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Sporadic fireball photograph by André Knöfel from Mt. Teide, Tenerife, on November 17-18, 1992. The photograph was exposed between 1^h00^m and 1^h59^m UT using a Zodiak fish-eye lens, $f = 35$ mm, $f/3.5$ and an ISO 800/30° film. The fireball occurred near the eastern horizon and was not seen visually.

In this issue:

In case of non-delivery, return postage guaranteed. Please return to:
v.u.: Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium

WGN, Vol. 21, No. 1, February 1993, pp. 1–52

Contents

Useful Information

The April Issue *(WGN 21:2)*

The *April issue* is expected to be mailed early, during the last week of March 1993. Therefore, contributions are due *March 5* 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.

From the President

Jürgen Rendtel

The year 1992 will certainly be famous for the strong return of the Perseid meteor shower and the rediscovery of its parent comet, P/Swift-Tuttle. Since the appearance of an additional activity peak in 1988, meteor observations have given an indication that the approach of the parent comet to perihelion was imminent, whereas in the past, rich meteor showers were observed after the comet's discovery.

In apparent contradiction to this extraordinary event, the observed meteors totals for 1992 will be significantly lower than for previous years due to unfavorable circumstances around the maxima of the main meteor showers in 1992. Despite the moonlit skies, however, much valuable Perseid data were obtained in 1992. Observers are understandably excited by the prospects for the next Perseid peak in 1993.

Data gathered in previous years are now subject to several detailed studies. More global analyses are to be published in WGN. *Such reports are possible thanks to the efforts of many observers worldwide. The observations contain enormous amounts of information which ensure reliable conclusions and make the results of interest for professional meteor workers. Therefore I would encourage all observers using any observational technique to continue the good work.*

The IMO*'s* Fireball Data Center (FIDAC) *took over the role of main data collector of fireball events from the Global Volcanism Network (formerly Scientific Event Alert Network). In this respect,* FIDAC *now becomes the main source for fireball data on a global scale.*

Members of the IMO *know each other mainly through the journal* WGN. *Personal contacts are restricted to the* IMC*s or other, rather rare occasions. Therefore I enjoyed the attendance of a large group of Japanese meteor workers at the* 1992 IMC. *The talks we had helped lead to a better understanding about each other. The* 1992 IMC *must be regarded as an extraordinary event also because of the number of professional meteor astronomers present. It was a good plan to hold our* IMC *just before another professional conference at the same site. However, this cannot be expected to happen each year. As was initiated in the 1992 volume of* WGN, *I would also like to see photographs of the* IMO *members in our journal to reflect the fact that* IMO *is an organization consisting of living persons. Furthermore I would like to encourage everybody to not hesitate in contacting other members. I think a large amount of correspondence may help to keep a high level of interest in our field. Personal contacts also permit members to make an informed decision when it comes time to vote for candidates presenting themselves for certain tasks in the* IMO *such as the new Council to be elected in 1993. This method is still superior to simply reading the limited information available in the "Who is who." and making such a decision.*

The 1993 IMC *is going to take place in Southern France. There are already requests to hold future* IMC*s throughout the world. One of the next events will surely be held outside Europe—probably in North America. Many new members from this part of the world have joined the* IMO. *As the* IMO *in an international organization, I am sure that other future* IMC*s will be held in other parts of the world as well.*

I wish all members and friends of the IMO *a prosperous New Year with extraordinary events expected to happen this summer and with continued development of our* IMO.

A Refereed Section in WGN

Marc Gyssens

Of course, I cannot but agree with the words of our President and join him in wishing you the very best for 1993. In our continuous strive to improve the standards of WGN, *1993 will be an important marker. Already for several years, the call for a form of refereeing in our journal has been getting louder and louder. In particular, the discovery by the* IMO *of a double Perseid peak and its connection to the events that lead to the rediscovery of Comet P/Swift-Tuttle made it clear that the* IMO*'s global analyses needed and deserved a "stamp of trustworthiness."*

In order to meet this desire, a refereeing procedure was worked out and tried in the June issue, in which the results of the Aquarid Project appeared as the first refereed article of our journal. As the procedure worked out satisfactorily, we decided to have a refereed section as a regular feature in WGN *starting with this issue. We were fortunate in finding many professional and serious amateur meteor workers prepared to assist us with the refereeing procedure. From now on these referees constitute the Editorial Board of our journal; you can find their names on the inside of the back cover. We are very grateful for their help.*

More concretely, you might wonder what changes this new feature of our journal may involve when you want to submit an article to WGN. *In point of fact, for most articles little will change. We deliberately chose to keep the scope of the refereed section very restricted: this section, called "Progress in Meteor Science," will only contain articles on analyses of global data, analyses of data obtained by professional equipment, articles of a theoretical* *nature, and review articles. In each issue, the section will start with a concise statement of the article's purpose. It is the editor who will decide whether or not an article qualifies for the refereed section. It must be emphasized here that this decision will be based solely on the nature of the article and does* not *constitute a judgment on its quality.*

The sole purpose of the refereed section is to give more credibility to the results that are the product of the combined efforts of our observers world-wide and to encourage professionals to consider publishing in WGN *on a more frequent basis. The last thing we want to do is to create a journal in which amateurs would not feel at home anymore; the narrow scope of this new section is the best guarantee that this will not happen.*

As it has been a long time since we last gave instructions to authors of WGN *we will do this again in the next issue. In that article, we will also give more details about the refereeing process. However, it should now be clear that for most submissions nothing will change, a fact reflected in the almost unchanged lay-out of this issue. Therefore, continue sending us your articles, letters, observing reports, etc. as you used to do. Remember this is your journal: how interesting it is depends on your contributions!*

From the Treasurer

Ina Rendtel

1. Gifts from members and subscribers

In 1992 the following people paid more than required for their membership or subscription or for the publications they ordered. Their financial contribution helped a lot to finance the production of *WGN*. Gifts are welcome and help to keep the subscription low for those who cannot afford to pay more than 25 DEM.

The donators were:

> Gene Abraham, Birger Andresen, Ben Apeldoorn, Rainer Arlt, David Asher, Godfrey Baldacchino, Luis Bellot, Martin Beech, David Bender, William Black, Evelyne Blomme, Peter Brown, Hen Li Chung, Nic de Kort, Vincent Devore, Massimo Dionisi, Marc de Lignie, Roberto Gorelli, Marc Gyssens, Roberto Haver, Robert Hawkes, Nick Harvey, Trond Erik Hillestad, David Hughes, David Jenkins, Carl Johannink, Klaas Jobse, Colin Keay, André Knöfel, Ralf Koschack, Masahiro Koseki, Gotfred Kristensen, Jean C. Lernould, Richard Livingstone, Tony Markham, Alastair McBeath, Bruce McCurdy, Michael Olason, Dan Olson, Joseph Pedroncelli, Graham Pointer, Leo Rajala, Marc Renusch, Ina Rendtel, Jürgen Rendtel, Tom Roelandts, Paul Roggemans, Hans-Georg Schmidt, Fintain Sheerin, George Spalding, Duncan Steel, Jeroen Van Wassenhove, Cis Verbeeck, Junichi Watanabe, Noel White, Robert White, Erich Weber, Jean-Marc Wislez, A. Grupacio Astronomica de Barcelona.

2. Exchange of publications with currency-controlled countries

Last year, several members arranged an exchange subscription to *WGN* with colleagues in currency-controlled countries. We hope that as a result everybody received the publications he or she expected. If you have not received what you ordered, please report such facts to the Treasurer.

For 1992, the following arrangements are possible for subscribers wishing to help their colleagues in currency-controlled countries:

- *Czech Republic:* Order the Atlas Brno (gnomonic) for 5 DEM from the *IMO* and for every 5 copies sold cover the subscription of a Czech reader. As orders are booked by the *IMO* and copies have to be sent from Brno, this procedure may take up to 3 months. If you ordered an atlas and did not receive it in 3 months, please inform the Treasurer.
- *Hungary:* order the Proceedings of the *1989 IMC* from the *IMO* for 12 DEM and help our Hungarian friends to cover their subscription. Copies can be ordered through the *IMO* treasurer.
- *Other currency-controlled countries, such as Russia, the Ukraine, Slovakia, Bulgaria, Tadjikistan, etc.:* It is possible to make donations to the *IMO* fund for assistance to members from currency-controlled countries (for a subscription or for a publication), or you can help by paying for a specific person with whom you made an agreement for some exchange. If you want to obtain a specific publication, for instance Russian astronomical journals, the Minor Planets Ephemerids for 1991, 1992, etc., contact the Secretary-General who will try to arrange this exchange.

3. Complaints about not receiving ordered publications

In general, we receive very few complaints, but every now and then it may happen that parcels disappear or are destroyed in the mail. If you do not receive what you ordered from or through the *IMO* in, say about 3 months after your order was placed, do not hesitate to contact the Treasurer. It may happen that something goes wrong in our administration, due to misunderstandings, or because of unclear orders.... Sometimes we receive money without any clue regarding purpose or sender!

New Version of "Who is Who?"

Paul Roggemans

IMO members will find in this issue of *WGN* a personalized letter with their data the way are stored in our database as of January 20. (Changes received after that data are not included.) Please check your data, such as activities, phone number, e-mail, etc. We want to have correct data, so please contact the Secretary-General about possible corrections and deletions!

In case you are an *IMO* member and no letter is enclosed in your issue, you should also report this to the Secretary-General. If you are not yet an *IMO* member and should like to become one, ask for an application form. You become a member by completing and returning this form and paying an entrance fee of 5 DEM on top of the *WGN* subscription fee. I want to emphasize that these formalities as well as the extra fee are due only the first year of your membership; after that year, your membership will be renewed automatically each time you renew your *WGN* subscription at the usual rate.

Good communication is essential in every association; it is an issue of special concern in an international one. In the *IMO* we are enjoying an "active" social life, with an enormous amount of communication. As a result, the *IMO* is based on good relationships among its members and on people working together and keeping in touch as good friends, despite the large distances. A document such as "Who is Who?" plays an important role in this social aspect. The *IMO* is one of the very few societies that can offer such a "Who is Who?" so please help us in keeping it as complete and correct as possible. Thank you for your cooperation!

Letters to WGN

compiled by Marc Gyssens

Radio reflection duration and visual magnitude

The letter of 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, triggered a lot of reactions. They follow below.

I read with interest the letter to *WGN* from George in which he notes that meteor radio reflection duration does not correspond well with meteor visual magnitude.

This phenomenon is related, at least in part, to the polarization and to the directionality of the reflected signal. Most commercial radio transmitter antennae are vertical one-quarter wavelength monopoles that broadcast signals which are linearly polarized with a vertical orientation of polarization. Most radio receiver antennae are linearly polarized, and so will be more sensitive to signals whose polarity matches the orientation of the receiving antenna. Therefore, the strength of the detected signal will be related to the orientation of the receiving antenna. But also, it seems likely that the efficiency of the reflection will be related to the orientation of the meteor trail with respect to that of the transmitting antenna. Moreover, it is well known that a change in the polarization of electromagnetic waves often occurs upon their reflection. So polarization is an important cause of variability of detected signal strength. Regarding the direction of reflection, the ionized meteor trail will reflect radio waves preferentially at an angle of reflection that equals the angle of incidence, somewhat like light reflecting from a mirror. Thus, the orientation of the meteor path with respect to the positions of the transmitter and receiver is an important determinant of the strength of the detected signal. These two phenomena—polarization and directionality of the signal—are not accommodated by the simple radio devices amateurs use for meteor counts, so that there is a poor correspondence between detected radio signal strength and meteor visual magnitude.

Roger Venable, December 29, 1992

I have always been a little unsure about the link between the visual magnitude of a meteor and the duration of the corresponding radio echo. But when I say this, I also want to point out that the duration of the reflection is still a good hint for the brightness of the meteor. It is certain that a brilliant meteor will give rise to a massive and powerful radio signal.

On August 4, 1989, I started keeping a journal with entries of meteors observed both visually and by radio. These meteors were registered by my pen recorder. Figure 1 shows the connection between the visual magnitude and the signal duration for each meteor. The meteors included were of magnitude 2 or brighter. Fainter meteors very seldom had durations over 1 second. The graph is based on 264 meteors observed from August 4, 1989, until October 31, 1992. The horizontal axis specifies the magnitude, whereas the vertical axis gives the logarithm of the signal duration. As you can see, it is easy to draw an upper and a lower limit for the data points; beyond these limits you will find hardly any data points. Likewise one can draw a line through the average values.

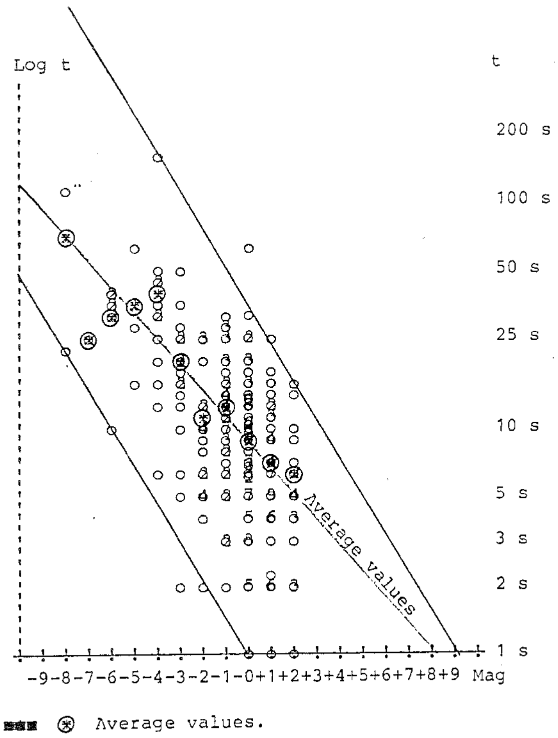

Figure 1 – Relation between visual magnitude and reflection duration.

Therefore, you can use the radio signal duration as a hint for the visual magnitude of the meteor. I do realize, however, that scientifically useful conclusions cannot be drawn on the basis of 264 meteors. On the other hand, you cannot neglect 264 meteors totally. Besides that, there are other sources indicating the same result.

There are several reasons why signal duration cannot be converted to visual magnitudes just like that, but the main one is the role played by the position of the meteor with respect to the antenna. I have noticed that meteors, positioned 90° from the antenna direction show signals with very suppressed amplitudes. Their starting point can of course be clear, but soon they disappear into the background radio noise. I noticed this effect particularly when I was actually listening to the radio signals. The pen recorder registers the signals in a better way.

Meteors within 30° to 60° from the antenna direction create very clear signals and disappear late in the background noise. This effect is also noticed to some degree in the meteors 120° to 150° from the antenna. The speed of the meteors influences the signal duration also, of course, and very powerful persistent trains prolong the signal durations.

It is my experience that all visual meteors give radio signals when I use my pen recorder, but it is not always possible to separate the signal from the background noise during a listening session.

For your information: I have registered over 2 025 464 radio meteors by pen recorder in the period from August 4, 1989, to December 31, 1992. In this period I have observed 3109 visual meteors, 264 of which were also observed by radio.

I am glad that we have the opportunity to discuss this matter, because we should not draw wrong conclusions about the fireballs.

Gotfred Møbjerg Kristensen, January 1, 1993

Both letters above confirm the same picture: there is some relationship between visual magnitude and radio reflection duration, but this relationship is much more nebulous than what is suggested by the formula used in several IMO *publications. In his reaction below, Paul Roggemans traces back the origin of that formula and concludes that it is of little value.*

Several years ago I asked for an explanation of the relationship between echo duration and visual magnitude, as described by André Knöfel of *FIDAC* in the *WGN Report Series*, vol. 2, 1989, and it turned out that nobody actually could give me an explanation! One radio observer did have a graph from the Computer Commission but that graph unfortunately had no reference. Being very familiar with the meteor literature, I could remember I had seen this graph in the Proceedings of the *1986 International Meteor Weekend* in Hingene, Belgium. It was part of an article "Radio Meteor Work" by Jeroen Van Wassenhove, on p. 73 of these Proceedings. There, Jeroen Van Wassenhove derives the formula

$$M = \frac{-\log T + 0.288}{0.18},$$

hence this is *not* a formula by Davis, Greenhow, and Hall, as incorrectly stated by André Knöfel in vol. 2–4 (1989–1991) of the *WGN Report Series*.

Now, what is the value of Jeroen Van Wassenhove's formula? To be brief: very little! In his above-mentioned article, Van Wassenhove gives almost no explanation about the graph from which the formula is derived. The graph shows an enormous scatter on the individual data points. I speak about a clustered cloud of data points rather than a linear relationship between $\log T$ and M! The number of observations that were used to derive the formula is not stated, but is probably only 60–70: likely too few. As a reference, the article does quote the "Radio Handbook," but what I found there is a poor and misleading summary of McKinley's "Meteor Science and Engineering" (1961), pp. 230–232. In this book, we find the values copied in the "Radio Handbook," but with better explanations. Moreover, McKinley refers to some interesting research papers on this topic: one is an article by P.M. Millman and D.W.R. McKinley (*Canad. J. Phys.* 34, 1956, pp. 50–61) and another is by J. Davis, J.S. Greenhow, and J.E. Hall (*Proc. Royal Society*, Series A, 253, 1959, pp. 130–134).

All these references concern backscatter radio work only! Moreover, the equations differ for different streams and depend also upon elevation in the atmosphere, velocity, distance to the observer, the type of meteoroid (density), wavelength, radiant elevation, etc.... Most of these factors are unknown in forward scatter. Furthermore, very few bright meteors—I found only 2—were ever documented by visual/photographic data and radio echo measurements simultaneously. Extrapolating the assumed linear relationship towards the extremely bright meteors while ignoring most elements that play a role is certainly not reliable and should be avoided.

George Zay made a very good observation and his letter reminded me of what I have told before to the *FIDAC*. The estimate of a visual magnitude from long-duration echoes obtained with forward scatter should be left out of the annual report. The subject needs a more detailed study taking into account all factors in the ionization process. The formula presented to amateur radio observers is not reliable and is best ignored!

Paul Roggemans, January 19, 1993

The 1993 IMO International Meteor Conference

Puimichel, France, September 23–26

Paul Roggemans

A remarkably quick response to the announcement of the 1993 IMC in the last issue was received by the author. People started registering as soon as the December issue had reached them. It would appear that Puimichel is a particularly attractive site to host an *IMC*. Given the response we received and are still receiving, we expect that all available places will be booked in just a few months. For those who would like to participate we strongly suggest forwarding your registration form to the Secretary General and the pre-payment to the Treasurer as soon as possible to ensure a reservation. Late registrants will still have the opportunity to stay in a nearby hotel, but the accommodation included in the inexpensive registration fee is limited to 40 persons.

The author has been in Puimichel in December and has used his stay to prepare the *1993 IMC* to the extent that this was possible. Several practical aspects were considered, in particular the sleeping accommodation. The observers' residence where most participants will sleep is rustic, but comfortable. Rooms where usually 4 to 5 people sleep will be shared by 7 to 8 participants. People desiring more privacy or the comfort of a hotel room should contact the organizer to make special arrangements. It should be noted that the *IMC* is the first conference ever organized in Puimichel, so we may be starting a new tradition!

Below you will find additional updated practical information regarding the conference. Once again, do not wait to return your registration form if you wish to stay on-site at Puimichel! **We are almost fully booked!** For your convenience and as a courtesy to our new subscribers for whom this is their first issue we have reprinted the registration form.

Transport and traveling: As Puimichel is a very small village, it is possible that it will not be on your map. The village is situated not far from Digne, in the Haute-Provence. By car, you can reach Puimichel either from Marseille via freeway A 51-E 712 to Sisteron (exit "La Brillane-Oraison") or from Lyons via the freeway to Grenoble and then via route N 75 to Malijai. A small road (route D 12) connecting Oraison to Malijai leads to Puimichel. The nearest train station to Puimichel is La Brillane-Oraison. It is served from Marseille by 4 trains a day. We will try to organize a shuttle-service from the railroad station to Puimichel; for specific arrangements, please contact the organizer. For those participants flying into France, the closest major airport is Marseille.

The IMC from September 23 to 26: For the conference proper we will use an old Romanesque chapel, rebuilt as a multi-purpose meeting room that can seat 100. Meals will be taken at the observers' residence, the building in which the sleeping accommodation is also situated. Normally, the bedrooms are arranged in such a way that 20 to 25 observers can be accommodated, but with some inventiveness this number can be increased to 35–40. Some separate houses and hotel rooms can also be used to accommodate participants, at a supplement in price, of course. The Puimichel kitchen can provide meals for 40 to 50 people, although this requires great effort on the part of the cooks. The meals in Puimichel are very famous among regular visitors; my own experience is that more and better food is served there than anywhere else I have been. For instance, wine is served with the meals at no extra cost.

In addition to the lectures, we also plan an excursion. We intend to rent a bus to tour the region and to visit the famous Verdun Canyon. After we return, we may have an open-air barbecue.

During the entire *IMC*, drinks will be continuously available.

The pre-conference period of September 18 to 22: If at least 15 persons register for this period, the price will be 150 FRF per person, per day for full board (the normal rate being 240 FRF). We anticipate that this number will be reached. An extended stay at Puimichel permits several practice-oriented activities involving observing techniques etc. for which there is not sufficient time at the actual *IMC*, and hence will make your traveling expenses better pay off!

International Meteor Conference

Puimichel, France, September 23–26, 1993

Registration Form

Each individual participant should fill out a form and return it to Paul Roggemans, Pijnboomstraat 25, B-2800 Mechelen, Belgium, **before the end of 1992**! Late registrations are accepted on a place-availability basis only! Your registration will be guaranteed only after Ina Rendtel received at least the pre-payment of 100 DEM. If you strongly wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars. More information can be obtained from Paul (phone: +32-15-41 12 25).

Name: ______________________ Birth date: __________

Address: ______________________________________

____

Phone: ____________ Fax: ____________ E-Mail: ____________

- ○ wishes to register for the *IMC* from September 23 to 26;
- ○ intends to participate, cannot yet register, but wishes to stay on the mailing list;
- ○ wishes to stay in Puimichel before the *IMC* from __/__/1993 onwards at a price between 150 and 240 FRF per day;
- ○ prefers more private accommodation in a separate house within walking distance of "La Remise," at a supplement in price;
- ○ prefers a single/double room in a hotel at 10 min. driving distance from Puimichel, at a supplement of appr. 40 DEM per night.

I intend to travel by ______, together with ______________________

____

For participants interested in car-pooling:

- ○ I have __ free places in my car from ______________;
- ○ I would like a ride to Puimichel from ______________.

For participants wishing to contribute to the program:

Lecture: ______________________________________

Duration: ______min. Required equipment: ______________________

Workshop or discussion: ______________________________

Poster presentation: ______________________ Space: ______ m^2

Either the entire fee of 180 DEM or a pre-payment of at least 100 DEM should be sent to the Treasurer, *Ina Rendtel*, in the same way as your membership/subscription fee. Recall that Ina cannot accept bank checks! People wishing to pay in other currencies (USD, GBP, or JPY) should contact the appropriate *IMO* officer for exchange rates. Participants paying only 100 DEM have to pay the remainder upon arrival in Puimichel in French Francs, being 300 FRF.

Method and date of payment: ______________________ Amount: __________DEM

Date and signature,

At Puimichel, several large telescopes are at the disposal of amateurs: a 45-cm, a 52-cm, and a 106-cm reflector with CCD. The area is also excellent for spending your holidays; weather in September is usually pleasant. People already having registered and wishing to stay in Puimichel before the conference as well should write to Paul Roggemans. It is also possible to register for the period September 18-22 without attending the *IMC*.

In the past, many suggestions have been made regarding the need for combined visual, radio, and telescopic observations, and numerous people have expressed the need to get observing instructions directly from the *IMO* officers. Staying at Puimichel from September 18 to 22 will permit you to realize these possibilities. We strongly encourage you to take advantage of them!

