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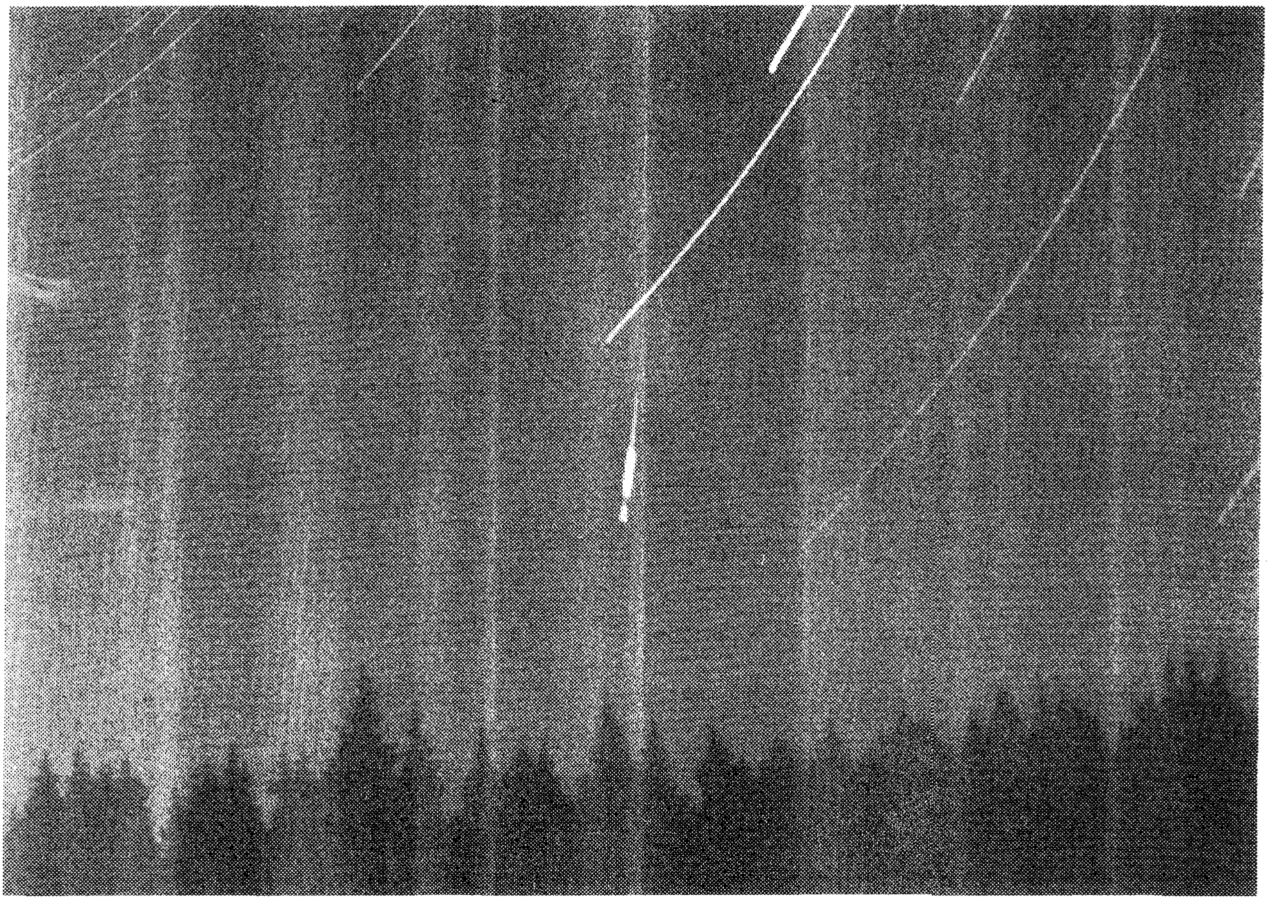

This beautiful magnitude −1 Perseid in Auriga-Gemini was photographed by Pavol Rapavý (Žliabky—Slovak Meteor Expedition) on July 30, 1995, at $0^h46^m57^s$ UT. The exposure was made from 0^h06^m till 1^h19^m UT with a 30 mm $f/3.5$ lens on FOMA 400 film.

In this issue:

- Practical information for all observers
- More on the Leonids and α-Monocerotids
- Tunguska-like events in the Amazon rain forest?
- History of meteor astronomy
- Observing meteors with video and radio
- Fireballs and meteorites
- Observational results

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Contents

Useful Information

The February Issue *(WGN 24:1)*

The *February issue* will be mailed during the second week of February Contributions are due on *January 19* at the latest. They should be sent to *Marc Gyssens*.

From the Editor-in-Chief

Marc Gyssens

WGN *closes the year with another thick issue, and rightfully so, as there is a lot to say, too. Clearly, nobody can claim that these are boring times for meteor observers: expected and unexpected outbursts of meteor showers abound. What the Leonids failed to deliver this year was made up for by the α-Monocerotids. Well over a year ago, following up on a 10-year periodicity of the α-Monocerotids suggested by several authors, the* Meteor Shower Calendar *pointed the observers' attention to the possibility of an outburst in the following, cautious terms:*

> Several unusual returns of this minor stream have occurred, when very short-lived bursts of high rates have been seen. A ten-year periodicity has been suggested in these events, which were primarily noted in 1925, 1935, and 1985. This year would be a good time to try to confirm the reality of the situation, provided plenty of observers collect and accurately report their results.

More recently, observers were reminded of this possibility through Sky and Telescope.

A much more detailed study of the occurrence of α-Monocerotid outbursts was made by Peter Jenniskens in Astronomy and Astrophysics, *and he used his findings to make a* prediction*—that the outburst would actually happen—in the June issue of this journal. As Paul Roggemans's prediction of a Perseid outburst in 1991 lead to enhanced vigilance by the Japanese observers without which the short-lived outburst may well have been missed, Peter Jenniskens's prediction had a similar effect for the recent α-Monocerotid outburst. The wealth of observational data of all forms that resulted from enhanced observers' awareness outnumbers all data that were previously available for this shower and will undoubtedly provide us with the opportunity to learn a lot more about this poorly known shower. Peter Jenniskens deserves most of the credit for this success, and we like to take this opportunity to congratulate him with his prediction having come true.*

In this issue, you will find a—very preliminary—report on the α-Monocerotid outburst based on the data available to him at the time of writing, as well as a few reports from various observational sites, including Ondřejov Observatory. You will also find a preliminary report on this year's Leonids, which did produce enhanced activity, though less spectacular than last year, but probably no outburst, though this needs confirmation.

There is of course a lot more in this journal, but you should find out for yourself! I already look forward to 1996 and wonder what excitement the upcoming year will bring to meteor observers. Until the next issue—that is, if you have not forgotten to renew! For your convenience, we have repeated the relevant information from last issue below.

Renew Your IMO Membership/WGN Subscription Now!

Ina Rendtel

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Last year, we had to run on and off to the post office to send out copies of *WGN* to late renewers. Please save the already overloaded *IMO* officers this extra work by renewing right now. All information is concisely summarized below.

International payments invariantly involve costs. Therefore, if you also wish to buy greeting cards (see previous issue) or other *IMO* publications (outside back cover of previous issue and this issue), it is a good idea to combine this with your renewal in one order and one payment. *New* IMO *publications* are the long-awaited and completely rewritten Visual Handbook, Report 7 containing the 1994 visual observations, and the Proceedings of the 1995 *IMC*. You can also pay your subscription for *two* years.

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- **in the United Kingdom:** proceed as above, or pay to *Alastair McBeath*, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- **in Japan:** pay to *Masahiro Koseki*, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
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Letters to WGN

compiled by Marc Gyssens

Asteroid named after Dutch meteor observer

Urijan Poerink informs that an asteroid has been named after a well-known Dutch meteor observer.

In February of this year, an asteroid has been named after the Dutch amateur astronomer Ben Apeldoorn. Apeldoorn is a prominent and very active member of the Meteor Section of the Dutch *NVWS*. The asteroid is now called "5885 Apeldoorn."

The *IAU* motivated its decision as follows: "Discovered 1973 September 30 by C.J. van Houten and I. van Houten-Groeneveld on Palomar Schmidt plates taken by T. Gehrels. Named in honor of Berend Caspar Jan Apeldoorn (born 1944), Dutch amateur astronomer, on the occasion of his 50th birthday. Since 1961, Ben has specialized on meteors and meteorites, observing meteors both visually and photographically. He has written many articles on astronomy for astronomical periodicals and yearbooks, as well as for general magazines and newspapers. Apeldoorn still makes important contributions to the popularization of astronomy and is a member of the Meteor Section of the Dutch Society for Meteorology and Astronomy. Name proposed by the discoverers following a suggestion by F. Bettonvil, chairman of the Meteor Section."

About September 28, 1995, "5885 Apeldoorn" is in opposition. At that time, its distance to the Earth is 2.293 AU and its brightness +16.6. The asteroid is a common main-belt object with a period of 5.49 years.

Urijan Poerink, July 17, 1995

Dark meteors

Below is a response by Alastair McBeath to some of the reactions to his article on "dark meteors" in the June issue.

I was most interested to read the responses to my "Dark Meteors" article in June's *WGN* (23:3, pp. 91–96) in the August issue.

These letters, plus conversations with numerous people at the *IMC* in Brandenburg, tend to confirm the view that a great many meteor observers have seen such events—the proportion of observers may be as high as 50–70% from several quick "straw polls" I have conducted. They are, however, rare, as I pointed out earlier. There has long been a tendency to dismiss such unusual events by supposed "serious" meteor workers, with the result that almost no one properly records what occurs when a dark meteor is seen anymore. This creates a lack of usable data which simply feeds the prejudices of those who wish to disregard anything they cannot personally envisage (stones cannot fall from the sky because we see no stones there to fall, etc.). Even if some of the effects producing dark meteors are "psychological" or "physiological," what exactly is the psychology or physiology of our seeing them? I have never found descriptions of what these potential explanations might be anywhere, and their most common usage is as a cover-all term of disregard by those who feel the topic unworthy of investigation.

That some dark meteors are effects within the eye, probably associated with floaters or "noise" in the eye-brain system, is almost unavoidable, but equally some may be real. Most such "noise" is normally filtered out by the brain, but occasional linear objects can be created in the field of view this way. The experiment is best carried out indoors in a darkened room once the eye is dark-adapted, but requires concentration to properly note, due to the efficiency of the eye-brain's filtering system. One interesting point to come from the *IMC* discussions was that a very small number of objects which may be dark meteors have been recorded on video by Marc de Lignie and the Dutch video workers. More details on these events are being sought as I write this.

I also came upon a reference by Ohman [1] which may be of interest here. Ohman's paper describes light and dark shadow band effects created by air turbulence (using specific examples of candle flames and jet aircraft trails), due to the slightly different refractive indices of the air reflecting and refracting light around the turbulence. Ohman suggested it might be possible to observe such effects with meteor trails too, but perhaps some of the dark meteors we see are a form of this phenomenon, with meteors otherwise too faint to be seen. Our understanding of just how the Earth's upper atmosphere behaves is still too incomplete to be sure what might be feasible in these terms.

David Holman's point about the effects on the eye at an adrenaline shock are something I have noted too, but I generally find there is an instantaneous brightening of my visual system followed immediately by a spell where the sky is noticeably darker. This fades to normal relatively quickly, and is a contrast change only. As Holman noted, it does not actually improve the eye's sensitivity, and may well be associated with the ganzfeld state.

I would also like to thank Marco Langbroek for his fascinating note. Another area I am presently looking into involves tracing the history of the western constellations back to Sumerian times (ca. 3000 BCE), and his reference to Akkadian cuneiform texts on meteors is not something I have yet come across, although the Babylonian/Hittite/Akkadian omen texts are generally well known.

[1] Ohman, Y., "On the possibility of observing reflection phenomena in meteor trails", in *Asteroids, Comets Meteors* II, Lagerkvist, C.I., Rickman, H., eds., Uppsala University Press, 1986, pp. 599–602.

Alastair McBeath, September 25, 1995

We also received a reaction from Godfrey Baldacchino to this controversial topic.

It was a pleasure reading Alastair McBeath's well researched and balanced article on the dark meteor phenomenon [1]. The concluding appeal towards an open mind is surely wise, all the more in the face of so many unknown variables which influence human behavior, the meteor watcher not excepted.

I have personally seen dark meteors on more than one occasion. I find that the best way of describing these is as negative images of meteors, because they otherwise share so many of the same characteristics of "normal" meteors: in terms of length, velocity, or thickness of path.

A Maltese colleague and former fellow meteor observer, David Gatt, had also noted "dark" meteors during his watches. He wrote thus in an attempt to obtain further information on the phenomenon in the now defunct meteor journal *Meteoros*:

> *On one or two occasions... I observed streaks very similar to those of meteors, except that these appeared black against the faint sky glow.* [2]

This "letter to the editor" generated two responses. The first by J. Cooper recommended that

> *... they [i.e., dark meteors] must be optical illusions. As the eye focuses on a star, the retina must become desensitized at the star's point of focus and hence any movement of the eye gives the impression of a black streak.* [3]

A thoroughly plausible explanation, no doubt, but for an important detail. If the argument were valid, dark meteors would be rather common, definitely much more common than they are reported to be.

In another letter, K.V. Pilon pronounces, rather dogmatically,

> *Fatigue... Probably the most striking example of fatigue: one where you experience a "black meteor" taking off. It has all the characteristics of a bright, fast meteor, but it is black, and it also does not exist. Don't expect your observing partner to call it out, because it only existed within your system.* [4]

Here, there is no attempt at building a scientific and therefore refutable relationship between the state of tiredness and the dark meteor event; we are thus expected to accept this pronouncement blindly.

May I suggest the following three initiatives:

1. First of all, whether dark/black meteors exist or not in the real world is a matter worth pursuing for science's sake. But the point which needs to be driven home above all is that *the dark meteor phenomenon exists*. It is certainly very real for all those, including myself, who have witnessed it. They may have remained perplexed and surprised at the unexpected sighting; utterly embarrassed and perturbed at having seen a "non"-event; or taken it as an indication that they are not as alert and awake as they might have assumed. Either way, the event for them is real. Let us remove it from the meteor watcher's skeleton cupboard.
2. Secondly, it may be opportune to set up a *Dark Meteor Database* within the *IMO*. This would document the sightings of these events along with other details surrounding the context in which the dark meteor was observed—details which may, in the long run, throw some light (I mean metaphorically!) on the whole phenomenon. For instance, this database may help to answer one crucial question I would like to pose about these dark sightings: are there any records of dark shower meteors—that is, dark meteor trails which appear to radiate from an active radiant? Such an important shred of evidence would decidedly shift the balance in favor of physical and objective genuinity and against subjective illusion.

3. Thirdly, may I suggest a slight refinement to the four explanations (i.e., eye defects, physiologically based optical illusions, atmospheric effects and genuine dark meteors) proposed by Alastair in his WGN article. This is to consider dark meteors as *psychologically induced optical tricks*. We are already faced with a difficulty in classifying real, genuine meteors on the threshold of visibility. The "A-B-C" reliability classification used at times in activity calculation is a reflection of this quandary; but it offers no real solution: what weighting is to be assigned to a "C" meteor? We already know that the chances of observing, say, a +6 magnitude, short trailed meteor with a +6.0 limiting magnitude are very slim—yet many such meteors are reported. How many of these are actually real events? Do observers typically allow themselves the benefit of the doubt, becoming more prudent and stringent only once they feel that their observed meteor quota somehow matches the expected and predicted value? Part of the answer may lie in a conscious or pre-conscious desire, not only to see meteors, but to see more. (Admit it: we would all—scientific concerns apart—rather have a higher activity rate than that purportedly in force.) Is the dark meteor event indicative of this wicked, naughty (dark!) yearning for more? Is the dark meteor a quasi-real extrapolation of a wish fulfillment?

It would be stimulating to have further views on this subject in *WGN*; and, if anything, assess how many of the 250-odd *IMO* members have (n)ever seen a dark meteor.

[1] A. McBeath, "Dark Meteors", *WGN* 23:3, June 1995, pp. 91–96.

[2] D. Gatt, "Dark Meteors?", *Meteoros* 11:4, July 1981, p. 81.

[3] J. Cooper, "Dark Meteors Again", *Meteoros* 11:5, September 1981, p. 94.

[4] K.V. Pilon, "Letter to the editor", *Meteoros* 12:2, January 1982, p. 19.

Godfrey Baldacchino, July 1, 1995

Meter-sized bodies in the Perseid stream

Dr. Ryabova kindly communicated us the following note.

In October the annual conference "Computer Methods of Celestial Mechanics" took place in St. Petersburg. I think that maybe the information contained in one of the reports [1] is of interest for readers of *WGN*.

In the period August 9–15, 1995, observations of objects in the vicinity of the Perseid radiant were carried out using a 1-m telescope with CCD-camera in Simeiz, Crimea. Four objects with diameters from 3 to 28 meters were registered. At least two of them passed at a distance of 60 000 km from the Earth and one (with a diameter of 3 m) entered in the Earth's atmosphere.

For the observations and the processing of results, the authors used their own original technique.

[1] Bolgova G.T., Barabanov S.I., Mikisha A.M., Smirnov M.A., "Observations of bodies of meter and decameter size in the radiant of the Perseid meteor shower", in *Computer Methods of Celestial Mechanics '95*, Abstracts of All-Russian Conference with International Participation, St. Petersburg, 1995, p. 43 (in Russian).

Galina Ryabova, Tomsk Research Institute of Applied Mathematics and Mechanics, November 8, 1995

Frequently Asked Questions on Observing Methods

compiled by Rainer Arlt

How should the observing fields be distributed over the sky when observing in a group?

A group observation is much more fun than sitting alone somewhere in the field. Notwithstanding, there is no other difference between a group observation and that of a single observer. Each of the participants produces his own, independent observational record. There is no need to cover the entire sky with observing fields, neither is it recommended.

The observing fields are best placed when the observers can easily distinguish the meteor showers active. This would mean that all the participants of a group observation look into the same direction. This is in fact no problem as their average rates give a more significant value for the meteor activity than the rates of a single observer. On the other hand, if cameras are operated during the observation, it is very important to record the times of bright meteors which might be photographed. Observing in different directions increases the chance to get the appearance times for most of the bright meteors.

The following rules may be considered when planning a group observation:

- Experienced observers discriminating all the radiants active should face a direction close to the minor-shower radiants. During the Perseids, this corresponds to fields in Pegasus and eastern Vulpecula which are close to the radiants of the Aquarids and the κ-Cygnids.

- Observers who only discriminate major-shower and other meteors can scatter their fields of view around the radiant of the major shower, in a distance of 20° to 60°. During the Perseids these fields can be, e.g., in Cepheus, Ursa Minor, Camelopardalis, Andromeda, Pegasus, and Pisces.
- No observer should face a direction which is 180° in azimuth from the radiant when the radiant is lower than about 50°. Do not use Aquila, Hercules, Ophiuchus, or more southerly constellations during the activity period of the Perseids.
- No observer should look at fields with elevations lower than 40°.
- If cameras are operated or if the observation takes place in an area covered by network cameras, each observer should carry an accurately set watch to determine the appearance times of bright meteors with an accuracy of 1 s.

Observing Coffins

George Zay

1. Introduction

Observing meteors is not necessarily a warm-climate activity. Cold-climate observers can still participate by using an *observing coffin*. Yes, there is such an item and this is the only term I have ever heard them referred as. For meteor observers in cold climates, ply-wood boxes are constructed to insulate them from extreme cold temperatures.

I am not able to provide any type of construction plans here, but if I describe some concepts, perhaps the "handyman" type will be able to pick up on it and design his own observing coffin to suit their needs. Most boxes are custom-made because no two observing locations are the same.

2. Basic design

The basic design is a simple, long wooden box big enough for one individual. The lid will close so as to cover the observer from mid-body on down. A small mattress can be placed inside. On top of this you can place your sleeping bag. This is the basic design to keep direct wind and cold air contact from the observer.

3. Deluxe model "A"

To expand further, if you are close to an electrical outlet, you can line your sleeping bag with an electric blanket. Be sure to take necessary precautions by observing proper wiring techniques. Do not ground yourself out!

4. Deluxe model "B"

Another concept to consider is to place your basic designed box on the roof of your house. Make sure it is secured, for on a sloped roof, you might find yourself in a record breaking, unguided one man Bobsled heading for town. Some heating conduit can be channeled into the bottom or side so that a steady flow of warm air can keep you toasty.

For people that have access to an Astronomy Club's private observing site, perhaps a small one-room wooden shack can be built with a box or two permanently mounted on its roof? One of the advantages would be to keep the observer off the ground to provide a better view. I observe from something similar on top of my flat roofed observatory. It is reassuring to know that I am above the range of any nocturnal critters that may be prowling about. It is amazing how bunny rabbits, field mice, and the like can make an observer near the ground feel like dinner for some predator... especially when you know there are some genuine predators lurking about. If nothing else, a sense of security is present when you are above ground.

5. The heavenly model

One other idea to consider... if you got the nerve. If you want a fancy already made box with only some minor modifications to be made, you can visit any local funeral home. They have an assorted selection to choose from. No doubt, there are some obvious drawbacks to consider. You might want to make sure that the lid can be opened from the inside. It is possible that a gust of wind might come along and close it up on you. If you get stuck in that thing for too long of a time, you might as well just stay put. If you survive such an experience, you might also have to seek counseling, but look on the bright side!

If nothing goes wrong, you can have some successful observations in relative style and comfort. And when it is time to depart this world, you will already have your eternal "house" paid for. You would not only get more bang for your buck, but for once this would contradict the saying of "you cannot take it with you."

Hopefully I have planted some ideas into someone's mind. Not everybody will benefit from this, but for those that will, it is something to consider.

Hints for Photographic Meteor Observations

Jürgen Rendtel

In the *Photographic Observers' Notes*, we mainly followed the activity of selected meteor showers which are either of particular interest because of the lack of respective data, or which probably supply a larger number of meteors to be photographed.

This time, I want to draw your attention to one aspect of meteor photography which requires a very fast reaction and, of course, a solid portion of good luck: meteor train photography. It is known from various photographes that a persistent train may well contribute to the photographic "efficiency" of a meteor. So, if the train significantly adds to a meteor's photographic magnitude, why not trying to photograph the train itself? The major problem is the mostly short duration of such train phenomena. Only very few last for more than 20 seconds or so. Hence there is not a single second to be lost after such a train appears.

When preparing for such a program, a few things can be foreseen and therefore arranged in advance. First, we need a high-speed film, which perhaps has to be pushed when developed. I strongly recommend black and white film, also because its treatment can be done in your own lab rather than giving it to a commercial lab. Next, we will choose a fast lens, but here we have to come to a compromise. In the event of a train, we have to point the camera towards the respective field. This takes a little time. The smaller the field of view, the more accurate we have to adjust the camera, and hence we will lose more time when using a narrow field lens. Of course, a wide angle lens does not need such a precise adjustment, but the (linear) aperture of a lens with the same focal ratio but longer focal length f is smaller. This linear diameter determines the efficiency of the lens. Consequently, we will arrive at a standard lens of $f = 50$ mm and a large focal ratio ($f/d = 2.0$ to 1.0 (if you can afford that)).

Now being under the night sky, we have to prepare the camera for its purpose as well. First, it has to be in reach from the observer's hand(s) on a tripod which is not completely fixed but slightly adjusted. In the case of a train, the observer has to move the camera immediately to the train's position without first manipulating at the tripod, but also without the necessity to fix it at the final position. This requires some preparation in the workshop, perhaps. Next, we need a release which allows to open the camera shutter fast. Some cameras do allow electronic remote releases. Mechanical cameras require a cable release. Another possibility is to keep the shutter already open, but the lens covered by a soft piece of cloth which has to be removed only. It is suggested to try different methods.

It is difficult to recommend an exposure duration. It depends on the brightness and the duration of the train. If the distortion of the train is remarkable, it may be of interest to obtain a series of such photographs. However, this will be restricted to the very rare event of very bright trains.

The meteor showers are quite distinct regarding the portion of trained meteors. Cometary showers, such as the Orionids, Leonids, Perseids, and η-Aquarids generally contain a larger portion of trained meteors, while, e.g., the Geminids are almost the opposite. Although there is plenty of time until these showers return, I suggest to deal with some tests well in advance, and it may be that a sporadic or minor shower meteor becomes a test object. Good luck.

Visual Observers' Notes: January–February 1996

Jeff Wood

1. Introduction

Although early January begins with the major shower, the Quadrantids, this period is generally characterized as one with low rates, and so must therefore hold little interest to the meteor observer. This attitude, however, is based on a misconception. Even though rates may be low, there is still much to see as southern hemisphere observers and those in the northern hemisphere who have braved the winter weather have discovered.

Table 1 below gives an overview of some of the showers to be seen in January and February 1996. Table 2 shows observing conditions during these months moon-wise.

2. Quadrantids

The Quadrantids are only observable from the northern hemisphere. There, during the last few hours before sunrise on the mornings of January 2-3 and 3-4, rates more than 30 meteors per hour can be recorded under good sky conditions. When we consider that the radiant altitude is still fairly low at this time, the corrected rates give a ZHR comparable to that of the η-Aquarids, Perseids, and Geminids, thus making the Quadrantids a truly major shower.

Table 1 – Some of the showers to be seen in January and February 1996.

Shower	Activity	Maximum		Radiant			V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	Diam.	(km/s)		
Quadrantids (QUA)	Jan 01–Jan 05	Jan 04	282°7	230°	+49°	5°	41	2.1	120
Coma Berenicids (COM)	Dec 12–Jan 23	Dec 19	268°	175°	+25°	5°	65	3.0	5
δ-Cancrids (DCA)	Jan 01–Jan 24	Jan 16	297°	130°	+20°	10°/5°	28	3.0	4
α-Centaurids (ACE)	Feb 01–Feb 21	Feb 07	318°	210°	−59°	4°	56	3.0	6
δ-Leonids (DLE)	Feb 15–Mar 10	Feb 25	336°	168°	+16°	5°	23	3.0	2
γ-Normids (GNO)	Feb 25–Mar 22	Mar 14	353°	249°	−51°	5°	56	2.4	8
Virginids (VIR)	Jan 25–Apr 15	Mar 25	4°	195°	−04°	15°/10°	30	3.0	5

Table 2 – Moonlight and observing conditions in January–February 1996.

Date	k	Date	k
Friday December 29	0.52+	Friday February 02	0.94+
Friday January 05	0.99+	Friday February 09	0.83−
Friday January 12	0.69−	Friday February 16	0.13−
Friday January 19	0.04−	Friday February 23	0.20+
Friday January 26	0.35+	Friday March 01	0.83+

New Moon:	December 22, January 20, February 18
First Quarter:	December 28, January 27, February 26
Full Moon:	January 5, February 4, March 5
Last Quarter:	January 13, February 12, March 12

The Quadrantid radiant is situated in the northeast corner of the constellation of Bootes which used to be known as Quadrans Muralis from which the shower's name derives. Quadrantid meteors are very brilliant, and many produce trains. Frequent poor weather has meant that data on this shower are comparatively scarce. Thus with reasonable Moon conditions just prior to sunrise, observers are encouraged to brave the cold of winter and observe this shower in 1996. The maximum is expected around January 3, 5^h UT, favoring Europe. However, as this prediction may be incorrect by up to 5 hours, observers should be alert well before and after this time!

3. Coma Berenicids

This shower is active from December 12 to January 23. Although maximum occurs on December 19, rates are still moderate during January. The Coma Berenicids are best seen during the last few hours before sunrise from the northern hemisphere. They are fast meteors with a $V_\infty = 65$ km/s. Observers should have their field center situated no further than 30° from the radiant. All possible Coma Berenicid meteors should be plotted.

Table 3 – Radiant positions of the Coma Berenicids.

Date	α	δ	Date	α	δ
Jan 01	186°	+20°	Jan 10	194°	+17°
Jan 05	190°	+18°	Jan 20	198°	+15°

4. 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 monitor the period January 12 to 24 since before this time there will be interference from the Moon. 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. Therefore, the radiant diameters to be taken into account for shower association of meteors of different radiant distances differ a bit from those of sharply defined radiants (see [1]). The relevant part of the table concerned is reproduced below as Table 5.

Table 4 – Radiant drift of the δ-Cancrids. The x, y coordinates 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					

Table 5 – Optimal radiant area to be assumed for shower association of ecliptical radiant complexes. The major axes are given (α/δ).

Radiant distance	15°	30°	50°	70°
δ-Cancrids	20°/15°	25°/20°	27°/22°	30°/25°
α-Crucids	20°/15°	25°/20°	27°/22°	30°/25°
Virginids	30°/20°	32°/25°	35°/26°	40°/30°

5. 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_∞ = 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 6 – 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

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 then, the *IMO* has for the time being to incorporate all of the Virginids seen into the one "shower." The "Virginids" are active from January 25 to April 15. They have a V_∞ of 30 km/s and are reknown as fireball producers, though their population index r of 3.0 indicates there are many fainter members as well.

The *IMO* would appreciate your efforts to monitor this shower in 1996. 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. As for the δ-Cancrids, please use Table 5 for determining the radiant area.

Table 7 – Radiant drift of the Virginids. x, y coordinates 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			Mar 15	189	−02	45	146	202	155
Feb 13	167	+09	125	181			Mar 25	195	−04	15	138	183	150
Feb 23	174	+05	103	169	256	179	Apr 04	200	−06			169	144
Mar 05	182	+01	74	157	226	164	Apr 14	204	−08			157	138

7. α-Centaurids

The α-Centaurids produce a good display of meteors each year for southern hemisphere observers. They are active from February 1 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 1996, there is plenty of interference from the Moon around maximum.

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 $\delta = -50°$.

8. Call for radio observations

In the past, Dirk Artoos has noticed enhanced radio activity on January 22-23 several times. This can hardly be a coincidence any more. The highest peak occurred during early morning hours ($\lambda_\odot = 301.^\circ 7$, eq. 2000.0). Therefore we suggest radio observers to be alert between January 19 and 25.

9. Call for plotting meteors

In the past, the *Visual Observers' Notes* have featured other "meteor showers," especially for the Southern Hemisphere. Observers are encouraged to look out for activity from these. Such activity, however, will need to be confirmed by plotting any meteors seen to determine the radiant positions.

Reference

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

Telescopic Observers' Notes: January–February 1996

Malcolm J. Currie

Recent reports have come from Mark Vints, Javier Méndez Álvarez, Torsten Hansen, Chris Hall, and two new observers: Tom Crann from Sunderland, UK; and Raymond Berg of Crown Point, Indiana, USA. I apologize to correspondents and observers for the recent silence, due to a lot of pressure at work; the pressure will ease in December, and I will be writing to you shortly.

Forthcoming events

After the excitement of recent months, one could be forgiven for staying in the warm during these months, perhaps concentrating on analysis rather than observation. The extreme temperatures, especially if the air is damp, and the strong moonlight during the only major shower—the Quadrantids—are compelling reasons for not venturing out. On the other hand the skies are often at their clearest and darkest and there are several decent telescopic showers.

Most of these are situated close to the ecliptic. The best known are the *δ-Cancrids* which are active for three weeks during most of January. This year, observations should be possible from around January 10 until the shower ends. Like many ecliptic showers it has an extended elongated radiant, possibly with distinct sub-radiants.

The aim of telescopic observations is to study the radiant structure. Given the low rates, perhaps two per hour, this program requires the efforts of many observers over several years. The meteors are slow to moderate speed, which should help aid accurate plotting. Suggested charts are 81, 100, 104, 144, 146, and 78 during the evening. Try to use at least three fields per night. The δ-Cancrid shower is observable from all latitudes and is the main project for this period.

The *Coma Berenicids* also give weak telescopic activity until late January. There may be several related showers in this area during this period known by various names such as 38 Lyncids and Leo Minorids. Scarce data makes it hard to see a pattern in the activity, and is not helped by diffuse radiants. However, all seem to be rich in faint meteors and have a high velocity. The Coma Berenicid radiant rises around 23^h, so observations can only commence after about 1^h, beginning from around January 15. Suggested charts are 106 and 124, and 65 and 126 are an alternative pair after 3^h.

