density profiles are only as reliable as the profile of the population index.

5. Comparison with previous returns

It has been contended that the Quadrantids have a variable time and strength of maximum activity from year to year. However, previous analyses as well as model calculations [6,9,10] were based on the data obtained by single observers or groups [11] or individual radar stations [12]. Also, general descriptions (e.g., [13]) refer to such data sets. Analyses of visual observations from only one site or country will certainly lead to this conclusion due to the circumstances described in the Introduction.

It is also possible that worldwide data will give poor information concerning the peak of the stream. Imagine, for example, a peak occurring at about 15^{h} UT, i.e., daylight in most parts of Europe. This corresponds to $10\text{–}11^{\mathrm{h}}$ local time (LT) on North America's East Coast to about 7^{h} LT on the West Coast so the peak will occur in daylight from there. For Japan this would correspond to approximately 23^{h} LT which is 3 hours after the radiant reaches its lowest point and when it is at about 15° elevation. For Asia and eastern Europe the period would also mark the time the radiant is at its lowest point. As a result, in this scenario only observers in Alaska and on Pacific Islands would see the maximum.

From this example and for all the reasons listed in the Introduction, it is therefore quite exceptional for the shower maximum to be monitorable from one particular place under acceptable circumstances. The largest observed rates of the shower will vary greatly from year to year depending on the part of the activity profile observable from a set location.

For streams without considerable variations in the activity profile it is possible to determine an average profile by superposing data from several years. But if the stream does vary in its activity profile from year to year, this method is hardly applicable.

To study the average variations it is necessary to obtain a complete profile per year. Generally, this is only possible by means of global cooperation amongst meteor observers. But even now with the *IMO* and the evolution it has known, it is very difficult to obtain a reliable and complete activity profile for the Quadrantids due to unfavorable circumstances. There will always be parts of the profile based on few observations.

For the analysis of variations of the activity profile, only the reliable parts of the profiles of the individual years should be used.

The *VMDB* contains valuable Quadrantid data for 1986, 1987, 1989, 1990, and 1992. These data were analyzed, using the procedure applied to the 1992 data. Only results which can be considered reliable are then compared amongst the different profiles.

6. Population index

Only for the 1992 return were there enough data to obtain a profile of the population index.

For the years before 1989, not a single value could be computed due to lack of data. In 1989 and 1990, mostly European observers reported magnitude distributions. For these years, it was possible to compute an average r-value for the European observing window. The result is shown in Table 4.

Table 4 – Population indices r computed from data of 1989 and 1990.

Year	$\lambda_\odot$ (2000.0)	r	Observers	Meteors
1989	282°83	2.23 ± 0.13	4	423
	283°58	2.13 ± 0.15	4	212
1990	283°28	2.41 ± 0.08	8	721

As can be seen in Figure 8, the values of 1989 and 1990 fit the 1992 profile very well. Therefore we suspect that the population index profile does not vary significantly from year to year. However, the amount of data for the years prior to 1992 is small, hence variations of the profile cannot be excluded. This also holds, of course, for longer-term variations.

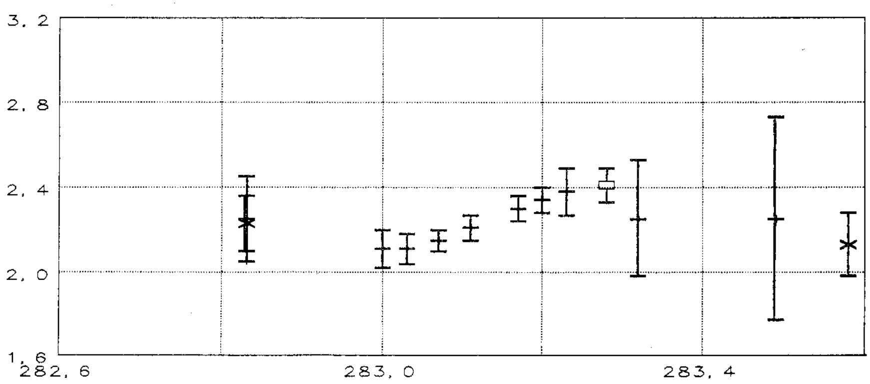

Figure 8 – Values of the population index r obtained from data of different years (crosses for 1989, squares for 1990, and pluses for 1992).

7. ZHR profile

To avoid systematic errors introduced by large and uncertain correction factors, only ZHRs corresponding to a radiant elevation greater than 20° and a limiting magnitude better than 5.0 were computed.

The ZHR profile was computed without perception correction by applying the sliding average procedure [3] including outlier rejection. The sampling period was 0.°2 shifted by 0.°1. The profiles of the individual years are shown in Figures 9–13.

To filter out the reliable parts of the individual profiles, an objective measure for the reliability of the individual data points has to be found. If a particular data point is based on the average of only a few observations, the standard deviation of the average is not a suitable measure for reliability. The reliability of an average ZHR value increases with the number of contributing observers, their effective observing time, limiting magnitude, and radiant elevation. If we divide the total number of meteors N from which a mean ZHR was calculated by this average, we get the equivalent effective observing time T_{eq} during which an observer with limiting magnitude 6.5 and the radiant at the zenith had to watch to obtain the same results:

$$T_{\mathrm{eq}} = \frac{N}{\mathrm{ZHR}_{\mathrm{avg}}}.$$

The quantity T_{eq} is a suitable measure for the reliability of an average ZHR. If, for instance, one observer observes for 1 hour with a limiting magnitude of 6.5 and 30° radiant elevation, his T_{eq} is 0.5 hours, since the zenith correction factor C_z equals 2. In the same manner, T_{eq} is reduced if the limiting magnitude is less than 6.5. Figures 9–13 show T_{eq} for every data point.

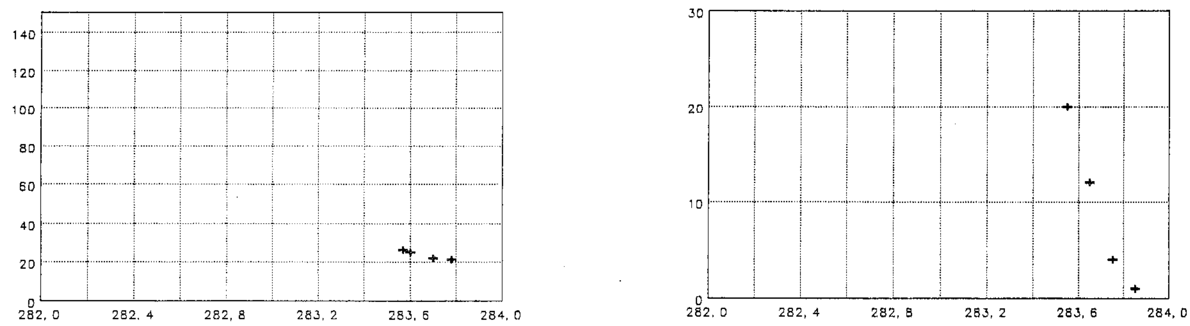

Figure 9 – ZHR profile of the 1986 Quadrantids *(left)*. In the adjacent diagram *(right)*, T_{eq} is shown for each of the ZHRs displayed in the profile. Only a few observations were available.

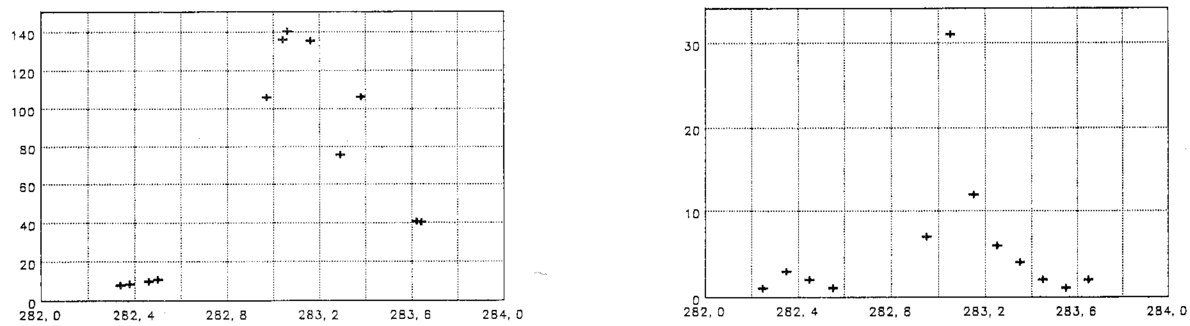

Figure 10 –Same as Figure 9, for the 1987 Quadrantids. In this case, there is good observational data around the peak.

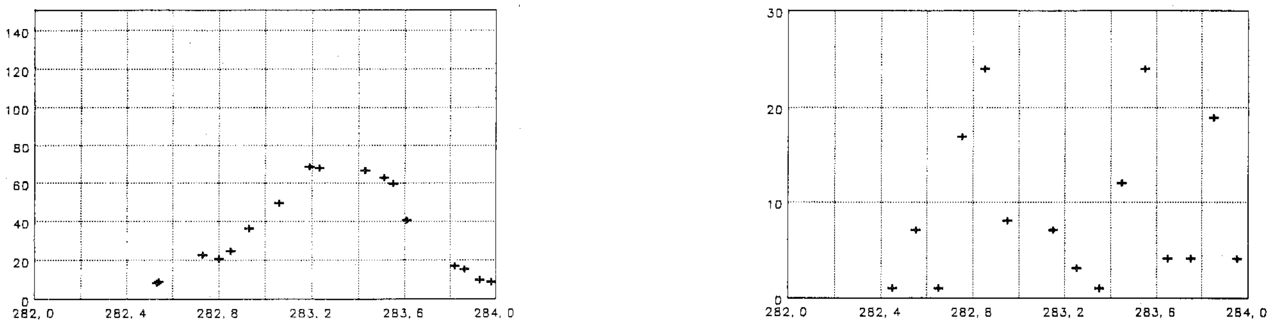

Figure 11 –Same as Figure 9, for the 1989 Quadrantids. The period is covered with good data.

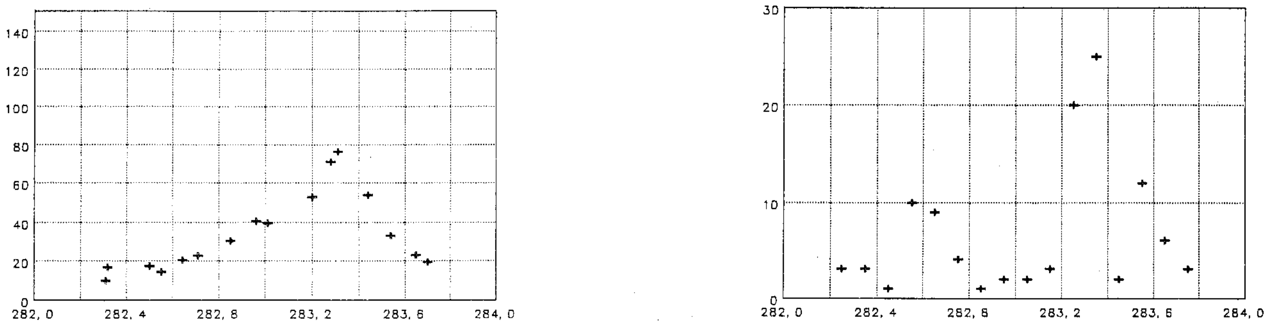

Figure 12 –Same as Figure 9, for the 1990 Quadrantids.

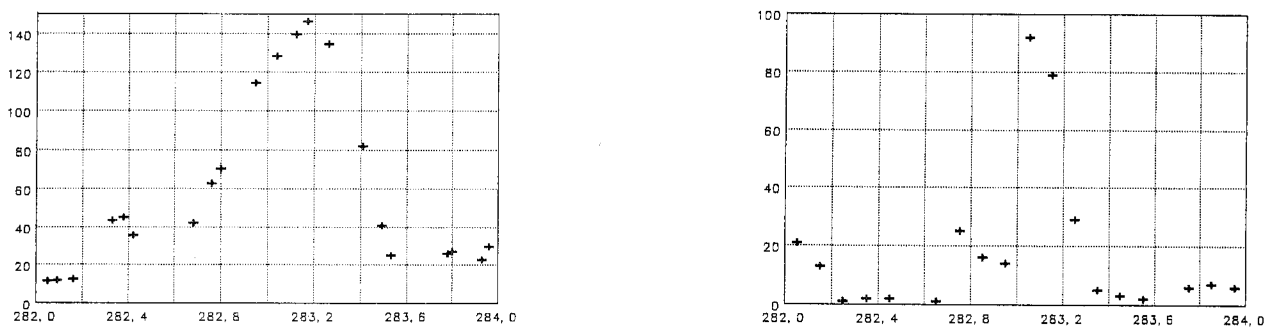

Figure 13 –Same as Figure 9, for the 1992 Quadrantids. The quality of the 1992 analysis becomes obvious. Note the different scale of the ordinate axis.

To consider a data point reliable, a minimum T_{eq} of 4 hours was chosen. All data points based on $T_{\mathrm{eq}} > 4$ hours were plotted in Figure 14. This figure contains the reliable parts of the ZHR profiles of the individual years that can be compared.

It is quite obvious that the parts of the 1989 profile are shifted by about $0\overset{\circ}{.}15$ against the profiles of the other years. This implies that also the maximum of the 1989 profile, which was insufficiently documented by observations, may have occurred later than in the other years.

For other years there is no obvious shift, but small offsets $\Delta\lambda_{\odot} < 0\overset{\circ}{.}1$ cannot be excluded.

In years where the maximum period $\lambda_{\odot} = 283\overset{\circ}{.}0$ to $\lambda_{\odot} = 283\overset{\circ}{.}25$ was sufficiently covered by observations (1987, 1992) the maximum ZHR reaches about 140. In 1989 and 1990 the peak rates were about 80, but this is based on very little T_{eq}. It is possible that a difference of this order is caused by systematic effects introduced by too little observational data. More likely, the maximum ZHR was in fact lower in 1989 and 1990 than in 1987 and 1992.

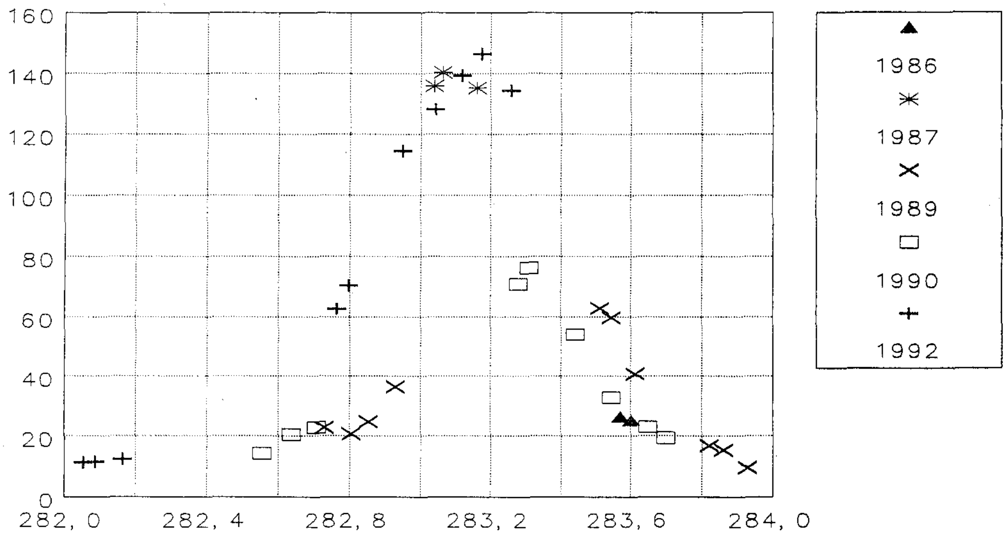

Figure 14 –Reliable ZHR values ($T_{\mathrm{eq}} > 4$ hours) from different years superposed in one diagram define an "average activity profile" for the period 1986–1992.

For 1990, there is a strong indication that the peak ZHR was considerably lower than in 1992. Figure 14 does not show an offset in solar longitude between the 1990 and 1992 profiles. The 1990 ZHR values for $\lambda_{\odot} = 282\overset{\circ}{.}75$ and $\lambda_{\odot} = 283\overset{\circ}{.}3$, however, are only about half that of the corresponding 1992 ZHRs. Similar differences of the peak ZHR between 70 and 190 are reported from other analyses summarized in [11] and [13]. Bearing in mind the restrictions inherent in gathering data from one site, these results should be checked carefully before using them for further analysis.

Finally, it can be concluded that there is *certainly* an offset in solar longitude of the ZHR profile between different years and *probably* a variation of the maximum ZHR.

