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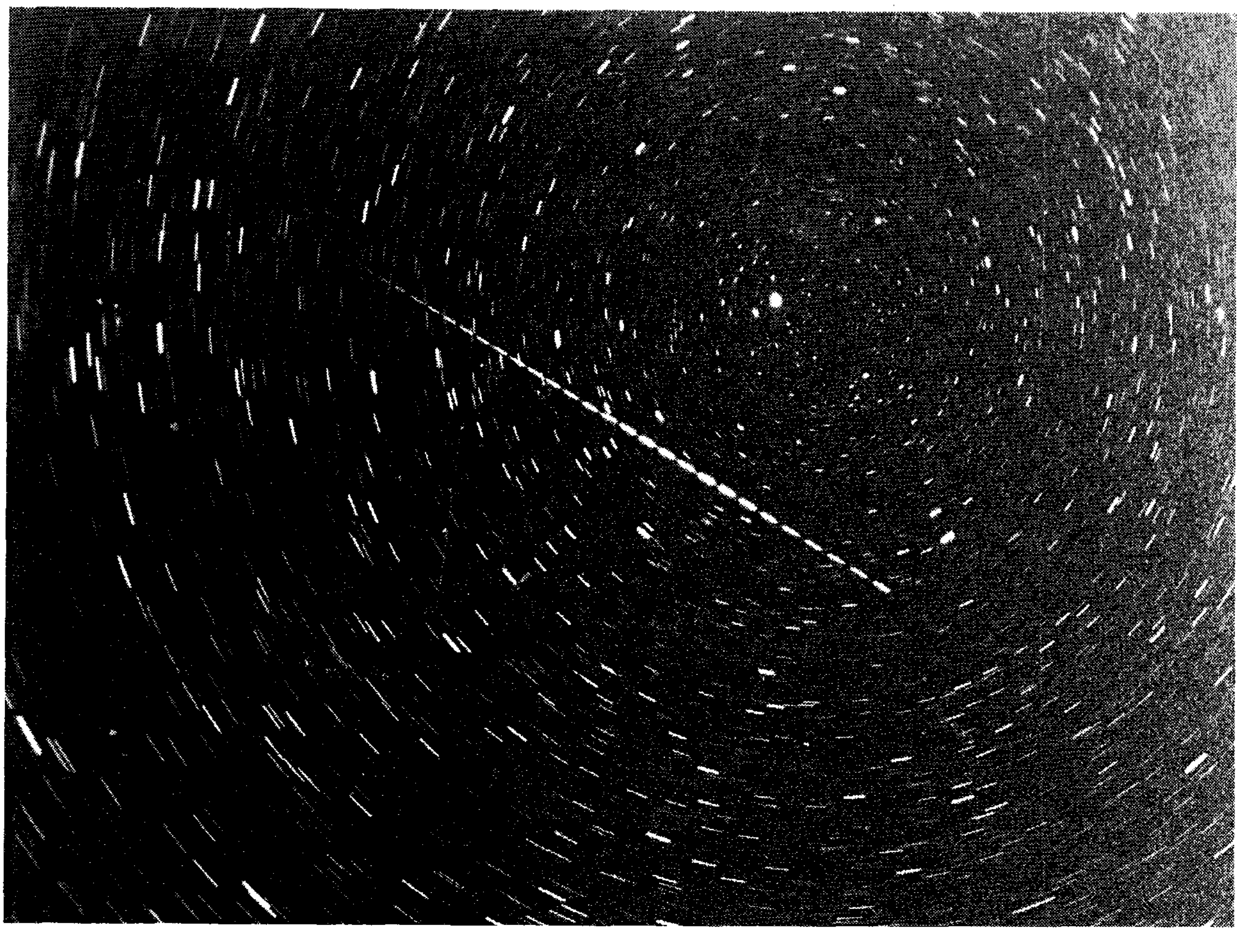

This beautiful magnitude −3 Perseid in Ursa Minor was photographed by a team of the *Dutch Meteor Society* (Koen Miskotte, Robert Haas, Marco Langbroek, Casper ter Kuile) from Biddinghuizen, the Netherlands, on August 14, 1994, at $2^h12^m53^s$ UT. The exposure was made from $2^h10^m00^s$ UT till $2^h19^m58^s$ UT with a 1.8/50 lens on Kodak Tri-X film developed in Kodak T-max 400 at 20° C during 5–7 minutes.

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

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Contents

Useful Information

The February Issue *(WGN 23:1)*

The *February issue* will be mailed during the first week of February. Contributions are due *January 13* at the latest. They should be sent to *Marc Gyssens.*

Reflections on Meteor Astronomy and Education

Marc Gyssens

Just days ago—from November 25 to 30—I had the opportunity to participate in a workshop on astronomy teaching in European secondary schools, sponsored by the European Southern Observatory (ESO) and the European Union, and organized at the ESO Headquarters in Garching near Munich, Germany. Although the subject of the workshop is generally outside the scope of this journal, I want to highlight one aspect of its outcome that may also have some bearing on us.

It was generally felt by the representatives of the 17 participating European countries that not only there was not enough astronomy in the curricula of the (secondary) schools, but also that what was taught of astronomy was scattered over too many subjects. A consequence of this is that the majority of people never get a global picture of the Universe and their place in it that is consistent with the findings of modern astronomy. I suspect that the situation in many non-European countries is not that much different. From the lectures that were given and the discussions that followed, two reasons emerged for this flaw in our education systems:

1. *Not much has changed to the way in which science is taught since the beginning of the century: science is still being presented as a collection of several disciplines, each with a separate existence and identity, between which there is only loose interaction. Although this perception of science is completely obsolete—the various disciplines of science are now regarded as views of the same world at different scales and levels of complexity—the modern approach to science apparently has reached neither the general public nor the policy makers who could have implemented it in our schools. As a consequence of this failure, modern astronomy—perhaps the most interdisciplinary science subject—cannot find its rightful place in the current curricula.*
2. *Earth was, for a long time, considered a safe sanctuary within the Universe, sufficiently shielded by its atmosphere from adverse cosmic influences. The events that led to the Arizona Meteor Crater or the Tunguska catastrophe were regarded as "exceptions confirming the rule." Consequently, all of astronomy that does not directly pertain to the Earth, its cycles, and movements was considered non-essential for a general education.*

The participants concluded that astronomy has been instrumental in providing us with a more comprehensive vision of science and the Universe we live in as well as in showing that the vulnerability of Earth not only stems from the behavior of its inhabitants but also from external causes. As such, the proper teaching of astronomy is essential if we want our children to receive the necessary scientific and cultural background needed to function properly and responsibly in an increasingly complex society.

Having said this, I am especially struck by the important role that tiny meteoroids have recently played in the change in our vision of science just described and which has become more accentuated during the last decade.

The Voyager missions have initiated a long and still ongoing series of discoveries in the Solar System each of which makes it more and more clear that the 19th-century classification scheme of planets, satellites, asteroids, comets, and meteoroids is no longer tenable. More and more links are established between objects of these formerly separated categories while others are suspected. As a consequence, meteoroids are gaining in importance; these mostly tiny objects may even provide clues to the very origin of the Solar System. The new Solar System is a lot more unified that the old one...

After all the controversy that was stirred during the most recent rage of "dino-mania" on a possible cosmic cause for the extinction of the dinosaurs, the impact of Comet P/Shoemaker-Levy 9 made the plausibility of such a scenario painfully clear to everybody. Never again will the Earth be as safe a place as it was before...

Now, what has all of this to do with the International Meteor Organization*? Although the* IMO*'s goals pertain to meteor study as opposed to popularization of meteor astronomy, it would be foolish of us to let the wave of public interest in this area of astronomy created by the recent dino-mania, the media-interest in the rediscovery of Comet P/Swift-Tuttle and the 1993 outburst of the Perseids, and last but not least Shoemaker-Levy's dramatic rendez-vous with Jupiter go unnoticed. This is all the more true, because the enhanced activity of this year's Leonids, on which we report extensively in this issue, makes it clear that this wave of interest can and will not die before the turn of the millennium. In our excitement over the Leonids, we should also not forget that the Perseids have not yet "returned to normal." An analysis of global data on the 1994 Perseid return is published in this issue. For all these reasons, it is vital that the* IMO *provides the media, national, regional, and local organizations, and educators with reliable information on the events to come and makes clear that the importance of the tiny particles we study goes beyond the beautiful shows they can stage. In this way, we ensure the emergence of a new generation of dedicated meteor observers who can continue and further the work we are all involved in.*

Meanwhile, enjoy this issue as well as any Christmas or New Year holidays you may have!

1995 Membership and Subscription Renewal

Ina Rendtel, Paul Roggemans, Marc Gyssens

Below, we summarize the information given in the previous issue. We thank all those who already renewed and urge all those who did not yet renew to do so at once!

1. How much do I have to pay?

WGN 1995 via surface mail	35 DEM	25 USD
WGN 1995 via airmail	50 DEM	35 USD
FIDAC News 1995	15 DEM	10 USD
Combined Subscription (*WGN*, *FIDAC*, Report 7)	70 DEM	50 USD
Combined Subscription with airmail for *WGN*	90 DEM	65 USD
Supporting Members add at least	15 DEM	10 USD

Together with your renewal, you may also pay for the following:

1. an order of any of the publications you may find on the outside back cover;
2. your registration for the 1995 *International Meteor Conference* (see elsewhere in this issue).

Notice that larger international payments result in relatively smaller transfer costs!

2. To whom do I have to pay?

- *To the Treasurer*:
Ina Rendtel, Gontardstraße 11, D-14471 Potsdam, Germany,
Postal giro account 5472 34-107,
Post office code 100 100 10, Postgiroamt D-10916 Berlin
(post office code and postgiroamt to be mentioned with account number)
- *Or to the appropriate person below*:
  - *For the United Kindom*: Alastair McBeath, 25 West Park, Morpeth, Northumberland, NE61 2JP, England.
  - *For Japan*: Masahiro Koseki, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
  - *Elsewhere outside Europe*: Peter Brown, Dept. of Physics, Univ. of Western Ontario, London, Ontario, N6A 3K7, Canada. (Notice that the USD subscription rate for *WGN* via surface mail is 25 USD instead of 30 USD as was mentioned in the previous issue. We apologize for the mistake.)

The 1995 International Meteor Conference

Brandenburg, Brandenburg, Germany, September 14–17, 1995

Ina Rendtel, Jürgen Rendtel, and Rainer Arlt

The 1995 *International Meteor Conference* will be held near the city of Brandenburg in the German state of the same name. The city of Brandenburg is one of the oldest in the region established in AD 928.

The meeting takes place in a kind of youth hostel at the shore of one of the many lakes in this area. We hope to continue this series of meetings in the minds of participants because of their entire atmosphere. For participants arriving earlier or leaving later to combine their journey with some sightseeing, for example, we offer assistance in getting this organized. Please contact one of the organizers. Although the conference site is only about 10 km from the city of Brandenburg, direct access by public transport is somewhat limited (small number of buses plus a walk). That is why we ask that you indicate on the registration form whether you need to be picked up at the railroad station or somewhere else.

We will send out intermediate information bulletins to all people indicating their interest, including all necessary travel information. On average the weather in September is characterized by calm, mild conditions. However, almost no place in Europe can guarantee dry, warm weather during this period of the year.

In order to indicate interest in participating or to register, please follow the information given on the form printed on the next page.

International Meteor Conference

Brandenburg, Germany, September 14–17, 1995

Registration Form

Each individual participant should fill out a form and return it to Ina Rendtel, Gontardstraße 11, D-14471 Potsdam, Germany, as soon as possible. The deadline is March 31, 1994. Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 100 DEM.

If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: ______________________________ Birth date: ______________

Address: ____

____

____

Phone: ______________ Fax: ______________ E-Mail: ______________

- o wishes to register for the 1995 *IMC* from September 14 to 17;
- o intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by ________, together with ______________________

Additional requests:

- o I need to be picked up at the Brandenburg railroad station;
- o I need travel information from ______________ to Brandenburg.

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 190 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. Remember that Ina cannot accept bank checks! People wishing to pay in other currencies (USD, GBP, or JPY) should contact the appropriate *IMO* contact person for exchange rates.

Participants paying only 100 DEM have to pay the remaining 90 DEM upon arrival in Brandenburg.

Date and signature: ____

1994 Supporting Members and Subscribers

compiled by Ina Rendtel and Marc Gyssens

The following people paid for Supporting Membership in 1994:

Per Aldrich, David Bender, Peter Brown, Vincent Devore, Ichiro Hasegawa, Werner Hasubick, Lars Trygve Heen, Masao Kinoshita, Masahiro Koseki, Gotfred M. Kristensen, Gary Kronk, Jean-Christophe Lernould, Marc de Lignie, Michael Luciuk, Norman McLeod, Dan Olson, Philip Roberts, Hans-Georg Schmidt, John Paul St. Peter, Kazuhiro Suzuki, Richard Taibi, Yuko Takeuchi, Yasuhiro Tonomura, Masayoshi Ueda, Mark Vints, Erich Weber, Yasuo Yabu, Takatsugu Yoshida, and George Zay.

We graciously thank all these people for their support which allows us to produce this publication at an acceptably low cost. Unfortunately, few Supporting Members or Subscribers made use of the possibility we offered them to have a photograph and an accompanying description published in *WGN*. Please do not be shy or overly modest and use this opportunity! In this way, names become faces!

Finally, we also like to thank those members or subscribers who did not pay for Supporting Membership or Subscription but nevertheless sent a gift to the *IMO* in 1994. Their names are as follows:

Ben Apeldoorn, Rainer Arlt, Neil Bone, Vance Brooks, Peter Craven, Peter Gural, Marc Gyssens, Chris Hall, Trond Erik Hillestad, Klaas Jobse, Toshio Kamimura, André Knöfel, Richard Livingstone, Umberto Mule Stagno, Alastair McBeath, Ina Rendtel, Jürgen Rendtel, Paul Roggemans, George Spalding, Enrico Stomeo, Casper ter Kuile, Noel White, Robert White, Zidian Wu, Jeff Wood, and Richard Zimmerman.

Letters to WGN

compiled by Marc Gyssens

We received two letters from our regular correspondent, George Zay, both dealing with strange phenomena in the sky. They are published below.

Mysterious sonic booms

On October 11, 1994, a mysterious rumbling sound occurred that lasted for several seconds in the San Diego County area of Southern California. Again on November 10, 1994, a similar event occurred. They were both reported throughout the county from places separated by about 75 km. All the seismographs detected nothing unusual and the local military denied they were doing anything that would cause such an effect. Although the military are usually suspected as being the originators of such booming noises, I tend to feel that they are overly accused. Ever since I witnessed my first and only sonic producing meteor [1], I wondered about the mysterious sonic booms that occur from time to time. With just recollection to go on, it seems like about once a year a sonic boom occurs that no one is able to explain. If I dare assume that the military are truthful, I would like to speculate that the strange sounds could be meteor-related. I live near the coast and sometimes the US Navy fires their big guns off ships hundreds of miles out to sea during training exercises. On occasions these sounds are heard along the coast and the Navy acknowledges that they were the cause. It is explained that the sound is somehow carried ashore, where it effectively turns a large coastal area into a big sonic receiver. I do not know what the estimated rate is for a given area to be visited by sound-producing meteors. Perhaps a reliable means of determining this may lie in noting the number of times per year that mysterious sonic booms occur within any given region. This given area may be identical to the combined regional coverage of all local newspapers, TV, and radio stations. I would be interested in knowing if others recall their local news media reporting strange sonic noises about once or twice a year. This might be an area in meteor science that may be worth investigating, or at least keep in the back of one's mind for future thought.

[1] G. Zay, "Fireball over San Diego County", *WGN* 21:1, February 1993, p. 47.

George J. Zay, November 12, 1994

"IUFLO" sighted over Southern California

On November 1, 1994, near 3^h06^m a.m. PST (11^h06^m UT) a "IUFLO" was sighted by George Zay and Robert Lunsford while meteor observing. Since I do not believe in UFOs of the extra-terrestrial kind, I chose to call them "IUFLOs," that is, "Initially Unidentified Funny-Looking Objects." What we saw was a diffuse light low on the horizon. At first, I thought it was an airplane and I had some crud in my eyes, but it was stationary and getting larger. It quickly grew to a size about twice that of a Full Moon and was about as bright as a crescent Moon's earthshine. Its shape was somewhat like that of a funnel on its side. The color was also like that of earthshine. The whole event appeared and quickly dissipated within about 2 minutes. Later on, we were able to conclude that the apparition occurred near Leo's sickle. We also soon concluded that it must have been somebody's barium-in-space experiment studying the effects of solar wind or something similar.

No doubt, what little of the public that saw this, would have quickly concluded that it was a genuine UFO. The devilish nature in me was sorely tempted to call the local news media to report a UFO sighting, and then sit back and watch the circus begin. I can safely say that with all the observing time behind me, I have yet to see something that I feel could not be logically explained. I am afraid I am not a member of the traditional UFO believers. Maybe I could be if E.T. phoned me personally from home or dropped in for a chat.

George J. Zay, November 12, 1994

Frequently Asked Questions on Observing Methods

compiled by Malcolm J. Currie

What is the best telescope or binocular for seeing telescopic meteors?

There is no single best-buy telescope or binocular. There is a wide selection of suitable instruments; the choice will depend on the quality of your observing site, your eyesight, observing goals, and how much you wish to pay or what is already available. However, there are two main factors that should influence your choice: *the instrument should have a low power and a wide apparent field of view.* They both affect the number of meteors seen in a given time. Let us consider these in more detail.

The magnification per unit aperture

You must have a low magnification for a given size of objective lens or mirror. To put that into numbers, the magnification should be in the range of 1.4–2.0 times the aperture in centimeters. So, for example, a 7×50 binocular has a magnification 1.4 times the aperture in centimeters, and a 10×50 has magnification twice the aperture. To explain how these numbers arise here is a brief optics lesson. If you hold a telescope or binocular to the light and away from your eye, you will see a small illuminated disk. This is called the exit pupil. Its diameter is given by the telescope aperture divided by the magnification. As this is just the inverse of our factor, a given factor produces a certain sized exit pupil regardless of the telescope's aperture. So returning to our specific limits, a factor of 1.4 times has a 7-mm exit pupil and a 2.0 times has a 5-mm beam. For normal mortals, a 7-mm beam is as much as the pupil of the dark-adapted eye can handle, for older observers even this may prove to be too wide. Also, if you are located at a site with some light pollution, a slightly higher magnification will let you see more meteors as the contrast is improved. Through the telescope, most meteors appear as lines rather than points, but nevertheless, like for stars, you can still see fainter with additional magnification. You can only take this so far. As the magnification is increased, the true field of view is decreased, and the area of atmosphere being viewed reduces as the inverse square of the magnification, and so the observed rate falls. That is not all. Due to the increased magnification the apparent speed of the meteors is accelerated, which reduces the apparent brightness of meteors, and so more meteors will pass through the field undetected. There comes a point where the improved visibility of faint meteors is offset by the loss of area being viewed. This is approximately twice the aperture in centimeters.

Binoculars with 6-mm exit pupils are unfortunately much rarer than the standard 7-mm ones, though it is getting better. For example, Celestron produce a 7×42, and an 8×50. If sky conditions are too bright, you can always stop down the objective lens to give better contrast.

The apparent field of view

The apparent field of view is governed by the eyepiece design. You can derive it from the product of the magnification and the true field of view. So, for example, a 10×50 binocular, with a $6°$ true field, has an apparent field of $60°$. A wide field of view will encompass more of the sky, and hence you will see more meteors. The recommended range is $45°$–$70°$, with $50°$–$60°$ being preferred. You may be wondering why we set an upper limit. One of the principal reasons for observing telescopic meteors is to investigate radiant properties by plotting meteor paths accurately. As the apparent field of view enlarges, the average plotting accuracy goes down. So ultra-wide fields ($> 65°$) are best for determining rates, and hence deriving the time of maximum for a shower; whereas for field sizes around $50°$ rates are still reasonable (because the eye perceives only a fraction of the meteors in the outer $10°$ annulus) and accurate positional data can be obtained. Given the choice between the two, you should err on the side of the smaller apparent field as it offers more flexibility and science. Also, ultra-wide eyepieces or binoculars are either very expensive if they give pinpoint images across the entire field, or give increasingly distorted images towards the periphery of the field. Below $50°$ the loss of sky coverage starts to become important. If rates become too low boredom and loss of concentration can soon set in.

Binocular versus telescope

Binocular vision is the natural way to look, and since comfort is a critical consideration for the telescopic observer, a binocular is preferred to a (monocular) telescope. There has been debate in the literature by how much it improves the limiting magnitude from nothing to about a magnitude. A telescope with a star diagonal is more flexible for viewing fields close to the zenith, and if you want a larger aperture, will be far less expensive. Angled binoculars only seem to come with large apertures and even larger price tags.

Aperture

Aperture is less critical, and *IMO* observers' apertures range from 40 mm to 300 mm, though most are in the range 50–80 mm. Certain showers like the Perseids are progressively weaker towards fainter magnitudes and this suggests a small aperture is best, say a 6×30. Increasing the aperture increases the average meteor magnitude and so exaggerates any mass-sorting within the stream, and will give improved plotting accuracy. The intermediate apertures (50–80 mm) look best.

Optical quality

The quality of the optics can make a big difference to the performance. Remember that you will be observing for long periods and considerations like accurate collimation and pinpoint images will reduce strain. This consideration can outweigh some of those mentioned already. For example, a quality 7×42 is going to let you see more meteors than a cheap 8×50.

In conclusion, an 8×50 or 10×60 binocular with a 55° apparent field would be excellent for telescopic meteors. Many other similar combinations will perform well too.

Visual Observers' Notes: January–February 1995

Jeff Wood

1. Introduction

Despite often low rates and the winter in the northern hemisphere, there are plenty of things to be seen by the diligent observer at this time of the year. See also the *IMO 1995 Meteor Shower Calendar*.

Table 1 below gives an overview of some of the showers to be seen in January and February 1995. Table 2 shows observing conditions during these months moon-wise.

Table 1 – Some of the meteor showers to be seen in January and February 1995.

Shower	Activity	Max	Radiant			Drift		V_∞	r	ZHR
			α	δ	Diam.	$\Delta\alpha$	$\Delta\delta$			
Coma Berenicids	Dec 12–Jan 23	Dec 19	175°	+25°	5°	+0°.8	−0°.2	65	3.0	5
Quadrantids	Jan 01–Jan 05	Jan 03	230°	+49°	5°	+0°.8	−0°.2	41	2.1	110
δ-Cancrids	Jan 05–Jan 24	Jan 17	130°	+20°	10°/5°	+0°.9	−0°.1	28	3.0	5
α-Crucids	Jan 06–Jan 28	Jan 19	192°	−63°	10°/5°	+1°.1	−0°.2	50	2.9	5
α-Carinids	Jan 24–Feb 09	Jan 31	95°	−54°	5°			25	2.5	
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	
α-Centaurids	Jan 28–Feb 21	Feb 07	210°	−59°	4°	+1°.2	−0°.3	56	2.0	25+
o-Centaurids	Jan 31–Feb 19	Feb 11	177°	−56°	6°	+1°.0	−0°.3	51	2.8	
δ-Leonids	Feb 05–Mar 19	Feb 15	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

Table 2 – Moonlight and observing conditions in January–February 1995.