Around January 22–23, there is the mystery radio shower. In 1995, we may have detected a brief flurry of activity from this shower giving a meteor every few minutes at $\lambda_\odot = 302\overset{\circ}{.}7$, but its situation could only be only confined to a long arc of a great circle passing through Lynx and Auriga before the activity had vanished. We badly need more than one independent observation to pinpoint this shower. If there is a shower at the same solar longitude, it will occur some 6 hours later, thus favoring North America. Of course, this is a big "if," so European observations would also be most welcome for this night, and especially ones carried out in the small hours. Be vigilant and ready to switch to an appropriate chart should any unusual increase in rates from a single direction occur. Besides the charts for the δ-Cancrids you should have a few in reserve, such as 22, 40, 55, and 59, in case this shower reveals itself.

Not far displaced along the ecliptic from the δ-Cancrids, are the *α-Leonids*. This shower is not in the *IMO* radiant list, but it offers good telescopic rates. Its maximum is not known. Gary Kronk believes the maximum to be in the final week of January from $\alpha = 156°$, $\delta = +9°$ but telescopic results suggest that it might be earlier. This shower can be studied simultaneously with the δ-Cancrids. Of those charts already listed, the best for α-Leonids are 104 and 146. Chart 41 would be a useful adjunct. Also during January's dark period are the *α-Hydrids* emanating from around $\alpha = 135°$, $\delta = -05°$. It gives a decent telescopic flux, but can only be well observed by those south of 45° N. At this time there are two suspected radiants from the environs of the ecliptic showers, for which confirmatory observations are needed. The *δ-Leonids* are yet another ecliptic minor shower. It yields weak rates during February. The meteors' low velocity should help to identify them from the sporadic background. In 1996, the broad maximum occurs during February's New-Moon period offering a chance to collect some rare telescopic data on this shower. Radio data suggest a southern telescopic branch, but its alleged maximum coincides with the Full Moon. Suggested charts are 82, 104, 106, 125, and 147. In late February the odd Virginid can be seen radiating from Leo too. Use the same charts with the possible addition of 123. There is always the chance of finding other showers, especially during sessions towards dawn where coverage has been abysmal, and would be just reward.

Theoretical Radiants of Minor Planets and Comets

Dirk Artoos

Table 1 – Theoretical Radiants of Asteroids and Comets in January–February 1996.

Name	$\lambda_\odot$	Date	α	δ	V_∞	Distance
P/1969 IX (Tago-Sato-Kasaka)	281°79	Jan 02	232°	−57°	49 km/s	0.01207 AU
P/1995 O1 (Hale-Bopp)	282°42	Jan 03	234°	+30°	51 km/s	0.10092 AU
P/1819 IV (Blanpain)	283°80	Jan 04	337°	−38°	18 km/s	0.07540 AU
P/1888 III (Brooks)	284°32	Jan 04	132°	−37°	44 km/s	0.16490 AU
P/1870 IV (Winnecke)	285°00	Jan 05	159°	− 6°	65 km/s	0.10240 AU
P/1792 II	286°96	Jan 06	216°	+15°	65 km/s	0.04623 AU
1994 AW 1	287°77	Jan 09	237°	+46°	17 km/s	0.16762 AU
P/1991 h1 (Mueller)	288°79	Jan 09	159°	+31°	54 km/s	0.00190 AU
P/1966 IV (Ikeya-Everhart)	289°29	Jan 09	113°	−38°	35 km/s	0.06260 AU
P/770	289°32	Jan 09	157°	−20°	59 km/s	0.08086 AU
P/1852 III (Biela)	290°50	Jan 11	1°	+43°	18 km/s	0.19640 AU
1993 QA	290°58	Jan 11	52°	−51°	14 km/s	0.13216 AU
P/1806 I (Biela)	291°36	Jan 11	358°	+47°	18 km/s	0.16660 AU
1994 LX	292°57	Jan 12	80°	−71°	26 km/s	0.17100 AU

Table 1 – Continued.

Name	$\lambda_{\odot}$	Date	α	δ	V_{∞}	Distance
Toro (1685)	293°21	Jan 13	299°	+ 4°	17 km/s	0.05751 AU
P/1787 (Mechain)	294°01	Jan 14	162°	−12°	63 km/s	0.09356 AU
1993 BW 2	294°22	Jan 15	308°	−78°	18 km/s	0.08789 AU
Aten (2062)	294°92	Jan 15	142°	−45°	15 km/s	0.09775 AU
P/1979 X (Bradfield)	295°07	Jan 15	226°	−32°	64 km/s	0.14074 AU
Hathor (2340)	295°11	Jan 15	140°	+ 4°	17 km/s	0.10129 AU
1991 BA	295°92	Jan 16	108°	+19°	21 km/s	0.00145 AU
P/1759 III (Great Comet)	296°63	Jan 16	211°	−15°	72 km/s	0.04875 AU
1994 PC 1	297°52	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 (Great Comet)	300°78	Jan 20	233°	−33°	65 km/s	0.10515 AU
P/1840 I (Galle)	301°01	Jan 21	129°	−28°	40 km/s	0.03849 AU
P/1672	302°54	Jan 22	259°	+21°	50 km/s	0.03452 AU
1993 TZ	302°19	Jan 22	326°	− 1°	16 km/s	0.07199 AU
1995 DV 1	303°46	Jan 23	356°	−15°	16 km/s	0.04962 AU
1991 AQ=1994 RD	303°70	Jan 23	131°	+22°	27 km/s	0.03552 AU
1994 AH 2	303°73	Jan 23	109°	+ 4°	22 km/s	0.11336 AU
1992 QN	304°36	Jan 24	123°	+48°	16 km/s	0.13440 AU
1993 VD	306°64	Jan 26	152°	+15°	19 km/s	0.03198 AU
1989 QF	309°01	Jan 29	137°	+26°	17 km/s	0.04066 AU
P/1833 (Dunlop)	310°68	Jan 30	138°	+23°	33 km/s	0.03332 AU
P/1947 X (Honda)	313°52	Feb 02	216°	+30°	61 km/s	0.13124 AU
P/1939 III (Jurlof-Achmarof-Hassel)	314°26	Feb 03	254°	− 4°	64 km/s	0.03822 AU
1995 CS	314°79	Feb 04	310°	−21°	28 km/s	0.00072 AU
P/1857 I (d'Arrest)	315°14	Feb 04	263°	+23°	52 km/s	0.01231 AU
P/1472	317°76	Feb 06	201°	− 4°	25 km/s	0.06820 AU
Adonis (2101)	319°93	Feb 09	314°	−16°	27 km/s	0.01209 AU
1993 QA	320°18	Feb 09	24°	−54°	14 km/s	0.05148 AU
P/868	320°41	Feb 09	186°	+35°	46 km/s	0.02735 AU
1994 CB	322°88	feb 11	215°	+50°	15 km/s	0.15871 AU
P/1947 III (Becvar)	323°45	Feb 11	237°	+11°	67 km/s	0.04749 AU
P/1941 II (Friend-Reese-Honda)	323°35	Feb 11	321°	+3°	25 km/s	0.08722 AU
P/1743 I	323°74	Feb 12	354°	− 7°	22 km/s	0.03815 AU
P/1861 III (Tuttle)	324°51	Feb 13	238°	−45°	70 km/s	0.10028 AU
P/1931 IV (Ryves)	325°43	Feb 14	281°	−21°	59 km/s	0.12833 AU
P/1985 III (Honda-Mrkos-Pajdusakova)	325°52	Feb 14	329°	−18°	27 km/s	0.06120 AU
P/1990 XIV (id.)	325°64	Feb 14	329°	−18°	27 km/s	0.06142 AU
Camillo (3752)	327°64	Feb 14	228°	−86°	32 km/s	0.04467 AU
P/1858 IV (Bruhns)	326°66	Feb 15	275°	+12°	56 km/s	0.04309 AU
P/1797	326°81	Feb 15	212°	+10°	61 km/s	0.13908 AU
P/1699 I	327°01	Feb 15	267°	+11°	58 km/s	0.09687 AU
Nereus (4660)	327°02	Feb 16	2°	+ 9°	13 km/s	0.00530 AU
P/1854 IV (Klinkerfues)	327°42	Feb 16	307°	+37°	33 km/s	0.02241 AU
P/1766 II (Helfenzrieder)	327°80	Feb 16	161°	+16°	30 km/s	0.13004 AU
Pan (4450)	327°92	Feb 16	157°	+19°	21 km/s	0.02631 AU
P/1771 (Messier)	328°57	Feb 17	349°	+22°	22 km/s	0.17934 AU
1994 GV	328°64	Feb 17	100°	+25°	14 km/s	0.00637 AU
1995 FO	328°69	Feb 17	358°	−43°	15 km/s	0.13171 AU
1987 OA	329°96	Feb 18	333°	−26°	22 km/s	0.08062 AU
P/1902 II (Grigg-Skjellerup)	330°07	Feb 18	133°	+ 1°	21 km/s	0.13781 AU
1995 CR	331°76	Feb 20	303°	+ 0°	31 km/s	0.01383 AU
P/1964 VI (Tomita-Gerber-Honda)	228°50	Feb 27	276°	−15°	66 km/s	0.16069 AU
P/1976 IV (Bradfield)	340°59	Feb 28	12°	−63°	35 km/s	0.00643 AU

The Leonids

Another Leonid Enhancement

Bulletin 7 of the International Leonid Watch

Peter Brown and Jürgen Rendtel

The 1995 return of the Leonid meteor shower was well covered by amateur observers. From a preliminary analysis of the visual and forward scatter observations, the shower showed a statistically significant enhancement at the level of 2–3 × over the quiet-time Leonid flux profile in the interval lasting at least during $\lambda_\odot = 234.^\circ5$–$235.^\circ5$, with a broad maximum in the region $\lambda_\odot = 235.^\circ0$–$235.^\circ4$. A possible higher "outburst" level of activity near $\lambda_\odot = 235.^\circ0$ is not yet confirmed and is thus omitted from this first analysis.

1. Introduction

As reported in Bulletin 6 of the *ILW* [1], the fifth *ILW* period (November 5–25, 1995) showed strong promise of yielding enhanced activity over the long term (pre-1994) activity profiles. Better lunar conditions than in 1994 were also expected to contribute to a more precise profile with lower correction values applied to these visual data. While some lunar interference was still present in the early morning observations for observers (which led to extremely high correction factors), there are enough visual Leonid counts under good skies made in 1995 to allow a first analysis of the activity near the long-term peak at $\lambda_\odot = 235.^\circ3$. While the enhancement in 1995 was probably not as great as in 1994 [2], there are clear indications that the flux was about 2–3 times the long-term average.

2. 1995 visual observations

To date, one week after the Leonid peak, 1423 Leonids have been reported to the *IMO* observed in the interval $\lambda_\odot = 234°$–$236°$ (2000.0) by 34 observers. This is by far the most successful Leonid campaign to date and we expect to receive substantial amounts of additional reports in the coming months. A great deal of magnitude data has also been submitted and we hope to present this in the complete analysis of the 1995 return in the next *ILW* Bulletin. A standard value of $r = 2.0$ has been calculated from all available magnitude data between November $17.^h0$ UT and November $19.^h0$ UT. This was used for all the observations reported here, though it is quite probable that this value varied through the stream. The interval for which we have the most data is the 48 hours centered about the long-term peak at $\lambda_\odot = 235.^\circ3$. All initial raw ZHR counts were selected such that the total correction factors were less than 5 and then binned in increments of $0.^\circ01$ of solar longitude, and then a 3-point averaging was performed over this final dataset. Obvious outliers were also removed, though this amounts to a small fraction of the total dataset. There were observations made in the interval $\lambda_\odot = 234.^\circ9$–$235.^\circ0$ which showed a systematic shift such that the recorded ZHR values were near to or in excess of 100. These values have been removed from this preliminary analysis, but we hope to include these and other measurements made during this interval in a more complete analysis in the next Bulletin. Hence, we cannot strictly rule out the possibility that a short, intense burst of activity occurred in this interval, but observations made on either side of this time do not support ZHRs that high.

The final ZHR curve constructed in this manner is shown in Figure 1. Over much of this interval, the ZHR is actually fairly constant somewhere between 20-30. This is more than a factor of 2 above the long-term average maximum ZHR of approximately 10 [3]. A small increase near $\lambda_\odot = 235.^\circ3$ is probably the result of inclusion of some observers with known high perception, though further analysis of this feature will be performed when all data are available. It has been suggested [4] that the peak in activity associated with the outburst in 1994 occurred substantially later than the long-term maximum quoted here close to $\lambda_\odot = 235.^\circ9$ at a position not yet significantly covered by the data at hand. It will be interesting to see if any feature present in 1994 near this longitude repeats in 1995, though this is difficult to predict in advance.

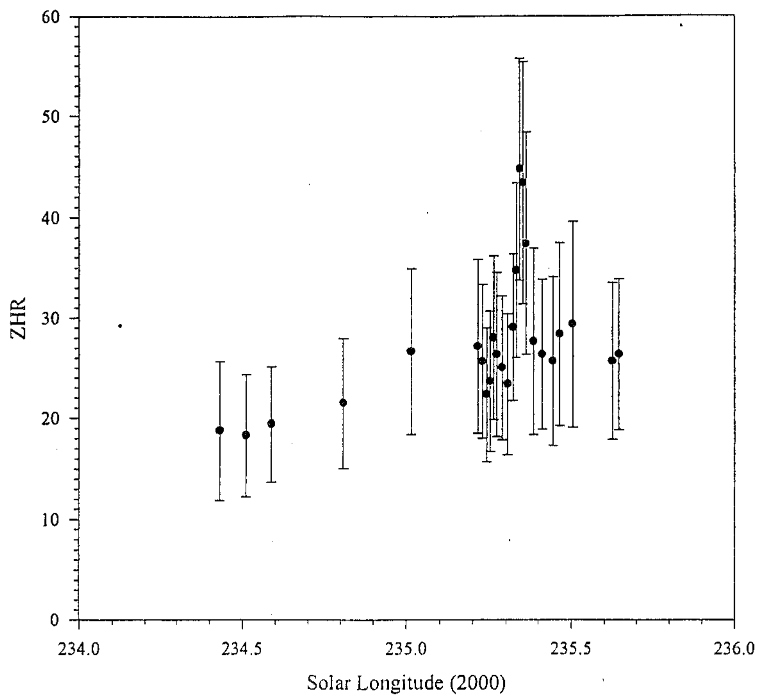

Figure 1 – Preliminary activity profile of the 1995 Leonids.

3. Radio results

In general, radio forward scatter systems can detect overdense echoes with little regard to scattering geometry as these become non-specular shortly after formation [5] and hence provide a reasonable estimate of the flux in the long duration echo classes. Underdense echoes are more problematic to interpret with these systems and cannot generally be related directly to any changes in flux without detailed corrections for geometry.

Shelby Ennis observed the shower at 144 MHz via forward scatter in Kentucky, USA, and recorded little increase in activity right through $\lambda_\odot = 236°$. He noted the following [6]:

> *Monitored the 144.278 beacon in EN15 (South Dakota, I think) a good part of Friday afternoon, had some nice long bursts* 16^h00^m–18^h00^m *UT November 17 with few to no pings. (Radiant set about* 19^h30^m *UT or so). There were not an exceptional number of bursts—maybe one every 10 minutes—but this is quite unusual for that time of day when we usually would get nothing. This morning (November 18), got a few pings at around* 9^h20^m *UT November 18, lasting 10–15 minutes; but no bursts longer than about 5 sec.*

It is interesting to note that the one time period from this report in which some unusual activity is noted (16^h00^m–18^h00^m UT on November 17) also corresponds to the period near $\lambda_\odot = 235.^\circ9$ where unusually high visual activity was reported from Japan, but not included in the visual analysis as stated earlier. This period needs additional observational data of any type.

From=20Europe, the radio FS of Maurice De Meyere from Deurle, Belgium, appears to have detected an increase in echoes closer to November 18, 4^h–7^h UT ($\lambda_\odot = 235.^\circ4$–$235.^\circ5$) [7]. These radio observations also showed enhancement between 0^h and 1^h UT on November 18. In fact, the entire period from 0^h UT to 7^h UT on November 18, when observations ceased, showed activity above the previous days and suggests a broad level of increased flux over this entire period. Since the radiant does not rise from this location until close to 0^h UT, it appears this observation is in accord with the visual observations.

4. Conclusions

The results to date from the 1995 Leonid return suggest a broad, relatively long-lived increase in rates at an enhancement level of 2–3 over the quiet time Leonids over the interval lasting from at least $\lambda_\odot = 234.^\circ5$ to $\lambda_\odot = 235.^\circ5$ with the highest activity reached in the interval $\lambda_\odot = 235.^\circ0$–$235.^\circ4$. Some evidence, both from visual and radio data, also exists for a much higher flux near $\lambda_\odot = 235.^\circ0$, but this needs additional confirmation. The full magnitude of the increase and its total duration must wait until all observations have been submitted for analysis in the next *ILW* Bulletin.

Acknowledgments

The authors wish to thank all the observers who sent in Leonid data promptly after the peak. We will list all observers contributing to the final profile in the next *ILW*.

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[2] Jenniskens, P., "High Leonid Activity on November 17-18 and 18-19, 1994", *WGN* 22:6, December 1995, p. 194.

[3] Brown, P., "Bulletin 5 of the International Leonid Watch (ILW)", *WGN 22:6*, December 1994, pp. 190.

[4] Jenniskens, P., "The first in a new series of Leonid outbursts", in *Proceedings of IAU 150: The Physics, Chemistry and Dynamics of Interplanetary Dust*, submitted, 1995.

[5] Millman, P.M., "The Meteor Radar Echo-An Observational Overview", *Astron. J.* 67, 1962, p. 235.

[6] Ennis, S., *personal communications*, November 18, 1995.

[7] Steyaert, C., *personal communications*, November 19, 1995.

A Second Leonid Outburst in 1995

Peter Jenniskens, NASA/Ames Research Center

A first evaluation of the 1995 Leonid activity is given based on observations available to the author. Based on the evaluations, expectations are given for the 1996 return.

After its first awakening in 1994 [1], the 1995 return of the Leonid stream was well observed. A first impression has already been given by Jürgen Rendtel in an *IMO* meteor shower circular under the header: *short summary: no outburst* [2]. (*See also the previous article*, ed.) This short communication is to point out that there was in fact a meteor outburst in the present year of the *International Leonid Watch*, the disagreement being merely one of semantics, however. I adopt the following definition of a *meteor outburst*: any significant increase of rates above the usual annual meteor stream activity [3]. In most cases, those enhancements will be due to relatively fresh cometary ejecta that have not scattered so widely as to become part of an annual stream.

The 1995 Leonid stream was well observed, amongst others in a campaign by the *Dutch Meteor Society* with photographic stations in Spain and California. At the time of writing, only a very small portion of the visual observations have been extracted from the tape recordings and prepared for analysis. Visual data are available from Marco Langbroek, Koen Miskotte (Gaudix, Spain) and the author (San Jose, California) [4]. Additional visual counts were kindly provided by Carl Johannink (the Netherlands), Neil Bone (UK), and a long series of counts by George Zay (California). The resulting ZHRs are shown in Figure 1 and were calculated for an adopted magnitude distribution index $r = 2.3$ and a radiant altitude dilution exponent $\gamma = 1.4$.

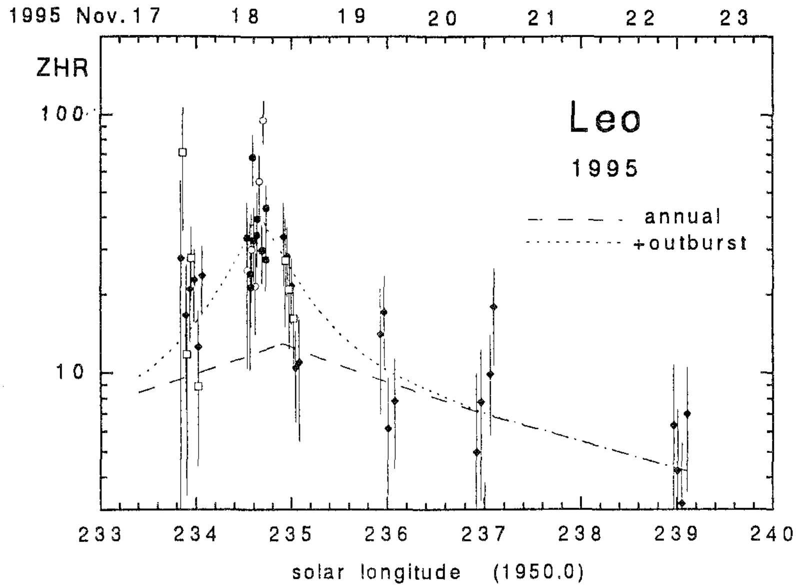

Figure 1 – ZHRs of Leonids in 1995.

I confirm the impression by Neil Bone and others that the Leonid rates were *substantially better than in the late 1970s, 1980s and early 1990s* [5]. Rates were enhanced on November 17 and 18, with best rates over Europe during the night of November 18. The peak rate was about ZHR $= 32 \pm 5$ at a time that annual Leonid activity was about ZHR $= 12$. The peak rate is in good agreement with rates calculated by Rendtel [2], but is also 2–3 times higher than normal rates, sampled in many time intervals in a systematic way and confirmed by at least five independent visual observers. In summary: there was an outburst.

The outburst is confirmed by radio meteor scatter data by Ilkka Yrjola from Kuusankoski, Finland, who kindly forwarded his data shortly after the event. At this time, I know of similar results by Maurice de Meyere, Deurle, Belgium, and Peter Bus, Groningen, the Netherlands. Yrjola's counts of meteor reflections for the past three years (Figure 2) show nicely the significant increase of Leonid rates in 1995. On November 18, the count rose above the typical sporadic background at this time of year (dashed line), while no such increase was observed in 1993. The radio data, too, suggest that the event was of long duration as in 1994. After correction for observability [6], I have a peak at $\lambda_\odot = 234\overset{\circ}{.}60 \pm 0\overset{\circ}{.}05$ (1950.0) and an exponent $B = d\log \mathrm{ZHR}/d\lambda_\odot = 1.0 \pm 0.1$. Hence, rates started to increase at about $\lambda_\odot = 233\overset{\circ}{.}6$ and the event was over by $\lambda_\odot = 235\overset{\circ}{.}6$. Visual observations suggest a peak at about $\lambda_\odot = 234\overset{\circ}{.}65 \pm 0\overset{\circ}{.}10$. In addition, the mean reflection duration was much longer than those of the sporadic meteors, consistent with a high abundance of bright meteors (as mentioned by many visual observers).

Assuming that Leonid rates would follow patterns of activity during the last return in the 1960's, I was expecting a broad activity profile of relatively bright Leonid meteors, with peak activity of about ZHR $= 40$ (30 from the outburst, 10 from the annual stream), an exponent of $B = 1.05 \pm 0.1$ and a time of maximum at solar longitude $\lambda_\odot = 235\overset{\circ}{.}2 \pm 0\overset{\circ}{.}1$ (Noting that the time of maximum could well scatter considerably around the node of the comet orbit at $\lambda_\odot = 234\overset{\circ}{.}5$) [7]. A dotted line in Figure 1 shows that expected activity profile, and there is agreement with observations. Disappointing to me was only that the peak did not happen over California; much to the joy of European observers who had a very good time.

I conclude that, thus far, the Leonids behave much the same way as during the previous return. If this trend is going to continue next year, then there will again be a broad shower of bright Leonids but with higher rates, perhaps up to ZHR $= 100$. In addition, observers are requested to keep paying attention to a possible narrow component of faint Leonids that may start to appear on top of that broad shower in 1996 or 1997, most likely somewhat after the solar longitude $\lambda_\odot = 234\overset{\circ}{.}5$ (1950.0).

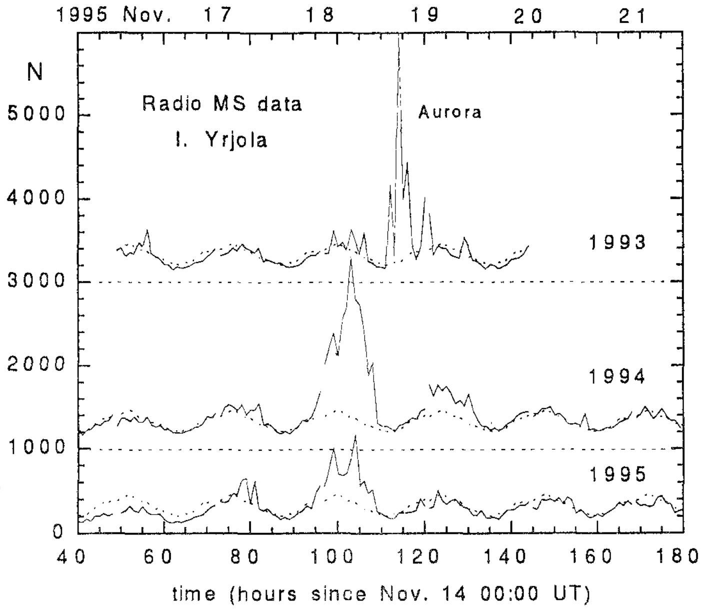

Figure 2 – Reflection count at 87 MHz during the past three years. Note the increase of rates on November 18, 1995, and the absence of such peak in 1993. The 1993 data contain some narrow spikes due to aurora. Data: Ilkka Yrjola.

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The α-Monocerotids

Activity Burst of α-Monocerotids on November 22, 1995

Jürgen Rendtel

A short-duration activity outburst of the α-Monocerotids has been observed on November 22, 1995, between 1^h15^m and 1^h45^m UT. The highest EZHR occurred in the 10-minute interval 1^h25^m–1^h35^m UT and reached 350 ± 40. Higher EZHRs can be derived from shorter intervals. The peak time derived from the available data is 1995 November 22, $1^h28^m \pm 5^m$ UT, or $\lambda_\odot = 239\overset{\circ}{.}321 \pm 0\overset{\circ}{.}004$ (2000.0). The FWHM of the peak as derived from the 10-minute intervals amounts to $0\overset{\circ}{.}019$ in solar longitude or 27 minutes. The population index r has been found to be $r = 2.51 \pm 0.05$. Assuming an atmospheric entry velocity $V_\infty = 60$ km/s, the peak number density is 50×10^{-9} km^{-3}. This is comparable to the 1991 Perseid peak figures.

1. Introduction

The three short-time high-activity events of the α-Monocerotids in 1925, 1935, and 1985 gave rise to expectations that another outburst might occur in 1995 [1–5]. Indeed, such an activity has been widely observed from Europe in the early morning of November 22. The reported durations of the previous observed outbursts was of the order of 15 minutes only. Contrary to the older records, we this time have a complete record of the ascending and descending branch—if this term can be used at all.

The very first analysis presented here includes immediate reports obtained via phone and e-mails from the following observers:

Luis Bellot, Jiří Borovička, Roberto Gorelli, Roberto Haver, Alberto Latini, Alastair McBeath, Sirko Molau (and the MOVIE video camera), Jürgen Rendtel, Francisco Reyes, Ulrich Sperberg, Pavel Spurný, and Siegfried Stapf.

2. Magnitude and activity data

The magnitude data reported by some of the observers allowed to calculate the population index r for the outburst period. Both the combination of all magnitude data—considering the limiting magnitudes of the observers—and the average of r-values obtained from individual magnitude distributions yield $r = 2.51 \pm 0.05$. The portion of bright shower meteors has been reported to be small, no fireballs were mentioned.

The activity started *from zero* and reached *immediately* a very high level. Most interestingly, observers reported almost exactly the same minute of the activity begin. The average of all this information yields $1^h13^m \pm 2\overset{m}{.}4$ UT. Although it has to be checked with further reports, there seems to be a systematic shift from southeast to northwest, or east to west. Italian and Slovak observers give 1^h10^m UT as the start time, while Central European observers report 1^h12^m–1^h14^m UT, while a Spanish report indicates 1^h16^m or 1^h17^m UT as the start time. Data provided in full details have been split into intervals as shown in Table 1 for this analysis.

Table 1 – Intervals chosen for the ZHR analysis of the α-Monocerotids.

Time (UT)	Duration (min)
Before 1^h00^m	approximately 60
1^h00^m–1^h15^m	15
1^h15^m–1^h25^m	10
1^h25^m–1^h35^m	10
1^h35^m–1^h45^m	10
1^h45^m–2^h00^m	15
After 2^h00^m	approximately 60

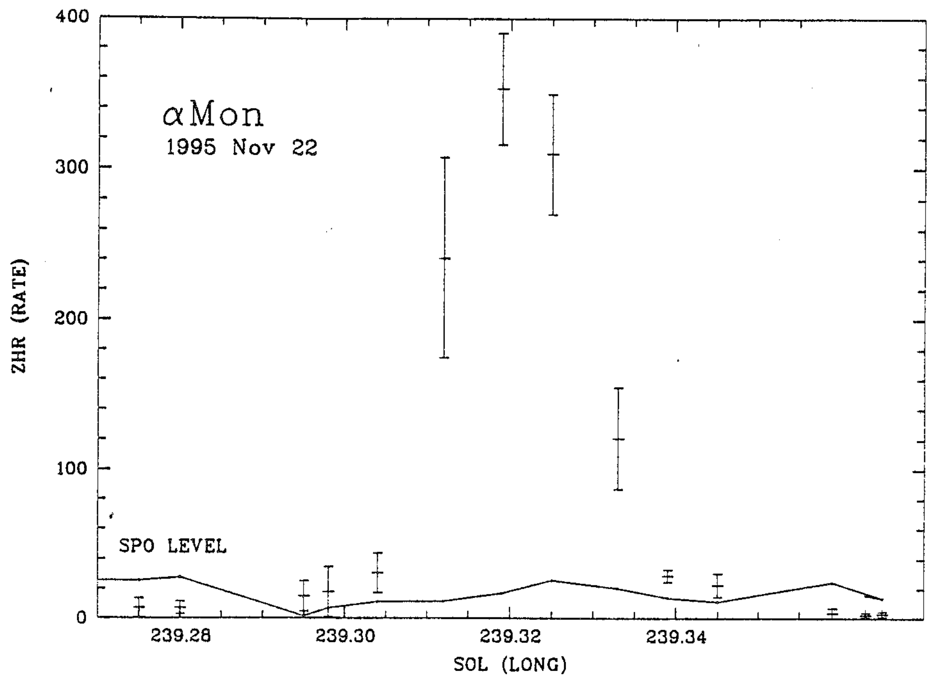

Figure 1 – Preliminary activity profile of the 1995 α-Monocerotids.

The sampling period for the determination of the ZHR profile was 0°014 in solar longitude, the interval was then shifted by 0°007 to obtain ZHR averages. The resulting profile is shown in Figure 1. The maximum for 10-minute counts occurred at $\lambda_\odot = 239.^\circ321 \pm 0.^\circ004$ (2000.0), or on November 22, $1^h28^m \pm 5^m$ UT. The full width at half maximum (FWHM) of the peak is only 27 minutes or 0°019 in solar longitude. Considering shorter time intervals, one may find EZHRs being higher by a factor of about 2.

Knowing the population index r and the atmospheric entry velocity V_∞, we may also calculate the number density. However, the velocity is not yet known exactly, and we assumed a value of $V_\infty = 60$ km/s. Probably, the multi-station photographs obtained by Dutch observers in Spain [6] will provide us with precise velocity and orbital data. The peak ZHR of 350 corresponds to a number density for meteoroids of at least 10^{-3} g (about magnitude +3.5 or brighter) of $(50 \pm 25) \times 10^{-9}$ km^{-3}, or 50 meteoroids in a cube of 1000 km edge length. The particle flux of meteoroids of at least 10^{-3} g is then 3×10^{-6} km^{-2}s^{-1}. These figures are comparable to the number density found in the 1991 Perseid peak [7, pp. 276–279], but lower than the number densities derived from the maximum periods of the Quadrantids and Geminids.