Quadrantid maxima of different activity have been reported in the past [14,11,9]. Old observations rarely allow the calculation of rates comparable to our ZHR. Prentice [14] reduced the rates for zenith position of the radiant applying a factor $\sin(h + 6°)$ with h the radiant elevation. In the case of low radiant position this tends to undercorrect the rates. However, no correction for the limiting magnitude was done in his work. As the rates are based on single observations (Table 5), they possibly do not represent the maximum. The average in other years listed in [14] is about 45. Therefore, the value ZHR = 79 in 1922 should be regarded as a high rate. In Table 5, we summarize all activity peaks which likely showed enhancements.

Table 5 – Quadrantid maxima with higher than average activity. In the case of summarized observations, the radiant elevation h refers to an average value for the period of the peak. Otherwise, the elevation is given according to the source cited. For the applied correction, see the explanations in the text.

Year	h	Qua	ZHR	Remarks and source
1864	19°	100	131	120 min; A.S. Herschel [14]
1909	57°	210	202	70 min; P.M. Ryves [14]
1922	16°	34	79	70 min; F.W. Denning [14]
1965	≈ 30°		190	[15]
1970	≈ 20°	3183	150	105 observers in UK and US [11]
1987	≈ 30°		150	this study
1992	≈ 60°	18434	145	this study

Let us consider the returns of 1864, 1909, and 1922 [14], as well as the returns of 1965 and 1970 [15], all of which showed higher than normal activity. Furthermore we may add the returns of 1987 and 1992 to the list from this study. Going back in time, the "high peaks" back to 1922 can be fitted with each other using the mean orbital period of the Quadrantid shower of 5.38 years [16] or 5.36 years [5]. This is not the case for the 1909 peak, and also the 1864 peak does not fit well with this period, but would do so with a slightly shorter one.

With an aphelion distance for the average Quadrantids of 5.7 AU, being very close to Jupiter's orbit (5.2 AU), the orbit of the Quadrantids is closely tied to that of Jupiter. Therefore, considerable changes in the shower may occur over a period of nearly 130 years.

8. Conclusions

In our study, we find a smooth profile of the population index r of the Quadrantids. Before and after the maximum period it resembles the value of the sporadic meteors. The lowest value of $r = 2.1$ occurs when the peak activity level is reached. Additionally, we find an increase of the population index r during the night of the activity maximum. This is probably not a real characteristic of the shower, but an effect resulting from changing entry angles. The peak was covered by European observers. During their observational period the elevation of the radiant steadily increased. Therefore, the increase in r from 2.1 to 2.4 within 6 hours should be regarded as an artifact.

The maximum values of the ZHR and number density curves derived from the Quadrantids 1992 show nearly no effects of mass segregation. The peaks for fainter meteors ($m \leq 6.5$) and brighter meteors ($m \leq 0.4$) occur at nearly the same time, while Šimek's [9] figure shows that the number of radar echoes of $1\ \mathrm{s} \leq T \leq 8\ \mathrm{s}$ duration is the highest about $\Delta\lambda_\odot = 0\overset{\circ}{.}3$ earlier than for echoes of $T > 8$ s.

The Quadrantid peak is very narrow. Its FWHM is $\Delta\lambda_\odot = 0\overset{\circ}{.}6$ or 14 hours. The activity reaches the level of background activity about 14 hours before and after the peak.

When comparing activity profiles of earlier returns obtained from data representing a restricted longitude range, these data must be checked very carefully because of the widely varying observational circumstances of the returns. Analyses of global data from 1986 to 1992 show that an offset of the peak in solar longitude may occur. As well, different peak activity levels seem to have occurred in the past as well as in some recent returns. Although such data should be treated with caution, there is a possible connection with the mean orbital period of the Quandrantids of 5.38 years.

Observations of the Quadrantids require global cooperation, since the crossing of the central part of the stream happens within about 14 hours. Because of possible time shifts of the peak, all observers should be alerted in order to obtain sufficient data from sites with radiant elevations greater than 20°.

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Received February 1993; revised April 1993; accepted May 1993.

Ongoing Meteor Work

Perseids 1993: The Big One?

Joe Rao

The chance of a very significant, if not substantial display of Perseid meteors may occur in 1993. For the first time since the Leonids of 1966, there exists a very real prospect of a full-fledged "storm" of meteors occurring, thanks mainly to the recent return of the Perseids parent comet, P/Swift-Tuttle. The anomalously high Perseid activity noted over the Far East and Asia in 1991 and 1992 seemingly heralded P/Swift-Tuttle's arrival, and may be heralding a truly stupendous shower for 1993.

The author proposes that, unlike the previously accepted concept of the Perseids as an evenly distributed stream, a dense concentration of meteoric material accompanies P/Swift-Tuttle in its orbit. In addition, he demonstrates that the orbits of Earth and this comet have drawn closer to each other by more than 0.022 AU since the early 18th century; it is also noted that after 1737, likely due to planetary perturbations and non-gravitational forces, the comet experienced a dramatic shift inward toward the Sun at its perihelion point. This is confirmed by way of presenting a list of previous possible apparitions dating backwards in time, to the ninth century A.D.

A prediction for a possible "burst" of Perseid activity is attempted: the Earth will follow P/Swift-Tuttle to the descending node by just under 224 days and the distance between the Earth and comet orbits is only 0.00094 AU with the Earth passing inside the comet's orbit. If the particles follow the comet's orbit exactly, the shower maximum should occur on August 12.052, 1993. This highly favors Europe, and might allow high Perseid activity to be detected as far west as the Canadian Maritimes and the United States East Coast. However, observers are cautioned that the behavior of the peaks in 1991 and 1992 with respect to the comet's nodal longitude suggest that the 1993 peak may actually occur closer to August 11.932.

A look back at Perseid activity at P/Swift-Tuttle's last visit in 1861–1863 suggests unusually high Perseid rates, with the "suggestion" that the 1863 display may have approached the level of a meteor storm. The author makes a comment (based solely on the Perseid observations made in 1991 and 1992) that peak activity in 1993 is not likely to last more than one hour, adding that the geometry between the Sun, Earth and comet in 1993 seemingly favors an even greater enhancement of Perseid activity than what was seen in 1863. Orbital similarities between the great Leonid storm of 1833 and the upcoming situation for the 1993 Perseids are brought to light. The intrinsic brightness for P/Swift-Tuttle and other storm-producing comets are compared.

Finally, a very rare phenomenon (possibly similar in nature to the Zodiacal Light) is briefly discussed: the prospect of actually detecting the particles producing the Perseid stream in interplanetary space just prior to or just after encountering the Earth.

1. Introduction

For those who have a particular interest in meteor observing, there has been a keen sense of anticipation as we moved into the decade of the 1990s. For many years, hopes have been high that before the end of this decade, Earth would be treated to a stupendous "storm" of meteors; the entire sky becoming ablaze with a celestial pyrotechnics display. Such an extremely rare conflagration of Solar System debris can only occur after our Earth makes a close approach to a passing comet. As a comet nears the Sun, tiny particles are shed from its nucleus. Thus its orbit is not an imaginary path through space like Earth's, but a continuous "river of dust" moving in the same direction as the comet. Each time Earth crosses one of these dust rivers, it collides with millions of tiny orbiting particles that have been released into space in the wake of their parent comet.

Observers viewing a collision between the Earth and a tiny comet particle will typically see a fast-moving streak of light in the night sky—a "shooting star." Meteor streams contain such particles (meteoroids) traveling in roughly parallel orbits, and the collision of many particles with the Earth's atmosphere causes a meteor shower. There are about a dozen annual meteor showers (tens of meteors per hour), and hundreds of minor ones (mostly so weak that the word "shower" is a great exaggeration). It would seem that in these cases that the parent comets disintegrated into meteor streams eons ago, and the streams themselves have almost completely diffused into space, making them hardly distinguishable from sporadic meteors.

Then there are the meteor storms.

On these very rare occasions, large numbers (thousands) of meteors are seen in a very short interval of time... a few hours or less. Yet, even in such a meteor storm, the individual meteoroids are at least 30 kilometers apart in space. Meteor storms are made of particles that are still mainly bunched-up or clumped together near the parent comet, while the annual showers have an even spread of particles along an orbit which the Earth intersects at least once a year. The last time such a grand display occurred was in November of 1966, when the Leonid meteors put on one of the greatest displays in history, with maximum rates for the West Coast of North America briefly attaining 2400 meteors per minute, or 144 000 per hour! The comet from which the Leonids are derived (1965 IV P/Tempel-Tuttle) has a period of about 33 years and is due to return to the vicinity of the Sun in late February, 1998. Thus it would seem that another great meteor storm will become increasingly possible as we progress toward the years 1998 or 1999.

However, it now appears that we might not have to wait that long for a chance at seeing such a magnificent spectacle. An interesting opportunity could present itself to us in this current year of 1993. It is not the Leonids, however, that may bring us this storm of meteors. For this year's potential sky spectacular comes from what only a few years ago would have been considered to be a completely unexpected source, namely the annual Perseid meteors of August.

Astronomy books and reference texts often refer to the contrasts between the Leonids and the Perseids. The Leonids are usually defined as a periodic stream of which the Earth crosses the main "clump" of meteoric material every 33 years and causes shooting stars to come raining down from the starry sky in a meteor storm. As for the Perseids, here is an example of a "typical" definition taken from the 1971 edition of the *Encyclopedia Brittanica*:

> *In the case of the Perseid shower ... the dispersion (of particles) around the orbit is so complete that no evidence of long term periodicity can be found.*

Such a widely accepted categorization for the Perseid shower has only recently changed. This annual display, which has always been considered to be an excellent example of fairly reliable and steady meteor stream has, over the past two years, given strong signals that an impending meteor storm may indeed be brewing. In 1991, a surprising "burst" of Perseid activity was noted by amateurs in Japan. Some estimations placed the hourly rate in excess of 450. Then, in 1992, despite the bright light of a nearly Full Moon and generally unfavorable weather conditions, sky watchers in the Orient and across Asia again saw another striking Perseid shower. Even where skies were cloudy and hazy, came reports of brilliant fireballs appearing *like small moons flying behind the clouds, or lightning flashing during a storm.*

This unprecedented burst of activity was ending as darkness fell on Europe, but even amateurs as far away as the Netherlands reported Perseids, despite bright evening twilight, that rivaled Venus, and accompanied by luminous trains lasting for many seconds.

2. The theory of orbit closure

It is well documented that the progenitor of the Perseid meteors, P/Swift-Tuttle, has played a significant role in the recent increase in Perseid activity seen during the past two years. The hunt for and the eventual recovery of this comet by Japanese amateur Tsuruhiko Kiuchi on September 26 of last year, brought to a close one of the most interesting chapters in the recent annals of cometary astronomy. But of greater interest now is how the comet's recent passage through the inner Solar System will affect the 1993 Perseids. In many ways, the recovery of P/Swift-Tuttle was the final missing piece in the puzzle that had been developing over recent years surrounding the Perseid stream (Figure 1). Whereas the material responsible for producing the traditional Perseid showers has been "laid down" over hundreds and thousands of years, this new brief, sharp maximum is likely being caused by a very localized region of particles, far more thickly clustered together and in the immediate vicinity of the comet (Figure 2).

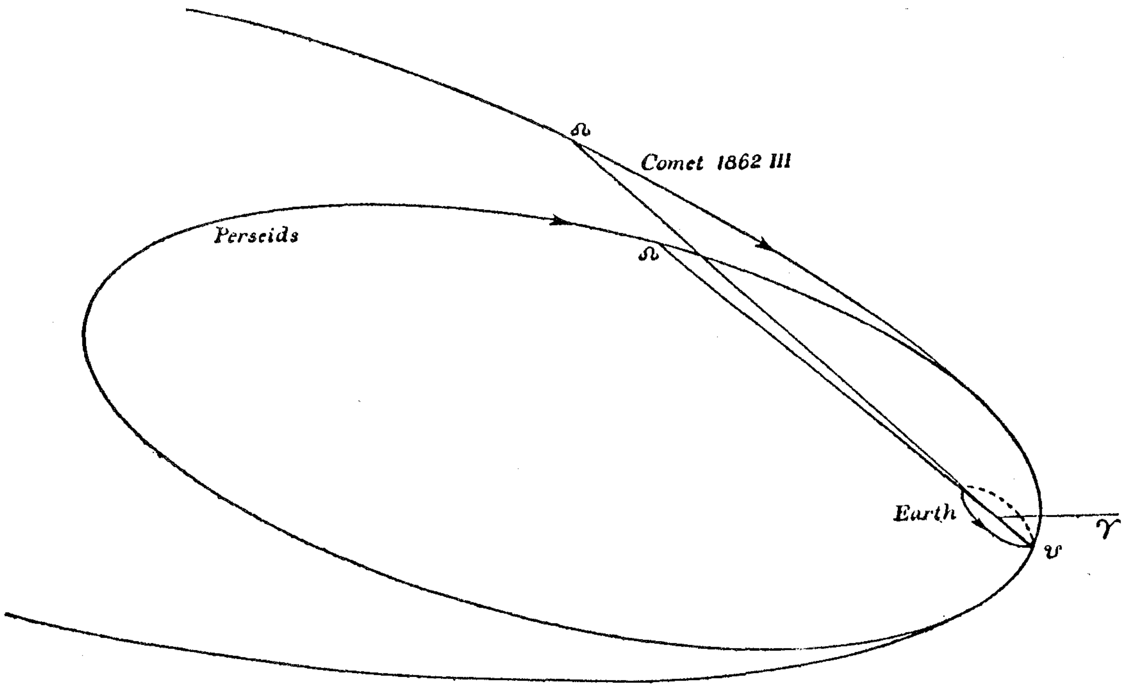


Figure 1 – The orbits of the Perseid meteor stream as determined by radio-echo observations compared with the orbit of Comet P/Swift-Tuttle. Projection is on the plane of the comet's orbit. Diagram from *Meteor Astronomy* by A.C.B. Lovell (1954).

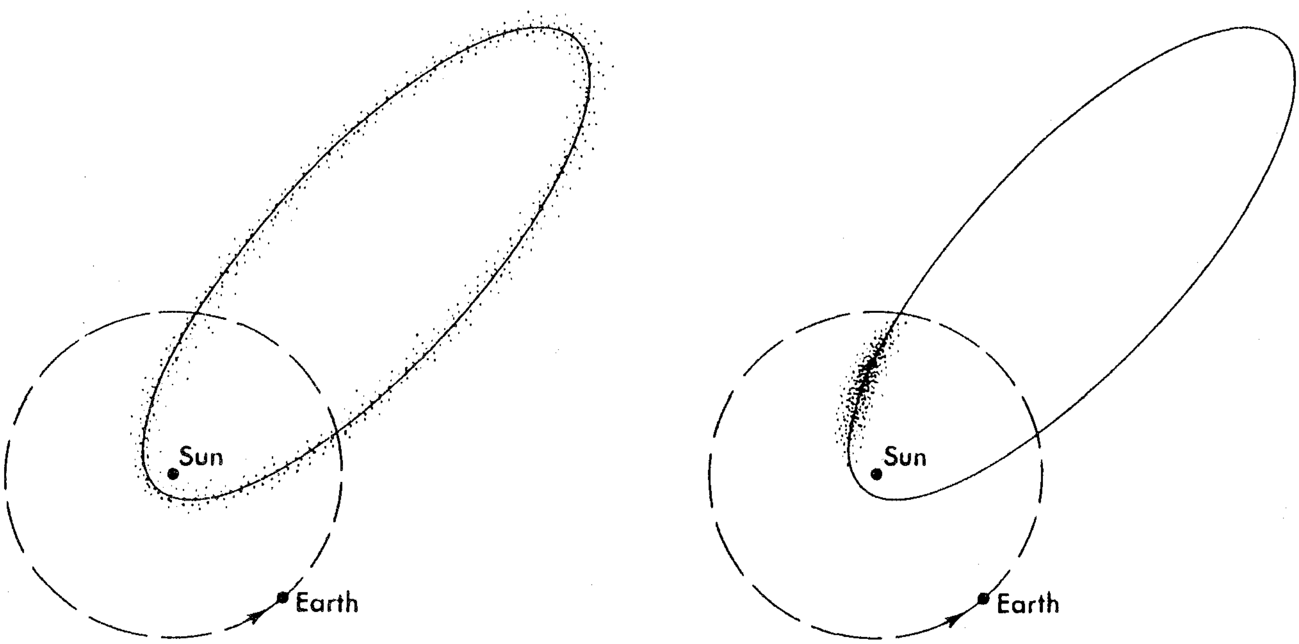


Figure 2 – *At left*, meteoroids are strung out uniformly in their orbit; *at right*, a meteoroid swarm "bunched up." Diagram from *Meteors and Meteoroids* by David C. Knight (1969).