Finally, we remind people wishing to stay at Puimichel during other periods than those mentioned above should write or phone directly to *Arlette Steenmans, Association Newton 406, La Remise, Puimichel, F-04700 Oraison, France, tel. +33-92-79-94-28* in French, English, Dutch, or German.

FIDAC News—A New Publication from the IMO

André Knöfel

The Global Volcanism Network (GVN—formerly SEAN) of the Smithsonian Institution discontinued the publication of fireball observations and meteorite fall reports at the end of 1992. The editors of the Bulletin of the Global Volcanism Network asked the Fireball Data Center (FIDAC) to continue the collection of such data and the publication of the reports. For this purpose, the IMO will start bimonthly publication of FIDAC News beginning in February 1993. This bulletin will be dedicated primarily to the publication of observations of fireballs and meteorite falls, generally in more detail than the GVN Bulletin recently had. Furthermore, we also intend to report results concerning investigations regarding fireballs and meteorites. The annual subscription rate is 15 DEM or 10 USD. You can order FIDAC News in the same way you pay for your WGN subscription.

Visual Observers' Notes: March and April 1993

Jeff Wood

In March and April, only the δ-Pavonids and the April Lyrids are active among the major showers. However, these months are characterized by a whole host of minor streams that makes observing especially after midnight most interesting when rates in dark skies can reach over 20 meteors per hour on occasions. As well, is the unusual number of brilliant fireballs that emanate out of the Scorpius, Libra, Centaurus and Virgo regions. Two of these seen on March 18, 1983, and April 6, 1975 were recorded as -19 and -15 respectively!

Table 1 lists some of the meteor showers to be seen in March and April 1992. Table 2 shows moonlight and observing conditions. The illuminated part of the Moon is always given for 0^h UT on the date indicated. The dates of the phases of the Moon are also given in UT.

The Visual Commission of the *IMO* although requiring data on all streams realizes practical considerations like work, study, family, Moon and weather prevent people from observing regularly on a day by day basis throughout most of the year.

With this in mind, it has been decided to encourage everyone who has time to observe to concentrate on a couple of showers per month rather than the whole lot. This means we should be able to get a good set of data on these few rather than sparse data on many showers. The showers chosen for special investigation for the months of March and April are the Virginids, δ-Leonids, γ-Normids, δ-Pavonids, α-Scorpids, π-Puppids, and the theoretical radiants of 1863 Antinous and 1981 Midas.

1. Virginids

This shower is very complex and is active from February 1 through to May 30. There are many subradiants and submaxima. Observers are encouraged to continue the project outlined in the Visual Observers' Notes for January and February 1992 [1].

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

Shower	Activity	Max	Radiant			Drift		V_∞	r	ZHR
			α	δ	Diam.	$\Delta\alpha$	$\Delta\delta$			
Virginids	Feb 01–May 30	several	195°	−04°	15°/10°			30	3.0	5
θ-Centaurids	Jan 23–Mar 12	Feb 01	210°	−40°	6°	+1.°1	−0.°2	60	2.6	
δ-Leonids	Feb 05–Mar 19	Feb 16	159°	+19°	8°	+0.°9	−0.°3	23	3.0	3
γ-Normids	Feb 25–Mar 22	Mar 14	249°	−51°	5°	+1.°1	+0.°1	56	2.4	8
δ-Pavonids	Mar 11–Apr 16	Apr 07	308°	−63°	10°/15°	+1.°2	+0.°1	59	2.6	13
Scorpid/Sagittarids	Apr 15–Jul 25	several	260°	−30°	15°/10°			30	2.3	10
Lyrids	Apr 16–Apr 25	Apr 22	271°	+34°	5°	+1.°1	0.°0	49	2.9	var
π-Puppids	Apr 15–Apr 28	Apr 23	110°	−45°	5°	+0.°6	−0.°2	18	2.0	var
α-Bootids	Apr 14–May 12	Apr 26	218°	+19°	8°	+0.°9	−0.°1	20	3.0	3
η-Aquarids	Apr 19–May 28	May 03	336°	−02°	4°	+0.°9	+0.°4	66	2.7	50

Table 2 – Moonlight and observing conditions in March–April 1993.

Date	k	Date	k
Friday February 26	0.17+	Friday April 02	0.70+
Friday March 05	0.84+	Friday April 09	0.93−
Friday March 12	0.82−	Friday April 16	0.30−
Friday March 19	0.16−	Friday April 23	0.01+
Friday March 26	0.07+	Friday April 30	0.55+

New Moon:	February 21, March 23, April 21
First Quarter:	March 1, March 31, April 29
Full Moon:	March 8, April 6, May 6
Last Quarter:	March 15, April 13, May 13

2. γ-Normids

This shower is often misnamed the Corona Australids due to a transcription error by the great New Zealand meteor worker R. MacIntosh in 1935. The γ-Normids are active from February 25 through to March 22. A variable maximum of 3 to 15 meteors per hour occurs on March 14. They are fast meteors and are best seen from the southern hemisphere in the pre-dawn hours.

The *IMO* urgently requires observations of this stream. In 1993, the periods February 25–March 3 and March 13–22 should be monitored. Observers should locate their field center no more than 40° away from the radiant and plot all possible γ-Normids seen. If observers wish to monitor both the δ-Pavonids and the γ-Normids, the field center must be located around $\alpha = 270°$ and $\delta = -55°$.

Table 3 – Radiant positions of the γ-Normids.

Date	α	δ	Date	α	δ
Feb 25	234°	−53°	Mar 14	249°	−51°
Mar 03	237°	−52°	Mar 19	254°	−50°
Mar 08	242°	−52°	Mar 22	258°	−50°

3. δ-Pavonids

The δ-Pavonids are thought to have been formed from the debris of Comet P/Grigg-Mellish (1907 II). Observations to date indicate that the shower produces variable activity with rates at maximum varying in the range of 5 to 15 meteors per hour. With the radiant reaching its greatest altitude in the southern hemisphere skies in the pre-dawn hours, the δ-Pavonids should provide moon-free viewing for most of their period of activity except from April 2 to 13. The δ-Pavonids appear to have several maxima during the period March 30 to April 10, apart from the major one that occurs on the morning of April 7. Even though most of the maximum period is ruined by the Moon, the *IMO* encourages observers to monitor the build-up and decline of the shower. They should locate their field center no more than 40° away from the radiant and ensure that all meteors seen are plotted.

Table 4 – Radiant positions of the δ-Pavonids.

Date	α	δ	Date	α	δ
Mar 11	296°	−65°	Apr 05	307°	−63°
Mar 21	301°	−64°	Apr 10	309°	−63°
Mar 31	305°	−63°	Apr 15	311°	−62°

4. April Lyrids

The Lyrids are active from April 16 to 25 reaching a maximum of between 10 and 15 meteors per hour on April 22. On a few occasions, the most recent being in 1982, rates have been much higher almost reaching 100 meteors per hour. The Lyrids' parent body is comet P/Thatcher (1861 I). In 1993, the Lyrid activity period is virtually moon-free and so the *IMO* urges all observers to give them special scrutiny. With a V_∞ of 49 km/s care needs to be taken when identifying meteors as Lyrids. Observers should ensure that the center of their field of view is no more than 40° from the radiant. Also they should plot all meteors seen unless the ZHR exceeds 10 when countings are permitted. Only at maximum is this likely to be the case.

Table 5 – Radiant positions of the Lyrids.

Date	α	δ	Date	α	δ
Apr 16	265°	+34°	Apr 22	271°	+34°
Apr 19	268°	+34°	Apr 25	274°	+34°

5. α-Scorpids

The α-Scorpids are one of the major components of what Hoffmeister called the Scorpio-Sagittarius complex of showers. This ecliptic stream is active from March 26 to June 4 with a broad maximum of between 4 and 8 meteors being reached during early May. The α-Scorpids are well known for the many brilliant yellow, orange and green fireballs they produce. Few, however, leave a persistent train. With a velocity V_∞ of 35 km/s, and several other Scorpio-Sagittarid radiants active in the same region of the sky, especially in May and early June, special care needs to be taken when recording and classifying these meteors. Observers should plot all possible α-Scorpids seen. They should center their field of view no more than 30° from the radiant.

Table 6 – Radiant positions of the α-Scorpids.

Date	α	δ	Date	α	δ
Mar 26	236°	−21°	May 05	246°	−24°
Apr 05	238°	−21°	May 15	249°	−25°
Apr 15	241°	−22°	May 25	252°	−25°
Apr 25	244°	−23°	Jun 04	254°	−26°

6. π-Puppids

The π-Puppids are a young meteor shower having been recorded only over the last 20 years. Their parent body is comet P/Grigg-Skjellerup. The π-Puppids are a periodic shower occurring in great numbers every five years. Rates therefore range from almost zero up to 40 per hour. The last strong activity was in 1987. In 1992, a maximum ZHR of 2 was obtained. It is hoped that rates will be considerably better in 1993.

The π-Puppids are a southern hemisphere shower and are best seen during the early evening hours. They are very slow meteors and often have a yellow-orange hue. Many fireballs are produced.

The 1993 return will be moon-free, and so observers are encouraged to monitor the shower. They should center their field no more than 40° from the radiant and plot all possible π-Puppids seen unless the rate exceeds 10 per hour when counts are permitted.

Table 7 – Radiant positions of the π-Puppids.

Date	α	δ	Date	α	δ
Apr 17	106°	−44°	Apr 23	110°	−45°
Apr 20	108°	−45°	Apr 26	112°	−46°

7. Theoretical radiants of 1863 Antinous and 1981 Midas

The Earth has a closest approach to the orbit of the minor planet *1863 Antinous* on April 6 (distance: 0.178 AU). Possible meteors have a V_∞ of 19.6 km/s and should radiate from $\alpha = 204°$, $\delta = +32°$ (April 6), $\alpha = 212°$, $\delta = +31°$ (April 16) [2].

A closest approach with the orbit of *1981 Midas* occurs on March 20 (distance: 0.001 AU). Possible meteors have a V_∞ of 30.1 km/s and a radiant at $\alpha = 205°$, $\delta = +35°$ (March 10), $\alpha = 213°$, $\delta = +34°$ (March 20) [2].

The orbits of both asteroids come close to that of the Earth's and the values of V_∞ make it possible to observe showers related to one or both objects. Due to the close approach and the high V_∞, 1981 Midas is the more favored candidate. The theoretical radiant positions provide northern hemisphere observers with the better viewing conditions though they can be observed in both hemispheres in the evening skies.

It should be noted that the theoretical radiant positions may differ somewhat from the actual observed ones by some degree. This means that it is impossible to carry out shower associations and obtain ZHRs using standard observing procedures.

What needs to be done is to investigate whether or not there is a significant radiant in the vicinity of the predicted one. In order to do this, observers should center their field of view at a distance of less than 20° from the predicted radiant position and plot all meteors seen that radiate from an area of about 25° around the predicted radiant position onto the Atlas Brno gnomonic charts. The X,Y-coordinates of the plots should be measured (see [3]) and reported in the table format described in the Aquarid Project (see [4]). Please of course mention the chart number.

In 1993, the *IMO* requests that observers watch the 1863 Antinous radiant from March 27 to April 2 (radiant position $\alpha = 200°$, $\delta = +32°$) and from April 12 to 16 (radiant position $\alpha = 210°$, $\delta = +31°$). The 1981 Midas radiant is relatively moon-free and so should be monitored from March 13 (radiant position $\alpha = 208°$, $\delta = +35°$) to March 30 (radiant position $\alpha = 220°$, $\delta = +33°$).

All possible meteors from these radiants should be plotted.

8. α-Bootids

This shower can be seen from April 14 to May 12. With a maximum on April 26 most of its period of activity is moon-free in 1993. The *IMO* requests that observers make the α-Bootids a priority project this year. They should center their field of view no more than 40° from the radiant and all possible α-Bootids should be plotted.

Table 8 – Radiant positions of the α-Bootids.

Date	α	δ	Date	α	δ
Apr 16	207°	+20°	Apr 28	218°	+19°
Apr 20	211°	+20°	May 02	222°	+19°
Apr 24	214°	+19°	May 06	225°	+18°

9. Final remarks

In those instances where counting is permitted, the meteor's angular velocity should be taken into account. As a courtesy to our new readers, we reprint the relationship between the meteor's angular velocity, height, and distance to the radiant for various values of the stream's geocentric velocity in Table 9.

References

[1] J. Wood, R. Koschack, D. Artoos, "Visual Observers' Notes: January–February 1992", *WGN* 19:6, December 1991, pp. 222–224.

[2] Duncan Olsson-Steel, "Theoretical Meteor Radiants of Recently Discovered Asteroids and Comets and Twin Showers of Known Meteoroid Streams", *Australian Journal of Astronomy*, April 1988, pp. 93–101.

[3] R. Koschack, "Comments for Visual Observers", *WGN* 18:6, December 1990, pp. 197–198.

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

Table 9 – 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: March and April 1993

Malcolm J. Currie

1. Virginids

Whatever the lunar chiaroscuro, these two months always permit viewing of the *Virginids*. These comprise numerous associated showers, all of low activity, each of which lasts typically for a few days, but may persist for a few weeks. The paucity of meteors makes it difficult to derive meaningful hourly rates; however, it is still possible for us to determine the locations and activity periods of the component showers. For example, see Alastair McBeath's analysis of 69 meteors [1].

There is a puzzle judging from the historical radiant data, in that there are inconsistencies between the numerous authors. This may simply reflect the transient properties of certain radiants, or observational errors, or indeed both. To find out the true behavior of this radiant complex will need many years of careful plotting by many observers using a variety of techniques. This is an ambitious aim, but in my view it is only possible by *IMO*, because of its number of observers and their geographical spread.

Telescopic observations should use at least three field centers each separated by about 20°, and displaced a similar angle from the ecliptic. For the March and April new-moon periods, the average centers should be at $\alpha \approx 175°$ and $\alpha \approx 200°$, respectively. The moderate angular speed and faint average magnitude of Virginid meteors makes them suitable for telescopic detection. The declination of the showers favors observers south of latitude 40° N. This arrangement should also enable the detection of other minor radiants in the vicinity.

2. Lyrids

The *Lyrids* are well placed in 1993. They are a shower that has variable peak rates, and it is capable of strong, short-lived bursts of swift and *faint* meteors. Therefore we should monitor them at every opportunity. The Lyrids have not been well observed, especially telescopically. Reasons for this include poorer weather at this time of year, and the fact that the radiant does not attain a high altitude until after midnight.

The Lyrid stream is believed to be at least 2600 years old. However, it does not show the characteristic signs of aging such as nodal evolution and the effects of dispersive forces. The latter conclusion is based upon the synchronous time of maxima for the visual and photographic meteors. Given sufficient data it would be interesting to find out whether the telescopic peak occurs at approximately the same time as that of the visual meteors. Generally, the smaller meteoroids will disperse more quickly, and the activity curve of telescopic meteors is broader and less peaky than that seen by visual observers. We can also look for this. Further aims are to measure the radiant position and size throughout the shower, and to determine the population index for the faint Lyrids.

Given that we know so little about the faint meteors in this shower, I should like northern telescopic observers to concentrate on the Lyrids after 23^h local time during the period April 17–25, not just on the night of the visual maximum. You will have to reselect the pairs of field centers as the radiant elevation climbs steeply after midnight. The centers should be about 15° from the radiant and oriented such that paths of Lyrid meteors traced back will intersect near right angles at the radiant.

While those in the north are savoring the Lyrids, southern hemisphere observers should keep a eye open for the *π-Puppids*. There may be stronger than normal activity in 1993. Although it is famed for bright meteors, as far as I know nobody has investigated the shower by telescopic means. If visual rates are high there will surely be some smaller particles present for the telescopic observer to record. Their passage would be made obvious by their low angular velocity. There is also the chance to see a visual meteor pass through the field—always a thrilling sight, especially if it leaves a persistent train that drifts and decays.

3. Other showers

The first week of the *η-Aquarids* is also well placed. The goals of studying the Halleyid showers have been discussed in earlier Telescopic Notes, see for example [2].

Of the minor showers the *α-Bootids* are well placed. The shower is rich in faint meteors and has a diffuse radiation area. We should look to see if this area is composed of more than one center. This analysis should be a by-product of data collected for the Virginids.

References

[1] A. McBeath, "UK Visual Results for the Virginids, 1988–1992", *WGN* 20:6, 1992, pp. 227–237.

[2] M.J. Currie, "Telescopic Observers' Notes", *WGN* 18:5, 1990, pp. 180–182.

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.

Perseid Meteor Shower Activity in 1992

Miloš Šimek

Results of the 1992 Perseid radar observations at Ondřejov are discussed. The presented activity profiles in different echo duration groups show dominant peaks at $\lambda_\odot = 138\overset{\circ}{.}7$ and $\lambda_\odot = 139\overset{\circ}{.}15$ (eq. 1950.0). The proportions of fragmenting particles in 1992 and 1991 were found to be higher than in previous years.

1. Introduction

The first results of the 1992 Perseid observations from the northern hemisphere, summarized by Brown et al. [1], point out the high activity of the shower near $\lambda_\odot = 138\overset{\circ}{.}75$ (eq. 1950.0), some 11 hours before the usual peak at $\lambda_\odot = 139\overset{\circ}{.}20$ reported by Lindblad and Šimek [2], Šimek and McIntosh [3], and Šimek [4] from long-term series of radar observations in Sweden, Canada, and Czechoslovakia in the period 1953–1985. Belkovich et al. [5] confirmed the occurrence of a later maximum position from 1986–1989 radar observations in Kazan.

Unusual Perseid activity had already occurred in 1991. Observations of this outburst are described by Roggemans et al. [6], Grishchenyuk [7], Šimek [8], Watanabe et al. [9], and others. They placed the first peak at $\lambda_\odot = 138\overset{\circ}{.}8$, which is close to the 1992 solar longitude reported by Brown et al. [1]. A similar but only slight enhancement of the activity at the same solar longitude was already found in the above mentioned observations from Onsala, Ottawa, and Ondřejov.

The 1992 Perseid observations complement our 19 yearly samples of the shower since 1958. The Ondřejov radar is operating at a radio frequency of 37.5 MHz with a pulse power of about 20 kW. Its antenna system is steerable in azimuth but fixed at an elevation angle of 45° above the horizon. The width of the radiation pattern between the half-power points in the vertical plane is about ±26°. One antenna is used for transmitting and receiving, having a TR switch to go between these modes. The limiting radio magnitude was found from simultaneous radar-telescopic observations to be $+7.5 \pm 0.6$. The antenna follows an azimuth differing by 180° from that of the shower radiant during the whole observation period.

2. Activity profiles

The 1992 shower activity was investigated in four different echo duration groups: $0.5\ \text{s} \le T < 1.6\ \text{s}$, $1.6\ \text{s} \le T < 10\ \text{s}$, $T \ge 10\ \text{s}$, and $T \ge 1\ \text{s}$. The last one represents an activity profile of typical overdense meteor echoes. Znojil et al. [10] derived a duration-absolute magnitude relation based on Perseid radar-visual simultaneous observations at Ondřejov in 1972 and 1973 which can be presented in the form

$$M_z = (2.45 \pm 0.50) - (2.31 \pm 0.45) \log T$$

where M_z is the absolute magnitude and T is the echo duration in seconds. The resulting values of M_z are summarized in Table 1.

Table 1 – Relationship between echo duration and absolute magnitude

Echo duration (T)	0.5 s	1.0 s	1.6 s	10.0 s
Absolute magnitude (M_z)	3.2 ± 0.3	2.5 ± 0.3	2.0 ± 0.3	0.1 ± 0.5

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WGN, the Journal of the International Meteor Organization, Vol. 21, No. 1, February 1993, pp. 13–18.

Shower rates were obtained after subtracting background rates from the observed ones as was described in [11] and [3]. The Perseid background mean patterns from the period 1958–1992 were applied in the analysis. Resulting shower rates were already corrected for the response function of the radar which takes into account the shower radiant zenith angle and corresponding antenna sensitivity patterns.

These shower activity rates N_r versus the solar longitude (eq. 1950.0) are shown in Figures 1–4, where N_r are in arbitrary units. The solar longitudes of the activity peaks are summarized in Table 2.

Table 2 – Activity peak positions (eq. 1950.0) for four different echo duration (T) groups.

$0.5\ \mathrm{s} \leq T < 1.6\ \mathrm{s}$	$1.6\ \mathrm{s} \leq T < 10.0\ \mathrm{s}$	$T \geq 10.0\ \mathrm{s}$	$T \geq 1.0\ \mathrm{s}$
$138^{\circ}.70 \pm 0^{\circ}.05$	$138.74 \pm 0^{\circ}.10$	$138^{\circ}.70 \pm 0^{\circ}.05$	
$139^{\circ}.00 \pm 0^{\circ}.05$	$139^{\circ}.10 \pm 0^{\circ}.05$	$139^{\circ}.04 \pm 0^{\circ}.11$	$138^{\circ}.90 \pm 0^{\circ}.05$
$139^{\circ}.20 \pm 0^{\circ}.05$			$139^{\circ}.16 \pm 0^{\circ}.10$
$139^{\circ}.66 \pm 0^{\circ}.10$	$139^{\circ}.50 \pm 0^{\circ}.05$		
$140^{\circ}.25 \pm 0^{\circ}.11$	$140^{\circ}.18 \pm 0^{\circ}.11$	$140^{\circ}.11 \pm 0^{\circ}.11$	$140^{\circ}.20 \pm 0^{\circ}.05$
		$140^{\circ}.50 \pm 0^{\circ}.05$	

We see that the nature of the meteoroid flux depends on the investigated echo duration group in terms of not only the strength but also the positions of the maxima. Some of these maxima were found in previous studies which were summarized in [8]. The main attribute of the 1992 activity seems to be a dominant peak at $\lambda_{\odot} = 139^{\circ}.70$ which was witnessed by many visual and radio groups, as reported in *WGN* 20:5. This is one of the main similarities with 1991 Perseid features.

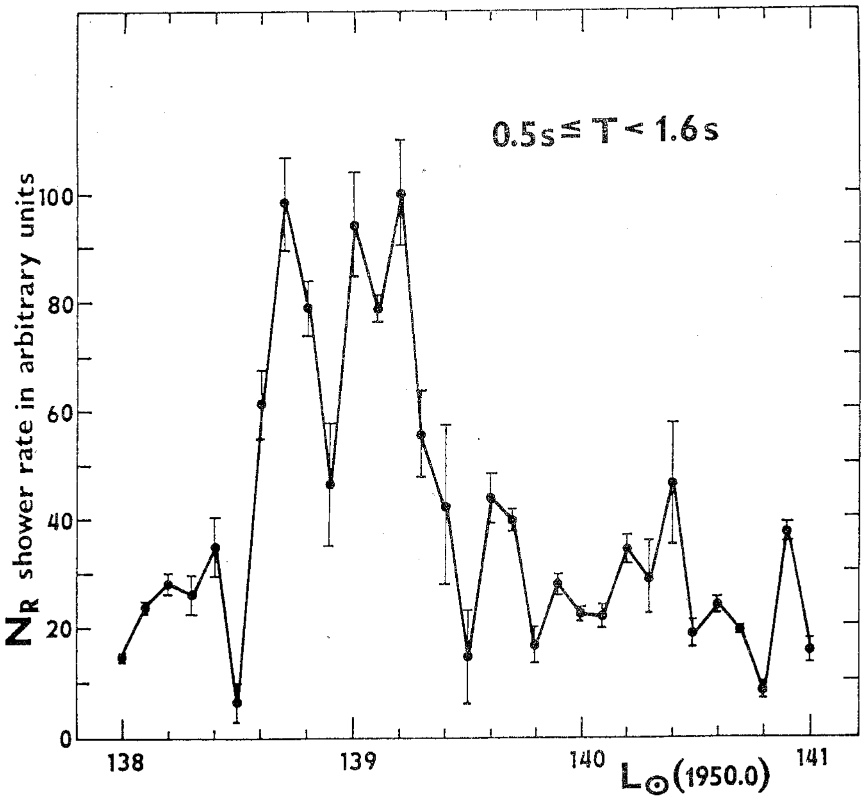

Figure 1 – The 1992 Perseids activity versus solar longitude (eq. 1950.0), in arbitrary units, for $0.5\ \mathrm{s} \leq T < 1.6\ \mathrm{s}$.