The 1925, 1935, and 1985 observations yielded only a rather rough radiant position. This will certainly be changed after the analysis of the 1995 data, because we now have both a larger number of meteor plots and, with higher precision, video recordings. The plots indicate a radiant position which is slightly north of the position listed, e.g., in the *IMO* meteor shower working list. In the *IAU* Circular [8] on this event, Haver and Gorelli gave $\alpha = 113.^\circ5$, $\delta = -03°$, and Nagy, Sárenczky, and Tepliczky gave $\alpha = 116°$, $\delta = +04°$. My first estimate yielded $\alpha = 113°$, $\delta = -03°$, but a revision of all plots of shower meteors yields $\alpha = 111°$, $\delta = +02°$.

3. Conclusions

Since their discovery, the α-Monocerotids have been fairly regularly monitored. Normally, the activity is very low, sometimes almost undetectable [5, pp. 244–246]. The sudden activity bursts observed in the past suggest that a regular monitoring of the α-Monocerotids is worthwhile. Despite the fact that the 1995 event fits the suspected 10-year periodicity, similar short-term outbursts may have passed unnoticed. A first check of *VMDB* files shows that this is easily possible, since the observers have to exactly be in the right position and the Moon should not interfere too strong. Table 2 summarizes the situation for the period between the 1985 and 1995 outbursts.

Table 2 – Times of the return of the $\lambda_\odot = 239.^\circ32$ position and phase of the Moon k in the years between the 1985 and 1995 outbursts, and for 1996.

Year	$\lambda_\odot = 329.^\circ320$	k
1985	Nov 21 11^h50^m UT	+0.70
1986	Nov 21 18^h05^m UT	−0.75
1987	Nov 22 00^h15^m UT	+0.00
1988	Nov 21 06^h20^m UT	+0.95
1989	Nov 21 12^h35^m UT	−0.36
1990	Nov 21 18^h40^m UT	+0.18
1991	Nov 22 00^h50^m UT	−1.00
1992	Nov 21 07^h00^m UT	−0.14
1993	Nov 21 13^h00^m UT	+0.49
1994	Nov 21 19^h15^m UT	−0.88
1995	Nov 22 01^h25^m UT	−0.01
1996	Nov 21 07^h30^m UT	+0.89

A careful inspection of Table 2 shows that there is often quite a narrow window for observations since the radiant reaches sufficient elevations only after local midnight, and the Moon further narrows the effective interval, particularly because there are rather few bright shower meteors.

Kresák [9] pointed out that the α-Monocerotids are an extremely condensed stream. The majority of particles does not seem to be dispersed, and the particle stream must almost be like a torus. The rates of the order of 3 to 5 reported annually do not coincide with the position of the peak but occur at $\lambda_\odot \approx 240°$. Although the 1996 window is small due to the waxing Moon, observers in the respective time zones (UT + $1^h\!.5$–$3\overset{\circ}{.}5$, i.e., about 20° W to 60° W longitude should try to observe in order to obtain further hints on a periodicity.

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The Visual Observation of the Outburst of the 1995 α-Monocerotids in Ondřejov

Jiří Borovička and Pavel Spurný, Ondřejov Observatory

An activity profile of the α-Monocerotid outburst on November 22 UT, obtained from visual observations at Ondřejov Observatory, is presented.

We watched the Monocerotid meteors visually at the Ondřejov Observatory (λ = 14°47′ E, φ = 49°55′ N) on the night of November 21-22, 1995. The night was perfectly clear, the best in several weeks. The expected short-duration shower at an unknown time [1] called for a long continuous observation. Because of strong frost, we adopted the strategy of observing from our office through large windows. This enabled a sufficiently large field of view in the southern direction, covering the azimuths nearly from 320° to 50° and zenith distances from 30° to 85°. A limiting magnitude of +6 was achieved. Both observers were watching the same part of the sky. In fact, one of us (Pavel Spurný) saw almost all meteors reported here, while the second one was recording the meteor counts. The meteor counts given here are therefore perfectly applicable to a single-observer observation.

Our watching started at 22^h54^m UT. Almost immediately, one meteor which could have been a Monocerotid was seen. Another possible Monocerotid was recorded at 23^h42^m. The classification of these two meteors as Monocerotids is, however, uncertain, because the actual position of the radiant was not known at that time. The first certain Monocerotid was seen at 1^h12^m, only a few minutes before the main outburst. In the meantime, seven other, non-Monocerotid, meteors were seen between 23^h00^m and 0^h00^m UT, but only two between 0^h00^m and 1^h00^m UT.

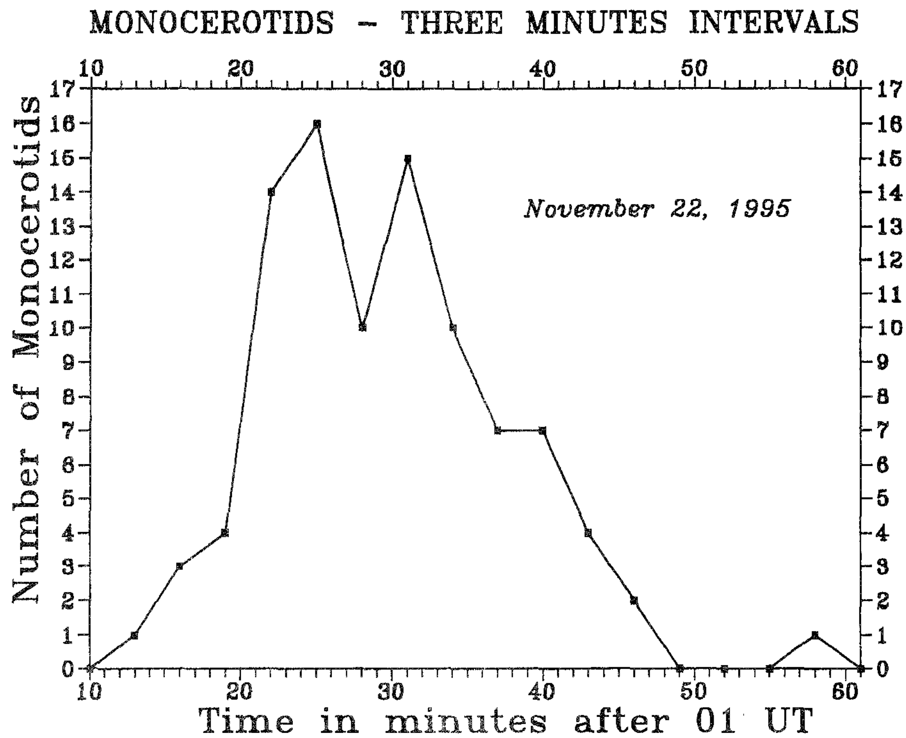

Figure 1 – Activity profile of the 1995 α-Monocerotids as observed from the Ondřejov Observatory.

Table 1 – α-Monocerotid counts on November 22, 1995, between 1^h12^m and 2^h21^m UT in one-minute intervals. (Only the minutes part of each interval is mentioned.)

Interval	12	15	16	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Monocerotids	1	1	2	3	1	2	5	7	5	5	6	2	4	4	4	5	6
Interval	33	34	35	36	37	38	39	40	41	42	43	46	47	57	04	10	21
Monocerotids	6	1	3	3	1	3	3	3	1	2	2	1	1	1	2	1	1

The counts of the certain Monocerotid meteors in one-minute intervals are given in Table 1. The profile of the outburst is presented in Figure 1.

In Figure 1, the numbers of meteors summed over three minutes intervals have been plotted to obtain a smoother curve. It can be seen that we have observed a double maximum. The minimum between the two maxima is, however, at the limit of statistical significance, so its reality will remain doubtful if not confirmed by other observations. On the other hand, the frequency at about 1^h28^m UT was certainly not higher than in the minutes before and after this time. We therefore conclude that the shower either (and more probably) exhibited two maxima, the first of about five minutes long from 1^h22^m to 1^h27^m UT, and the second of about four minutes long from 1^h30^m to 1^h34^m UT, or one broader maximum from 1^h22^m to 1^h34^m with nearly constant frequency throughout its duration. To obtain the equivalent zenithal hourly rates (ZHR) in the first case, we used two minutes counts. During both maxima, 12 meteors in two minutes were seen, corresponding to 360 meteors per hour. The zenith distance of the radiant at that time was $z_R = 52\overset{\circ}{.}5$. The correction factor $1/\cos^\gamma z_R$ is equal to 2 assuming $\gamma = 1.4$ [2]. So, a ZHR of about 700 is obtained. In the minimum between the two maxima the ZHR is estimated to be about 400. In the interpretation as one "broad" maximum, we sum up all meteors in the 12-min maximum, obtaining 59 meteors and ZHR of about 600.

The remarkable feature of the frequency profile is a very steep rise of the frequency after 1^h20^m UT compared with the slower decay after the maximum. The strong activity of the shower, with at least one observed meteor per minute (ZHR > 120), lasted for 25 minutes from 1^h19^m to 1^h44^m UT. Before 1^h10^m UT, the activity was very low with ZHR < 5. On the other hand, a significant tail activity was present after the outburst, with ZHR $\approx$ 15 between 2^h00^m and 2^h30^m UT. This confirms the asymmetric nature of the shower. Our observation was finished on 2^h40^m UT.

Individual meteors were not plotted. However, the position of the radiant was estimated to $\alpha = 113°$, $\delta = -01°$ (2000.0) with a possible error of 2° after the outburst, mainly on the basis of meteors observed near the radiant. This position is about 5° to the north from the radiant positions reported previously [2].

Among the 98 meteors observed, only three were brighter than magnitude 0. During the main outburst, one −3 meteor was seen, and, surprisingly, among the four meteors observed after 2^h00^m UT, one was of magnitude −2, and one of magnitude −1.

In summary, the predicted outburst of Monocerotid meteors in 1995 [1,3] really occurred and reached a peak ZHR of 600–700. The center of the outburst (not necessarily the peak activity) occurred at $\lambda_\odot = 238^\circ\!.637$ (1950.0), which is 25 minutes later than in 1985 and 55 minutes earlier than in 1925 [2]. When the data from this contribution are combined with the results of other groups in Europe, the 1995 outburst will certainly become the best documented Monocerotid outburst. Besides the visual observations, also radar data and TV spectrograms were obtained in Ondřejov.

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Observing α-Monocerotids from Lelekovice

Vladimír Znojil and Kamil Hornoch

An activity profile of the α-Monocerotid outburst on November 22 UT, obtained from visual observations at Lelekovice in the Czech Republic, is presented.

Favorable radiant position and good weather, even though the visibility was slightly poorer, allowed us to follow the whole duration of the shower under fairly constant conditions. It was observed by Kamil Hornoch from Lelekovice ($\varphi = 49°21'$ $\varphi = 16°39^m$). The shower occurred in the interval 1^h18^m–1^h53^m UT). During this period, 60 meteors were recorded, 53 of which were Monocerotids. The cloudiness was 0%, and the limiting magnitude was +5.9.

The average brightness of the plotted Monocerotids was +3.40, and the brightness of the sporadic meteors, which were seen either during the first interval or during further observing carried out by the same observer under the same observing conditions, was +3.27. According to calculations based on [1], we obtain $r = 3.3 \pm 0.4$ (under the presumption that $r = 3.2$ for the sporadic meteors). The relevant value of the correction factor for the limiting magnitude (to +6.5) is 2.05. The numbers of observed Monocerotids in 2-minute intervals are in Table 1.

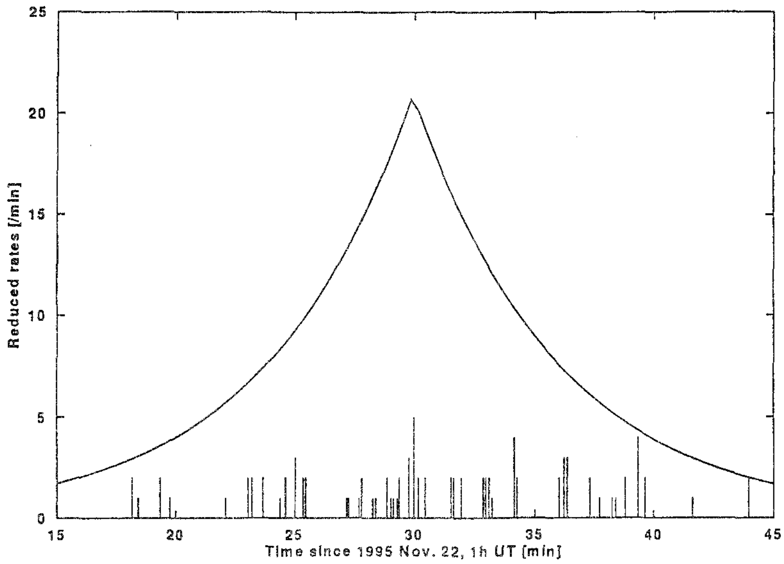

Figure 1 – Activity profile of the 1995 α-Monocerotids as observed from Lelekovice, Czech Republic.

Table 1 – Two-minute interval counts for the 1995 α-Monocerotid observations from Lelekovice, Czech Republic.

Interval (UT)	Mon	Interval (UT)	Mon
1^h18^m–20^m	4	1^h32^m–34^m	5
1^h20^m–22^m	0	1^h34^m–36^m	2
1^h22^m–24^m	4	1^h36^m–38^m	5
1^h24^m–26^m	6	1^h38^m–40^m	5
1^h26^m–28^m	4	1^h40^m–42^m	1
1^h28^m–30^m	10	1^h42^m–44^m	1
1^h30^m–32^m	6	1^h44^m–46^m	0

The great and rapid changes of the hourly rates makes estimating the maximum time by the common method, i.e, by making a histogram of the meteor numbers in the particular intervals, very complicated. However, the fact was used that the whole phenomenon was observed, and, therefore, the moments of the distributions of the times of the individual meteors were calculated. The individual meteors were weighted by the correction to a zenithal radiant and standard observing conditions. The higher moments allowed for the possibility of expressing the changes of the hourly rates by the double-exponential distribution, which is used, e.g, in [2,3].

The time of maximum is $1^h29^m\!.9 \pm 2^m\!.8$, which is November 22.062 ± 0.002 UT, and was calculated from the distribution function of the times of the individual meteors. The time of maximum corresponds to solar longitude $\lambda_\odot = 239^\circ\!.253 \pm 0^\circ\!.003$ (1995.0), or $\lambda_\odot = 238^\circ\!.625 \pm 0^\circ\!.003$ (1950.0). The typical halfwidth of the maximum was only $5^m\!.98 \pm 1^m\!.21$. The ZHR at the maximum is 1250 ± 220. These data agree in an excellent way with the data of the former shower of Monocerotids [3] (maximum in in the interval $\lambda_\odot = 238^\circ\!.617$–$238^\circ\!.749$ (1950.0) and the maximum hourly rate in the interval from ≥ 600 to ≥ 2300).

The obtained hourly rate function is plotted in Figure 1. Appearances of individual meteors are marked on the x-axis. They are divided into 4 groups, according to their brightness in whole magnitudes, the halves of magnitudes being ignored.

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Ongoing Meteor Work

Two "Tunguskas" in South America in the 1930's?

Duncan Steel, Anglo-Australian Observatory

There is evidence that there were two massive bolide explosions which occurred over South America in the 1930's. One seems to have occurred over Amazonia, near the Brazil-Peru border, on August 13, 1930, whilst the other was over British Guyana on December 11, 1935. It is noted that these dates coincide with the peaks of the Perseids and the Geminids, although any association with those meteor showers is very tentative. The identification of such events is significant in particular in that they point to the need for a re-assessment of the frequency of Tunguska-type atmospheric detonations.

In 1989 an article by N. Vasilyev and G.V. Andreev in this journal [1] drew attention to a discussion, published in 1931 by L.A. Kulik [2], of a possible Brazilian counterpart to the Tunguska bolide explosion of 1908. The Brazilian event, which occurred on August 13, 1930, was described in the papal newspaper *L'Osservatore Romano*, the report being derived from Catholic missionaries working in Amazonia. That report, in Italian, was used as the basis of a front-page story in the London newspaper *The Daily Herald* (since closed down), which was published on March 6, 1931, and then seen by Kulik. For the interested reader, a copy of the story in *The Daily Herald* accompanies this article.

The locality of the explosion gives it its name: the Rio Curaca event. This is close to the border between Brazil and Peru, at $\varphi = 5°$ S, $\lambda = 71\overset{\circ}{.}5$ W.

Both of these newspaper stories were discussed in a recent paper by Bailey and co-workers [3], who provide an English translation of the story which appeared in *L'Osservatore Romano*. Since that paper should be accessible to many readers of *WGN*, I will not give an extensive account of it here. I will, however, just mention that although the eye-witness accounts given do cover the phenomena which one might expect to be produced by a massive bolide, there are some other interesting reported observations which would require some explanation. These include the following:

1. An ear-piercing "whistling" sound, which might be understood as being a manifestation of the electrophonic phenomena which have been discussed in *WGN* over the past few years.
2. The Sun appearing to be "blood-red" before the explosion. I note that the event occurred at about 8^h local time, so that the bolide probably came from the sunward side of the Earth. If the object were spawning dust and meteoroids—that is, it was cometary in nature—then, since low-inclination, eccentric orbits produce radiants close to the Sun, it might be that the solar coloration (which, in this explanation, would have been witnessed elsewhere) was due to such dust in the line of sight to the Sun. In short, the Earth was within the tail of the small comet, if this explanation is correct.
3. There was a fall of fine ash prior to the explosion, which covered the surrounding vegetation with a blanket of white: I am at a loss with regard to this, if the observation is correct (and not mis-remembered as being prior-, rather than post-impact).

Bailey et al. also discuss the fact that the Rio Curaca event occurred on the day of the peak of the annual Perseid meteor shower, but conclude that this is likely to be purely a coincidence. The date is also close to August 10, on which day in 1972 a large bolide was filmed skipping through the upper atmosphere above western Wyoming and Montana, departing from the Earth above Canada [4]. Again, this may be merely a coincidence.

A brief discussion of the event is also given by R. Gorelli in the August 1995 issue of *Meteorite!* magazine.

Menace of Meteors Like Huge Bombs from Space

HURRICANE OF FLAME

BLAZING BOLTS FIRE FORESTS

MANKIND'S LUCK

Another colossal bombardment of the earth from outer space has just been revealed.

Three great meteors, falling in Brazil, fired and depopulated hundreds of miles of jungle.

NEWS of this catastrophe has only now reached civilisation because the meteors fell in the remote South American wilderness.

It was yet another lucky escape of mankind from an appalling and unrealised peril.

The last great meteor fell in Siberia in 1908, in a district so remote that only last year were details of its destruction given to the world.

Had either of these two meteor falls chanced to strike a city in a densely-populated country, frightful loss of life and damage would have been caused.

"A meteor," Mr. C. J. P. Cave, an ex-president of the Royal Meteorological Society, stated recently, "carries in front of it a mass of compressed and incandescent air.

"When it strikes the earth, this air 'splashes' in a hurricane of fire . . ."

The Brazilian meteors are reported (says the Central News) by Father Fidello, of Aviano, writing from San Paulo de Alivencia, in the State of Amazonas, to the papal newspaper, "Osservatore Romano."

BLAZING FOREST

The meteors fell almost simultaneously during an amazing storm.

Terrific heat was engendered. Immediately they struck the ground the whole forest was ablaze.

The fire continued uninterrupted for some months, depopulating a large area.

The fall of the meteor was preceded by remarkable atmospheric disturbances.

At 8 o'clock in the morning the sun became blood-red, and a penumbra spread all over the sky, producing the effect of a solar eclipse.

Then an immense cloud of reddish powder filled the air and it looked "as if the whole world was going to blaze up."

WHISTLING SOUND

The powder was succeeded by fine cinders which covered trees and vegetation with a blanket of white.

There followed a whistling sound that pierced the air with ear-breaking intensity, then another and another.

Three great explosions were heard and the earth trembled.

The Siberian meteor of 1908 completely destroyed the forest over an area of 70 miles in diameter.

Its roar was heard 600 miles away, and its glare maintained twilight all night even in England.

I now move on to the suspected explosion over British Guyana in 1935. The main source for information on this event is a story entitled *Tornado or Meteor Crash?* in the magazine *The Sky* (the forerunner of *Sky and Telescope*) of September 1939 [5]. A report from Serge A. Korff of the Bartol Research Foundation, Franklin Institute (Delaware, USA) was printed, he having been in the area—the Rupununi region of British Guyana—a couple of months later. The date of the explosion appears to have been December 11, 1935, at about 21^{h} local time. I might note that this is near the date of the peak of the Geminid meteor shower, but yet again this may be merely a coincidence. The location is given as being near $\varphi = 2°10'$ N, $\lambda = 59°10'$ W, close to Marudi Mountain.

Korff's description suggested that the region of devastation might be greater than that involved in the Tunguska event itself. On his suggestion, a message was sent to William H. Holden, who in 1937 was in the general region with the Terry-Holden expedition of the American Museum of Natural History. That group hiked to the top of Marudi Mountain in 1937 November and reported seeing an area some miles across where the trees had been broken off about 25 feet above their bases, although regrowth over two years in this tropical jungle had made it difficult to define the area affected. Holden confirmed, on returning to New York, that he believed the devastation was due to an atmospheric explosion of cosmic origin. An explorer and author, Desmond Holdridge, also visited the region in the late 1930's and confirmed the suspicion that a comet or asteroid detonation was responsible.

Korff obtained several local reports. the best being from a Scottish gold miner, Godfrey Davidson, who reported having been woken by the explosion, with pots and pans being dislodged in his kitchen, and seeing a luminous residual trail in the sky. A short while later, whilst prospecting, he came across a devastated region of the jungle he estimated to be about five by ten miles (8 by 16 kilometers), with the trees all seeming to have been pushed over.

Holden was unsure of the origin of the flattening of the forest, and pointed out that similar destruction can result from tornados. Holdridge, however, reported eye-witness accounts in accord with a large meteoroid/small asteroid entry, with a body passing overhead accompanied by a terrific roar (presumably electrophonic effects), later concussions, and the sky being lit up like daylight. A local aircraft operator, Art Williams, reported seeing an area of forest more than twenty miles (32 kilometers) in extent which had been destroyed, and he later stated that the shattered jungle was elongated rather than circular, as occurred at Tunguska and would be expected from the air blast caused by an object entering away from the vertical (the most likely entry angle for all cosmic projectiles is 45°).

There is a report of the Guyanan event, largely derived from the account in *The Sky*, in the newsletter *Meteor News* for March 1974. Apparently as a result of that, the publishers (Karl and Wanda Simmons, of Callahan, Florida) had some correspondence with a Mr. F.A. Liems of Paramaribo, Surinam, concerning a possible crater/event at Wayombo in that country; he gives the location as $\varphi = 5\overset{\circ}{.}25$ N, $\lambda = 56\overset{\circ}{.}05$ W. The letters date from 1976; apparently Liems died in 1982. In 1990, as a result of Andreev's article in *WGN* about the Brazilian event, Wanda Simmons sent copies to him, and he kindly sent copies on to me. Various notes/maps/letters are included, but it is difficult to know what to make of them: my impression is that this concerns something that occurred some time ago, not in this century, and its linkage with an incursion by an asteroid or comet is far from clear.

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The Makings of Meteor Astronomy: Part XI

Martin Beech, University of Western Ontario

The early 19th century saw the realization that various ideas on the origin of meteoroids could be tested by appealing to direct observations. The reflection theory of John Lubbock is reviewed, and the role of observations to vindicate and later dismiss the theory are discussed.

1. The art of experiment

It might fairly be said that experimental meteor astronomy began with Heinrich Brandes and Johann Benzenberg in 1798. As we saw last time [1] these two enthusiasts set about recording two station observations of meteors with the intention of determining meteor heights and velocities. Their work was largely successful in that it provided the first clear, experimentally derived evidence in support of Chladni's hypothesis [2] that meteoric bodies (what we would call meteoroids) entered the Earth's atmosphere from outer space.

The collection of two-station meteor observations became decidedly envogue during the first half of the 19th century [3] and the initial, somewhat ambiguous results of Brandes and Benzenberg were not only strengthened, but confirmed beyond any reasonable doubt. Meteoroids did indeed enter the Earth's atmosphere from outer space.

The extraterrestrial origin of meteoroids was not solely confirmed by two station observations. Indeed, the clearest demonstration that (at least some) meteoroids entered the Earth's atmosphere from outer space was the observation of meteor radiants. The earliest detection of a shower radiant was that witnessed during the 1833 Leonid storm. The implied consequences of a shower radiant were fully realized by Dennison Olmsted [4] (and others), but it was incorrectly concluded that the meteoroids emanated from a region situated several thousand kilometers above the Earth's surface. (We shall not pursue the background to Olmsted's reasoning here, but his conclusions were largely the result of woefully inaccurate determinations of Leonid meteor velocities). It is probably safe to claim that the 1833 Leonid storm and the establishment of several groups interested in observational meteor work were the two key events that established modern meteor astronomy.

2. An aside on practicalities

To the author's knowledge (and I expect letters on this point) only two practical, that is utilitarian applications of meteor astronomy have ever been developed. Probably the best known of these applications is that of meteor burst communication, which allows the exchange of data through the forward scatter of radio waves from meteor trails. The only other application (?) is that of longitude determination, which is essentially based upon two-, or more-, station observations of a meteor's beginning and end points.

The idea that bright meteors and fireballs might be utilized in the determination of differences in longitude was first mooted by Edmund Halley in 1719 [5]. Halley's idea was further discussed by George Lynn in 1727 [6], and while Lynn suggested that "common meteors" might also be used for the purpose of determining longitudes, he never actually made the appropriate observations.

It appears that the first practical determinations of differences in longitude by two-station meteor observations were published independently at essentially the same time, in 1839, in America and Germany. The German group collected their observations on the night of August 11, 1839, while the American group had collected their observations on November 25, 1835, but did not published their results until later [7]. Comparing the two-station meteor reductions with those obtained by more traditional methods revealed that the meteor based results were in agreement to within a few tenths of an arc minute—not bad given the inherent difficulties of the observations.

While two-station observation of meteor trails can in principle (and indeed in practice) be used to determine differences in longitude, it was apparently not tried very often.

3. Lubbock's reflection theory

By the mid-19th century, it was well established that meteoroids had an extraterrestrial origin. What had not been established, however, was the origin of the meteoroids themselves. Some researchers argued that the meteoroids moved through space at random [8], while others suggested that they were, in fact, small Earth satellites.

The reflection theory of John Lubbock (1803–1865) was developed in an attempt to discern the origin of (some) meteoroids. What is particularly interesting about Lubbock's theory, however, is that it builds upon the idea of experimentation. Writing in 1848, Lubbock began by drawing attention to a commonly observed characteristic of meteors. Specifically he noted that no attempts had *been made to explain the cause of the sudden disappearance of shooting stars* [9]. To this "observed" characteristic of meteors, he suggested three possible explanations:

1. *the body shines by its own light, and then explodes ... breaking into minute fragments too small to be longer visible to the naked eye;*
2. *such a body having shone by its own light, suddenly ceases to be luminous*, and
3. *the body shines by reflected light of the sun and ceases to be visible by its passing into the Earth's shadow, or, in other words, is eclipsed.*

The key point that Lubbock wished to bring out from his list of options was that, *although the first two suppositions leave us without instruction as to the orbit or position in space of the body in motion, the case is far different on the third hypothesis; for knowing the time when and the place in the heavens where the star* [meteor] *disappeared, the elements of the geometry of three dimensions furnish the means of determining the exact distance of the body from the place of the spectator*. Lubbock further argued, *if, therefore, all the observations of the disappearance of meteors on any given night were examined, they might be discussed in two ways; either upon the hypothesis of their accompanying the Earth in its orbit as satellites, or upon the hypothesis of their moving round the sun.*

Lubbock developed a series of equations that could be combined with observations to determine the distance to the end point of a meteor's trail, but did not attempt any reductions. Indeed, Lubbock noted that *in practice this method is beset with great difficulties*. Undaunted by the inherent difficulties, however, Archibald Smith not only refined Lubbock's mathematical analysis, he also applied the results to one particular set of observations [10]. Smith found that the distance to the body of the meteor observed was 1721 miles *and that entry into the Earth's shadow was the true cause of the* [meteor's] *disappearance*. Smith also explained the observed variations in the meteors light output in terms of its passage through the penumbra and umbra of the earth's shadow. While Smith made no general statements about Earth-orbiting versus "wandering" meteoroids, he did conclude that the meteor he had analyzed was in orbit about the Earth.

It is fair to say that Lubbock's reflection theory did not gain any great following. Indeed, the theory was summarily dismissed as unviable by Robert Greg (1826–1906) in an article published in 1860 [11]. Greg neatly countered the reflection hypothesis by appealing (again) to the observations. He noted in particular that one could observe meteors in the zenith even at local midnight. He also offered the following calculation: in order to see a meteor at say, 45° to the horizon, at local midnight, the distance to the meteoroid would have to be in excess of 5500 miles. This distance, Greg argued, was *far too great to admit of our seeing ordinary shooting stars*. Having no knowledge of the typical size, or reflectivity of meteoroids Greg's conclusion was in reality on uncertain ground, but his arguments are certainly not unreasonable.

Ultimately, the main reasons behind the demise of Lubbock's reflection theory were the development, and acceptance, of ideas relating to the physical interaction of solid bodies with the Earth's atmosphere. These ideas, which we shall explore next time, were developed chiefly by such scientific luminaries as Humphrey Davy and James Joule.

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Prediction of Meteors Associated with 1993 QA

Ichiro Hasegawa

Radiant points and orbital elements are given for possible meteors associated with near-Earth object 1993 QA around the time of its closest approach on February 7, 1996.

Asteroid 1993 QA, a near-Earth object, was rediscovered by J.V. Scotti, and improved orbital elements were computed by Marsden [1]. According to Marsden, this object will approach the Earth on February 7, 1996, at a distance of 0.071 AU. Radiant points and orbital elements (referred to equinox 2000.0) of meteors associated with 1993 QA are predicted using Hasegawa's method [2], and given in Table 1. It is noted that, in the Catalogue of Meteorites [3], five meteorite falls are recorded in an interval of only 0°5 width between solar longitudes $\lambda_\odot = 313°0$ and $\lambda_\odot = 313°5$ during the years of 1810 and 1938 [4].

Table 1 – Radiant point and orbital elements for meteors associated with 1993 QA (all referred to eq. 2000.0). The geocentric velocity is denoted as V_G and the distance between the orbits of Earth and 1993 QA as Δ.

$\lambda_\odot$	Date	Radiant		V_G	Δ	Orbital elements			
	(UT)	α	δ	(km/s)	(AU)	q'	ω'	Ω'	i'
312°0	Feb 02	33°1	−52°3	8.4	0.070	0.968	337°6	132°0	12°2
314°0	Feb 04	31°8	−52°2	8.5	0.067	0.965	335°6	134°0	12°3
316°0	Feb 06	30°6	−52°0	8.6	0.065	0.961	333°7	136°0	12°4
318°0	Feb 08	29°5	−51°6	8.7	0.063	0.958	331°7	138°0	12°4
320°0	Feb 10	28°4	−51°2	8.8	0.063	0.954	329°8	140°0	12°5
322°0	Feb 12	27°4	−50°7	8.9	0.065	0.951	327°8	142°0	12°6
324°0	Feb 14	26°5	−50°1	9.0	0.068	0.946	325°9	144°0	12°6
326°0	Feb 16	25°6	−49°4	9.0	0.072	0.942	323°9	146°0	12°6

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The 1994 η-Aquarids: A Tentative Global Analysis

Godfrey Baldacchino

What may be the first global analysis ever of the η-Aquarid meteor stream is undertaken with respect to the 1994 display. Data relating to 1140 shower meteors reported by 28 observers from all 5 continents is analyzed. This suggests a higher-than-expected maximum earlier than announced, but the absence of meteor magnitude data prevents a more sophisticated analysis.