When this new feature first began to be recognized in 1988, it was virtually indistinguishable from the "traditional" maximum, but since 1991, as the comet approached, we have entered a region of particles, that has only been very recently ejected—perhaps no more than two revolutions ago. It is obvious that this material is less dispersed and richer in larger particles. As was noted near the beginning of this article, the original concept was that this material was evenly spread-out across the comet's orbit.

However, now there is a reason to believe that, in the same manner as the Leonids' parent comet, there is a tremendous concentration or "knot" of cosmic debris that is accompanying P/Swift-Tuttle as it moves around the Sun. This knot had been "masked" from our view for all these years simply because the Earth never fully encountered it. Calculations that I made in June of last year, and confirmed by Dr. Brian G. Marsden of the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, indicates that the distance between the orbit of Earth and P/Swift-Tuttle have drawn closer together over the past two centuries.

In fact, according to another orbital expert, Dr. Donald K. Yeomans of the Jet Propulsion Laboratory in Pasadena, California, the orbits are presently separated by a mere 0.00094 AU (140 000 km) at the descending node, compared to 0.005 AU in the 19th and 0.023 AU in the 18th century. This, I feel, is the key to why there are no records that exist of any remarkable Perseid showers in the 18th century, while there were indeed spectacular displays during the 1861 to 1863 time span—the years that surround the previous apparition of P/Swift-Tuttle. Earth probably grazed a portion of that thick concentration of material during 1861–1863. In the current situation, with the near-coincidence of the two orbits separated by less than 0.001 AU, it becomes obvious that Earth is now in the process of passing almost directly through this fresh "knot" of material during 1992–1993. Incidentally, at the next return of the comet in July 2126, the Earth-comet orbit separation (according to Dr. Marsden) will actually become very slightly larger at 0.003 AU.

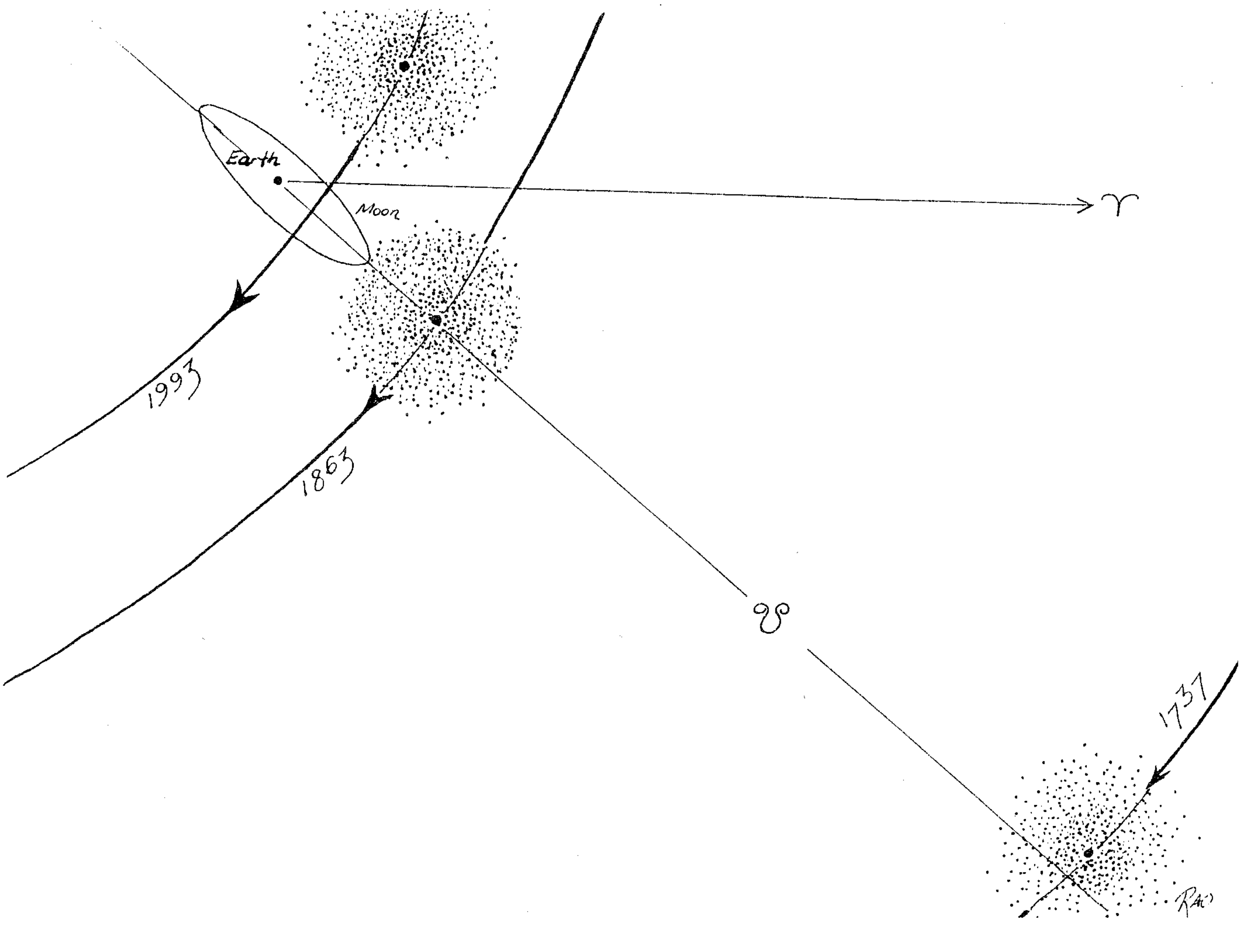


Figure 3 – The relative proximity (to scale) of the Earth-Moon system, compared to Comet P/Swift-Tuttle at the descending node of the comet's orbit for its three most recent apparitions. Note that in 1993, the comet's orbit is more than 2.5 times nearer to Earth than is the orbit of the Moon. Circular stippled areas indicate the approximate linear diameter of the comet's coma.

It should be stressed that the current configuration between Earth and P/Swift-Tuttle is quite unique—at least over this past millennium (Figure 3). In November, 1992, at my request, Dr. Marsden kindly supplied past perihelion dates and perihelion distances of Comet P/Swift-Tuttle going back to the year 826 A.D. While it is likely that orbital elements of this comet for earlier possible returns will become increasingly refined with the passage of time, these rough data provided by Dr. Marsden (summarized in Table 1) indicate that through eight revolutions of P/Swift-Tuttle from 826 A.D. to 1737 A.D., the perihelion distance varied little from an average of 0.975 AU. As a result of this, the separation between the orbits of Earth and comet also changed little; my own rough calculations show an average separation of about 0.02 AU. Apparently, after the 1737 apparition, *a significant shift in the comet's orbit inward toward the Sun* occurred, leading to the closure of the separation between Earth and comet.

In fact, the perihelion distance of P/Swift-Tuttle shrank from a maximum of 0.9800 AU in 1737, to 0.9627 AU in 1862 down to the current minimum of 0.9582 AU in 1992.T

Table 1 – Changes in perihelion distance of P/Swift-Tuttle.

Perihelion date	Perihelion distance
826, April	0.977 AU
950, April	0.976 AU
1079, September	0.972 AU
1212, November	0.974 AU
1348, May	0.975 AU
1479, October	0.970 AU
1610, February	0.977 AU
1737, June	0.980 AU
1862, August	0.963 AU
1992, December	0.958 AU

3. When and where will the Perseids "burst" in 1993?

What part of the Earth will be most favored to see another potential "burst" of Perseid activity in 1993? The calculation is simple enough, provided one knows exactly the plane of the orbit of the meteors, for the encounter must take place at the moment when the Earth crosses that plane (the descending node).

If we suppose that they are moving in the same plane as P/Swift-Tuttle, then we should reach the Perseid maximum as we cross the orbital plane of the comet on August 12, at 1^h15^m UT. This would favor all of Europe and might even include a part of eastern North America where darkness will be falling during the early evening of August 11 (Figure 4). The trouble with this prediction is that the main meteor swarm has apparently been shifting slightly in its position relative to the orbital plane of the comet. The 1992 shower occurred very nearly at the moment the Earth crossed the plane of the comet's orbit and about 4.5 months (141 days) ahead of the comet itself.

But the 1991 shower occurred about 0.1 day later (see Table 2). Does this mean that, by virtue of simple extrapolation, the 1993 shower will come about 0.1 day earlier than when Earth crosses the comet plane? Perhaps August 11, near 22^h20^m UT, will be when the greatest concentration of meteoroids will be encountered. This will be 8.5 months (almost 224 days) behind the comet. If so, then Europe would still be in a fine position, as well as portions of western Asia. Unfortunately, an earlier arrival time means the burst would occur during the afternoon hours for North America.

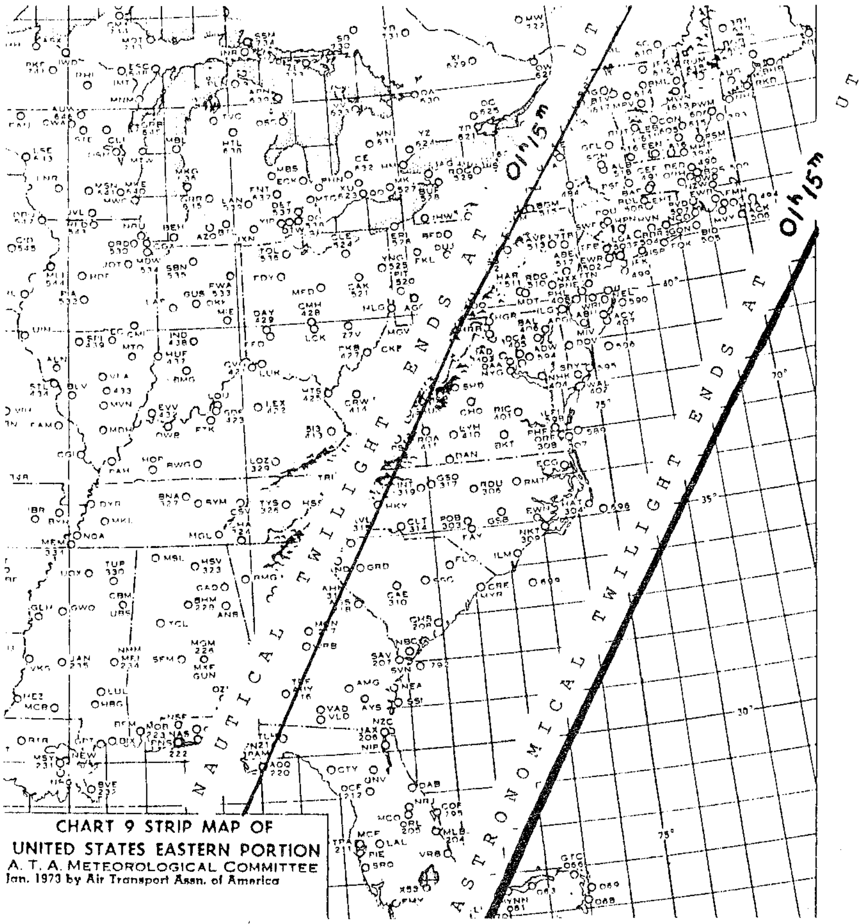


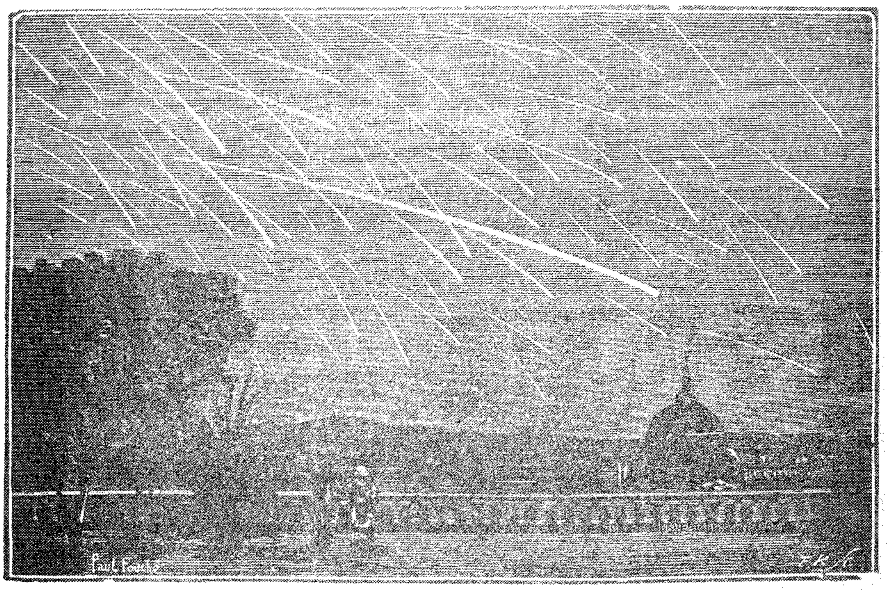
Figure 4 – Boundary lines depicting where nautical and astronomical twilight will be ending in the US and Canada at the moment that Earth is passing through the descending node of Comet P/Swift-Tuttle (August 12 at 1^h15^m UT = August 11 at 21^h15^m EDT). To the left of the "nautical twilight ends" line, the sky will likely be too bright to make any meaningful observations, while over the central and western portion of North America, the Sun will still be above the horizon. Diagram by J. Rao.

Table 2 – Observed and forecast data for the 1991, 1992, and 1993 outbursts

Earth at node	Maximum	Difference	Comet from node
1991 Aug 12, 13^h31^m UT	Aug 12, 16^h22^m UT	$+2^h51^m$	−506.5 days
1992 Aug 11, 19^h26^m UT	Aug 11, 19^h24^m UT	-0^h02^m	−141.4 days
1993 Aug 12, 01^h15^m UT	Aug 11, 22^h22^m UT	-2^h53^m	+223.7 days

4. What to expect

Weather forecasters sometimes find it useful to study a past large-scale synoptic weather pattern which resembles a current situation in its essential characteristics. *(Mr. Rao is a meteorologist, Ed.)* Such is called an "analog," and its use is based upon the assumption that two similar synoptic weather patterns—an intense storm, for example—will retain some similarity through at least a short period of further development. This having been said, is it possible to "analog" a potential meteor storm?



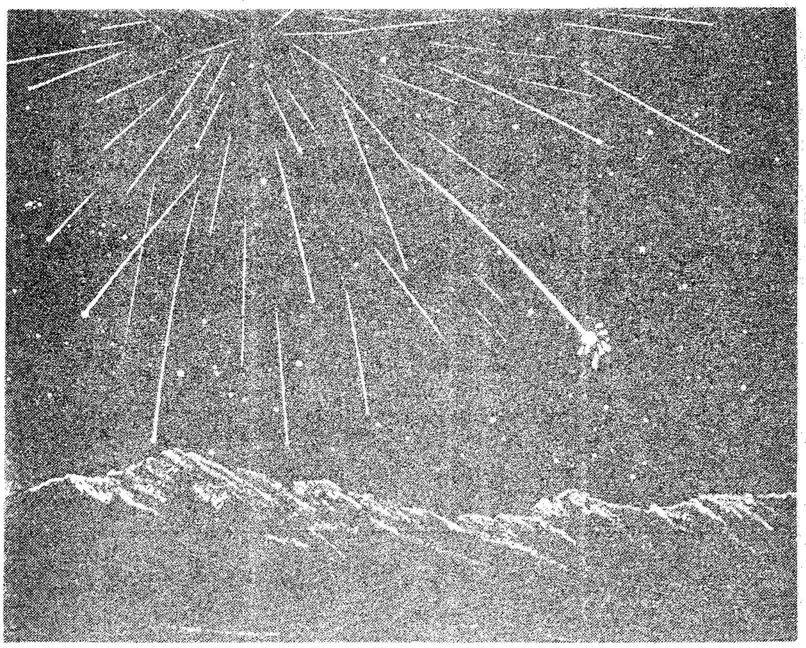


Figure 5 – In the *Monthly Notices of the Royal Astronomical Society*, 1872, pp. 355–359, meteor observer Alexander S. Herschel saw fit to make comparisons of the 1863 Perseid shower with the great Andromedid (Bielid) meteor storm of November 27, 1872. This implies that the 1863 Perseid display provided a far-greater complement of meteors than is usually the case. The top Andromedid illustration is taken from *Popular Astronomy* by Camille Flammarion (1894) and the lower illustration is a different interpretation of the same display from the archives of the *American Museum of Natural History*. As a side note, it is interesting to point out that Flammarion did not actually see the Andromedid storm, noting: *Convalescent from a fever caught in the Pontine Marshes, I was obliged to go into the house immediately after the setting of the Sun... what disappointment I felt next morning when, on going to the Observatory, Father Secchi informed me of that event! This wonderful rain of stars fell almost before my eyes, so to say, and I shall never cease regretting not having seen it.*

If we look back to the behavior of the Perseids in the years surrounding the previous apparition of P/Swift-Tuttle, it is found that reports of exceptional Perseid displays were seen in 1861 an 1862, mainly from the Far East. This situation is quite similar to what thus far has been observed in the current apparition for 1991 and 1992. And if what happens in 1993 is anything like what happened in 1863, then a very exciting event may be in store for those fortunate to be gazing skyward at the right time from the right place.