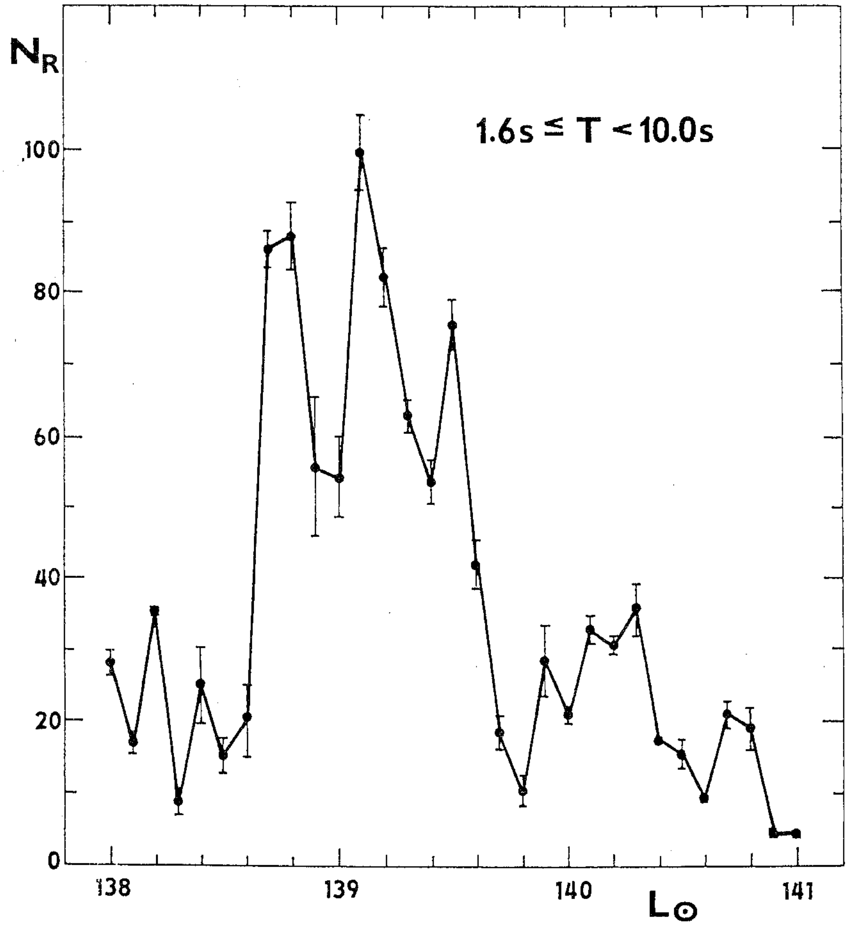

Figure 2 – The 1992 Perseids activity versus solar longitude (eq. 1950.0), in arbitrary units, for 1.6 s $\leq T <$ 10.0 s.

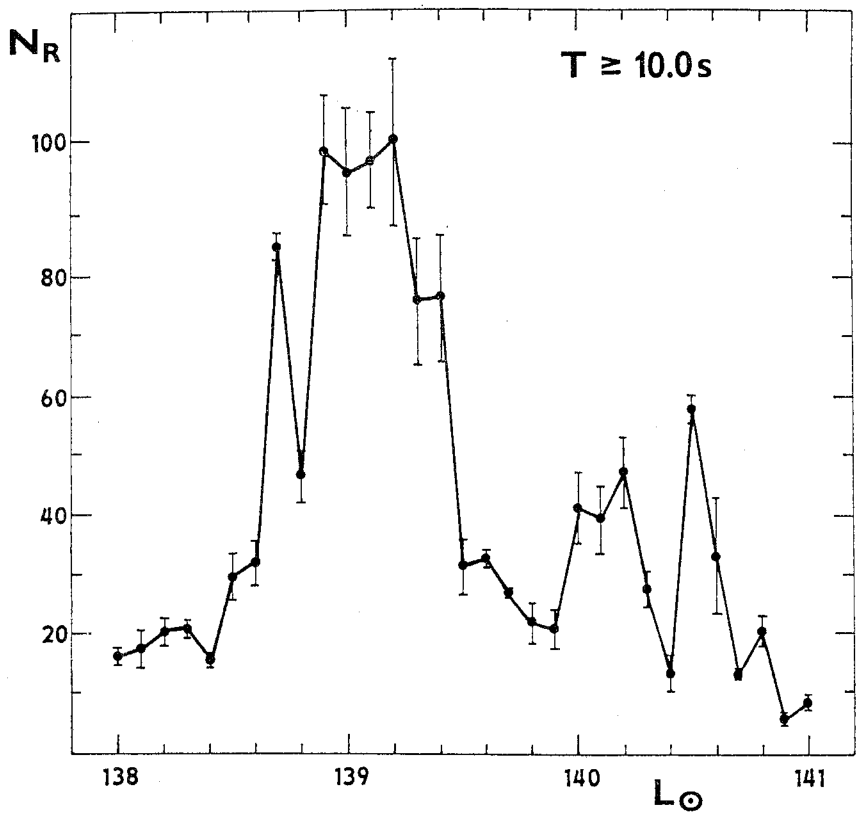

Figure 3 – The 1992 Perseids activity versus solar longitude (eq. 1950.0), in arbitrary units, for $T \geq$ 10.0 s.

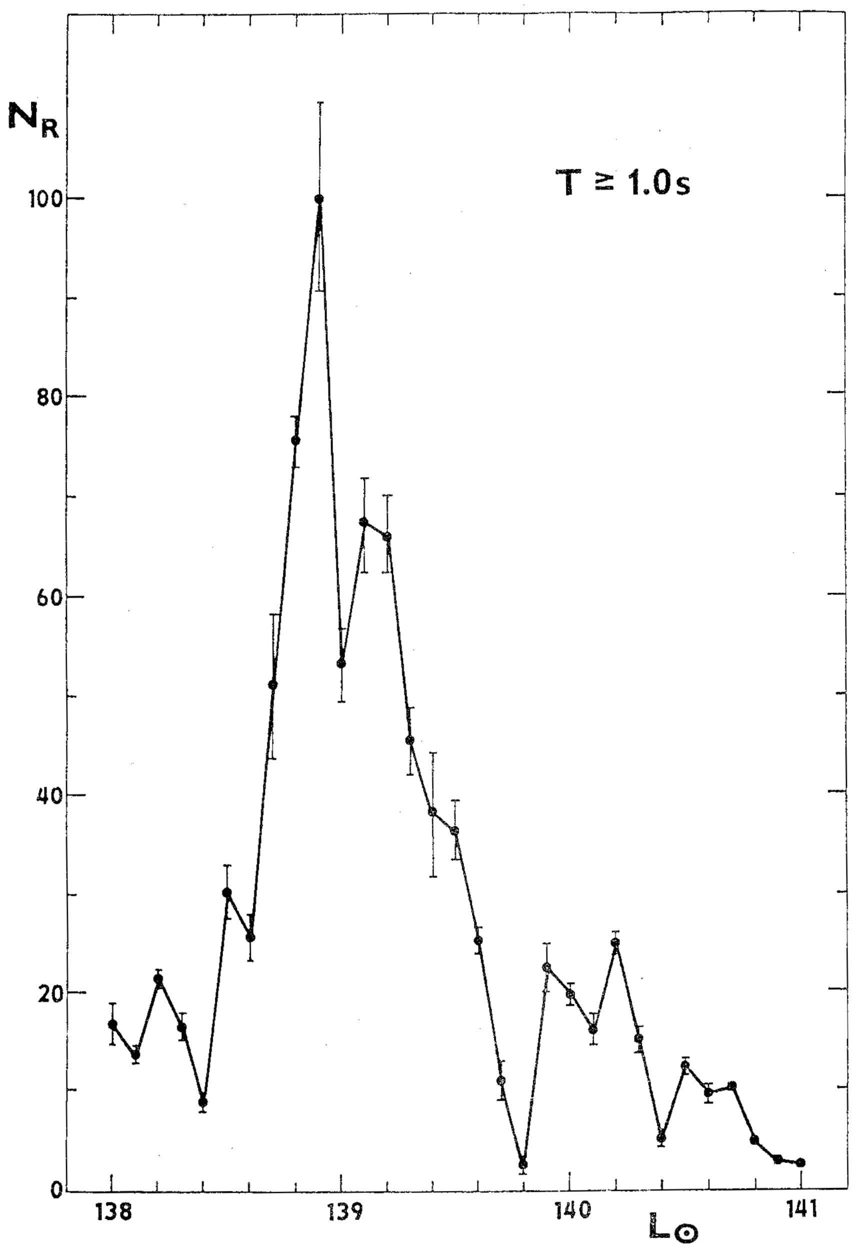

Figure 4 – The 1992 Perseids activity versus solar longitude (eq. 1950.0), in arbitrary units, for $T \geq 1.0$ s.

3. Fragmentation

We found an unusually high proportion of meteor echoes indicating a fragmentation process in 1991 and 1992. This initiated further analysis of the 1989–1992 observations from that point of view. For comparison, 1989 and 1990 observations were also considered. Fragmenting echoes appeared mainly in the same longitude range in 1991 and 1992, i.e., $138\overset{\circ}{.}4 \leq \lambda_\odot \leq 139\overset{\circ}{.}0$, while in 1990 and 1989 the fragmentation was more pronounced at $139\overset{\circ}{.}0 \leq \lambda_\odot \leq 139\overset{\circ}{.}5$. A direct comparison of the rates of fragmenting meteoroids in different years but in similar ranges of solar longitude is inappropriate because the rates of fragmenting meteoroids are influenced by the time during the day of the observation. Such a dependence is known from the analyses of head echoes which can be easily confused with fragmenting echoes in the case of low-power radars and high-velocity meteors such as the Perseids. Fragmenting meteors are distinguished from normal meteors in that they produce echoes at points on the trail far removed from the point of perpendicular reflection. The echoes are then characterized on the range-time record as multiple-echoes at different ranges. The envelope of the echo beginnings is not smooth as in the case of meteors showing a head-echo but is reminiscent of the head-echo hyperbolic shape.

For the analysis the solar longitude range $138^\circ\!.6 \le \lambda_\odot \le 139^\circ\!.5$ was considered. Because of the incomplete sample in 1989, proportions of fragmenting echoes in total counts of echoes having durations greater than 0.4 s were calculated from the summation of all such echoes for all hours in the diurnal cycle. Results are presented in Table 3.

Table 3 – Proportion of fragmenting echoes.

1989	1990	1991	1992
$2.7\% \pm 1.6\%$	$5.2\% \pm 0.8\%$	$9.1\% \pm 2.3\%$	$8.1\% \pm 2.1\%$

We see that the 1991 and 1992 returns may be classified as having a higher proportion of fragmenting meteoroids. It would be very interesting to compare this result with photographic records where the fragmenting process is more evident. The proportions in Table 3 could be interpreted as the behavior of younger particles recently ejected from the parent comet which are more fragile than older particles which have orbited the Sun for many revolutions. For older particles this stage of easy fragmentation may already be over.

It is evident that particles belonging to dominant activity peaks in 1992 and 1991 at $\lambda_\odot = 139^\circ\!.7$ and $\lambda_\odot = 139^\circ\!.8$ respectively, having been ejected during previous approaches of Comet 1862 III P/Swift-Tuttle [12], were formed in narrow filaments the orbital parameters of which did not favor observations before 1991.

4. Mass distribution

The mass distribution indices of overdense echoes having durations $T \ge 0.4$ s were examined separately in the regions of both dominant peaks centered ± 4 hours around $\lambda_\odot = 138^\circ\!.7$ and $\lambda_\odot = 139^\circ\!.15$, respectively. The slope of the linear portion of the $\log N$ versus $\log T$ curve was considered as the best representation for determining the mass distribution index s from the formula

$$\log N = -\frac{3}{4}(s-1)\log T$$

where N is the cumulative number of echoes having durations of at least T. It was found that the first peak is characterized by $s = 1.58 \pm 0.02$ and the second by $s = 1.39 \pm 0.02$. The discrepancy in both s-values could lead to the misinterpretation that it confirms the different nature of the particles in the two parts of the stream according to their age. Šimek [13] proved that the mass-index s shows a strong diurnal variation probably due to the different chemical and physical conditions controlling the ozone concentration as the dominant destructive agent of ionized meteor trails in the meteor zone, as was suggested by Jones et al. [14]. Values of mass-distribution indices from Šimek [13] averaged over the same hours giving $s = 1.59 \pm 0.03$ and $s = 1.33 \pm 0.01$ are not far from the results of the 1992 observations. From this point of view we may conclude that the particles which formed a peak at $\lambda_\odot = 138^\circ\!.7$ in 1992 have a mass distribution similar to what is generally accepted for the Perseids. This could be in contradiction with the supposed low age of the particles in the new filaments which were exposed to non-gravitational forces in planetary space and therefore should be rich in small particles which would be reflected by a higher s-value. This discrepancy can be explained by the mass range of the analyzed sample where radiation forces have minimum efficiency.

5. Conclusions

The 1992 Perseids were characterized by at least three anomalies: First, the appearance of a dominant activity peak at $\lambda_\odot = 138^\circ\!.75$, which is apparent in all investigated groups of echo durations with $T \ge 0.4$ s. Second, the proportion of meteoroids showing a fragmentation process when penetrating the atmosphere is higher than in recent years. Third, the activity structure is not uniform. It is characterized by several separated parallel filaments the nature of which depends on the investigated particle mass range and on their positions with respect to the central comet orbit. All these features are common for both the 1991 and 1992 observations. The geometrical configuration of the 1993 return described by Roggemans [12] is in favor of a spectacular event which should be well-observed by all possible means, and then carefully analyzed.

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The 1991 Geminid Meteor Shower

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The results of the 1991 *IMO* Geminid observing project are presented. In all 163 observers observed over 32 000 shower meteors in the week-long project extending from December 11–16, 1991. This leads to statistically reliable results. The application of perception corrections should reduce systematic errors, but nevertheless artifacts in the activity curve may occur. The peak ZHR rate of 110 was reached at $\lambda_\odot = 262^\circ\!.3$. A preceding maximum is clearly defined in the ZHR curve at $\lambda_\odot = 261^\circ\!.35$. The ZHR curve is best described as skewed toward pre-maximum nights. The visual ZHR peak coincides with the core of the stream containing most of the larger meteoroids, while smaller particles appear over a wider region also showing more maximum-like structures before the main peak of number density is reached.

1. Introduction

In 1991, the most successful Geminid watch yet analyzed by the *IMO* was carried out with over 32 000 shower meteors having been recorded. This represents an extraordinary observational effort for a northern winter stream and permits a detailed analysis to be undertaken. This amount of data is almost three times larger than in 1990. We are particularly grateful to the 163 observers who contributed to this work and made the analysis one of the most reliable ever presented for the stream:

Ben Apeldoorn (209, 9^h50), Igor Aren (68, 2^h50), Rainer Arlt (515, 13^h76), Kremena Baltova (26, 3^h42), Luis R. Bellot (184, 2^h28), Igor Benyo (16, 2^h60), Lance Benner (53, 3^h92), Paul Bensing (179, 6^h92), Felix Bettonvil (164, 6^h48), Garcia Blanca (145, 2^h85), Ragnar Bödefeld (109, 3^h64), Grant Bonnel (317, 5^h58), Francisco Campos (43, 2^h38), Maurice Clark (117, 5^h13), Martin Coroneos (128, 4^h07), Peter Cornille (127, 3^h00), Luigi d'Argliano (114, 3^h02), Albert de Clerck (63, 3^h50), Niek de Kort (289, 9^h37), Stefano del Dotto (38, 3^h54), Werner Depoorter (62, 3^h50), Vincent Devore (145, 7^h22), Massimo Dionisi (78, 6^h67), Aaron Doherty (143, 3^h08), Darren Ferdinando (51, 2^h68), Keiiti Fukui (220, 7^h00), Azumi Fuse (14, 0^h33), Kai Gaarder (291, 7^h75), John Gallagher (40, 20^h99), Mirjana Galicic (35, 1^h12), Jaroslav Gerboš (15, 2^h55), Ivanka Getsova (9, 1^h63), George W. Gliba (105, 5^h00), Daniel Glomski (261, 6^h88), Mark Glossop (275, 10^h73), Roberto Gorelli (94, 4^h17), Valentin Grigore (191, 11^h15), Robert Haas (230, 9^h99), Torsten Hansen (212, 9^h75), Takema Hashimoto (357, 7^h75), Werner Hasubick (116, 3^h00), Robert Hays (6, 1^h00), Zoltán Hevesi (337, 7^h75), Trond E. Hillestad (611, 12^h14), Sinobu Iida (37, 4^h88), Sinichiro Isii (70, 4^h70), Akihiro Isobe (64, 5^h87), Daiyu Ito (114, 4^h86), Kiyoshi Izumi (118, 3^h52), Anne Jokinen (110, 4^h83), Jules Jonlet (136, 5^h00), Toshio Kamimura (2, 1^h97), Aram Karalič (101, 2^h48), Junji Kawamura (31, 2^h92), K. Kawabata (122, 2^h27), Akos Kereszturi (645, 15^h00), Timo Kinnunen (427, 7^h34), Rado Klemencic (77, 2^h50), André Knöfel (1540, 40^h60), Bernhard Koch (1041, 34^h20), Korlevic Korado (98, 2^h17), Kazimierz Kosz (5, 1^h95), N. Kosiyama (229, 3^h13), Ralf Koschack (1405, 28^h79), Gotfred M. Kristensen (82, 7^h65), T. Kurosawa (194, 4^h69), Ralf Kuschnik (21, 2^h25), Gabor Kutrovatz (399, 10^h75), Alberto Latini (51, 2^h58), Robert Lunsford (689, 12^h96), Ismo Luukkonen (131, 3^h75), Irena Macek (140, 3^h42), Kouji Maeda (37, 1^h67), Veikko Mäkelä (186, 5^h75), Katuhiko Mameta (296, 9^h63), Adam Marsch (2, 4^h57), Takuya Maruyama (174, 5^h50), Tony Markham (14, 4^h36), Yukihisa Matumoto (22, 1^h72), Alastair McBeath (140, 19^h92), Stefano Minardi (44, 1^h00), Edmond Miroen (74, 3^h00), Koen Miskotte (475, 20^h98), Hidekatu Mizoguchi (56, 4^h19), Naomi Muto (77, 3^h66), Tivadar Nagy (33, 4^h46), Atanas Nikolov (28, 3^h88), Michael Nolle (84, 2^h50), John Odgers (189, 3^h06), H. Okayasu (25, 2^h45), Masayuki Oka (84, 4^h50), Kazuhiro Osada (444, 6^h96), Urška Pajer (16, 1^h75), Alessandro Pieri (102, 3^h50), George Platt (183, 8^h03), Ghislain Plesier (271, 11^h65), Kalman Posztobanyi (190, 8^h75), Mateja Raic (28, 1^h93), Leo Rajala (282, 15^h27), Pia Rämä (78, 2^h08), Pavol Rapavy (5, 2^h60), Renata Recsek (55, 3^h00), Ina Rendtel (572, 10^h77), Jürgen Rendtel (527, 31^h44), Francisco Reyes Andres (3, 2^h12), Paul Roggemans (1439, 40^h32), Tuomo Roine (90, 2^h05), Roope Ruotsalainen (62, 6^h50), Holger Sack (135, 4^h12), Toru Sagayama (195, 6^h48), Kotaro Sakuma (12, 1^h80), Krisztián Sárneczky (481, 17^h25), Hiromi Sato (88, 15^h94), Koetu Sato (10, 4^h40), Tatuo Sato (202, 12^h00), Daan Schroyens (1577, 25^h29), Thomas Scott (108, 3^h08), René Scurbecq (126, 3^h13), Takashi Sekiguchi (468, 13^h01), Yumiko Sekine (119, 4^h82), Gregory Shanos (127, 6^h00), Brian Shulist (465, 5^h90), Yasuo Shiba (147, 4^h78), Darren Simpson (12, 1^h90), Karl Simmons (70, 2^h88), Robert

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The analysis was done with the *Visual Meteor Database (VMDB)* and the programs implemented by Paul Roggemans and Ralf Koschack.

2. Methods

The knowledge of the population index r and its variation with time is the first step in any ZHR calculation. Therefore, the individual r-values must be calculated from the magnitude data in the *VMDB* [1]. Some criteria were adopted to screen out only the most reliable data:

1. The difference between the faintest magnitude class and the limiting magnitude should be larger than 2;
2. Five consecutive classes with at least 3 meteors in each class should be available in the magnitude distribution;
3. The number of shower meteors in a magnitude distribution should be larger than 20 and;
4. The correlation coefficient in the linear regression with the perception-corrected number of meteors as the dependent variable and the magnitude class as the independent variable should be higher than 0.98 [2]. This value was chosen from experience as being a good discriminator between good and bad data.

The list with r-values is averaged according to adopted intervals and overlaps (step sizes). The procedure then applies an outlier rejection algorithm to the mean values. The outliers are discarded when being off the confidence intervals of 90, 95 or 99%. Since the distribution of the single values is only nearly Gaussian and in order to keep the calculation time acceptable, the outliers are not found by an iterative procedure but by a stepwise (always terminating) determination of the mean (of all members) and the cancellation of values that lie off the mean by more than $1.645\,\sigma$, $1.960\,\sigma$, or $2.576\,\sigma$, respectively [3].

The resulting r-profile can be used for the ZHR calculations. Again all individual rates are reduced to ZHRs with r-values obtained by linear interpolation of the profile data. The ZHRs can be averaged for certain intervals using the outlier rejection procedure. With these means the perception coefficient for each observer is determined [4]. In principal, an interval used for the computation of perception coefficients should have constant activity. Otherwise observations at the beginning of the interval are corrected towards the mean of the period, resulting in correction factors larger than 1, for the case of increasing activity and factors smaller than 1 for decreasing activity. However, since the coefficients of overlapping intervals are averaged (sliding mean) it is sufficient that the change in activity is linear. Imagine two partly superposed intervals covering an increasing activity profile. A value which contributes to both intervals will get a perception coefficient smaller than 1 according to the mean of the left interval, and a factor larger than 1 considering the right mean, thus avoiding this problem. Finally, the mean of the coefficients determined in this way should be approximately as valid as the result obtained if the activity were constant. Only intervals with very rapidly changing activity are not applicable for the perception coefficient determination. Therefore, it is not possible to determine perception coefficients for all observers involved. The ZHRs of these contributors are not corrected by a limiting magnitude offset Δlm.

The individual ZHRs are re-computed with these perception coefficients and averaged for a ZHR profile applying the outlier rejection method. Hence, we may assume that observers for which no perception coefficient is available, do not affect the average ZHR. If their results required a large Δlm, the outlier rejection would omit their values. Hence they may increase the scatter, but should not significantly shift the average. Since the amount of available data varies strongly during the activity period of a shower, it is possible to define different period lengths for both the r- and the ZHR-profile. Data far from the maximum may be averaged with interval lengths larger than or equal to 1° of solar longitude. Near-maximum nights can be split up into fairly small periods. If the data is poor even around the maximum, it is likely arbitrary activity frequencies will appear when using interval lengths smaller than 1°. The Geminids, however, provided us with enough meteors that we could use relatively small intervals.

3. Magnitude data and the population index

In earlier analyses, rate data were the central quantity of interest. It is now clear, however, that the population index r is the fundamental quantity to permit further analysis. Thus we must first determine a profile for the value of r for the passage of the Earth through the meteor stream.