1. A comparative advantage

In his overview of the *IMO*'s *Visual Meteor Data Base* (*VMDB*), Rainer Arlt comments on the "very heavy contrast between northern and southern latitudes" when it comes to the geographical distribution of observing sites reporting meteor observations to the *VMDB* [1]. Granted, Rainer is correct in claiming that "a lot of new results were possible if a larger number of high-quality observations from southern latitudes were available." The situation, however, is not all tragic for the southerly-placed. Even with the existing distribution of observing sites reporting to the *IMO*, the relatively southerly sited have a strange comparative advantage.

Within just one-eighteenth (some 5.5%) of the world's latitudes—from some 35° N to 45° N—are to be found over 90% of *IMO*-reporting meteor watchers. Moreover, these are also very unequally distributed along longitude. Indeed, practically all of these 90% occupy three discrete longitudinal "windows:" 70° W to 120° W; 10° W to 35° E; and 140° E to 150° E, approximately [2]. Assuming that they are equally active, just a little more than a quarter of the available longitudinal band is being utilized by these observers.

The picture is somewhat different when observers operating from more southerly latitudes are considered. The North-American, European and Japanese windows are still covered, albeit with far less observer density; but added to these are other longitudinal bands, thanks to observers located in Brazil, Hawaii, the Canary Islands, Kazakhstan, South Africa, Jordan, China, Western Australia and New Zealand. This detail on better longitudinal spread implies that, if observers can be counted upon at critical moments, the *IMO*'s southern flank is in a much better position to monitor rapid changes of activity in dynamic showers than the northern counterpart, this apart from the more conventional monitoring of these annual, stable meteor showers whose relatively southerly radiants elude the bulk of observers stationed in unfavorable northern latitudes.

2. The η-Aquarid Meteor Stream

One of the most important of the latter meteor showers is definitely that associated with the η-Aquarid stream. One of the seven strongest annual meteor showers, the η-Aquarid radiant is, however, the one with the lowest declination—0° approximately. The other six (Quadrantids, April Lyrids, Perseids, Orionids, Taurids, and Geminids) have radiant declinations ranging from +14° to +58°.

Therefore, while on the paper the η-Aquarid stream enjoys a predicted maximum activity rate of some 60 meteors per hour [3]—the strongest annual performance quotient after the Quadrantids, Geminids and Perseids—their coverage sadly is not in proportion to their strength.

There was only temporary heightened interest in the shower in the 1980s as part of the *International Halley Watch*, since this shower, as the Orionid stream, is associated with debris emanating from this famous comet which returned within the vicinity of the Sun and the Earth in 1985-86.

Interest has now once again subsided, to the extent that, although favorably placed with respect to moonlight, this shower was not even included in the *IMO* 1994 Observer's Calendar [4]; a slip admitted by the calendar compiler who, from his northern latitude, has few possibilities of seeing its shower members [5].

The *Malta Astronomical Society Meteor Group* had set out to exploit its locational "comparative advantage" by organizing a visual observational project to monitor the η-Aquarid stream during the 1994 display. The results of this project have already been published [6]. We are now going one step further and a preliminary global analysis of the 1994 η-Aquarid display is being presented.

3. Collaboration

This analysis was at all possible thanks to the generous collaboration of like-minded societies, *IMO* colleagues, and the existence of the *IMO*'s VMDB. Maltese colleague Adrian Galea handled most of the necessary correspondence. Neil Bone, Director of the Meteor Section of the *British Astronomical Association*, passed the relevant details of η-Aquarid observations carried out by Colin Henshaw from South Africa and Tim Cooper from Botswana reporting to the *BAAMS*; George Zay from California passed on details of his own watches; Gilberto Klar Renner has published a synoptic account of his group's observational results from Porto Alegre, Brazil [7]; while Rainer Arlt kindly sent the relevant entries from the *IMO*'s *VMDB* [8], including a significant amount of Japanese observations.

4. Observers

In summary, the data from 21 observers from Australia, Botswana, Brazil, Japan, New Zealand, South Africa, and the USA were added to those of 7 other Maltese observers. Note that the longitudinal spread of these observers meant that they could still cover comfortably the activity of the η-Aquarid radiant on a round-the-clock basis. Solar longitude data confirms that this coverage is practically complete at around the predicted maximum—$\lambda_\odot = 45\overset{\circ}{.}5$ (2000.0), around May 6, according to [3]. The full international team of contributors thus comprised the following:

> Anna Baldacchino (BALAN), Godfrey Baldacchino (BALGO), Edwin Camilleri (CAMED), Mark Chamberlain (CHAMA), Maurice Clark (CLAMA), Tim Cooper (COOTI), Luís Antônio da Silva Machado (DA AN), Franco Gatt (GATFR), Antoine Grima (GRIAN), Takashi Hasegawa (HASTA), Colin Henshaw (HENCO), David Holman (HOLDA), Kiyoshi Izumi (IZUKI), Kazuko Kawamura (KAWKA), Peter Knowles (KNOPE), Sandro Lanfranco (LANSA), Robert Lunsford (LUNRO), Hidekatu Mizoguchi (MIZHI); Darlan Moraes (MORDA); Umberto Mule' Stagno (MULUM), Luís Antônio Reck de Araújo (RECLU), Gilberto Klar Renner (RENKL), Roberto Scorbie (SCORB), Richard Taibi (TAIRI), Hiroyuki Tomioka (TOMHI), Graham Wolf (WOLGR), Yasuo Yabu (YABYA), and George Zay (ZAYGE).

5. Analysis

Regretfully, many observations were not accompanied by a magnitude distribution of the shower and/or sporadic meteors observed. As a result, zenithal hourly rate computation using the magnitude ratio technique could not be resorted to. This is a severe blow since much of the potential of a global analysis is immediately lost. Consequently, it was decided to adopt a very approximative technique which assumes a steady sporadic background rate of 12 meteors per hour under standard sky conditions (stellar limiting magnitude of +6.5). I prefer this technique in such situations as an alternative to ZHR formulae which involve a string of computations, each of which are liable to error.

The derived η-Aquarid ZHRs are tabulated in Table 1.

The data in Figure 1 are difficult tot interpret, because no activity trend is discernible. This is mainly because, irrespective of the sophistication of computation, activity rates will ultimately always depend on the actual number of meteors seen. Most of the rates reported in Table 1 are based on a very weak meteor count base.

A clearer activity profile is likely when these data are filtered to comprise only those watches where, in each, at least 20 shower meteors are reported. This shortlists the number of watches from 77 to just 20, bearing some 64% of the total number of shower meteors reported, as listed in Table 2.

Table 1 – ZHR data for the 1994 η-Aquarids. Solar longitudes refer to eq. 2000.0.

$\lambda_\odot$	Obs.	$T_{\rm eff}$	η-Aqr	ZHR	$\lambda_\odot$	Obs.	$T_{\rm eff}$	η-Aqr	ZHR
39°652	BALGO	1.0	1	4 ± 4	45°623	DA AN	1.2	26	29 ± 6
41°576	COOTI	1.0	4	12 ± 6	45°623	MORDA	1.2	21	24 ± 5
42°532	BALGO	1.0	1	21 ± 12	45°623	RENKL	1.2	20	17 ± 4
42°532	BALAN	1.0	1	21 ± 12	45°623	RECLU	1.2	24	39 ± 8
42°872	LUNRO	2.8	7	5 ± 3	45°991	WOLGR	1.5	14	96 ± 26
42°893	ZAYGE	1.9	28	2 ± 2	46°016	WOLGR	0.5	14	28 ± 28
43°230	CLAMA	1.5	39	31 ± 5	46°024	CHAMA	1.0	6	28 ± 6
43°472	MULUM	1.8	24	19 ± 4	46°064	CHAMA	1.0	7	49 ± 7
43°496	COOTI	1.6	28	131 ± 25	46°091	IZUKI	1.2	3	35 ± 20
43°802	ZAYGE	1.0	3	55 ± 24	46°118	CLAMA	0.8	19	5 ± 3
43°842	ZAYGE	1.0	8	41 ± 20	46°158	CLAMA	0.9	24	12 ± 3
43°847	LUNRO	2.0	45	35 ± 8	46°198	CLAMA	0.4	19	20 ± 5
44°073	WOLGR	1.5	21	51 ± 11	46°350	BALGO	1.0	8	22 ± 8
44°086	CHAMA	1.0	5	24 ± 3	46°350	BALAN	1.0	6	17 ± 7
44°113	KNOPE	1.5	13	19 ± 5	46°353	GATFR	1.1	6	11 ± 5
44°238	CLAMA	1.1	39	19 ± 4	46°354	GRIAN	1.1	9	23 ± 8
44°428	CAMED	1.8	7	18 ± 7	46°352	LANSA	1.1	7	10 ± 4
44°430	HENCO	1.0	11	22 ± 7	46°346	MULUM	1.8	39	31 ± 5
44°432	MULUM	1.8	36	29 ± 5	46°591	RENKL	2.3	49	11 ± 2
44°432	BALGO	1.0	6	21 ± 9	46°591	RECLU	2.3	59	18 ± 2
44°434	BALAN	1.0	9	63 ± 19	46°591	MORDA	2.3	49	15 ± 2
44°434	HENCO	1.0	20	31 ± 7	46°633	TAIRI	1.4	6	8 ± 3
44°438	HENCO	1.0	23	32 ± 7	46°967	WOLGR	1.5	24	28 ± 8
44°441	HENCO	1.3	2	100 ± 21	46°994	CHAMA	2.0	13	19 ± 7
44°778	ZAYGE	1.0	7	8 ± 3	47°022	KNOPE	1.5	9	20 ± 5
44°818	ZAYGE	1.6	3	48 ± 9	47°037	YABYA	1.7	9	8 ± 3
45°042	CHAMA	1.0	5	23 ± 10	47°057	MIZHI	0.8	11	77 ± 23
45°045	WOLGR	1.5	11	16 ± 4	47°116	CLAMA	0.8	16	6 ± 2
45°055	TOMHI	2.4	10	15 ± 5	47°136	CLAMA	0.9	20	14 ± 3
45°065	KAWKA	0.9	2	7 ± 4	47°156	CLAMA	0.8	26	24 ± 5
45°075	HASTA	1.5	11	7 ± 2	47°306	BALGO	1.0	5	10 ± 4
45°100	IZUKI	1.2	11	16 ± 5	47°306	BALAN	1.0	2	4 ± 3
45°105	MIZHI	0.8	12	37 ± 11	47°946	TOMHI	1.4	2	5 ± 4
45°125	CLAMA	0.9	22	18 ± 4	47°950	SCORB	1.5	13	31 ± 9
45°165	CLAMA	0.8	32	30 ± 5	47°967	YABYA	2.3	1	1 ± 1
45°205	CLAMA	0.6	19	36 ± 8	47°973	MIZHI	0.9	5	9 ± 4
45°390	BALGO	1.0	3	11 ± 6	48°538	TAIRI	2.0	5	4 ± 2
45°390	BALAN	1.0	2	6 ± 4	49°891	WOLGR	1.5	9	21 ± 7
45°416	COOTI	1.0	7	39 ± 10					

6. Discussion

These "refined" data is more instructive, although the time span is compressed relative to the previous table.

They now suggest a heightened activity, with a peak higher than normally expected, and a full day earlier than announced as well. The highest activity reaches a ZHR of 70 at around solar longitude $\lambda_\odot = 43\overset{\circ}{.}48$ (2000.0), corresponding to May 4 at $2^{\rm h}$ UT.

This figure and data are both approximate since there are no preceding watches to establish a prior rate and trend. Also, they are based on a single observation, which calls for additional caution.

Table 2 – Filtered 1994 η-Aquarid data (cfr. Table 1).

$\overline{\lambda}_\odot$	Observers	η-Aqr	ZHR
43°48	COOTI-MULUM	52	70 ± 10
43°48	COOTI-MULUM	52	70 ± 10
43°85	LUNRO-ZAYGE	73	41 ± 5
44°15	CLAMA-WOLGR	60	35 ± 5
44°44	HENCO-MULUM	79	38 ± 4
45°16	CLAMA	27	30 ± 5
45°62	RECLU-DA AN-MORDA-RENKL	91	27 ± 3
46°25	CLAMA-MULUM	112	21 ± 2
46°59	RENKL-RECLU-MORDA	157	15 ± 2
46°97	WOLGR	24	28 ± 8
47°14	CLAMA	62	14 ± 3

The activity then subsides, reaching the "normal" and expected level of ZHR = 38 at around May 5 at 2^h UT. The decline continues regularly and steadily, except for a sharp hiccup at solar longitude $\lambda_\odot = 46\overset{\circ}{.}79$, corresponding to around May 8 at 17^h UT.

This corresponds to the maximum of the Halleyid stream, active from a practically identical radiant position. However, caution is also called for here, because this higher activity level is shown by a single observation only.

Very soon after, Aquarid/Halleyid activity is down and at par to its sporadic background.

7. Conclusion

The early heightened registration of the reported maximum activity for the 1994 η-Aquarid display needs to be confirmed. One outcome of this preliminary analysis is to highlight the importance of a sufficiently large meteor database to make any activity computation worth its while. Furthermore, the absence of magnitude distributions for shower meteors and their sporadic background renders futile any serious activity assessment.

The southern flank of the *IMO* would contribute much more to the global meteor effort by boosting up its number of observers, these complementing its reports with the expected meteor magnitude distributions per watch.

In this way, it would be able to provide an ever stronger contribution towards the better understanding of the η-Aquarid stream as well as of meteor activity from other low-declination radiants.

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New Results from Video Meteor Observations

Sirko Molau

An analysis of video observations of the 1995 Quadrantids and the 1993 and 1994 Perseids is presented. For the Quadrantids, the radiant obtained is in good agreement with the literature value, and no indications for sub-radiants were found. For the Perseids, the picture was not so clear, but no significant evidence for a sub-radiant structure could be found, either. For the 1993 Perseids, the existence of meteor clusters was examined. Some evidence was found for meteor clusters on a very short time scale (1–2 s). On larger time scales, no indications for clustering were found.

On several occasions [1,2], I have presented our video system MOVIE. First results from the analysis of video meteors were presented on last year's *IMC* [3]. Since then, we had some more successful video observation sessions and did a lot of new investigations with the video data.

This January, we observed the Quadrantids near Hannover, Germany, and recorded more than 100 meteors parallel to our visual observations on video tapes (among them a nice magnitude −4 δ-Cancrid in Canis Major) with MOVIE [4]. In the following weeks, I analyzed the Quadrantid tapes as well as the Perseid video from August 11-12, 1993, which remained unprocessed up to that time. There were another 250 meteors on these tapes, recorded during 7 hours of observation in the Black Forest Mountains in Germany. After finishing this huge task (all video data are now stored in PosDat format and available for every interested observer from Visual Commission Director Rainer Arlt), I had the necessary data basis for interesting research work in different fields of meteor astronomy and did some first calculations. The results were presented at the annual meeting of the *Arbeitskreis Meteore* in Kirchheim in March 1995. A summary of the most interesting conclusions is presented below.

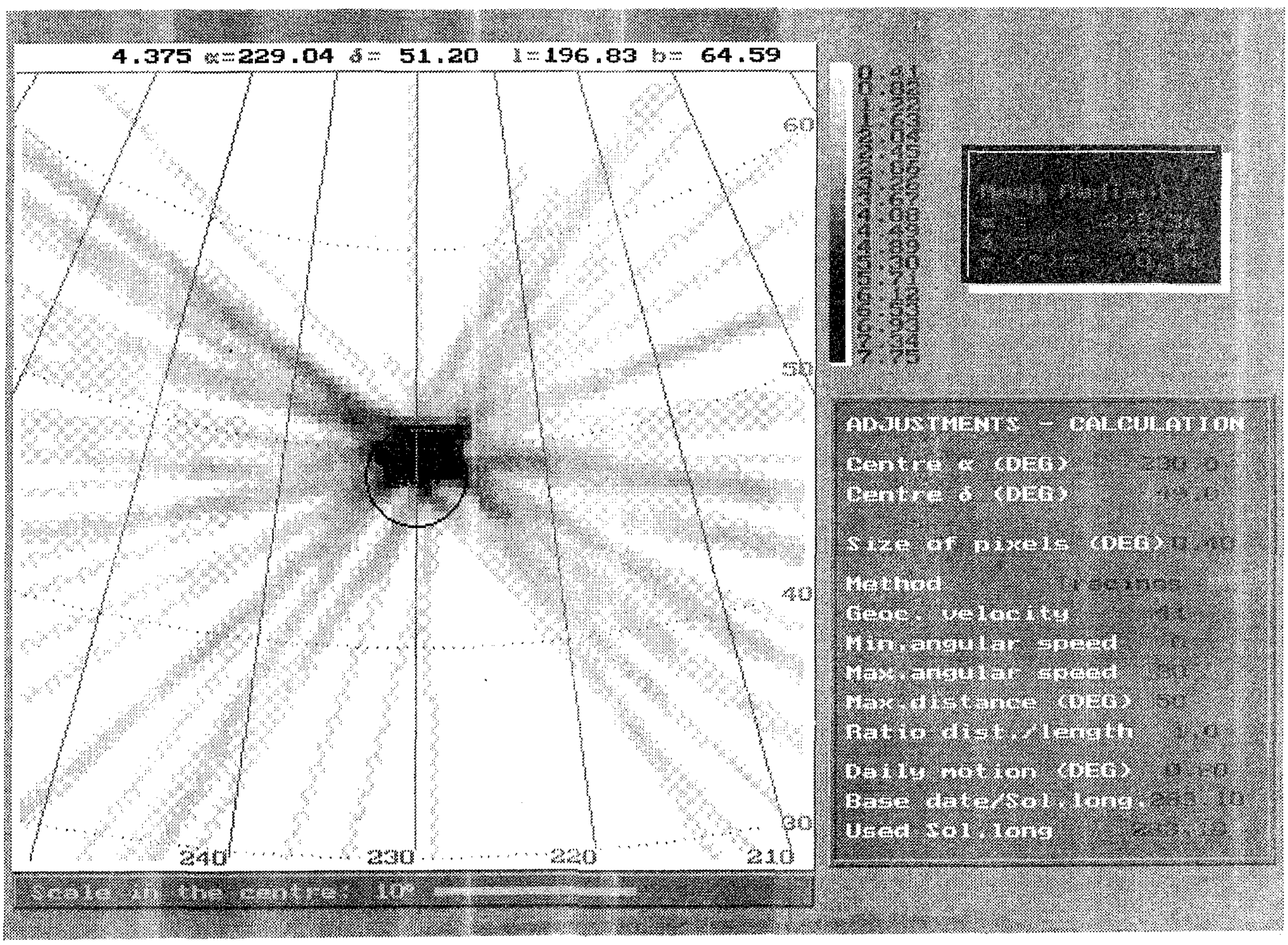

Figure 1 – Radiant plot for 39 Quadrantids from January 3, 1995, using the tracing method.

One of the main goals of our video work is the accurate determination of radiant positions connected with the search for sub-radiant structures. At the *IMC* in Belogradchik, Bulgaria, I presented a first radiant plot for the 1994 Perseids. Unfortunately, the result of bad weather conditions last year is that most of the recorded meteors were far away from the radiant, in the Summer Triangle, and only very few in other regions of the sky, such as Andromeda/Pegasus. So the resulting plot [3] showed only an elongated, inaccurate maximum near the predicted radiant position. No reliable conclusion could be made on whether or not there are faint structures in the shower radiant of the Perseids.

This year, we planned to observe the Quadrantids at a distance of about 30° from the radiant, because we wanted to obtain precise double-station video observations in collaboration with our Dutch friends from the *NVWS*. Unfortunately, clouds forced us to stop our observations early in the morning, and a guy called Murphy did the rest of the job: we had to finish just at the time when the second video team 20 km away restarted their observations after their sky became clear. Thus, again, we did not manage to record double-station meteors. In addition, our mounting did not drive the video system, because it was too cold (−8° Celsius). This is why the radiant slowly rotated into the field of view, and we captured many short meteors around the radiant. Last but not least, someone stumbled in the middle of the night over a power socket, which caused the lens heating to stop working. Even though the resulting ice layer on the lens became thicker and thicker with time, it finally was a quite successful observation. We found almost 80 Quadrantids on the video tapes and could produce a nice radiant plot for this shower.

Figure 1 shows this plot using the tracing method of Rainer Arlt's RADIANT software, Figure 2 contains the same 39 meteors using the intersection method.

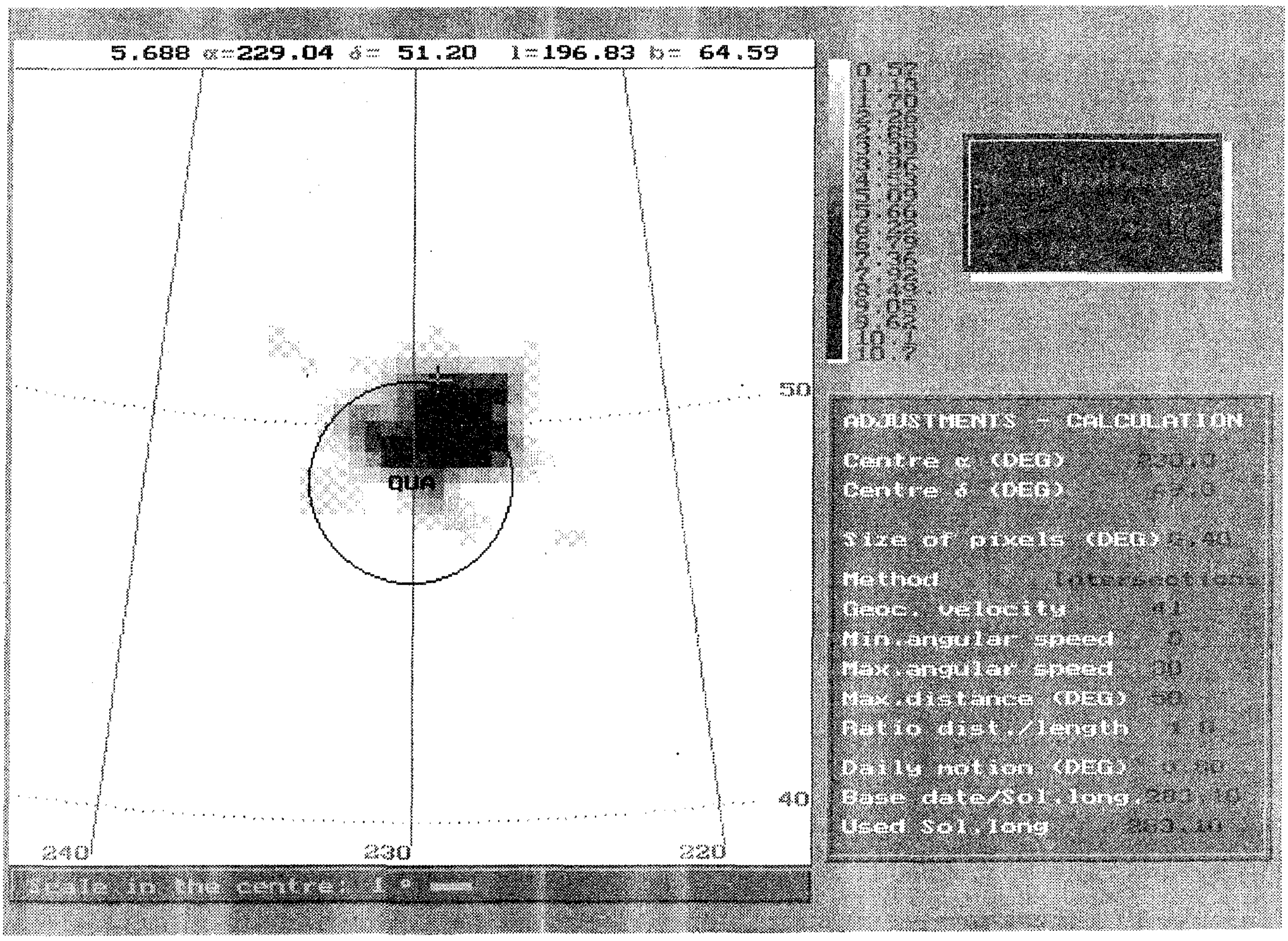

Figure 2 – Radiant plot for the 1995 Quadrantids using the intersection method.

In the tracing method (Figure 1), complete meteor trails are traced back to the radiant, whereas, in the intersection method (Figure 2), only the intersection point between two distinct meteor tracings are shown.

It is obvious that the "theoretical" position of the radiant (shown in the figures as a black circle with a diameter of 5°) given in the *IMO* publications is very good. Furthermore, there is no sub-radiant structure visible, even though the plot is very accurate and could show such features. So, the absence of distinct structures within the Quadrantid radiant at the level of about 1° is the main result of this analysis. As usual, I tried to obtain a nice picture of the shower (Figure 3), which looks quite different from the Perseid image I presented last year (Figure 4) at the *IMC*.

The meteors near the radiant are very short; we even recorded two pointlike meteors, which did not move at all. In addition to this image, I produced a computer animation, that shows the meteors appearing and disappearing dynamically around the radiant of the Quadrantids. During a few seconds, 18 meteors with different lengths, velocities, and brightnesses are visible on the screen, which illustrates all the well-known effects of meteor showers quite impressively. After I have converted this animation into a standard format, I will make it available to everybody interested in it via WWW (`http://www.tu-chemnitz.de/~smo/meteore/quad95.html`) or by other means.

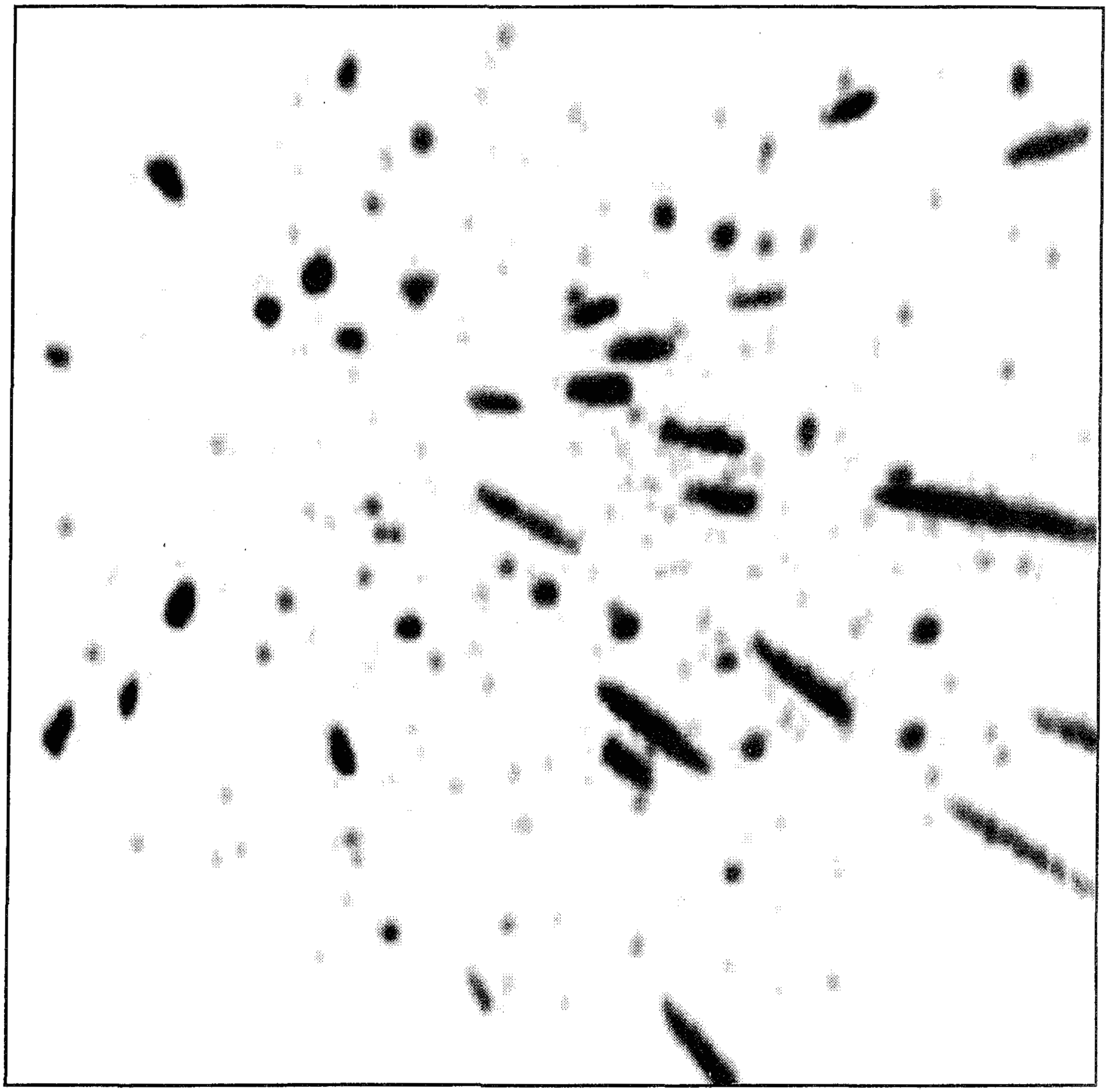

Figure 3 – Shower picture of the 1995 Quadrantids.

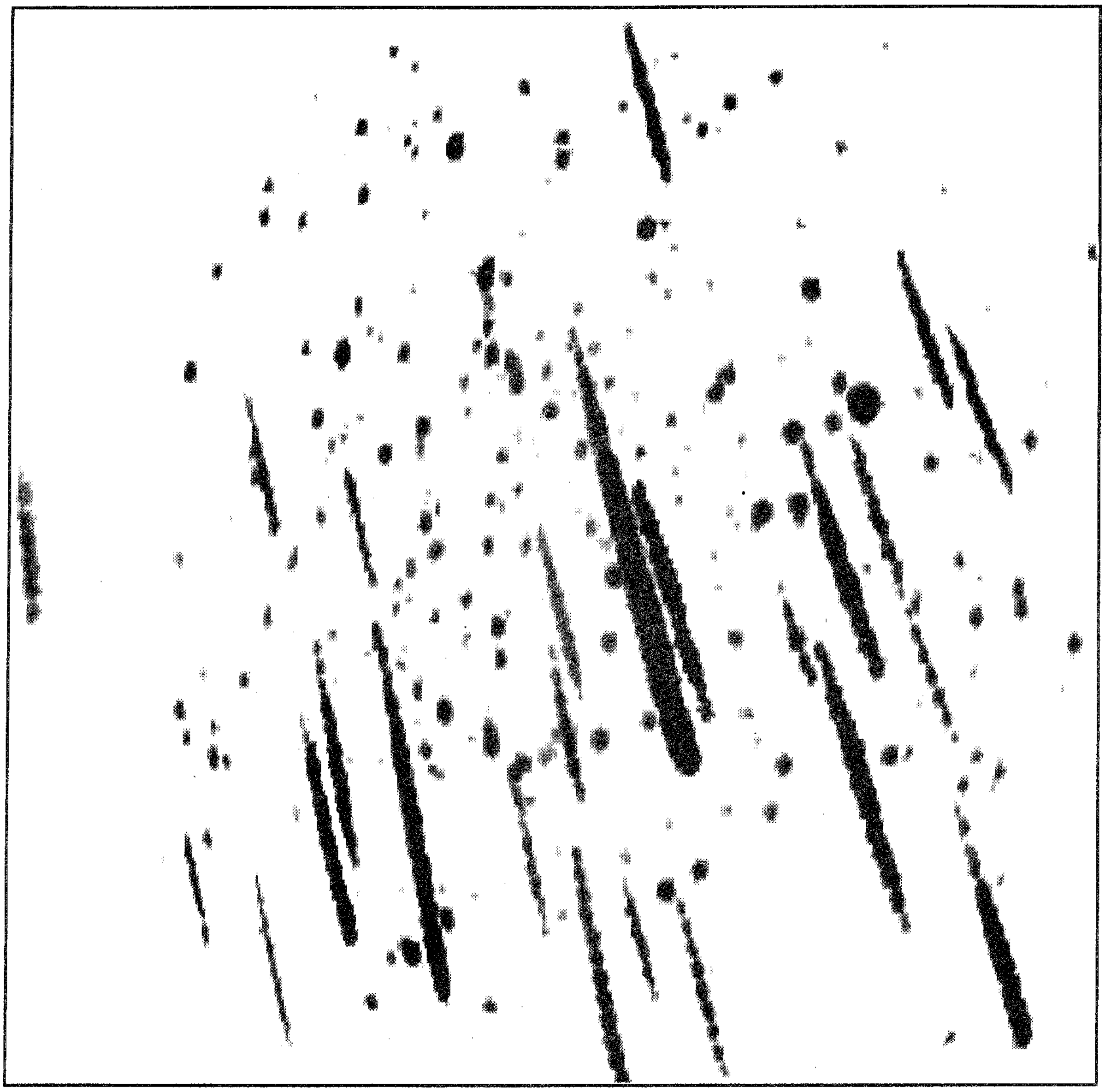

Figure 4 – Shower picture of the 1994 Perseids.