The assiduous meteor observer William F. Denning referred to 1863 as a year with *three to four times the normal Perseid rates.* Later, in 1872, another noted observer, Alexander S. Herschel, in making notations concerning the Andromedid meteor storm of that year (Figure 5), made favorable comparisons to two other great shooting star showers: the Leonids of November 1866 and the *marked maximum* of the Perseid shower in 1863. Herschel apparently thought enough of the 1863 Perseids to put it in the same league with two legitimate meteor storms!

Interestingly, however, it also appears that very different degrees of meteor activity were reported from places not very far apart on a global scale. This phenomenon has also been noted with the recent Perseid showers of 1991 and 1992. Perhaps this is an effect due to very localized filaments of intense activity. Indeed, in the case of a "storm" situation, it will be very important to try to judge to the nearest minute when the heaviest activity takes place in your area so that a reliable comparison can be made with other locations.

As for the duration, if a storm does indeed materialize, it would be very surprising if it lasted more than an hour. This was the case during the heavy Perseid showers of the last two years. Indications are that the most intense activity exceeded half the maximum for only about 60 minutes. A simple calculation, based on the Earth's orbital speed and the angle at which it intersects the Perseid stream indicates that the width of this stream amounts to approximately 65 000 km, the width of the part that contains the greatest concentration of meteoroids.

In 1993, we will be closer to the comet than in 1863: about 224 days past the nodal crossing point as compared to 332. Also, as previously noted, the orbital distance between the Earth and P/Swift-Tuttle is noticeably smaller by some 607 000 kilometers.

Most intriguing of all, the orbital geometry between the Earth and Comet P/Swift-Tuttle for August 11-12, 1993, is somewhat similar to the conditions that lead to the legendary Leonid storm of November 13, 1833 (Figure 6)! On that occasion, the orbital separation between the Earth and Comet P/Tempel-Tuttle was on the same order of magnitude as now (0.0013 AU), with the Earth following the Leonid comet to the nodal crossing point by about 308 days. (The Leonids however, are chiefly on the inside of the Earth's orbit, whereas the Perseids are on the outside.)

And among the comets that are still "intact" and producing meteor showers, P/Swift-Tuttle is intrinsically one of the brightest (along with P/Halley and P/Thatcher) by far. Using the old H_{10} system in which one can compare comets' relative brightnesses at 1 AU from the Sun, comet expert John E. Bortle provides absolute magnitude values of +4.5 for P/Swift-Tuttle, as compared to +9.5 for P/Giacobini-Zinner (Draconids) and a possibly overly-optimistic +9.0 for the Leonids' P/Tempel-Tuttle. The famous Andromedid storms of course, were produced by the pulverized remains of P/Biela, which was torn apart in 1846 and which has failed to reappear since 1852. In regard to P/Swift-Tuttle, Bortle also notes that it is *four to ten times brighter than the average long-periodic comet.*

Such a comet could certainly be considered a prodigious dust-producer and indeed in early November of 1992, observations using the International Ultraviolet Explorer satellite, indicated a gas-to-dust ratio slightly higher than P/Halley and higher than most comets. It is quite possible to expect that, in view of the very small distance between the Earth's and comet's orbit, we may very well encounter dust that was released as recently as 1737, and "maybe" even in 1862!

Finally, as if the chance of a meteor storm were not enough, the Perseid stream may actually become visible in interplanetary space, shining by reflected sunlight! In 1978, W.J. Baggaley of the University of Canterbury (New Zealand) directed attention to just such a curious phenomenon that has attended some intense meteor showers, such as the 1866 Leonids and the 1872 Andromedids. This phenomenon, attested to by a number of observers, consists of a faint, diffuse glow of the night sky, in the general direction of the meteoroid particles. During the great Leonid display of November 13-14, 1866, which was extensively observed in Great Britain in clear, moonless skies, Dr. Baggaley brings attention to a glow in the sky that was likened to *an aurora with an absence of any streamers.* Since the Sun was spotless and magnetic records at Greenwich indicated very quiet conditions, Dr. Baggaley attributed the glow's cause to sunlight scattered from fine meteoric dust accompanying the Leonid swarm in its orbit.

My calculations indicate that just prior to when the Earth passes through the plane of the comet's orbit, the stream of approaching meteoroids may show up as a glow roughly 10° to the south of Algol. The receding meteor stream would be a similar glow in the southern constellation of Triangulum Australe, on the opposite side of the sky. Because of the aforementioned narrowness of the stream, this effect may not last more than several hours.

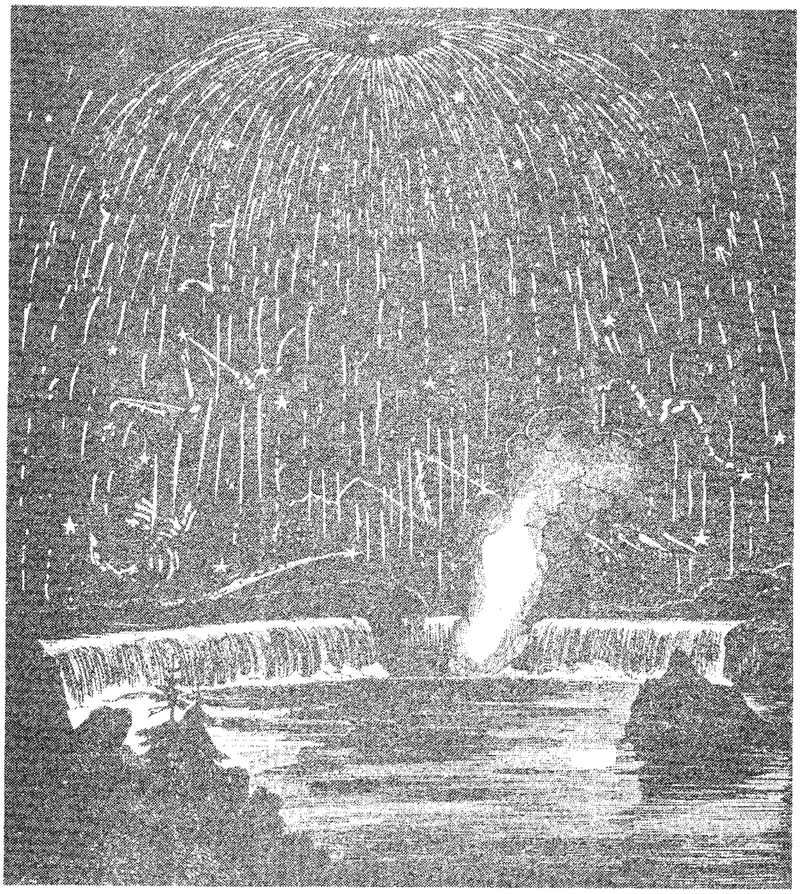


Figure 6 – A contemporary print of the great Leonid meteor shower of November 13, 1833, as seen at the Niagara Falls. The geometric position of the Earth, relative to P/Swift-Tuttle is somewhat similar to the 1833 situation of Earth relative to the Leonid parent comet, P/Tempel-Tuttle. While this seems to be a very promising comparison, perturbations affecting the respective meteor streams and the overall dust distribution surrounding both comets are not very well known. Still, the comparison is intriguing.

5. Conclusion

In their book *Observe Meteors*, David Levy and Stephen Edberg comment that, to actually witness a meteor storm, *must be a supreme honor accorded to people who grace this planet.* Indeed, such a sight might be among the rarest and most dramatic of astronomical sights that an amateur may ever hope to observe. A "potential opportunity" to see one first-hand might come along perhaps only two or three times during one's life, and even then, there are no guarantees that the hoped-for spectacle will come off. One of those "potential opportunities" will be presented to us this year on the night of August 11-12. Indeed, even Dr. Marsden, who, by his own admission, tries to avoid making predictions on meteor showers, thinks that this year's circumstances makes the possibility of a great shower worthy of mention: *If we do* not *get great Perseids this year, we shall never get them!* Although it appears that Europe will have the ringside seats for this hoped-for event, observers in all parts of the world should still be on high alert and keep a careful watch. It could truly be a night to remember.

Acknowledgements

I would like to thank the following individuals for helping me with the preparation and development of this article: *Dr. Brian G. Marsden* of the Smithsonian Astrophysical Observatory, for taking time out of his busy schedule to check all my figures, as well as provide the very latest orbital information on Comet P/Swift-Tuttle as it became available; *Dr. Donald K. Yeomans* of NASA's Jet Propulsion Laboratory, for making suggestions and providing some of his own orbital data for P/Swift-Tuttle; *Dr. Edward M. Brooks* of Boston College, who edited my book on the 1991 solar eclipse, and who was kind enough to critique the original manuscript for this article; *Mr. John E. Bortle* of W.R. Brooks Observatory in Stormville, New York, for providing magnitude information on comets for use in this article, and who has always made himself available to this writer over the years for any query made to him concerning the subject of comets; my wife, *Renate Rao*, for making useful comments and corrections to the first draft; and finally *Ms. Sandi Kitt* of the Perkin-Elmer Memorial Library of New York's Hayden Planetarium for all the xeroxing of historical literature on past meteor showers.

Editorial postscript:

We would like to add a few comments to the excellent and comprehensive outlook on a possible major Perseid outburst given above by Joe Rao:

1. *Mr. Rao does not mention that a study by Dr. Yeomans on comet P/Tempel-Tuttle (parent body of the Leonids) and other work on P/Giacobini-Zinner (Giacobinids or Draconids) point out that the largest dust concentration is behind the comet, and indeed Leonid and Draconid storms have always occurred after the passage of the parent comet. Of course it is dangerous to generalize from so small a sample, but if the situation is similar for P/Swift-Tuttle, we have an extra argument to expect enhanced activity.*
2. *Mr. Rao discusses the time of maximum activity (around* 1^h *UT if coinciding with the Earth passing the comet's descending node) and suggests that it might occur up to 3 hours earlier if the shift from 1991 to 1992 will have continued. We think one should be very careful with such considerations. It is by no means certain that the outbursts in 1991 and 1992 were caused by the same filament! As meteor storms usually occur near the parent comet's node, we favor* 1^h *UT as the most likely time of maximum.*
3. *However, it is by no means certain that the 1993 Perseid activity will be characterized by a unique, sharp peak. In comparison with great meteor storms in the past such as the 1833 Leonids, it must be noticed that while storm activity is usually of very short duration, highly increased activity is around during a much longer period, even up to a few days in extreme cases. In this respect, it should be noted that the few accounts we have on the 1863 Perseids* do not *specify a particular time, suggesting the activity was around for most of the night.*

It is therefore very possible that highly increased activity will be present during the entire night of maximum, and even during the night before and after, and that during the night of maximum the Earth may or may not pass through one or several very dense filaments causing short storm-like outbursts. While the greatest possibility for the Earth to pass through such a filament will occur around 1^h UT, this might nevertheless happen earlier or later, or even several times, or not at all. It is therefore necessary to be on alert the entire night of maximum as well as the nights before and after to obtain a comprehensive picture of the 1993 Perseids' behavior and to make sure not to miss anything major!

3. *Finally, we should like to point out the apparent dissimilarity in the dust distributions present about P/Tempel-Tuttle and P/Giacobini-Zinner in making comparisons with the Perseids. While the dust does lag temporally behind both comets, in the case of the Leonids there is little doubt the highest dust concentration is spatially outside the comet's orbit, while for the October Draconids, the 1933 and 1946 storms occurred with the Earth inside the comet's orbit. It is also noteworthy that there was a time between 1966 and now when another meteor storm seemed imminent: October 9, 1972. On that date, the circumstances of encounter with the Draconid stream were discussed in much the same way as the 1993 Perseids; the time after the comets passage was only 59 days and the distance between the Earth's orbit and the comets was only 0.00074 AU, even smaller than the 1993 encounter parameters with the orbit of P/Swift-Tuttle. The activity was monitored both on the ground and by plane in 1972 and reached only slightly elevated levels. The key appears to have been that the Earth passed outside the comet's orbit, while the dust appears to preferentially evolve inside Giacobini-Zinner's orbit.*

   The key question, then, is where does the dust evolve to about P/Swift-Tuttle? It is presently an unanswerable question and so anything might happen this August, but consider this fact; P/Swift-Tuttle has had an orbit outside the Earth's for more than a millennium and yet, except for the uncertainly high levels in 1861–1863, only the passage in 826 had very high activity noted within a decade of the comets perihelion time. The other 7 perihelion passages show no sign of marked activity increases in the ancient records, though increased activity of streams such as the Leonids are extensively documented.

In view of this mixed evidence we can only repeat what Paul Roggemans said elsewhere in this issue: it would be foolish not to prepare for storm-like activity or not to point the attention of the media to this distinct possibility, but at the same time we should remain cautious and make clear to everybody that meteor storms cannot be predicted. Even if storm-like activity does not occur, we should not be too disappointed for, after all, this would only confirm how little we actually know about the supposedly best-known meteor shower and emphasize the need for much more extensive observations.

Another point which has yet to be made is the archiving of observations should a meteor storm occur. It is most important that observers keep special track of the data they collect, both visually and photographically as these will possibly be the subject for scrutiny for many years to come. So do not let the 1993 Perseids overwhelm you (should it become a storm) to the point where no useful data is taken—otherwise our ability to predict such events in the future will not grow in any significant degree. The message is enjoy the event, but be well prepared: read again the guidelines given by Jeff Wood, Malcolm Currie, Ralf Koschack and Robert Hawkes, and Paul Roggemans and do implement them in your observations.

Finally, no matter how the Perseids will perform, think also about WGN *when all the fuss is over! We hope to receive your observational report for inclusion in the Journal and—above all—your photographs of th event! As already said so often, receiving enough photographs to produce a front cover every two months is a lingering problem; it is our hope that the 1993 Perseids will at least solve this problem!*

Marc Gyssens and Peter Brown

In the summer of 1992, Dr. Kidger submitted an article discussing the prospects for a return of Comet P/Swift-Tuttle. By Murphy's Law, P/Swift-Tuttle returned by the time the author had just completed a revision of his article. As the article contained much interesting historical and factual information, I suggested to Dr. Kidger that he rewrite the article in a retrospective style, in light of the comet's rediscovery. The result of this effort follows below; due to space limitations though, the article had to be significantly shortened. (Ed.)

Comet P/Swift-Tuttle and the Perseids

Mark Kidger, Astrophysical Institute of the Canaries

From mid-1991 until its eventual recovery, comet observers have been waiting for the return of Comet P/Swift-Tuttle. The evidence surrounding its possible return was highly contradictory: on the one hand, Perseid activity over the last few years seemed to suggest that the comet was approaching; on the other hand, its return was also awaited in 1981 (partially on the basis of similar evidence from the Perseids), yet it did not appear. The Perseid outbursts witnessed in 1991 and 1992 greatly strengthened the case for Comet P/Swift-Tuttle being nearby, but did not in any way prove it. What clues can the Perseids provide to us about Comet P/Swift-Tuttle? In this article we discuss in detail the "Perseid connection" with Comet P/Swift-Tuttle from a historical view point and also in light of the 1992-1993 return.

1. Comet P/Swift-Tuttle

On June 16, 1862, the American comet hunter Lewis Swift discovered a new comet in the constellation of Camelopardus. Three nights later, Horace Tuttle also located the same object at Harvard Observatory. As a result the comet was named "Swift-Tuttle." Both discoverers had a distinguished comet hunting history. Lewis Swift discovered 13 comets, although, with the exception of Comet P/Swift-Tuttle, none was especially important. This number of discoveries, however, has been surpassed by very few people. Horace Tuttle discovered 10 comets, again a more than respectable total, amongst which P/Swift-Tuttle and P/Tempel-Tuttle, both parent comets of a major meteor stream (the Perseids and Leonids respectively), were the most important.[1]

The comet passed perihelion on August 23 at 0.9626 AU from the Sun. At the start of September the magnitude peaked at 2.5 according to later research by Kresák and Kresáková [1]. At this time the comet also developed a prominent tail some 30° long. More curiously, it also developed a prominent anti-tail half a degree long. However, after its closest approach to the Earth, Comet P/Swift-Tuttle faded rapidly and was last seen on October 31. From the light curve it is possible to estimate that the comet's absolute magnitude was 4.0 [2]. This absolute magnitude is exceptional for a periodic comet: only Comet P/Schwassmann-Wachmann 1, with an absolute magnitude of 3.1 is intrinsically brighter, whilest Comet P/Halley has an absolute magnitude very similar to that of P/Swift-Tuttle [2]. Hence, presumably, the size of the nucleus of the comet is probably similar to that of Halley and, thus, very large compared to other periodic comets.