To get an impression of the distribution of the observational data, we first calculated all values of r from individual observers without averaging. This shows which intervals are best covered with observations and which suffer from a paucity of data. Due to the waxing moon most observations were carried out after midnight local time. It becomes obvious that the good weather over Europe around the Geminid maximum resulted in a huge number of observations. In addition, most of the other intervals are well-covered by observers. Therefore it was possible to calculate a complete r-profile between $\lambda_\odot = 257°$ and $\lambda_\odot = 264°$. Of course, the most interesting variations will happen around the stream's core. Due to the huge amount of data, it was possible to calculate averaged r values for intervals of 0°6 length shifted by 0°3 (see the Introduction). In Table 1 the values of r and the respective errors are given. The number of meteors included for each average indicates its reliability. These data are shown graphically in Figure 1.

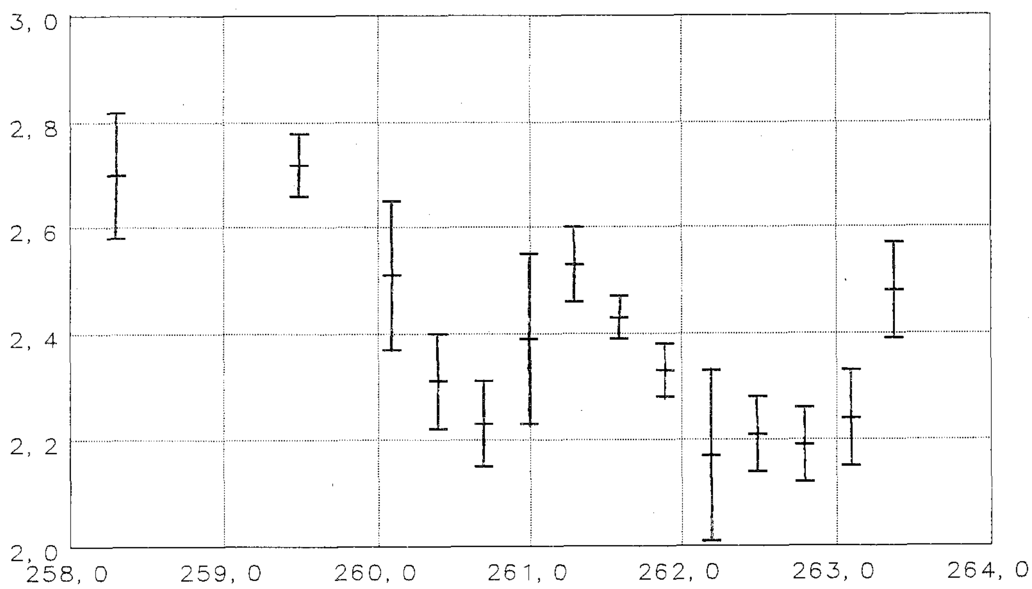

Figure 1 – Profile of the population index r of the Geminids. The calculated figures are given in Table 1. Within the most interesting period, $\lambda_\odot = 260°$ to $\lambda_\odot = 263°$ (eq. 2000.0), we were able to apply a short averaging interval of 0°6 length which is shifted by 0°3. The characteristic features of this graph also occur if other interval lengths and starting points are used.

Table 1 – Profile of the population index r for the 1991 Geminids derived from the magnitude distributions of the observers listed in the Introduction.

$\lambda_\odot$ (2000.0)	Obs	Gem	r	$\overline{\text{lm}}$
257°921	3	155	2.736 ± 0.167	5.94
258°265	4	195	2.704 ± 0.122	6.11
259°563	5	475	2.722 ± 0.063	6.65
260°241	5	319	2.512 ± 0.144	6.37
260°540	18	1510	2.309 ± 0.091	6.48
260°619	16	1532	2.228 ± 0.081	6.47
261°388	12	1667	2.527 ± 0.071	6.44
261°635	52	6686	2.429 ± 0.041	6.38
261°712	43	5881	2.325 ± 0.047	6.34
262°235	5	1017	2.171 ± 0.156	6.44
262°626	26	2952	2.210 ± 0.070	6.26
262°949	5	281	2.242 ± 0.090	6.34
263°433	2	102	2.482 ± 0.093	6.25

It is worthy to note that we checked whether the profile shown is independent of the choice of the interval length and the start time for the averaging procedure. We chose longer intervals (up to 1°0) as well as shorter ones (down to 0°5) for the central region of the shower. Of course, the averaged values (averaged r for the average solar longitude as described above) differ slightly from one series to the next, but all the profiles clearly show two characteristic features. These features are two dips in r at $\lambda_\odot = 260°7$ and $\lambda_\odot = 262°2$. These two periods were obviously characterized by a larger portion of bright meteors. Between these dips we see a clear maximum in r at $\lambda_\odot = 261°3$ indicating that there was an interval with a significantly larger portion of fainter meteors.

4. The ZHR profile

From the diverse list of observers given at the beginning of this paper it should be clear that there were experienced observers as well as more seasonal observers active during the shower. As a result, the individual ZHRs show a large scatter. To handle such data sets, the derivation of perception coefficients was introduced [4]. These coefficients can be determined within periods which show an almost constant level of activity as described above. In this case observers with different perceptions should note the same ZHR. From previous analyses it was found that systematic differences can be eliminated best when the limiting magnitude of the observer is taken into account in the corrections.

Six periods of almost constant activity were chosen for the calculation of the perception coefficients. These intervals show a high level of activity so that the individual ZHRs are based on a relatively large number of Geminid meteors. Table 2 gives the individual coefficients Δlm. These represent the equivalent change in the lm needed to offset the observers perception. No coefficients are obtained for those observers having not been active during the chosen intervals mentioned above.

Having determined these corrections, we can now calculate the average activity profile (Figure 2). It shows the maximum to be at about $\lambda_\odot = 262°3 \pm 0°1$ (eq. 2000.0) with a ZHR of 110. Additionally, we see a preceding maximum at $\lambda_\odot = 261°35$ and a local maximum at $\lambda_\odot = 260°3$. Here the ZHR is of the order of 100 and 40 respectively. The data are given in Table 3. The number of shower meteors demonstrates the reliability of the derived figures. But the ZHR is not a physical quantity, rather it only gives the corrected visible number of meteors of at least $+6^{\text{m}}5$. It has previously been described in detail how the values of the population index r and the observed ZHR together may lead to information about the meteor stream [1].

Table 2 – Perception coefficients P and Δlm correction for the observers who observed within the reference intervals used for the determination of the perception.

Observer	Int	P	Δlm	Observer	Int	P	Δlm
Apeldoorn Ben	6	0.84	-0.262 ± 0.415	Nagy Tivadar	2	0.48	-0.947 ± 0.071
Arlt Rainer	7	0.94	-0.085 ± 0.181	Odgers John	1	1.53	$+0.460$
Bensing Paul	3	0.70	-0.449 ± 0.106	Osada Kazuhiro	5	1.85	$+0.771 \pm 0.126$
Bettonvil Felix	3	0.69	-0.428 ± 0.128	Pajer Urska	1	0.84	-0.223
Bödefeld Ragnar	2	0.80	-0.258 ± 0.062	Pieri Alessandro	2	0.82	-0.229 ± 0.000
Campos Francisco	1	1.00	-0.002	Platt George	6	1.45	$+0.408 \pm 0.229$
Clark Maurice	8	0.91	-0.169 ± 0.362	Plesier Ghislain	3	0.53	-0.742 ± 0.115
Coroneos Martin	5	1.53	$+0.410 \pm 0.226$	Posztobanyi K.	4	0.62	-0.720 ± 0.643
d'Argliano Luigi	4	1.06	$+0.053 \pm 0.292$	Rajala Leo	3	1.81	$+0.576 \pm 0.287$
De Clerck Albert	1	0.68	-0.438	Rama Pia	1	1.85	$+0.778$
de Kort Niek	6	1.03	-0.016 ± 0.416	Recsec Renata	6	0.69	-0.480 ± 0.271
del Dotto Stefano	2	0.28	-1.430 ± 0.000	Rendtel Ina	7	0.98	-0.044 ± 0.290
Devore Vincent	2	0.94	-0.061 ± 0.021	Rendtel Jürgen	12	0.94	-0.104 ± 0.246
Dionisi Massimo	2	0.72	-0.380 ± 0.001	Reyes Andres F.	2	0.24	-1.780 ± 0.014
Doherty Aaron	6	0.79	-0.309 ± 0.142	Roggemans Paul	12	1.05	$+0.024 \pm 0.305$
Ferdinando Darren	2	1.55	$+0.513 \pm 0.021$	Roine Tuomo	1	1.54	$+0.487$
Fukui Keiiti	8	1.13	$+0.151 \pm 0.105$	Sack Holger	3	0.80	-0.273 ± 0.227
Fuse Azumi	2	0.42	-1.100	Sagayama Toru	12	0.89	-0.157 ± 0.246
Gallagher John	2	0.18	-1.740 ± 0.021	Sárneczky K.	10	1.12	$+0.129 \pm 0.148$
Gliba George W.	2	0.69	-0.375 ± 0.022	Sato Hiromi	4	0.50	-0.964 ± 0.804
Glomski Daniel	2	1.43	$+0.430 \pm 0.030$	Sato Koetu	2	0.15	-2.140 ± 0.226
Glossop Mark	9	1.43	$+0.414 \pm 0.181$	Sato Tatuo	10	0.96	-0.072 ± 0.273
Gorelli Roberto	2	0.62	-0.558 ± 0.155	Schroyens Daan	10	1.29	$+0.286 \pm 0.233$
Grigore Valentin	4	0.97	-0.049 ± 0.195	Scott Thomas	1	1.70	$+0.602$
Haas Robert	3	0.56	-0.744 ± 0.163	Scurbecq René	1	1.28	$+0.281$
Hashimoto Takema	11	1.28	$+0.229 \pm 0.514$	Sekiguchi Takashi	6	1.88	$+0.776 \pm 0.115$
Hasubick Werner	2	0.75	-0.360 ± 0.328	Sekine Yumiko	8	1.16	$+0.160 \pm 0.276$
Hevesi Zoltán	4	1.08	$+0.064 \pm 0.231$	Shiba Yasuo	6	1.03	$+0.008 \pm 0.264$
Hillestad Trond E.	6	1.30	$+0.295 \pm 0.200$	Shulist Brian	6	1.16	$+0.176 \pm 0.153$
Iida Sinobu	6	0.30	-1.500 ± 0.211	Simon Robert	2	0.30	-1.640 ± 0.615
Ito Daiyu	6	0.85	-0.238 ± 0.396	Simpson Darren	2	1.77	$+0.568 \pm 0.021$
Izumi Kiyoshi	4	0.94	-0.084 ± 0.336	Sioi Hiroyuki	6	0.81	-0.268 ± 0.120
Jokinen Anne	1	1.68	$+0.661$	Smith Barry	1	1.40	$+0.367$
Karalič Aram	2	1.43	$+0.431 \pm 0.168$	Smith J.N.	1	1.15	$+0.142 \pm 0.021$
Kawabata K.	6	1.17	$+0.197 \pm 0.104$	Soumanis Peter	1	1.61	$+0.516$
Kawamura Junji	2	1.37	$+0.404 \pm 0.031$	Sperberg Ulrich	1	0.94	-0.075
Keresztūri Akos	12	1.10	$+0.102 \pm 0.218$	Stapf Siegfried	12	0.96	-0.064 ± 0.207
Kinnunen Timo	2	1.80	$+0.701 \pm 0.146$	Stomeo Enrico	2	0.84	-0.305 ± 0.742
Klemencic Rado	1	1.39	$+0.373$	Stomeo Stefano	2	1.07	-0.060 ± 0.430
Knöfel André	10	1.24	$+0.218 \pm 0.385$	Ströbele Stefan	2	1.30	$+0.284 \pm 0.212$
Koch Bernhard	10	1.12	$+0.129 \pm 0.214$	Tanaka S.	4	1.18	$+0.204 \pm 0.125$
Korado Korlevic	2	1.31	$+0.318 \pm 0.289$	Tepliczky István	5	0.66	-0.553 ± 0.359
Koschack Ralf	10	0.91	-0.115 ± 0.101	Toenessen Morten	1	0.89	-0.145
Kosiyama Nobuyuki	8	1.11	$+0.107 \pm 0.277$	Tomioka Hiroyuki	6	0.56	-0.783 ± 0.454
Kristensen Gotfred	1	0.52	-0.825	Törrönen Tuomas	2	1.48	$+0.443 \pm 0.486$
Kurosawa T.	8	1.46	$+0.471 \pm 0.174$	Ueda Masayoshi	3	1.36	$+0.369 \pm 0.010$
uschnik Ralf	2	0.42	-1.090 ± 0.014	Uehara Satosi	6	0.71	$+0.457 \pm 0.206$
Kutrovatz Gabor	4	0.83	-0.224 ± 0.095	Ueno Toshihiko	4	0.78	-0.345 ± 0.201
Latini Alberto	1	0.86	-0.196	Uyama Yoshiaki	7	0.60	-0.651 ± 0.197
Lunsford Robert	10	0.90	-0.179 ± 0.335	Van Biesen Johan	1	1.22	$+0.229$
Luukkonen Ismo	1	0.95	-0.063	Varsek Alen	3	1.46	$+0.442 \pm 0.098$
Mäkelä Veikko	2	1.25	$+0.264 \pm 0.197$	Verbeeck Cis	1	1.25	$+0.253$
Maeda Kouji	2	1.02	$+0.026 \pm 0.001$	Vigh Imola	11	1.03	-0.095 ± 0.665
Mameta Katuhiko	11	0.92	-0.115 ± 0.242	Vinken Wim	1	1.03	$+0.032$
Maruyama Takuya	4	1.46	$+0.476 \pm 0.171$	Winkler Roland	4	0.28	-1.490 ± 0.567
McBeath Alastair	2	1.12	$+0.109 \pm 0.257$	Wislez Jean-Marc	1	1.33	$+0.323$
Miroen Edmond	1	0.98	-0.026	Wood Jeff	9	2.22	$+0.835 \pm 0.114$
Miskotte Koen	4	0.89	-0.165 ± 0.249	Yabu Yasuo	13	1.01	-0.021 ± 0.320
Muto Naomi	4	1.11	$+0.123 \pm 0.060$	Zampatori David	4	1.44	$+0.384 \pm 0.303$

Table 3 – Calculated ZHRs for the entire activity period of the Geminids 1991 using the perception corrections and the r profile determined in the beginning.

$\lambda_{\odot}$ (2000.0)	Interv.	Gem	ZHR	Spor	HR	$\overline{\mathrm{lm}}$	r
255°452	8	28	3.5 ± 0.3	134	16.8	6.36	2.74
255°822	12	51	3.3 ± 0.4	196	12.8	6.62	2.74
256°961	21	150	8.9 ± 2.1	302	17.9	6.52	2.74
257°408	24	195	7.2 ± 1.3	322	11.8	6.67	2.73
258°295	40	326	6.9 ± 0.9	450	9.5	6.47	2.72
259°113	59	907	13.0 ± 8.0	979	14.0	6.48	2.70
259°543	42	820	15.4 ± 0.9	782	14.7	6.56	2.68
259°777	9	152	17.1 ± 1.6	102	11.5	6.37	2.62
260°280	21	323	37.9 ± 2.0	293	34.4	5.94	2.39
260°302	27	451	41.8 ± 2.1	420	38.9	6.02	2.37
260°546	40	1287	32.1 ± 1.0	482	12.0	6.53	2.26
260°631	63	2091	29.5 ± 0.8	732	10.3	6.56	2.25
260°723	42	1314	30.3 ± 1.4	494	11.4	6.54	2.25
260°915	16	800	60.9 ± 7.3	190	14.5	6.52	2.36
261°055	10	401	55.7 ± 9.6	13	2.0	6.47	2.41
261°312	36	1289	100.5 ± 2.0	669	51.9	6.01	2.51
261°361	50	1962	106.7 ± 5.3	955	51.9	6.07	2.50
261°611	95	5948	83.3 ± 1.4	1020	14.3	6.23	2.42
261°677	150	9780	82.6 ± 1.2	1698	14.3	6.35	2.40
261°773	82	5819	89.5 ± 2.5	1056	16.2	6.46	2.36
261°949	19	1495	105.2 ± 5.7	200	14.1	6.31	2.29
262°204	31	1478	100.5 ± 3.8	331	22.5	5.97	2.20
262°322	85	3735	111.2 ± 1.0	1028	30.6	5.79	2.19
262°403	81	3653	97.6 ± 2.5	863	23.1	5.79	2.20
262°647	91	4224	59.4 ± 1.5	685	9.6	6.25	2.20
262°702	104	4282	49.5 ± 1.7	953	11.0	6.39	2.19
262°813	34	1126	35.3 ± 2.3	406	12.7	6.41	2.20
262°954	4	135	26.6 ± 13.5	37	7.3	6.14	2.22
263°305	12	111	19.7 ± 2.3	182	32.3	6.07	2.38
263°499	19	179	13.3 ± 2.1	291	21.7	6.19	2.44
263°913	10	76	8.6 ± 0.3	145	16.4	6.20	2.48
264°524	8	23	5.5 ± 1.9	146	35.1	6.08	2.48
264°627	3	13	6.5 ± 4.8	40	19.9	5.97	2.48
265°998	1	1	0.4 ± 0.8	3	5.0	6.23	2.48

5. Number density profiles for different mass ranges

To begin with, we calculated the number density for meteoroids in the Geminid stream which cause meteors of at least absolute magnitude +6.5. The result is shown in Figure 3.

There is a distinct peak after a steep increase in the number density just at the beginning of the central part of the shower at $\lambda_{\odot} = 261.^{\circ}3 \pm 0.^{\circ}15$. This also coincides with the peak in the r profile. Looking at the ZHR graph (Figure 2) we also see a first activity peak at exactly this position. Hence we know that we passed a part of the Geminids containing a lot of small particles, thus causing the higher r as well as the first high ZHR. The main ZHR maximum at $\lambda_{\odot} = 262.^{\circ}3$ is less prominent in Figure 3. It appears as a shoulder in the already declining part of the graph. When looking at these graphs, we should bear in mind that the number density given in Figure 3 is the sum of meteors of magnitude +6.5 or brighter.

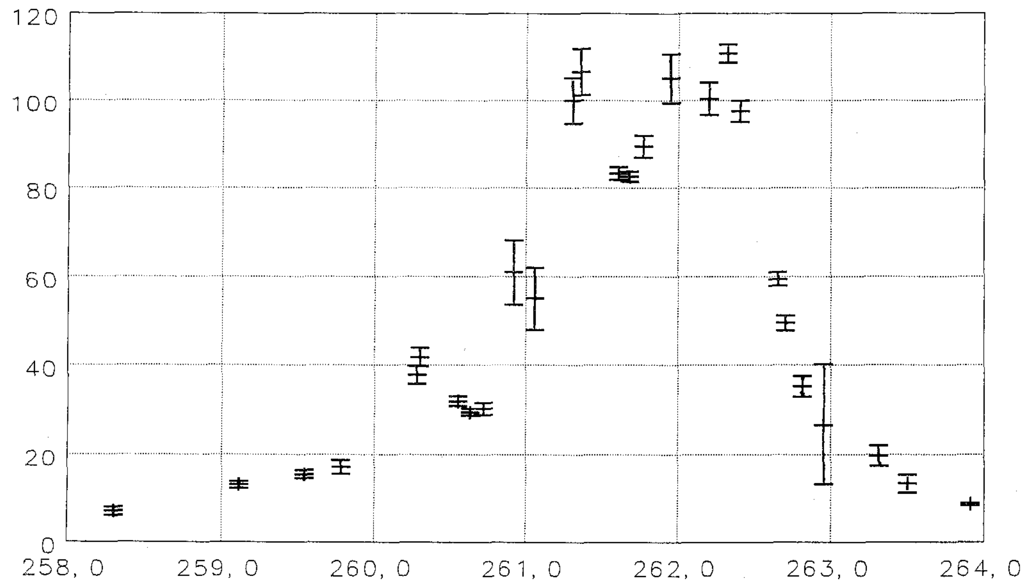

Figure 2 – ZHR profile of the Geminids 1991. The increase is less steep than the decrease in activity after the peak. The maximum consists of the "main peak" at $\lambda_\odot = 262.^\circ 3$ and a preceding maximum at $\lambda_\odot = 261.^\circ 3$ (eq. 2000.0).

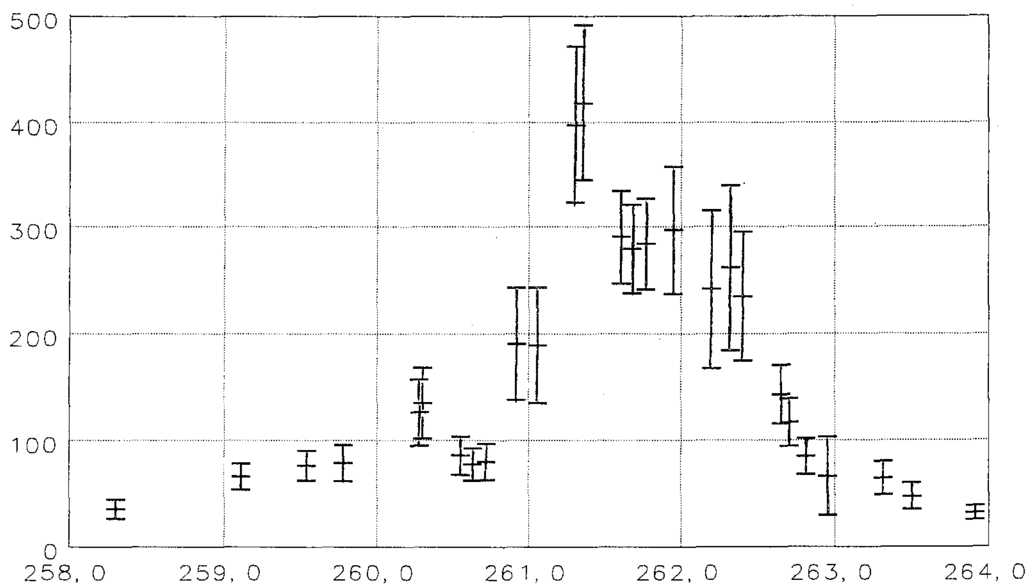

Figure 3 – The number density profile seems to be different from the findings for the ZHR profile. Since the first increase of activity at $\lambda_\odot = 261.^\circ 3$ coincides with the high value of r seen in Figure 1, we see a part of the Geminids containing many small meteoroids, thus producing the peak in the number density of meteoroids causing meteors of +6.5. When crossing the Geminid stream, we first meet the smaller meteoroids. The main ZHR peak at $\lambda_\odot = 262.^\circ 3$ coincides with the dip in the r profile. Consequently, this peak is much less prominent in the small meteoroid number density where it occurs as a shoulder.

According to the models introduced in the calculations, a meteoroid of +6.5 is caused by a Geminid particle of 0.6 mg entering the Earth's atmosphere at 35 km/s. Such a transformation from brightness into particle masses includes additional uncertainties. But even if the numbers are uncertain by a factor of 5, the profile for the larger particles (masses of 100 mg or more) clearly contains another feature, as shown in Figure 4.

Of course, the number of such meteoroids is some orders of magnitude less than the number of 0.1-mg meteoroids. Therefore, the features occurring in the profile for larger particles are hardly visible in the profile shown in Figure 3.