Date	k	Date	k
Friday December 30	0.09−	Friday February 03	0.11+
Friday January 06	0.25+	Friday February 10	0.72+
Friday January 13	0.87+	Friday February 17	0.97−
Friday January 20	0.90−	Friday February 24	0.34−
Friday January 27	0.20−	Friday March 03	0.03+

New Moon:	January 1, January 30, March 1
First Quarter:	January 8, February 7, March 9
Full Moon:	January 16, February 15, March 17
Last Quarter:	December 25, January 24, February 22

2. Quadrantids

Named after the now defunct constellation Quadrans Muralis, the Quadrantids are the first major shower to occur each year. They are active from January 1 to 5 with a maximum ZHR of around 110 on January 3 predicted for 1995 to occur around 23^h UT. The Quadrantids are relatively fast meteors ($V_\infty = 41$ km/s) which radiate from $\alpha = 230°$ and $\delta = +49°$. The radiant diameter is 5°. They are best observed from the northern hemisphere in the last few hours before sunrise. With a New Moon on January 1, they will provide very good viewing in 1995!

3. δ-Cancrids

Very little is known about this stream which can be seen from either hemisphere during mid-January. The δ-Cancrids therefore need urgent attention from meteor observers. The δ-Cancrids are best seen during the early to middle part of the night. Meteor workers should particularly monitor the first half of the activity period, as there will be little interference from the Moon at that time. As rates are low, observers should ensure they center their field of view no further away than 30° from the radiant and also plot all possible δ-Cancrids seen, as this ecliptical shower has a complex radiant structure.

Table 3 – Radiant drift of the δ-Cancrids. The x, y coordinates (in mm) refer to chart 8 of the *Atlas Brno 2000.0.*

Date	α	δ	x	y	Date	α	δ	x	y
Jan 05	116	+22	288	236	Jan 20	130	+19	237	216
Jan 10	121	+21	269	228	Jan 25	134	+18	223	210
Jan 15	125	+20	252	222					

4. α-Crucids

The α-Crucids are active from January 6 through to 28. With a radiant occurring near the Southern Cross this southern hemisphere stream has a complex activity period with several submaxima occurring on or around January 12, 15, 19, and 24. The January 19 peak seems to be the greatest at which time the ZHR can reach upward of 5. The α-Crucid meteors are fastish and often colored. Since they have relatively low rates, all possible α-Crucids should be plotted. Observers should center their fields around $\alpha = 160°$ and $\delta = -55°$ so that both the tail of the Puppid/Velids and the α-Crucids may be monitored simultaneously. As there is a Full Moon on January 16, meteor workers should concentrate on the period January 5–14 in 1995.

5. α-Carinids

The α-Carinids are a virtually unknown southern hemisphere stream. They are active from January 24 to February 9 reaching a sharp maximum on January 31 of between 5 and 10 meteors per hour. Observations to date seem to indicate that this stream is quite variable and more research is urgently needed. The year 1995 promises to be a good time to view the α-Carinids which are best seen in the evening.

6. Virginids

As there are a large number of low activity radiants close together, it is very difficult to delineate what branches of the Virginids are active at which time and also to classify each individual meteor seen into its appropriate stream. Consequently, observations over the years have shown a whole myriad of Virginid showers, some real, some fictitious. Also reported rates have varied from nil to over 10 meteors per hour! With this in mind, the *IMO* has, for the time being, incorporated all of the Virginids seen into the one "shower." The "Virginids" are active from February 1 to May 30. They have a V_∞ of 30 km/s and are renowned as fireball producers, though their population index r of 3.0 indicates there are many fainter members as well.

Table 4 – Radiant drift of the Virginids. The x, y coordinates (in mm) refer to charts 8 and 5 respectively of the the *Atlas Brno 2000.0.*

Date	α	δ	x_8	y_8	x_5	y_5	Date	α	δ	x_8	y_8	x_5	y_5
Feb 03	159	+15	149	199			Apr 04	200	−06			169	144
Feb 13	167	+09	125	181			Apr 14	204	−08			157	138
Feb 23	174	+05	103	169	256	179	Apr 24	208	−09			146	135
Mar 05	182	+01	74	157	226	164	May 04	211	−11			137	129
Mar 15	189	−02	45	146	202	155	May 14	214	−12			128	126
Mar 25	195	−04	15	138	183	150	May 24	217	−13			120	123

The *IMO* would appreciate your efforts to monitor this shower in 1995. Intending observers should locate their center of field of view no more than 40° away from the radiant and should plot all meteors seen. Since the Virginids have a velocity typical of the sporadic background and also come from a large radiant area, careful attention to path length and angular velocity should be given before classifying a meteor as Virginid.

7. θ-Centaurids

This shower has a complex radiant structure and is active from January 23 to March 12. With the complex radiant structure also comes a complex activity period with several submaxima. The main ones seem to occur on or around February 1, 21 and 26 with a peak ZHR of between 5 and 10 meteors per hour. θ-Centaurid meteors are fast and often leave a train. They are also noted for producing fireballs of a lemon yellow or greenish hue. They are best seen in the morning hours from the southern hemisphere. Observers should center their field of view around $\alpha = 200°$ and $\delta = -50°$ to aid in separating the θ-Centaurids from the other two Centaurid showers that occur at a similar time in mid February. In late February and mid March, the observer's field should be centered around $\alpha = 200°$ and $\delta = -20°$ so that the θ-Centaurids and the Virginids can both be monitored. All possible θ-Centaurids should be plotted.

8. α-Centaurids

The α-Centaurids produce a good display of meteors each year for southern hemisphere observers. They are active from January 28 through to February 21 with a sharp maximum on February 7. For most of their period of activity ZHRs range between 1 and 3 meteors per hour, but at maximum, rates generally rise to between 5 and 10 meteors per hour. Every 5 to 6 years, the maximum activity seems to be greatly enhanced and on two notable occasions in 1974 and 1980, rates exceeded 25 per hour. Always this enhancement has been short-lived lasting no more than 2–3 hours. The α-Centaurids are fast meteors which are noted for their brightly colored fireballs. Many α-Centaurids also leave a train. In 1995, there is virtually no interference from the Moon, except toward the end of the activity period.

This year, southern hemisphere observers are encouraged to make this shower priority viewing. If ZHRs are less than 10, then all possible α-Centaurids should be plotted. If ZHRs exceed 10, then they may be recorded in the manner of the major showers. To avoid confusion with the other Centaurid showers, observers should watch for the α-Centaurids with a field center at $\alpha = 200°$ and $\delta = -50°$.

9. o-Centaurids

The o-Centaurids are a minor shower that occurs during a similar time to the other two February Centaurid showers. The o-Centaurids are active from January 31 through to February 19 with a maximum ZHR of about 5 meteors per hour occurring on February 11. The o-Centaurids are visible only from the southern hemisphere and can be seen in dark skies during the late evening hours post-maximum when the Moon has waned sufficiently for the shower to be observed. The o-Centaurids are fast meteors. Observers should plot all possible o-Centaurids seen. To aid in identification, their center of field of view should be located at $\alpha = 200°$ and $\delta = -50°$.

10. δ-Leonids

The δ-Leonids are thought to possibly be related to the minor planet 1987 SY and so a top priority of the *IMO* is to investigate the activity of this shower to see if this is indeed the case. Despite some interference from the Moon during early February, much of their activity period can be observed in dark skies. δ-Leonid meteors are of average brightness, slow in speed ($V_\infty = 23$ km/s) with very few leaving a train. Since there are numerous sporadic meteors as well as the Virginid meteor shower occurring in the vicinity of the δ-Leonid radiant area, great care needs to be taken in identifying them. Observers should center their field of view around $\alpha = 180°$ and $\delta = +20°$ or $\alpha = 160°$ and $\delta = 0°$. As the δ-Leonids are few in number, all should be plotted. Meteors coming from the radiant area should only be classified as δ-Leonids if their path lengths and their angular velocities are appropriate.

Table 5 – Radiant drift of the δ-Leonids. The x, y coordinates refer to chart 8 of the the *Atlas Brno 2000.0.*

Date	α	δ	x	y	Date	α	δ	x	y
Feb 05	141	+25	202	234	Feb 28	161	+18	144	210
Feb 10	145	+24	189	228	Mar 05	165	+17	131	205
Feb 15	150	+22	176	223	Mar 10	169	+15	119	201
Feb 20	154	+21	164	218	Mar 15	173	+13	105	196
Feb 25	158	+19	151	213	Mar 20	177	+12	92	192

Photographic Observers' Notes: January–February 1995

Jürgen Rendtel

The only major shower active in this period is the Quadrantids. The activity is restricted to a few days, and in fact we normally get a substantial number of bright photographic meteors only on the maximum night. However, it is important to obtain photographs of Quadrantid meteors occurring during other nights near maximum. The most suitable fields are west of the radiant before local midnight, and east or northeast of the radiant after local midnight. For standard lenses, the field centers could be at $\alpha = 170°$, $\delta = +40°$ and $\alpha = 260°$, $\delta = +50°$, respectively.

The radiant of the Ecliptical Meteor Complex has moved into Cancer by mid January. Relatively little is known about the radiant structure and the activity level during this period of the year. There is only the δ-Candrids listed as a shower in the list for visual work, until the Virginid Complex takes over as the source of ecliptical meteors (from February 1 onwards). Earlier radiant analyses hint at a complex structure of the Virginids with a wide radiation area. This cannot be split into sub-showers for activity determination by visual methods, but we could try to obtain some data about the possible structure of this complex by photographic records.

Single-station photographs may be used for radiant searches as described with the Sagittarid Complex [1]. The most suitable field centers for standard lenses are at $\alpha \leq 100°$, $\delta \approx +15°$ and $\alpha \geq 180°$, $\delta \approx +15°$. The use of a rotating shutter with known interruption frequency is recommended.

Remember that the time of the meteor's appearance is very important, and we also need to know the start and end of the exposure with an accuracy of at least ± 5 seconds. Other, more general notes about the photographs can be found in [1].

References

[1] J. Rendtel, "Photographic Observers' Notes: May–June 1994", *WGN* 22:2, April 1994, p. 34.

Telescopic Observers' Notes, January–February 1995

Malcolm J. Currie

Although there were many clear nights during late September and early August in England, Chris Hall's and my observing plans were limited by cirrus and fog to just two nights each of δ-Aurigid coverage, though we amassed some 160 meteors in 10.2 hours. Chris Hall had better fortune a month earlier, submitting fifty recordings on three nights during only 4.25 hours in less than ideal conditions. This emphasizes the good rates to be had during neglected September. Unfortunately, only one of these nights encompassed the dates of the α-Triangulids I observed. Of the fifteen meteors seen on September 8-9 between 21^h25^m and 23^h47^m UT, two appeared from the direction of the radiant, however their above-average speed suggests that this identification is questionable. The other nights' observations include what appears to be δ-Aurigid meteors as early as September 2-3 radiating from midway between Algol and α Persei (4 meteors from 58), and $\alpha = 67°$, $\delta = +52°$ (3 or 5 meteors). The low numbers makes this preliminary graphical analysis uncertain. We need more telescopic observers. Also on September 2-3, the strongest source (7 or 9 meteors) appears to be a diffuse area around $\alpha = 135°$, $\delta = +78°$ seen from six different fields. Southern Piscid activity of about 2 meteors per hour was seen on September 2-3 and 6-7. A more detailed analysis will begin once all the data are on-line in PosDat format.

Readers of Spanish might like to know that Javier Méndez Álvarez has produced a 140-page manual for telescopic observers including charts entitled *Manual de Observaciones Telescópicas de Meteoros* available at cost price.

Forthcoming events

The highlight of this period is undoubtedly the *Quadrantids*. This fleeting shower is famed for its exhilarating electric-blue meteors. The strength of the return is unpredictable—the peak visual ZHR could be anything between 70 to 200—though some suspect a periodicity equal to the 4.5-year orbital period, or longer, perhaps connected to the influence of Jupiter. Activity only lasts for a few days and visually the shower's half-life is approximately 8 hours. The stream's orbit is evolving rapidly, and there is evidence of mass-sorting. The telescopic maximum occurs earlier than the visual peak by some 1.2 hours for each magnitude difference in mean meteor brightness. So the best telescopic show will be around January 3, 15^h–19^h UT, and the best situation would be the north-west rim of the Pacific. European and North-American observers should still see good telescopic Quadrantid rates that night because the smaller particles are more dispersed and, apart from around the maximum, the shower is rich in faint meteors.

Given sufficient observations, we can estimate the time of the telescopic maximum and compare it with the visual peak. Besides obtaining more data on the shower evolution, telescopic observers can also study the radiant properties. The radiant area is diffuse away from the maximum, though telescopic results suggest that it comprises many streamlets of which we see only a fraction in any one year. At maximum the radiant is more concentrated though this could be one high-density streamlet that is rich in bright meteors dominating the others. More observations are needed throughout the shower's duration during many returns to determine if this is true and if there is any pattern present.

The position of the Quadrantid radiant in north-eastern Bootes means that it is is low before midnight and greatly reduces the observed rates. For best results, watch after midnight and especially between 2^h local time and dawn. This limited observability coupled with the sharp peak, and the fickle weather for the northern latitudes that are favored for this shower, emphasizes the importance of coverage from most time zones throughout the period January 1–7. There will be no interference from moonlight.

As the radiant has a wide range of elevations during the night and there is a strong latitude dependence it is hard to specify a simple list of suggested charts. For each hour or so during the night select two fields with elevations of at least 40°, and that are 10°–25° from the radiant. The configuration should be that meteors seen in the field when traced back to the radiant will intersect at near right angles. Some useful chart pairs include 25 and 29/44, 64/65 and 28.

The remainder of the period is for the connoisseur of minor showers. Many are in the same region of the sky and so can be observed simultaneously. The *δ-Cancrids* are moderate-speed meteors present throughout most of January though in 1995 moonlight ruins the maximum. This shower like many near the ecliptic has a long duration, a large and elongated radiant area with possible sub-radiants, and an abundance of faint meteors. Observations in the week after the Quadrantids and in late January are especially needed. Our goal is to map the radiant structure from accurate plots of meteor trails and compare that with the visual data. Smaller apertures are preferred as the shower seems to have few very dim meteors.

The *α-Leonids* is virtually a telescopic shower. It occurs during January and February, though we have yet to determine its activity dates. It may even begin in December though our earliest observations are for January 10. In 1995 we might be able to pin down the start date, if not the end. Radio data from the 1960's suggest a maximum in late January and a cessation in mid-February. In recent years it has given decent rates comparable with the peak of the Perseids at these magnitudes. The proximity of the δ-Cancrid radiant should not hinder the interpretation of the data provided there is a prudent selection of fields. Charts 79, 80, 82, 104, and 144 form an arc north of the radiants from the Sickle to Canis Minor, and will serve for both showers. Try to use at least three of these in a given night. Those lucky enough to be in the warmth of the southern summer nights can use charts 104 and 144–146.

The *α-Hydrids* are present in the latter half of January. The radiant is approximately $\alpha = 135°$, $\delta = -05°$ on January 20 and seems to have a moderate telescopic flux. Also at this time there are a couple of suspected radiants that I would like confirmed or otherwise. To reduce any chance of bias I will not say where they are. They can be studied concurrently as α-Leonids using the same charts.

From mid-December through January there are several weak radiants of swift, faint meteors in Lynx, Leo Minor, and Coma which may form a single shower. The best known are the *Coma Berenicids*. The cloudy or cold weather prevalent at this time in the north, and their pedestrian rates means that we know little of these showers. During the Quadrantid period these minor showers can be monitored during the first half of the night, though after that post-midnight effort is desirable. Please try to expand our knowledge with some long-duration observations. Suggested charts include 61, 80, 83, 104, 105, and 126. Notice this includes two of those given earlier. It is probably better to concentrate on either these showers or the ecliptic ones mentioned above rather than attempting to cover them both. Observations using either set of charts will still show meteors from all these showers.

Radio observers have noticed a burst of increased faint-meteor activity around January 22-23. The source of this additional flux has yet to be identified. If it is a shower, it could well be most prominent at telescopic brightnesses as limited visual observations have yet to reveal the nature of this enhancement. Therefore I urge observers not to miss any clear nights around these dates. There is a waning gibbous Moon that will reduce rates, but not fatally. The radio observations suggest that the radiant has a right ascension that encompasses the Leo Minor and Coma region mentioned above. If you notice a preferential direction for meteors, you may need to select other charts located nearer to the source in order to pinpoint it.

Turning to the first half of February, the slow-moving *α-Aurigids*—best known for their brilliant fireballs—can also produce telescopic rates of 2 or 3 per hour. The maximum is around February 7 from $\alpha = 74°$, $\delta = +42°$. Unfortunately, by the peak there will a First-Quarter Moon with which to contend. Evening watches are favored. There are many suitable charts pairs such as 78 and 96, or 37 and 42 which are further from the Moon.

The *δ-Leonids* are also slow moving, and active during February to mid-March peaking around February 22 from an average radiant $\alpha = 159°$, $\delta = +19°$. Some may even be seen in late January too. The visual rate is low, but this shower probably contributes at telescopic magnitudes. There may even be a telescopic southern component, and its alleged maximum on February 3 will occur in dark skies. Use the Leo Minor-Coma set of charts except 104 and 126.

Finally, in late February there will be the occasional early *Virginid*. The radiant areas include Leo at this time. Suggested additional charts are 82, 123, and 125.

Observing under winter conditions is especially demanding so take frequent breaks so that you can concentrate on meteors and not frostbite.

Theoretical Radiants of Minor Planets and Comets

Dirk Artoos

Below is a list of theoretical radiants of minor planets and comets, some of which may cause meteor activity during January and February.

Table 1 – Theoretical radiants of asteroids and comets in January–February 1995.

Name	$\lambda_\odot$	Date	α	δ	V_∞	Distance
P/1979 X	295°.08	Jan 15	226°	−32°	64 km/s	0.14082 AU
Hathor (2340)	295°.12	Jan 15	140°	+04°	17 km/s	0.10129 AU
1991 BA	295°.92	Jan 16	108°	+19°	21 km/s	0.00145 AU
P/1759 III	296°.63	Jan 16	211°	−15°	72 km/s	0.04876 AU
1994 PC1	297°.53	Jan 17	113°	−49°	22 km/s	0.01555 AU
P/1299	298°.77	Jan 19	158°	−17°	58 km/s	0.09900 AU
P/1770 II	300°.78	Jan 20	233°	−33°	65 km/s	0.10515 AU
P/1840 I	301°.02	Jan 21	129°	−28°	40 km/s	0.03849 AU
1993 TZ	302°.19	Jan 22	326°	−01°	16 km/s	0.07199 AU
P/1672	302°.54	Jan 22	259°	+21°	50 km/s	0.03452 AU
1991 AQ=1994 RD	303°.7	Jan 23	132°	+22°	27 km/s	0.03552 AU
1993 VD	306°.64	Jan 26	152°	+15°	19 km/s	0.03198 AU
1989 QF	309°.02	Jan 29	137°	+26°	17 km/s	0.04066 AU
P/1833	310°.7	Jan 30	138°	+23°	33 km/s	0.03332 AU
P/1947 X	313°.5	Feb 02	216°	+30°	61 km/s	0.13124 AU
P/1939 III	314°.26	Feb 03	254°	−04°	64 km/s	0.03822 AU
P/1857 I	315°	Feb 04	263°	+23°	52 km/s	0.01231 AU
P/1472	317°.7	Feb 06	201°	−04°	67 km/s	0.06832 AU
Adonis (2101)	320°	Feb 09	314°	−16°	27 km/s	0.01209 AU
P/686	320°.4	Feb 09	186°	+35°	46 km/s	0.02735 AU
P/1947 III	321°.7	Feb 11	237°	+11°	67 km/s	0.04749 AU
1994 CB	322°.8	Feb 11	215°	+50°	15 km/s	0.15871 AU
P/1941 II	323°.35	Feb 11	321°	+38°	25 km/s	0.08722 AU
P/1743 I	323°.7	Feb 12	354°	−08°	22 km/s	0.03815 AU
P/1861 III	324°.5	Feb 13	238°	−45°	70 km/s	0.10028 AU
P/1931 IV	325°.4	Feb 14	281°	−21°	59 km/s	0.12833 AU
P/1858 IV	326°.6	Feb 15	275°	+12°	56 km/s	0.04309 AU
P/1797	326°.8	Feb 15	211°	+10°	61 km/s	0.13908 AU
P/1699 I	327°.01	Feb 15	266°	+11°	58 km/s	0.09687 AU
P/1854 IV	327°.4	Feb 16	307°	+37°	33 km/s	0.02241 AU
P/1766 II	327°.8	Feb 16	161°	+16°	30 km/s	0.13004 AU
P/1771	328°.58	Feb 17	349°	+22°	21 km/s	0.17934 AU
1994 GV	328°.64	Feb 17	100°	+25°	14 km/s	0.00637 AU
P/1902 II	330°.07	Feb 18	133°	+01°	21 km/s	0.13781 AU
P/1964 VI	338°.5	Feb 27	276°	−15°	66 km/s	0.16069 AU
P/1976 IV	340°.6	Feb 28	12°	−63°	35 km/s	0.00643 AU

The Leonids

Significantly Enhanced Leonid Activity in 1994

Bulletin 5 of the International Leonid Watch

Peter Brown

Combined results of Leonid data gathered in the interval 1988–1993 are used to derive a complete ZHR profile of the stream. This result supersedes the ZHR curve presented in Bulletin 2. The 3rd *ILW* period was characterized by no significant rate increases. The Leonid return in 1994, on the other hand, was characterized by rates which do signify an increase in activity over the quiet intervals so far studied during all previous *ILW* periods. There are indications in radio forward-scatter observations that some increased Leonid activity may have begun as early as $\lambda_\odot = 235\overset{\circ}{.}4$ (eq. 2000.0), whilst visual observations suggest strongly that some level of enhanced activity was present in the interval $\lambda_\odot = 235\overset{\circ}{.}66$–$236\overset{\circ}{.}0$. Earlier visual observations near $\lambda_\odot = 235\overset{\circ}{.}0$ show no clear evidence of unusually strong rates. It is concluded that the first "wave" of new material from Comet P/Tempel-Tuttle was encountered by the Earth in 1994, though an accurate characterization of the rate increase in terms of activity and total duration of the outburst are not yet possible due to a paucity of data.