The next interesting shower have been the Perseids.

It took me several days to analyze all the meteors from their maximum night in 1993, but then I had a database with more than 300 shower meteors available. Contrary to last year, almost all meteors in 1993 were recorded in the morning hours and came from the Andromeda/Pegasus region, so the data sets from both years complement one another very good. The accuracy of parts of the data is not as good as for the Quadrantids, because I used an earlier version of the analysis software last year. In return, I had a ten times as much meteors available for the radiant plot. Figure 5 gives the distribution of 228 Perseids around the radiant. Their mean distance from the radiant is obviously still quite large, the outer dark ring marking a distance of 100° from the center . Figures 6 and 7 show the radiant plot for these meteors, again using the tracing and intersection method of RADIANT.

The meteors scatter more around the radiant, so the resulting peak is not as sharp as for the Quadrantids. The mean position of the radiant fits again quite well with the data given in *IMO*'s meteor shower list. There are some minor sub-radiant structures visible in the plot, but I do not believe in the significance of these irregularities. As the positional accuracy of each single meteor was rather poor near the radiant and the distribution of the meteors was still not optimal, these structures are most probably artifacts.

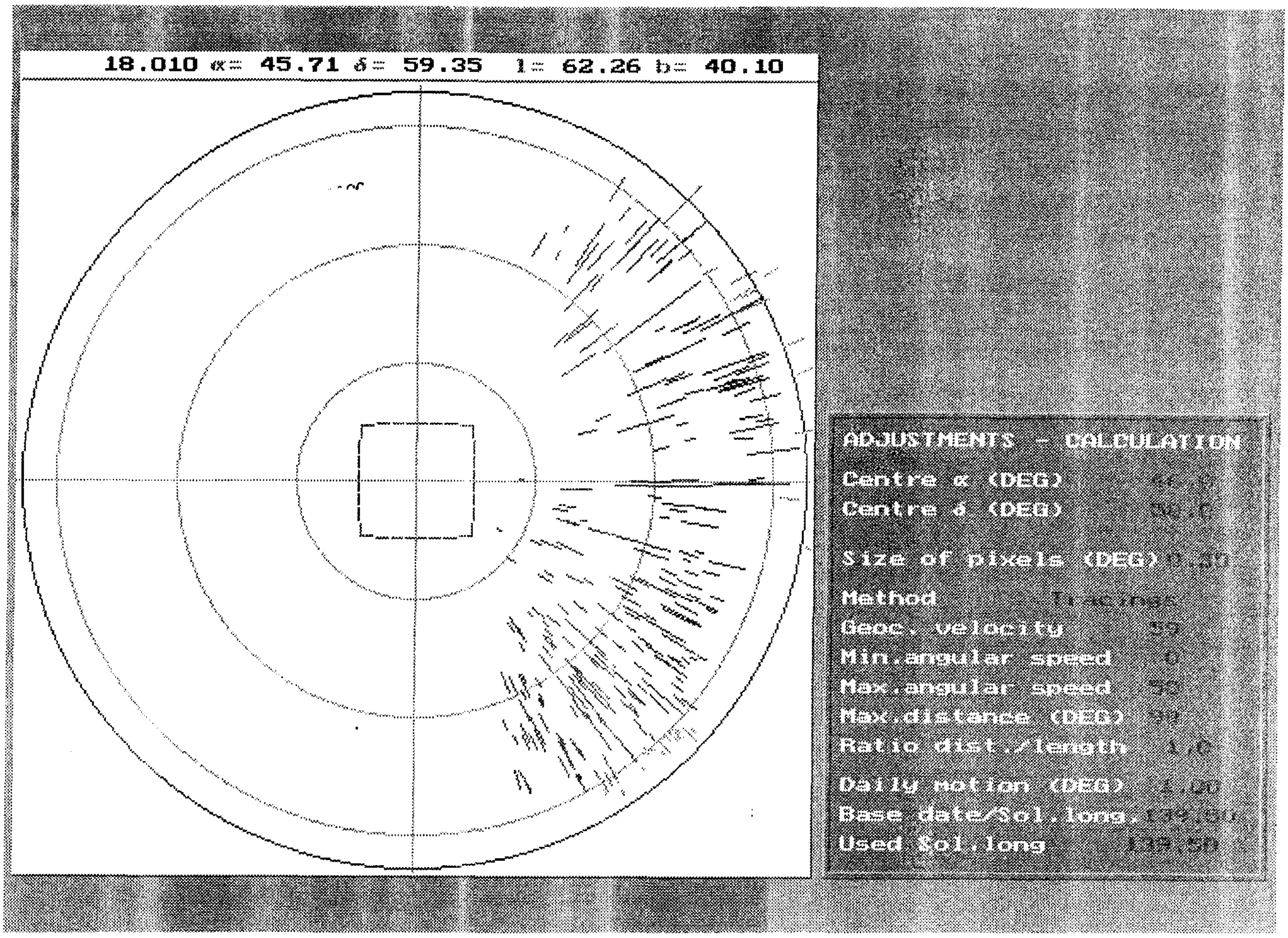

Figure 5 – Distribution of 228 Perseids around the radiant using video observations from August 1993 and 1994.

One more interesting fact is the good agreement in the radiant position using two different methods (tracings/intersections). It seemed to me, that especially for higher numbers of meteors the latter method would give better results, but both of them are equivalent at first glimpse. Only the radiant position obtained using the probability algorithm shows a bigger difference, which is a subject of further investigation.

Beside the determination of radiant positions, also ZHR calculations are an interesting area for video observers as shown at the last *IMC*. Some strange effects like abnormal high meteor rates during twilight were found at the first analysis but not confirmed yet. The determination of zenithal rates for this year's Quadrantids was especially complicated due to the mentioned "frozen lens" and the resulting large drop of the system's limiting magnitude. Nevertheless, Jürgen Rendtel and I could show [5] a good qualitative correspondence of visual and video rates near the maximum. There is, for instance, a narrow peak in both activity graphs at 23^h15^m UT, which lasted only about 20 minutes.

One of the most interesting topics for me is the search for meteor clusters . In a paper from 1992 [6], I had analyzed our visual meteor observations from that year searching for cluster effects and found absolutely nothing. Even though we had a good data basis (several hundred meteors observed from three visual observers in six successive nights with a time accuracy of 1 second) due to our computer based observation [7], the distribution of the meteors matched exactly the one expected for particles randomly distributed in space.

Two months ago, I repeated this calculation for our video observation of the Perseid maximum night in 1993. This time, I had to apply a special transformation first, because the standard formulae work only for constant meteor activity. This was definitely not the case a few hours before the sharp ZHR peak.

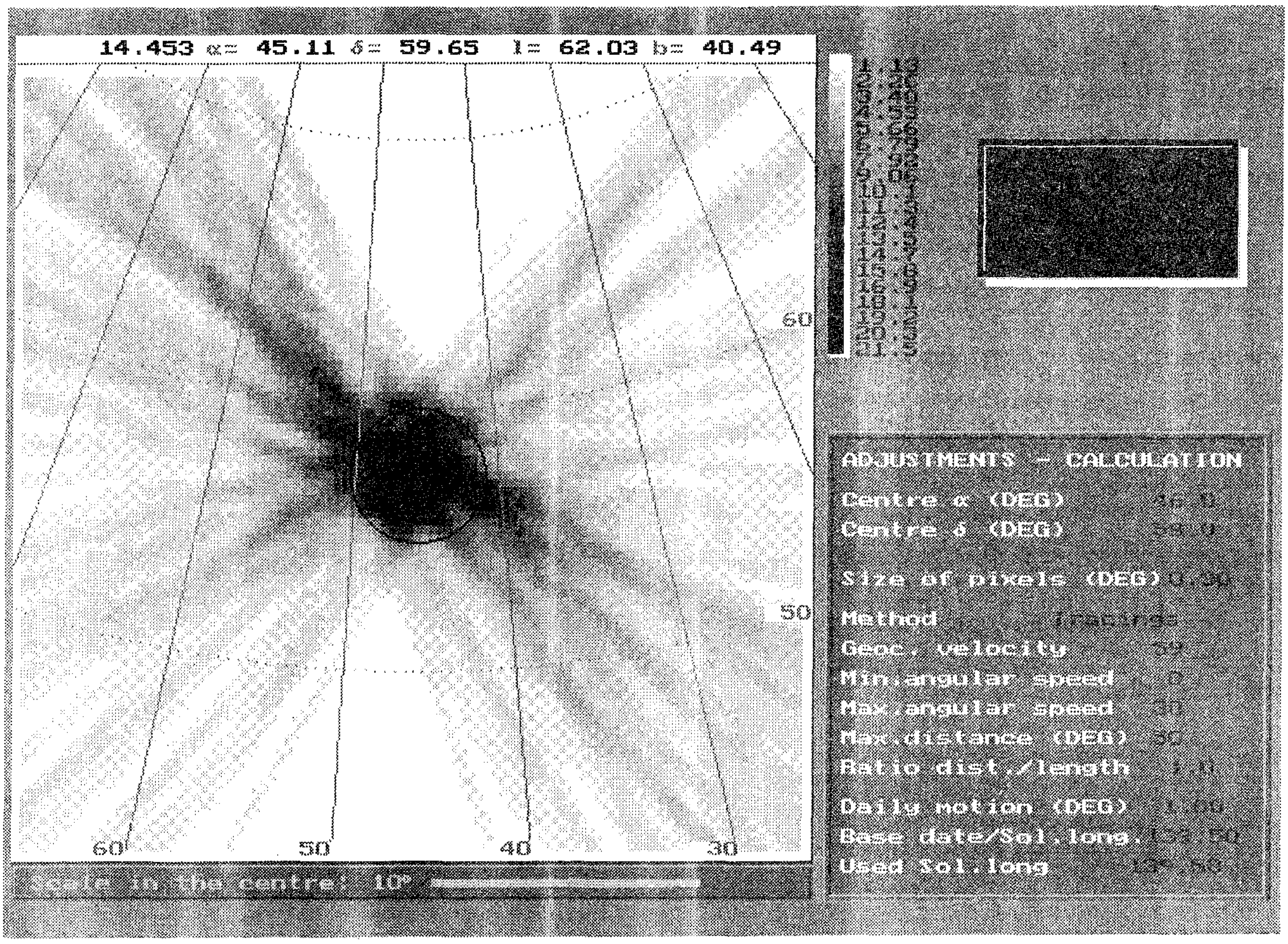

Figure 6 – Radiant plot for the Perseids using the tracing method.

Using the same time resolution as for the visual analysis in 1992, I found again no evidence for any type of clustering [8].

Figure 8 gives an idea how good the theory for randomly distributed particles (exponential distribution) fits the observational results. The distance between two successive meteors is plotted on the x-axis, grouped in intervals of 20 seconds length. The y-axis gives the percentage of each class compared to the whole number of 337 pairs of meteors.

My suspicion now was that clustering appears only on very short time scales (1–2 seconds), which might be smeared out in the 20 second intervals given above. So I did another calculation with an interval length of only 1 second, which is presented in Figure 9. Here I used cumulative intervals to have more meteors in each class and obtain better statistics by.

Again one can clearly see, that there is almost no difference between (clusterless) theory and video observation. If you look close enough to the very first intervals (up to a time distance of 12 seconds), however, you will see that the observation shows always slightly more meteor pairs than expected! To make this clearer, I added another graph to the diagram, which represents the relative differences between both values. We find a surplus of 57% in the first (meteor distances less than or equal to 1 second) and more positive differences in the following intervals.

This finding implies that there really might be some type of clustering of meteors at the Perseid maximum. Looking at the statistics we should not forget that this is a weak first clue: 57% surplus simply means that we observed 11 pairs of meteors instead of 7 expected from theory. A surplus of 30% of meteor pairs with less than or equal to 3 seconds distance stands for 21 pairs instead of 16.1. Furthermore, I had to apply the mentioned special transformation for variable ZHRs, which makes the results even more inaccurate.

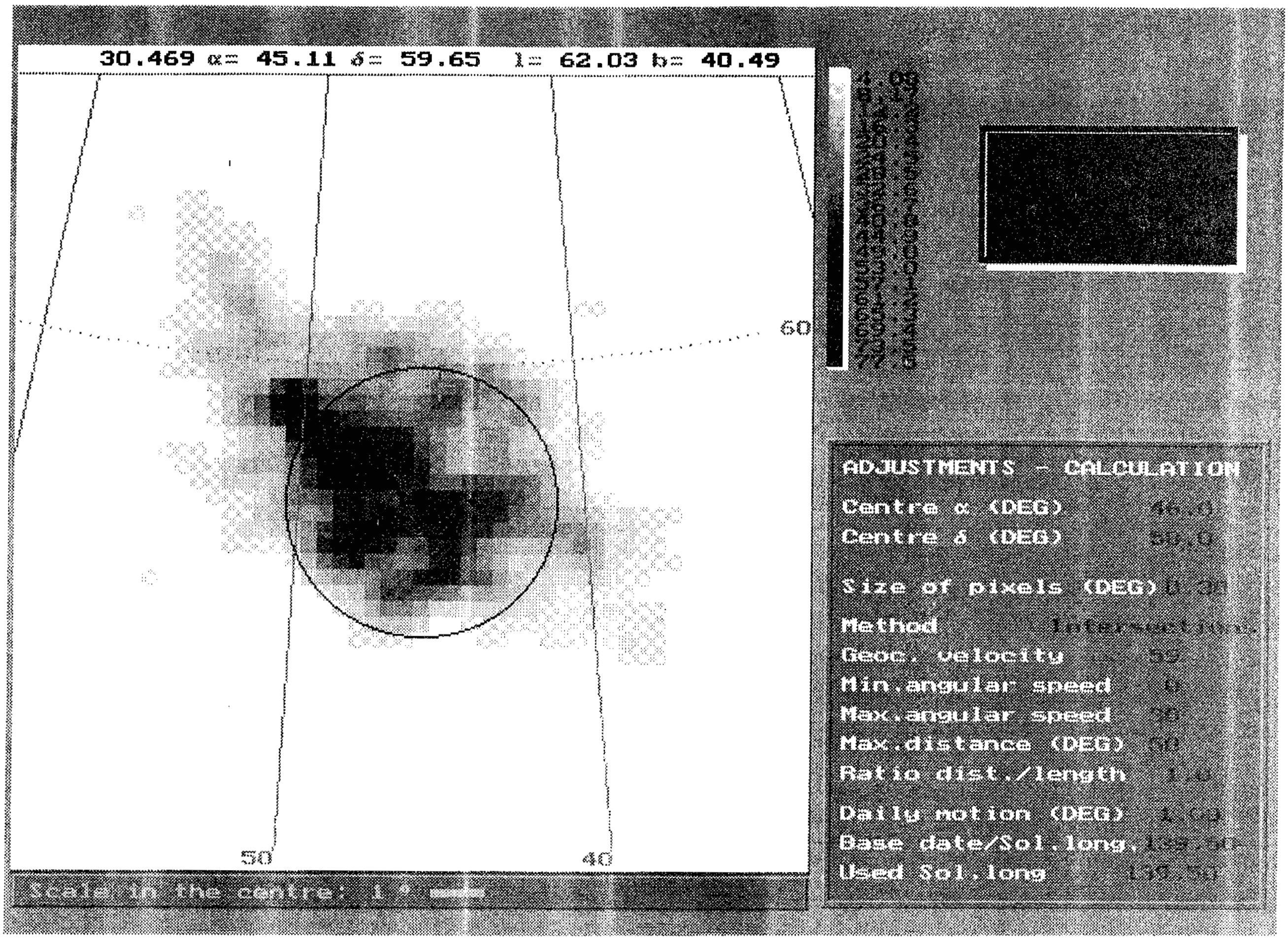

Figure 7 – Radiant plot for the Perseids using the intersection method.

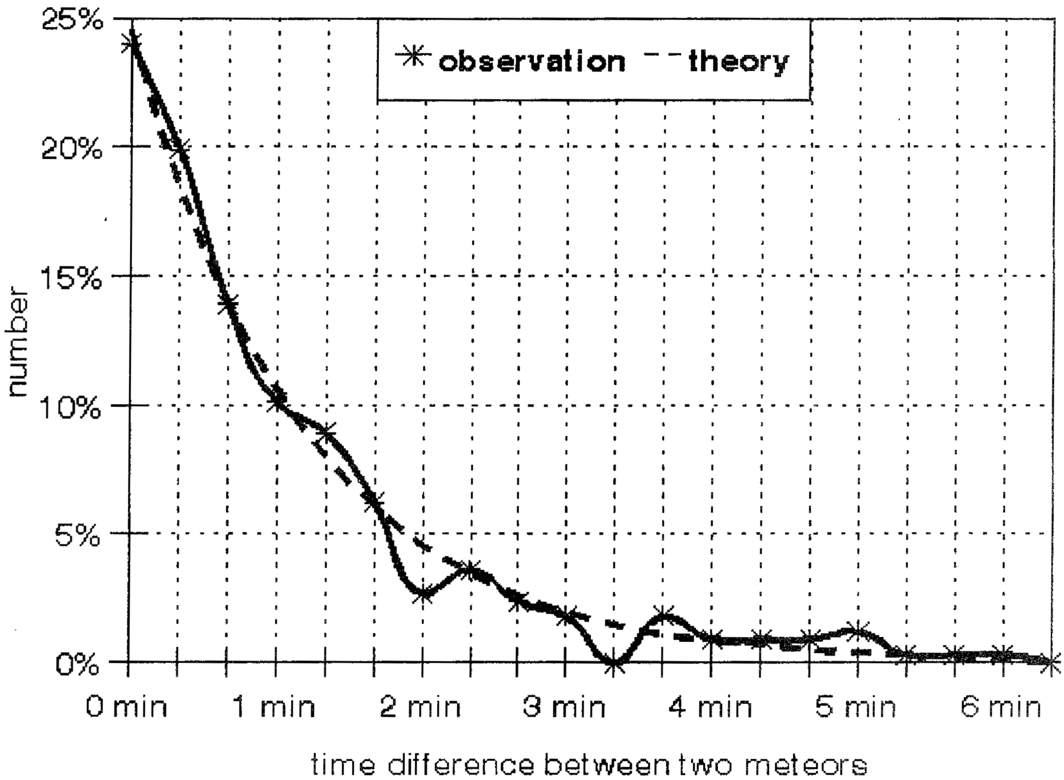

Figure 8 – Meteor cluster analysis with 20 s intervals for 338 meteors on August 11-12, 1993.

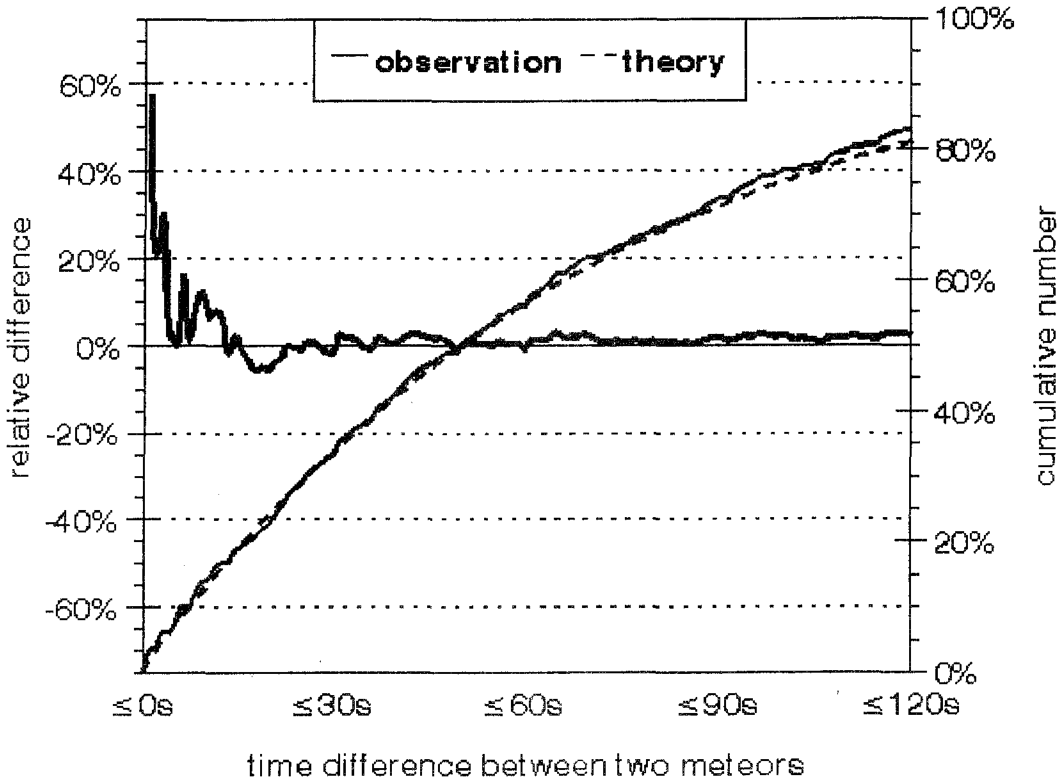

Figure 9 – Meteor cluster analysis with cumulative intervals for 338 meteors on August 11-12, 1993.

At least, we have here for the first time a quantitative indication for a cluster effect at a low level of about 1.5%. This number results from additional computation to find the best fit between observation and theory and should be regarded as a dimension for the phenomenon only. All values between about 0.5% and 3% are thinkable too, because the calculations were quite unstable in relation to the used interval length and model. Again, the data basis is still not complete enough to give more precise statements at this time.

There are other interesting effects, which have to be confirmed in the future too. In Belogradchik, I showed that visual observers regularly underestimate meteor brightness by about 1 magnitude [3]. A possible explanation is, that we estimate the brightness from the impression of the whole meteor trail, whereas video systems determine it at a scan rate of 25 measurements per seconds and therefore really obtains the absolute maximum brightness. This effect was dominant during the latest analysis of the Quadrantids and Perseids too. Our latest video data provide a good basis for statistical analysis of meteor light curves along their path. This work remains for the next months.

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Systematic Errors on Visual Meteor Brightness Estimates

Sirko Molau

From simultaneous visual-video observations, it follows that visual observers systematically underestimate the magnitude of a meteor by about half a magnitude or more. The error seems to be independent of meteor brightness and angular velocity. The hypothesis that the difference is due to the fact that with the video system the maximum brightness of the meteor is recorded, whereas the naked eye would tend to "average" the brightness of the meteor over the duration that the meteor was visible, could be confirmed nor rejected.

Video systems can deal with many different tasks in meteor astronomy. Due to their sensitivity and accuracy, they are used to obtain data about meteor showers, telescopic meteors, orbits, meteor light curves, spectra, and other properties [1]. Visual like video records can also support the training of new observers to show them what to expect and what they have to look for. Last but not least, we can check the reliability and accuracy of visual observations with them. Since our video system MOVIE [2] has almost-visual characteristics, it is very useful in this latter field.

At the 1995 *IMC*, it was shown that plottings of even inexperienced visual observers result in quite accurate radiant positions [3,4], even though the errors of individual meteors are relatively big. Another problem are meteor brightness estimates: as described in [5], we have recognized a constant shift of 0.5 to 1 magnitude of visual estimates based on double observations with MOVIE in the summer of 1994 (i.e., visual observers underestimate the brightness significantly). I planned to analyze other sets of data to check this result and find out possible reasons for this considerable difference. Since all our video tapes are analyzed now, I could examine the data from the 1993 Perseid maximum in detail and came up with some interesting results.

The study was based on 213 meteor brightness estimates from 3 observers (Kathrin Düber (`DUBKA`), Sirko Molau (`MOLSI`), and Mirko Nitschke (`NITMI`)) referring to 106 meteors recorded with MOVIE. I considered only events where the visual and video times agreed with certainty. Especially from the morning hours, I had to reject many double observations because the time assignment was not sure anymore in intervals with several meteors per minute.

First of all, the general trend reoccurred: all three observers underestimated the meteor brightness by half a magnitude or more on average. Table 1 shows the mean difference between the visual and video meteor brightness and the standard deviation. It must be mentioned that all visual estimates were made in steps of 1 magnitude, whereas the video brightness was computed with a resolution of 0.1 magnitude.

Table 1 – Mean errors on meteor brightness estimates for three visual observers.

Observer	$\overline{m_{\text{vis}} - m_{\text{vid}}}$	St. dev.	Meteors
`DUBKA`	+0.45	1.08	70
`MOLSI`	+0.94	0.95	69
`NITMI`	+0.68	0.82	74
Average	+0.69	0.95	213

There are differences between the observers, but part of the higher values for `MOLSI` and `NITMI` result from only a few meteors in the strong morning twilight. In the absence of reference stars, brightness estimates became especially difficult. Hence, the meteors were underestimated more strongly. Nevertheless there is a systematic error of about half a magnitude.

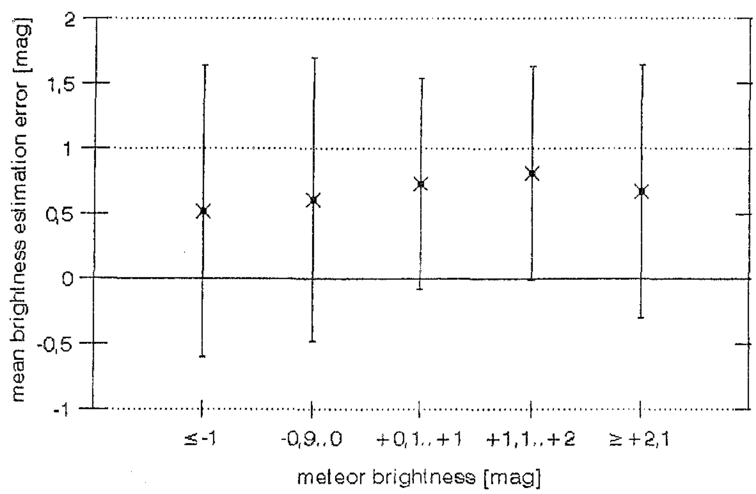

Figure 1 – Dependency of errors on brightness estimates on meteor angular velocity.

My first explanation for the effect was based on the properties of the estimating procedure: a visual observer watches an event which lasts only a fraction of a second. He estimates the brightness later by comparing the remembered impression of the meteor with known stars. Thus, he considers unconsciously the appearance of the whole event whereas video systems measure the meteor brightness frame by frame and obtain the real maximum value. It is now important to know whether or not the errors vary with the meteor angular velocity. We could expect that fast meteors are more strongly underestimated than slower ones.

The result of that analysis is given in Table 2 and Figure 1.

Table 2 – Dependency of errors on brightness estimates on meteor angular velocity.

Meteor ang. velocity	$\overline{m_{\text{vis}} - m_{\text{vid}}}$	St. dev.	Meteors
$\leq 15°/s$	+0.75	1.03	42
16–20°/s	+0.68	0.97	92
21–25°/s	+0.60	1.48	63
$\geq 26°/s$	+0.36	0.63	16

Table 2 gives the average values for all three observers to get better statistics from bigger numbers of events. Surprisingly, the table seems to suggest that brightness estimates are better for faster meteors; at least they do not become worse.

I would conclude from these data that the systematic error on the estimates is independent of the apparent meteor velocity. This is supported by the fact that the error development showed different trends for the three single observers. One has to consider the large scatter of the values, too. The standard deviation is generally very high. Especially the last row is based on only very few video meteors and should therefore not be taken into consideration. The standard deviation does not represent the accuracy of the difference in this case. To cross-check the result, I have interchanged the variables and looked for the dependency of the meteor angular velocity on the calculated errors on the estimates.

The result is shown in Table 3.

It is obvious that variable meteor velocities do not influence the investigated systematic error. Another analysis dealt with the error dependency from the meteor brightness. I had the impression that especially fainter meteors are stronger underestimated. Table 4 and Figure 2 show the error distribution for different brightness classes averaged for all three observers.

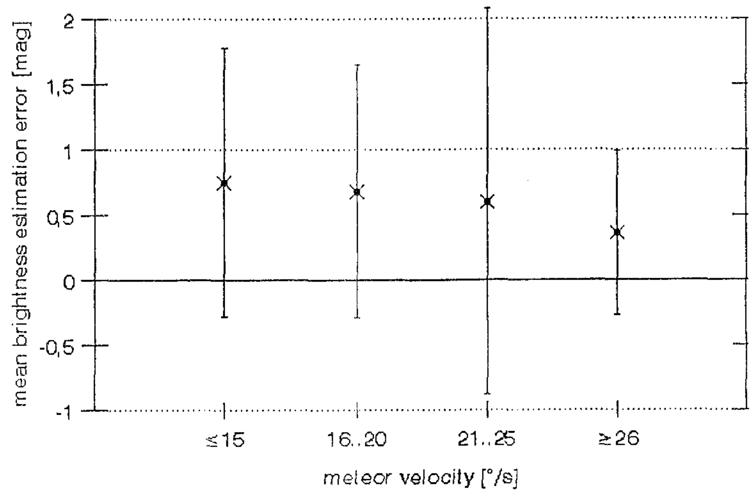

Figure 2 – Dependency of errors on brightness estimates on the meteor brightness.

Table 3 – Dependency of meteor angular velocity on the errors on the brightness estimates.

Error on brightness estimate	Average ang. velocity	Meteors
$\geq +1.6$	18°3/s	43
$+1.0 - +1.5$	19°5/s	58
$+0.5 - +0.9$	18°5/s	34
$0.0 - +0.4$	18°8/s	33
≤ -0.1	19°4/s	45

Table 4 – Dependency of errors on brightness estimates on the meteor brightness.

Meteor brightness	$\overline{m_{\text{vis}} - m_{\text{vid}}}$	St. dev.	Meteors
≤ -1.0	+0.52	1.12	38
$-0.9 - 0.0$	+0.61	1.09	59
$+0.1 - +1.0$	+0.73	0.81	47
$+1.1 - +2.0$	+0.81	0.82	50
$\geq +2.1$	+0.67	0.97	19

We should leave out the last row in Table 4, because faint video meteors are difficult to measure. The SNR becomes that bad that slight fluctuations can have strong effects on the calculated meteor brightness. There is, as expected, a nice trend that bright meteors are better estimated than faint ones. However, this trend does not hold for all three single observers and the cross-check table (Table 5) does not support that thesis either.

Table 5 – Dependency of meteor brightness on the errors on the brightness estimates.

Error on brightness estimate	Average magnitude	Meteors
$\geq +1.6$	+0.27	43
$+1.0 - +1.5$	0.48	58
$+0.5 - +0.9$	0.54	34
$0.0 - +0.4$	0.83	33
≤ -0.1	−0.21	45

In Table 5, large positive differences seem to result from brighter meteors, whereas good estimates come in average from fainter ones. There is a sudden change in the trend for overestimated meteors which is hard to explain. It might be influenced by errors of the brightness calculation routine due to "burnt out" meteors even though this effect was already taken into consideration.