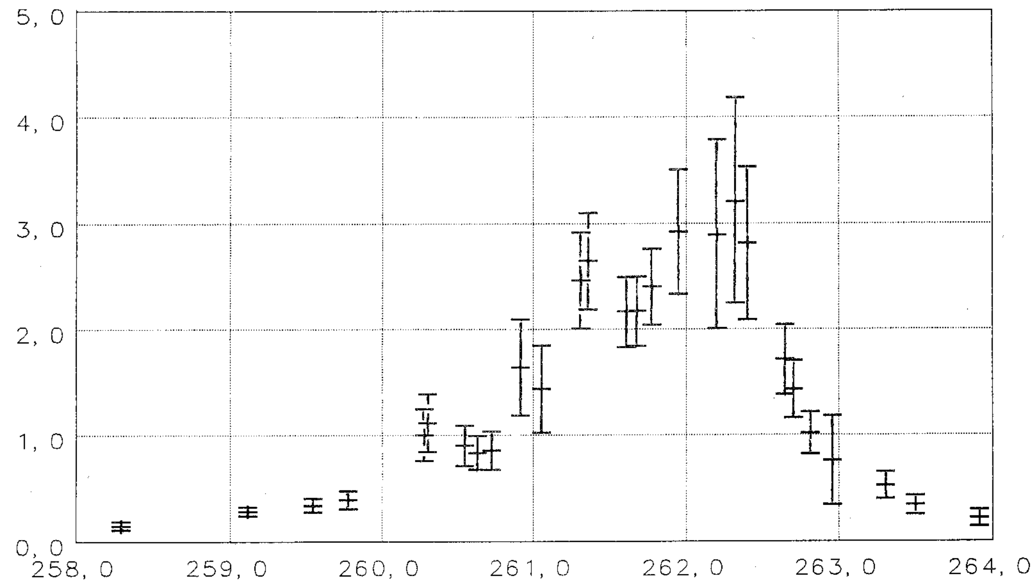

Figure 4 – Geminid number density profile for particles of at least 100 mg, corresponding to meteors of +1.0. The density peak for these larger meteoroids coincides with the visual ZHR peak at $\lambda_\odot = 262\overset{\circ}{.}3$, demonstrating that the larger particles are concentrated in the core region of the shower. Furthermore, the profile is more symmetrical than the one consisting of mainly smaller meteoroids (see Figure 3).

The mass of 100 mg corresponds to Geminid meteors of magnitude +1. The peak of this graph clearly coincides with the visual ZHR-peak. We may conclude that the main peak is chiefly caused by larger meteoroids. In this case, the lower r (Figure 1) and the high ZHR indicate the large proportion of brighter meteors, thus of larger meteoroids.

The number density profile for these larger meteoroids looks more symmetrical than the profile for the faint meteors. We would like to draw your attention to the very different scales for the number densities in Figures 3 and 4 when you compare the peaks and see how pronounced they are.

6. Discussion

The last major visual analysis of the Geminids was of the 1990 return by Roggemans [5]. He found the peak to be at $\lambda_\odot = 262\overset{\circ}{.}26$. A similar analysis in 1988 [6] found a peak at $\lambda_\odot = 262\overset{\circ}{.}08$, and a local maximum at $\lambda_\odot = 260\overset{\circ}{.}6$. The peak ZHR rates of 110 and 120 respectively from these previous studies are similar to the 1991 results which show the peak ZHR to be about 110 and the spatial number densities at the ZHR-peak from [5] are also roughly equivalent to the present work at about 300 particles per 10^9 km^3. The maximum in the present work at $\lambda_\odot = 262\overset{\circ}{.}3$ is in satisfactory agreement with those studies. We note that the sliding mean used in the 1990 study was $0\overset{\circ}{.}3$ length shifted by $0\overset{\circ}{.}16$, and in 1988, $0\overset{\circ}{.}25$ length shifted by $0\overset{\circ}{.}04$ increments which implies that features in the $0\overset{\circ}{.}1$–$0\overset{\circ}{.}3$ size range may not be fully resolvable; as a consequence the uncertainty in the peak time is roughly of this order. We note that this is also a limitation in the present work where $0\overset{\circ}{.}6$ lengths have been shifted $0\overset{\circ}{.}3$ also implying resolutions in the $0\overset{\circ}{.}3$ range. It is instructive to note that previous visual studies give $\lambda_\odot = 262\overset{\circ}{.}0$ as the time of maximum (see [7] and [8] for example). It is, however, also important to note that these studies were much smaller than our analysis and were not truly global in nature, so their accuracy is more open to question. In the previous analyses, each average of the ZHR (as well as of other figures) was considered to represent the center of the interval. This is only valid if the individual ZHR values are at least roughly equidistant in time, whereas we have to deal with data points being distributed according to the observed intervals. In the present work, this limitation was removed as the solar longitudes in the intervals were also weighted and averaged; hence the present analysis may be considered the more reliable, at least from this standpoint.

Clearly, the most outstanding features of the present ZHR curve are the triple maxima, in particular the prominent double peak near maximum activity. We note that these maxima occur at roughly $\lambda_\odot = 260^\circ\!.3$, $\lambda_\odot = 261^\circ\!.3$, and $\lambda_\odot = 262^\circ\!.3$. This 1° advancement pattern is clear and suggests that enhanced activity is being detected by the same group(s) each day. Indeed, these maxima all coincide with the observing window where Japanese observations are dominant. Changes in the interval sizes for the calculation of perception coefficients failed to remove these features; in fact the average perception values for the observers in this window is very near 1, and therefore not different from the other observers. The fact that no such periodicity is observed in the r-profile attests to this fact. This strongly suggests that unusual perceptions are not to blame. The periodicity in the ZHR maxima, the fact that no studies have convincingly detected such strong activity at the positions of the first two maxima in the past, and the fact that the weight of the data in these observing windows is contributed by one group alone, suggest to the authors that the first two maxima may be systematic artifacts of as yet unknown origin. This would then also apply to the abnormally high spatial number density associated with the peak at $\lambda_\odot = 261^\circ\!.3$. The possibility that this activity is real cannot be ruled out, however, and future analysis will be needed to decide upon the reality of these features. Indeed, it is appropriate to mention the extensive radio observations by the Ondřejov radar [9,10] which suggest that the smaller particles are encountered first and that the maximum contains the largest particles (as a result of the Poynting-Robertson effect which sorts the masses), a picture which is verified with the r-profile in this study. The analysis of visual observations by Spalding [7] also revealed a similar particle sorting. On theoretical grounds, Ryabova [11] has argued for a double maxima in the Geminid stream, the first main maximum rich in small particles and the later main maximum containing an abundance of large particles. This stratified "two-jet" model of the Geminids arose only in ejection simulations employing cometary type emission and would lend indirect support for a cometary origin for 3200 Phaethon. This is essentially the picture presented here. If these features are found to be real and not artifacts by similar global observations in the future it would necessarily lend strong support to her model.

One feature that recent visual studies do appear to agree on is the presence of a ZHR "plateau" about $0^\circ\!.5$ wide. In 1991, this occurred roughly between $\lambda_\odot = 261^\circ\!.3$ and $\lambda_\odot = 261^\circ\!.7$ (if we take the first maxima to be spuriously high in activity), while in 1990 it occurred about $0^\circ\!.5$ later. These skewed rate profiles or even double peaks have been predicted in studies by Fox et al. [12,13] and also by Jones [14]. The results in [12] are particularly similar to what has appeared in these recent global visual analysis. While Jones explains this profile in terms of a hollow cylindrical stream model (or meteoroid torus), Fox et al. suggest that the effect is due to the cross-section of the stream's intersection with the ecliptic plane. The latter model also suggests that if the stream can be considered as "sweeping" over the Earth's orbit then the negligible change in peak activity times since stream observations were recorded in the mid-18th century can be resolved. In this scenario the nodal regression is precisely compensated by the sweeping of the stream over the Earth's orbit. A more detailed study building on the model presented in [13] by Jones and Hawkes [15] also suggests small nodal retrogression as well as predicting a slow broadening of the shower duration with stream age. The model presented in [12] further suggests that activity should begin to wane after the mid-1960s with the stream nearly disappearing during the 21st century. The 1991 analysis and the recent series of global visual studies suggest the Geminids are still very strong and there is no conclusive evidence to suggest that the stream has decreased since the 1960s or 1970s; to the contrary the peak rates have actually become larger than reported in earlier visual studies [7,8,16]. While this is more likely due to the differences in the methods employed to reduce the data we may still state that no convincing evidence of decreasing Geminid rates has been uncovered. Many decades of comparable global studies such as this one will be necessary to address accurately this point.

Finally, we note that the width of the stream in 1991 as measured at its half-maximum from the ZHR profile amounts to $1^\circ\!.0 \pm 0^\circ\!.2$ before maximum and just over $0^\circ\!.5 \pm 0^\circ\!.2$ post-maximum. The activity declines very sharply after $\lambda_\odot = 262^\circ\!.0$, reaching background levels in just over one day.

7. Conclusions

The 1991 Geminid stream showed a maximum ZHR of 110 at $\lambda_\odot = 262.^\circ3$ corresponding to a spatial number density of roughly 250 ± 70 particles per 10^9 km^3, the peak ZHR corresponding to activity from larger particles. A preceding maximum was visible in the ZHR data at $\lambda_\odot = 261.^\circ35$ rich in smaller particles, though its true nature can only be determined from future studies. Shower activity returned to background levels by $\lambda_\odot = 263.^\circ5$. For future Geminid campaigns, observers are encouraged to concentrate on more than just the night of the peak, at least two nights of observation around this date are of great interest for investigation of the shower's structure.

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Ongoing Meteor Work

Predictions of Radiants Associated with Minor Planets

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This is a continuation of our predictions in [1]. Here, predictions are presented of meteor orbits and radiant points associated with Earth-approaching minor planets discovered between January 1990 and August 1992.

In Table 1, predicted positions (α and δ for eq. 2000.0) of radiant points and the meteors' geocentric velocities are given for the date when the heliocentric distance at a particular point on the parent body's orbit is equal to that of the Earth. The solar longitude of that date referred to the mean equinox of 2000.0 is denoted by $\lambda_\odot$. The symbol Δ denotes the separation between the orbits of the parent body and the Earth in AU, ω', Ω', and i' are the adjusted angular orbital elements of the meteor orbit, and q' the adopted or adjusted perihelion distance. More details on the method used for these predictions can be found in [2].

Predictions given by Steyaert [3,4,5] and Artoos [6,7] are also useful references, and a catalogue of Apollo-Amor type minor planets will be published elsewhere [8].

For (4015) 1979 VA = P/Wilson-Harrington (1949 III) and (5011) Ptah = 6743 P-L = 1983 TF3, new predictions of meteor radiants are given here.

Table 1 – Predictions of meteor radiant points associated with a minor planet

Object	$\lambda_\odot$	Date	α	δ	V_G	Δ	ω'	Ω'	i'	q'
(4015)	168°7	Sep 12	279°3	−25°8	8.6	0.048	13°2	348°7	0°6	0.996
P/W.-H.	181°9	Sep 25	268°4	−23°2	8.2	0.049	180°0	181°9	0°0	1.003
	190°3	Oct 04	261°8	−21°3	8.5	0.048	171°7	190°3	0°5	0.996
(5011)	235°0	Nov 18	42°0	+00°8	12.2	0.089	61°3	55°0	5°3	0.818
Ptah	359°0	Mar 20	4°3	+23°1	12.5	0.027	117°6	359°0	7°2	0.818
(5143)	107°8	Jul 10	98°2	+14°9	25.7	0.064	249°5	287°8	8°5	0.419
1991 VL	248°7	Dec 01	76°9	+27°3	25.4	0.140	288°7	248°7	4°3	0.419
(5189)	47°8	May 09	213°0	−12°9	12.7	0.063	247°1	47°8	0°1	0.810
1990 UQ	181°0	Sep 24	195°0	+00°5	12.8	0.045	113°8	181°0	2°5	0.810
1984 QY1	172°0	Sep 15	6°1	+11°9	35.5	0.142	308°0	172°0	15°8	0.219
1990 BA	302°6	Jan 23	27°1	+27°2	4.6	0.006	180°0	302°6	2°0	0.984
1990 HA	13°7	Apr 04	31°5	+03°9	15.9	0.010	299°3	193°7	3°8	0.791
	254°2	Dec 06	53°5	+22°4	15.8	0.062	238°8	254°2	1°4	0.791
1990 MF	107°0	Jul 09	248°5	−23°8	8.7	0.032	37°5	287°0	0°4	0.951
	178°2	Sep 21	215°3	−07°5	8.7	0.017	146°2	178°2	1°6	0.951
1990 OS	138°9	Aug 12	249°7	−24°9	9.8	0.010	49°1	318°9	1°0	0.903
	231°6	Nov 15	257°9	−24°8	9.7	0.070	316°4	51°6	0°5	0.903
1990 SM	164°3	Sep 07	164°4	+18°7	25.5	0.091	79°2	164°3	10°4	0.485
	324°3	Feb 13	148°2	−00°5	25.6	0.022	99°5	144°3	11°5	0.485
1990 SP	208°3	Oct 22	33°1	−26°6	11.8	0.072	66°1	28°3	12°9	0.830
1990 SS	342°8	Mar 04	334°2	+45°7	14.1	0.103	134°0	342°8	18°5	0.894

Table 1 – continued.

Object	$\lambda_\odot$	Date	α	δ	V_G	Δ	ω'	Ω'	i'	q'
1990 TG1	125°.2	Jul 28	142°.0	+18°.1	17.3	0.157	113°.3	125°.2	1°.6	0.764
	354°.4	Mar 15	157°.4	−06°.8	17.8	0.080	64°.2	174°.4	7°.8	0.764
1990 UA	55°.9	May 17	223°.1	−15°.0	14.9	0.012	250°.8	55°.9	0°.7	0.770
	195°.8	Oct 10	204°.7	−10°.4	14.8	0.017	290°.8	15°.8	0°.1	0.770
1990 UN	222°.9	Nov 06	28°.6	+03°.2	12.7	0.036	62°.5	42°.9	3°.0	0.807
	348°.2	Mar 09	359°.4	+09°.6	12.7	0.022	117°.3	348°.2	3°.5	0.807
1990 VA	181°.4	Sep 24	184°.4	+33°.9	10.6	0.144	70°.2	181°.4	11°.6	0.710
1991 AQ	142°.1	Aug 15	139°.2	+12°.3	24.5	0.020	260°.4	322°.1	3°.0	0.499
	304°.7	Jan 25	132°.3	+20°.8	24.4	0.034	277°.7	304°.7	2°.5	0.499
1991 BA	84°.3	Jun 15	93°.6	+26°.3	18.0	0.020	105°.3	84°.3	1°.6	0.713
	298°.3	Jan 18	110°.2	+18°.5	18.0	0.000	71°.3	118°.3	2°.0	0.713
1991 BN	108°.9	Jul 11	271°.6	−34°.1	10.0	0.020	60°.7	288°.9	3°.2	0.869
	225°.2	Nov 08	242°.9	−12°.7	9.9	0.042	124°.5	225°.2	2°.5	0.869
1991 CS	156°.9	Aug 30	322°.6	+68°.3	19.5	0.022	249°.3	156°.9	37°.1	0.917
1991 DB	28°.9	Apr 19	118°.7	−20°.0	6.9	0.153	1°.1	208°.9	7°.3	1.004
	338°.5	Feb 27	131°.8	−19°.5	11.4	0.158	51°.0	158°.5	11°.5	0.885
1991 DG	14°.3	Apr 04	158°.9	−31°.4	10.4	0.048	48°.8	194°.3	10°.8	0.929
1991 EE	48°.8	May 10	202°.2	−21°.9	14.6	0.148	55°.0	228°.8	4°.9	0.844
	159°.3	Sep 02	187°.5	+21°.0	15.3	0.030	125°.1	159°.3	9°.6	0.844
1991 FA	251°.2	Dec 03	340°.3	−07°.8	5.9	0.054	180°.0	251°.2	0°.1	0.986
1991 FB	19°.1	Apr 09	181°.1	+30°.4	12.1	0.122	218°.3	19°.1	9°.2	0.924
	57°.1	May 18	167°.7	+41°.0	8.7	0.098	180°.7	57°.1	7°.2	1.011
1991 GO	15°.0	Apr 05	10°.4	+21°.8	18.8	0.030	98°.8	15°.0	9°.5	0.663
	212°.9	Oct 27	33°.1	−03°.8	18.8	0.023	80°.6	32°.9	9°.6	0.663
1991 JG1	14°.0	Apr 04	83°.0	−70°.4	15.2	0.026	350°.4	194°.0	28°.0	0.998
1991 JR	60°.2	May 21	221°.1	+39°.6	7.4	0.050	207°.0	60°.2	10°.1	0.989
	86°.9	Jun 18	211°.1	+49°.8	6.3	0.078	180°.7	86°.9	9°.0	1.016
1991 JW	89°.0	Jun 20	267°.8	+22°.2	5.2	0.089	266°.5	89°.0	7°.1	0.915
	247°.1	Nov 30	222°.4	−71°.2	5.8	0.034	288°.6	67°.1	8°.5	0.915
1991 JX	97°.3	Jun 28	185°.2	−07°.3	8.1	0.036	0°.1	277°.3	1°.0	1.017
1991 JY	58°.6	May 20	325°.9	+46°.5	23.9	0.118	37°.4	58°.6	49°.0	0.597
1991 OA	84°.0	Jun 15	167°.5	−14°.9	8.3	0.065	359°.7	264°.0	4°.1	1.016
1991 RB	171°.3	Sep 14	10°.9	−38°.2	16.5	0.052	77°.5	351°.3	19°.3	0.749
1991 TB2	63°.1	May 24	52°.5	+14°.3	27.6	0.124	249°.9	243°.1	5°.1	0.394
	203°.5	Oct 17	30°.8	+12°.0	27.5	0.150	109°.2	23°.5	0°.6	0.394
1991 TF3	161°.9	Sep 05	176°.5	−44°.5	12.0	0.105	328°.7	341°.9	12°.7	0.957
1991 TT	229°.3	Nov 12	284°.7	+55°.8	6.8	0.148	181°.9	229°.3	11°.8	0.990
1991 TU	196°.1	Oct 10	328°.8	+26°.6	7.5	0.006	218°.4	196°.1	7°.7	0.945
	267°.1	Dec 19	303°.4	−07°.8	6.3	0.126	147°.3	267°.1	2°.2	0.945
1991 VA	122°.4	Jul 25	275°.8	−20°.9	7.7	0.115	228°.6	122°.4	0°.6	0.926
	213°.5	Oct 27	229°.7	−46°.0	8.5	0.008	317°.6	33°.5	6°.5	0.926

Table 1 – continued.

Object	$\lambda_\odot$	Date	α	δ	V_G	Δ	ω'	Ω'	i'	q'
1991 VE	214°.4	Oct 28	185°.9	−09°.5	21.1	0.058	221°.3	34°.4	6°.4	0.299
	297°.3	Jan 17	143°.6	+10°.0	20.9	0.101	138°.0	117°.3	4°.1	0.299
1991 VK	248°.9	Dec 01	28°.8	+26°.5	9.7	0.067	219°.5	248°.9	3°.7	0.910
	328°.3	Feb 17	353°.9	+15°.4	9.8	0.051	139°.9	328°.3	4°.5	0.910
1991 XA	185°.5	Sep 28	310°.6	−25°.8	8.3	0.087	20°.2	5°.5	1°.6	0.979
	220°.9	Nov 04	284°.6	−41°.5	8.6	0.054	344°.9	40°.9	4°.2	0.979
1992 AX	336°.7	Feb 26	124°.3	−25°.2	10.1	0.137	43°.0	156°.7	11°.9	0.921
1992 BF	235°.4	Nov 18	216°.5	−10°.1	8.1	0.123	56°.6	235°.4	1°.2	0.662
	347°.5	Mar 08	193°.9	+15°.7	8.7	0.067	304°.2	347°.5	6°.2	0.662
1992 DU	318°.3	Feb 07	281°.2	+55°.5	13.1	0.153	143°.2	318°.3	23°.5	0.957
1992 FE	88°.7	Jun 20	288°.6	−30°.0	11.9	0.059	125°.9	268°.7	3°.5	0.551
	336°.8	Feb 26	318°.1	−06°.0	11.9	0.035	57°.6	336°.8	4°.4	0.551
1992 HF	64°.8	May 26	243°.7	−39°.5	18.3	0.123	96°.2	244°.8	11°.3	0.610
	254°.4	Dec 06	251°.2	−05°.8	18.1	0.150	86°.5	254°.4	10°.0	0.610
1992 LC	41°.4	May 02	35°.8	+45°.1	19.6	0.114	111°.2	41°.4	16°.7	0.742
	264°.4	Dec 16	78°.1	−06°.6	19.6	0.120	66°.2	84°.4	16°.5	0.742
1992 LR	120°.9	Jul 24	205°.5	−15°.6	5.7	0.033	0°.0	300°.9	0°.8	1.016
1992 NA	177°.5	Sep 20	258°.9	−65°.1	9.4	0.023	0°.1	357°.5	9°.7	1.004
1992 QN	104°.4	Jul 05	107°.9	+14°.0	10.3	0.156	273°.9	284°.4	2°.8	0.772
	298°.0	Jan 18	120°.3	+35°.2	10.5	0.136	260°.4	298°.0	4°.8	0.772

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Erratum

communicated by Alastair McBeath

In *WGN* 20:6, December 1992, in my article on the Virginids, there has been an omission in the caption to Figure 8, on p. 236. The caption should have this sentence added: "The oval area shows the approximate position of Ellyett and Roth's Virginid radiant [5]."

In the photograph at the very end of the Virginid paper, on p. 237, both of us appear to be Jürgen. It would not really help to say that one of us has a beard and glasses either! In fact, Jürgen is the person at the right while I am the person at the left.

No Meteor Outburst On November 5, 1991

Peter Jenniskens, Mireille Cailloux, Marc de Lignie, and Jacob Kuiper

A meteor outburst was reported to have been observed from Manua Kea, Hawaii, on November 5, 1991, by occasional naked-eye observers. Attention to the unexpected meteor activity was drawn by an exceptional recording of what appeared to be meteor trails on two CCD images. In this paper we report the analysis of the CCD recordings and the visual observations.

The CCD images were obtained by B. Fort at the CFHT on Manua Kea Hawaii. Two exposures were taken of the same field starting at 09^h22^m and 10^h01^m UT with 30 minute exposure time. The field of view was about $7' \times 7'$ and an I filter was used, which selects light centered at 8320 Å.

Both images show a pattern of bands consisting of many small stripes. The bands are not an instrumental effect, because the bands follow the star background which in the second exposure is at a slightly different position on the CCD. However, the stripes within the bands are seen to move with respect to the stars, from left to right on the images. Part of the striping is due to movement of the features during the 30-minute exposure.

We exclude the possibility that this pattern is due to a meteor outburst. The trails are not homogeneously distributed on the CCD and are much shorter on the $7'$ wide CCD image than expected. More important, the pattern in both images is the same, which is not what is expected. The pattern on the CCD may be due to dust from the Pinatubo volcano, which erupted in July 1991. The unusual recording on the CCD images was due to a fully coincidental almost perfect tracking of the moving dust features during the exposure.

The reported meteor observations are few and by inexperienced observers and cannot be considered conclusive proof that a meteor outburst occurred. Only one useful count is available: 14 meteors in 15 minutes of observing time under excellent sky conditions between 10^h10^m and 10^h25^m UT. The activity did not vary significantly in the period 10^h10^m until 11^h45^m. We argue that the observations are consistent with usual sporadic meteor activity. The outburst was not confirmed by independent observers or from radio MS observations.