1. Introduction

As reported in Bulletin 4 of the ILW [1], despite poor lunar conditions, the 4th *ILW* period (November 5–25, 1994) showed strong promise of generating enhanced activity. Although the Full Moon interfered greatly, it does now appear that the Leonids did show some unusually strong activity as evidenced by a small number of visual observations. This conclusion is supported by radio data gathered during November 18. To put this outburst in context, we present a "final" quiet-time profile for the Leonids based on analysis of Leonid observations from 1988 to 1993. We note that as the Leonids showed enhanced activity in 1994; as such this ZHR profile will represent the working quiet-time profile for the Leonids for the rest of the *ILW*.

2. Observational data

From the observations gathered over the past 6 years and communicated to the *IMO*, the prevalent data are still rates. Some magnitude data exist and a number of observers have plotted quite extensively during the *ILW* periods in recent years. However, the magnitude data, in particular, are still very scarce and particularly important for a complete activity analysis of the stream.

We note that, as in Bulletin 2, no evidence exists to suggest that the Leonid activity up to 1993 showed substantial variations from year to year and as a result we are justified in combining data from different years. The resulting activity profile cannot be reasonably compared in accuracy to the major global analyses, primarily because no population index profile can be computed from the stream as a function of solar longitude. For the present analysis, it was possible to combine what little magnitude data are available and assume this value throughout. The resulting value of the population index r was found to be 2.03. To produce the ZHR profile in Figure 1, a total of 182 observers contributed 2697 Leonids in the period 1988–1993 during 1102.51 effective hours of observation. While this seems superficially to be only slightly more data than used for the first attempted ZHR-profile of the stream given in [2], we note that more strict selection criteria were applied in this case and as a result, the scatter in these data are less. No corrections for perception were used.

The main features of the curve are its relatively broad maximum and symmetry. The maximum for the stream seems to be centered at about $\lambda_\odot = 235\overset{\circ}{.}5$ (eq. 2000.0) with a width of approximately $0\overset{\circ}{.}5$. It seems quite unreasonable at present to try and define a specific hour for the stream maximum. The peak value of the ZHR (10) is lower than in the previous analysis, primarily because the r-value used there was 2.5. We note that the time of maximum given here corresponds to that found in the analysis in [2] to within the smallest interval size chosen ($0\overset{\circ}{.}3$) for this analysis.

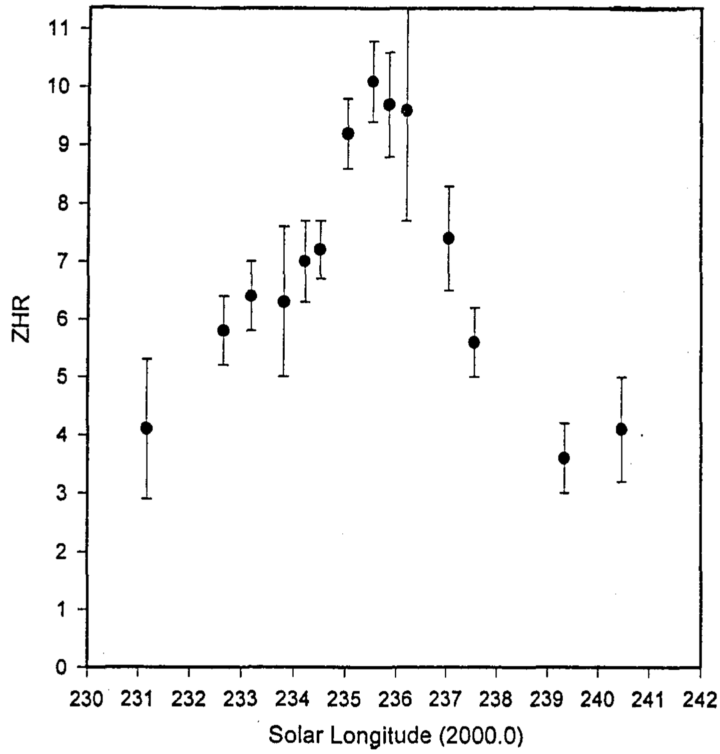

Figure 1 – Combined activity profile of the Leonids, 1988–1993.

3. Other Leonid research

As with past Bulletins, we list in the references some recent papers dealing with the Leonid stream and also some earlier Leonid work. Of particular interest is [3] which discusses the potential impact strong Leonid activity might have on Earth-orbiting satellites. The analysis presented in [4] gives a good overview of some of the best available visual observations during the last quiet time of the Leonids (pre-1961). In [5] some data concerning 7 stream members captured by video techniques primarily during the 1991 return are given along with orbital elements and radiant positions. An independent analysis of the activity of the Leonids from visual observations is given in [6]. Additional earlier data concerning Leonids is given in [7].

4. Visual observations in 1994

In total, only 4 observers have reported observations from November 18 UT. As a result there is little of significance that can be derived concerning the duration of the outburst. Table I summarizes the available observations. The visual data of Peter Jenniskens (Dutch Meteor Society) is summarized in detail in another article in this issue and is reproduced here with the kind permission of the author [8].

Table 1 – Visual observations during or near the Leonid maximum in 1994. For the meaning of ZHR_{min}, please refer to the text.

Date	Period (UT)	$\lambda_\odot$	Obs	T_{eff}	Lm	F	Leo	Spor	ZHR_{min}
Nov 17	09^h30^m–10^h30^m	234.°90	SHUBR	1.00	5.6	1.00	7	5	8
Nov 18	03^h20^m–04^h35^m	235.°66	TRIJO	0.95	3.7	1.24	19	0	30
Nov 18	04^h35^m–05^h10^m	235.°69	TRIJO	0.56	4.0	1.07	4	1	9
Nov 18	05^h33^m–06^h33^m	235.°74	VERDA	0.95	5.9	2.50	15	2	42
Nov 18	10^h16^m–11^h16^m	235.°93	SWADA	1.00	4.5	1.00	13	0	15
Nov 18	11^h16^m–12^h16^m	235.°97	SWADA	1.00	4.5	1.00	15	4	16
Nov 18	12^h40^m–14^h00^m	236.°04	JENPE	1.10	5.2	1.00	24	3	24
Nov 19	03^h53^m–05^h53^m	236.°75	REYFR	1.40	5.1	1.10	9	3	8
Nov 19	09^h45^m–12^h25^m	236.°96	JENPE	3.09	5.7	1.00	11	9	5

In addition to the observations given in Table 1, Bob Lunsford of Chula Vista, California, USA, observed the shower on November 17 and noticed no unusual activity up to about 13^h UT [9]. This is in accordance with the observations of Brian Shulist of Wilno, Ontario, Canada, whose fully-corrected ZHR value is only 15 at about the same time. David Swann noted that the activity he observed in the morning of November 18 was the strongest he has seen from the shower since 1968, during which time he has observed the return of the stream 17 or 18 times [10]. Given the very poor limiting magnitudes in Table 1, it is meaningless (and quite misleading) to calculate ZHRs. Without involving corrections for the lunar conditions, we can place a lower bound on the ZHR by correcting the observed rates for effective observing time, cloud coverage, and the radiant altitude alone. This is done in the last column in Table 1. The true ZHR is at least several times this value. It is apparent that from $\lambda_\odot = 235\overset{\circ}{.}66$ to $\lambda_\odot = 236\overset{\circ}{.}04$ (at least) there may have been enhanced activity. This corresponds quite well to the position of the plateau of higher activity given in the long-term ZHR profile in Figure 1.

Since the node of Comet P/Tempel-Tuttle is well before these observations, it would be interesting to see what activity was like in earlier intervals. We hope to present such observations in the next *ILW* Bulletin and compare this complete set of data with visual observations made during the early 1960s.

5. Radio Observations in 1994

Several radio observers monitored the Leonids in 1994. Among them was Shelby Ennis of Elizabethtown, Kentucky, USA. Ennis monitored the stream at 144.2 MHz, whence the reflections recorded represent only the largest particles in the stream. He listened from 22^h00^m to 01^h00^m UT on November 17-18 and detected no enhanced activity. On November 18, the apparent activity was higher: "On the morning of the 18th, we began monitoring 144.2 at about 12^h30^m UT. We immediately began hearing bursts. There was a definite peak about 13^h15^m with a number of long bursts and no pings... By 13^h30^m, there were almost no bursts. At about 14^h30^m, there were quite a few pings and very short bursts, but almost no longer bursts." Ennis reported that another Radio Ham amateur in New Jersey noted that highest activity was reached between 12^h30^m and 13^h30^m UT on November 18, while a radio operator in Florida also working on 144.2 MHz detected a peak from 13^h30^m to 14^h30^m. The latter observer noted many long echoes in this interval. Ennis comments that the Leonids this year were similar to a normal peak for the Geminids or Perseids he has heard in many past years [11].

A dedicated meteor forward scatter system operated by Ilkka Yrjola in Finland also detected increased activity [12]. The raw data from his system at 87.36 MHz may indicate a relatively broad peak with activity earlier than the previous reports suggest. Beginning at about 0^h UT on November 18 and continuing until about 12^h UT, activity substantially higher than on November 17 and 19 at the same time was noted. A peak reflection rate was reached at 7^h UT on November 18; the value was between 4 and 5 times higher than on November 17 or 19. It was also noted that the average duration of the longest reflections during this time interval was some 31 seconds in comparison to 10 and 16 s respectively for November 17 and 19.

The possibility that substantial activity occurred earlier than visual observations presently suggest is further supported by radio forward-scatter observations from Japan. Kazuhiro Suzuki [13] notes that the forward-scatter system at the Damine Meteor Observatory operating at 46.5 MHz recorded slightly enhanced activity between 20^h and 24^h UT on November 17. In particular, the number of long duration echoes was some 3-5 times the norm for this time of the year.

Since these radio data must be corrected for the scattering geometry which affects the smaller (and hence more numerous) echoes, these trends should be considered strictly qualitative and merely suggestive. As well, the radiant for the shower is only above the horizon from about midnight until early afternoon local time at temperate northern latitudes. As a result, these radio data may point to a broad level of activity not registered completely from any one station.

6. Conclusions

From visual observations, it appears that some level of enhanced Leonid activity was present at least during the interval $\lambda_\odot = 235.^\circ66$–$236.^\circ0$ while radio observations suggest that activity may have started as early as $\lambda_\odot = 235.^\circ4$, but this is uncertain. There is no indication in the present observational records of significant activity beyond $\lambda_\odot = 236.^\circ0$. It is emphasized again that these collection of data are still too small for any solid conclusions about the outburst to be made.

Acknowledgments

I would like to thank the observers who contributed their results for this early analysis of the 1994 Leonids. The expert help of Rainer Arlt is also gratefully acknowledged in generating the activity curve for the Leonids from *VMDB* data for the period 1988–1993.

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Observations of the 1994 Leonids from Spain

Josep M. Trigo

An observation made by the author from Castellon, Spain, at $\lambda = 0°$ W and $\varphi = +40°$ N during the night of November 17-18, 1994, showed possibly enhanced activity from the Leonid Meteor Shower between 3^h20^m UT and 5^h10^m UT.

My observations are summarized in Table 1. The center of the field of view was near Procyon (α CMi). The possible activity ZHR-wise is between 100 and 200 meteors per hour, but great caution with these figures is needed because of the very poor sky conditions! Figure 2 shows the magnitude distribution that was obtained. During the observation, the author also photographed with a 20 mm camera and a TMAX 3200 film. A possible Leonid fireball was captured.

Table 1 – Rate data of the author's observations during the night of November 17-18, 1994.

Period (UT)	T_{eff}	Lm	F	Leo	Tau	Spor	Comments
17^h39^m–17^h59^m	0.29	4.0	1.00		0	0	Radiant below
20^h10^m–20^h21^m	0.16	4.0	1.11		0	0	horizon
03^h20^m–03^h30^m	0.16	3.9	1.11	4	0	0	Fireball, −4
03^h30^m–03^h40^m	0.15	4.0	1.17	4	0	0	Fireballs, −3, −4
03^h55^m–04^h05^m	0.16	3.5	1.25	2	0	0	Fireball, −4
04^h05^m–04^h15^m	0.16	3.0	1.33	3	0	0	
04^h15^m–04^h25^m	0.16	3.5	1.33	3	0	0	Fireball, −5
04^h25^m–04^h35^m	0.16	4.0	1.25	3	0	0	
04^h35^m–04^h45^m	0.16	4.0	1.11	2	0	0	
04^h45^m–04^h55^m	0.16	4.0	1.05	2	0	0	
04^h55^m–05^h10^m	0.24	4.0	1.05	0	1	1	

Table 2 – Magnitude distribution of the Leonids observed by the author during the night of November 17-18, 1994.

Magnitude	−5	−4	−3	−2	−1	0	+1	+2	+3
Leonids	1	2	1	4	1	1	2	7	3

High Leonid Activity on November 17-18 and 18-19, 1994

Peter Jenniskens, NASA/Ames Research Center

This year, Leonid rates that were significantly above annual rates were observed in Spain by Josep M. Trigo and in California by the author on the night of November 17-18. Rates were still above normal on November 18-19. Radio meteor-scatter observations by Eisse Pieter Bus from Groningen, the Netherlands, confirm the presence of many bright Leonids on November 17-18. This report is a presentation of the raw data and gives an early (preliminary) analysis that perhaps needs adjustment when more data become available.

Introduction

I was fortunate to be among observers catching a glimpse of a Leonid outburst last November 17-18, 1994. This is probably the first in a series of outbursts that was due to start [1,7]. Last year, peak rates were still close to normal with Leonid rates comparable to sporadic rates and ZHR of order 10–20 [2–5]. This year, early in the morning of November 17-18, Leonid rates were as high as ZHR = 70. In an attempt to share the beauty of the spectacle with other observers, I sent out an outburst alert. In the days after, a report was prepared with the help of members of the *Dutch Meteor Society* and the *International Meteor Organization*, containing the first available raw data and a preliminary analysis. This text was released in two parts a mere two and three days after the event respectively, and these results should be considered as preliminary. Below is a reproduction of the messages. A more extensive analysis will be published elsewhere.

1. High activity of Leonids on November 17-18 and 18-19—Part I

The Bay Area in California had fortunate weather conditions during this year's Leonid return. Clear skies prevailed in the period November 15-16 to 19-20, except for the period between 8^h and 14^h UT on November 17, when we attempted to photograph the Leonids from three sites (observers included Tom and Ingeborg Rice, Rick Morales, Duncan McNeill, Frank Dibbel, Kari Salomaa, Kathy Black, and Mike Wilson). Unfortunately, that night was spoiled by a continuous cloud cover and occasional rain showers. Further south, Bob Lunsford (San Diego, California) saw 5, 1, 6, and 14 Leonids in periods of 1.25, 1.0, 1.0, and 1.0 hours at a limiting magnitude of 5.2–5.4. The next night, November 17-18, was clear except for some scattered clouds in the beginning of the night. A large workload allowed me to start observing only at 12^h34^m UT. I immediately saw two bright Leonids in the first two minutes. A regular watch started at 12^h40^m UT and I continued until twilight set in at 14^h00^m UT. The sky conditions were poor because of a Full Moon and also because I was observing from within the city of Mountain View. I estimated the limiting magnitude at 5.1, rising to 5.3 at the end of the observing period. My raw counts are shown in Table 1. The corresponding magnitude distribution is shown in Table 2.

Table 1 – Rate data of the author's observations of the 1994 Leonids on November 18, 1994.

Time (UT)	T_{eff}	Lm	Leo	Spor
$12^{h}_{\cdot}60$	0.16	5.1	3	0
$12^{h}_{\cdot}92$	0.14	5.1	2	0
$13^{h}_{\cdot}08$	0.14	5.1	3	0
$13^{h}_{\cdot}23$	0.11	5.1	2	0
$13^{h}_{\cdot}42$	0.13	5.2	1	0
$13^{h}_{\cdot}60$	0.14	5.3	4	1
$13^{h}_{\cdot}75$	0.14	5.3	4	2
$13^{h}_{\cdot}92$	0.14	5.3	5	0
Total	1.10	5.2	24	3

Table 2 – Magnitude distribution of the Leonids obtained from the author's observations on November 18, 1994.

Magnitude	−2	−1	0	+1	+2	+3	+4	+5
Leonids	1	2	4	1	2	3	5	0

The −2 meteor mentioned in Table 2 had a typical Leonid-like appearance: a symmetric light curve with a flare in the middle. The meteor appeared in the zenith and had a persistent train that was visible in the Full Moon glow for about 4 seconds. The meteors radiated from a point in the head of Leo, at about $\alpha = 151°$, $\delta = +21°$ (eq. 2000.0). I did not spot a meteoric glow in the direction of the true radiant (note however: bright sky background).

The rate of Leonids was surprisingly high and continuous during the observations. A message was spread two hours after the event, hoping that other observers might confirm the high rates.

The night after this event, November 18-19, was clear again. I observed from a location outside the city, mainly to establish a comparison of sky conditions with a similar near-Full Moon. The sky appeared clearly more transparent. Indeed, I estimated a limiting magnitude of 5.6–5.8 which probably compares well with the 5.1–5.3 from downtown Mountain View. The sporadic rate was also a bit higher. The Leonids were still active, as shown in Tables 3 and 4.

Table 3 – Rate data of the author's observations of the 1994 Leonids on November 19, 1994.

Time (UT)	$T_{\rm eff}$	Lm	Leo	Spor
$09^{\rm h}.70$	0.40	5.6	1	2
$10^{\rm h}.50$	0.97	5.6	2	4
$11^{\rm h}.50$	0.97	5.7	6	3
$12^{\rm h}.38$	0.75	5.8	2	0
Total	3.09	5.7	11	9

Table 4 – Magnitude distribution of the Leonids obtained from the author's observations on November 18, 1994.

Magnitude	−2	−1	0	+1	+2	+3	+4	+5
Leonids	0	0	2	2	1	3	1	2

Table 5 shows the ZHRs calculated for the data available to me on the evening of November 19. These are preliminary results. I assumed $r = 2.15$ for November 17-18, $r = 2.35$ for November 16-17 and 18-19. I have taken a zenith exponent $\gamma = 1.4$ in the radiant altitude correction $\sin(h_{\rm rad})^{-\gamma}$. I assumed a perception of 1.0 for both observers. All solar longitudes given in this article refer to eq. 1950.0.

Table 5 – ZHR data for the Leonid observations of Bob Lunsford and Peter Jenniskens between November 17 and 19, 1994.

Lunsford (San Diego, CA) November 17			Jenniskens (Mountain View, CA) November 18			Jenniskens (Mountain View, CA) November 19		
$\lambda_\odot$ (1950.0)	Time (UT)	ZHR	$\lambda_\odot$ (1950.0)	Time (UT)	ZHR	$\lambda_\odot$ (1950.0)	Time (UT)	ZHR
234°.20	$10^{\rm h}.00$	40 ± 18	235°.320	$12^{\rm h}.60$	66 ± 38	236°.207	$09^{\rm h}.70$	15 ± 15
234°.24	$11^{\rm h}.00$	6 ± 6	235°.333		48 ± 34	236°.240		9 ± 6
234°.29	$12^{\rm h}.00$	27 ± 11	235°.340		71 ± 41	236°.283		18 ± 7
234°.33	$13^{\rm h}.00$	50 ± 13	235°.346		59 ± 42	236°.320	$12^{\rm h}.38$	6 ± 4
			235°.362		78 ± 39			
			235°.368		77 ± 38			
			235°.374	$13^{\rm h}.92$	95 ± 43			

I conclude that the activity on the night of November 17-18 was a factor of 9 higher than normal (ZHR = 9 [6]), while rates on November 16-17 were close to normal (ZHR about 23). The rate on the night of November 18-19 was still a factor of three higher than normal (ZHR = 3). This suggests that the activity extended for more than a day. This is consistent with the observations prior to the return of the parent comet in 1966 [7]. This year, however, the time of maximum seems to have been after passage of the node of the comet, which is at $\lambda_\odot = 234°.55$–$234°.58$.

2. High activity of Leonids on November 17-18 and 18-19—Part II

By November 20, details became available of the meteor scatter observations of Peter Bus (Groningen, the Netherlands), and the visual observations by the Spanish observer Josep M. Trigo from Castellon (Spain). The analysis of the raw data is still preliminary. However, the raw data themselves do confirm high activity of Leonids on November 17-18.

The radio meteor scatter data by Eisse Pieter Bus were forwarded to me by Hans Betlem of the *Dutch Meteor Society*. There is no clear increase of numbers visible in these counts. However, the reflections on November 17-18 lasted typically much longer than those on the other nights. The total dead time due to long-lasting trains (in minutes) is given in Table 6.

Table 6 – Radio meteor scatter data by Eisse Pieter Bus.

Period (UT)	Nov 17	Nov 18	Nov 19
06^h–07^h	2.8	21.0	3.5
07^h–08^h	2.0	27.0	1.2
08^h–09^h	4.4	27.2	0.4
09^h–10^h	1.6	9.4	0.4
10^h–11^h	0.0	9.2	0.4
11^h–12^h	0.3	5.3	1.1
12^h–13^h	0.0	2.0	0.0

The receiver was listening to a radio station in Poland and the geometry antenna-receiver was most favorable around 6^h30^m UT. Later in the observing run, not only the geometry became less favorable, but also the Leonid radiant altitude decreased. Peter Bus calculated the reflection rates in Table 7, assuming an activity of zero on November 18-19, which counts have been subtracted. This analysis is preliminary and awaits a more careful reduction of the data. The table lists the calculated rate and between square brackets the number of reflections on which they were based. Values between normal brackets are uncertain because of a low radiant altitude.

Table 7 – Preliminary reduction of radio meteor scatter data by Eisse Pieter Bus.

Period (UT)	Nov 17	Nov 18
06^h–07^h	23 [22]	21 [20]
07^h–08^h	20 [18]	21 [19]
08^h–09^h	17 [14]	22 [18]
09^h–10^h	18 [11]	28 [17]
10^h–11^h	21 [7]	50 [16]
11^h–12^h	(20 [4])	(75 [15])
12^h–13^h	(10 [1])	(150 [15])

The feature that stands out in this table is that the number of strong reflections decreased on the night of November 16-17 with a decreasing radiant altitude and less favorable antenna geometry, but remains constant on November 17-18. The result is an increase of rates during the night of November 17-18 after correction for antenna geometry. This effect is only strengthened when also a radiant altitude correction is applied. The radio data, therefore, show an increase in rates between 6^h and 13^h UT.

The visual observations by Josep M. Trigo were kindly forwarded to me by Luis Bellot of the *International Meteor Organization*. The observing site was Castellon (Spain), and the observer has a reported perception well above the average (around 1.5). The raw counts and the overall magnitude distribution are shown in the previous article [8, Tables 1 and 2].

The reported limiting-magnitude values (between 3 and 4 in steps of 0.5) are much less than my estimates from downtown Mountain View (with a thick smog layer). I assume that the sky condition estimate is not on the same scale as my estimates. Therefore, I have calculated zenith hourly rates assuming $r = 2.15$, limiting magnitude as given, and a perception of 1.5 (A) and an alternative set of values (B) for $r = 2.35$, a limiting magnitude of 5.6 rising to 5.8 and a perception of 1.0. The results are shown in Table 8.