The controversial nature of the orbit of Comet P/Swift-Tuttle has been much commented upon. The observations of the comet lasted for a total of three and a half months, although the arc which was observed astrometrically was shorter, being from July 22 to October 22. However, over this period some 212 positional measurements were made [3]. The result is that the database is adequate to calculate a moderately accurate orbit, but insufficient for a really precise calculation. It is well known that the estimated period from the observations was 119.6 years, though in the fourth edition of the *Catalogue of Cometary Orbits* published by Brian Marsden in 1982, the

[1] Another of his comet discoveries, P/Tuttle, is also the parent comet of a meteor shower (the Ursids).

period is given as approximately 120 years with a possible error of 2 years [3]. Thus Comet P/Swift-Tuttle should have reappeared at the end of 1982. However, it failed to return.

2. Previous returns of Comet Swift-Tuttle?

There were two obvious possible explanations as to why Comet P/Swift-Tuttle was not seen in 1982: *(i)* the comet did return, but was not seen, or alternatively, *(ii)* that the calculated orbit is incorrect.

Brian Marsden is one of the leading cometary scientists to have studied the possibility of a simple error in the calculation of the orbit. Marsden studied the ephemerides of historical comets to see if any of them could conceivably have been a previous apparition of Comet P/Swift-Tuttle [4]. One hundred and twenty years prior to 1862 was 1742: was there a comet with a similar orbit to P/Swift-Tuttle which was observed around 1742? There was just one comet observed in 1742, but its orbit was completely different to that of Swift-Tuttle and, as its orbit was based on 100 observations there is no doubt that it was not P/Swift-Tuttle.

If we look at the years prior to and before 1742 we find that there are just two comets that look remotely similar to the orbit that we are looking for: these are 1737 II and 1768. Marsden suggested as far back ago as 1973 that the comet of 1737 is a prior apparition of Comet P/Swift-Tuttle. A similar conclusion was reached seventy years earlier by Lynn [5], although less rigorously. In Table 1 the orbit of Comet 1737 II is compared with that of Swift-Tuttle.

Table 1 – The orbits of Comets 1862 III (P/Swift-Tuttle) and 1737 II (P/Kegler) (Eq. 1950.0). "Obs" is the number of astrometric observations which were made. The name of Comet 1737 II is often spelled "Kogler," although "Kegler" is now the standard spelling which is adopted in catalogues.

Apparition	Comet 1862 III	Comet 1737 II
T	August 23.4097	June 03.53
q	0.962638	0.8381
e	0.960427	1.0
ω	152°7660	129°96
Ω	138°6849	135°99
i	113°5596	063°84
Obs	212	8

As can be seen from Table 1, there are more differences than similarities between the orbit of Comet P/Swift-Tuttle and that of the comet of 1737. However, one must bear in mind that Comet P/Kegler was only observed for 8 days (July 2–9, 1737). Clearly the orbit of Comet Kegler is very uncertain, especially when we bear in mind the lack of precision of the astrometric observations of the 18th century. The longitude of the node of Comet P/Swift-Tuttle and of Comet P/Kegler are in good agreement and the perihelion distance is fairly similar, but the inclination of the two orbits is very different. However, the scarce astrometric data available for Comet 1737 II is hardly sufficient to define the inclination with exactitude. One other piece of information that favors the identification of the comet of 1737 with Comet P/Swift-Tuttle is that its absolute magnitude was 4.8 [2] ... within the error limits this value is identical to that of Comet P/Swift-Tuttle.

There is no record of any comet observed at the start of the 17th century which might have been a previous return of this same object. Neither is there evidence of a possible return at the end of the 15th Century. Brian Marsden suggested that there might have been a possible return in 1348 [4], although there is no comet recorded for that year in the Catalogue of Comets. Despite this, there was a curious observation made from close to Paris in August 1348, although it might have been nothing more than a bolide [6]. There was a comet observed between July 31 and August 3 of 1345 which might conceivably have been a previous return of P/Swift-Tuttle, though Brian Marsden notes [6] that *as far as I can understand the observations, it seems that the comet of 1345 came down from the Draco/Ursa Major region towards Gemini and Orion, and it seems a little hard to make this agree with a radiant in Perseus.* Either way, the average period over these five centuries is close to 130 years, much greater than the 119.6 years previously supposed.

On linking the observation of Comets P/Kegler and P/Swift-Tuttle, Brian Marsden came up with a provisional perihelion date of November 25, 1992, with a possible error of two months [7,8,9]. However, he assured me (the weekend before the 1992 Perseid maximum) that *nobody will be more surprised than me to see Swift-Tuttle return at the end of this year.* This last comment is very revealing! It is hard to recall how uncertain the prediction of the 1992 return seemed to be until P/Swift-Tuttle was recovered in late September. The Japanese comet hunter Kiuchi was the first to spot the comet, with 25 × 150 binoculars, at $18^{\mathrm{h}}10^{\mathrm{m}}$ UT on September 26, as a magnitude 11.5 object in Ursa Major. The identification with P/Swift-Tuttle was suspected immediately, but not confirmed for another 24 hours. The initial estimation of the date of perihelion was early December (very rapidly revised to the 13th), just 18 days later than Marsden's prediction [10].

One extremely worrying point is the question of just why a periodic comet with an absolute magnitude similar to that of P/Halley should have been seen so infrequently, when P/Halley has been seen with the naked eye for about 30 consecutive returns since 240 B.C. and was probably also observed in the winter of 1159-1158 B.C. What is more, only in 164 B.C. and in the even fainter 1986 return has P/Halley failed to get brighter than magnitude 2 (i.e., easy naked eye visibility) [11,12].

The reason appears to be P/Swift-Tuttle's orbit, which only permits a reasonably close pass by the Earth ($\Delta < 0.5$ AU) if perihelion occurs between June and September, whilest P/Halley has never had a minimum geocentric distance greater than 0.5 AU in any of its historical apparitions. Numerous studies have been made of the history of the orbit of Comet P/Swift-Tuttle over the last two thousand years [13,14]. These have shown quite conclusively that there have been no close approaches of the comet to the Earth between 188 A.D. and 1862 (even the 1737 apparition had a minimum geocentric distance of 0.55 AU and an estimated maximum brightness of $m_1 = 4.0$).

It is obvious that, in 188 A.D., P/Swift-Tuttle did make a close approach to the Earth (closer than 0.23 AU) which perturbed the orbit significantly. With so few observations available, it is not possible to model the non-gravitational parameters with sufficient accuracy to determine just how close an approach was made to the Earth in 188 A.D. Assuming a significantly closer approach than 0.23 AU in 188 A.D. allows the comet to make a comparatively close approach in 68 B.C. too and fit, if only approximately, the observations of a comet seen in that year.

Looking forward in time the situation is more favorable: the 1737 apparition was the first of a sequence of moderately and very close approaches to the Earth allowing P/Swift-Tuttle to become a bright or very bright object in 1862 and in both of its next two apparitions: 2126 and 2261. In 2126, it may even reach negative magnitude with a close approach to the Earth approximately 19 days later, on July 30. There was some unfortunate speculation [15] that a collision with the Earth might occur on August 14, 2126; this would have required the comet to pass perihelion during a two hundred second long window on July 26, 2126, something that did not seem very plausible statistically [16] and has since been ruled out definitively [14].

3. Comet P/Swift-Tuttle and the Perseids

One way of getting more information about the comet lies with the Perseids. In 1862, the Italian Giovanni Schiaparelli (later better known for his observations of Martian canals) realized that the orbit of Comet P/Swift-Tuttle was very similar to that of the Perseids [17]. This was the first time that a clear relationship was demonstrated between a comet and a meteor shower.

The first observations of the Perseids date back to the year 36 A.D., when the Chinese noticed a shower coming from Perseus on July 17, almost a month earlier than the current date of maximum. Later, at the end of July 714 A.D., the Chinese again noticed the existence of the shower. Despite the fact that there are many records of the Perseids after this date, made from China, Korea, Japan, and Europe, the annual nature of the shower was not realized until 1836.

Just what the exact structure of the Perseid radiant is in terms of sub-radiants has been a highly controversial topic which it is not the purpose of this work to judge. At present, the principal radiant is accepted to be at $\alpha = 3^h04^m$ and $\delta = +58°$, in the extreme north of the constellation and almost exactly between Perseus and Cassiopea. However, when the radiant was formally identified for the first time by the American Professor John Locke [18], on August 8, 1834, it was close to the star Algol... a long way from the present position (see Table 2). Some Perseids can still be seen radiating from this point (my own observations since 1975 suggest that at least the Algol radiant of the several proposed sub-radiants presents significant activity from year to year), but they are a small minority of the total. Two years later the Belgian, Quetelet, announced for the first time [19] that the shower was annual, the first annual shower to be recognized, whilest two years after this, E.C. Herrick also concluded independently [20], that the Perseids were an annual shower.

Table 2 – The change in the position and date of maximum of the Perseids over the last two centuries. Although the right ascension has stayed constant, both the date of maximum and the declination of the radiant have shown a considerable change. References: 1834 [18]; 1890 [21]; 1990 [22].

Date of maximum	α	δ	Year
August 09	03^h06^m	+41°	1834
August 10	03^h04^m	+57°	1890
August 12.85	03^h04^m	+58°	1990

Evidence that there was important activity from the south of Perseus during the last century, a long way from the current radiant, is provided by a surviving plot of observations of the Perseids by William Denning, made in an unspecified year of the latter half of the last century and plotted in gnomonic projection [23]. The observing method described by Denning is virtually identical to that used by the most advanced meteor observers now. The observations of the radiant at $\alpha = 02^h56^m$ and $\delta = +25°$ were presented by Denning as a typical example of a meteor radiant and the radiant position is very well defined although even further to the south than Locke's position. However, the right ascension and dates of activity are the same for all three radiants, though they lie along a wide range of declination. Interestingly, Denning does not refer to this shower as the Perseids, but rather describes it as a *shower observed ... from Musca*; Musca Borealis being a now defunct constellation formed from some faint stars in Aries.

Even though it is now felt, with good reason, that Denning was somewhat over-generous in his catalogue of radiants in listing no less than 4367 individual radiants, based on some 15 000 meteors recorded in 20 years of observations, the evidence in this case is pretty convincing (see Figure 1). Despite his occasional serious errors (e.g., a firm belief in stationary radiants), Denning was a fine observer and his work is often greatly underestimated by contemporary meteor researchers.

However, if all the proposed sub-radiants are genuine, this is a curious and perhaps highly significant fact. It is also reasonable to suppose that the 1862 apparition of P/Swift-Tuttle may have significantly changed the distribution of activity so that other sub-radiants may have been significantly more active in the past than at present. Some doubt has been expressed [24] as to whether or not this apparent change reflects a real displacement of the radiant in declination, or simply the inadequacy of radiant determination methods in the middle of the last century.

However, a difference of 16° degrees is so large that it can hardly be imagined that it is due to observational error.[2]

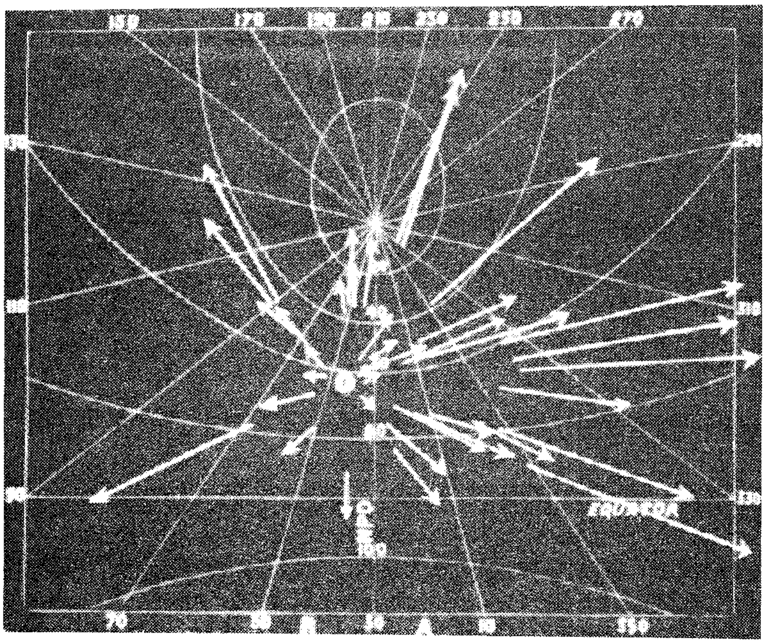


Figure 1 – Perseid observations by Denning.

The popular name for the Perseids, "The Tears of Saint Lawrence," is due to the date of maximum in the last century. The day of the festival of Saint Lawrence is August 10, but the shower occurs approximately 1.4 days later each century [25] as it follows the siderial and not the tropical (calendar) year, thus the date of maximum observed by the Chinese and the present one do not agree.

In 1861, 1862, and 1863, the maximum of the Perseids was especially prominent [6]. It has also been reported [26] that *the extraordinary Perseid shower of 1862 occurred at the time when P/Swift-Tuttle was a naked eye object*, the implication being of an extraordinarily high ZHR (over 250?) in 1862. In 1866, the Director of Brera observatory in Milan began some important research in the new science of meteoritics. Often one does not award sufficient merit to the huge amount of work that Giovanni Virginio Schiaparelli did to develop a scientific base for the study of meteors. Schiaparelli developed a mathematical formulation for the calculation of the orbit of a shower from observations of the position of the radiant and to calculate the velocity of the meteors from the observed rate of activity. Starting from the well-determined position of the radiant, Schiaparelli was able to calculate a very good orbit. At once he realized [27] that the result was very similar to the orbit of Comet 1862 III P/Swift-Tuttle, calculated by Theodor von Oppolzer [28]. Schiaparelli concluded correctly that the meteors came from the comet. This was the first time that the link was proven between a comet and a shower: later the Leonid storm in the same year of 1866 and the Bielid storm in 1872 showed once and for all that Schiaparelli was right.

There are two very interesting points in the link between the Perseids and P/Swift-Tuttle. The first is the small mystery of the change in the radiant position between 1834 (when it was

[2] *I must, however, stress that the very early meteor observers worked under fairly primitive conditions and used inadequate tools (such as celestial globes) compared to our standards, leading to large errors. Radiant determinations by Packendorf in 1837 and Erman in 1839 on August 9 and 10 yield declinations varying between 50° and 57° and right ascensions between* 2^h28^m *and* 3^h00^m*. The declinations obtained by these and other astronomers in the 1830s and 1840s are more consistent with the present-day values than with those of Locke. As far as Denning is concerned, it must be emphasized that his active period was* past *1862. It is also very questionable whether a radiant 30° away from the main Perseid radiant can still refer to this meteor stream. Finally, determinations of sub-radiants based on visual observations often are not very reliable.* (Ed.)

identified) and 1890, discussed above. The second is the apparent increase in the activity of the Perseids one year before and after the previous apparition of Comet P/Swift-Tuttle. This makes one think that the stream material may concentrate close to the comet in its orbit. This is a typical characteristic of a comparatively young shower. It was Urbain Le Verrier who, in 1867, explained why the Leonids did not give an intense shower every year: gravitational perturbations by the planets (principally Jupiter) are logically going to disperse the stream material all around the orbit over the course of thousands of years [29]. In the case of the Perseids, the fact that we see a shower of fairly constant intensity every year means that that the stream is an old one (i.e., the material has been dispersed all round the orbit of the comet) but, an increase in the activity coincident with the return to perihelion of the parent comet indicates, at very least, that there is still a higher density of material concentrated close to the comet than in the more distant parts of the orbit.

4. Perseid activity and the return of Comet P/Swift-Tuttle

Even before the return of P/Swift-Tuttle, the original orbit calculated by von Oppolzer was rapidly outdated by Hayn, of the University of Göttingen (in 1889) [30] and, later, by Marsden and Sekanina (in 1973) [4]. Yet, while the orbit was revised and recalculated, the errors remained the same and the error quoted by Marsden and Sekanina for perihelion time was still two years. One of the biggest problems was the fact that the October 1862 observations showed big deviations from the orbit calculated from those made during the period June–September. This could be due to systematic observational errors, or to a sudden change in the non-gravitational parameters. Even now, the problem of the large deviation of the October 1862 observations has not been solved.