1. Introduction

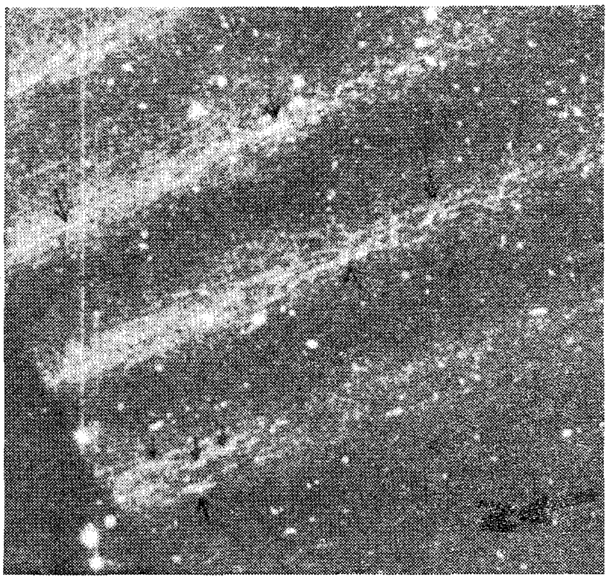
Shortly after the famous night of November 8-9, 1991, when polar lights colored the skies red and green and visual observers were watching possible meteors from Comet P/Hartley 2, the unexpected message came that a meteor outburst had been seen over Hawaii. The message was very exciting, because not only was a meteor outburst seen, but it was said to have been recorded on CCD images. This would be the first meteor outburst recorded on CCD images. It would allow a very accurate determination of the position and size of the radiant of the meteors.

Meteor outbursts are not a rare phenomenon. We estimate that about one outburst is visible each year. Most of these do not rise to very high activity, and the reported peak rate of 70–100 meteors per hour (15-minute interval) would make this a typical case. Because of the unexpected character of these events, good observational data of meteor outburst are rare. They last typically one hour, during which time the activity is increasing and decreasing exponentially [1].

This paper describes the CCD images and gathers all available observations of meteor activity on the night of the observation, November 5, 1991. Unfortunately, we conclude that the unusual pattern of bands and stripes on the CCD image is not due to meteor activity and that the visual observations do not indicate that a real meteor outburst occurred.

2. The CCD images

A Charged Coupled Device (CCD) is an electronic photographic plate, where light releases electrons in the "emulsion", which are collected in small potential wells (pixels or image elements). The CCD used at the CHFT 3.6-m telescope has 2048×2006 of such pixels. The field of view is $7' \times 7'$ ($0.202''$ per pixel). During the night of November 5, a field in Pegasus ($\alpha = 0^h25^m29\overset{s}{.}2$, $\delta = +17°03'35''$) was exposed that was relatively devoid of galaxies and stars. In front of the CCD was an I filter (8320 Å central wavelength and 1950 Å passband). Two exposures of 30 minutes were obtained. The first exposure was started at $9^h22^m56^s$ UT. The field of view at that moment was at 92° azimuth (East) and 65° elevation.



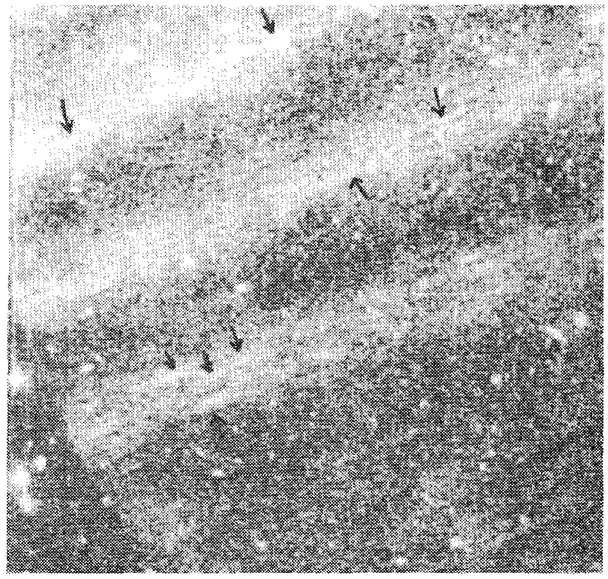


Figure 1 – *Left:* CCD image (I-filter) taken between 9^h23^m and 9^h53^m UT on November 5, 1991. The center of the field of view is near $\alpha = 0^h25^m29^s.2$ and $\delta = 17°03'35''$. *Right:* CCD image taken between 10^h01^m and 10^h31^m UT. The central position is slightly shifted relative to the former.

Figure 1 *(left)* shows this first image. The image is obtained by sequentially transferring the collected electrons of each pixel to the next pixel and counting them at the edge of the CCD. Leakage of electrons causes some vertical stripes in the image starting at the position of bright stars (Figure 1). There is a sensitivity drop in the lower left corner of the CCD. The remarkable feature on the image in Figure 1 are the bands that consist of many small trails and that appear to converge to a point left of the field of view.

At $10^h01^m19^s$ UT, a second exposure was started. The field of view was slightly shifted in order to allow the discrimination between instrumental and celestial features (Figure 1, *right*). At the end of the second exposure the telescope pointed at an azimuth of 107° and an elevation of 81°.

3. Visual observations

During the second exposure, it occurred to the observers that these strange bands could be due to meteors. Norman Purves went outside at 10^h10^m UT. Until 10^h25^m UT, he saw 14 meteors "that radiated from a point near the southern edge of the Pegasus square." While he was looking at that spot where the telescope was pointing, he reportedly observed three blinkers, weak flashes of light which did not move. At that moment he listened if sounds could be heard, which was not the case. The meteors were "of brightness +1 to +5, blue or greenish white of color and about 1.25–1.5 times faster in angular speed than a satellite in a low earth orbit." The meteors were faster than he could remember of other streams. There were at most a few persistent trains of meteors brighter than magnitude +3. At about 10^h55^m, until 11^h05^m UT, he went outside again. There was no clear increase of meteor activity compared to the previous period. He also watched between 11^h37^m and 11^h45^m UT. Dr. Fort went outside for a short period of time at about 10^h10^m, accompanied by K. Morton. In 5 minutes, he saw about 1 meteor per minute. He was at the same location as Norman Purves and watched in about the same direction. He also noticed the blue color of the meteors.

The sky limiting magnitude was high. The seeing was $0''.5$ or better and the sky was of photometric quality, transparent without a trace of cirrus. According to Norman Purves, this was no exceptional night for Hawaii. Dr. Fort, however, said it was the clearest night he had experienced in ten years of occasional observing runs at CHFT. With an adopted limiting magnitude of 6.9, the ZHR from Norman Purves' data becomes 23 ± 8 (with $r = 3.4$), and the sporadic hourly rate becomes 12. On average 5 out of the 14 meteors should have been sporadic under these conditions. It is extremely unlikely that all those meteors radiated from the same point. This count is valid for the period 10^h10^m to 10^h25^m UT. No counts are available for the other observing periods.

Note that the rate is much less than the reported rate of 70–100, which is obtained when the observing period is shortened by taking into account the night adaptation of the eyes, less attention of the observers towards the end of the period, and not excluding sporadic meteors.

At first, other observers also were reported to have noticed the meteor outburst. One observer, W. Golish, operator at the NASA IRFT, is known to have observed one meteor of "possibly less than 0.0 magnitude." Other observers at the NASA IRFT, the JCMT, and the Hawaii 2.2-m telescope were reported to have seen "some of the meteors." In order to obtain more specific information, we designed an electronic questionnaire one month after the event, which was distributed by Norman Purves. Unfortunately, nobody responded. The meteor outburst is also not confirmed by observers from the MS group of amateur meteor observers at Oahu Main Island (message of D. Meisel [3]). From Europe no increased activity was noticed the night before and after the event [2], which is what would be expected, however, independent of there actually having been an outburst. We conclude that it is not certain at all that there was a meteor outburst. Most notable is that no outburst was recorded by radio meteor scatter. However, there is a possibility that the activity was too low to be noticed or that no radio MS observers were active.

The evidence of a meteor outburst therefore heavily depends on the visual observations of Norman Purves. The numbers of observed meteors (14 in 15 minutes) is not exceptionally high. Without the spurious "blinkers," and for a limiting magnitude of 7.2, the sporadic hourly rate would be only 20 ± 6, which is quite usual for an observer with good perception observing in the fall.

4. No meteors on the CCD images!

Thanks to the support of Dr. Fort and system manager M. Cailloux of the Observatoire Midi-Pyrenées in Toulouse, we were able to analyze the raw data at the Leiden Observatory.

Figures 1, *left* and *right*, show about 80% of the whole image. The bands are almost perfectly north-south oriented. North is to the left of the figures.

Figures 1, *left* and *right*, immediately exclude that the bands and stripes are caused by a meteor outburst. The two consecutive images (30 minutes exposure time each) show the same pattern of bands and stripes. A meteor outburst would have produced a random distribution of stripes on the images. The grouping of small stripes in the set of bands and the regular spacing of the bands is not characteristic of a meteor outburst, for which we would have expected a more homogeneous distribution of featureless stripes. Each meteor would traverse the whole plate ($0^\circ\!.1$ wide). If they had appeared head on, the meteor trails would appear almost starlike, but again homogeneously spread over the CCD image, and different in the two consecutive images. Internal scatter in the orbits usually results in a radiant with a diameter of $0^\circ\!.1$ or larger.

5. What else?

The bands are shifted on both CCD images in such a way that they follow the sky image. The bands are therefore not an instrumental effect. It is also unlikely that the bands are due to a bright light source outside the dome, because the telescope's orientation changed significantly during the exposure. Therefore, the bands must be due to something in the Earth's atmosphere or in the sky.

There were no bright celestial light sources just outside the field of view. On November 6, the Moon was new, the planets were not nearby in the sky and the nearest bright star (γ Peg) was at more than 2° distance.

The phenomenon is atypical for the celestial sphere. It was not seen in later exposures in other locations of the sky. Half an hour before the first exposure, an image was obtained at $\alpha = 0^h24^m$ and $\delta = 16^h54^m$, about 1° in position off from the field of view mentioned above. This image shows, marginally, one band. We conclude that the phenomenon was characteristic of this part of the sky only and was seen for at least 1.5 hours. We exclude the possibility that this is due to interstellar matter. The pattern is not characteristic of interstellar "cirrus," which is also usually not seen at 8320 Å. The phenomenon would certainly have been noticed before. The only suggestion that we have is that these bands and stripes are due to dust of the Pinatubo volcano, which erupted in July 1991. Images of Pinatubo dust are known to consist of regular wind-formed patterns. In that case we expect some movement of the structure with respect to the stars.

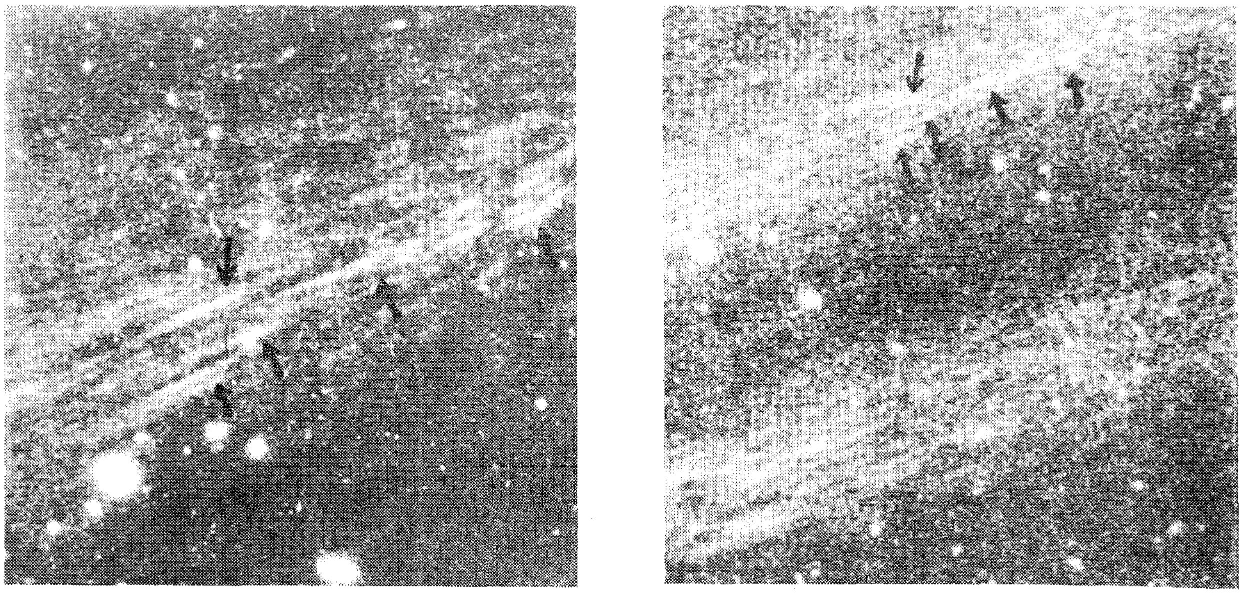


Figure 2 – *Left:* Enlargement of the central part of Figure 1 *(left)*. Arrows indicate the positions of structures which can also be seen in the photograph at the right. *Right:* Enlargement of Figure 1 *(right)*. The arrows indicate the structures marked in the photograph at the left. Notice that the structures have moved with respect to the triangle of stars to the left.

Figures 2, *left* and *right*, show enlargements from Figures 1, *left* and *right*, which reveal the structure in the bands. In between the bands there are no stripes. Each stripe is only about 15″ long (1 meter at 10 km). Within the band, the stripes are nearly parallel. With arrows we have marked a number of features in the images that can be seen in both CCD exposures. We conclude that the bands follow the star pattern, but in the bands the stripes move from left to right. It is noticeable that there is some space between the stripes from one image to the next. From this we conclude that the stripes had intrinsic length. A bar that moves by about half its length would produce a typical stripe.

One should keep in mind that during the exposure the telescope orientation changed from an azimuth of 92° and an elevation of 65° to an azimuth of 107° and an elevation of 81°. In order to have this image recorded, the dust must have been tracked fairly accurate. While the dust moved slowly from east to west, the telescope was following the bands by pure coincidence. The movement of the features in the band does not reflect the telescope's movement in azimuth, which should result in a south to north movement of the features. The opposite has been observed. The features themselves may have moved in a north-to-south direction.

Only in this direction of the sky, could such recordings have been possible. The angular velocity of the dust bands can be calculated from the angle over which the telescope moved during the exposure. This amounts to some 18° per hour. At a distance of typically 10 km, the projected velocity would be some 3 km/h.

6. Conclusions

On November 5, 1991, there probably was not been a meteor outburst.

The meteor outburst is not recorded on the CCD images as was reported. The CCD images contain patterns of bands and stripes that cannot be due to meteors. The bands follow the sky background on the CCD, while the stripes are moving from north to south (left to right in the image) across the sky. From this we conclude that the pattern is caused by a phenomenon in the Earth's atmosphere, most likely by volcanic dust from the Pinatubo volcano.

The reported visual observations depend on one inexperienced observer only. The observation can be accounted for by normal sporadic activity. There is no independent confirmation of the outburst by visual or radio MS data

Acknowledgements

We thank Norman G. Purves (night assistant at CFHT, Manua Kea, Hawaii) and Dr. Bernard Fort (Observatoire Midi-Pyrenees Toulouse) for their generosity in providing us all available data.

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The Makings of Meteor Astronomy: Part II

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The first coherent theories of the Universe to embrace the meteoric phenomena were developed by the Greek Philosophers. A variety of explanations were given for the appearance of shooting stars, but the dominant idea to emerge was that they were of atmospheric origin.

1. What is in a name?

According to Ayto [1], the word *meteor* is derived from the Greek *meteoron* which described something high up, and was used specifically to denote phenomena that occurred in the sky or heavens. The word "meteor" first entered the English language in the 16th century through the medieval Latin *meteorum*. As we shall see below, the term "meteor" initially referred to any atmospheric phenomena, and it is clearly the derivative of the modern day *meteorology*. It was not until the end of the 17th century that the word "meteor" was used to mean shooting star only. The term *meteorite* was coined much later in the early 19th century, and H.A. Newton introduced the term *meteoroid* in 1865 to describe pre-atmospheric bodies [2].

In the discussion below, we shall mostly use the word "meteor" in its modern form, i.e., to mean a shooting star. For those that worry about correct word usage a full outline of IAU-approved meteor terminology is given in Millman [3].

2. A beginning

One of the earliest attempts at an explanation of the meteoric phenomena was offered by Anaxagoras of Clazomenae [4] who lived circa 500 B.C. to 428 B.C.

The cosmological model developed by Anaxagoras envisioned the stars and planets to be made of stone. These bodies shone because of their very motion, and were carried around the Earth by an extremely pure and rarefied form of air called aether. The aether, it was argued, pervaded the whole universe, and was in constant rotational motion.

Rather than being made of stone, Anaxagoras argued that the shooting stars were in fact pockets of ignited aether. In this way, Anaxagoras considered the shooting stars to be of atmospheric origin. Indeed, Anaxagoras drew a parallel between the shooting stars, lightning, and Earth quakes. All these phenomena, he argued, were caused by ignited aether. If the ignition took place high in the atmosphere a shooting star was seen; if the ignition took place lower in the atmosphere then lightning was observed; and finally if the ignition occurred underground then an Earth quake resulted [5].

Although Anaxagoras drew no parallels between what we would call meteors and meteorites, he did believe that stones could fall from the sky. Writing in his *Lives of the Noble Grecians and Romans*, Plutarch (circa 46–120 A.D.) explains that Anaxagoras predicted the fall of a stone (meteorite) in 467 B.C. The stone, which fell at Aegospotami, was apparently displayed to visiting dignitaries for many years. Writing in the first century A.D., Gaius Plinus Secundus, or more commonly Pliny the Elder (23–79 A.D.), commented that the stone was still to be seen, and that "it is the size of a wagon-load and brown in color" [6].

That his prediction of a stone fall came true was lucky for Anaxagoras. We now, of course, know that no such prediction can be made. Interestingly, however, an explanation of why Anaxagoras may have thought a stone might fall has been given by West [7]. At the time that Anaxagoras made his prediction, a bright comet was also visible in the sky [8]. West has suggested therefore that if the comet's nucleus split, or maybe underwent some dramatic brightening, then Anaxagoras, who believed that comets were produced when the "light" from two stars "merged," might have thought that a large stone splinter had been thrown off. This stone splinter would ultimately fall to Earth since the Earth, as Anaxagoras viewed matters, was at the center of the Universe.

Diogenes of Apollonia (400–325 B.C.) developed a cosmology that was very similar to that of Anaxagoras [4]. He believed, however, that the universe contained both visible, and invisible stars made out of pumice-stone. While the visible stars remained in permanent motion about the Earth, the invisible stars occasionally fell back to Earth, and in so doing created what we would call a bright meteorite dropping fireball.

3. Meteorologica

By far the most influential work to emerge from Ancient Greece on matters meteorological was that by Aristotle (384–327 B.C.). Aristotle's ideas on the formation of all meteoric phenomena (i.e., shooting stars, comets, thunder, lightning, frost, snow, hail, etc.) are contained in his *Meteorologica* which was written circa 357 B.C.

Aristotle believed that all things were made from four basic building blocks: air, fire, water, and earth. Each of these elements had its own hot/cold, dry/moist qualities, and ideally Aristotle reasoned each of the elements occupied its own special region in the space below the Moon's orbit (the first celestial sphere). Since Aristotle believed that the heavens were perfect in both design and operation, he could not allow such erratic things as shooting stars to be anything but terrestrial, that is, upper-atmosphere phenomena. In this manner, Aristotle reasoned, like Anaxagoras before him, that the shooting stars were simply ignited vapors. Unlike Anaxagoras, however, Aristotle argued that the meteor-producing exhalations had a terrestrial origin.

Aristotle explained in his *Meteorologica* that the heat of the Sun generated exhalations from the Earth. In this way, he reasoned, the various atmospheric phenomena were produced according to the form (that is the qualities) of the exhalations, and on how they intermixed. Two types of exhalation were generated when the Sun heated the Earth. Water produced a moist vapor, while parched land gave off a dry, windy exhalation. This latter vapor, since it was dry and fire-like, rose to the top of the sub-lunary sphere.

Once a sufficiently large quantity of vapor had collected in the sub-lunar region, then according to the prevalent conditions, the vapor was ignited to produce either a shooting star, or a comet if a steady supply of new vapor was available. Aristotle distinguished several types of shooting stars, and we shall discuss these next time.

By virtue of his belief that the heavens were incorruptible, Aristotle rejected outright the idea that stones might fall from the sky. In this respect, Aristotle explained that the apparent stone fall ("predicted" by Anaxagoras) at Aegospotami was an illusion. The stone did not fall from the heavens, but had been lifted and carried by a violent wind to the place were it fell. The strong winds that did the carrying, he further argued, were the result of atmospheric disturbances produced by the comet which was visible at the time of the apparent fall.

4. Different views

The teachings of Epicurus of Samos (341–270 B.C.) were in complete contrast to those of Aristotle. Epicurus believed that the universe was both infinitely old and infinitely large. It was further permeated by a vacuum, and contained a large but finite number of small solid particles, or atoms. These atoms were the basic building blocks of every object in the universe. The Epicurian, or atomistic, cause was championed by the Roman poet Lucretius Carus (99–55 B.C.). In his great poem *De Rerum Natura*, Lucretius attempted to outline the superiority of the atomistic doctrine over the teachings of Aristotle. As far as the shooting stars were concerned, Lucretius explained [9] that the atoms which comprised "fire" had weight, and that "the nocturnal torches of the sky in their lofty flight draw in their wake long trails of flame in whatever direction nature has set their course." Diogenes Laertes in his *Lives of the Philosophers* also explained that Epicurus envisioned that the shooting stars might be the result of friction between the stars, and occasionally due to the meeting of atoms capable of generating fire. In this sense, Epicurus did not necessarily believe that all shooting stars were of atmospheric origin.

Like Epicurus, Pliny the Elder advocated a non-atmospheric origin for the shooting stars. Writing in his *Natural History*, Pliny explained [10], "when the stars are believed to fall, what happens is that owing to their being overfed with a drought of liquid they give back the surplus with a fiery flash." Pliny also argued, however, that there are some "meteoric lights that are only seen when falling." While he strongly doubted that Anaxagoras had been able to predict the fall of the meteorite at Aegospotami, Pliny did contend that it was well known that stones often fell from the sky.

5. Next time

What can we conclude from the foregoing discussion? It is clear that diverse ideas existed throughout the classical era. Both atmospheric and non-atmospheric origins for the shooting stars were presented by the ancient scholars. Likewise, the possibility of stones falling from the sky was a certainty for some, and an anathema to others. Ultimately Aristotle's ideas gained supremacy, and the rival philosophies fell into disfavor. We shall continue exploring the legacy of the Classical Philosophers next time.

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Interview Series

Dr. W.G. Elford

Peter Brown and Malcolm Currie

The following is the first in a series of interviews made with distinguished professional meteor astronomers. The purpose of the series is to give another perspective on the work undertaken by professional meteor workers and provide a more personal contact between professional and amateur meteor workers. This interview was conducted on July 4, 1992, at Smolenice, Slovakia, after the *International Meteor Conference.*

Question: Where were you born and educated?

Answer: I was born in Adelaide in South Australia and educated there. I was very fortunate that just after the war there was a major change in the size of the university, and being a local person who had just finished his 4th year honors program I was taken on as a lecturer. That was in 1949. I then went on to do a higher degree in the early 1950s in meteor work in Adelaide.

Q: What attracted you to the field of meteor science?

A: It came about somewhat serendipititously. Sir Leonard Huxley who was the first senior academic in the new post as head of the Department after the war had arrived from the UK in 1949. He was interested in the ionosphere, and just before he left for Adelaide he had had some conversations with Bernard Lovell who was a great advocate for doing radio meteor work in the southern hemisphere and suggested this to Huxley. About the same time a member of the staff of the Defense Department, David Robertson, wished to take up work for a higher degree at the University of Adelaide. He had a lot of experience in radio Doppler work, basically missile tracking techniques. It was the conjunction of his experience and our enthusiasm that caused us to take up Lovell's suggestion. Our earliest work was not directly in meteor astronomy, however. We looked through the literature and attempted to a find a niche our group could fill. What we found was the work of Manning from Stanford who was using meteor trails for wind measurements and decided this was as good a place as any to start.

Q: What was your doctoral topic?