Table 8 – ZHR calculations for the Leonid observations of J.M. Trigo using different sets of basic assumptions.

$\lambda_\odot$ (1950.0)	ZHR (A)	ZHR (B)
234°934	180 ± 90	80 ± 40
234°941	180 ± 90	80 ± 40
234°958	110 ± 80	30 ± 22
234°966	230 ± 130	41 ± 23
234°972	155 ± 90	40 ± 23
234°979	103 ± 60	39 ± 23
234°991	26 ± 18	10 ± 7

In both cases, the resulting ZHR values are significantly above the annual rate (about ZHR = 13) and they, therefore, confirm the high Leonid activity on November 17-18. The uncertainty in the limiting magnitude leaves some doubt about the time of maximum of the Leonid peak. If the limiting magnitude estimates are taken at face value (A), then Josep Trigo would have the higher rates and the peak would be at about 5^h UT. However, that would contradict the meteor-scatter account of increasing rates. Also, a significant increase of radio rates over the counts on November 16-17 is expected if the maximum was as early as 5^h UT when receiver and antenna were in a favorable position. The counts by Bob Lunsford on November 16-17 are too low by a factor of two to allow a maximum as early as 5^h UT, November 18, and a symmetric profile (as usual, [9]). From these arguments, I opt for the alternative ZHR values (B), which are in agreement with Bob's counts and qualitatively in agreement with the meteor scatter data. In combination with the observations of November 18-19, these data put the maximum at about 14^h UT, at the time of the observations in California.

Based on the data available to me on November 20, 1994, I conclude that the maximum of the Leonid outburst probably fell at around 14^h UT ($\lambda_\odot = 235^\circ\!.4$, eq. 1950.0). The decrease away from maximum had slope $B = 1.1$ and $\mathrm{ZHR}_{\max}$ about 70, where ZHR(outburst component) = $\mathrm{ZHR}_{\max} \times 10^{(-B\times|\lambda_\odot - 235^\circ\!.4|)}$. This corresponds to a duration of 0.8 days above the $1/e$ times maximum activity value, which is the same duration as in 1961 and 1965 [7,9]. These observations probably provide the first indication of the parent comet's return to perihelion. The high activity classifies as a meteor outburst, which is likely the first in a series of many to come.

I want to thank Jose Trigo, Peter Bus and Bob Lunsford for their contribution to this report and am grateful for the kind mediating role of Luis Ramon Bellot of the *International Meteor Organization* and Hans Betlem of the *Dutch Meteor Society*. This work was done while I held a National Research Council-ARC Research Associateship.

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The Leonid Radiant Position during 1994–1999

Ichiro Hasegawa

Coordinates of the Leonid radiant point are provided for various solar longitudes between 1994 and 1999.

A return of the parent comet of the Leonids, P/Tempel-Tuttle, to its perihelion in 1998 is predicted, and strong activity of the Leonid shower is expected then. The following predictions for the radiant position of the Leonids were computed by the q-adjusted method for solar longitudes between 230° and 240° in steps of 1°. This method, proposed by the author, was published in 1990 [1]. The predicted orbital elements of P/Tempel-Tuttle, calculated by Yeomans [2], are as follows (eq. 2000.0):

$$T = 1998 \text{ Feb } 28.01 \text{ TT} \qquad \omega = 172\overset{\circ}{.}5050$$
$$q = 0.976539 \text{ AU} \qquad \Omega = 235\overset{\circ}{.}2632$$
$$e = 0.905509 \qquad i = 162\overset{\circ}{.}4883$$
$$a = 10.334730 \text{ AU} \qquad P = 33.2238 \text{ years}$$

The heliocentric distances of the Comet's and the Earth's descending node are 0.9805 AU and 0.9885 AU, respectively. The coordinates of the predicted radiant position are shown in Table 2 as a function of solar longitude (eq. 2000.0). The corresponding dates are shown in Table 3.

Table 1 – Prediction of the radiant position of the Leonids.

$\lambda_\odot$	1994 (UT)	α	δ	V_g (km/s)	Δ (AU)
230°0	Nov 12.55	149°8	+23°0	70.5	0.028
231°0	Nov 13.54	150°5	+22°8	70.6	0.023
232°0	Nov 14.54	151°2	+22°6	70.6	0.018
233°0	Nov 15.53	152°0	+22°3	70.6	0.014
234°0	Nov 16.52	152°7	+22°1	70.6	0.009
235°0	Nov 17.52	153°4	+21°8	70.6	0.008
236°0	Nov 18.51	154°1	+21°6	70.7	0.009
237°0	Nov 19.50	154°8	+21°3	70.7	0.012
238°0	Nov 20.49	155°5	+21°0	70.7	0.016
239°0	Nov 21.48	156°3	+20°8	70.7	0.020
240°0	Nov 22.47	157°0	+20°5	70.7	0.025

Table 2 – Solar longitude and corresponding date (UT) from 1995 to 1999.

$\lambda_\odot$	1995	1996	1997	1998	1999
230°0	Nov 12.82	Nov 12.07	Nov 12.33	Nov 12.58	Nov 12.84
231°0	Nov 13.81	Nov 13.06	Nov 13.32	Nov 13.58	Nov 13.83
232°0	Nov 14.80	Nov 14.06	Nov 14.31	Nov 14.57	Nov 14.82
233°0	Nov 15.80	Nov 15.05	Nov 15.31	Nov 15.56	Nov 15.82
234°0	Nov 16.79	Nov 16.04	Nov 16.30	Nov 16.56	Nov 16.81
235°0	Nov 17.78	Nov 17.03	Nov 17.29	Nov 17.55	Nov 17.80
236°0	Nov 18.77	Nov 18.02	Nov 18.28	Nov 18.54	Nov 18.79
237°0	Nov 19.76	Nov 19.01	Nov 19.28	Nov 19.53	Nov 19.79
238°0	Nov 20.75	Nov 20.00	Nov 20.27	Nov 20.52	Nov 20.78
239°0	Nov 21.74	Nov 21.00	Nov 21.26	Nov 21.51	Nov 21.77
240°0	Nov 22.73	Nov 21.99	Nov 22.25	Nov 22.50	Nov 22.76

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The Leonids of November 13–14, 1866, as Witnessed from Malta

Adrian Galea

A reconstruction is made of the 1866 Leonid storm as seen from Malta using original accounts.

1. Introduction

One of the most spectacular showers in the past few centuries has undoubtedly been the Leonid meteor shower. Active from November 15 to 20 annually, the rates of the Leonid meteor shower are normally low, typically with a ZHR of around 10. What we are actually observing when we glimpse a Leonid meteor is the debris left over by repeated passages of Comet P/Tempel-Tuttle, a link Schiaparelli is credited with making. The shower is striking because while activity is normally low, it shows a periodic variability with outbursts running into thousands of meteors per hour occurring every 33 years. This is caused by the Earth passing through a denser cloud of debris in the vicinity of the comet, while in normal years the activity represents debris which has spread all along the Comet's orbit.

The first recorded account of the Leonid meteor shower appears to be an Egyptian account dated AD 899 [1]. More recently, Alexander von Humboldt together with Aimé Boupland recorded the Leonid meteor storm of November 11, 1799 [2]. On November 12, 1833, an immense storm was observed from the West Indies and Canada with an estimated 200 000 meteors falling in an interval of 6–7 hours [3].

After searching ancient documents for accounts of Leonid showers, Professor Hubert A. Newton at Yale College, USA, confidently predicted the date of the next storm. Observers throughout Europe were regaled with another spectacular display on the night of November 13-14, 1866. Estimates of rates vary from 2000 to 5000 meteors per hour [4].

2. The 1866 Leonids: the Malta experience

Recent research has allowed the author to reconstruct what happened on the night of Wednesday to Thursday, November 13-14, 1866, when several people in Malta witnessed the Leonid meteor storm [5].

The cloudless, moonless night sky was set alight by an immense number of meteors of several colors, moving from east to west for a duration of about five hours. The frequency was greatest from midnight to 2^h a.m. and peaked at around the latter. Local people who were unaware of the predictions of such a storm and who did not understand the nature of a meteor storm were surprised. Farmers and fishermen who witnessed the event were struck by fear. One of them was quoted to exclaim *anche il firmamento e in rivoluzione* [6].

An interesting description of the events followed in the local newspapers by two persons, who together with other colleagues, had witnessed the event. The first was signed W.W. and described the display as follows:

> *Sir,*
>
> *Many of your readers, no doubt, will feel interested by any information they can receive respecting the prodigious shower of meteors, which, according to the calculations and prognostications of astronomers, was expected to fall on the 13th or 14th of November.*
>
> *Having had a splendid demonstration in Malta of the correctness of these calculations, I have taken the liberty to send you by the earliest opportunity a few particulars of this truly wonderful phenomenon as displayed to observers in this island.*

During the evening of the 13th, many fine meteors appeared in different parts of the heavens, and about midnight they began to fall in great numbers. From midnight till half-past 1, the greater part of these meteors became visible west of a line reaching from Sirius, past the north star to the northern horizon. But from half-past 1 till after 2, when the shower was at its maximum, *there was scarcely a part in the visible heavens that was not brilliantly illuminated by the beautiful fiery shower.*

The scene was then truly grand and imposing. Fireballs and shooting starts darted, with few exceptions, from east to west across the sky, with immense velocity, describing large arcs, and leaving in their paths splendid luminous trains or bands, which remained visible for a considerable time. These bands were, generally, nearly white, but several exhibited tints of red and blue.

The night was extremely calm and clear, so that the glancing balls and fiery showers were beautifully and vividly displayed against the clear, dark blue sky. The shower continued from midnight till 3 a.m., and during that time many thousands of meteors must have fallen within the range of our vision. Many of theses were of a startling size and brightness.

The scene, I assure you, Sir, was one of the most sublime that I ever beheld. In fact, it was far beyond anything I ever expected to see, and it would be presumptuous of me to attempt a description. I and those with me could only continue to gaze in delighted wonder, and utter exclamations of surprise and admiration. I am quite sure that no person who witnessed the strange phenomenon will ever cease to remember it with feelings of astonishment and pleasure. [7]

The other letter was from J.P.H. Boilneau, M.B. Assistant-Surgeon, 29th Regt., describing the spectacle as follows:

Sir,

Many of your readers will be interested to find that a celestial phenomenon, which from the history of meteoric epochs I infer has been witnessed in England, has also been observed in the Mediterranean.

At 2 a.m. on the 14th inst. I was called by some brother officers to see the shooting stars. On reaching the roof of the house, the spectacle presented by the heavens was certainly most remarkable; flashes of light appeared to traverse the firmament in various directions and in such rapid succession that they seemed quite innumerable.

As usually observed, shooting stars appear as bright spots traversing the heavens, their course being marked by a defined bright line of very transient duration, the eclipse being rather sudden.

The meteors we observed were somewhat different, and may be thus characterized:

In magnitude and degree of brightness they were variable, some being small and faint, others as large and splendid as the most brilliant planets. Their line of flight was apparently a right line, their extinction was sudden; but that of the nebulous tail they left behind them was quite gradual, lasting for some seconds. This luminous train was much broader than the bright meteors which seemed to give it birth; and in its character bore the same relation to it that the light of a lamp seen through a ground glass shade does to the light itself; these tails by estimation varied from 10 deg. to 40 deg. in length. No two crossed each other or moved in opposite directions; all seemed to emanate from the same region, and this was at the hour mentioned between the east and south-east points of the compass, between Regulus, in Leo, Alphard in Hydra, and Procyon in Canis Minor, probably nearer the former; from this center they appeared to diverge, some passing towards Ursa Major, others towards Ursa Minor, Cassiopeia, Perseus, Andromeda, Taurus, Aries, Orion, etc.

A vast number originated near the zenith, but all seemed to come from the same focus. A very few were observed near the southern horizon, which appeared to pass from north to south; but it is to be noted that their prevailing direction was from east to west.

Our lowest computation of their number was 200 per minute, but in all probability they were passing at the rate of 500 or 600. It was quite impossible to count them: as three or four observers expressed themselves, It was like a shower of hail.

They were not confined to any limited area of the firmament, but appeared in all directions, from the zenith to the horizon.

Some 15 intelligent sentries on duty that night were interrogated with a view to determine the duration of this remarkable phenomenon, with the result that it lasted about four hours, commencing at 1 a.m. and ending about 5 o'clock, but the maximum *occurred between 2 and 3 o'clock. One old soldier of 20 years' service stated that he had never before witnessed so strange a sight.*

An analysis of the meteorological observations taken at Malta during the present month shows no deviation from the ordinary character of the season:

	12 hours previously	12 hours afterwards
Barometer	30.064 deg.	28.98 deg.
Attached thermometer	67 deg.	67 deg.
Dry bulb thermometer	66 deg. 8 min.	67 deg.
Wet bulb thermometer	58 deg. 7 min.	62 deg. 3 min.
Direction of wind	N.E.	N.E.
Force of wind (estimated)	1	1
Ozone scale	5	5

The night was unusually cold. The minimum *thermometer in air marked 57.9 deg.; the lowest recorded for six months, being 3 deg. lower than any other recorded since the 1st inst. The mean of the* minimum *of the last four Novembers is 58.3 deg.*

The Moon set at 9.17 p.m., and the sky was cloudless. Thus the night was very favorable for observation.

On the following night, I watched for a recurrence of the phenomenon, but saw only one meteor, shooting across the Lynx from west to east, a few minutes before 1 o'clock.

Thus is the meteoric epoch of the 13th or 14th of November established by one more fact. [8]

The eyewitness accounts cited above prompted the interest of "a Foreign Resident" who wrote in asking for details about the meteor storm, and who promised to forward any observations to Professor H.A. Newton at Yale College, USA, who had so accurately predicted the return of the storm. [9]

The previously cited W.W. obliged by writing a more detailed and vivid description of the night, which follows below:

Sir

A few days ago my attention was directed to a letter, which appeared in your paper the 13th inst., containing several questions, proposed by the celebrated Professor Newton, for the purpose of eliciting as much information as possible about the wonderful shower of meteors that was witnessed on the morning of the 14th of November.

If you think that the following particulars and observations, respecting that beautiful phenomenon, may serve as answers to any of Professor Newton's queries, you will, perhaps, kindly grant them a place in your columns. I was aware that Professor Newton *had traced the historical records of the maximum recurrence of this very shower in 11 instances, and had predicted the day and hour of its cyclical return this year, and my confidence in the correctness of his calculations was sufficiently strong to keep my eyes open, and cause me to take up a convenient position for observing the expected exhibition.*

A little before midnight, a beautiful meteor made its appearance, glancing along the north-west quadrant, a little above the horizon. Another, and another quickly followed, and by 12.10 a.m., 17 had been counted. During three quarters of an hour, large meteors, in gradually increasing numbers, continued to fall in the same portion of the sky, all taking a similar direction, down towards the west. These all had fine trains and described arcs of 25 or 35 deg.

About 12.45, meteors commenced to fall rapidly along a line extending to the south-east, passing through Cepheus, Cassiopeia, Perseus, Taurus, and Orion. Up to this time I did not perceive any falling in Leo, although that constellation was above the horizon and distinctly visible. At 1.30, there was rather a sudden increase, and the shower became more extensive. At this time the radiant in Leo appeared brilliantly conspicuous, and continued distinctly manifest for three quarters of an hour, sending forth glancing balls in all directions, the trains of which made that portion of the sky resemble a grand wheel. From 1.45 to 2.20, when the shower was at its maximum, meteors were falling, as has been very significantly expressed, like a shower of hail; and the blue vault of heaven was magnificently beautiful, being traced almost all over with luminous trains. The principal radiants, however, were displayed within a zone of the heavens bounded on the west by a line from Cepheus to Arietis, and one on the east, from below Ursa Major to Hydra. Nearly all the meteors left trains, and if the paths in which they move had been produced back the majority of them would have converged to Leo.

The following numbers may convey some idea of the increase, maximum, and diminution of frequency. They denote the number of meteors per minute, for each quarter of an hour between 12 and 3 a.m.: 1; 2; 9; 32; 47; 59; 150; 400; 500; 125; 41; 25. Those representing the maximum, according to the estimate formed at the time, are not too high, as the meteors were then falling at the rate of 15, 20, and upwards per second. This rate was not, of course, quite constant.

The largest and most brilliant meteors, and those that left the most enduring trains, darted forth from the vicinity of Taurus and Orion. They passed near our zenith, and described arcs from 50 deg. to 80 deg. in length. I had no means for measuring their velocity, or the time they were in sight, but some, I think, may have been visible 2 seconds.

The trains seemed like luminous gas, or small atoms of incandescent matter left by the burning pellets in their passage through the atmosphere. Apparently, they were not very high, perhaps not higher than ordinary, fleecy clouds. I did not refer their position to any fixed star, but they seemed quite stationary. Their color was, with few exceptions, nearly white with a bluish tinge. A few were red, but there was not one remarkably yellow.

Among the many speculations to which these fiery showers give rise, are the following questions: Where and how do these bodies become luminous or ignite, and what becomes of these millions of tiny planetoids? I am aware that the generally received theory, with respect to their luminosity, is, that the resistance and friction of the atmosphere, through which they glide, with immense velocity, are quite sufficient to produce the required amount of heat. But, I could not help thinking while watching the late remarkable shower that the nature of the elements of which they are composed, and chemical affinity, may have something to do with their sudden ignition.

> *The wonderful spectroscopic investigations, made by A.S. Herschel, prove, almost beyond doubt, that the luminous, yellow trains of the August Meteors are produced by the presence of an extraordinary amount of the vapor of sodium. It is also indicated that, at least, one other substance, either potassium, sulphur, or phosphorus, is present. The presence of this other element, according to A.S. Herschel, in greater proportion gives to the trains of the November Meteors their peculiar bluish-white tinge.*
>
> *Now, if this hypothesis is correct, and the metals sodium and potassium are the principal constituents of such meteors, then their sudden and startling ignition, combustion, and dissipation will no longer appear strange or mysterious to any person who has seen exactly similar effects produced, when the metals alluded to have been heated to vapor or thrown into water. The rocket-like explosion of some of the meteors may easily by accounted for in the same manner.*
>
> *Meteoric Astronomy is now engaging a great amount of attention; and, by the assistance of the spectroscope, these celestial wanderers will soon be better understood; and, thus, another leaf in the wonderful and glorious book of Nature, will be unfolded and illuminated.* [10]

Expectations were dampened by poor displays in 1899 and 1933. The next return in 1966 provided American observers with a display of 60 000 meteors per hour over a 40-minute interval, the best ever recorded Leonid rates. [11]

Historically, the most significant displays have been in years when Earth has passed the stream orbit just after the Comet has passed. With the Comet P/Tempel-Tuttle due to return in 1997, the potential for strong displays in 1998 and 1999 exists, especially for observers in the United States and the Far East, with the possibility of increasing rates in the years leading up to them. [12]

Acknowledgment

The author wishes to thank the staff of the National Library, Malta, Ms. Anne-Marie Vella, Dr. Godfrey Baldacchino, and Mr. Antoine Grima.

Notes and References

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[7] *The Malta Times and United Services Gazette*, December 6, 1866.

[8] ibid.

[9] *The Malta Times and United Services Gazette*, December 13, 1866.

[10] *The Malta Times and United Services Gazette*, January 3, 1867.

[11] N. Bone, "Observer's Handbook of Meteors", 1993, p. 59.

[12] ibid., p. 116.

The 1994 Perseids

A First Global Analysis of the 1994 Perseids

Jürgen Rendtel

This preliminary analysis is based on more than 18 000 Perseids recorded by more than 80 observers covering over 750 hours of effective observing time. The high Perseid peak recurred in 1994 at $\lambda_\odot = 139\overset{\circ}{.}595 \pm 0\overset{\circ}{.}007$ corresponding to 11^h UT on August 12, and was observed from various sites in North America. The population index r was lower during this peak period ($r_P = 1.8$) than during the regular Perseid maximum around $\lambda_\odot \approx 140°$ ($r_M = 2.1$). The minimum of r coincides with the activity peak. The maximum equivalent ZHR (based on 10 minute counts) of the peak was EZHR $= 250 \pm 45$. This is lower than in 1991 and 1993. The regular maximum reached a level of ZHR ≈ 90 which is also lower than in 1991 and 1993.

1. Introduction

After the surprising occurrence of a strong ZHR peak during the 1991 Perseids and the extreme expectations during the 1993 return, the 1994 recurrence became an almost routine observation. However, there were a number of open questions. Recent model calculations [1] indicated that the 1994 return of the sharp Perseid peak might be comparable to the 1993 event. The precise time of peak activity was not predictable, though. Considering the shifts observed in the previous years, the most probable time was August 12, $9^h30^m \pm 3^h$ UT. Thus the most favorable region for observations was in the western part of the United States. Some observers in central and southern California suffered from clouds brought inland by a hurricane west of the coast. On the other hand, northern California and Oregon were cloudless during the respective period.

All previous Perseid outbursts were not optimally observed: in 1991 the observers, of course, were not prepared to record such a high activity. The Full Moon coinciding with the 1992 peak and the earlier than expected time of the peak resulted in data of poor quality only. In 1993, the peak occurred later than expected. Consequently, most European observers finished their observing during twilight, while the eastern parts of North America had poor skies and cloudy weather. The collection of data from many observers, however, resulted in a global analysis with reliable results [2]. However, data in the immediate vicinity of the peak, corresponding to the ascending branch and the descending branch of the higher activity, respectively, were from different observational sources, and hence suffer from problems caused by combining these data (e.g., the perception correction in the case of the Geminid maximum as discussed in [3]). In 1994 data sets of both the ascending and descending branch were obtained by the same observers under (almost) constant conditions with small corrections. These observations should enable us to determine more about both the peak itself and the observer's perception under these conditions (as already attempted in [4]). This will be the subject of another analysis.

2. The 1994 return

When observers in Europe finished their watches on August 12, 1994, at about 3^h UT, the ZHR was at a level of 50. Observers in North America continued without a gap this year (due in part to better weather conditions), and thus we have a continuous series of data from sites where the radiant was high in the sky. Activity did not change until 7^h UT, when a slight increase was noted. Between 9^h30^m and 10^h UT, the ZHR exceeded 100 and the increase continued. This was reported by observers in the eastern part of the United States: as in 1993 in Europe, they witnessed the ultimate rise to maximum in the bright morning twilight. Just around 11^h UT, the ZHR peaked at 250 followed by a remarkably steep decrease. About 40 minutes later, the ZHR fell to almost 100. As already pointed out, we do have counts of the entire profile obtained under constant circumstances, since the twilight permitted observations until 12^h UT in California. This is most important for the determination of the population index r from the magnitude data.