I can conclude from the analysis that there is a systematic error in visual meteor brightness estimations in the order of half a magnitude which is independent from both meteors brightness and velocity. The suggested explanation for this effect could neither be proved nor rejected, but we have to consider such systematic errors if we want to derive physical shower properties based on visual brightness distributions.

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Applying State-of-the-Art Video and Computer Technology to Meteor Astronomy

Peter S. Gural

An *Automated Meteor Detection System* (*AMDES*) is described. It involves the use of low-cost, off-the-shelf imaging hardware, a personal computer, the application of image processing algorithms, and the development of software for a real-time automated meteor detection capability.

1. Introduction

In light of the recent collisions between the fragments of Comet Shoemaker-Levy and the planet Jupiter, there has developed an increased awareness among the public of the possibility the Earth may encounter a large meteoroid in the near future. In order to prevent a major catastrophe from occurring, it becomes necessary to systematically search for and identify Earth-crossing meteoroids and comets before they collide with the Earth [1]. Very often, cometary bodies that have earth crossing orbits have been associated with meteor streams that are seen on an annual basis as meteor showers. Several of the major meteor showers that have been studied and whose orbital elements are known, have been associated with periodic comets [2] such as Comet P/Halley (Orionids), Comet P/Swift-Tuttle (Perseids), and asteroid 3200 Phaethon (Geminids). This meteoric phenomenon has its origins in the material released from the outgassing of a comet whose ejected dust particles get distributed along the comet's orbit. If the cometary orbit and thus its debris stream cross the orbit of the Earth, then we witness a meteor shower. In addition, large non-cometary meteoroid bodies have been suspected to also have smaller particles strewn along their orbits due to impacts with other meteoroids thereby also possessing a debris stream. It is proposed that detection of the larger parent bodies would be possible through the study of the orbits of the small particle meteor streams associated with comets and asteroids. If the meteor streams are visible from Earth as meteor showers, then the parent body must also be Earth-crossing and potentially dangerous.

2. Purpose for new instrumentation

Although many major meteor streams have been well studied and their parent bodies identified, there still exist a large number of minor streams, unverified streams, and sporadic meteors for which no association is available. This is due to a lack of accurate measurements in sufficient quantity and quality to identify and/or verify meteor streams and their orbits. The primary cause is that weak meteor streams compete with sporadic meteors in numbers of observed events, making radiant association difficult due to poor statistics. In addition, there is the unavailability of low cost, low-light sensitive, automated meteor detection equipment for the field that would be more sensitive and accurate than visual observers. Although a tremendous amount of the meteoric data till now has been provided by the amateur visual meteor observer network, in order to study the minor meteor streams to sufficient detail, an automated meteor detection system that exceeds human visual magnitude limits is required. The use of such a system in the systematic study and evaluation of meteors, meteor streams, and their orbits, would help in addressing the issues associated with detecting potentially dangerous Earth-crossing comets and asteroids as well as furthering basic knowledge of meteoric phenomena.

Meteor astronomy to the present time has relied on a number of observing techniques and technologies to monitor the near-Earth small particle environment. These have included a worldwide network of visual observers, small frame camera and Schmidt camera photography, and radio/radar measurements. Visual observation by amateur meteor astronomers has provided the bulk of the information currently available about meteor stream structure, density, mass distribution, and yearly variability. Double-station photographic techniques have provided orbital information yielding cometary and asteroid associations of meteor streams with Earth-crossing objects. Radar observations have extended the observing coverage to 24 hours per day and has provided information on the sub-micron sized particle distribution of meteor streams.

With the advent of modern video and computer technology, another class of instrumentation could be added to those techniques currently utilized in the field of meteor astronomy. The system to be described herein involves the use of low-cost, off-the-shelf imaging hardware, a personal computer, the application of image processing algorithms, and the development of software for a real-time automated meteor detection capability. The instrumentation is referred to as the *Automated Meteor Detection System* (*AMDES*). The basic system consists of a fast, wide field lens, image intensifier, and CCD camera all coupled to a real-time detection capability in a PC-sized computer system. It will provide the following capabilities and enhancements over current observational approaches:

1. fully automated, all-night continuous coverage with no human subjectivity in perceived meteor magnitudes, track, or radiant association;
2. deeper detection limits to 9th magnitude increasing the quantity of meteor track data available for study;
3. extended spectral coverage of the image intensifier into the near infra-red, thereby increasing detection probability;
4. medium resolution accuracy of one arc minute for recording of track;
5. precise timing of CCD frames to 1/30 second provides accurate velocity measurements, time and date stamp, and subsequent orbit determination in a dual station set-up;
6. higher detection rates than by photographic or visual observer methods; and
7. low hardware cost of 8000 USD per system composed of a single imager and computer.

Note that the magnitude limits and resolution capabilities were based on a system with a 10° field of view. Adjusting the focal length of the leading objective lens can provide either higher resolution and fainter meteor detection or wider fields of view with a loss in limiting magnitude.

AMDES can provide automated measurements, enhanced detectability, and improved accuracy in a small and inexpensive package, easily portable and simple to set up at any site world-wide.

3. Current capabilities

Compared to current systems available, *AMDES* does have many advantages. Visual observations suffer from human eye limitations and individual subjective biases. The limit of the human eye under optimal seeing conditions is at best magnitude +6.5 and then only over less than a 5° field of view [3]. Outside that angular region the sensitivity drops off dramatically yielding a brighter limiting magnitude with respect to look angle. The detection angular capability thus widens with increasing meteor brightness, but offsetting that is the reduction in the number of meteors visible above a certain limiting magnitude. The result is that most meteors seen by visual observers lies in the +3 to +4 magnitude range. Secondly, the human eye can detect only in the visual frequency band and misses some of the meteor spectral energy in the near infra-red. Third, even experienced meteor observers can have variable detection thresholds during the night, require observational breaks, and make errors in estimation or recording vital information. Fourth, the accuracy of hand-plotted meteor tracks are on the order of one-half degree and highly dependent on the observer's knowledge of the sky and the ability to remember positions of an event that occurs in less than one second.

Photographic observations correct for the difficulties of accurately plotting meteor tracks and are capable of measuring meteor paths to within tens of arc seconds. The limit of photographic methods lies in the sensitivity of film to record down to only magnitude +2 for small-frame 35-mm cameras [4]. Such a reduced brightness threshold results in fewer meteors recorded and thus fewer measurements available for statistical studies. In addition, proper timing of an event in a several minute exposure can be difficult to accomplish. The development of film and the scanning of negatives is also a time-consuming process. Currently, there are no batteries of cameras set up in the US for the purposes of meteor research, but there does exist a network of cameras operating in Europe.

Radar and radio observations can work around the low detection statistics by observing the smaller-sized meteoroid particles that enter the Earth's upper atmosphere and leave an ionization trail that scatter and reflect electromagnetic waves. Since these smaller-sized particles are far more numerous than those that produce visual meteor trails, many events can be recorded. In addition, radar can operate day and night giving twenty-four hour coverage with good statistics. The latest generation of radar meteor detectors, such as operating in Australia, can determine a reasonable orbit. The drawbacks are the extreme expense involved of 1 million USD per system, selection effects limiting cross sectional and evolutionary studies of streams, and no systems operating in the northern hemisphere that produce accurate orbital data.

Video observations have only recently reached a point where off-the-shelf hardware is available at extremely low cost making the wide area distribution of imaging systems possible. Current efforts along these lines have resulted in detection limiting magnitudes of +8 using second generation image intensifiers coupled with CCD cameras [5,6]. The major drawback is that the night's observations are videotaped and then played back over several hours requiring a human observer to spend a large fraction of time searching for meteor events on a TV monitor. Many of the same disadvantages of direct visual observations apply again to this method of meteor observation. Further improvements beyond this current capability are necessary in order to make video systems competitive with visual and photographic observational techniques.

4. Issues that amdes can address

AMDES can provide the capabilities necessary to address the basic deficiencies indicated above. Improved night sky coverage, deeper magnitude limits for meteor detection, and higher accuracy in track can all be used to advance the current state of the knowledge in meteor astronomy. In addition, full automation of the detection processing would result in more consistent data by removing human biases induced by fatigue, errors in track due to large look angles, or the inherent signal losses of storing and retrieving images off video tape. With the use of a common set of equipment and algorithms, a uniform basis of sensitivity and detection would become available.

Currently, there is little work being done in this country in the field of meteor research by professional astronomers. The field has been left largely to the realm of the amateur observer. World-wide there is a network of meteor observers that are organized by the *International Meteor Organization* (*IMO*) where interesting work has been done and could be further pursued using data supplied by *AMDES*. A better understanding of meteoroid origins, evolution, cometary associations, stream structure, thickness, mass distribution, existence of sub-radiant streams, and identification of stream composition would be possible. With a larger number of events captured in a dual station system, one could identify new streams and verify only marginally detected minor streams. Such detection could lead to the discovery of a meteoric stream orbit that could be associated with an unknown, but potentially dangerous, Earth-crossing parent body. Given the estimated orbit, a search could be mounted for the parent body over a much reduced portion of sky than present day asteroid hunting programs currently scan.

The system could also be configured for extremely low cost per unit (2000 USD) as a fireball/meteorite fall detection system. This would help in identifying the origins of some of the larger fragments of infalling meteoroids and where other potential sources of Earth-crossing asteroids may arise. In addition, the study of sporadic meteors through the study of their orbits, origins, and annual variability, would lead to a better understanding of these apparently random events. Does the sporadic background, which makes up a significant portion of observed meteors, have some common origin that presents a heretofore unknown collision threat? All these observations and studies would be feasible with fielded pairs of *AMDES* world-wide set-up up as dual station meteor monitoring networks.

5. Objective

The objective for *AMDES* would entail four stages of development. Portions of the first stage such as the hardware configuration for the imager have been examined and have already been exercised in the field by a number of researchers. The critical test for *AMDES* at this point in time is to demonstrate the proof of concept of automated video meteor detection on a low-cost computer platform. The four stages are outlined as follows:

1. Demonstrate a prototype imaging system that is both low-cost and portable, using readily available off-the-shelf hardware components. Currently an imager for 4000 USD has been built and can easily reach a stellar limiting magnitude of +9. Further investigation into a trade-off of field of view, meteoric limiting magnitude, better imaging components, and cost needs to be made.
2. Integrate the imaging system with an automated monitoring, detection, and archival computer system that would be able to evaluate the imager data in real time. The development of the control and detection software would entail this phase of research. Current technology and availability of hardware indicate a Pentium-based PC equipped with a frame grabber board could be assembled today and have sufficient processing and data bus transfer capacity to operate at the 30 Hz frame rate of the imaging camera. At this time, the development of an automated computer detection capability is the critical component of this entire project. This stage would entail the proof of concept for *AMDES* to demonstrate real-time image collection and meteor detection.
3. Develop and demonstrate a dual station detection system integrating data from nearby multiple sites for determination of meteor orbits. This stage requires the development of software for field of view recognition, data track validation, atmospheric and image plane reduction and correction, magnitude estimation, and, finally, orbital element computation. Many of the algorithms are already available and need only be integrated together into an analysis software package.
4. Establish fielded *AMDES* sites in the US and world-wide to collect meteoroid stream data creating a central clearinghouse for data collection, dissemination, and analysis. The data would be distributed to all interested professionals, entered into the *IMO* databases, and be

generally available to the public. Research to be conducted would involve searches for new meteoroid streams, validation of suspected streams, determination of the origins of sporadic meteors, while adding to the understanding of the evolution, dynamics, composition, and structure of meteoroid streams. The fielded site could be simple dual station systems with single detectors or more elaborate remotely operated full sky coverage from a bank of detectors. Operation of systems could be established at current observatory sites, placed in the hands of amateur astronomical organizations, or even placed within educational institutions.

6. Specific goals

Single prototype imager/computer

- Specify system requirements and goals for a workable, low-cost automated meteor detection system.
- Evaluate imaging hardware for best low-cost solution.
- Construct a prototype imager to
  - evaluate detectability limits;
  - examine field of view trade-off;
  - impact of lunar phase on detection capability;
  - assessment of improvement over currently fielded systems.
- Develop real-time software for proof of concept with capability for
  - 30 Hz image frame grabbing;
  - concurrent frame grabbing and frame summation;
  - meteor track detection;
  - archival storage of image frames flagged as a detection.
- Develop post-processing software for
  - star field identification and frame corrections;
  - meteor track position in stellar coordinates;
  - atmospheric corrections, magnitude and velocity estimation;
  - report generation and gnomonic projection of tracks.
- Monitor major and minor meteor streams evaluating radiant position, radii, drift, and time variability.
- Demonstrate extremely low-cost fireball/meteorite fall detector.

Multiple imager/computer—single site

- All-sky coverage for new stream search and minor stream validation.
- Monitor several radiants simultaneously.
- Composition analysis of meteoroid streams using spectral filters on multiple units.

Multiple sites

- Demonstrate orbital element estimation from dual station data integration.
- Probe issues that are addressable from knowing orbital elements:
  - meteor stream structure;
  - sporadic meteor origins;
  - stream associations with known cometary and asteroid bodies;
  - define search limits for undiscovered parent bodies.
- Full night-time coverage including northern and southern hemispheres.
- Coordination of efforts from a single location connected via Internet for data collection and dissemination.

7. AMDES system description

The critical element in the *AMDES* project development is in the construction of a functional detection system. This would involve the coupling of a low light level imaging system with a real-time image analysis computer system. The configuration includes an imaging system with mount, monitor, recorder, and computer for real-time/post processing, described below:

Imager sub-system

The basic components of the imager sub-system are filter, lens, image intensifier, transfer optics, and a low-light level frame rate CCD camera. The front end filter can be employed as a means to enhance contrast for poor lunar lighting conditions or for spectral analysis using standardized color filters. By using an R60 red filter, the detrimental effects of bright moon-lit nights can be minimized by enhancing the meteor's contrast against the background sky in the red portion of the spectrum. In addition, spectral colors could be obtained simultaneously on multiple *AMDES* to do composition studies specific to each meteoroid stream.

The objective lens is one of the most critical elements in the imager and controls the ability to achieve a high input signal to noise ratio into the intensifier. It is best to boost the gain at this stage of the optical path to minimize noise by using fast lenses with short f ratios. Use of a readily available and high-quality fast camera lens will mitigate the need for higher gain in the intensifier stage with its associated higher noise levels. Specification of the required field of view, whether it be all-sky to telescopic, will determine the focal length required for the lens. Issues of lens vignetting are of far less importance than speed of the optics, since, in the design configuration proposed, only the central portion of the lens is actually imaged by the intensifier. Typical system characteristics for various lenses are given later in Table 1. The lens chosen should be free of spherical aberration and also be coma-corrected. Spectrally, the lens should be clear in the visible and near infra-red. Note that standard video camera lenses should not be used as they employ infra-red blockers for proper color balance and would reduce sensitivity of the system to the near infra-red.

As part of the lens configuration, an electronic focuser could be added for automated remote focusing in situations where lenses may be interchanged often and hands-off operation of the focus is a requirement. For cases where a single lens would be used exclusively, the focuser would not be necessary, as the lens could be pinned permanently to the correct focus. Finally, a coupler stage is necessary to mate the lens's mounting system to the C-mount threaded barrel of the image intensifier ($1''$, 32 tpi).

The image intensifier proposed for this work is a three-stage multi-channel plate generation 2.5 intensifier tube with automatic gain control. Gains can vary from 10^4 to 10^5 with good linearity across the tube, low-cost of 3500 USD for a scientific grade unit, and light in weight. Spectral response is in the 400–950 nanometer range, which pushes further into the near infra-red than second generation tubes. The near infra-red sensitivity of these tubes has been conjectured to aid in the detectability of fainter meteors. These tubes have already been used in a number of astronomical applications. The output from the intensifier, which is at visible wavelengths, must be focused onto a CCD chip via a set of transfer optics. The transfer lens arrangement must be optimized for a given chip size which, in the past, has been composed of a coated optics six element $f/1.1$ flat field design.

The CCD detector is a low-light sensitive, high-resolution, black-and-white frame rate camera with peak spectral response in the visible wavelengths. Its output is a standard NTSC TV signal with fully interleaved images produced at a 30 Hz rate. This rate provides sufficient temporal resolution to capture a meteor event across several frames and allow for estimation of velocity. In addition, there is no non-imaging dead time associated with downloading frames from camera to computer. The collection of each frame separately with time tagging eliminates the problems associated with meteor event time estimation, correlation between dual-station measurements, and chopping wheel inaccuracies. The alternative of using an integrating type CCD camera has the advantage of containing a complete meteor track on one image and no frame grabber required with the computer. However, the disadvantages that ruled out its use are lower light sensitivity than frame rate cameras, slower download time to the computer resulting in dead observing time, and higher levels of integrated background noise.

Mount/monitor/recorder

The mounting system for the imager can consist of a simple tripod for fixed azimuth and elevation orientation or a sophisticated remote operated equatorial mount with tracking drive. The latter would have the capability to slew to a particular radiant position through a remotely operated command link-up. The monitor's purpose would be for the early development stages where verification of proper signal receipt and manual focusing on site would be necessary. This would consist of a portable 5 inch black-and-white TV monitor. Though the purpose of *AMDES* is to automatically record only meteor events via computer, in the early development stages is would be necessary to simultaneously record the images on tape. The best video recorder on the market for this purpose is a Hi-8mm VCR recorder which retains image resolution down to that available in the original signal. The tapes could be played back into the computerized detection processing sub-system to examine alternate detection and processing algorithms with only small losses in signal fidelity.

Computer processor sub-system

The basic computer proposed for this effort involves the use of a 90 MHz Pentium processor. Alternate processors such as the PowerPC have sufficient computational speed for the necessary image processing, but currently lack supporting hardware such as the frame grabber board needed as an interface to the CCD camera. The basic computer would be equipped with 32 Mbytes RAM for storage of multiple frames for summation on the fly, at least a 500 Mbyte hard disk, a floppy for data output, and remote communication capability for each imager.

The frame grabber board must be capable of grabbing NTSC fully interleaved 510×492 pixel images at a 30 Hz rate and transfer the complete images over the computer's PCI bus to the computer memory with no dead time. The individual frames will be summed by the CPU while the next set of images are collected by the frame grabber board. This requires a board with concurrent image grabbing and data transfer capability (asynchronous processing). The summation is done to develop a linear track on the image for input to the meteor detection algorithm. The computer processor and data bus should be fast enough to sum these images in real time and exercise the detection algorithm at the 30 Hz rate of the camera output. An alternative is to use a summation-capable frame grabber board which offloads the computational load from the computer processor at the cost of losing the individual frames and much higher overall system cost. With this type frame grabber, the velocity information can still be backed out by electronically chopping the image (leaving out every nth frame in the image summation).

The real-time processing will require the development of software for the frame grabber control and image download running in parallel with the fast integer summation and linear track detection algorithms. The detection algorithm will be based on either a Hough transform line searching algorithm working on the summed image or a motion detection algorithm working across several individual frames. Part of this algorithm will involve the development of a noise subtraction algorithm to enhance the signal track to noise ratio and increase the detection probability. Once a detection is made, image storage of all the contributing individual frames will also be done in real time with a time/date stamp accurate to 33 ms.

The post-processing algorithms that will operate on images containing a meteor detection can be exercised in an off-line mode. These algorithms involve the development and incorporation of software for star field identification, pointing direction determination, plate constant evaluation, application of correction terms, meteor track coordinate estimation, magnitude estimation, velocity estimation, radiant association, and report/gnomic projection generation. The final set of information is sufficiently reduced in data bandwidth that results could be transferred via floppy or downloaded over a remote hookup. For dual-station work, additional algorithms for meteor event correlation, radiant association, and orbit determination would be necessary [7].

Current system availability

A prototype imager sub-system has been constructed and is currently operating having achieved the levels of capability under skies with limiting visual magnitude of +5.5 listed in Table 1.

Table 1 – Achievements of the current prototype under skies with limiting visual magnitude of +5.5.

Lens	Field of view	Limiting magnitude
28 mm, $f/1.8$	$12^\circ \times 16^\circ$	+8.0 stellar
50 mm, $f/1.4$	$6\overset{\circ}{.}5 \times 9^\circ$	+9.0 stellar

These results neglect gains that could be obtained from using faster lenses and applying image processing enhancement. It also neglects any detectability gains due to the near infra-red sensitivity of the intensifier as this test only evaluated stellar images and not meteor tracks. This also neglects losses from less integration time per pixel for a moving meteor trail relative to a stationary stellar source. Further work needs to be done to determine the cost/capability trade-off for an optimally priced system.

Currently, a complete single-station *AMDES* with the capabilities listed above can be obtained for 8000 USD in hardware costs. To develop the real-time detection software and construct a complete single integrated system, the total cost is estimated to be 30 000 USD. For dual-station work, the cost for initially developing software to interface multiple station data with the orbit determination algorithms is estimated to be 50 000 USD. After the initial software development, the costs would be limited to analysis and hardware purchases. For improved limiting magnitudes, finer angular resolution, better detectability, far more expensive imaging components can be obtained thus raising the single unit hardware costs.

8. Summary

Given the current state of the art in video and computer technologies, it is proposed that a fully automated meteor detection and monitoring system could be developed and fielded at low cost. Multiple systems could be distributed worldwide to provide 24-hour night coverage of meteor activity with operation of the systems done from a remote location. The capabilities of *AMDES* significantly improves upon that of visual, photographic, and radar techniques by providing both greater quantity and quality of meteoric event data useful for orbit estimation. The data collected would be used to advance the state of research in meteor astronomy, aid in identifying potential orbital parameters for large earth crossing meteoroids and comets, and establish a more active role for meteor research within the United States.

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The Spatial Distribution of Potential Forward Scatter Reflection Points

Cis Verbeeck

A forward scatter set-up can only detect those meteors which lie above the Earth's tangent planes (i.e., horizons) in transmitter and receiver. For other meteors, the transmitted signal will not reach the meteor or the reflected signal will not reach the receiver. The present paper determines the explicit shape of the potential reflection zone of points satisfying the above condition, as well theoretically as in some numeric instances.

1. The potential reflection surface

Consider a forward scatter set-up with transmitter T and receiver R, at a distance d (along a straight line through the Earth) from each other. Denote the Earth radius by R_E, and consider the right-handed orthonormal coordinate frame with origin in the center O of the Earth, x-axis in the direction T–R, and z-axis in the direction O–M, where M is the middle of T and R (see Figure 1). We want to determine the zone of the points where a meteor could reflect the radio waves transmitted in T to the receiver R. Let us assume that all potential reflection points are situated at a fixed altitude h above the Earth surface. Consequently, these points lie on the sphere $x^2 + y^2 + z^2 = (R_E + h)^2$, and the sought-for zone is a surface. The length A defined in Figure 1 is given by

$$A = \sqrt{R_E^2 - \frac{d^2}{4}}. \tag{1}$$

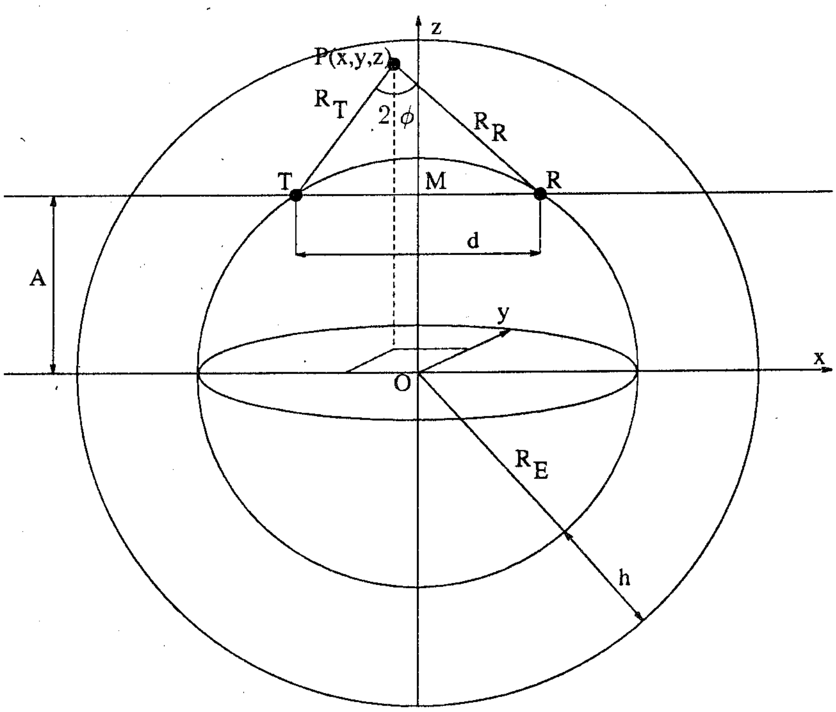

Figure 1 – Geometry of the discussed set-up.

The only condition for $P(x, y, z)$ to be a potential reflection point is that P lie above the Earth's tangent planes in T and R, and at an altitude h above the Earth surface. The tangent plane in T is described by

$$-\frac{d}{2}\left(x + \frac{d}{2}\right) + A(z - A) = 0 \text{ or } z = \frac{1}{A}\left(\frac{d}{2}x + \frac{d^2}{4} + A^2\right), \tag{2}$$

whereas the other tangent plane is given by

$$\frac{d}{2}\Big(x - \frac{d}{2}\Big) + A(z - A) = 0 \text{ or } z = \frac{1}{A}\Big(-\frac{d}{2}x + \frac{d^2}{4} + A^2\Big). \tag{3}$$

This means the potential reflection points $P(x, y, z)$ satisfy

$$z = z(x, y) \geq \frac{1}{A}\Big(\frac{d}{2}|x| + \frac{d^2}{4} + A^2\Big), \tag{4}$$

with

$$z(x, y) = \sqrt{(R_E + h)^2 - x^2 - y^2}\,. \tag{5}$$

So we infer

$$(R_E + h)^2 - x^2 - y^2 \geq \frac{1}{A^2}\Big(\frac{d}{2}|x| + \frac{d^2}{4} + A^2\Big)^2,$$

whence

$$y^2 \leq -\frac{d^2 + 4A^2}{4A^2}x^2 - d\frac{d^2 + 4A^2}{4A^2}|x| + (R_E + h)^2 - \Big(\frac{d^2 + 4A^2}{4A}\Big)^2. \tag{6}$$

The right hand side of (6) is a parabola in $|x|$, with discriminant

$$D = \frac{d^2(d^2 + 4A^2)^2}{16A^4} + \frac{d^2 + 4A^2}{A^2}(R_E + h)^2 - \frac{(d^2 + 4A^2)^3}{16A^4} = \frac{d^2 + 4A^2}{A^2}(h^2 + 2R_E h) > 0.$$

Thus the parabola has two different roots, and since the coefficient of x^2 is negative, the opening of the parabola points down. Therefore the right-hand side of (6) is positive if and only if $x_1 \leq |x| \leq x_2$, where $x_1 < x_2$ are the roots of the considered parabola. We obtain the following values for x_1 and x_2:

$$x_{1,2} = \frac{d\,\dfrac{d^2 + 4A^2}{4A^2} \pm \sqrt{D}}{-\dfrac{d^2 + 4A^2}{2A^2}}$$

$$= -\frac{d}{2} \pm \frac{\sqrt{(R_E^2 - d^2/4)(h^2 + 2R_E h)}}{R_E}\,.$$

More precisely,

$$x_1 = -\frac{d}{2} - \frac{\sqrt{(R_E^2 - d^2/4)(h^2 + 2R_E h)}}{R_E} < 0 \tag{7}$$

and

$$x_2 = -\frac{d}{2} + \frac{\sqrt{(R_E^2 - d^2/4)(h^2 + 2R_E h)}}{R_E}\,. \tag{8}$$

The latter root is positive for realistic values of d, R_E, and h. Now the x-values which render the right hand side of (6) positive are precisely those which satisfy $-x_2 \leq x \leq x_2$. These are the x-values that are the first coordinate of some potential reflection point. For $-x_2 \leq x \leq x_2$, the condition on y for $P(x, y, z(x, y))$ to be a potential reflection point is that y satisfies (6), i.e., $-y_1(x) \leq y \leq y_1(x)$, where $y_1(x)$ is given by

$$y_1(x) = \sqrt{-\frac{d^2 + 4A^2}{4A^2}x^2 - d\frac{d^2 + 4A^2}{4A^2}|x| + (R_E + h)^2 - \Big(\frac{d^2 + 4A^2}{4A}\Big)^2}$$

$$= \sqrt{\frac{-4R_E^2}{4R_E^2 - d^2}x^2 - \frac{4dR_E^2}{4R_E^2 - d^2}|x| + (R_E + h)^2 - \frac{4R_E^4}{4R_E^2 - d^2}}\,. \tag{9}$$

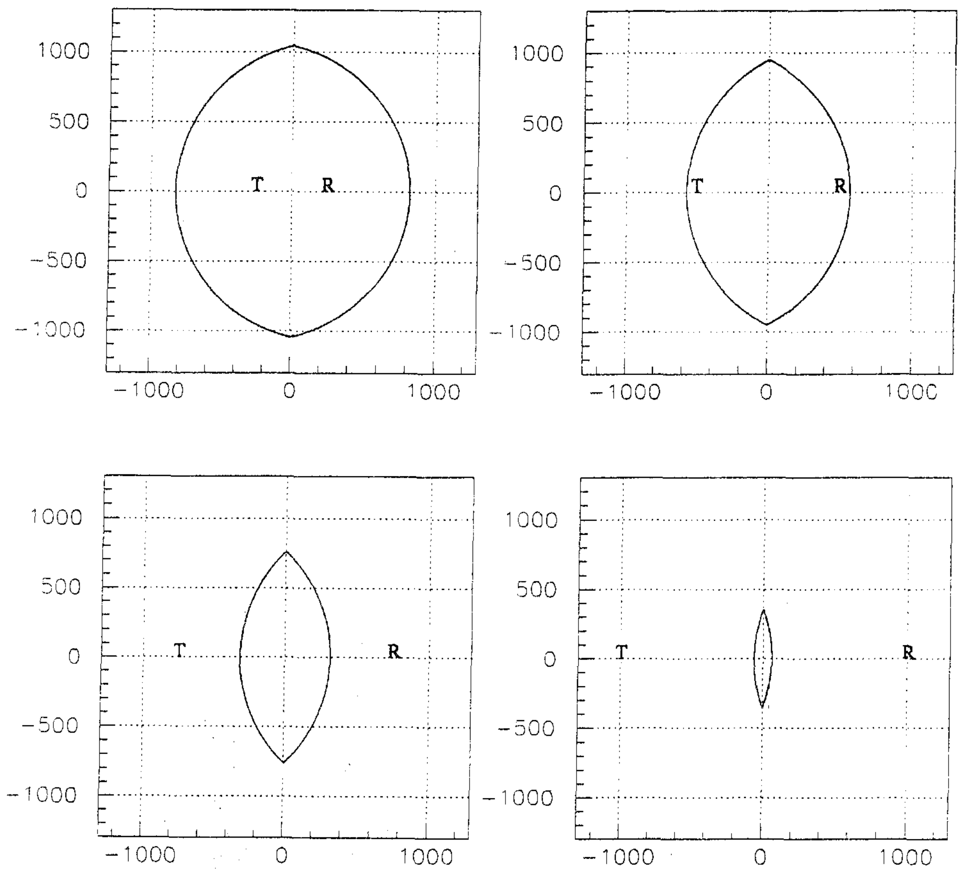

Figure 2 – The projection of the potential reflection surface on the $z = 0$ plane for $h = 90$ km. The upper left, upper right, lower left, and lower right figures show the projections for $d = 500$ km, $d = 1000$ km, $d = 1500$ km, and $d = 2000$ km, respectively.