A: My Ph. D. was in upper atmosphere meteor wind drifts, though about 25% of my project did deal with meteor astronomy as an adjunct. I realized that the data we had collected in December 1952 occurred over the Geminid period. I had no great understanding of the astronomy of meteors at the time, though I had always had an interest in astronomy as a young boy. In fact, I remember that when I was in primary school asking my father one evening why those two clouds did not move. Of course they were the Magellanic Clouds and so did not move. I also used to count the shooting stars at night, and had some idea that there were 5–10 of these per hour visible with the naked eye.

It turned out that when we were measuring the position of the meteor trails for the wind work we had both position and height. By doing some processing we got data out about the Geminids, such as rates and height distributions. We knew we could relate height with diffusion and thus got an early indication of the diffusion coefficient as a function of altitude using the Geminids. We also determined the radiant of the shower.

The next year having recognized that we had detected the Geminids in 1952 we set up a combined radio-visual watch for the 1953 Geminid return. We enlisted the help of about 20 amateurs from Adelaide and we all sat out under the warm summer sky to observe the shower. Unfortunately, we obtained only a few visual-radio coincidences.

Q: Could you describe some of your collaborations with other meteor astronomers over the years?

A: I suppose my mentor was Huxley. He was a great scientist and his interest was in the diffusion of electrons in gases. He also had a great interest in astronomy and the history of astronomy in particular. In his first year he produced a course for the university and the community in general relating to astronomy. He also became involved in the Astronomical Society of South Australia and became one of the first academics to give some leadership to the amateurs in South Australia.

I was also involved with Alan Weiss early on. He came into the field and made some dramatic advances in meteor astronomy. When he came back from the war he took up a science degree and it immediately became obvious that he was very talented. It is on record that his 4th year honors papers were all marked at 100%, a feat that has not been equaled since. Huxley always said that he was the most brilliant student he ever had. He stayed on at Adelaide and Huxley suggested that he should go to Jodrell Bank and learn about meteor radars after he finished his higher degree. So he went and learned from Kaiser and Lovell how to build radar systems. When he returned, we found an old service 200 MHz, 50 kW radar and he modified it to operate at 67 MHz and then built the antenna systems according to the designs from Jodrell bank.

Q: What sort of computational hardware were you able to use in the early reductions?

A: Our first computer was a Brunsviga used by Weiss. This was worked by hand and he did all his computations on it. Weiss was the first to appreciate the changing flux of meteors over the Earth during the year. He used this computer to do all the transformations from the raw radar data to the actual fluxes to obtain this result.

The next generation of computers were electromechanical in nature and soon after the university began to bring in digital computers. The computers in the early days at the university were slow and not very powerful. In 1961, one of my graduate students, Carl Nilsson, undertook the meteor orbit survey and had the problem of reducing the 2000 meteor orbits obtained. The computers at the university were not large enough to handle this job, but fortunately we had friends in the defense establishment who had access to computers that could do the work. But of course we had very low priority and Nilsson would take the stacks of cards to the operating room in this defense establishment and leave them to be processed. A week later he would return and the cards were still there as other projects had priority. To speed up the process, he would imprint on the leading sheet of the work order: "To the operator: if you hand this sheet to C.S. Nilsson, this will guarantee you at least 6 bottles of beer." From that point on all his work orders were filled within 24 hours and the work was finished in short order.

We did build some analog type of computers in the Department to reduce the radio data. These were to assist us in reading the film records of the meteor echoes. Earlier, the records were on paper film which were 100 feet long and contained many meteor echos. Later we used 35-mm film and these rolls could be up to 300 feet long. To accomplish reading these we hired several young ladies and they were trained to read the film records. However, I always insisted that all my students read at least 10% of the radar film data right through the process just to check out things and get their feet wet. For this process we built a viewer and reader and some automatic readouts connected to a punch card machine. Of course the process is quite different today.

Q: Could you describe some of the work done by some of your other graduate students?

A: Nilsson undertook the first serious observational work with me in radio meteor astronomy. I think this orbital work was quite significant. Nilsson later joined the Division of Oceanography in the public service. He initiated the idea of dropping floats with beacons from aircraft off the East coast of Australia to detect big swirls in the ocean there.

Nilsson worked with Bob Roper. Roper used some of the same data as Nilsson utilizing the Doppler echo of the meteor to get ideas about turbulence in the atmosphere. Roper went on to Georgia Tech., and continues to do work in this area. About 1968-69, another student, Grant Gartrell, repeated some of the orbital work that Nilsson did. We were interested in getting deceleration data so we added a fourth station at a greater distance. Before this we had separations of the reflection points on the trail of about 2 km, and with this new setup this increased to 6–10 km and perhaps we could see velocity changes. We were marginally successful with the deceleration work and as a by-product we got out more orbits. Unfortunately some of the orbits were never processed and the records remained in Adelaide.

Some years later, in the mid-1980s, Duncan Steel arrived in Adelaide after working with Jack Baggaley from New Zealand. He used the orbital data from the Adelaide surveys and did a search between asteroidal orbits and the data from Adelaide. From this he discovered that several of the Apollo asteroids have some meteor activity associated with them. This of course was a very great find and shows that the old data still have much useful information contained within them.

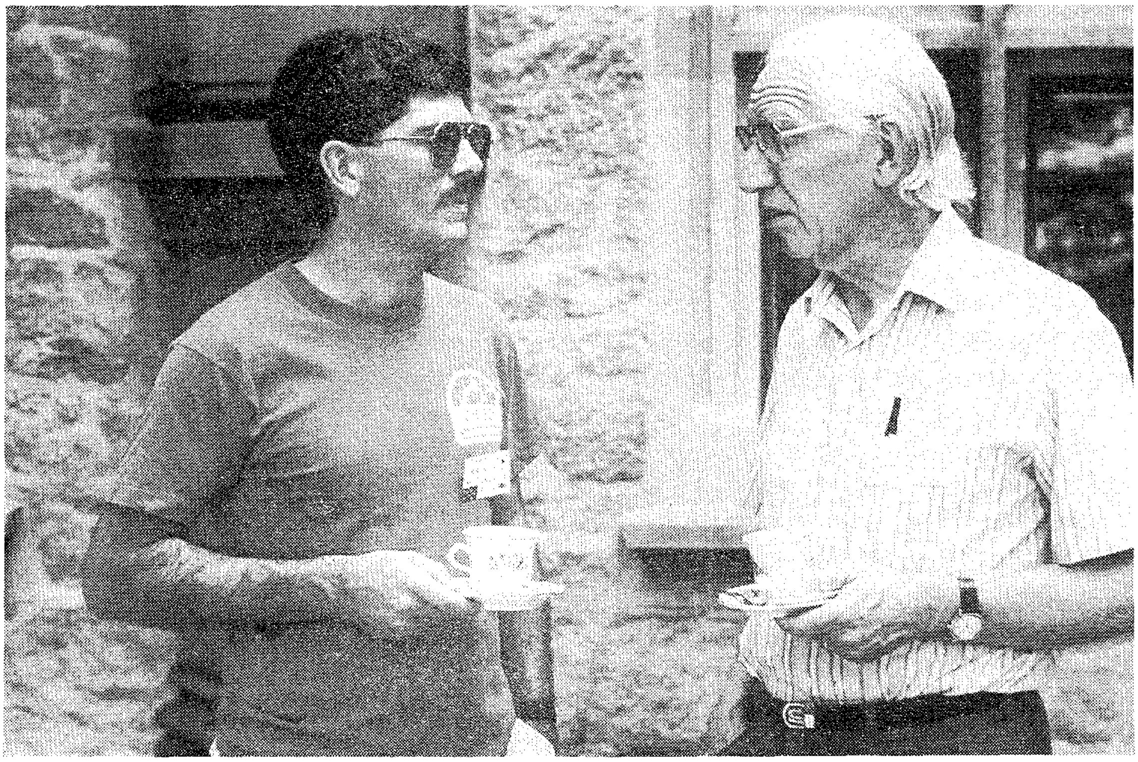

Figure 1 – Duncan Steel *(left)* and Graham Elford *(right)*, discussing during coffee break at the 1992 *IMC* in Smolenice, Slovakia.

Q: Who would you single out as having had the most impact on the field of meteor astronomy?

A: Without doubt, I would have thought that Peter Millman made the greatest contribution to meteor astronomy. I met him first in 1964, after joining the Hawkins-Southworth team at the Smithsonian Astrophysical Observatory. I suppose it was that year, living in the atmosphere of the SAO, that turned me into a meteor astronomer.

Much of the radar data there was read using trained summer students. None of the senior people had ever really seen these data, and I was quite astonished at this fact. When they asked me to do something with the results, the first thing I asked was to see the original film records. They were astounded that I wanted to get my hands dirty, but I insisted. I put the films up on the projector and compared them with the records the students had made and realized that about two thirds of what they were reading was noise and not meteors. These were the data from the system in Illinois.

Getting back to the original question, while I would claim that Millman was the most significant astronomer in meteor studies, he was closely followed by Whipple. They were the two great figures in the field. I was able to work under Whipple during my short time at the SAO. At the end of my time at the SAO in 1965 he invited me to stay permanently, but I declined for the simple reason that we had a young daughter at this time, and I decided that if we stayed there she would be brought up as an American child, and I wanted her to be brought up as an Australian. In fact, this was the right decision as the group closed down about 5 years later when Whipple went into semi-retirement. With this change the entire Harvard radio project came to an end, which was a shame since it was never properly brought to fruition. Even all the data were not fully utilized, and there are still data left to be analyzed. Hawkins left the group and began writing astronomy books for children while Southworth left and disappeared from meteor astronomy: I do not know what happened to him. Southworth was really the driving force behind it all as he had an excellent understanding of the physics involved and he wrote the analysis routines.

Q: Do you consider yourself more a radio physicist or meteor astronomer?

A: A radio physicist. I suppose this is because I realized that a radio technique is not just a technique which you can apply to a particular problem. I am interested more in how you can use radio techniques to understand the world in which we live. I maintain this as my central research aim. In Adelaide I have been involved in what was called the radio physics group, of which meteor studies was one aspect, as was upper-atmosphere work. We were interested in any ways in which you could sense the environment with radio techniques.

Q: Was your group ever directly involved with the space program?

A: Yes. We had a rocket program operating out of Woomera. This was the rocket range for testing of British projectiles. The British were quite interested in the properties of the atmosphere at about 100 km as were the Americans as the space program was underway, and they were interested in re-entry problems for their vehicles. So they had a deep interest in the properties of the atmosphere all over the world. We linked into this research effort through the American Air Force which had huge grants for this kind of research. In fact, most of our meteor studies money in the 1960's came from the USA. As long as we did something related to atmospheric work they were happy to provide the funding. There was also a local program to instrument small rocket vehicles and we got some free rides on vehicles in this way and conducted numerous experiments.

Q: Are there any incidents that stand out in your memory as unusual during your meteor research?

A: The first anecdote I can recall involved our first meteor system. This was for determining meteor winds, as we called it. We had to calibrate our antenna system, and so we got a small aircraft to fly back and forth. David Robertson elected to go up with the aircraft, which was an old bi-plane, to help spot the markers we set out for the plane. They had only been going for about half an hour when they landed in a nearby field. He came across and the first thing he said was "Have you seen my glasses?" He had looked out apparently to see the markers and watched as his glasses flew off into a tailspin over the side.

Another interesting story occurred during the Orionids in 1950, our first observations. We set up some equipment in a number of hotels in the country around Adelaide. *(Interviewers' note: in Australian parlance , "hotel" means the same as a British pub, or bar; that is, a hostelry where alcoholic beverages are sold.)* One of the students working with us by the name Liddy had a family who was in the hotel business in the smaller towns and naturally we choose these hotels. We borrowed some receivers and some wire recorders. These wire recorders came before tape recorders and were the first magnetic recorders which used a thin wire very much like fishing wire. We set these out at these remote sites about 50–100 km from Adelaide. Robertson was a ham radio operator and he had obtained a war surplus transmitter. Now, the ham operators were not supposed to produce more than 50–100 W, but this transmitter put out more than 1kW. So our first observations were with Robertson's illegal transmitter in the hills above Adelaide and we went out to these remote sites and we recorded radio meteors. We were getting all these whistles and we had not realized that these diffraction signals are what you would expect to hear. We still have a few which we transcribed at the time. These were the first radio meteor observations made from Australia.

Another interesting anecdote involves snakes at our field stations. One of our students was putting a cable under one of the buildings at the field station and he went to the other side to pick up the other end. He found that it was not a cable at all but a small dangerous ground snake. If he had been bitten he would probably have ended up in hospital being administered anti-venom. He would never go under the buildings again after that.

Perhaps our most celebrated event occurred when Roper and Nilsson were establishing their multi-station systems to record the orbital information. One of the outstations we used was a disused railway siding, though the railway line was frequently used. The railway company agreed to this arrangement as it helped to cut down on vandalism which was quite frequent in these remote areas. In fact, to prevent such problems we dug holes in the ground and put all the receiving equipment in big metal containers about 1 m^3 in size and then put a lid on them with the antennas sticking out. The problem was that any metal object in these remote areas were good targets for the local people who were out shooting.

But of course these remote stations had to be serviced about once every week. On one particular occasion, Nilsson and Roper were going to the disused railway site. Now the background to this story was that Roper had caught polio in the early 1950s and he has had to use crutches ever since he was a teenager. It was quite a tribute to him as often he could do more on crutches than other able-bodied students could do, as he learned to be more efficient with his limited mobility. On this particular day, Nilsson and Roper were traveling on a backroad across the railway line and onto the disused siding. Normally the car is left some distance from the rail line and the students could walk to the siding, but on this day Nilsson decided to try to save time and drive over the tracks. Naturally, the car was unable to make it and it got stuck half-way across the track.

Nilsson was trying to find a branch to lever the car off the track, when they realized that a train was due in the next few minutes. Since it took many hundreds of meters for the large trains to slow down, Roper went ahead on the tracks to flag down and stop the train, which the driver did. Of course, since the train stopped and ended up being somewhat late, the engineer had to report that he had been stopped by a fellow out in this remote section of track waving his crutches to get the train to stop. Eventually Nilsson and Roper had to come before the Commissioner of Railways and explain exactly what had happened.

Q: What do you see as the role of the amateur meteor radio observer?

A: One of the great difficulties in the work I have been involved with is that a student comes in, works on a project and then when the student graduates, the project is often moth-balled. Hence in the university environment, many of these projects have very short time scales. This is where amateurs could be useful; universities are not good places for long-term recording of observations. In fact, we had argued with our grant commissions that we should have money for ongoing operations. This we did get for the meteor wind work, but we had to go though many problems to try and communicate this to the grant committees.

In meteor astronomy I think there is a very important role that amateurs can play to maintain ongoing observational programs. Their dedication and their continuing activities over many years makes them valuable assets for the radio meteor astronomy community. In particular if they could work together as an organization this aspect could be fully exploited, as the *IMO* might be able to do. You cannot set up this sort of group at a university for the long-term over a global scale at all. Doing the long-term observing programs is where amateurs are most valuable.

I think the use of forward scatter in amateur meteor work needs serious investigation by professionals to define programs and help get the amateurs started. Calculating the response function for various systems might be where the professionals could come in and then encourage the amateurs to start making the observations. I think that the amateurs should be working towards automating the systems, using PCs and recording the data in this way.

At the same time I think it is good for the amateurs to be there doing some hands-on work and listening to the signals. Then they can go away and still leave the system recording. I think the excitement of hearing the rates change and that sort of thing is very appealing to amateurs. This allows some of the excitement of the event to be directly communicated to the observer in real-time.

Another area amateurs in radio meteor work can contribute to is whether the sporadic complex is a whole series of small streams or not. Some of the small changes in activity witnessed by amateurs using radio systems undoubtedly are related to small streams that may be missed by visual observers. The thing is to go out and get some data: this is what will trigger your interest and get you motivated. Of course some understanding of the mechanisms involved is appropriate, but certainly go and collect some data. The existing observations using forward scatter are quite useful, but more work needs to be done on the proper interpretation of the raw results. By setting up a group of people with a transmitter site and several receiver sites, separated by perhaps 500 km, you may be able to get some good data on radiant areas, with the full interpretation later on.

Q: For the future of radio meteor astronomy, what are some of the areas you see as being quite important?

A: I think the orbit work is still of interest, since the only way to look at the daytime streams is with radio techniques. The use of radio techniques to study the influx rate of meteoroids is also quite important. The effect of the echo height ceiling is quite critical here and I think many people are "re-discovering" this selection effect again. As a result many of the smaller meteors may not be detected. So really we are seeing the bottom tail of the size distribution with the radio techniques at higher frequencies. This is a real problem with high velocity meteors, such as the Perseids.

Fireballs and Meteorites

Physical and Climatic Data for New Zealand Observed Electrophonic Fireballs

Graham W. Wolf

The author's own 14 electrophonic fireballs were observed from three New Zealand sites over a two-year period from 1985 to 1986 inclusive. These were Fairfield, Saddle Hill (both near the author's former South Island home), and the R.F. Joyce Observatory at West Melton near Christchurch, which is administered by the Canterbury Astronomical Society (CAS). Many of these observations have been briefly reported in the Society's monthly magazine *CASMAG*. Whilst some other New Zealand observations are briefly mentioned, the data herein are by the author himself.

1. Introduction

Several members of the Canterbury Astronomical Society have observed electrophonic fireballs at some time or other. Carter National Observatory (CNO) Scientific Officer Frank Andrews heard one whilst inside an observatory dome making photographic observations, which were subsequently ruined by the fireball's brilliant glare. He likened the electrophonic sound to that of a car tyre crunching over gravel. Clive Rowe once heard a -6 electrophonic fireball whilst in the remote Southern Alps (with its low rural ambient noise level). He said it made a distinct "whine."

Peter Carrington, whilst at the R.F. Joyce Observatory at West Melton in March 1986, observed a -13 fireball fall slowly and almost vertically to the North. He heard an instantaneous "crackling" sound, and thought he was watching an incoming ICBM, and that the end of the world had come! The former Meteor Section of the Royal Astronomical Society of New Zealand (RASNZ) which was disbanded in 1984, used to receive reports of electrophonic sounds from the general public in New Zealand. In *Meteor Bulletin* 19, dated April 1983, issued by its then director Ken Morse, there were two reports from Nelson and Lower Hutt, dated January 7 and April 13 respectively. Both reported "hissing" sounds.

A more famous New Zealand fireball passed over Opotiki (pronounce *oh-po-t-kee*) at 3^h12^m UT on June 12, 1989, at a brightness of −18. Its azimuth was 34° and its passage made an angle of 8° to the horizon. Two reports of electrophonics came from Matata (pronounce *mah-tah-tah*), and one observer from the region of the forestry logging town of Kawerau (pronounce *kah-were-ow*) reported hearing "fizzing" sounds as the electrophonic fireball passed over. The author's own 14 electrophonic fireballs observed in 1985 and 1986, are the only New Zealand examples for which detailed physical and climatic data exist.

Table 1 – Observing site key.

Location	Longitude	Latitude	Elevation
Fairfield (FF)	170°383 E	45°902 S	80 m
Saddle Hill (SH)	170°367 E	45°923 S	472 m
West Melton (WM)	172°350 E	43°501 S	50 m

Table 2 – Physical data.

Date	Time (UT)	Site	M_v	Dur	Train	Size	Sounds	Deto
1985 May 06	$17^h48^m50^s$	FF	−20	3 s	530 s	30′	wh,cr	38.2 s
1985 Aug 15	$08^h16^m44^s$	FF	−10	5 s	28 s	10′	sw	72 s
1986 Feb 17	$17^h10^m55^s$	SH	− 9	3 s	5 s	8′	wh	52 s
1986 Feb 19	$16^h47^m12^s$	SH	−10	2 s	10 s	6′	wh	45 s
1986 Feb 20	$16^h20^m38^s$	SH	−10	1 s	5 s	8′	wh,fi	86 s
1986 Feb 20	$16^h23^m16^s$	SH	− 8	2 s	2 s	6′	wh,po	98 s
1986 Feb 20	$16^h35^m02^s$	SH	− 5	1 s	18 s	8′	wh	65 s
1986 Feb 20	$18^h01^m28^s$	SH	− 6	9 s	6 s	6′	po	
1986 Feb 20	$18^h29^m22^s$	SH	− 9	6 s	2 s	8′	wh	
1986 Jun 16	$08^h28^m40^s$	FF	− 7	4 s	1 s	4′	wh	48 s
1986 Aug 12	$06^h38^m40^s$	FF	− 8	8 s	52 s	10′	hi	
1986 Aug 28	$10^h12^m06^s$	FF	− 5	2 s	5 s	3′	sw	
1986 Dec 08	$13^h24^m06^s$	WM	− 7	7 s	18 s	10′	wh	
1986 Dec 09	$11^h22^m22^s$	WM	− 5	2 s	4 s	6′	wh	

Table 3 – Electrophonic sounds.

Sound		Author		SEAN	
Code	Name	*N*	%	*N*	%
wh	whine	10	59%	6	7.4%
po	popping	2	12%	4	4.7%
sw	swishing	2	12%	9	10.6%
cr	crackling	1	6%	8	9.4%
fi	fizzing	1	6%	1	1.2%
hi	hissing	1	6%	15	17.6%
	Other	0		42	49.4%

In Table 2, $M_{\rm v}$ is the visual estimated brightness of the fireball, "Train" is the duration of the smoky train in seconds, "Size" is the estimated angular size of the fireball head in arc minutes, "Sounds" are according to the *Wolf Electrophonic Sound Reporting Code (WESRC)* system outlined in the *1991 Potsdam IMC Proceedings* [1] and set out in more detail in Table 3, and "Deto" is the sonic delay time from end point in seconds, the first being timed with a stop-watch, the rest were counted out. A blank entry in this column indicates that no sonics were observed for that electrophonic fireball.

It can be seen that of the author's own 17 observed electrophonic sounds from 14 events in New Zealand, the most prevalent is "whine," which occurred in 10 cases (59%). However, by comparison, for the 85 electrophonic sounds reported to the *Scientific Event Alert Network (SEAN)* from 1980 to 1990, the most prevalent is "hissing," which occurred in 15 instances (17.6%), followed by "swishing" (10.6%), and "crackling" (9.4%). The six types of electrophonic sounds that the author observed in 1985 and 1986 only account for 50.6% of the total *SEAN* reported sounds. A fuller report of these *SEAN* reported sounds, called the *SEAN Electrophonics Catalogue (SEC)* is contained in the *1991 Potsdam IMC Proceedings* [2].

It can be seen from Table 2 that the average brightness was −9, which seems to agree with overseas reported data. The average duration was about 4 s, and the average train nearly 50 s (somewhat biased by the 530 s recorded by the brightest fireball). The average angular size was 9′, and the average sonic delay time was found to be 64 seconds.

Table 4 – Climatic data.