The analysis was done from a (large) subset of the data sent in. Since it was intended to present this overview at the end of 1994, not all data are in the *VMDB* files yet. The sample used for this analysis contains data of almost 18 000 Perseids observed in more than 750 hours effective observation time by more than 80 observers.

3. The population index

The most interesting part of the r-profile in Figure 1 is the peak period. Here, the value of r is lower than before and also lower compared with the average, or normal maximum around $\lambda_\odot = 140^\circ\!.0$–$140^\circ\!.5$. This was not seen as clearly during the previous returns, as explained in the Introduction.

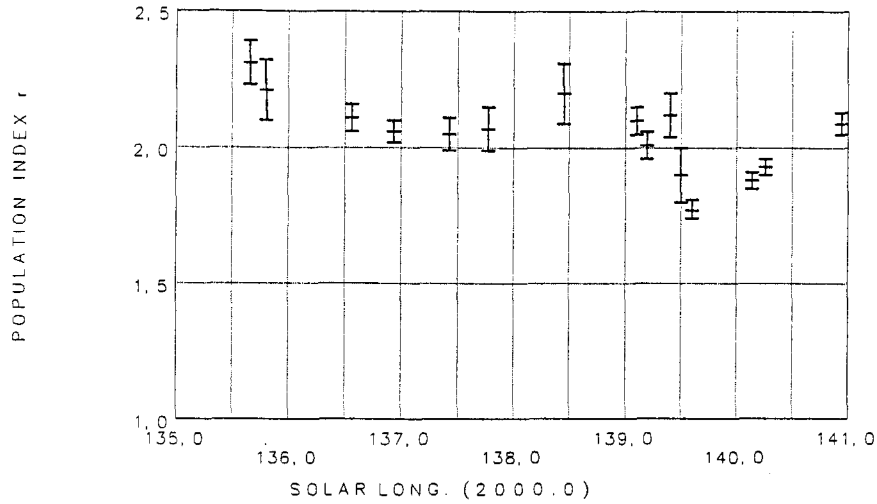

Figure 1 – Variation of the population index r for the period August 8–13, 1994. The profile around the peak at $\lambda_\odot = 139^\circ\!.595$ is shown in more detail in Figure 2. August 8 to 11 corresponds to the activity plateau of the Perseids at a ZHR level of roughly 30. In this period, $r \approx 2.1$ with only slight variations. The values of r are averages of 1°-intervals in solar longitude, shifted by $0^\circ\!.5$.

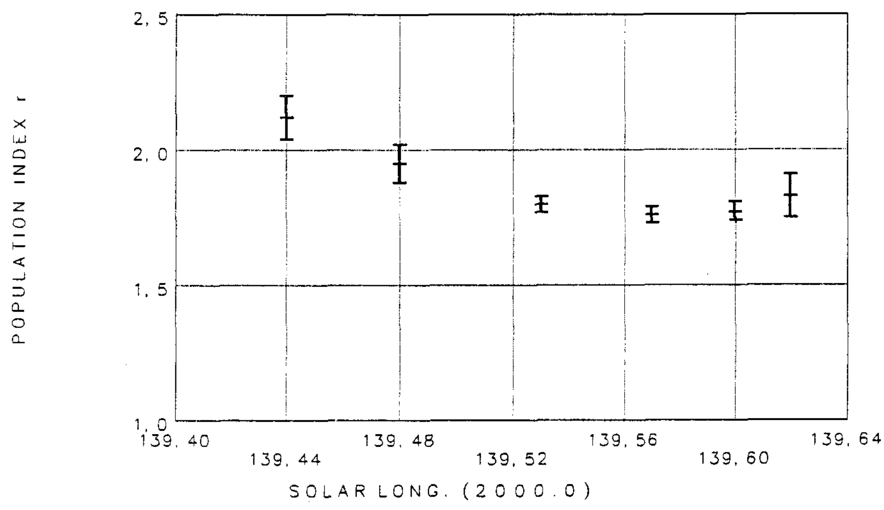

Figure 2 – During the ascending branch of the activity, the radiant elevation steadily increased for all observers. Although the change in the entry conditions should lead to an increase in r [6], we observe a net decrease and a significant minimum coinciding with the EZHR peak. Observations were sufficiently complete in 1994 to calculate reliable r-values for 1-hour interval lengths. Note the small error bars which suggest interpretation of the variations as real changes of r. The value of r of the new meteoroid population should be even lower as discussed in the text.

Figure 2 shows this phenomenon in more detail. Note that 0°04 corresponds to 1 hour.

Surprisingly, the increase of r with an increasing radiant elevation which was observed during the 1992 Quadrantid return [5] and later explained by Bellot [6] by varying entrance condition of the shower meteors with the radiant's elevation, did *not* occur during the 1994 Perseid peak. This was not to be derived from the previous data series because of their composition. But the 1994 Perseids were observed under quite similar conditions as the 1992 Quadrantids: the radiant elevation steadily increased until the end of the observations, i.e., until the peak was entirely passed. What we see is just the opposite tendency: the value of r *decreases* as the radiant approaches the zenith. If we consider the effects discussed by Bellot [6] acting here as well, we should assume an even lower minimum value of r.

Furthermore, the value of r during peak activity in 1994 is very close to the corresponding values of the returns in 1991 ($r_P = 1.9$, [7]) and 1993 ($r_P = 1.8$, [2]). The value of $r_M = 2.1$ found for the regular maximum is almost identical for all returns from 1991 to 1994 [2,7]. Again, we should consider that in 1994 the period around the peak is covered by more continuous and homogeneous data sets compared with the combined data obtained at various sites in previous returns. This does not devalue the earlier global data analyses, but the fewer corrections which are needed, the fewer systematic effects which are likely to be introduced. Thus we may now conclude more reliably that the particle population observed during the peak period is different from the average, older material observed outside this region. This difference should be even somewhat larger than determined by the difference in the population index r shown in Figures 1 and 2 because the total number of meteors (say, 200 per hour around the peak) also includes a portion of the regular material (approximately 40 per hour, or 20%).

4. The activity profile

There exists little experience with the observation and analysis of very high meteor activity. The measure we are used to is the ZHR. The peaks we observed for the Perseids recently last for less than an hour. Within one hour, the observer witnessed a substantial part of an activity profile, and if we use the term ZHR in its original sense, the rates were much lower. However, we simply use the quantity ZHR for shorter intervals, such as 15 or even 10 minutes, knowing that this measured rate did not last for an hour, but rather is an extrapolation of the instantaneous activity averaged over a smaller time interval. Immediately after the 1993 return (and again in 1994), there occurred notes about ZHRs of 700 or so. Most of these turned out to be derived from counts during intervals of less than 10 minutes. Of course, one may find very short intervals (such as single minutes) with 5–10 Perseids, and we could calculate a "ZHR" from these. It is obvious that these numbers have a completely different meaning. Firstly, they are based on a small sample, and, secondly, this sample is to a large extent determined by accidental factors (such as the appearance of a number of shower meteors quite close to each other in the sky). Furthermore, one bright fireball with a persistent train may attract the observer's attention and may let him miss other, faint shower meteors appearing in the same minute. Analyses of 1993 data indicates that count intervals of less than 10 minutes are the limit for accurate representation of the activity level observed in the Perseid peaks [4]. This may be somewhat shorter if the rates further increase. In order to make obvious that the rate is obtained from intervals which are significantly shorter than one hour, I propose use of the term "equivalent ZHR" (EZHR).

Figure 3 shows the ascending branch of Perseid activity as derived from the global data. As in 1993 [7], there is only little fluctuation in the rates. The peak itself at $\lambda_\odot = 139°595 \pm 0°007$ is well defined by 2 interval averages based on 10 independent count intervals containing a total of more than 700 Perseids. This time corresponds to 11^h UT on August 12, 1994.

More detailed analyses of the immediate peak period will be carried out for individual returns. The maximum EZHR for 10 minute counts slightly exceeded 250. This seems to underline the steady decrease of the highest rates after the 1991 peak (Table 1).

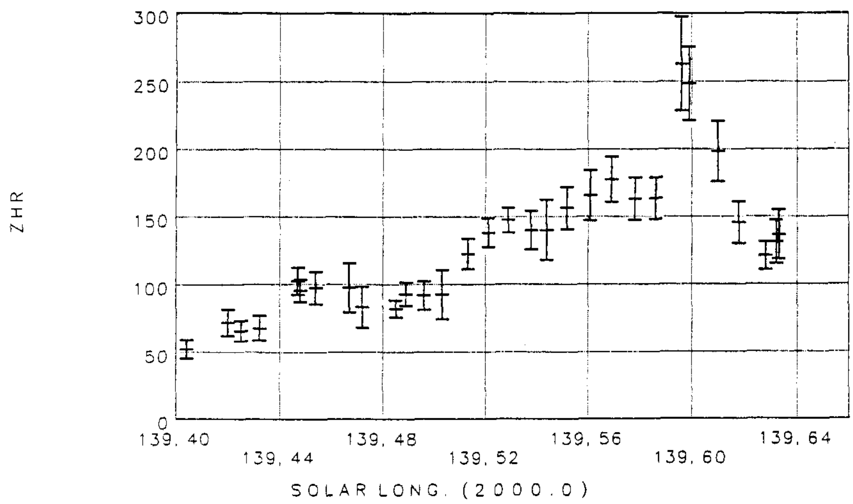

Figure 3 – Ascending branch of activity and the peak at $\lambda_\odot = 139\overset{\circ}{.}595 \pm 0\overset{\circ}{.}007$. The increase of the equivalent ZHR (EZHR) is continuous, and the peak is well pronounced. Here we shifted a sampling interval of $0\overset{\circ}{.}016$ length (20 minutes) by $0\overset{\circ}{.}008$, using only the count intervals of $\leq$ 15 minutes. More detailed analyses using only strictly identical count intervals are the subject of a further analysis. Here, we have to expect some smearing because the 15 minute count intervals are not identical and thus we in fact average over more than 20 minutes.

Table 1 – Highest recorded equivalent ZHRs during the Perseid peaks of 1991 to 1994. The 1992 result should be left out from further conclusions because all data suffered severely from disturbance by the Full Moon.

Year	New peak		Regular maximum	
	r_P	EZHR	r_M	ZHR
1991	1.9	350	2.1	120
1992	(2.1)	(250)	(2.1)	(90)
1993	1.8	300	2.0	110
1994	1.8	250	2.1	90

In Figure 4, we show the ZHR profile for the period which includes both the peak and the regular maximum. The ZHR of the regular maximum was just below 100. This seems a little lower than the average of the 1991 and 1993 returns when the ZHR of the maximum at $\lambda_\odot \approx 140°$ reached 120 [7] and 110 [2], respectively. Before we try to interpret this, we should include all available data and also consider the error bars of all rates found.

After the peak time was passed, the ZHR fell to about 80 before climbing to the regular maximum. This is exactly the ZHR that was previously observed when $139\overset{\circ}{.}6 < \lambda_\odot < 139\overset{\circ}{.}9$ before the new peak occurred (see, e.g., [8]). So we may state that the new peak represents additional activity superposed with the average rate we know from the regular Perseid returns.

5. Conclusions

Although this analysis is only based on part of the available data, the results can be expected to be quite close to the final values. This is particularly valid for the peak period. Further analyses will deal with details in the immediate vicinity of the peak.

A result which was not as prominent in the analyses of 1991 to 1993 Perseid data is the behavior of the population index r during the peak activity period. Despite the effects discussed by Bellot [6], the value of r *decreased* with increasing radiant elevation.

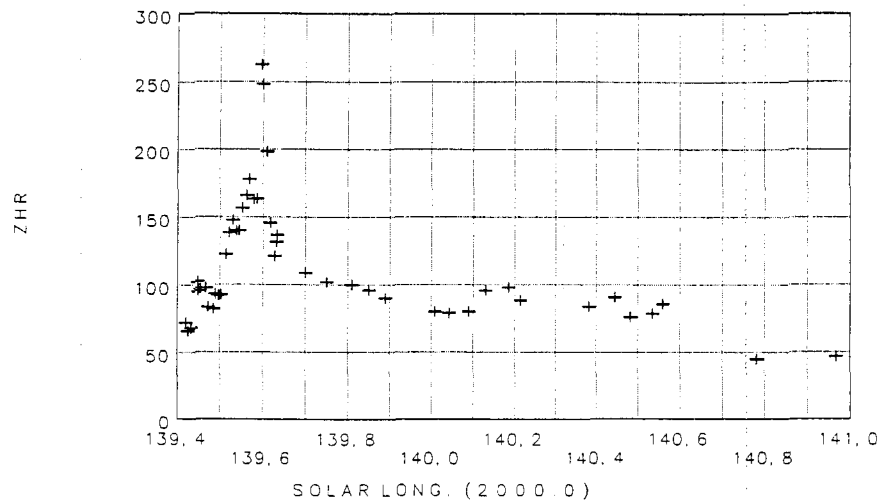

Figure 4 – The two Perseid maxima. The peak of fresh material at $\lambda_\odot = 139^\circ\!.595 \pm 0^\circ\!.007$ and the regular maximum at $\lambda_\odot = 140^\circ\!.1$–$140^\circ\!.6$ according to the preliminary analysis. For œ[Athe regular maximum we used sampling periods of $0^\circ\!.2$ length (5 hours), shifted by $0^\circ\!.1$. The five data points between $\lambda_\odot = 139^\circ\!.7$ and $\lambda_\odot = 139^\circ\!.9$ are averages of Japanese data submitted by Junichi Watanabe and added to the profile.

Combined with the fact that the observed particle population at the peak consists of approximately 20% "old" particles (not belonging to the peak caused by freshly released meteoroids), this means that the population index r of the new material is even lower than the value of $r = 1.8$ derived from the observations. This was not clearly visible in the 1991 and 1993 data because of the composition of the data.

The uncertainties of all parameters obtained from light-disturbed observations, such as in 1992, underline that such data can only be used for deriving upper/lower limits of some parameters.

The shift of the new peak relative to the nodal crossing time for P/Swift-Tuttle was of the same order as observed between the previous returns. The analysis indicates that the 1995 peak should be expected to be weaker than in 1994, occurring on August 12 at $17^{\mathrm{h}} \pm 3^{\mathrm{h}}$ UT.

6. Acknowledgments

I wish to thank all observers who sent in their data very soon after the Perseids. This enabled us to present a very first analysis at the *International Meteor Conference* in Belogradchik, Bulgaria [9]. The immediate contact with Peter Brown after the peak observations also enabled the *IMO* to report a reliable overview for the *IAU Circulars*.

Special thanks go to Junichi Watanabe of Japan for sending some data from Japanese observers before we obtained the actual raw data for input into the *VMDB*. This allowed us to fill in the gap between the peak and the "traditional" maximum.

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BAA Observations of the 1994 Perseids

A Preliminary Report

Neil Bone

Despite rather poor weather conditions over the British Isles, several *BAA* observers obtained good data on the 1994 Perseids. This very preliminary report, based on results submitted within three weeks of the maximum, gives some idea of the activity levels at the "traditional" maximum on August 12-13, 1994.

The Perseids have long been the most popular meteor shower for observers in the UK, inevitably attracting a lot of casual interest. Experienced *BAA* (*British Astronomical Association*) observers, too, have covered the shower over many decades, as shown by extensive data in the *BAA* archives. Several Perseid returns in the 1980s were met with intense coverage, notably 1980 [1], 1983, 1985, 1988, and 1989. Good results were also obtained in 1991 and 1993 [2].

Circumstances for the 1994 return were such that, while likely to miss any continuing activity from the "early" Perseid maximum associated with recently-ejected material from P/Swift-Tuttle [3], observers in the UK and elsewhere in Western Europe should have been ideally placed to see the "traditional" maximum around $\lambda_\odot = 140^\circ\!.0$ (eq. 2000.0).

Intending observers were, as in previous years, issued with instructions, and urged to cover as many nights as possible during the opening fortnight of August. Contributing UK observers are listed below:

M. Ashworth, S. Ashworth, S. Beaumont, G. Bone, N. Bone, P. Brierley, D. Briggs, K. Brill, F. Brown, G. Bryant, J. Carroll, D. Cooper, A. Drummond, J. Duthie, S. Evans, L. Green, M. Green, M. Harris, P. Haworth, R. Johnson, N. Kiernan, J. Lancashire, C. Lintott, A. Lloyd, K. Mackay, A. McBeath, T. McEwan, T. Markham, J. Mason, T. Moseley, C. Newman, G. Parsley, G. Pointer, V. Robertson, J. Rowlands, J. Shanklin, A. Simmons, G. Simmons, D. Simpson, G. Spalding, C. Steele, D. Storey, M. Taylor, C. Thompson, C. Traynor, A. Vincent, M. Willis, and I. Wood.

In the event, weather conditions were once again the dominant influence on the success of the *BAA*'s Perseid project. Much of the UK had a fine night on August 8-9, but thereafter a slow-moving Atlantic depression caused problems, particularly in the south of the country. A timely clearance brought excellent skies over Scotland, Northern Ireland and north England on August 12-13. Observers further south enjoyed their best conditions on the two nights following maximum.

Corrected ZHRs for the best-covered intervals are given in Table 1. Values of $r = 2.35$ for Perseids, and $r = 3.42$ for sporadics were adopted as previously [1].

Table 1 – BAA data for the 1994 Perseids.

Aug	UT	$\lambda_\odot$	$T_{\rm eff}$	Lm	Spor	HR	Per	$h_{\rm rad}$	ZHR
8	23^h49^m	$136^\circ\!.27$	17.00	5.41	71	16.1 ± 1.9	121	$41^\circ\!.3$	27.6 ± 2.5
11	23^h31^m	$139^\circ\!.13$	3.67	5.35	11	12.3 ± 3.7	47	$42^\circ\!.0$	51.1 ± 3.5
12	22^h31^m	$140^\circ\!.05$	4.83	6.10	28	15.3 ± 2.9	150	$37^\circ\!.2$	60.4 ± 4.9
12	23^h37^m	$140^\circ\!.09$	5.33	6.03	31	16.9 ± 3.0	193	$43^\circ\!.4$	72.6 ± 5.2
13	00^h30^m	$140^\circ\!.13$	5.83	6.00	27	12.5 ± 2.4	219	$49^\circ\!.6$	68.2 ± 4.6
13	01^h22^m	$140^\circ\!.16$	4.83	5.84	25	18.8 ± 3.8	212	$55^\circ\!.2$	81.1 ± 5.6
13	02^h19^m	$140^\circ\!.20$	5.75	5.69	19	11.6 ± 2.7	219	$62^\circ\!.4$	80.3 ± 5.4
13	22^h48^m	$141^\circ\!.02$	14.90	5.65	67	12.8 ± 1.6	180	$37^\circ\!.7$	40.8 ± 3.0
14	01^h07^m	$141^\circ\!.19$	13.42	5.83	76	13.1 ± 1.5	248	$53^\circ\!.1$	41.5 ± 2.6
14	23^h30^m	$142^\circ\!.01$	7.62	5.53	36	15.8 ± 2.6	76	$41^\circ\!.1$	35.2 ± 4.0
18	02^h13^m	$145^\circ\!.00$	2.50	5.83	18	16.4 ± 3.9	21	$62^\circ\!.6$	16.8 ± 3.7

From these preliminary results, it is obvious that the UK was, indeed, too far east to detect anything of the novel peak early on August 12 [4]. This is also borne out in results from A. Pace (Malta), and C. Durman, C. Osborne, and B. Ewen-Smith (COAA, Portugal). Activity close to the regular maximum on August 12-13 appears perfectly normal on the basis of these early results. Confirmation of this view again comes from Malta and Portugal.

Figure 1 presents global magnitude histograms for sporadics and Perseids over the interval August 1-2 to 17-18, inclusive.

The usual excess of bright Perseids relative to the contemporaneous sporadic background is evident. Numerous very bright events were reported on the nights close to maximum. Persistent trains were reported in association with 18.0% of the Perseid meteors, compared with 5.5% of the sporadic meteors.

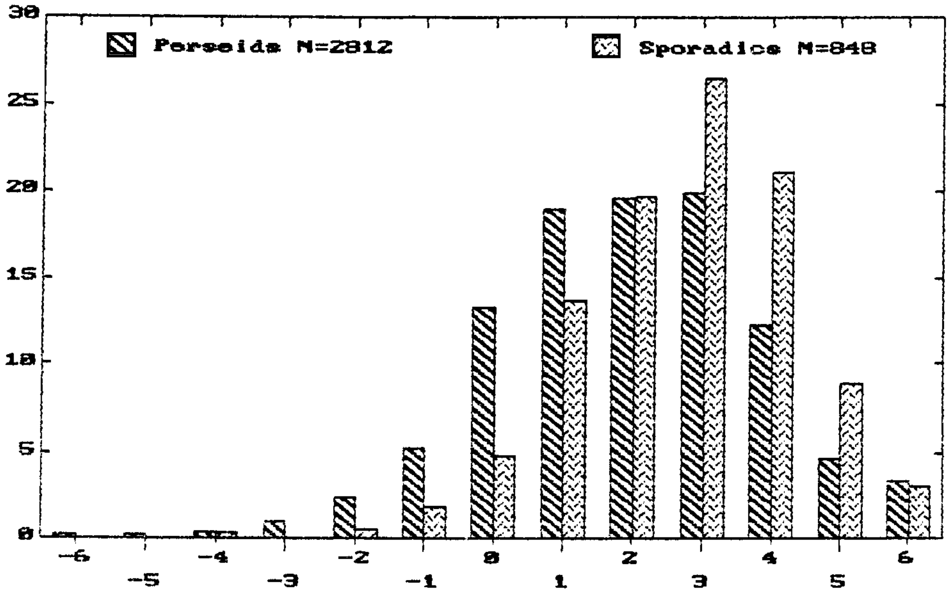

Figure 1 – *BAA* Perseid and sporadic overall percentage-wise magnitude distributions in 1994.

At the time of writing, reports continue to arrive in large numbers daily, and a full, formal analysis must wait until later in the fall. This highly preliminary report should, however, serve to provide an indication of activity on the night of the regular maximum, August 12-13. As always, thanks are due to all contributing observers.

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Photographs requested!

When meteor shower outbursts happen such as of the 1991, 1992, 1993, or 1994 Perseids, or the 1993 Orionids and the 1994 Leonids, we hear about a lot of bright fireballs that were seen and, in several instances, also photographed.

Yet, few photographs actually reach us. If you have a nice meteor photograph, please send it to us! While we cannot guarantee its publication—we have to take into account the extent to which the photograph is actually reproducible—it nevertheless has a great chance. At the same time, you help us avoid having to settle on lesser photographs to have at least something on the front cover!

The 1994 Perseids in Bulgaria

Ivanka Getsova

An overview is given of some Bulgarian observations of the 1994 Perseids around their maximum. No unusual activity was detected.

For a period of 5 days, between August 10 and August 15, Ivanka Getsova, Ivan Dimitrov, Ivelina Momcheva, Ivo Kavlakov, and Radostina Torova observed the activity of the Perseids from a place called Karandila. The observing site has the following coordinates: $\lambda = 22°22'$ E, $\varphi = 42°43'$ N and an altitude of 950 meter. It is situated north-east of Sliven.