The potential reflection surface has now been characterized. It is symmetric with respect to the planes $x = 0$ and $y = 0$. Before we proceed, we make some cautioning remarks.

1. All the above results are based on the assumption that all meteor reflections take place at altitude h above the ground. Tto investigate meteor parameters, one should of course perform the relevant calculations for several values of h. One could also consider the combined potential reflection surfaces for all altitudes h as the real zone of all potential reflection points.
2. Only the geometrical constraints on reflection points due to the relative positions of receiver and transmitter on Earth are considered here. Of course, shower meteors are subject to important additional geometrical constraints.
3. A point in the potential reflection zone will only give rise to a reflection if it is well-oriented [1]. Belonging to the reflection zone is only a necessary condition for reflection.
4. Meteors appearing in some parts of the reflection surface are more likely to be observed by the receiver than similar meteors in other parts of the reflection surface. Actually, the power received by the receiver depends on the distance from the meteor to transmitter and receiver and highly depends on the forward scatter angle ϕ and the gain of the antennas in the direction of the meteor. This means that meteors are more likely to be observed in some areas of the potential reflection surface than in other areas.

2. The reflection surface numerically

We can now calculate and plot the reflection surface for specific values of d and h. We will set $R_E = 6366$ km. Figure 2 shows the projections of the reflection surface on the $z = 0$ plane for an altitude h of 90 km, and for d-values of 500, 1000, 1500, and 2000 km, respectively. The positions of transmitter and receiver are denoted by T and R, respectively.

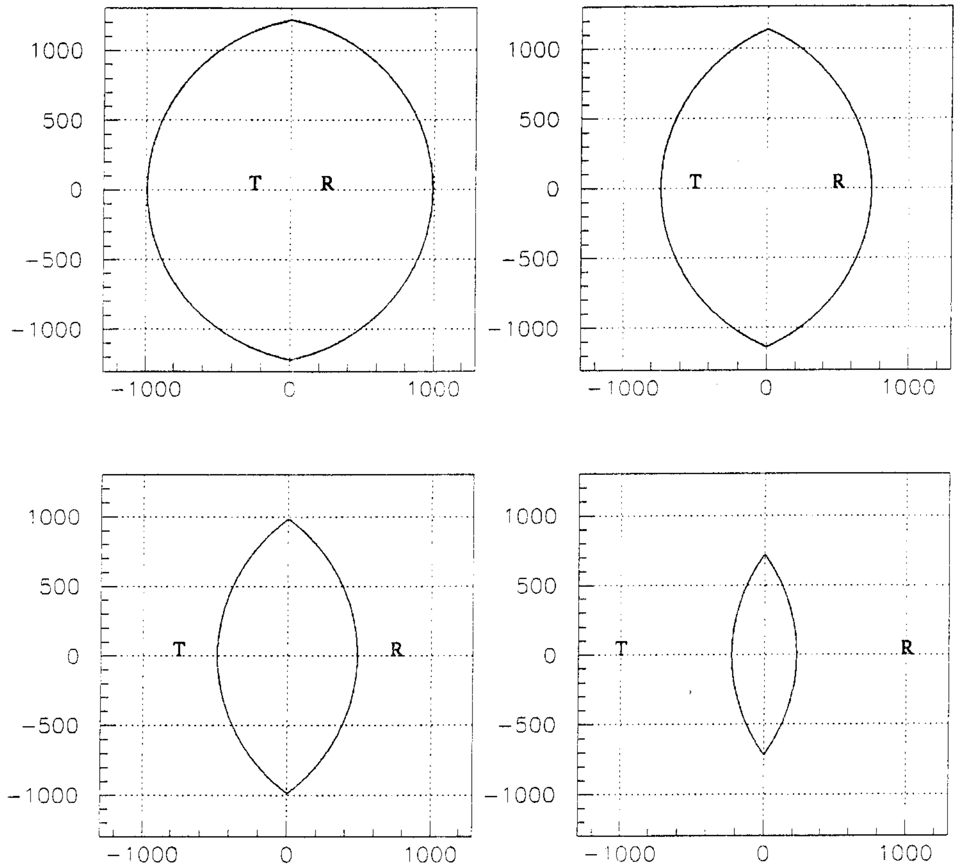

Figure 3 – Projection of the potential reflection surface on the $z = 0$ plane for $h = 120$ km. The upper left, upper right, lower left, and lower right figures show the projection for $d = 500$ km, $d = 1000$ km, $d = 1500$ km, and $d = 2000$ km, respectively.

Notice that the reflection surface is very large for $d = 500$ km, and becomes smaller and smaller with increasing d. For $d = 2000$ km, the reflection surface has almost vanished. Also, we observe that the reflection surface is larger in the y-direction (perpendicular to the line T–R) than in the x-direction (the direction T–R). As the distance d increases, the maximal y-value $y_1(0)$ of the surface decreases more slowly than its maximal x-value x_2. This means the reflection surface gets more oblong with increasing d.

Figure 3 shows the projection of the reflection surface for $h = 120$ km, and for d-values of 500, 1000, 1500, and 2000 km, respectively. We notice the same patterns as in Figure 2: the surface is large for $d = 500$ km and gets smaller as d increases. Here also the surface is larger in the y-direction than in the x-direction and gets more oblong as d increases. The only difference with Figure 2 is that all reflection surfaces are a little larger for $h = 120$ km than for $h = 90$ km. It is clear, however, that the reflection surface depends mainly on d, and h has only a secondary influence on the dimensions of the surface.

3. Measuring the reflection zone

We can calculate the surface S of the potential reflection surface. It is given by

$$S = 4 \int_0^{x_2} \int_0^{y_1(x)} \sqrt{1 + \left(\frac{\partial z}{\partial y}\right)^2}\, dy\, dx \,. \tag{10}$$

By equation (5), $z = \sqrt{(R_E + h)^2 - x^2 - y^2}$, whence

$$\frac{\partial z}{\partial y} = \frac{-y}{\sqrt{(R_E + h)^2 - x^2 - y^2}}\,, \tag{11}$$

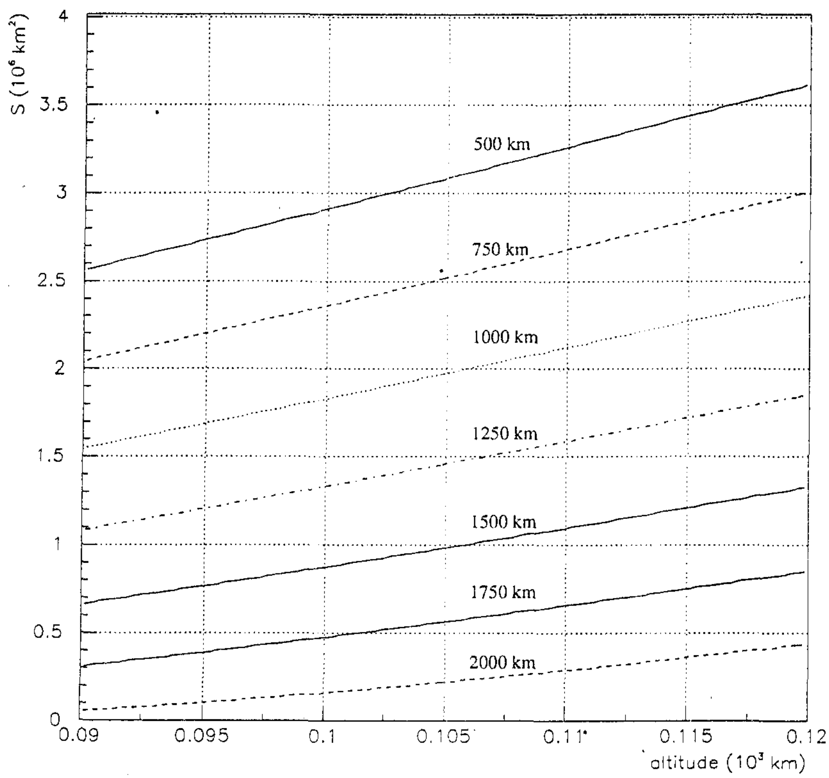

Figure 4 – The surface S of the reflection surface as a function of the altitude h, for several values of the distance d between transmitter and receiver (indicated next to the corresponding curve).

which implies

$$S = 4 \int_0^{x_2} \int_0^{y_1(x)} \sqrt{\frac{(R_E + h)^2 - x^2}{(R_E + h)^2 - x^2 - y^2}}\, dy\, dx$$

$$= 4 \int_0^{x_2} \sqrt{(R_E + h)^2 - x^2} \,.\, \arcsin\Big(\frac{y_1(x)}{\sqrt{(R_E + h)^2 - x^2}}\Big)\, dx\,. \tag{12}$$

We have calculated this integral with the trapezoid rule for various values of d and h. The result can be seen in Figure 4, which shows S as a function of the altitude h, for several values of d (notice that h is given in units of 10^3 km and S in units of 10^6 km^2). As one can see, the curves are not completely smooth as a result of the errors in the numerical integration. However, it is clear that these errors are very small (in fact only merely visible). Of course, the surface is largest for $d = 500$ km. For this d-value, S ranges from 2.6 million square kilometers ($h = 90$ km) to about 3.6 million square kilometers ($h = 120$ km). All curves are nearly straight lines, increasing slightly with increasing altitude. The curves get gradually lower as d increases. For $d = 2000$ km, S ranges from about 0.05 million square kilometers ($h = 90$ km) to 0.4 million square kilometers ($h = 120$ km).

Figure 5 shows the volume V of the potential reflection *zone* (i.e., the combination of the reflection surfaces for all altitudes h between 90 km and 120 km) as a function of d. To obtain this volume, We calculated the integral

$$V = \int_{90\ \mathrm{km}}^{120\ \mathrm{km}} S(d,h)\, dh$$

with the trapezoid rule (notice that d is given in units of 10^3 km and V in units of 10^6 km^3). The result is a nearly straight curve between $V = 90$ million cubic kilometers ($d = 500$ km) and $V = 7$ cubic kilometers ($d = 2000$ km).

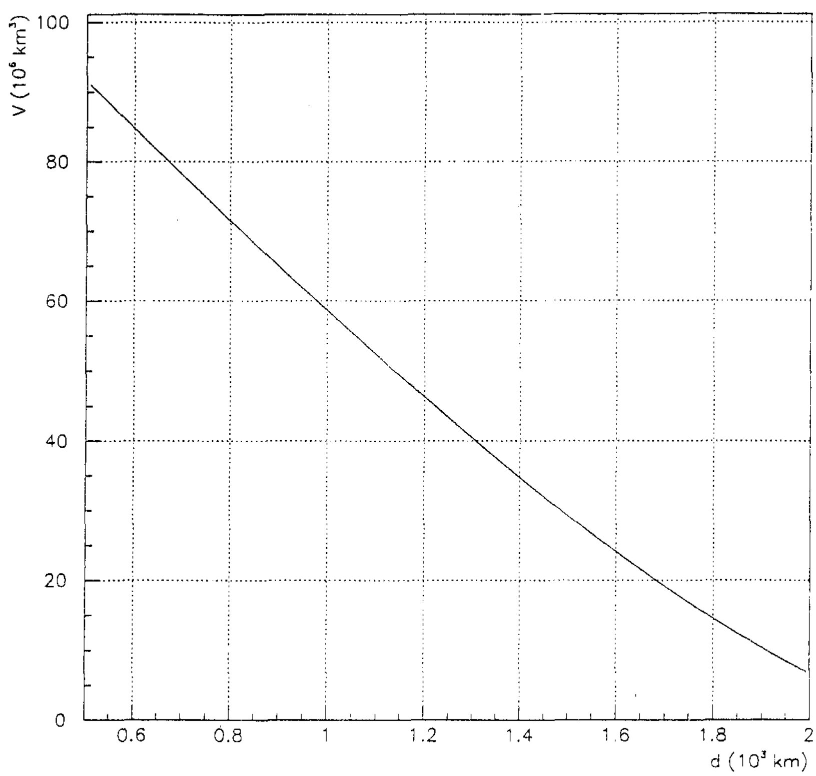

Figure 5 – This figure shows the volume V of the potential reflection *zone* as a function of the distance d between transmitter and receiver.

Notice that meteors in some parts of this volume are more likely to be observed than similar meteors in other parts. Consequently, the volume V is not necessarily proportional to the number of meteors observed with the given set-up.

4. The apparent size of the reflection surface

The interested radio observer will also wonder what the reflection surface looks like from his point of view, i.e., the receiver. For instance, one could calculate the maximal height α above the horizon (in the receiver) reached by points of the surface.

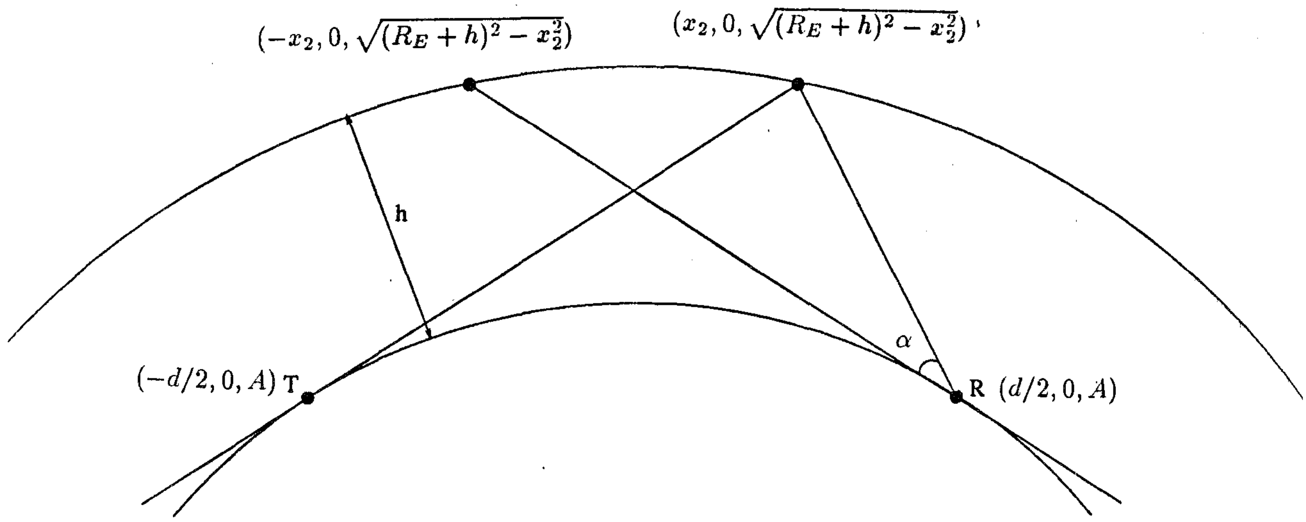

Figure 6 – The angle α.

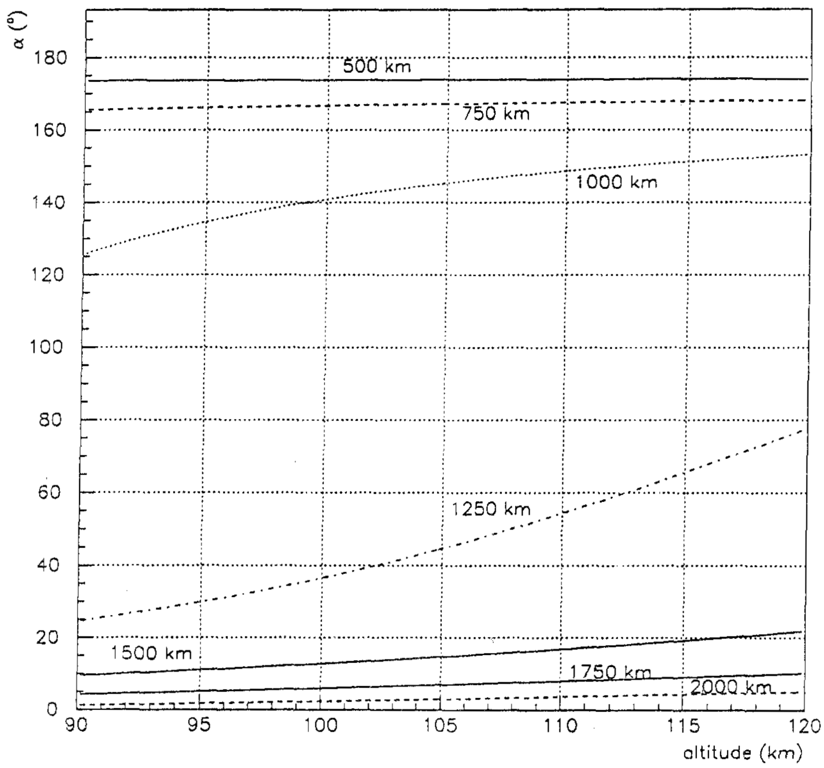

Figure 7 – The height α defined in Figure 6 as a function of the altitude h, for several values of the distance d between transmitter and receiver (indicated next to the corresponding curve).

Figure 6 illustrates that α can be written as:

$$\alpha = \arccos \frac{(-x_2 - d/2, 0, \sqrt{(R_E+h)^2 - x_2^2} - A) \cdot (x_2 - d/2, 0, \sqrt{(R_E+h)^2 - x_2^2} - A)}{||(-x_2 - d/2, 0, \sqrt{(R_E+h)^2 - x_2^2} - A)|| \cdot ||(x_2 - d/2, 0, \sqrt{(R_E+h)^2 - x_2^2} - A)||}.$$

Figure 7 shows the height α as a function of h, for several values of d. Since the reflection surface is large for $d = 500$ km, we expect α also to be quite high for $d = 500$ km. Indeed, α has a nearly constant value of 174°, almost an entire half circle! For $d = 750$ km, α decreases a little, but remains essentially large and nearly constant as a function of h. For $d = 1000$ km, we see that α is not constant any more, but increases from 125° (for an altitude of 90 km) to a little above 150° ($h = 120$ km).

The curve for $d = 1250$ km is much lower than the previous ones. Here, α increases from 25° ($h = 90$ km) to about 75° ($h = 120$ km). It is evident that values of d between 1000 km and 1250 km (and perhaps d-values in a little broader interval too) give rise to heights α which are very altitude-depending. Looking at the α-curves for $d = 1500$ km, 1750 km, and 2000 km, we see that α is again nearly altitude-independent, but now has very low values (below 10° in the latter two cases).

Figure 8 shows the height α as a function of d, for several values of h. Notice the steep decrease of α between about $d = 1000$ km and $d = 1500$ km.

5. Applications

Since we now know the shape of the potential reflection surface, we can investigate how radio meteor parameters such as ϕ, R_T, and R_R (see Figure 1) vary throughout the surface.

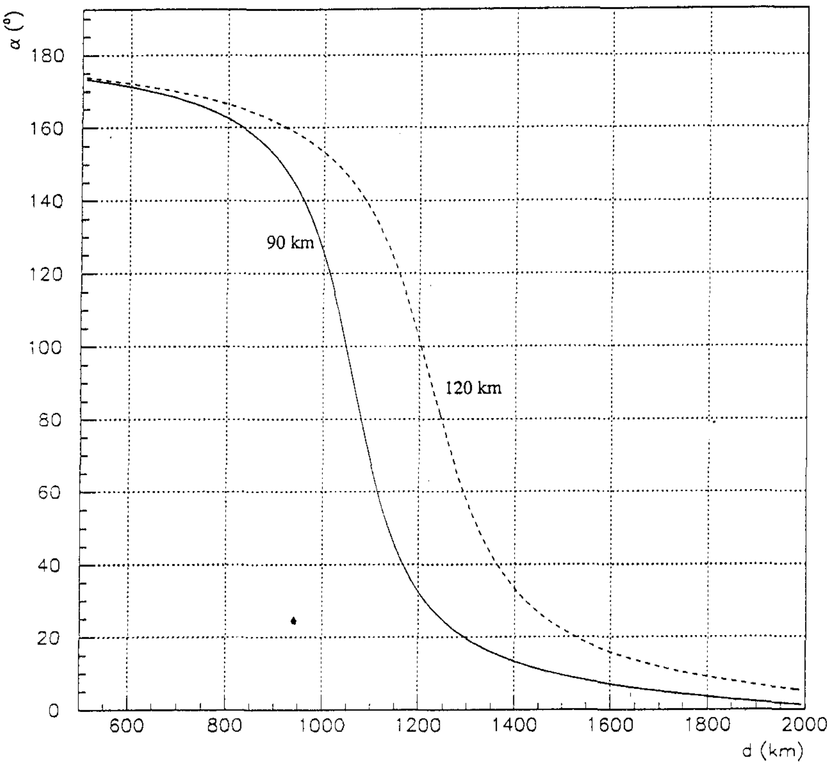

Figure 8 – The height α defined in Figure 6 as a function of the distance d between transmitter and receiver, for several values of the altitude h (indicated next to the corresponding curve).

These parameters occur in many formulae describing the reflection phenomenon, so it is interesting to know their numerical distribution. An investigation of the distribution of the length of the first Fresnel zone and the power profile has also been presented at the 1995 *IMC* in Brandenburg.

6. Conclusion

The potential reflection surface at an altitude h and for a distance d between transmitter and receiver is the set of all points $P(x, y, z)$ (w.r.t. the coordinate frame chosen in Section 1) with

$$
\begin{aligned}
-x_2 \leq x \leq x_2, \\
-y_1(x) \leq y \leq y_1(x), \\
z = \sqrt{(R_E + h)^2 - x^2 - y^2}\,.
\end{aligned}
$$

For low values of d (500 km), the reflection surface is very large. Its size decreases with increasing d, until it almost vanishes for $d = 2000$ km. The surface is longer in the direction perpendicular to the line transmitter–receiver than in this direction, and it becomes more oblong with increasing distance d.

Acknowledgment

I am very grateful to Jean-Marc Wislez for discussions and suggestions which improved this paper substantially. I also appreciate the use of his plotting software.

Reference

[1] D.W.R. McKinley, "Meteor Science and Engineering", McGraw-Hill, New York, 1961.

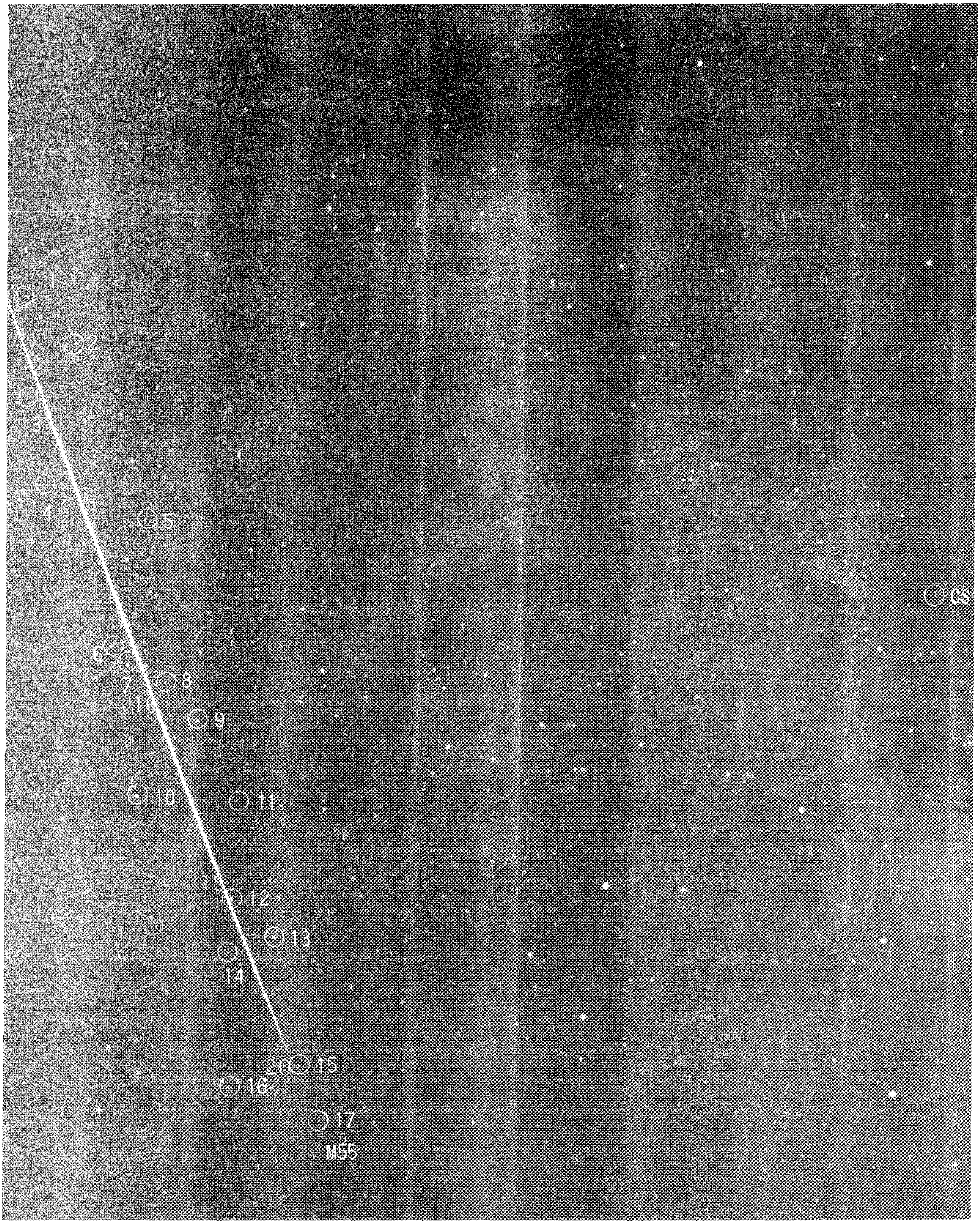

Figure 1 – Digitized image of the fireball JN940508 taken by M. Nagao using AF Nikkor 35 mm $f/2$ lens. The numbered, encircled stars are reference stars. The positional accuracy is about 30″.

Fireballs and Meteorites

Fireball over Japan

May 8, 1994, $17^h46^m50^s$ UT

C. Shimoda, M. Nagao, S. Suzuki, K. Ohtsuka, and Y. Shiba

The results of orbital calculations of a fireball of magnitude about −8 photographed in the Japanese Fireball Network on May 8, 1994, are presented.

A fireball (JN940508) of magnitude about −8 on May 8, 1994, $17^h46^m50^s$ UT, was photographed from three different sites in Japan. One image was obtained at the Hario Station of the Japanese Fireball Network using a Canon FD fish-eye lens (15 mm, $f/2.80$) and a rotating shutter, while the other two images were coincidentally taken by M. Nagao and S. Suzuki from other distant sites, during an exposure for a photograph of the Milky Way or constellations, using wide-angle lenses of 35 mm and 40 mm focal length, respectively. These images were scanned and digitized using a Centris 650 Macintosh computer (MC68040, 25 MHz) and a Nikon COOLSCAN film scanner (maximal resolution of 2700 dpi), and the measurements were performed on the computer display using image processing software for the first time (Figure 1).

The results are shown in Table 1 and Figures 2 and 3.

Table 1 – Trajectory and orbital data (eq. 2000.0) of the fireball JN940508.

Time	May 8, 1994, $17^h46^m50^s$ UT
Apparent Radiant	$\alpha = 300.^\circ01 \pm 0.^\circ10$ $\delta = 70.^\circ60 \pm 0.^\circ08$
Corrected Radiant	$\alpha = 301.^\circ65 \pm 0.^\circ10$ $\delta = 72.^\circ44 \pm 0.^\circ08$
Begin point	$\lambda = 138.^\circ04460$ E $\varphi = 34.^\circ9251$ N $h = 86.20$ km
End point	$\lambda = 137.^\circ93162$ E $\varphi = 34.^\circ5736$ N $h = 36.05$ km
Trail length	64.61 km
Velocity (km/s)	$V_\infty = 27.0 \pm 0.4$ $V_G = 24.6 \pm 0.4$ $V_H = 38.1 \pm 0.3$
Ang. orbital elements	$\omega = 158.^\circ5 \pm 0.^\circ3$ $\Omega = 47.^\circ9835$ $i = 39.^\circ6 \pm 0.^\circ5$
Lin. orbital elements	$e = 0.657 \pm 0.021$ $q = (0.9851 \pm 0.0002)$ AU $a^{-1} = (0.3495 \pm 0.0215)$ AU^{-1}

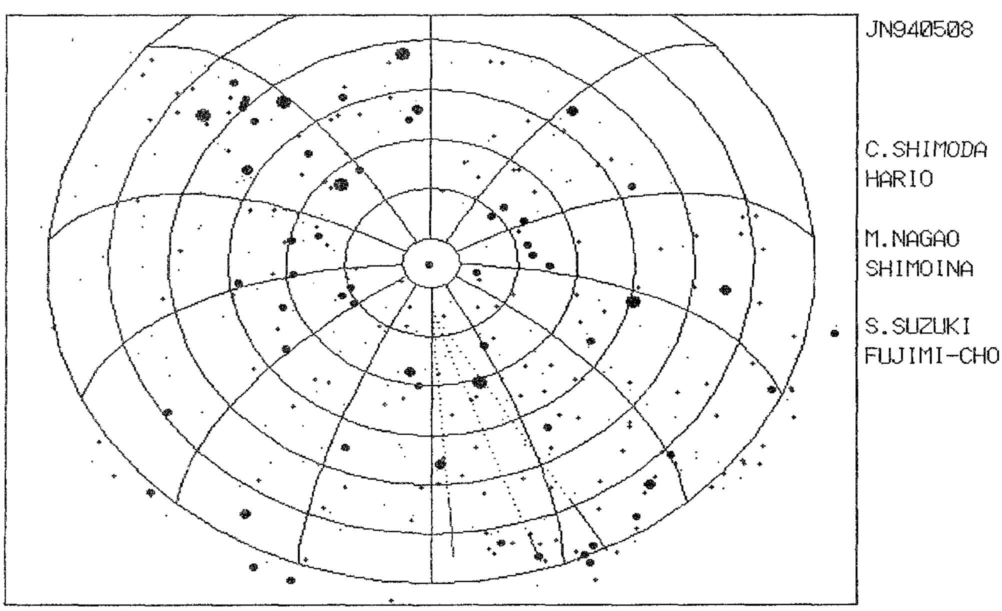

Figure 1 – Observed trajectory of fireball JN940508 against the sky background.

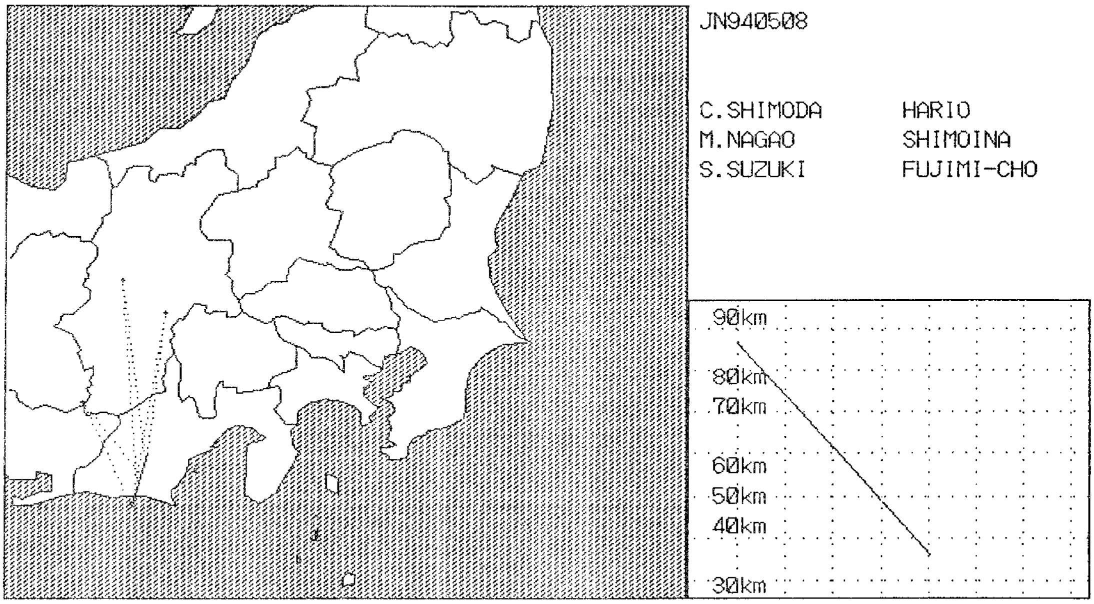

Figure 3 – Ground-based trajectory of fireball JN940508.