Date	Time (UT)	Temp	Humidity	Pressure	Wind
1985 May 06	$17^{\rm h}48^{\rm m}50^{\rm s}$	3.2° C	80%	1008 hPa	calm
1985 Aug 15	$08^{\rm h}16^{\rm m}44^{\rm s}$	3.0° C	80%	1016 hPa	calm
1986 Feb 17	$17^{\rm h}10^{\rm m}55^{\rm s}$	6.8° C	80%	1007 hPa	E 2
1986 Feb 19	$16^{\rm h}47^{\rm m}12^{\rm s}$	5.5° C	70%	987 hPa	N 1
1986 Feb 20	$16^{\rm h}20^{\rm m}38^{\rm s}$	6.1° C	45%	1001 hPa	NW 4
1986 Feb 20	$16^{\rm h}23^{\rm m}16^{\rm s}$	6.4° C	45%	1001 hPa	NW 4
1986 Feb 20	$16^{\rm h}35^{\rm m}02^{\rm s}$	6.5° C	50%	1001 hPa	NW 4
1986 Feb 20	$18^{\rm h}01^{\rm m}28^{\rm s}$	6.8° C	60%	1001 hPa	NW 4
1986 Feb 20	$18^{\rm h}29^{\rm m}22^{\rm s}$	6.8° C	60%	1001 hPa	NW 4
1986 Jun 16	$08^{\rm h}28^{\rm m}40^{\rm s}$	2.8° C	65%	1023 hPa	calm
1986 Aug 12	$06^{\rm h}38^{\rm m}40^{\rm s}$	8.2° C		1018 hPa	
1986 Aug 28	$10^{\rm h}12^{\rm m}06^{\rm s}$	5.1° C		1018 hPa	
1986 Dec 08	$13^{\rm h}24^{\rm m}06^{\rm s}$	7.2° C	60%	1023 hPa	calm
1986 Dec 09	$11^{\rm h}22^{\rm m}22^{\rm s}$	7.6° C	62%	1020 hPa	calm

In Table 4, the numbers in the last column indicate wind velocities in knots. It can be seen that the majority of electrophonic fireballs observed here, took place when ambient temperatures were relatively modest, usually below 10° C. Also, there was little if any wind present at the time. Barometric pressure ranged from 987 to 1023 hPa, and therefore does not seem to have had any contributing influence, at least in these recorded cases. For more detailed information on the 1985 May 6 event, please refer to [3].

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Fireball over San Diego County

Southern California, USA, December 13, 1992, $5^h48^m52^s$ UT

George J. Zay

A −15 fireball was seen over Souhtern California on December 13, 1992. Meteorite-dropping is not excluded.

On the evening of December 13, 1992, Robert Lunsford and I were observing a pretty good Geminid show. Suddenly, a brilliant meteor appeared near Orion's belt. I started yelling to Bob to "Look Up! Look Up!" and he replied with: "Oh My! Look at that! Oh Wow!" Those were our descriptions of a magnitude −15 sporadic. As we were gathering the pertinent data and our composures as well, a single, very loud thunderclap occurred. We immediately looked at our watches for the exact time. The shock wave came exactly 2 minutes and 46 seconds after the fireball first appeared. I was lucky enough to have my chart recorder operating at that moment, recording radio reflections. The chart recorder was synchronized with the exact time. It showed the fireball to appear at exactly $5^h48^m52^s$ UT on the evening of December 13, 1992. The recorder showed a strong radio signal of exactly 18 seconds. There were no visible persistent trains. The fireball had a pale blue-white color. Its velocity appeared slightly lower than that of the Geminids. I would say it was near 28 to 30 km/s. It lasted 2.5 seconds. The limiting magnitude was 5.2. The fireball was brighter than a Full Moon by far. When observed, it just kept getting brighter and brighter. At the end it faded out with a continued dull red glow (like a lit cigarette thrown into the dark) for several degrees. Then it disappeared. The meteor started at $\alpha = 6^h11^m$, $\delta = -01°$ and ended at $\alpha = 3^h03^m$, $\delta = +63.°5$. The exact geographical coordinates of my observing site are $\lambda = 116°38'13''$ W, $\varphi = 32°50'00''$ N, and $h = 1003$ m.

There were several reports to the news media and local fire stations of an explosion and possible plane crash, but nothing was found. I personally feel that this meteor made it to the ground. I suspect an area near the cities of Ramona and Escondido as possible landing site. It is not likely to be recovered there, unless it nailed somebody right between the eyes. And since I have not seen anything in the newspaper obituaries to indicate this, a possible meteorite may have landed anonymously. I am presently trying to pinpoint an approximate landing area by means of plotting the directions the thunderclap seemed to come from various witnesses with respect to their location. I do not have the mathematical expertise, but I was hoping that I gave enough information to all of you in *IMO* Land to find someone able to plot something, whether it be on Earth or in space; or at the very least associate it with a meteor shower.

Meteorite Fall over Croatia on January 19, 1993

compiled by Peter Brown

On January 19, 1993, around 3^h UT, a very bright fireball was seen over northern Italy. Seperate reports at the time suggested the same fireball dropped a meteorite on a house in Croatia, killing two persons.

According to an Austrian newspaper, "a meteorite fell on a house in Poreč, Croatia, killing two old brothers living there." This event happened on January 19, 1993. Poreč is situated near the Adriatic coast, about 50 km south of Trieste in Italy. An Italian newspaper reports a meteor that passed over northern Italy on January 19 at about 3^h UT. People heard a loud boom, and saw the sky being illuminated as during daylight. This phenomenon lasted about 10 to 20 seconds. Also shock waves were reported. Newspapers speculated that it was a meteor that went straight on Croatia. Later investigation of the related deaths revealed they were not associated directly with the fireball, and no meteorites have been recovered from this event.

A Leonid Fireball over Japan

November 17, 1992, 15^h09^m UT

K. Osa and Y. Shiba

A simultaneous visual-photographic observation of a Leonid fireball is described.

(Observation by K. Osa.) On the night of November 17, 1992, I was taking photographs of the Polaris region with a 150 mm lens in order to measure stars. The exposure ended at 15^h05^m UT, so I left my house to close the shutter. It was about $15^h08^m30^s$ UT then. I looked up at the sky to evaluate the cloud conditions, but there were only thin high altitude clouds to the south of Lepus when the Moon started rising from the top of a nearby the hill. The camera body was wet with dew, so I inspected the front of the lens with a flashlight. Then I looked up to the sky, and a very bright elongated cloud was visible between Procyon (α CMi) and the southern part of Eridanus. At first, it seemed an after-image of my flashlight because the cloud was so clear. Immediately I looked at my watch: it was $15^h09^m24^s$ UT. Then I observed variations in the cloud, which made me think it was a fireball trail. The brightest part varied between magnitudes 0.3 and 0.8. Then the cloud began to spread mainly southward from the east end towards Saiph (κ Ori) (see Figure 1). I was able to observe it visually until $15^h13^m45^s$ UT.

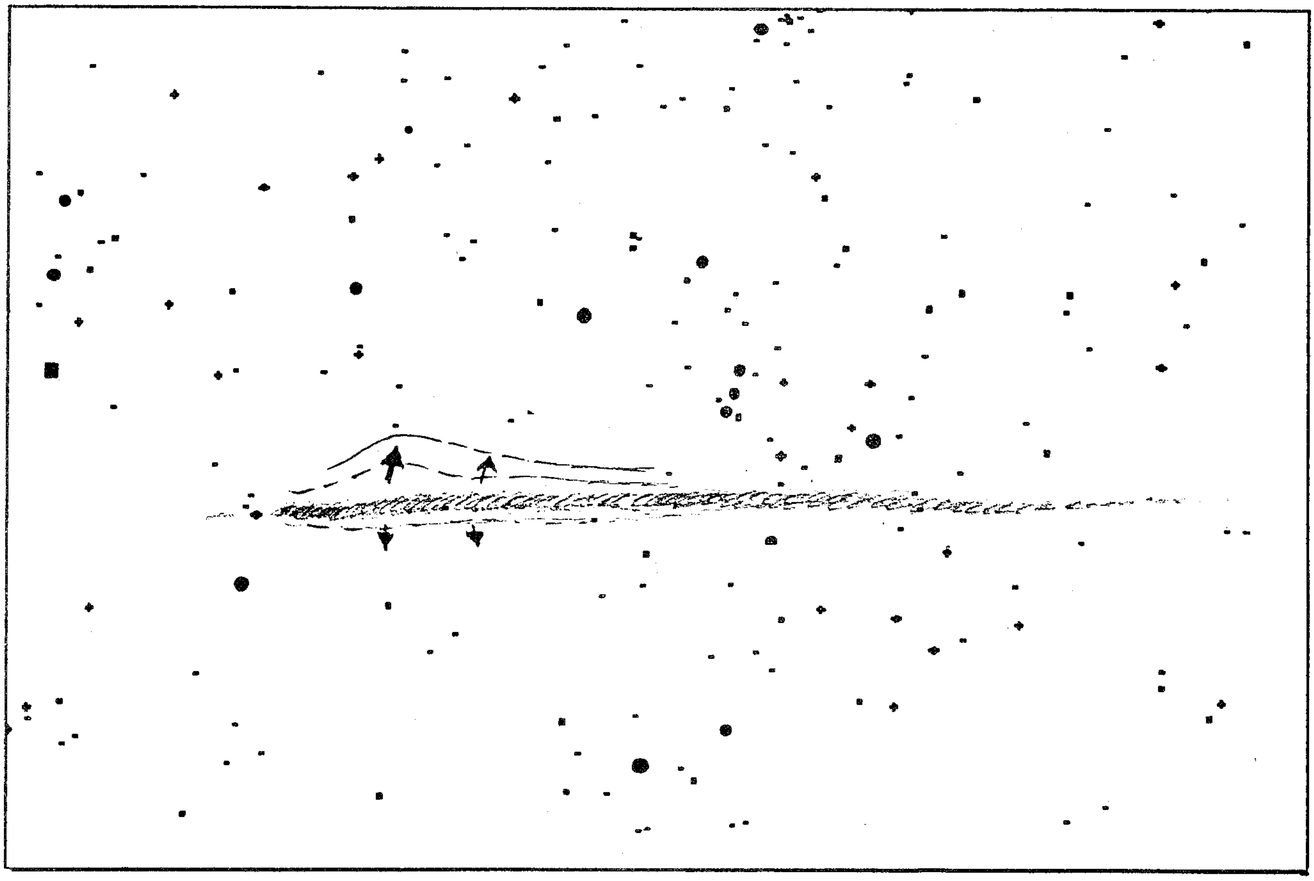

Figure 1 – Fireball train observed by K. Osa. Orion is near the center of the figure.

The following day, I reported the event to Mr. M. Satake, but I hesitated to call the phenomenon a fireball train, particularly since I had never observed a fireball train of that brightness. If it were a cloud, the Moon's position might very well explain the brightness of the object. In addition, there are small mountains 1 km south of my house above which the low atmosphere is easily disturbed, leading to cloud formation. But I judged it was a fireball train from the way in which it disappeared. From my observations, I felt the fireball to have come from the east where the Leonid radiant was at the time. The fireball magnitude must have been -5 to -6.

It turned out that I saw the same fireball photographed by Y. Shiba, as is apparent from a comparison of both data. My observing site is Kameoka-shi, Japan ($\lambda = 135°35'20''$ E, $\varphi = 34°58'56''$ N, $h = 212$ m).

(Photographic data by Y. Shiba.) The photograph shown in Figure 2 was exposed on November 17, 1992, from $15^h00^m00^s$ to $15^h29^m58^s$ UT. The camera used was a Canon T-70 with a 15 mm $f/2.8$ fish-eye lens. There were 10 shutter breaks per second. I used T-Max 400 film, which was developed in Copinal, diluted 1:10, at 21–22° C for 13 minutes. The photograph was made from Kobe-shi, Japan ($\lambda = 135°07'28''$ E, $\varphi = 34°42'59''$ N, $h = 318$ m).

Assuming that the fireball appeared at $15^h09^m00^s$ UT, it must have started near $\alpha = 116.°67$ and $\delta = +12.°74$, and ended at $\alpha = 80.°95$ and $\delta = -02.°80$. The backward prolongation of the fireball missed the Leonid radiant center ($\alpha = 152°$, $\delta = +32°$) by only 0.°5. The fireball had an estimated magnitude of -8 to -10.

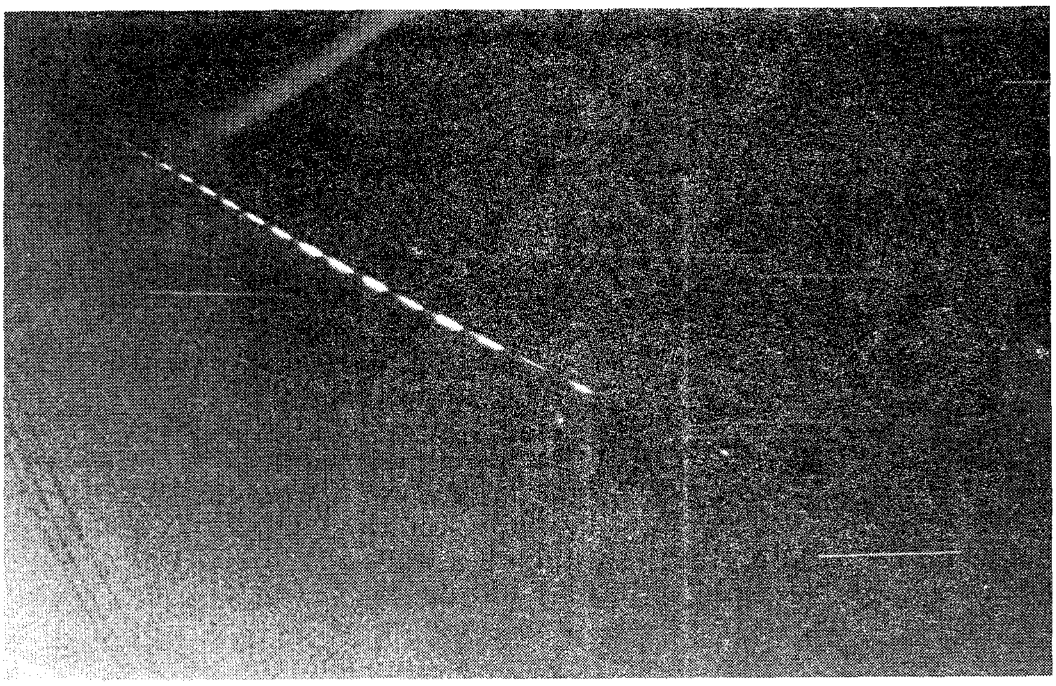

Figure 2 – Fireball photographed by Y. Shiba.

Observational Results

The 1992 Perseids in Crimea

A.I. Grishchenyuk

An overview is given of the Crimean observations of the 1992 Perseids in the night of August 11-12.

The observers that started watching Perseids after 20^h40^m UT on August 11 were astonished by the lack of shower meteors. The Full Moon was an important factor giving rise to this impression. It turned out that observers in Eastern Europe had enjoyed a beautiful Perseid rain.

Five groups of observers were active in Crimea in August, 1992. The most experienced observers watched from Pochtovoe, 16 km south-west of Simferopol (A.I. Grishchenyuk et al.), Simferopol (V. Martynenko et al.), the Crimskoe Primorje (East Crimea, near Feodasia), Sudak, and Malorechenskoe, near Alushta.

The shower's peak was predicted for the night of August 11-12 around 22^h UT, so that almost all European observers would be able to see it. However, the shower did not behave as expected, and had its maximum a few hours earlier. It was an amazing spectacle that lasted for about one and a half hour. An overview of the author's observations from Pochtovoe is given in Tables 1 and 2.

Table 1 – Uncorrected Perseid rates obtained by the author from Pochtovoe, Crimea, on August 11-12, 1992.

Time (UT)	T_{eff}	Lm	Per
19^h50^m	1.07	5.5	82
20^h55^m	0.72	5.4	21
22^h07^m	1.62	5.6	64
23^h40^m	0.83	5.7	18
00^h30^m	1.00	5.7	30
01^h20^m	0.50	5.8	22
01^h45^m	0.50	5.5	9

Table 2 – Magnitude distribution for the Perseids on August 11-12, 1992, as observed by the author from Pochtovoe, Crimea.

Mag	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	Tot	$\overline{m}$
Per	2	3	2	9.5	22	41	34	66.5	52.5	13.5	246	1.26

After the outburst, observers had the impression that the meteor shower "tap" had been turned off. Few meteors were observed for one hour after 20^h40^m UT.

In Crimskoe Primorje, observers started at 18^h30^m. During a little over 2 hours, they saw about 100 Perseids each under a limiting magnitude of 5.0–5.2. The moonlight interfered severely with the observations. It is very difficult to estimate ZHRs under these conditions, but we estimate them as more than 500 and less than 700.

The physical properties of the Perseids in these particle clouds were very interesting. At the same time one could observe both orange and violet meteors (!), which is quite non-characteristic for the Perseids. The presence of violet was noted by observers from all Crimean groups. They all stated that the meteors were blue with a violet edges. The tendency of meteors to appear in groups lasting for 3–5 seconds after a 20–30 second interval of no activity was very distinct. As in 1991, there was a deficit of first magnitude meteors. Our calculations show that the Perseids had their peak at $\lambda_\odot = 139\overset{\circ}{.}43 \pm 0\overset{\circ}{.}02$ (2000.0) in 1992. This indicates a shift of the stream's mass center.

The 1991 and 1992 Perseids in Bulgaria

Atanas Nikolov and Peter Dalakov

An overview is given of 1991 and 1992 Perseid observations from Sliven, Bulgaria.

1. The 1991 Perseids

During five nights (August 9-10 to 13-14), seven of us followed the activity of the Perseid Meteor Shower. The group consisted of the following observers:

Kremena Baltova (BALKR), Ivanka Getsova (GETIV), Stanimir Kolev (KOLST), Krasimir Manov (MANKR), Atanas Nikolov (NIKAT), Kostadin Petkov (PETKO), and Peter Dalakov (DALPE).

In total, we registered 430 Perseids and 500 sporadics during an effective observing time of 18 hours. On average, the limiting magnitude was 6.5. About 28% of the meteors showed a train. We often noted that the meteors appeared in small groups.

2. The 1992 Perseids

In 1992, our interest in the Perseid meteor shower was quite strong, particularly after having read the many articles published on the topic. The observers were NIKAT, DALPE, and MANKR. Uncorrected counts for the night of August 11-12 are shown in Table 1.

Table 1 – Uncorrected Perseid counts from Sliven, Bulgaria, on the night of August 11-12, 1992.

Period (UT)	Rad. Elev.	NIKAT	DALPE	MANKR
19^h20^m–20^h20^m	15°	25	15	15
20^h20^m–21^h45^m	25°	30	16	16
22^h00^m–23^h00^m	35°	20	3	0
23^h00^m–00^h30^m	45°	42	30	15

From the very beginning, we were "drowned" by extremely bright meteors. We were particularly impressed by a magnificent magnitude −10 fireball that for 4 seconds crossed half of the celestial hemisphere with a fiery veil and, after having disappeared, left a train that for 10 seconds kept our memory of the fireball alive. Eleven more fireballs with magnitudes between −3 and −9 proved to us once more that meteor observing is a most attractive subject for an amateur astronomer! Fax:+(3822)+230450

International Conference on Ecological Consequences of Collisions of the Earth with the Solar System Small Bodies

(Dedicated to 85th anniversary of the Tunguska Event)

communicated by Gennadij Andreev

The Commission on Meteorites and Cosmic Dust of the Siberian Branch of the Russian Academy of Sciences, the Tomsk Branch of the Astronomical-Geodetical Society, the Tomsk Branch of the Agency for Bio-informatics and Human Ecology, and the Tomsk State University have agreed to hold the International Conference (during the *Fourth International Tunguska Expedition*) "Ecological Consequences of Collisions of the Earth with Solar System Small Bodies," dedicated to the 85th anniversary of the Tunguska event.

Place of the meeting

The Tunguska Meteorite Reservation.

Time of the meeting

July 20–23, 1993.

Program

- Physical, chemical and orbital characteristics of small bodies crossing the Earth's orbit;
- Probability and prediction of collisions of small bodies with the Earth;
- Physical-mathematical description of collisions of the Earth with a small body;
- Ecological (atmospheric, climatic, geophysical, geological, biological) consequences of collisional processes; and
- Problems of preventing collisional events.

Scientific Organizing Committee

G. Andreev (Tomsk, co-chairman), Ph. Bagnal (Tyne and Wear), L. Giuzeppe (Bologna), A. Grishin (Tomsk), E. Kolesnikov (Moscow), V. Korobeynikov (Vladivostok), V. Krivitskay (Moscow), G. Plekhanov (Tomsk), H. Rickman (Uppsala), Yu. Shukolukov (Moscow), E. Sobotovich (Kiev), N.Vasilyev (Tomsk, chairman).

Some information

The assembly place for all participants of the meeting is Tomsk on July 19 (or earlier, if requested). Between Tomsk and Vanavara we will operate a special flight on July 20 at 9^h p.m. (Tomsk time). The opening of the meeting is planned in Vanavara at 14^h–15^h p.m. (local time) on July 20. Then, all participants will be brought to the center of the Tunguska catastrophe (to the Kulic houses) by that evening by helicopter. At this site, there is the necessary accommodation for a conference and for living such as some houses, tents for camping, a kitchen, and an open place with roof and tables.

The meeting closes on the evening of July 23, and in the early morning of July 24 those who wish to leave will have a flight from the Tunguska Reservation to Vanavara, followed in the afternoon by a flight from Vanavara to Tomsk.

Registration and payments

Those wishing to participate should request a pre-registration form from Gennadij Andreev (see at the end of this article). Deadline for the receipt of the pre-registration form is March 15, 1993. Registration of participants will take place at Tomsk State University. The registration fee is 100 USD for the meeting.

The payment for full accommodation in Tomsk is 50 USD per day. The payment for full accommodation during the meeting (Vanavara and Tunguska Meteoritic Reservation) is 20 USD per day. The payment for the flight Tomsk-Vanavara and Vanavara-Tomsk is 300 USD. Aircraft tickets (helicopter) Vanavara-Tunguska Reservation and back are 50 USD each.

More information

Andreev Gennadij, Astronomical Observatory of the Tomsk State University, Box 1106, SU-634 010, Tomsk, Russia; phone: +7-3822-909 721 (8^h–16^h UT) or -212 466 (17^h–6^h UT); Fax: +7-3822-230 450; e-mail: broker@siberia-ltd.tomsk.su.

Fourth International Tunguska Expedition

July–August, 1993

communicated by Gennadij Andreev

The Commission on Meteorites and Cosmic Dust of the Siberian Branch of the Russian Academy of Sciences, the Tomsk Branch of the Astronomical-Geodetical Society, and the Independent Complex Tunguska Expedition agreed to hold the *Fourth International Tunguska Expedition (ITE93)*. *ITE93* will take place in the Tunguska Meteoritic Reservation during July and August of 1993. More information can be obtained from Gennadij Andreev (see the end of the previous article). As for the International Conference dedicated to the 85th anniversary of the Tunguska Event, the deadline for returning the pre-registration form is March 15.

The program will reflect the study of the ecological consequences of collisions of the Earth with the small bodies of the Solar system using as a basis the thorough investigations of the Tunguska catastrophe; at estimating the probability of such events and giving a prognosis of the Earth colliding with known small bodies; and at working out international measures for the Earth's safety. The program contains the following complex problems:

1. Elemental and isotopical bio-geo-chemistry of the fall region;
2. Geophysical consequences of the Earth colliding with small bodies of the Solar system;
3. Ecological (medical and biological) consequences of collisional events;
4. Estimation of the probability of the Earth colliding with the small bodies of the Solar system; and
5. Working towards international measures to defend the Earth against collisions with small bodies in the Solar system.

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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, in most beautiful surroundings. At last an opportunity is provided to South-European observers to come to an *IMC* nearby, and to the others to meet them!

Also the choice of the conference site makes it possible for participants to come earlier to observe, and use this unique opportunity to compare one's own observations with those of colleagues abroad!

But do not be late! The number of participants that can stay in Puimichel is limited, and only a few more places are available! Rush your registration form to Paul Roggemans if you do not want to miss this unique event! It would be a pity if you could not participate at the 1993 *IMC* just because you returned your form late!

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

Still available: Proceedings
International Meteor Conference 1991
Potsdam, Germany, September 19–22, 1991

The proceedings of this International Meteor Conference are still available! The book contains articles about various fields of meteor astronomy—almost entirely covering the conference.

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

These proceedings are published by the *International Meteor Organization* and can be ordered at only 10 DEM per copy (surface mail delivery).

At the same price, you can also still order copies of the proceedings of the 1990 *IMC*. The proceedings of the 1989 *IMC* is still available at 12 DEM. Make sure your collection of this valuable information is complete!