The weather was unusually hot and the observing conditions very good with the exception of the night of August 12-13, when clouds appeared. The mean limiting magnitude was about 6 and the highest average values of the ZHR we observed on August 12-13 and August 13-14 were 61 ± 6 and 51 ± 5 respectively (see Table 1). We did not observe a particularly large number of bright meteors. Contrary to our expectations, the Perseids displayed no spectacular activity.

On the night of August 13-14, we were surprised by the Northern δ-Aquarids. During the period 20^h43^m–22^h57^m UT, five meteors of this stream were plotted by the author close to the radiant, and we were able to define the radiant as $\alpha = 337°$ and $\delta = -04.^\circ3$.

It seems that the expectations for unusually high activity had an emotional rather than a rational basis. The careful study of the facts for the Perseid activity during the period 1862–1863 [1,2] showed that an hourly rate of 250–300 was possible. These values were reached and even exceeded in 1991 and 1993. However, this negative result is valuable as well. According to Bronshten [3], contrary to the case of the Leonids, the Perseids do not have very dense meteor clouds. This means that the mass of the stream is distributed more or less evenly along its orbit. That is why we can suppose that the Perseids are an old meteor shower.

Table 1 – Bulgarian data on the 1994 Perseids.

$\lambda_\odot$ (2000.0)	Date (UT)	r	Lm	ZHR (avg)
$138.^\circ094$	10.86	1.9 ± 0.1	6.28	6 ± 1
$139.^\circ087$	11.93	2.1 ± 0.1	6.06	33 ± 2
$140.^\circ035$	12.92	2.1 ± 0.0	5.63	61 ± 6
$141.^\circ014$	13.94	2.4 ± 0.1	6.02	51 ± 5
$142.^\circ039$	15.17	2.5 ± 0.1	5.99	23 ± 1

References

[1] Kidger M., *WGN* 21:3, June 1993, p. 121.
[2] Olson D. and Doescher R., *WGN* 21:4, August 1993, p. 175.
[3] Bronshten V.A., "Meteors, meteorites, meteoroids", Moscow, 1987, p. 16.

Postscript by the editor

When the above article was sent to us, the author was not yet aware of the 1994 Perseid outburst witnessed from the western United States. This does not, of course, invalidate the conclusion that Perseid activity outside of this outburst was normal or even somewhat below average. I do want to caution, however, that it is very dangerous to generalize conclusions about a shower's performance based on observations from one particular place to the entire activity period of the shower.

The 1994 Perseids in Jordan

Khalil Konsul and Khalid Tell

An overview is given of Jordanian observations of the 1994 Perseids.

The *Jordanian Astronomical Society* (*JAS*), previously the *Jordanian Amateur Astronomers Society*, organized an observing camp devoted to the 1994 Perseids.

The camp was held from August 10 to 13, in the hart of the desert, near the Al-Azraq Oases, about 150 km south of the capital city of Amman. The coordinates of the observing cite are $\lambda = 37°06'50''$ E and $\varphi = 31°43'00''$ N.

The participants were as follows:

Khalil Konsul, Khalid Tell, Sana'a Abdoh, Marwan Shweiky, Ibrahim Faza', Keiss Omary, Leila Karaky, Mohamet Shaukat, Ahmad Sha'ir, Ma'mer Al-Hadidi, Ziad Al-Saleh, and Atif Al-Odwan.

The desert observing conditions provided spectacular Perseid shows. In total, 870 Perseids were recorded including 19 fireballs, one of which had magnitude −9. Two other fireballs produced drifting trains. Tables 1 and 2 summarize the observational data obtained.

Table 1 – Summarized rate data of the Jordanian observations of the 1994 Perseids.

Night	Period (UT)	T_{eff}	Lm	F	Per	Sport
Aug 10-11	21^h30^m–22^h00^m	0.50	6.5	1.00	17	3
	23^h00^m–01^h00^m	2.00	6.5	1.00	59	22
	01^h00^m–02^h00^m	1.00	6.5	1.00	30	7
Aug 11-12	20^h00^m–22^h00^m	2.00	6.5	1.00	43	76
	22^h00^m–24^h00^m	2.00	6.5	1.00	105	76
	00^h00^m–02^h00^m	2.00	6.5	1.00	111	81
Aug 12-13	19^h30^m–22^h00^m	2.50	6.5	1.00	141	50
	22^h00^m–24^h00^m	2.00	6.5	1.00	177	60
	00^h00^m–02^h00^m	2.00	6.5	1.00	187	35

Table 2 – Summarized Magnitude distributions of the 1994 Perseids and corresponding sporadics as seen from Jordan.

Night	Shower	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$
Aug 10-11	Per					2	5	8	15	26	18	19	12	1	106	2.4
	Spor					1	1	6	4	8	4	4	4	0	32	2.0
Aug 11-12	Per		3	1	1	5	4	14	25	41	48	46	40	31	259	3.0
	Spor		2	0	0	3	9	8	22	31	41	55	37	25	233	3.2
Aug 12-13	Per	3	1	10	15	12	27	49	65	88	79	78	60	16	505	2.0
	Spor	1	1	0	0	4	4	4	9	25	27	28	45	3	151	3.1

Postscript by the editor

I want to remind all observers that, for reasons of space-availability, we generally only publish summarized observational results in our Bimonthly Journal, *except when special phenomena such as activity outbursts occurred. Nevertheless, it is vital that all observers submit* individual data *to the Visual Commission Director for inclusion in the* Visual Meteor Data Base (VMDB). *These individual are also published annually in the* Report Series.

Ongoing Meteor Work

The Makings of Meteor Astronomy: Part VIII

Martin Beech, University of Western Ontario

Ernst Chladni (1756–1827) is often considered to be the father of modern meteor astronomy. While his thesis of 1794 offered no essentially new or innovative ideas it did break important ground in showing the clear inadequacies of the then accepted model of fireball origins.

1. The importance of questioning

Ernst Florens Friedrich Chladni was a remarkable man. While he is most often remembered for his contributions to meteoritical science, Chladni also made fundamental contributions to the (then new) science of acoustics. Chladni is further credited with the invention of that most marvelous of instruments, the euphonium, or tenor tuba.

While it seems that Chladni was recognized as *a good man of science* [1], he was never able to secure a permanent university position. Instead, to make a living, he toured between university towns, where he gave public lectures on acoustics and general science.

The idea that Chladni might investigate the appearance and nature of fireballs arose from discussions, held in 1792-1793, between Chladni and George Lichtenberg. Lichtenberg was then professor of physics at the University of Göttingen. It appears that Chladni's interest in fireballs was peaked through a comment made by Lichtenberg in a lecture on meteoric phenomena. In particular Chladni quizzed Lichtenberg on why he described fireballs as being electrical phenomena. As we saw last time [2], Charles Blagden had championed (in 1783) the idea that fireballs were produced by the movement of *electrical fluids*. Chladni argued, however, that was it not surprising that electricity should be invoked to explain such bright phenomena, given the great height at which the fireballs were observed to occur; the "air" at such heights being so extremely rarefied. Lichtenberg was forced to agree with Chladni, and Chladni later wrote that *Lichtenberg replied that he and other physicists talked in terms of electric meteors because of the similarity between electrical flashes and meteors, but in truth they did not know what to make of them.* [1]

Chladni's work on fireballs and (what we call) meteorites was initiated by asking simple questions. He questioned the explanation of fireballs being electrical, and he questioned whether there were any connection between the falling of stone and iron masses from the sky and the appearance of fireballs. In order to answer such questions he scoured the Göttingen library, and later many other university libraries, for accounts of fireballs. He very quickly came to a series of conclusions that were far-reaching in their extent, and in 1794 published a book under the long title, *Concerning the Origin of the Mass of Iron Discovered by Pallas and Others similar to it, and Concerning a few Natural Phenomena Connected therewith.*

What Chladni had done was to collect as many eye-witness accounts of fireballs as he could find. He also examined the records that described the appearance and chemistry of various stones and irons which had supposedly fallen from the sky. From his researches Chladni essentially drew four conclusions:

1. masses do fall from the sky;
2. the appearance and chemistry of such masses (especially the iron ones) were very similar;
3. when masses fell from the sky they were always accompanied by accounts of fireballs; and
4. the masses could not be terrestrial in origin.

As is often the case with books that run counter to the main stream, Chladni's work was essentially greeted with stalwart silence. Indeed, writing 3 years after the publication of his book, Chladni commented, *I hesitated whether I should publish it, because I expected that it would meet with considerable opposition* [3].

It is interesting to make note of the fact that none of the conclusions presented by Chladni in his book were original to him. Many previous researchers had concluded that stones fell from the sky, still more had argued that such stones and irons had similar appearances and others, as we have seen in previous essays, had suggested that fireballs had a non-terrestrial origin. Chladni, however, was the first person to really pull all the evidence together. Even though Chladni presented a coherent string of arguments, linking the appearance of fireballs with the fall of objects from the sky, it was to take the best part of another fifty years to convince the scientific community, as a whole, that such objects actually came from cosmic space.

2. Eliminating the impossible

One of the first review's of Chladni's book was that published in the then newly established *Philosophical Magazine*. Edited by Alexander Tilloch, the magazine first appeared in 1798, and was intended to inspire the diffusion of *philosophical knowledge among every class of society, and to give the public as early an account as possible of everything new or curious in the scientific world.* The very first issue of the magazine carried an article entitled *An Account of Two Singular Meteors* [4]. This article is particularly interesting for what it implies about the general state of knowledge (in Great Britain at least) concerning meteors in the late 1790s. Firstly, one of the "meteors" referred to was in fact a parhelic display i.e., the word "meteor" as we know it had not been established prior to 1798, and secondly as to the origin of the fireball (that of March 8, 1798), Tilloch commented, *the common cause of these phenomena appears to be hydrogenous gas, set on fire, by some means, in the atmosphere.* Clearly, at this time Tilloch believed in an Aristotelean explanation for fireballs.

In spite of poor beginnings, in the sense of not presenting that which is new, the *Philosophical Magazine* came right-up to date in its second volume. In this volume, Tilloch gave a generally favorable review to Chladni's (1794) book, and he outlined in some detail many of Chladni's arguments. (Tilloch's comments are particularly useful today since the *Philosophical Magazine* is more generally available than Chladni's original text). Tilloch comments of Chladni's main conclusions:

> *The mass* [i.e., the meteorite found by Pallas] *could not have been produced by art, the burning of a forest, by lightning, or by volcanic eruption. It appears to him* [Chladni] *much more probable that it is of the same nature as the so called fire-balls (bolides) or flying dragons, and he quotes a variety of observations made of these phenomena; from which he endeavors to prove that they do not arise from an accumulation of the matter of the aurora borealis; a transition of electricity from one part of the atmosphere to another* [this is Blagden's model]*; an accumulation of porous inflammable substances in the higher regions, or the catching fire of a long train of inflammable air* [this is the Aristotelean model]*; but that the component parts must be considered dense and heavy, as their course shows in so apparent a manner the effects of gravity; and because the mass, though it distends to a monstrous size, retains sufficient consistency and weight to continue an exceedingly rapid movement through a very large space; without being decomposed or dissolved, not withstanding the resistance of the atmosphere.*

As we argued above, Chladni was not stepping very far from the main stream by making the claim that the fall of stones and irons (i.e., meteorites) is always accompanied by the appearance of a fireball. He did step out of the main stream, however, by asserting that the stones and irons were not formed in the Earth's atmosphere, but were objects that belonged to cosmic space. Tilloch summarizes Chladni's thoughts as follows:

> *There may be dense matters accumulated in smaller masses without being in immediate connection with larger planetary bodies, dispersed throughout infinite space* [this is similar to what Edmund Halley had said in 1714]*, and which being impelled either by some projecting power or attraction, continue to move until they approach the earth or some other body* [here is the realization that other planets will be struck by meteoritic masses]*; when being overcome by their attractive force, they immediately fall down.*

As to the manner in which Chladni believed that fireballs and the lesser shooting stars were formed, Tilloch explains,

> *By their exceedingly great velocity, still increased by the attraction of the Earth and the violent friction in the atmosphere, a strong electricity and heat must necessarily be excited, by which means they are reduced to a flaming and melted condition, and great quantities of vapor and different kinds of gases are thus disengaged, which distend the liquid mass to a monstrous size, till, by a still farther expansion of these elastic fluids, they must at length burst. Mr. Chladni thinks also that the greater part of the shooting-stars as they are called, are nothing else than fire-balls, which differ from the latter only in this, that their peculiarly great velocity carries them past the earth at a greater distance, so they are not so strongly attracted by it as to fall down, and therefore in their passage through the higher regions of the atmosphere, occasion only a transient electric flash, or actually take fire for a moment, and are again speedily extinguished, when they get to such a distance from the earth that the air becomes too much rarefied for the existence of fire.*

Several interesting points are apparent from Chladni's ideas on the origin and formation of fireballs.

The extra-terrestrial origin argument is reminiscent of that given, almost a century earlier, by Halley [5], and we can see that Chladni is offering nothing new in his explanation for the appearance of fireballs and shooting stars. Indeed, Chladni is essentially offering the very same argument that he had quizzed Lichtenberg over at the outset of his studies.

The argument concerning shooting stars is interesting since it is clearly based upon the observational fact that they (typically) have greater apparent velocities than fireballs.

While we have seen that Chladni's thesis is not essentially original, it does offer a coherent picture of the connection between the appearance of fireballs and the fall of stones and irons. Writing some 4 years after the publication of his book (in 1798), Chladni commented upon the general reception of his ideas. Again, a translation of Chladni's remarks are given in the *Philosophical Magazine* [6]. Chladni noted,

> *I have given a kind of explanation, which, however, romantic it may seem, yet agrees better, in my opinion, with the facts hitherto observed than any other, and is contrary to no laws of nature hitherto known. Some critics, as well as others, have ridiculed my singular hypothesis* [this is a rather grand claim]*, or condemned it altogether, but no one has yet confuted my principles, or given any other explanation that corresponds as well with facts... This much, at any rate, is proved, that all the phenomena which accompany fireballs, as well as the falling of masses... observed at the same time, cannot be explained from the accumulations in the upper regions of the atmosphere.*

Chladni may have not introduced new and novel arguments to explain the appearance of fireballs and (what we call) meteorites, but his contribution was truly important in that it clearly highlighted the inadequacies of the then accepted ideas.

By collecting together detailed eye-witness accounts of several stone and iron falls, and many fireball observations, Chladni was able to show a clear connection between the two phenomena. He was also able to demonstrate the clear weakness in the arguments that supposed the stone and iron masses formed in the Earth's upper atmosphere.

As to the extra-terrestrial origin of the fireball producing masses, by discrediting all the previously offered arguments, Chladni's ultimate thesis was based upon the maxim expounded (much later in the 19th century) by Conan Doyle's Sherlock Holmes, *when you have eliminated the impossible, whatever remains, however improbable, must be the truth.*

3. Next time

During the early years of the 19th century, Chladni, just as Halley and done one hundred years before him [5], wavered in his resolve, and at a one stage he even suggested that there may be two kinds of meteor, with one kind of meteor being formed in the Earth's atmosphere. We shall address these issues and describe a few of competitive meteor models next time.

References

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[2] M. Beech, *WGN* 22:4, October 1994.
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[4] A. Tilloch, *Philosophical Magazine* 1, 1798, p. 66.
[5] M. Beech, *WGN* 21:6, December 1993.
[6] A. Tilloch, *Philosophical Magazine* 2, 1798, p. 225.

Chladni and the Cosmic Origin of Fireballs and Meteorites

Two Hundred Years of Meteor Astronomy and Meteorite Science

André Knöfel and Jürgen Rendtel

The present article highlights the contributions by Chladni to the birth of modern meteor astronomy and meteorite science.

1. Introduction

The year 1794 may be regarded as the year of the birth of modern meteor astronomy and meteorite science. In April 1794, Ernst Friedrich Florens Chladni published the book entitled *Über den kosmischen Ursprung des Pallas-Eisens und anderer, ähnlicher Eisenmassen und einige damit in Verbindung stehende Naturerscheinungen* (On the origin of the irons found by Pallas and other, similar irons, and on some related natural phenomena). Chladni discussed the cosmic origin of meteorites and developed a connection to fireballs and meteors.

It was known for ages that stones may fall from heaven, for example the fall in the Albany mountains near Rome, Italy, in 625 BC, and the fall of Aigospotamoi in Thrakia at the Egos river, Greece, 465 BC. However, science at the end of the 18th century regarded the possibility of stones falling from the sky as unlikely.

2. Chladni's life

Ernst Friedrich Florens Chladni was born on November 30, 1756, in Wittenberg, Germany. He became interested in geographical and astronomical topics early in life. However, his father wanted him to study law. So, Chladni studied in Wittenberg and Leipzig, and he finished his studies with theses in philosophy and law. When his father died, Chladni decided to pursue his interest in natural sciences.

He gave lectures about natural sciences and mathematics at the University of Wittenberg. Because of the small salary, he tried to earn money by inventing and discoveries. He dealt much with acoustics. For example, Chladni's "Klangfiguren" (sound figures) are well known. The idea of visualizing oscillations by placing fine grain sand on a plate was generated from another (electrostatic) experiment done by Georg Christoph Lichtenberg (1742–1799). Lichtenberg produced a device to form electric discharges. He made these visible by putting resin dust on the carrier of the electric charges. Chladni also developed music instruments which he presented at lectures on his journeys throughout Europe.

In this way, he was able to access the libraries of several European universities, and furthermore meet leading scientists. One of the topics he discussed was the nature of fireballs. There was no satisfying explanation available for these events at that time. Chladni started to study the literature on the topic in 1793, and published his proposed solution to these phenomena in April 1794 in Leipzig and Riga (Latvia) simultaneously.

After this time, Chladni used his journeys to gather further information on fireballs and meteorite falls from various sources. He organized his itineraries around the study of unrecognized meteorites. Chladni published his documentation on fireballs and meteorite falls in 1819 in Vienna under the title *Über Feuermeteore und die mit ihnen herabgefallenen Massen* (On fiery meteors and the accompanying fallen masses).

Over the course of the years, Chladni gathered a substantial number of meteorite samples by exchange or as gifts. He determined that this collection should be given to the Mineralogical Museum of the Berlin University. The collection still exists in the Museum of Natural History of the Humboldt University in Berlin, and part of it can be visited in an exhibition about meteorites.

3. Chladni's book of 1794

As already mentioned, in the late 18th Century meteors were regarded as "airy dusts" which occasionally ignite, or which appear bright. Among many other sources, Chladni's book was based on discussions with Lichtenberg who accepted the standard point of view. When Chladni searched for the origin of fireballs, however, he recognized that he had to include the fallen stones in his investigation. His primary hypothesis, namely the connection of these two kinds of events, was entirely different from all other authors at the time. First, Chladni investigated observations and descriptions of fireball-like events which he had collected during his literature searches. Next, he removed all phenomena which were probably not related to fireballs (e.g., flashes). His definition of a fireball reads as follows:

> *A fireball is a rare phenomenon which starts like a bright star or a falling star at a large altitude and then rapidly moves downwards on a tilted trajectory, occasionally exceeding the Moon's brightness, often accompanied with flames, smoke, and sparks, and finally disrupts with intense sounds.*

This description sounds quite familiar to us now. Of course, some conclusions are uncertain or misinterpretations. His criteria concerning the size (brightness) of fireballs are too restrictive. Chladni himself commented that the descriptions may be very uncertain because of the short duration of the phenomena. The sounds were thought to be caused by the break-up of the meteoroid—supersonic effects were not discovered until later. Nevertheless, his book is the culmination of a serious literature search and a rigorously performed scientific analysis.

In Chapter 4 of his book, Chladni compared previous attempts to situate the origin of meteorites in interplanetary space. He favored the theories of Maskelyne (dense objects orbiting around the Sun), of Hevel, Wallis, and Hartsoeker (comet-like objects), and Halley (matter which is scattered over the "ordinary space"). In the next chapter, Chladni concluded that fireballs originate from outer space, and therefore move at high velocities. They should consist of heavy, dense materials. The light emission he assumed to be a result of conversion of frictional deceleration in the atmosphere into heat and "electricity."

Chladni was not sure about the origin of ordinary shooting stars. He suspected them to be quite similar to the fireballs, but passing the Earth at larger distances.

We have to bear in mind that the double-station meteor observations of Brandes and Benzenberg were carried out only 4 years later. Between September 11 and November 4, the two students found 22 common meteors of 402 observed from both sites near Göttingen, Germany. The heights derived from these observations proved Chladni's assumptions for normal meteors.

Chladni, however, had only descriptions of fireballs observed from several sites by eyewitnesses at hand.

Chladni found 16 events which clearly described meteorites falling after a fireball had been observed. Seven of these meteorites still exist today: Ensisheim, Ploschkowitz, Hraschina, Tábor, Albareto, Lucé, and Eichstädt.

When he compared the descriptions of meteorites, he found that most of these consisted of pure iron and showed a melt crust (he called it "Eisenrinde"). He searched further for similar specimens. Later, he found more meteorites being related to fireballs, for example the 15-ton Campo del Cielo in Argentina and the unusual "Pallas iron" from Krasnoyarsk in Siberia (800 kg). It should be noted that Chladni had seen pieces of the Pallas-iron directly, while he knew all other irons only from descriptions. Next, Chladni concluded that these meteorites could not be explained by assuming a terrestrial origin. In the vicinity of the fall locations, there was no volcanism, and also no ore melting took place in these areas. The shape and constitution also led Chladni to the assumption that they were of extra-terrestrial origin.

The last chapter contains a program for the ongoing research which Chladni tried to realize during his life. Before this, Chladni summarized his theory. He concluded that the iron rocks, fireballs, falling stars, and the stones fallen after fireballs are closely related. He also concluded that some large heavenly bodies much consist of heavy material. This was a daring statement at that time! Only stars, planets, and moons were accepted as existing in space. Chladni also suspected the existence of forces able to create or disrupt objects. The creation he assumed to be caused by the agglomeration of smaller pieces, or by the disruption of a huge mass. Furthermore, Chladni explained that leftover fragments from such a process could collide with created objects if the former are caught by the latters attraction. Because most of the meteorites found consist of iron, Chladni assumed that iron is the major constituent of the planets, and also that the Earth should contain a large portion of iron in its interior.