Comet P/Swift-Tuttle passed perihelion in 1862.6; thus, with a period of 119.6 years, it was supposed that it should return in 1982.2, that is, in the spring of 1982. The normal level of Perseid activity is 60–70 per hour but, in 1980 and 1981 the ZHR of the shower increased until it had passed well over 100 per hour. Everything seemed to suggest that Comet P/Swift-Tuttle was approaching. However, it was not seen, and by the mid-80s the activity of the Perseids had returned to its long- term level.

In 1991, something happened which was completely unexpected by the majority of observers but had, in fact, been tentatively predicted some months in advance [31]: the activity of the Perseids started to increase again and, this time, the increase was much greater than in 1980 and 1981, with an outburst with a ZHR in the order of 500 per hour. [32,33]

The observations made in 1992 are very uncertain. The information received from observers in Hungary and the Netherlands [34], Japan, and, to a certain degree supported by Swiss observers [6], indicate a very high level of activity for an hour or less. The first report was from a group of Hungarians who reported intense activity during twilight around 19^h00^m UT on August 11, dropping to normal before 20^h15^m UT. Various days later, after these results had been published on *IAU Circular* 5586, a Japanese group, observing with a naked eye limit of 3, reported seeing 200 meteors from 19^h00–20^h00^m UT. Radio observations suggest a very intense maximum between 18^h45^m and 19^h35^m UT, perhaps even more so than in 1991 [35]. Herman Mikuz also kindly forwarded me data [36] from groups at Ljubljana (Slovenia) and Istria (Croatia). Both saw high levels of activity on the evening of August 11. Their findings are compatible with most other groups apart from some of the higher Japanese estimates. Apparently, an outburst with a ZHR of the order of 500 or more occurred.

The activity observed later during the night of August 11-12 was consistent with a ZHR of around or less than 100 [37] but, as in 1990, the full moon and consequently bad conditions for observing do not allow anything to be concluded with certainty, mainly because the estimated naked-eye limiting magnitudes are unreliable. The following night, activity remained high as is suggested by observations communicated by Rafael Barrena [38].

Further data were received from Slovenia [39] and from Brian Marsden after "finishing" this article, along with comments on Norwegian observations [6] and further results from Tenerife [36]. They mainly confirm the general picture and predict the time of maximum in 1993 as August 12.05, an almost optimum hour for European observers.

5. A possible Perseid storm in 1993?

There has already been some suggestion that there may be a Perseid storm in 1993. This suggestion is based on somewhat slender evidence though. Whilest showers such as the Leonids, Bielids and Giacobinids have given major storm activity[3], there is no conclusive evidence that the Perseids have ever passed sub-storm level. Two major questions are raised: *(i)* are the Perseids potentially able to give a return at storm or minor storm level, and *(ii)* is a storm most likely to be seen in front of the comet, or after its pass?

In general, one might expect the strongest concentration of cometary dust are found behind the comet because, logically enough, this material lags the comet due to the influence of radiation pressure. Comparing the Perseids with the Leonids and that the Giacobinids, we find that indeed the Leonids only give storms after the comet has passed its node and major Giacobinid activity also occurs when the Earth crosses the orbit after the comet has passed, but lesser levels of activity have been recorded when the Earth crossed the orbit in front of the comet. The Bielid storm of 1872, however, occurred in front of the comet which is also the case for strong Bielid activity on other occasions.[4] I originally felt that, by analogy with the Leonids, the greatest probability of a Perseid storm would be in 1993, after the comet's pass, possibly just reaching minor storm level. Further research though leads me to believe that it is more likely that the Perseid maximum in 1993 will not be as strong as in 1992, although still at sub-storm level. The only reliable evidence of possible storm-like Perseid activity comes from 1861–1863 and 1991–1992. In P/Swift-Tuttle's 1862 return the strongest Perseid activity appears to have occurred slightly in front of the comet.[5] The strongest Perseid activity to date in the present apparition has also occurred slightly in front of the comet. However, the evidence is simply too scanty to be able to make a definitive prediction.

Another issue pointed out to me by Luis Bellot is the recent controversy in *WGN* [40] about Perseid periodicity. The data presented by Grishchenyuk and Levina give an average period between strong showers of 11.78 years, so nearly coincident with the 11.86 year orbital period of Jupiter that the difference is insignificant. It is almost certain that the effect, if genuine, occurs due to the influence of Jupiter and this is supported by a 1:11 mean orbit resonance of P/Swift-Tuttle with Jupiter [41]. As in the case of the asteroid belt, regions of the Perseid orbit subject to repeated perturbations will be cleared and the material concentrated in other regions. Despite the high inclination of the orbit of the Perseids the perturbations by Jupiter are still the dominant source of gravitational perturbations in the evolution of the distribution of material. The maximum of this cycle should have been in 1991.98, which may well explain why there was a strong Perseid return in 1991 which did not coincide with the node of Swift-Tuttle. Dependent on the spread of the material, this may have contributed in some degree to the good displays of 1981 (predicted maximum 1980.20) and 1992. The next maximum may be expected (if the data is correct), in the year 2003 (predicted maximum 2003.75 $\pm$ 23).

The best solution to the controversy about the periodicity would be to subject all 20th century Perseid ZHR data to a periodicity search, thus there would be no possibility that a false periodicity could be generated by accidental selection. This is unlikely to be practical due to the differences in both observing method and data reduction.

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[3] I would suggest the following definitions of the various levels of storm activity: $200 < \mathrm{ZHR} < 1000$: sub-storm level; $1000 < \mathrm{ZHR} < 5000$: minor-storm level; $\mathrm{ZHR} > 5000$: major-storm level.

[4] *It should be emphasized though that Comet Biela had already disintegrated by 1872!* (Ed.)

[5] *There are a few sources however (see the article by Rao in this issue) suggesting storm-like activity in 1863. If this were the case it nevertheless remains puzzling why no more evidence of it exists.* (Ed.)

One thing is beyond all possible doubt: a shower as strong as that seen by the Japanese and Hawaiians in 1991 and by different observers in 1992 can only be due to a "cometary" shower (like the Leonids, the Bielids, the Pons-Winneckids, or the Giacobinids) whose activity depends on the position of the comet in its orbit and the Earth's exact distance from the center of the tube of material ejected by the comet. The exact time of the outburst in 1991, however, does not agree with the exact time of the Earth's closest approach to Comet P/Swift-Tuttle, something that misled a lot of people. However, the solar longitude of the possible 1992 storm agrees perfectly with the comet's descending node, which is pretty conclusive.

One can however still wonder about the small but important change in the solar longitude of the outburst between 1991 and 1992. The reason for that is not obvious. Each year that passes brings us closer to the comet and to the material more recently expelled from it ("recent" meaning that it has probably been expelled in the last few centuries, although we have still not encountered the material released by the comet in its 1862 perihelion pass). Perhaps the change in solar longitude is due to the fact that we were still approaching the present position of the comet.

The activity curve of the Perseids in 1991 and, above all, the unusual strongly non-power law magnitude distribution [38,39], are highly suggestive that what we were classifying globally as the Perseids really consisted of two, very different showers. What can be termed the standard stream, or annual shower, showed its standard activity curve, with a fairly broad maximum preceded by a slow rise, although this maximum was rather higher than usual. Superimposed on top we also saw a shower with characteristics typical of what we can term a "cometary" shower. The main characteristic of such showers is their short duration and very variable intensity according to the position of the comet in its orbit.

The behavior of the Perseids in 1993 will be crucial to our understanding of what is happening. The peak activity could be seen in 1993, making that which has been observed in 1991 and 1992 no more than a small sideshow. It is also very possible that the strongest activity actually occurred in 1992 though. There is also another important historical datum in this respect: the years of especially strong Perseid maxima do not coincide with the years when we would expect Comet P/Swift-Tuttle to have returned to perihelion [6]. As such, the link between the comet and very strong Perseid showers, although present, is not yet completely clear.

Further ahead than 1993, the most probable effects are going to be a reduction of the ZHR and a progressive weakening of the peak corresponding to the present outbursts, presumably disappearing by 1997. The continued observation of this peak before the "traditional" peak of activity past that year would again raise doubts about its exact nature.

Acknowledgements

I would like to thank Brian Marsden for answering my questions and clearing up my doubts and Luis Bellot for debating the topic of Comet P/Swift-Tuttle and the Perseids with me and both of them for giving me the benefit of their thoughts and constructive criticism of my analysis. I would also like to thank Herman Mikuz for his invaluable aid in compiling Central European observations and many people who have contributed directly or indirectly either by passing me their observations, or by passing them through a third party.

Finally, I should thank Marc Gyssens for his very detailed comments on the first two versions of this article and for suggesting its restructuring in the light of the recovery of Swift-Tuttle, soon after the first version was written (and well before it could have been published), an event which had the effect of dropping a bomb on the original aim of this study.

I started to write the original version of this article on August 12, 1992, as part of the research for a book that I am writing and is due to be published in mid-1993.

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Radio Observations of Perseid Meteor Shower Outbursts in 1991 and 1992

Chikara Shimoda, Kazuhiro Suzuki, and Kouji Maeda

Strong Perseid activity was detected in Japan using FM radio observations in both 1991 and 1992. In those years, there were double peaks in the strong activity. The two peaks for the 1991 Perseids correspond to solar longitudes $\lambda_\odot = 139^\circ.55$ and $\lambda_\odot = 139^\circ.57$ (eq. 2000.0), with the outburst lasting for about 90 minutes. The two peaks for the 1992 Perseids correspond to solar longitudes $\lambda_\odot = 139^\circ.45$ and $\lambda_\odot = 139^\circ.48$ (eq. 2000.0), with the outburst lasting for about 120 minutes. Hence, the solar longitude of the outburst decreased by about $0^\circ.10$ from 1991 to 1992.

1. Introduction

The Perseids are one of the most famous meteor showers producing about 20–30 meteors per hour with the naked eye on August 12-13 every year with remarkable constancy. Comet 1862 III, P/Swift-Tuttle, is the parent comet of this meteor shower, and was predicted to return to the perihelion around 1981.

Though somewhat stronger Perseid activity was observed around 1980, Comet P/Swift-Tuttle failed to return in the early 1980s. From 1982 to 1990, the Perseids were characterized by normal activity. Observations of strong Perseid activity were obtained in both 1991 and 1992 [1], and the parent comet, P/Swift-Tuttle, was finally re-discovered in September 1992, by a Japanese comet hunter.

2. Instruments and methods of observations

In Japan, meteor radio observations using the FM broadcast band have been carried out since 1970 [2]. The method of observation is to count the meteor rate by utilizing the fact that ionized meteor columns reflect VHF waves.

Using an ordinary FM tuner, we can receive meteor echoes. There are nearly 200 FM radio stations operating in Japan; they broadcast in the frequency band 76–90 MHz. Adjusting an FM tuner to a distant FM radio station which is not usually received, we count the number of meteors by listening for momentary enhancements of the FM broadcasting signal from a distant station. The aerial used for this work is a Yagi antenna. It is ordinarily directed to the zenith. Meteor echoes are recorded on a chart by using a pen-recorder where the echoes are visible as a signal increase, or are simply counted.

3. Results of observations

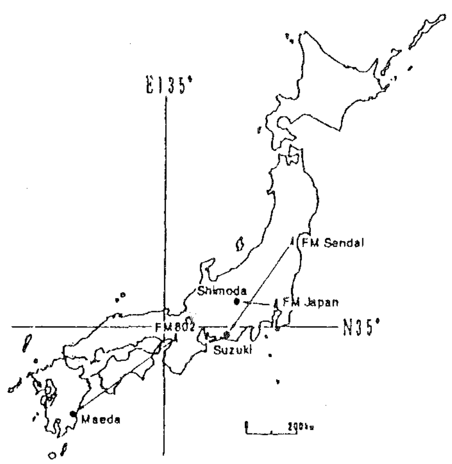

Figure 1 – Geometry of transmitting versus receiving stations

We observed the 1991 and 1992 Perseids by FM radio techniques as described above.

Table 1 and Figure 1 show the observers and observational parameters for this research. Figure 2 shows the evolution of the hourly rates of the *total* number of observed meteor echoes around the outbursts of the Perseids on August 12, 1991, and August 11, 1992. Figure 3 shows the evolution of the hourly rates of *long-duration* meteor echoes. Here, "long duration" is defined as lasting more than 3–10 seconds. The hourly rates were derived by a 15-minute step method. The results of the hourly rates of meteor echoes observed during August 10–13 in 1991 and 1992 are shown in Figure 4.

Table 1 – Observers and observational parameters for this radio research of the Perseid meteor shower. The following abbreviations are used: C, output from center-tuning meter; R, recorded with pen-recorder; SN, output from signal meter; Y3, 3-element Yagi; Y5, 5-element Yagi; Z, directed to zenith.

Observer	Location of receiv. stn.	Transmitting station	Receiv. and record. meth.	Aerial (direction)
Shimoda C.	Nagono Pref. $36^{\circ}.1$ N, $137^{\circ}.9$ E	FM Japan (80.7 MHz)	C R	Y5 (Z)
Suzuki K.	Aichi Pref. $34^{\circ}.8$ N, $137^{\circ}.3$ E	FM Sendai (77.1 MHz)	SN R	Y5 (Z)
Maeda K.	Miyazaki Pref. $31^{\circ}.9$ N, $131^{\circ}.4$ E	FM 802 (80.2 MHz)	C R	Y3 (Z)

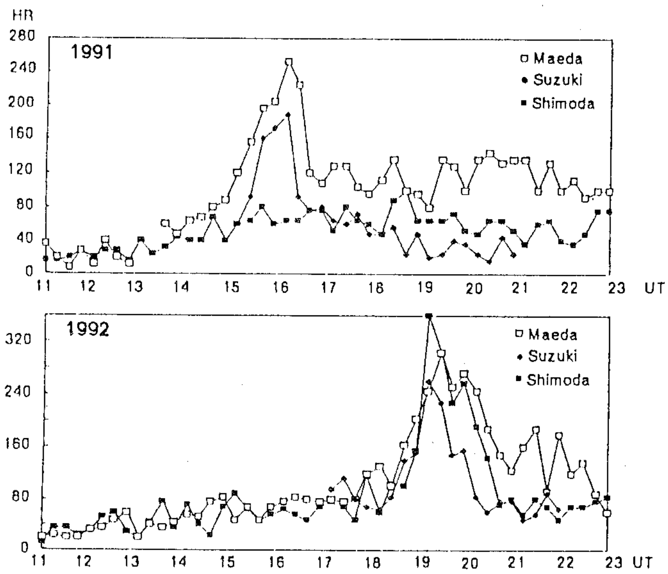

Figure 2 – Evolution of the hourly rates of the *total* number of observed meteor echoes around the outbursts of the 1991 and 1992 Perseids. The hourly rates were derived by a 15-minute step method.

4. Conclusions

Time of maximum activity

The outburst of the 1991 Perseids had two peaks (see Figures 2 and 3), the first one occurring at $\lambda_\odot = 139^{\circ}.55$ (August 12, 15^h40^m UT) and the second one at $\lambda_\odot = 139^{\circ}.57$ (August 12, 16^h10^m UT). At this time, the elevation of the Perseid radiant was about 40°. The outburst of the 1992 Perseids also had two peaks (see Figures 2 and 3), the first one occurring at $\lambda_\odot = 139^{\circ}.45$ (August 11, 19^h15^m UT), and the second one at $\lambda_\odot = 139^{\circ}.48$ (August 11, 19^h55^m UT). At this time the elevation of the radiant was about 65°. The solar longitude of the outburst in 1992 decreased by about $0^{\circ}.10$ compared to the outburst in 1991. (Eq. 2000.0.)

Duration of strong activity

Both in 1991 and 1992, the strongest activity of the Perseids occurred at a solar longitude different from that of the regular shower maximum. The outbursts of 1991 and of 1992 seemed to have been "added" to the common activity of the Perseids. According to Figure 2, the remarkably strong activity of the 1991 Perseids lasted for 90 minutes (from 15^h00^m through to 16^h30^m UT) on August 12. The strong activity of the 1992 Perseids lasted for 120 minutes (from 18^h30^m

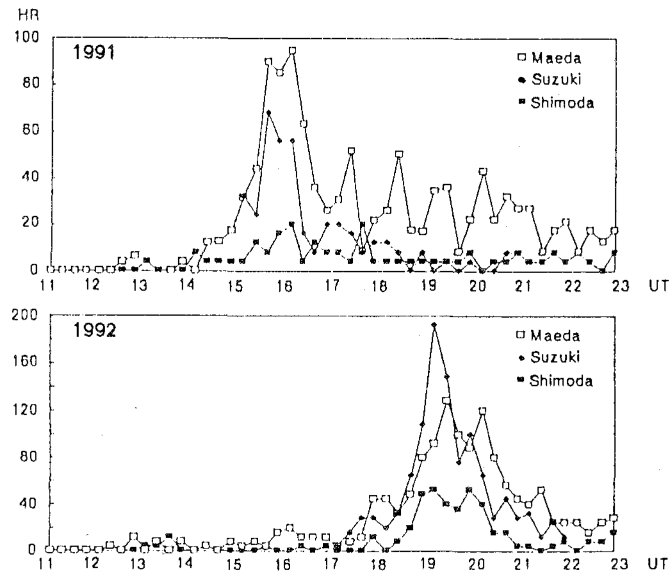

Figure 3 – Evolution of the hourly rates of *long-duration* meteor echoes around the outburst of the 1991 and 1992 Perseids. The hourly rates were derived by a 15-minute step method. "Long duration" is defined as lasting longer than 3–10 seconds.