4. Reactions to Chladni's book

When Chladni's book was published in 1794, almost all scientists denied Chladni's theory. Even Lichtenberg said that *he felt like he had been hit by such a stone* when he read the book. Members of the *Academie Française* attacked Chladni. J.A. Deluc stated that even if a stone would fall before his feet and he witnessed this, he would not believe it. His brother, G.A. Deluc, said that Chladni belongs to those who deny every world order and do not think to which extent they are guilty for *all evils of the world.*

The first scientists who accepted Chladni's theory were the astronomers Franz Xaver Zach and Wilhelm Olbers, and the geologist A.G. Werner. On April 26, 1803, an event occurred which helped supported Chladni's view: in L'Aigle near Paris, 2000–3000 stones fell after a fireball was seen. The stones were spread over an area of 4.5 km $\times$ 11 km. This exciting meteorite fall was investigated by J.B. Biot for the *Academie Française*. Eventually he confirmed that this was a meteoritic event. After this, the number of scientists accepting Chladni's theory increased.

Furthermore, the minor planets Ceres, Pallas, Juno, and Vesta were discovered between 1801 and 1807 by Piazzi, Olbers, and Harding. The existence of these objects also strongly supported Chladni's assumptions. They proved that there are indeed smaller objects in space. It took about 15 years until Chladni's theory was accepted by most of the scientists, and thus Chladni stated in his 1819 publication that those who are not convinced yet by the facts should stay with their obsession.

The September α-Triangulid Shower: Recent Telescopic Results

Malcolm J. Currie

I present an analysis of telescopic observations made during 1994 mid-September that confirms the existence of a weak shower radiating from near α Trianguli. Rates are only about 0.1 of the concurrent sporadic activity between September 8 and 10. On the night of the maximum—September 12—the rate tripled. The full-width half-maximum radiant size is approximately 2°5. Radiant motion is clearly evident and is estimated at $\Delta\alpha = +1.5 \pm 0.2$, $\Delta\delta = +0.4 \pm 0.2$ per day. The angular speed of the meteors suggests $V_\infty \approx 30$ km/s. I suggest reasons why the shower is difficult to observe that may explain the variance of the visual observations.

1. Introduction

Gary Kronk reported [1] that there may be a minor shower present around $\lambda_\odot = 169.5$ based on his own observations and others he compiled. The shower comprised slow meteors of mostly magnitudes +3 to +5 seen in the vicinity of the radiant at $\alpha \approx 30°$, $\delta \approx +29°$. Trawls through the archives produced no matching photographic orbits, but the database of orbits from 1960s radio-echo surveys (favoring faint meteors) revealed there was an α-Triangulid shower that best matches the visual observations. There has been some skepticism, as to whether this shower exists or not; some experienced observers failed to see any α-Triangulid meteors this year, while others have seen some. [2] Jürgen Rendtel finds no evidence for this shower in his 1992 and 1993 data. [3] Radio observations, which generally detect meteors corresponding to faint visual or telescopic magnitudes, made by Maurice De Meyere, also recorded a sharp enhancement to meteor rates around the time some visual observers noted a possible shower. [4] In this article, I report on my own findings for 1994.

2. Observations

All the observations reported here were made with a 127-mm refractor at 19.5 times magnification with a 2°6 field of view from Grove, Oxfordshire, UK ($\lambda = 1°26'$ W, $\varphi = +51°37'$). The main goal of the observations was to study the showers emanating from Auriga, Perseus, and Cassiopeia; however, some of the field centers were also well-placed to search for the putative α-Triangulid shower. On September 12-13, I selected an additional field—no. 139—for the α-Triangulids. Table 1 lists the charts used and their positions. All meteor paths were plotted in the usual way and speeds estimated to the nearest of six bins. The distances from the alleged radiant varied from approximately 15° to 50°.

Table 1 – The field centers used on each night. A number in parentheses gives the number of watches with the field if it was more than one.

Chart No.	Center α	Center δ	Night(s) used (September)
17	02^h02^m	+65°	8-9, 9-10, 10-11 (2), 12-13
19	05^h04^m	+63°	9-10, 10-11
36	01^h52^m	+56°	8-9, 10-11, 12-13
37	03^h28^m	+59°	8-9, 9-10, 10-11, 12-13
49	00^h56^m	+47°	8-9, 9-10, 10-11, 12-13 (2)
50	01^h38^m	+48°	10-11, 12-13
75	02^h56^m	+38°5	8-9, 9-10, 10-11, 12-13
76	03^h52^m	+34°	8-9, 9-10, 10-11, 12-13
139	01^h38^m	+08°	12-13

The journal of observations is presented in Table 2. I watched for 3.85 hours divided evenly on the earlier nights 4-5, 5-6, and 6-7 under similar or slightly worse conditions, totaling 64 meteors; there was no evidence of an α-Triangulid shower at these epochs, and hence these are omitted. Watches were made through most of the night (mean time around 0^h40^m), except on 9-10 where only the second half was clear, and 16-17 was during the last two hours of the night. For rapid analysis and publication, I made simple prolongations on *Atlas Brno* chart 1. To make Triangulid shower assignments, I considered the orientation, angular speed, and, for bright (brighter than +8) meteors, the path length. The quantity "Tri" is the number of probable α-Triangulid meteors, and "Other" is the total number of other meteors, of which approximately two-thirds are sporadic meteors. The half meteors are for possible shower members (where the shower-assignment criteria did not yield an unequivocal result, for instance due to uncertainty in the radiant diameter). The 14.5 α-Triangulid meteors on 12-13 include three possible members. The typical field limiting magnitude was +12.8, so that the reader may gauge the quality of the night, Table 2 includes the average naked-eye limiting magnitude ($\overline{\mathrm{Lm}}$).

The radiant positions presented in Table 2 are uncorrected for zenithal attraction. The right ascensions of the radiant were not as well determined as the declinations because of the selection of field centers, and the α-Triangulids appeared less frequently in the fields to the north of the radiant, as opposed to those to the east and north-east. In future years, we should have another field around π Andromedae (chart 73). The positions are quoted to the nearest $0\overset{\circ}{.}5$ in each coordinate, except for 8-9, where it is estimated to the nearest degree. This is all that the data warrant; it should not be regarded as the accuracy of the coordinates, which is hard to estimate given the small numbers of meteors and the analogue graphical reduction method. The accuracy is likely to be worse. A ball-park figure comes from assuming a Gaussian radiant, and dividing its radius by the square root of the number of observations. This gives values of $0\overset{\circ}{.}6$, $0\overset{\circ}{.}5$, and $0\overset{\circ}{.}4$ for 9-10, 10-11, and 12-13, respectively. Even with these uncertainties, a clear radiant motion is apparent and is approximately $\Delta\alpha = +1\overset{\circ}{.}5 \pm 0.2$, $\Delta\delta = +0\overset{\circ}{.}4 \pm 0.2$ per day. This motion in right ascension is higher than any shower in the *IMO* working list of visual showers though the error can easily account for that. (A proper RADIANT analysis is planned once the data are measured and entered into PosDAT format.)

Table 2 – The journal of telescopic observations, and the number of probable α-Triangulids and their mean radiant position. See the text for the precision of these values.

Date (Sep)	$\overline{\lambda_\odot}$ (2000.0)	Tri	Other	T_{eff}	$\overline{\mathrm{Lm}}$	Radiant (2000.0) α	δ
08–09	$166\overset{\circ}{.}1$	3	58	3.38	+6.5	25°	+27°
09–10	$167\overset{\circ}{.}2$	5	63	3.11	+6.6	26°	+28°
10–11	$168\overset{\circ}{.}1$	7	61	5.05	+6.45	$27\overset{\circ}{.}5$	$+28\overset{\circ}{.}5$
12–13	$170\overset{\circ}{.}1$	14.5	68.5	4.25	+6.6	$30\overset{\circ}{.}5$	+29°
16–17	$174\overset{\circ}{.}1$	1.5	21.5	1.28	+6.55		
Total		31	272	17.07	+6.55		

On September 10-11, the apparent radiant diameter was about $2\overset{\circ}{.}5$, but five of the meteors intersected within an area less than $0\overset{\circ}{.}5$ across. This does not imply that the radiant was actually that compact; however, such a concentration would be unlikely to arise due to chance. The diameter was 5° on 12-13, but with a full-width half-maximum of also around $2\overset{\circ}{.}5$. These dimensions take no account of the plotting errors. Figure 1 shows the prolongated trails in the Triangulum region on September 12-13 for those that come within 10° of the radiant region. The meteors seen from chart 139 have data-reduction plotting errors because the field center lies beyond the *Atlas Brno* chart, and so should be accorded lower weight.

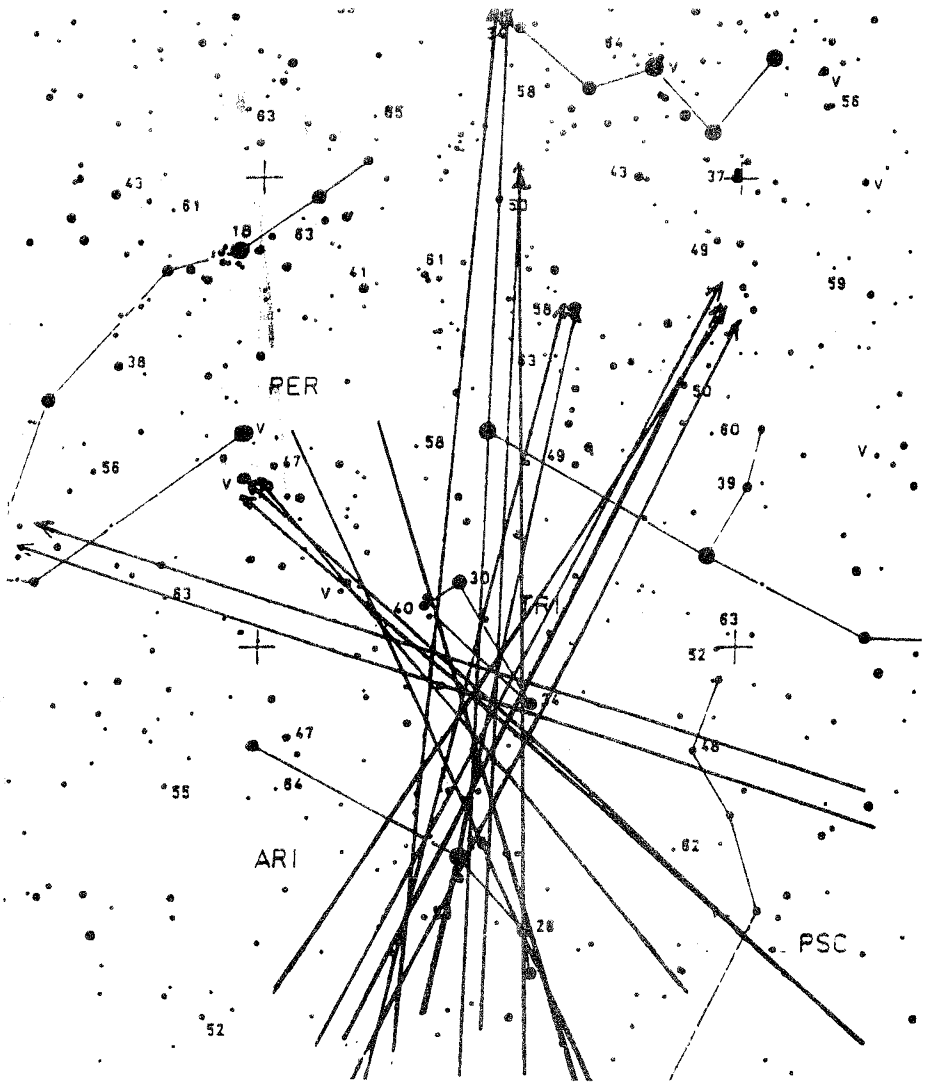

Figure 1 – Prolongated trails in the Triangulum region on September 12-13 for those that come within 10° of the radiant region.

Table 3 presents the magnitude distributions. I should compare the α-Triangulid distribution with that of the sporadics, but this must wait until I have identified the meteors from other showers. The α-Triangulids appear to be deficient compared with the other meteors faintward of $+9.5$. However, it should be noted that these are just the apparent magnitudes with no correction for the angular speed. Increasing angular speed reduces the apparent brightness. So although the α-Triangulid distribution has a brighter average magnitude than the other meteors, the sporadics and the Aurigid showers have higher average speeds. A back-of-the-envelope calculation using Znojil's formula [5] indicates that at least half of the difference is due to this speed-induced dimming. Given the low numbers of α-Triangulid meteors, I do not expect to see anything statistically meaningful. Ignoring the speed correction, the difference is not even a 2-σ result.

Table 3 – The apparent magnitude distributions of α-Triangulids and other meteors, September 8-9 to 16-17.

Shower	4.0	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	$\overline{m}$
α-Tri	1	1		1				1	3	4.5	4.5	6	5	2.5	1.5	9.32
Other	1	1	1	1	2	4	5	7	12	20.5	33.5	57	83	61.5	12.5	10.00

In general, the α-Triangulid meteors had medium or medium-slow speeds, as also found by Kronk. [1] Judging by the angular speed converted to degrees per second, the distance from the radiant and using the familiar table of angular velocity for different geocentric velocities and geometries, I conclude that $V_\infty \approx 30$ km/s. This could easily be 10 km/s in error. Using RADIANT, I should be able to derive a better estimate.

3. Discussion

There is strong support for an α-Triangulid shower on September 12-13. Within a quadrant centered in the middle of the observed fields 20° north of the α-Triangulid radiant oriented with the radiant at 45°, there were 28 meteors on September 12-13, of which more than half appeared to be α-Triangulids. Some of the remainder looks to be Southern Piscids. Thus it looks extremely unlikely to be a chance concentration of sporadic meteors, and it stands out from the background noise more clearly than the southern component of the δ-Aurigids.

The activity is barely detectable away from 12-13. Indeed, on their own, few would believe that there was a shower between September 8 and 11. However, the tightness of the radiant on 10-11 and the radiant motion support the notion that the shower persists feebly for about a week or so, but only gives significant activity within a day of its maximum. The mean period for my 12-13 observations was 13 hours later than the peak seen in 1993. The ZHRs for visual observers would be 1–2 away from maximum. Such a rate is undetectable by visual methods [6], especially if most observers are concentrating on the δ-Aurigids and therefore looking perhaps over 50° away from the radiant, where the angular speed of the α-Triangulids would be fast, indeed faster than that of the δ-Aurigids. If the α-Triangulids are predominantly faint visual meteors, the fall-off in their perception would be further excerbated. Poor sky conditions would also reduce the detection rate. Therefore, it is quite plausible that even experienced visual observers may have missed this shower, even close to its maximum if the skies were not near optimum.

Kronk [1] searched the archives and found several radiants from Hoffmeister [7] and the records of the *American Meteor Society*. These indicate α-Triangulid activity between $\lambda_\odot \approx 163°$ and 172°, which is in broad agreement with my observations.

For future work, I intend to look through observations made in earlier years for confirmation of this shower, and to see if there is any periodicity. The orbital period is such that, if there were periodic behavior, it would be most active about every eight years. The exact figure depends critically on the second decimal of the period. The observations reported so far do not disprove this hypothesis, though it is unfortunate that the radio surveys had a gap between 1965 and 1968. [1] As the flux is near the limit of detection, only a weak concentration might explain why the shower has only been seen occasionally. However, speculating even a weak periodicity is most likely an over-interpretation of limited data; from a theoretical standpoint, it seems unlikely that a concentration of meteoroids could persist given that particles have probably made over one hundred revolutions around a small orbit. Continuous radio observations using the same configuration and set-up over several years looks to be the best way to look for any periodicity. Video and telescopic observations will also be needed.

The Telescopic Commission welcomes further observational reports from this period of the year, and especially those from this year.

4. References

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On a Possible Outburst of the 1994 α-Aurigids

George Zay and Robert Lunsford

Occasional outbursts of the α-Aurigids have been reported in the past, namely in 1935 and 1986. This not too regularly observed shower may have had more frequent outbursts that have gone unnoticed due to a relatively short peak. The 1994 α-Aurigids may have produced a small outburst for two observers in Southern California. This is a report of their observations.

1. Introduction

Two experienced meteor observers teamed up for a continuous 5-day α-Aurigid vigil from their prime observing site in Descanso, California, USA ($\lambda = 116°38'13''$ W, $\varphi = 32°50'00''$ N, $h =$ 1003 m). The two-man team was made up by Robert Lunsford (`LUNRO`) and George Zay (`ZAYGE`). Each observer faced a slightly different direction when observing together.

2. Visual α-Aurigid results

Except for a 55 minute period on the night of August 31-September 1, the 1994 α-Aurigids were relatively quiet. On all 5 nights, the skies were clear and the Moon was primarily in the waning stages. Observations began on August 29-30 and ended on the night of September 2-3. A total of 37.06 hours of effective observing netted 366 meteors (53 α-Aurigids). The night of August 31-September 1 was a peak day, with 17 α-Aurigids observed by Robert Lunsford and 20 by George Zay. The number of α-Aurigids observed on the other nights was never higher than 7. More specifically, a peak of 11 (`LUNRO`) or 13 (`ZAYGE`) α-Aurigids was noted between 7^h22^m UT and 8^h22^m UT on August 31-September 1. During other one-hour periods on that night, α-Aurigid rates never got higher than 3. Tables 1–4 give some details.

Table 1 – 1994 α-Aurigid rate data summary.

Date	Obs	T_{eff}	$\overline{\text{Lm}}$	α-Aur	Spor
Aug 29-30	LUNRO	3.25	6.42	2	34
Aug 30-31	LUNRO	3.33	6.38	2	24
Aug 31-01	LUNRO	5.49	6.67	17	62
Aug 31-01	ZAYGE	8.39	5.58	20	65
Sep 01-02	ZAYGE	8.39	5.61	7	59
Sep 02-03	ZAUGE	8.21	5.67	5	67

Table 2 – 1994 α-Aurigid magnitude distributions.

Date	Obs	Shower	−3	−2	−1	0	+1	+2	3	+4	+5	Tot	$\overline{m}$
Aug 29-30	LUNRO	α-Aur					1		1			2	2.00
Aug 29-30	LUNRO	Spor	1			3	7	10	7	4	3	35	2.17
Aug 30-31	LUNRO	α-Aur				1	1					2	0.50
Aug 30-31	LUNRO	Spor				1	4	8	5	6		24	2.46
Aug 31-01	LUNRO	α-Aur		1		1	8	6	2			17	1.53
Aug 31-01	LUNRO	Spor	1	1		3	3	18	24	10	2	62	2.52
Aug 31-01	ZAYGE	α-Aur		1		1	9	3	3	2	1	20	1.75
Aug 31-01	ZAYGE	Spor	1		2	6	5	16	21	8	6	65	2.38
Sep 01-02	ZAYGE	α-Aur					1	4		2		7	2.43
Sep 01-02	ZAYGE	Spor				3	9	17	11	13	4	59	2.51
Sep 02-03	ZAYGE	α-Aur					2		1	1	1	5	2.80
Sep 02-03	ZAYGE	Spor		1		2	10	23	18	9	3	67	2.37

Table 3 – 1994 α-Aurigid hourly rate data on the maximum night of August 31-September 1.

Period (UT)	Obs	T_{eff}	$\overline{\text{Lm}}$	α-Aur	Spor	$\overline{m}_{\alpha\text{-Aur}}$	$\overline{m}_{\text{Spor}}$
03^h12^m–04^h18^m	ZAYGE	1.01	5.56	0	7		2.57
04^h19^m–05^h19^m	ZAYGE	0.93	5.70	0	6		2.50
05^h20^m–06^h20^m	ZAYGE	0.90	5.70	0	8		2.25
06^h21^m–07^h21^m	LUNRO	0.78	6.85	0	12		2.08
06^h21^m–07^h21^m	ZAYGE	0.92	5.70	0	7		2.43
07^h22^m–08^h22^m	LUNRO	0.91	6.87	11	9	1.27	3.00
07^h22^m–08^h22^m	ZAYGE	0.90	5.70	13	7	1.00	2.71
08^h23^m–09^h23^m	LUNRO	0.95	6.86	3	8	2.33	2.00
08^h23^m–09^h23^m	ZAYGE	0.91	5.70	2	10	3.50	1.90
09^h24^m–10^h24^m	LUNRO	0.95	6.80	0	13		2.54
09^h24^m–10^h24^m	ZAYGE	0.96	5.70	0	10		2.50
10^h25^m–11^h25^m	LUNRO	0.92	6.58	2	7	1.50	2.69
10^h25^m–11^h25^m	ZAYGE	0.93	5.56	3	4	3.66	2.66
11^h26^m–12^h24^m	LUNRO	0.95	6.04	2	7	1.50	2.71
11^h26^m–12^h24^m	LUNRO	0.91	5.34	2	4	2.00	2.00

Table 4 – 1994 α-Aurigid magnitude distributions on the maximum night of August 31-September 1.

Obs	$\overline{\text{Lm}}$	Shower	−3	−2	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}$
ZAYGE	5.70	α-Aur		1		1	8	2	1			13	1.00
ZAYGE	5.70	Spor	1					1	1	3	1	7	2.71
LUNRO	6.87	α-Aur				1	7	2	1			11	1.27
LUNRO	6.87	Spor	1						3	4	1	9	2.45

3. The α-Aurigid maximum night results

As already noted in the previous section, the period between 7^h22^m and 8^h22^m UT on August 31-September 1 displays a sudden increase in α-Aurigids. Also, the mean magnitude of the α-Aurigids during this period is 1.13, whereas the mean magnitude for the whole night is 1.55. (The mean magnitude for the whole period is 1.83.) This means that there were more bright meteors during the peak period. The train percentage for α-Aurigids brighter than magnitude +3 is about 70%, which is very high. Presumably, this is a reflection upon the number of bright meteors over dimmer ones. This is probably an indicator of an older and differentiated stream as much as that of the mean magnitudes [2].

4. The α-Aurigid results between 7^h22^m and 8^h22^m UT

The most striking feature is the cluster of α-Aurigid meteors of first magnitude and the relative absence of dimmer shower members from both observers (see Table 4). The most active period with its predominant bright meteors started at 7^h27^m UT with a first magnitude meteor and ended at 8^h17^m UT, also with a meteor of the first magnitude, thus lasting only 50 minutes. Also, during this time, the count could have easily been 15 for Zay, for while looking down to record data, Lunsford could be overheard announcing two additional α-Aurigids that would have most likely been noticed by Zay also... but that is the game. Nearly every meteor of magnitude +2 or brighter produced trains. This is not really a surprise when you take their velocity of 66 km/s into consideration. A high percentage of trains is expected from high velocity meteors brighter than the second magnitude [1]. The curious observation is the small number of magnitude +3 and dimmer meteors compared to what was observed, which would have brought the overall percentage down.

5. Color and radiant

Color was another feature that we felt was curious in regard to the Aurigid peak period. Nearly every α-Aurigid between 7^h22^m and 8^h22^m UT that was of second magnitude or brighter had a greenish grey look to Zay and a bluish look to Lunsford. The key here is that a color was perceived by both observers. Outside the peak period they were all white, even the relatively bright magnitude +1 meteors. We are convinced that the effect is real, or at least a consequence of a low radiant.

During the suspected peak, the radiant was around 13° above the horizon. This was determined by the use of a home-made clinometer. Therefore, all the α-Aurigid trajectories were quite long. Every one appeared to travel all the way across the sky. Several times, we had to look back to see the meteor's end.

6. The α-Aurigid ZHRs

Using 7^h49^m UT as the mean time for this 55-minute flurry, with 1.13 as an average mean magnitude gives me an estimated r-value of 1.2 [2]. The radiant was 13° above the horizon at 7^h49^m UT and the limiting magnitude was 5.70 for Zay and 6.87 for Lunsford. This gave a ZHR of 55 for Zay and 37 for Lunsford. We are a bit shaky on our math skills, but all the same, we believe we are in the ball park... or at least on the soccer field. The actual ZHR is probably somewhere in-between.

7. Conclusion

With the α-Aurigid radiant very low on the horizon, one would expect very long trajectories, as indeed was observed, whence both observers saw a relatively large percentage of the same meteors. We believe that an α-Aurigid outburst did occur. Whether confirmation will come, we do not know, but we highly recommend a diligent watch for this shower, during future observing years, to see if a short-lived burst is an annual event or patterns with intermittent years [3].

References

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[2] P. Roggemans, "Handbook for Visual Meteor Observations", *IMO*, 1989, p. 81.
[3] ibid., p. 142.

The Meteoroid Complex as a Tool of Investigation of the Evolution and Dynamics of the Solar System

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Research into the sporadic meteor background is advocated as a tool to obtain more information on the dynamics and evolution of the Solar System.

On the lines of current opinion, comets and asteroids are the parent bodies of meteoroids. The matter of the large bodies of the Solar System—Sun, planets (including the Earth and the Moon)—have modified very much as result of the force of gravity, internal heating, volcanic activity, and nuclear and chemical reactions. Cometary and asteroidal matter does not modify due to the small sizes of these celestial bodies and remains in the same condition as in the time of the formation of the planetary system. Therefore, the small bodies contain very important information on the conditions which were in the initial stage of formation of the Solar System. Due to technical difficulties and the high price involved in obtaining this primary matter from comets, asteroids, or the Moon, the investigation of meteoroids has a great cosmogonical significance.

Comparison of the meteoroid orbital element distributions derived from observations yields the opportunity of forecasting the availability of some classes or certain small bodies on definite orbits with definite physical properties.

According to ground-based observational results, especially radar observations (catalogues of orbits derived from observations in Harvard, Adelaide, Mogadisho, Obninsk, and Kharkov), sporadic meteoroids move on orbits with Keplerian elements which fill their entire phase volume. This volume is compatible with the conditions of intersections of meteoroid orbits with the Earth's orbit. Therefore, one has to use all methods of classical and modern celestial mechanics and the theory of dynamical systems to investigate the dynamics and evolution of the sporadic meteoroids. There are also combinations of the orbital elements a and i in radar catalogues which are absent in orbits of comets and asteroids.

The beginning of the era of space flight was an impulse for the further development of celestial mechanics. Also the awareness that the sporadic meteoroid complex is the aggregate of celestial bodies moving on orbits absent in comets and asteroids can also stimulate research in celestial mechanics. Besides, the results of meteor observations yield an opportunity for verifying involved theories in celestial mechanics.

Examples of such investigations are the work done on the dynamics of the Quadrantids, Comet P/Oterma, and secular resonances as a mechanism to get meteorites to the Earth.

Fireballs and Meteorites

σ-Hydrid Fireball over Japan

December 11, 1993, $14^{h}16^{m}05^{s}$ UT

C. Shimoda, K. Ohtsuka, T. Nakagawa, and Y. Shiba

The results of orbital computation of a fireball of magnitude −8 photographed over Japan on December 11, 1993, are presented. The fireball was a bright member of the σ-Hydrids.

A fireball (no. JN111293) of magnitude −8 was photographed at the Hario Station, using a fish-eye camera (f = 15 mm), in the Japanese Fireball Network on December 11, 1993, at $14^{h}16^{m}05^{s}$ UT ($23^{h}16^{m}05^{s}$ JST). Fortunately, another image of this fireball was incidentally taken by T. Nakagawa from another site, using a 6×7 camera with an f = 45 mm lens. Therefore, we could compute the trajectory and the orbital elements of this fireball. The film measurements and reductions were carried out by Y. Shiba and K. Ohtsuka, and orbital computations were done by K. Ohtsuka. The fireball passed over 77 km in trail-length during $1\overset{s}{.}3$.

The results are shown in Table 1.

Table 1 – Trajectory and orbital data of meteor JN111293 (2000.0).

Time of appearance	1993 December 11.59450 UT
Apparent radiant	$\alpha = 128\overset{\circ}{.}58$ $\delta = +02\overset{\circ}{.}04$ $\sin Q = 0.251$
Corrected radiant	$\alpha = 128\overset{\circ}{.}84$ $\delta = +01\overset{\circ}{.}66$ $\cos Z_{\rm rad} = 0.472$
Begin	$h > 103$ km
End	$h = 67.4$ km
Velocity	$v_\infty = 60.1 \pm 0.7$ km/s $v_{\rm geo} = 58.8 \pm 0.7$ km/s $v_{\rm hel} = 41.5 \pm 0.6$ km/s
Angular elements	$\omega = 119\overset{\circ}{.}8 \pm 2\overset{\circ}{.}0$ $\Omega = 79\overset{\circ}{.}648$ $i = 129\overset{\circ}{.}3 \pm 0\overset{\circ}{.}7$
Other elements	$e = 0.977 \pm 0.014$ $q = 0.256 \pm 0.001$ AU $a^{-1} = 0.087 \pm 0.058$ AU^{-1}

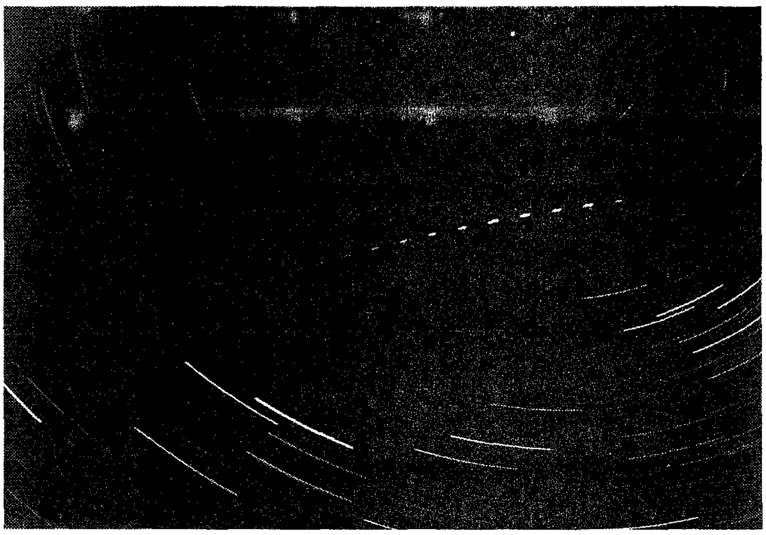

Figure 1 – Fireball JN111293 photographed at the Hario Station. The exposure was made from 22^h26^m to 23^h26^m UT.

JN 111293 was a bright member belonging to the σ-Hydrids. Terentjeva [1] found for fireball stream no. 71, approximately 500 fireball records (PN and MORP) in the *IAU* photographic meteor database. This stream corresponds to the σ-Hydrids. The orbital elements of JN111293 are very similar to those of Terentjeva's stream, shown below (angular elements were converted from eq. 1950.0 to eq. 2000.0):

$e = 0.999$	$\omega = 119\overset{\circ}{.}3$
$q = 0.253$ AU	$\Omega = 72\overset{\circ}{.}5$
$a^{-1} = 0.0088$ AU^{-1}	$i = 127\overset{\circ}{.}9$

We may regard the σ-Hydrids as a meteor stream being rich in large-sized meteoroids.

Reference

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Satellite Observations of the Daylight Fireball of May 29, 1994

Marco Langbroek

Satellite data on the May 29, 1994, extremely bright fireball are given and discussed.

The extremely bright daylight fireball that appeared over the North Sea on May 29, 1994 [1] has been observed by a US Defense satellite in infrared and visual wavelengths. The data, communicated to us by Edward Tagliaferry [2], give both additional information as well as a fine confirmation of earlier results on this magnificent fireball, one of the most brilliant fireball apparitions over the North Sea area in recent years.

The US Defense satellite detected the fireball detonation during 0.7 seconds at 9^h31^m UT. In visual wavelengths, the total radiated energy amounted to 4×10^{11} Joule or 0.1 kilotons working with a 6000 K black body. In visual wavelengths, the fireball peaked at a strength of 1.5×10^{12} Watt, which corresponds to an incredible absolute visual magnitude of -21.5! In infrared, the satellite obtained 80 seconds data on the persistent cloud left by the fireball.

The satellite data do not give information on the orientation of the fireball trajectory and angle of entrance. Thus, it is not possible to calculate an orbit using the satellite data. But the satellite observation does provide an accurate geographical position for the fireball trajectory, which was determined at latitude $\varphi = 52.^\circ 8$ N and longitude $\lambda = 2.^\circ 3$ E. To some extent this deviates, though not dramatically, from the results based on visual observations reported earlier in WGN by our colleagues Bettonvil, Neijts, and Apeldoorn of the *Dutch Meteor Section* (i.e., the Meteor Section of the Dutch *NVWS*). The fireball trajectory is located considerably further westward, closer to the British coast, than presented in their study [3]. The satellite observations are in good agreement with the results on the fireball trajectory location as published by Hans Betlem and the author of the *Dutch Meteor Society* [4–6] based on visual observations along the Dutch coast.

Acknowledgments

I thank Edward Tagliaferry for communicating satellite data and Peter Jenniskens and Dave Morrison (*NASA/Ames Research Center*) for providing contacts.

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Observational Results

SPA Meteor Section Results: January–June, 1994

Alastair McBeath

An overview of observations received by the *SPA Meteor Section* during the first half of 1994 is given. Highlights included a set of radio results obtained in March and April, details on a project covering the η-Aquarids from Malta in April–May, a possible meteorite fall over London in mid-May, and a spectacular fireball over the North Sea on May 29.

1. Introduction

Over the last few years, I have provided occasional reports on the activities of observers of the *JAS Meteor Section* to *WGN*. At the *JAS* meeting in January, 1994, a majority of the membership voted to change the Society's name to the *Society for Popular Astronomy*, so consequently, the acronym used in these reports has changed to *SPA*. The nature of the Society's aims and objectives has not changed, however, and all amateur astronomers, whether complete novices or experienced observers, are welcome to join and take part in the Society's activities. Though the *SPA* is based in Britain, membership is open to anyone, regardless of age, nationality or expertise. Anyone interested in joining can obtain information on doing so from me. The following three sections of this report give the observers, observing tallies, and details of the meteor activity recorded in two-monthly stages.

2. January–February

January's weather in the UK was rather poor, and February's still worse, but tallies were boosted by contributions from elsewhere, including extensive visual and photographic data summaries from the German *Arbeitskreis Meteore* (*AKM*) group, kindly forwarded by *IMO* President and leading observer Jürgen Rendtel. The German results are regularly published in the *AKM*'s monthly magazine *Mitteilungen des Arbeitskreises Meteore*, (contact Jürgen for subscription details), more popularly known as *MM*.

As a result, 18 people reported $37^{h}.9$ of visual observations for 452 meteors (180 Quadrantids and 29 Virginids) and over 660 hours of photographic exposures, but unfortunately only one trail has so far been reported, caught by Jürgen during February. The photographic totals were especially heightened since many of the German photographers routinely operate automatic camera systems as part of the *European Fireball Patrol Network*. One radio observer also submitted 240 hours of results containing 5220 echoes. Non-*AKM* observers, visual unless noted, active in January and February were Peter Craven (Finland), Shelagh Godwin, Valentin Grigore (Rumania), Terry Holmes (photography too), Tony Markham, Tom McEwan, Ian Rigney, George Spalding, and Robert White (radio). Details of the Quadrantid observations sent to the *SPAMS* have already been published in *WGN* earlier this year, and are not repeated here.

3. March–April

Neither month provided much improvement for British visual watchers, with overseas results again providing the bulk of the available information, notably the efforts of the *AKM* group in Germany. Jürgen Rendtel was the top visual observer, clocking up a fine $36^{h}.8$ during this spell.

Overall, 23 observers submitted $83^{h}.3$ of visual data, noting 546 meteors (87 Virginids); nearly 596 photographic hours for two trails; and $461^{h}.3$ of radio work recording 32686 echoes (over 30000 echoes in April alone).

Apart from the *AKM* photographers, a notable effort was made by Wes Donaldson on Alderney in the Channel Islands, who successfully operated Michael Maunder's camera set-up in Michael's absence on four nights in March and seven more in April, producing $56^{h}.5$ of exposures. Wes is the only photographer to have so far found any trails on his films from March or April, two possible Lyrids during April.

Robert White continued to provide some interesting radio results. He operated his receiver continuously between March 8–16, and again from April 16–27. As in January, these observations were made using a simple eastwards-facing dipole antenna, with the receiver tuned to 67.4 MHz, to pick up Budapest radio. Robert recorded peaks in his data on March 9 (about double the low activity on other dates nearby), April 21 and 22 (the Lyrid maximum), and April 25 (this a higher peak than for the Lyrids, but due to an unknown cause, possibly an atmospheric one). The April results seemed to be affected by a regular, diurnal, possibly Sun-related, mechanism. Figures 1 and 2 show graphs of the uncorrected hourly radio rates obtained during this spell.

Visual activity from the Virginids was never better than low, much as expected from northern hemisphere sites, and there was only slight evidence of enhanced activity during the late-March to mid-April period which generally brings the highest shower rates. The Lyrids were seriously affected by strong moonlight, and very few were noted at all. Other observers not already mentioned included Peter Craven (Finland), Tom McEwan, Vasile Micu (Rumania), Alexei Pace (Malta), Chris Watson, and Roy Watson.

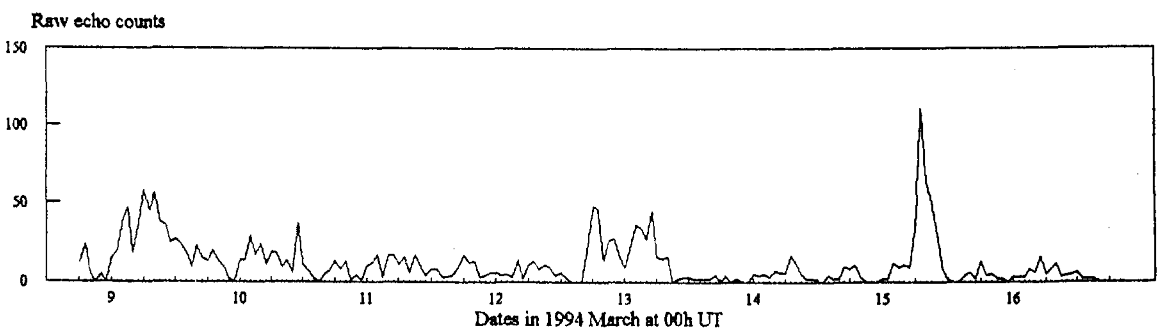

Figure 1 – Raw radio observations from March, 1994, obtained by Robert White.

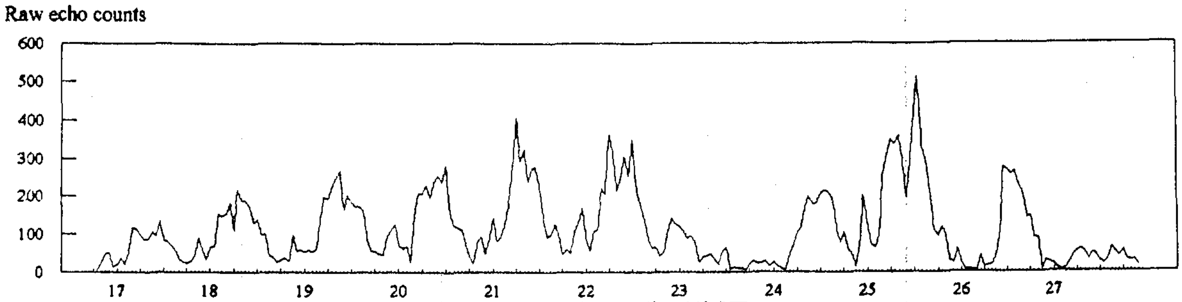

Figure 2 – Raw radio observations from April, 1994, obtained by Robert White. Note the different y-axis scale to Figure 1.

4. May–June

Unhelpful weather conditions, this time aided by bright all-night twilight especially during June, continued to plague British observers, and only Shelagh Godwin was able to report any visual watches from the UK. Luckily, people outside the British Isles were more fortunate. Again, *AKM* members provided the majority of data submitted, particularly Jürgen Rendtel and *IMO* Visual Commission Director Rainer Arlt, but a useful summary report on a project to cover the η-Aquarids by members of the *Astronomical Society of Malta*'s Meteor Group was provided by Adrian Galea too. Twenty-five observers recorded results, with over 393 photographic hours for, so far, one trail, and $95^{\mathrm{h}}.9$ of naked-eye watching for 924 meteors (including 189 η-Aquarids, 63 Scorpid/Sagittarids and 20 Virginids).

The η-Aquarid coverage was exceptionally good. Normally, an outstanding year contains a few shower meteors in the Section's files, since they are very difficult to note from British sites due to the shower radiant rising in strong twilight shortly before dawn, but 1994 saw the first possible η-Aquarid photographed trail in our archives too. Wes Donaldson, again operating Michael Maunder's camera set-up on Alderney, was the fortunate photographer. In Malta, Meteor Group Director Godfrey Baldacchino organized an η-Aquarid project, which ran from April 29-30 to May 7-8. It was a considerable success, especially considering the presence of the bright waning Moon for part of this time, the short possible watch times and the relatively low radiant elevation. Highest shower activity was recorded on May 4-5, but conditions prevented accurate ZHRs from being calculated. The best estimates suggest the ZHR may have reached about 40, however, and was probably around 20 on May 2-3, 3-4, and 6-7. The η-Aquarids were somewhat brighter than the sporadics, but not by a particularly significant margin. The full report can be found in [1]. Vasile Micu in Rumania also noted nine η-Aquarids.

An unconfirmed meteorite fall may have taken place at around $1^{\mathrm{h}}30^{\mathrm{m}}$ UT on May 14, 1994, at Walthamstow in London ($\lambda \approx 0°.0$ E, $\varphi \approx 51°.5$ N). The following extracts are taken from the report on the event and its follow-up submitted by *SPA* officer John Gutteridge:

> *...my wife and I were both woken by a loud rushing sound, followed by a loud bang emanating from the roof above us, and then the noise of something apparently bouncing down the roof. A hasty inspection of the front aspect of the house through the bedroom window revealed no obvious signs of anything on the ground. There were no people about, no sound of talking or running feet, no sound of aircraft flying overhead (we are on the flight-path of Heathrow airport but most flying ceases about 11 p.m.). At the moment we awoke, my immediate impression was that the roof had been hit by a meteorite. Inspection of the roof with binoculars from ground level on three accessible sides of the house next morning at $9^{\mathrm{h}}00^{\mathrm{m}}$ UT revealed no obvious signs of roof damage. The north-facing roof slope is difficult to see from the ground as it abutts* [sic] *the end of a terraced block with only a 2-meter gap between. Subsequent inspection of the roof and guttering at roof level brought neither meteoritic fragments nor indeed chippings*

of roof tiles to light. In the front garden on crazy paving, I did find what I thought might be meteorite remains alongside broken roof-tile particles, but inspection by Dr. Monica Grady, a geologist at the London Natural History Museum, proved negative. She suggested that a meteoritic hit was quite likely, but it had probably vaporized, or fragmentary remains lost in the nearby street. ...I searched the loft for signs of broken tiles or debris, but this also proved negative. The roof was built in the early 1930s and is still unlined, though the rafters have been filled with fiber glass in recent years. The result of this is that with heavy dust particles rising from traffic-laden London streets on two sides of the house the fiber glass is now blackened with grime and it is impossible to say whether any of it could be fragmentary meteoritic particles.

The final main event of this six month period came at 9^h30^m UT on May 29, a brilliant daylight meteor widely reported from southern Britain, northern France, Belgium, and the Netherlands, and which even managed to get mentioned on the national BBC radio news that morning. Further details on this event, which was not particularly well-reported from British sites, suggest that this object reached about magnitude −20 at best, and although there is some disagreement in the reports, the most likely trajectory puts the meteor over the North Sea. Many observers recorded yellow and red colors in the object, and several noted a persistent train, which may have been a dust train, that was seen for up to, or more than, 15 minutes. [2].

References

[1] G. Baldacchino, "The 1994 Eta Aquarids", *The Big Bang*, June 1994, pp. 5–6.

[2] C. ter Kuile, A. Knöfel, F. Bettonvil, *FIDAC News* 2:3, 1994, pp. 66–68.

Meteor Summer School, Kazan, Russia, July 18–31, 1994

Jean-Marc Wislez

At the 1993 *IMC* in Puimichel, Tom Roelandts, Werner Depoorter, Cis Verbeeck, and I presented our automated forward scatter radio meteor system named RAMSES. This led to a series of interesting discussions with other participants, in particular with Prof. Dr. O.I. Belkovich, a meteor astronomer from the university of Kazan, Russia. He developed a theory for the statistical reduction of radar observations, and offered us to visit his Meteor Department to learn about it.

Finally, Prof. Belkovich organized a Summer School in Kazan from July 18 to July 31, 1994. In Moscow, we were welcomed by Mr. V. Svetkov, the former director of the Moscow Planetarium and a meteorite scientist. He showed us the city and brought us to the train to Kazan.

The *Engelhardt Astronomical Observatory* (*EAO*), where we stayed and had lectures, is the observatory of the Kazan State University and consists of a small village around the telescope buildings. A part of the Meteor Department of the University is located at the *EAO*. They own a direction-finding meteor radar and have conducted many tests with respect to forward scattering of radio signals by meteors in the sixties and seventies. At present, beside the treatment of the observations of their radar, they are working on synchronization of clocks by means of meteor forward scatter and on the development of a method for the reduction of visual observations.

The main series of lessons was given by Oleg Belkovich and was about his statistical theory. This theory permits the calculation of the mass index from amplitude and duration distributions of the observed meteors, as well as the flux of sporadic meteors. It was developed for backscatter systems, but Prof. Belkovich assured us we would be able to derive the forward scatter equivalent ourselves. Currently, we are studying this theory in detail to be able to do the conversion.

During the second week of our stay, we got some lectures about antennae, meteor streams, observation of sporadic meteors, the fitting of radio meteor profiles and a method for reduction of visual observations. We also visited the meteor radar, as well as the experimental set-up for clock synchronization.

We would especially like to thank Oleg Belkovich, all other lecturers and guides, as well as the people of the *EAO* for their kind hospitality. We recommend interested meteor workers to participate in possible future versions of this Summer School.

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