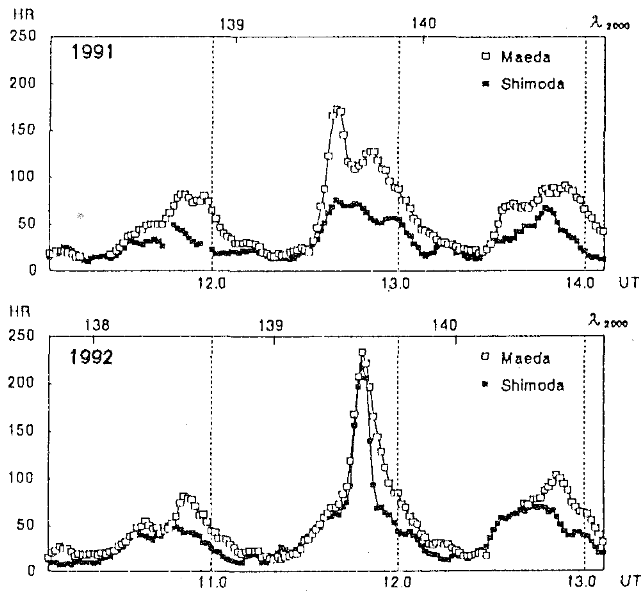

Figure 4 – Evolution of the hourly rates of the meteor echoes observed during August 10–13 in 1991 and 1992.

through to 20^h30^m UT) on August 11. Hence, the duration of the outburst in 1991 is estimated to have been about 30 minutes shorter than in 1992.

Hourly rate of meteor echoes at maximum activity

The maximum hourly rates of meteor echoes during the outburst of the Perseids was 3 times higher than usual in 1991, and about 3–5 times higher than usual in 1992.

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Observational Results

New Minor Shower in June?

José M. Trigo

This article refers to observations of a meteor shower, detected during an intensive watch of the June Lyrids in 1988 and 1990. The observations were carried out by members of the Spanish Meteor Society and collaborators of the Agrupación Astronómica of Tenerife.

1. Introduction

There exist only a few references to this newly observed radiant, yet its activity is mentioned in the works of *NAPOMS* in Australia. In [1], members of *NAPOMS* detected this radiant at $\alpha = 288°$ and $\delta = -05°$. They named the radiant the λ-*Aquilids* and determined its activity period as June 9–18.

During the observations of the June Lyrids that were carried out by Spanish observers in 1988 and 1990, the number of meteors detected from this region was high. For example, of the 122 meteors seen on June 17, 1990, 15% were λ-Aquilids.

We tried to identify the λ-Aquilids very conscientiously, in order to avoid including the high sporadic and Scorpid/Sagitarid activity with the new radiant's activity. The method applied by the author and Mark Kidger (Astrophysical Institute of the Canaries) is explained in [2]. The visual characteristics of this radiant are very important to be able to distinguish these meteors.

2. General results

During 1988, activity of this radiant was detected by the author and Vicente Soldevilla on the night of June 11-12, but the activity was very low. In 1990 the author received observations from the Canary Islands which gave supporting evidence for the radiant's existence. The ZHR obtained by this group on June 17, 1990, is 3–4 meteors, but the relative activity was 15%! Activity from the radiant was also registered by this group on June 24, 1990, but the ZHR was small. The relative activity on this night was 4%. The participating observers were

Javier Alonso, José Antonio Cáceres, David Hernández, Daniel Verde, Victor González, Dulce Plasencia, and Mark Kidger.

The velocity of the meteors was moderate, and the magnitude distribution of the meteors observed in 1998 and 1990 was as shown in Table 1.

Table 1 – Magnitude distribution of the λ-Aquilids in 1988 and 1990.

Magnitude	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}_{6.5}$
Number	2	0	4	5	4	9	4	28	2.85

The results obtained for the radiant position in visual observations were $\alpha = 282°$ and $\delta = -05°$ (June 11, 1988, 4 meteors one of which was stationary), and $\alpha = 295°$ and $\delta = -02°$ (June 17, 1990, 19 meteors). Data obtained during three radar studies, conducted during the 1960s, support the existence of this stream. The observations, mentioned in [3], are shown in Table 2. Sekanina indicated a maximum of the shower on June 17.5 in the year 1969!

Table 2 – Radar detections of the June Aquilids.

Period	α	δ	Author(s), nr. met.
June 13–19, 1961	293.°9	−08.°4	Nilsson, 4
June 1969	289°	−06°	Gartrell and Elford, 13
June 2–July 2, 1969	297.°1	−07.°1	Sekanina, 35

I would like to ask the *IMO*'s visual and radio observers to monitor this region during the next years.

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The 1992 η-Aquarids and Orionids from Rumania

Valentin Grigore

The results of two meteor expeditions organized by the author with his colleagues—the first such expeditions in Rumania—are presented.

1. The 1992 η-Aquarids

This expedition took place in the Carpathian Mountains (Piatra Arsá, $\lambda = 25°29'24''$ E, $\varphi = 45°22'42''$ N) at an altitude of 1950 m, between April 30 and May 3, 1992. The sky conditions were extraordinary. The mean limiting magnitude was 6.5, and sometimes even better (6.8 on May 1-2). Temperatures were $-2°$ C to $-5°$ C in the morning hours. On May 1-2, there was a strong wind.

The participants were

> Valentin Grigore (GRIVA, the organizer, from Tirgoviste), Adrian Sava (SAVAD, "Sage" Association, from Bucharest), Exarcu Laurenţiu (the secretary, a beginner from Bucharest), and Radu Dumitru (a beginner from Bucharest).

Valentin Grigore continued the observations at Tirgoviste ($h = 350$ m) on May 3-4 and 4-5.

The η Aquarids were observed for only about one hour before dawn when the radiant had risen sufficiently. Table 1 below gives the magnitude distribution of all meteors after applying a selection criterion. (In this table, the meteors seen by both observers were taken into consideration only once.)

Table 1 – Global magnitude distribution and train percentages (%) for the 1992 η-Aquarids and other showers observed.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$	%
η-Aqr		1	3	6.5	6	6.5	7	4.5	0.5		35	1.59	43%
α-Boo				0.5	0.5	0.5	3	2	1	0.5	8	3.31	0%
α-Sco			1	0	0.5	2.5	2	2.5	2.5		11	3.00	9%
Spor	1	0	0.5	12.5	19	35	53	66.5	30	5.5	223	3.11	7%

To avoid all confusion, I need to repeat here that the IMO *requires* individual *data. Nevertheless, it is justified to produce a combined magnitude distribution in a report such as this to give the reader a global idea of how the shower looked like. In this case, I would recommend just adding* *all data,* without *applying any selection criterion. In this way, the distribution thus obtained will be more representative of what an individual observer might expect to see. Applying a selection criterion is not recommended because it creates a bias towards the fainter meteors and becomes stronger with increasing number of observers.* (Ed.)

A remarkable -0.5 yellow-red η-Aquarid was seen on May 2-3 at 0^h41^m UT. Its remarkable trail was about 70° long with a train which persisted for 3 seconds. The best sporadic was a -3.5 green fireball. It had 6–7 little fragments (like fireworks), and it appeared on May 3-4 at 21^h52^m UT.

2. The 1992 Orionids

The Orionid expedition took place at Tirgoviste ($\lambda = 25°29'00''$ E, $\varphi = 44°57'18''$ N, $h = 350$ m). It started on October 21, but unfortunately the sky was cloudy until October 23. It was cloudy on October 24-25 as well. The expedition ended on October 26, but Valentin Grigore also observed on October 27-28 and 30-31 and November 5-6 and 16-17. The comet P/Swift-Tuttle was seen every evening with binoculars.

The participants were

> Valentin Grigore (GRIVA), Adrian Sava (SAVAD), Zoltan Deak (DEAZO, "Astroclub," from Bucharest), Exarcu Laurenţiu, and Vasile Micu (a beginner from Hunedoara).

A total of 733 meteors were seen during 40.18 hours of effective observing time.

The results obtained for the magnitude distributions use the same selection criterion as before (the meteors seen by two or three observers were taken into consideration only once) and are given in Table 2. *(Again, refer to my earlier comment, Ed.)*

Table 2 – Global magnitude distribution and train percentages (%) for the 1992 Orionids and other showers observed.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$	%
Ori			3	12.5	18.5	18	11	3			66	1.46	38%
Tau				0.5	4.5	3.5	2	2.5	0.5	0.5	14	2.36	0%
Tau S				2	2.5	9.5	8.5	3	0.5		26	2.37	0%
Tau N				5	10	5.5	5.5	6	3		34	2.25	9%
ε-Gem				1	1	2.5	1.5				6	1.75	33%
Spor	3.5	1	6.5	39	65.5	79.5	71.5	49	12.5	2	330	2.08	10%

We observed three remarkable sporadic fireballs during this observing period.

The first appeared on October 23-24 at 23^h19^m UT. It was of magnitude -3 in the beginning and -5 at the end. Its color was yellow and it had a persistent train which broke into two parts. The first part persisted for 4 seconds, and the second part for 20 seconds, as seen by the naked eye, and 80 seconds as seen with 15×60 binoculars. During this time (80 seconds), it was distorted and dispersed under the action of upper-atmospheric winds.

The second fireball appeared on October 25-26 at 19^h29^m UT. It was of magnitude -3, and had two remarkable features: its color and trail. Its color was orange in the beginning then turned to a rose color and ended in violet (very nice!). Its path was marked by small fragments trailing behind the main head.

The third fireball was of magnitude -6. It appeared on October 25-26 at 23^h16^m UT. The train of this meteor persisted for 4 seconds, whilest the meteor was white-green in color.

Possible Minor Stream Activity around July 21–22

Marco Langbroek

In July 1990, the author spent two weeks at the Puimichel Observatory in Southern France, mainly for deep-sky observing. Being a fanatic meteor observer, he filled the gaps between his allotted observing time on the telescopes with short observing sessions on July's ecliptic streams. The author always plots the observed sporadic meteors and members of minor streams on gnomonic charts. It was on the basis of these plottings, that the possible existence of a "new" minor stream active around July 21–22 has been found.

Upon examination, the plottings I made around July 21, 1990, seemed to show the activity of a radiant in the northern part of Cygnus, near ψ Cygni. Now one must be very cautious regarding the observation of "new" streams: take a random area in the sky, and you will always note some meteors coming from that point. This is especially the case under the excellent observing conditions of Southern France, where dark skies result in an apparently high sporadic background. However, there are a number of circumstances in favor for claiming a genuine stream in the case of the *ψ-Cygnids*. The observed meteors are quite similar in their characteristics and, more important, there is a second observation by another observer since last year.

In 1990, the author observed ten possible stream members during 4.25 hours of effective observing time, with limiting magnitudes of +6.4, +6.5, and +6.8, respectively, during the nights of July 20-21, 21-22, and 22-23, giving a ZHR of about 2 during the night of 21-22. No stream members have been detected while observing during other nights. This is the first point in favor of a genuine stream: the radiant is observed to be active only during a restricted period of three nights around July 21-22. But there is more. All supposed members of the stream are credited with the same characteristics while observing. They are all classified medium-fast, and lack evident colors or flares. No possible member showed a persistent train, not even the brighter members of +2 and +1. The plottings show that meteors appearing *further away* from the radiant established from the observations have *longer* trails than those appearing near the proposed radiant. Suggestively, one meteor appeared as a point meteor at the radiant position! From the plottings, a quite compact radiant of about 5° diameter could be derived, located near ψ Cygni, whence the name given here. The radiant is $\alpha = 19^{h}55^{m}$ and $\delta = +51°$ (eq. 2000.0).

After we had noticed the possible stream from the 1990 observations, we tried to get some independent confirmation of its existence. Dr. Peter Jenniskens examined the Harvard photographic list of meteors, but found that unfortunately the lists displays a gap of five days just around July 21-22 (!) in which no meteor has been photographed (not even a sporadic). Maybe this is the reason that the existence of a minor stream around this date was not known before.

In July 1992, however, another observer also observed possible ψ Cygnids. Michel van Vliet from Vlissingen, the Netherlands, observed some hundred meteors in the period July 17–23, 1992. Of these, fourteen meteors observed during the nights 20-21, 21-22 and 22-23 only (note the correspondence with the above dates!) might be ψ-Cygnids. They have all been classified medium-fast and showed no flares or persistent trains. Michael calculated a ZHR of about 3 from his observations. The radiant as established from his plottings is a few degrees in diameter, and centered less than 2° from the radiant position found by the author in 1990!

Combining the above arguments makes us believe in the existence of a genuine minor stream around July 21–22. However, one must still be very cautious in making such conclusions. For this reason, we would like to hear other observers' experiences regarding this possible stream. This year, observing conditions are quite favorable. New Moon on July 19 will ascertain dark skies around July 21-22. We strongly urge observations be made around that date: please be so kind as to send a copy of your observations to the author (address on inside back cover). Observations must include plottings on good gnomonic charts, a good limiting magnitude estimate, and information about velocities, flares etc. Include all meteors, not only the ψ-Cygnids. Also send your observations when you observe no possible shower members around the stated date!

The 1992 Perseids in Russia

A. Levina and V. Yaremchuk

During the maximum of the 1992 Perseids, Crimean observers in the region of Nizhnij Novgorod in Russia were very much plagued by poor weather conditions.

In August 1992, a group of five Crimean meteor observers watched the Perseid shower in the region of Nizhnij Novgorod (formerly Gorki), where observing sessions of young amateur astronomers were held. Observations were conducted far from towns and settlements, in skies without light pollution. Due to cloudless skies, the program was carried out even in the presence of the Full Moon. The group was also on duty when there were clouds. The latitude of the place of observation was $56°11'$ N, and the radiant rose quite early, but not very high. Observations lasted until dawn. Besides clouds, a dense haze was present during the whole period of the observations, due to local forest fires. Because of strong interference from moonlight, the limiting magnitudes were not very high, and ranged between 4.5 to 5.5.

The Perseids were active enough though; already in the first nights meteors appeared in groups. They were bright, had trains, and brought true pleasure to the observers. Before the maximum of the shower's activity, cloud-cover was about 20% to 50%, but the day before the maximum the night was clear!

Nevertheless, in spite of waiting, during the night of August 11-12, clouds thickened, and the cloudiness was 100%. During the whole night, Vega appeared once or twice, but disappeared again immediately. Nevertheless, 38 meteors were registered. For the first 10 minutes (20^h30^m to 20^h40^m UT), 16 meteors were noted. One could think that all these meteors were very bright. Most of these meteors were noted by a few observers simultaneously, which makes errors unlikely.

One particular layer of "fluffy" clouds had a striped structure, sometimes so uniform that the sight was striking. In the intervals between clouds one could see meteors only partly. The shower identification was made using the direction of the train. The cloudiness made the estimation of the meteor's brightness very uncertain. Estimation of brightness was practically impossible when there was 100% cloudiness.

The next day, the weather changed completely. Observations became impossible due to haze and two layers of clouds. On the nights of August 16-17 and 17-18, which were the last in the expedition, it was raining and no observations could be conducted.

The 1992 Perseids and Exploding Fireballs over Rumania

Valentin Grigore

An overview is given of Rumanian observations of the 1992 Perseids and 1992 Perseid fireballs including one that exploded. Two similar events that also happened near Tirgoviste ($\lambda = 25°29'00''$ E, $\varphi = 44°57'18''$, $h = 350$ m) are recalled.

1. The 1992 Perseids

Three observers watched the 1992 Perseids from three different Rumanian sites: Valentin Grigore from Tirgoviste, Adrian Sava from Bucharest, and Vasile Micu from Hunedoara. In total, 733 meteors were seen between July 27-28 and August 18-19 during an effective observing time of 56 hours. We saw 343 Perseids, 22 α-Capricornids, 59 Aquarids, 17 κ-Cygnids, and 292 sporadics. The sky conditions were very poor around the maximum of the Perseids. On August 11-12, all three persons started their observations after 20^h30^m UT, so they could not have seen the Perseid outburst. The magnitude distribution of the author's Perseid observations from Tirgoviste is given in Table 1. The mean limiting magnitude was +5.1.

Table 1 – Magnitude distribution for the 1992 Perseids, as observed by the author from Tirgoviste between July 27-28 and August 18-19.

Magnitude	−7	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}$
Number	1	1	3	2	6.5	30.5	37	28.5	9.5	4.5	0.5	124	0.91

2. The 1992 Perseid fireballs

During the observations, 15 fireballs were seen, of which 12 were Perseids and 3 sporadics. One of the most important events happened during the night of August 11-12, at 20^h15^m UT, at Tirgoviste. At that moment, I was walking to my observing site. Suddenly, the trees around me were very strongly illuminated for one second, although the moonlight was strong. I looked up in the sky immediately, but the fireball had disappeared. A similar event occurred the same night at 1^h29^m UT (then I saw the meteor and a persistent train for ten seconds) and on August 12-13 at 22^h16^m UT, too, but this event was less bright.

A −7 blue Perseid was seen in Tirgoviste on August 11-12 at 0^h47^m UT. It had a flare over half of its path. Its maximum brightness was reached after this flare, and its persistent train was broken in two parts, the first one persisting for 4 seconds and the second for 10 seconds. Possibly two people from two different sites in Bulgaria also saw this fireball, but, unfortunately, they did not plot it.

3. Exploding fireball over Rumania

The most noteworthy event during the 1992 Perseid campaign occurred on August 12-13 at $22^h14^m \pm 1^m$ UT. At that moment, the sky was very foggy with a limiting magnitude of about +3, and I had a break. Suddenly, I was scared by a strong explosion which happened in the NNW part of the sky at 30°–40° elevation. I was looking in that region, but I did not see anything. After the explosion followed an intense rumbling which persisted for almost one minute. This unusual event strongly shook the windows in the town of Tirgoviste (located at 4 km from my observing site) and many people were scared, too. The explosion occurred north of the town. No accidents were reported.

Similar explosions have occurred twice in this region in the recent past, but were of lesser intensity.

The first, on August 12-13, 1985, was caused by a brighter than −8 Perseid fireball which exploded in the northern part of the sky at 20°–30° elevation. After only 3–4 seconds, I heard the explosion sound, a short boom, implying that the fireball exploded about one kilometer from the observer. Its train persisted for 30 seconds. In that time, five bright Perseid meteors passed near this train. Afterwards, another four or five Perseids passed near the same place during a time-span of about 4 minutes. This event was nicknamed "the parent and his children."

Another explosion happened on February 22-23, 1986, at 22^h35^m, and was stronger than the 1985 explosion. I saw that event through the window of my house, with a view to the south. Although the sky was completely covered (it had snowed some time ago), it was strongly illuminated for two seconds. Almost instantaneously I heard a cracking noise.

Dutch 1992-93 Fall and Winter Observations

Koen Miskotte

Observations by the group *Delphinus* from Harderwijk, the Netherlands, are presented. The weather was bad in the period from September through the first half of January, particularly during the months of October and November. Due to the extremely warm North Sea waters, there were a lot of clouds and rain.

Observations were made during the nights of August 29-30 and September 23-24, 26-27, and 28-29. Only the author was able to make observations in this period. Several showers were observed, including, the Aurigids, Taurids, κ-Aquarids, and Piscids. A total of 112 meteors were seen during 11.25 hours of observing. No exceptional events were seen.

In October a big Orionid campaign was organized, but the bad weather only permitted observations on the nights of October 20-21 and 21-22. On the first night, only the author made observations under very hazy conditions and he saw eight meteors in one hour of effective observing time. The following night was better and during a number of extended very clear periods, Robert Haas and the author observed a total of 182 meteors. The highest Orionid hourly rate was reached between 2^h and 3^h UT with 16 meteors seen by the author with a limiting magnitude of 6.5 and an effective observing time of 0.96 hours in that period. Afterwards, the hourly rate decreased because of the rising moon. We were also able to photograph 2 meteors. The first was a slow sporadic of magnitude -2, which produced two flares. The second meteor was a brilliant -6 Taurid, with five or six flares. Only the second half of this meteor was captured on film with a broken-up trail visible on the negative. Both of these meteors were observed simultaneously at three *Dutch Meteor Society (DMS)* stations. The photographs are in the process of being measured and reduced by Hans Betlem, photographic coordinator of the *DMS*. Due to bad weather, Geminid observations were only possible on the night of December 17-18. The author saw 14 meteors (limiting magnitude 6.0), two of which were Geminids, and two which were Ursids.

The campaign established for the 1993 Quadrantids was very successful. Between December 28 and January 4, the weather was clear almost every night with only December 31-January 1 being misty. Three observers were active on the night of January 2-3. Between 1^h15^m and 6^h20^m UT, under extremely cold conditions ($-12°$ C), they saw 346 meteors. Quadrantid hourly rates increased from 6 to 25 per hour per observer, as expected. Even as early as the first night of the campaign, December 28-29, a few Quadrantids were seen. Hourly rates increased from 1 to 7 per hour during the period from December 28 to January 2. On the morning of January 4, under hazy conditions, a peak rate of 8 Quadrantids per hour per observer was seen.

A little "peak" in the activity of the Quadrantids around 2^h28^m UT on January 3 was very striking. For instance, the author observed between 2^h10^m and 2^h25^m UT a total of 2 Quadrantids and 3 sporadic meteors ($T_{\rm eff} = 15^m$, lm $= 6.4$), while between 2^h25^m and 2^h30^m UT, he noted 8 Quadrantids and 3 sporadic meteors ($T_{\rm eff} = 5^m$, lm $= 6.5$). Three of these were bright with magnitudes -0.5, -1.5, and 0, respectively! All of this occurred during just five minutes; it looked like the maximum... The following ten minutes yielded only 2 Quadrantids and 2 sporadic meteors. Are there any other observers who noticed this? A total of 533 meteors were seen during the Quadrantid campaign. We also took photographs, but the results were not known at the time this article was being written.

In retrospect, 1992 was a moderate year: only 1013 meteors were observed visually, and only 18 were photographed. Observers were Paul Bensing, Robert Haas, Koen Miskotte, and Bauke Rispens. The year 1993 promises to be very exciting; in particular, what will happen on the night of August 11-12? Some of the observers of *Delphinus* are going to Southern France in that period, as a part of a big *DMS* expedition. At least three, and possibly as many as five stations, will be installed in the Provence which will carry out visual, photographic and radio observations of the Perseids. The present year will also offer good prospects for the Lyrids, Orionids, Leonids, Geminids, and Ursids. Really, 1993 is due to become a superb year for meteor observers!

December 1992 and January 1993 Meteor Observations in New Zealand

Graham W. Wolf

Personal meteor observations from New Zealand for the period December 1992 and January 1993 are summarized. A dramatic improvement in weather and sky conditions has been noted in recent months, with the result that effective observing time in January 1993 alone almost exceeded the entire personal yearly total for 1992.

1. Introduction

Most of 1992 was either rained or clouded out for meteor observations, with only 46 clear dates being visually useful, a climatic problem widespread throughout New Zealand. The weather in New Zealand improved dramatically in December 1992 and January 1993, with over 20 nights in January alone being perfectly clear. In January therefore, whilest monitoring several radiants at once, the total effective hours observed has almost exceeded, in that month alone, the entire total for 1992. As an added bonus, at the 1993 *Stardate Astronomy Convention* near Mount Egmont in Taranaki, New Zealand, a magnitude −4 fireball was seen by several persons during an all-night observing run.

2. Meteor observations

After a rather lousy year weather-wise, things improved fantastically throughout December and January, with hardly any cloud or rain for over six weeks. During the 1993 *Stardate Astronomy Convention*, noted comet hunter Rod Austin and several others saw a magnitude −4 fireball traveling north from south across the top of Mt. Egmont, which itself is an 2520 meter volcanic cone (discovered in 1769 by Captain James Cook) and similar in shape to Japan's Mt. Fuji. The fireball started red in color, then went green, and flared brightly near end point, letting off four bright "sparks." It was moving at about 5°/s and left a train of 5 seconds. This took place at $12^h56^m12^s$ UT on January 23, during an all-night observing session at Rahotu (pronounce *ra-ho-too*), near Cape Egmont.

I have totaled my meteor observations for last year, and found that I did 128 hours of effective observing, and saw 620 meteors. Most of the showers that I observed were rather inactive, hence the low counts. Already, I have had an exceptional January 1993, with 114.5 hours and 435 meteors. Several of these dates, including 1993 *Stardate Astronomy Convention*, were all-night sessions, and rather grueling too, especially with up to three showers to watch at once. As the old proverb says... It certainly pays to strike whilest the iron is hot! Table 1 gives magnitude distributions for the showers observed in December and January. Over a 6-week period, I traveled extensively around the rural parts of the South Island to such places as Five Forks, Queenstown, Arrowtown, Kingston, Fiordland, Dunedin, Oamaru, and Marlborough. I managed to purchase plenty of souvenir postcards for Jürgen and Ina Rendtel, Paul Roggemans, and Alastair McBeath, which they have all enjoyed in the past.

Skies at night were consistently better than limiting magnitude 6.0, in a few cases better than 6.5, and in one case even 6.9! I even managed to observe during a night time Cook Strait ferry crossing on the "Arahura" (pronounce *are-rah-her-rah*), after arranging with the ship's Purser to have the stern deck lights turned off... a cunning move indeed! For the duration of the 3-hour crossing, skies were better than 6.5 zenith limiting magnitude.

In Table 1, `GEM` is the Geminids, `TPU` the Tau Puppids, `ACR` the α-Crucids, `PIP` the π-Puppids, `LVL` the January λ-Velids, and `ACN` the Alpha Carinids. The abbreviation `SPO` stands for sporadic meteors. Only two hours were able to be spent on the Geminids, on December 13, between 14^h00^m and 16^h00^m UT, when even then, the radiant was low on my local horizon, due to my southern latitude of 41°19′.

Table 1 – Magnitude distributions for the showers observed by the author in December 1992 and January 1993. Showers are identified by their *IMO* code.

Shower	−4	−2	−1	0	+1	+2	+3	+4	+5	Tot
GEM			3	7	15	24	35	5		89
TPU			4	8	13	15	17	8	4	69
ACR		3	5	10	17	27	26	14	7	109
PIP			1	6	10	8	4	3	1	33
LVL			1	6	5	5	8	7	3	35
ACN		1	2	3	5	9	8	5	2	35
SPO	1	3	4	14	22	36	32	20	6	139

Already, my small nation is contributing positively to global meteoritics, in spite of my being the only New Zealand member of the *IMO*. John Morgan of Nelson, who replotted the southern radiants in the 1970s for Bertil Lindblad of *IAU Commission* 22, is now nearly 80 years old, and has retired from meteor observing due to failing health. John Drummond of Gisborne regularly observes the η-Aquarids and Orionids for *IMO* Councillor Jeff Wood based in West Australia, but John was recently devastated by the lingering painful death of his young wife Elizabeth from terminal cancer, and it will be some time before he feels emotionally capable of observing again. I am sure all *IMO* members extend their deepest sympathy and best wishes to John; it was certainly sad to see her suffer so badly the last 18 months of her life.

I have not yet been able to get any other New Zealanders to join the *IMO*, but two young persons approached me for *IMO* pamphlets at the 1993 *Stardate Astronomy Convention* in late January, and expressed an interest in observing for the *IMO* using its methods and observing forms. Already, the *IMO* has been extensively promoted at the last two *Annual Conferences of the Royal Astronomical Society of New Zealand*, and has also been promoted by way of public lectures at the *Carter National Observatory* at the quarter million strong capital city of Wellington, where I am now employed as a public astronomer.

I hope to be able to obtain about three thousand dollars in scientific funding to attend the 1994 *IMC*, and finally meet my world-wide *IMO* colleagues at last. Over the last two years, I have written regularly across the world to senior *IMO* responsibles and observers. It is indeed pleasing to see photos of *IMO* persons in *WGN* from time to time, and I also feel an inner warmth in the fact that the *IMO* is indeed bringing all nations and human races much closer together in the common bond of friendly, global, united astronomy. Long may this happy situation continue!

JAS Meteor Section Results: 1993 Quadrantids

Alastair McBeath

A short review of 1993 Quadrantid data obtained from UK sites is given.

Weather conditions were poor over Britain from mid-August 1992 onwards, and most observers managed very little work at all. The sole bright spot was the Quadrantid shower in early January 1993, although even here, only six *JASMS* members were able to make useful contributions: Neil Bone, Shelagh Godwin, Richard Livingstone, Graham Pointer, Ian Rigney, and Roy Watson. All but two hours of the 17.9 hours reported by these six were put in on January 2-3, between moonset and dawn, with 100 Quadrantids and 64 sporadics seen in that time. Magnitude distributions for those recorded in good skies are given in Table 1. The mean limiting magnitude was 5.9 for these data.

Table 1 – 1993 Quadrantid and January sporadic magnitude distributions

Shower	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}_{6.5}$
Quadrantids	2	9	8	22	26	6	3	76	+2.8
Sporadics		5	8	17	21	6	3	60	+3.0

No Quadrantids left a train, although 4 (6.7%) of sporadics did so.

Activity levels for the shower were low—a mean ZHR of approximately 14 ± 2 was found for January 2-3 overall—but showed a tendency to rise towards dawn. Best rates at around 6^h–7^h UT were indicating a ZHR level in the high 20s, suggesting, along with the shower's faint meteor magnitudes, that the true peak may well have taken place much as expected, and probably before 12^h UT on January 3.

The 1993 Quadrantids in Slovakia

Peter Zimnikoval

An account is given of Slovakian observations of the 1993 Quadrantids.

On January 3, at the time of the supposed Quadrantid maximum, we observed the Quadrantids. The observation took place in two parts, in the morning before sunrise and in the evening after sunset. Five observers participated in this observation: D. Očenáš, J. Fabricius, S. Kaniansky, J. Škvarka and P. Zimnikoval. The morning observation was divided into two intervals, the first from 3^h07^m to 4^h07^m UT and the second from 4^h32^m to 5^h22^m UT. With average sky conditions (limiting magnitude about 5.8), 98 meteors were registered. The mean value of the ZHR was 25.3 in the first interval, and 18.2 in the second. The second part of our observations (January 3 after sunset) was from 16^h15^m to 16^h45^m UT, and was made as a control. Under bad sky conditions (almost Full Moon, low elevation of the radiant) we only saw one meteor.

Strong Radio Meteor Activity on April 18, 1993

Jeroen Van Wassenhove

A Belgian radio meteor observer reported strong meteor activity from an unknown source on April 18, 1993.

On April 18, 1993, Maurice De Meyere (Deurle, Belgium) detected 224 meteor reflections from 16^h58^m to 17^h28^m UT with an automated forward scatter system. He watched the reflections appear on his PC screen, which acts like a digital scope. During the same time of day on April 17, he detected 15 reflections, and on April 19 he had 19 meteor reflections. The frequency used is 66.17 MHz. If you can *confirm* or *deny* these observations, please let us know (address on inside back cover)! For the time being we do not know about stream activity in this period. The observed phenomenon is most probably not linked to the Lyrids (activity April 19–25). However, there have been unconfirmed reports in the past about meteor activity in the second half of April. The α-Bootids are another stream normally active later in the month.

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Do not miss it!

International Meteor Conference 1993

Puimichel, France, September 23–26, 1993

The 1993 International Meteor Conference will take place at the Observatory of Puimichel, in the French Haute-Provence, a most beautiful area. At last, an opportunity is afforded to South-European observers to come to an *IMC* that is nearby, and for others to meet them!

The choice of the conference site also makes it possible for participants to come earlier to observe, and use this unique opportunity to compare your own observing skills with those of colleagues abroad!

But, you must not hesitate any longer! The number of participants that can stay in Puimichel is limited, and only a few more places, at a small extra cost, are currently available. Contact Paul Roggemans immediately if you do not want to miss this unique event! It would be tragic if you were unable to participate in the 1993 *IMC* simply because you returned your form late.

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

What to do in case of a Perseid outburst on August 11-12, 1993:

Read the article on pp. 95–96 of this issue attentively!

As soon as you notice exceptionally high activity relative to your observing conditions, report to

- Puimichel, France, tel. +33-92 79 94 28, or
- Hove, Belgium, tel. +32-3-455 07 32.

Keep communications short! Avoid communication when a strong display is in full progress; only report at the beginning of unusual activity. Also do *not* use the above numbers for inquiries and do *not* pass these numbers on to the general public.

After your observations have ended, communicate a more complete report on the shower's activity

- by phone to Puimichel or Antwerp,
- by fax to Hove, fax +32-3-454 22 97, or
- by e-mail to Marc Gyssens, `gyssens@wins.uia.ac.be`.

The deadline for the complete preliminary report is August 12, 5^{h} UT.