Fireball over the Netherlands

November 5, 1995, 20^h35^m UT

communicated by Casper ter Kuile

A bright fireball passed over the eastern part of the Netherlands, and probably also over Germany, on November 5, 1995, 20^h35^m UT.

I was informed of the appearance of a very bright fireball over the eastern part of the Netherlands and probably as well over Germany. It appeared on Sunday, November 5, 1995, at approximately 20^h35^m UT. It could be as bright as the Full Moon. Fragmentations have been observed as far as we know at the moment. The fireball has been observed independently by two observers in the Netherlands. One of them is located in the western part near the coast and the other one some 100 kilometers east. Both observed the fireball in eastern direction.

Meteorite Fall over Perth, Australia

April 30, 1995, 17^h57^m UT

Graham W. Wolf

A thorough media and eyewitness study of this event has been made by the author.

On p. 96 of *WGN* 23:3 (june 1995), there is a brief 6-sentence report about the meteorite fall over Perth, Australia, on April 30, 1995, 17^h57^m UT. The report mentions an Internet comment bu Dr. Peter V. Birch of the Perth Observatory. A few days after the event, I made a thorough media and eyewitness study of this event. The results of this study—as well as reports on other Australasian meteorite falls, particularly in New Zealand—have been presented as posters at the 1995 *IMC* and will appear in the Proceedings.

Observational Results

SPA Meteor Section Results: February to April, 1995

Alastair McBeath

A review of data sent to the SPA Meteor Section during the early months of 1995 is presented and discussed. Poor weather once again dominated observing in Britain, but overseas contributions continued to ensure the Section kept abreast of what meteor activity is occurring generally. The main item of interest was the Lyrid return in April, which produced rates of around 20 m/h on April 22-23 as seen by German observers. One meteor train photograph was obtained from Romania, too.

1. Introduction

Table 1 shows the hours' and meteor totals achieved by those reporting results to the *SPA Meteor Section*.

Photographic totals were dominated by the German *Arbeitskreis Meteore* (*AKM*) observers, primarily operating wide-field and all-sky cameras as part of the European Fireball Network, although Vasile Micu in Romania contributed $10^{\mathrm{h}}\!.35$ photography, catching two Lyrid trails during April. Leading visual observers were also from the *AKM*, along with Graham Wolf in New Zealand, Vasile Micu in Romania and Martin Plater in Britain. The full list of visual workers who submitted data during these three months comprised

> *AKM* members (from Germany, and a lucky two—Rainer Arlt and Jürgen Rendtel—from Arizona and Texas in late April), Shelagh Godwin, Richard Livingstone, Tony Markham, Vasile Micu (Romania), Matthew Pearce, Martin Plater, and Graham Wolf (New Zealand).

In addition, around five hours of video data were reported via the *AKM* in *Mitteilungen des Arbeitskreises Meteore* (20:6, p. 4) by Sirko Molau, using the excellent MOVIE meteor video system. The observations were carried out on April 22-23.

Table 1 – Visual and photographic hours' totals and meteor numbers recorded in each month, including a partial breakdown of meteor types and numbers of photographed meteor trails notified so far.

Month	Visual	Vir	Sag	Lyr	Meteors	Photographic	Trails
February	$70^{\mathrm{h}}\!.33$	10	–	–	308	$268^{\mathrm{h}}\!.00$	1
March	$125^{\mathrm{h}}\!.81$	78	–	–	599	$437^{\mathrm{h}}\!.03$	0
April	$138^{\mathrm{h}}\!.04$	44	66	186	1108	$141^{\mathrm{h}}\!.71$	2

2. February

February is often a poor month for weather in northern Europe, and so it proved in 1995, as very few UK observations were possible. Some other European reporters were more fortunate, one or two of the *AKM* team seemingly able to conjure up clear nights at will at times (or perhaps simply better able to move to where the clear skies are quickly), and Graham Wolf also enjoyed some good nights during his late summer. Graham's work continued to add observations of previously unseen southern hemisphere showers to the Section's repertoire, most notably low rates of α-Centaurids (particularly obvious from February 5–12, but best average observed rates were never above 2-3 meteors per hour), γ-Normids (at the end of the month), plus a few possible θ- and o-Centaurids. Other minor shower members seen included some early Virginids and a few δ-Leonids, apart from the low sporadic rates typical of this time of year, certainly north of the equator.

3. March

From Britain, March continued the disappointing spell of weather. Overall, most observations submitted to the Section were completed within the first ten days of the month, or right at the very end. In New Zealand, Graham Wolf was very active, and managed to spot low rates from the γ-Normids up to mid month, with a slight indication that higher observed numbers were occurring around March 13 and 14. He also detected small numbers of β-Pavonids near March's end, despite quite poor limiting magnitudes at times. Here, as well as in Britain, Germany and Romania, low Virginid and δ-Leonid ZHRs were detected, neither very far from being lost in the sporadic background, however. Meteor of the session was over New Zealand, a stupendous magnitude -15 fireball on March 1 at 16^h45^m UT, which left a 60-second train.

4. April

In the UK, the Lyrids in particular were pretty well washed out over the whole country at their peak. As in March, the bulk of observations were carried out before mid-month, or in the closing days, with the exception of the marvelous efforts by 14 *AKM* observers and Vasile Micu for the Lyrids, especially around April 22 and 23. Graham Wolf continued his monitoring of the southern sky showers, with β-Pavonids in evidence particularly around April 6–8—observed rates were never above 2–3 an hour even on April 8 (10 in 5.5 hours with a clear limiting magnitude +6.7 sky), however. He also spotted some meteors from the Sagittarid complex and 6 π-Puppids in 14 hours between April 16–18, bringing the π-Puppid total to 7, since Jürgen Rendtel also spotted one shower member during a watch on April 23 from Tucson Mountain Park in Arizona ($\varphi \approx 32°13'$ N). Some Virginids, and a few early η-Aquarids rounded off the "minor" showers.

Greatest hopes were held out for the Lyrids, however, with reasonable moonlight conditions for the peak, expected around April 22. Most data came from the *AKM* on this shower, although Vasile Micu also reported that his best night for Lyrids was April 22, with two particular bursts of Lyrids around 21^h20^m UT and 22^h35^m UT. *AKM* data suggest that the Lyrids peaked between roughly April 23, 2^h and 10^h UT, probably closer to the former than the latter time, as ZHRs were about 20 at 2^h UT, but were just half that eight hours later. This is rather later than earlier predictions suggested (April 22, 15^h UT in the 1995 *IMO* Meteor Shower Calendar, for instance, based on $\lambda_\odot = 32.^\circ1$). A time nearer 2^h UT on April 23 would be closer to $\lambda_\odot = 32.^\circ5$ (eq. 2000.0). Further results from elsewhere will no doubt help clarify the true picture.

Vasile Micu was exceptionally lucky on April 19, when, at 22^h45^m UT, a superb magnitude -10 fireball appeared, which left a 30 second train. He had a camera on-hand, and swiftly took two photographs of this train. Unfortunately, the hand-held prints are not too easy to interpret, since there are few stars visible on the short exposures, and there are multiple images of the train to deal with too, but a pair of sketches illustrating what was seen accompany this article, based on these photographs and Vasile's meteor plot. The meteor may have been a Sagittarid (although its radiant would have been in Sagittarius, not Libra as we would expect in mid-April), or possibly a Virginid (from Area 8 found in the *JAS Meteor Section* survey of 1988–1992 [1]), but as the velocity was around 19°/s, this is probably too high for either source, so it may well have been a sporadic.

5. Conclusion

Despite the weather's attempts to hide what the meteors produced, our observers have once more helped ensure that it did not entirely succeed. My thanks as always go to the observers who have submitted data to the Section, whether as raw data, partly processed reports, or in letters. Please keep up the good work, and for the weather-battered British observers, remember it cannot last like this for ever!

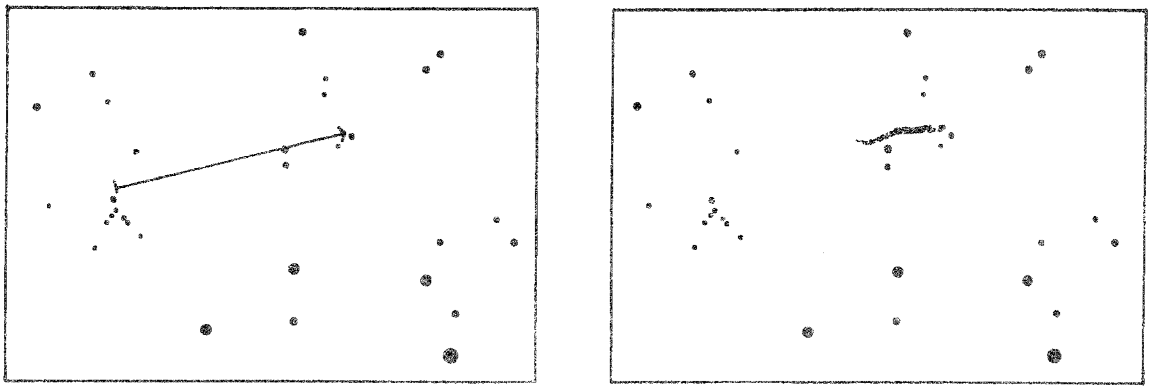

Figure 1 – *Left:* A sketch showing the meteor plot made by Vasile Micu of the −10 fireball observed at 21^h45^m UT on 1995 April 19. The meteor moved from Coma Berenices to Ursa Major. Leo is shown to the lower right of the drawing. *Right:* A sketch showing the most probable position of the train photographed by Vasile Micu, as seen about 10–20 seconds after the meteor appeared. Only the final flares on this meteor seem to have left a photographic train.

Reference

[1] A. McBeath, "UK Visual Results for the Virginids, 1988–1992", *WGN* 20:6, December 1992, pp. 226–237.

The 1995 Lyrids: Preliminary Results of the Dutch Meteor Society

Marco Langbroek

An impression and preliminary results are given of Lyrid observations by members of the *Dutch Meteor Society* (*DMS*). This year's Lyrid activity seems to have followed the standard behavior as given by [1] as far as our restricted sample allows conclusions. Peak rates probably occurred near $\lambda_\odot = 31.^\circ 8$ (1950.0). As in 1993 and 1994 [2,4], there is no evidence of enhanced activity during the interval $\lambda_\odot = 31.^\circ 27$–$31.^\circ 38$ (1950.0) in our data sample, the solar longitude window of recent historical Lyrid outbursts [2].

Weather conditions and weather predictions were the culprits which almost ruined our Lyrid campaign. Both were bad and changed rapidly. while the nights before April 20 suffered from cloud cover and interfering moonlight, hopes of most observers were high for the weekend of April 22-23. Theoretical maximum had been predicted to occur near local midnight of April 22-23 [1,3], extremely favorable. Weather predictions for April 21-22 and 22-23 changed rapidly however, and with continuous grey cloud covers after April 20 chances for a successful observational campaign seemed to become increasingly small.

The day of April 22 seemed like the worst nightmare of every observer: though it started with a short sunny period during the morning, soon a thick cloud cover developed and in the early evening the desperate observers were facing a drizzling rain! Weather officials spoke of a stable cold front which had come to a halt just above our country, and were very doubtful about the chance that it would disappear soon. Around 21^h local time, the campaign for that night was cancelled...

This decision turned out to be our big mistake. Around midnight, a miracle happened. While weather reports in Belgium and the Netherlands still prominently featured clouds, rain and sombre talk about stable cold fronts lingering around, not willing to pass by, in reality the cold front had begun to move and clouds disappeared.

When I woke up around 23^h45^m UT (1^h45^m a.m. local time), the sky was completely free of clouds and stars shone brightly. Not withstanding a little haze, the limiting magnitude was near +6.1, which is quite good given the urban area Voorschoten is situated in. With a growl, I cursed the weather officials and wished them to spend the rest of their worthless lives on a far, merciless island. It was too late to leave for our dark observing site at Biddinghuizen, which is a pity, since the interfering city light at Voorschoten prevents some of the fainter meteors to be seen. The night was gentle, however, and the Lyrids as well as the sporadic background were putting on a fine show. The stream was pretty active and it soon became clear that we were indeed observing right at the annual maximum. Lyrids appeared at a rate of about eight specimens an hour. Again, I noticed that showers with medium-fast meteors are much more impressive than showers with very fast meteors, even if they have a far lower level of activity. Each meteor takes long enough to have its own character. Eventually, 2.43 hours of effective observing time between 0^h00^m and 2^h30^m UT resulted in 40 meteors: 22 Lyrids, 16 sporadics, one μ-Virginid, and one α-Bootid (appearing as a point meteor at the radiant).

I was not the only one who noticed the change in weather conditions. At Varsseveld, Hans Betlem and ten of his pupils had, as usual, established an observing camp. While most of them were already asleep, Hans Betlem and Guus Docters van Leeuwen noticed the weather change during a last check of the sky and woke up the others. They have been active from about 23^h UT, both visually and photographically. At De Bilt, Casper ter Kuile noticed the clearing sky too and tried hastily to start up photographic activities, which failed due to the interfering city light. At Harderwijk, Koen Miskotte unfortunately slept through all of it: his alarm clock did not work properly. He got his revenge however two days later, during the night of April 24-25, when he observed 9 Lyrids during 3.8 hours with limiting magnitudes near +6.2.

On the other side of the world, events followed more or less the same kind of pattern. Peter Jenniskens had left for the island of Hawaii with a visual/photographic campaign with some friends in mind, but had to face cloudy skies for many days, and only part of the night of April 22 proved to be clear. He and John Swatek managed to observe several Lyrids from 12^h until 15^h UT, however. Their observations are important, because they covered the solar longitude window in which a possible enhanced activity [2] could occur. It did not, as far as we can judge from their observations.

Figure 1 shows a preliminary activity curve derived from observations by Peter Jenniskens (black dots), Koen Miskotte (black squares), John Swatek (downward pointing triangles), and the author (upward pointing triangles), complemented with observations by Hendrik Vandenbruaene (*VVS Meteor Section*, Belgium [5], open circles). The ZHR has been plotted on a singly-logarithmic scale [1]. Still missing in this picture are the observations by the team at Varsseveld, which still have to be reduced. ZHR values have been calculated following the procedure outlined in [1], with $\gamma = 1.4$ in radiant altitude correction and a population index of 2.7 (after [1]: the magnitude distributions of Peter Jenniskens and the author result in population index values of 2.7 an 2.6 respectively using the probability function in [1]). Observations with radiant altitudes below 20° have been rejected.

As far as conclusions are possible with this limited sample of data, the 1995 Lyrid activity seems to have followed the standard activity curve given by Jenniskens [1], represented by a dashed line in Figure 1. Maximum seems to have occurred near $\lambda_\odot = 31.^\circ8$ (1950.0), night time for western Europe indeed, agreeing well with the solar longitude Jenniskens [1] gives $\lambda_\odot = 31.^\circ7 \pm 0.^\circ3$. There is no evidence for enhanced activity during the interval of $\lambda_\odot = 31.^\circ27$–$31.^\circ39$ (1950.0), the solar longitude window in which Lyrid outbursts have occurred in 1803, 1922, 1945, and 1982 [2]. Since no outbursts were observed in 1994 [2] and 1993 [4] either, it seems that the period of about 12 years in which the outbursts in recent history can be placed is not a strict rule.

The visual campaign can be characterized as "moderately successful," despite all difficulties. The photographic campaign was less successful: though a handful of Lyrids have been photographed from the Netherlands and from Hawaii, none proved to be simultaneously recorded, alas.

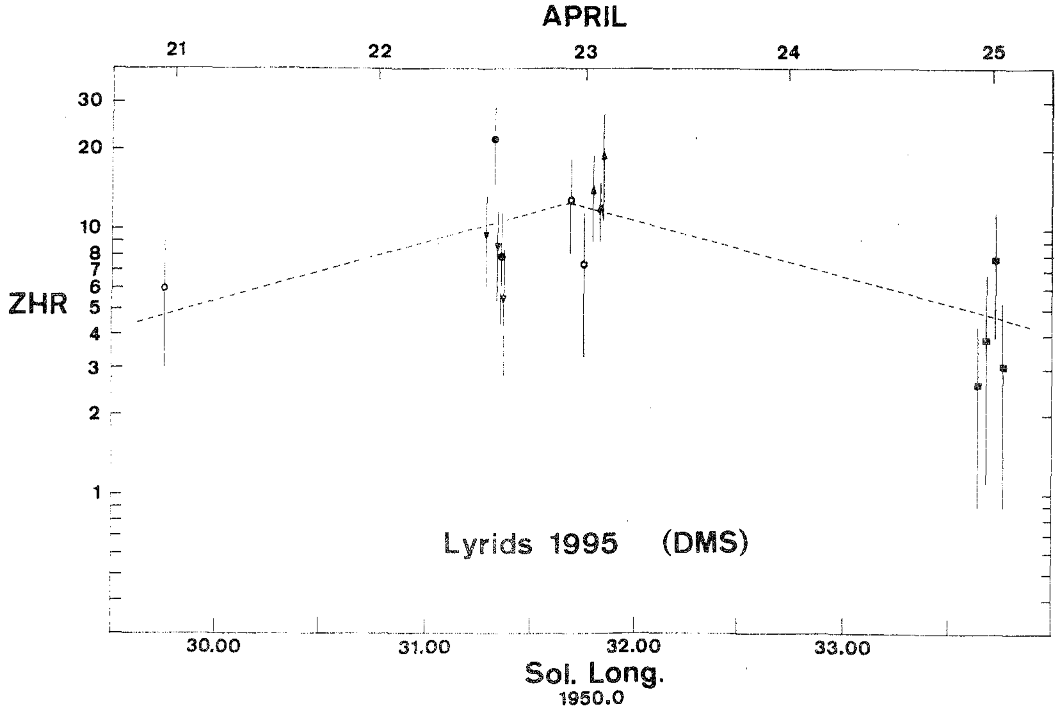

Figure 1 – Activity profile of the 1995 Lyrids.

Acknowledgments

I thank Hendrik Vandenbruaene (*VVS Meteor Section*, Belgium), Peter Jenniskens, John Swatek, and Koen Miskotte for communicating their observations.

References

[1] Jenniskens P., "Meteor Stream Activity I. The Annual Streams", *Astron. Astroph.* 287, 1994, pp. 990–1013.

[2] Jenniskens P., "Meteor Stream Activity II. Meteor Outbursts", *Astron. Astroph.* 295, 1995, pp. 206–235.

[3] Langbroek M., "Zwermenoverzicht 1995", *Radiant* 17, 1995, pp. 31–36.

[4] Jenniskens P., *personal communications*, 1995.

[5] Vandenbruaene H., *personal communications*, 1995.

[6] Miskotte K., *personal communications*, 1995.

The Tale of Two Mad Meteor Hunters

Marco Langbroek

Hunting for rare meteors can be an enjoyable pastime. For latitudes as far north as the Netherlands ($\varphi = 52°$ N), η-Aquarids are such meteors. The radiant rises only ten minutes before the start of astronomical twilight. Still, some Dutch observers are mad enough to hunt for stream members deep in twilight.

It is a gentle night early May. The calm pleasant sound of frogs is filling the air. The Dutch meadows are covered by a hazy blanket of humid air. Dawn is already in progress, and, one by one, the stars disappear in a soft blue turquoise sky. A last meteor appears from the east, arching a long trail across the brightening sky. It is accompanied by a savaged groan of excitement from the throat of a strange person, looking at the sky from a flat chair, wrapped up in a sleeping bag. This is the Mad Meteor Hunter, and the meteor is an η-Aquarid.

At southern latitudes, the η-Aquarids are the annual highlight for meteor observers. With an average ZHR of 36.7 ± 5.0 [1] the stream ranks fourth among all streams. Since Perseids and Quadrantids are as good as absent at southern latitudes and the Geminids are not too well-observable (summer in the southern hemisphere and thus short nights), this is the only well-observable major stream for them. At a first glance, the location of the radiant seems not too disadvantaged for observers at northern latitudes. With a declination of -1° and a right ascension of 338° (1950.0) [1] at maximum, the radiant has a more northern location than, for example, the δ-Aquarids and α-Capricornids. However, at latitudes as far north as the Netherlands ($\varphi = 52^\circ$ N), nights are already short early May and the radiant rises late and therefore stays extremely low. For Utrecht at the center of the Netherlands (a small country with dimensions of only 200 by 300 km), the radiant rises at 1^h08^m UT. Astronomical twilight already starts ten minutes later. At that moment, the radiant altitude is still below 10°. As seen from the Netherlands, activity is therefore restricted to one, incidentally two (and often zero...) meteors each night, during a short period of two or three days around maximum activity and deep in morning twilight. For Dutch observers, η-Aquarids are therefore extremely rare meteors indeed.

Still, a few observers are mad enough to think it is good sports to hunt for such a rare specimen deep in twilight. Peter Jenniskens tried so until 3^h00^m UT during the morning of May 5, 1989 but, alas, in vain. Koen Miskotte also tried in vain in 1993. This year, he and the author (observing locations Harderwijk, $\varphi = 52^\circ20'$ N, $\lambda = 5^\circ38'$ E, and Voorschoten, $\varphi = 51^\circ07'$ N, $\lambda = 4^\circ28'$ E) were more successful. Both observers completed a session on η-Lyrids (meteors of 1983 comet IRAS-Araki-Alcock) by turning their attention to η-Aquarids at the end of the nights of May 4-5 (Koen Miskotte) and 6-7 (Koen Miskotte and Marco Langbroek). Observations were extended until deep in twilight (until about 2^h15^m UT for Koen Miskotte and 2^h45^m UT for the author). This resulted in four observed stream members, given in Table 1.

Table 1 – This table presents some data of the η-Aquarids observed by Dutch observers on the nights of May 4-5 and 6-7, 1995.

Observer	DMS-code	Date	UT	Magnitude	$h_{\rm rad}$
Koen Miskotte	KMH	May 4-5	01^h50^m	+2	5°
Koen Miskotte	KMH	May 4-5	02^h08^m	+4	8°
Marco Langbroek	MLV	May 6-7	01^h26^m	+3	2°
Koen Miskotte	KMH	May 6-7	02^h12^m	+3.5	9°

Figure 1 shows the observed meteor trails plotted on a gnomonic chart [3]. All meteors were observed in a sky area at large distance from the radiant. Still, when elongated backwards, the trails intersect very close to the radiant positions at the given dates [1] (see Figure 2: zenith attraction is to be neglected with such fast meteors), Koen Miskotte's meteor of May 5, 1^h50^m UT, being the most deviant one. His meteor of May 7 may seem rather short for a meteor at such a large distance from the radiant, but the meteor in question was quite faint (+3.5) and twilight already strong, so he might only have seen the brightest part of the meteor. His meteor of May 5, 1^h50^m UT, left a persistent train of about one second. Note the meteor of Marco Langbroek on May 7, which was observed while radiant altitude was only 2°!

To our knowledge, these are the first η-Aquarid meteors observed from the Netherlands since observations by Rudolf Veltman in 1982 [2]. While hunting such extremely rare meteors deep in twilight might seem useless (and indeed for determining activity curves it is), in fact it is big fun and exciting and you feel deeply satisfied when you manage to observe one. Next year, morning twilights of early May will again be haunted by the two Mad Meteor Hunters.

Acknowledgment

I thank Michiel van Vliet for information on early May observations in the *DMS* visual archive.

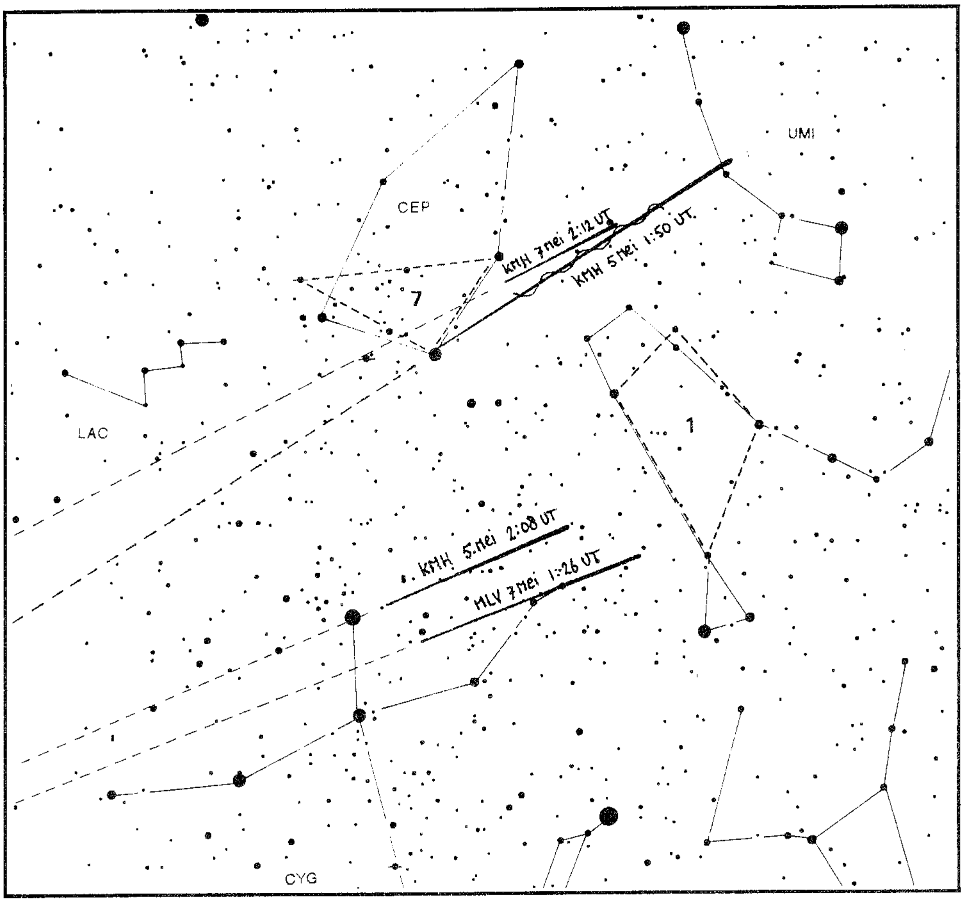

Figure 1 – Observed η-Aquarids.

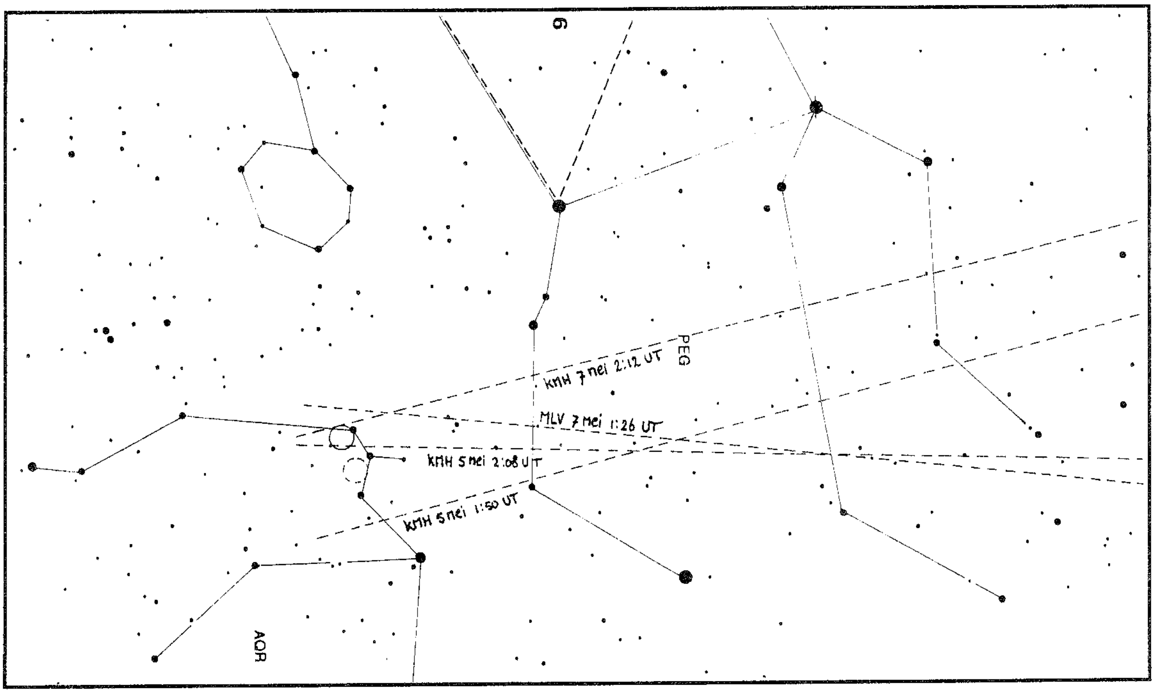

Figure 2 – Intersections of backward prolongations of the meteors in Figure 1.

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SPA Meteor Section Results: May and June, 1995

Alastair McBeath

A brief compilation of results provided to the *SPA Meteor Section* from May and June is given. The chief highlights were two bright fireballs, one seen primarily from sites around the Firth of Tay in Scotland on May 21, the other from North Island New Zealand on May 25, and quite a well-seen return of the η-Aquarids earlier in May. Some further news on a fireball observed over South Africa on 1994 September 14 is also given.

1. Introduction

Both May and June were reasonably successful months in 1995, largely thanks to support from observers not beset by British clouds and all-night twilight from late May onwards, in various parts of the world. Table 1 details the observing tallies thus far reported to the *SPA Meteor Section*.

Table 1 – Visual and photographic hours' totals and meteor numbers recorded in each month, including a partial breakdown of meteor types and numbers of photographed meteor trails notified so far.

Month	Visual	Vir	Sag	η-Aqr	Meteors	Photographic	Trails
May	$143^{h}35$	13	80	112	658	$138^{h}59$	1
June	$127^{h}07$	–	90	–	546	$113^{h}85$	0

Virtually all the photography was again carried out by members of the German *Arbeitskreis Meteore* (*AKM*) group, contributing to the European Fireball Network, although Vasile Micu in Romania also performed a small amount of camera-work too. The main visual observers were from the *AKM* and Graham Wolf in New Zealand, but the list also includes Vasile Micu in Romania, Tim Cooper in South Africa, and Martin Plater, Shelagh Godwin, and Alastair McBeath in Britain.

In addition to the recent data, Tim Cooper, leader of the *South African Astronomical Society's Comet and Meteor Section*, has sent in a report on South-African observations during 1994. In total, 34.6 visual hours of watching were carried out by four observers, the bulk by Tim himself, and some useful data was collected, especially on the η-Aquarids, indicating a main peak around May 4, 1994 (ZHR around 25–30). Several other minor showers were observed too, including the Aquarids and Capricornids of July–August, and one observer recorded Pegasid activity comparable to the sporadics on July 11, 1994, in a +6.0 limiting magnitude sky. Tim also provided some further news on a fireball noted in [1], details of which follow.

2. Fireball on September 14, 1994

Occasional bright meteor reports reach the news media, and one such event occurred in September 1994, when the BBC radio news mentioned a bright fireball over South Africa. Details submitted to Tim Cooper indicated that the object appeared at $19^{h}13^{m}$ UT on September 14, 1994, with a flight lasting over two minutes. Between five and seven lights were seen, whose combined brightness was like the Full Moon (magnitude about −14). They traveled north to south, leaving a faint trail after them, but no sounds were heard, and it seems likely the event was a satellite re-entry. The flight time alone makes it highly unlikely that this was a natural meteor.

3. May

Britain never enjoys good conditions for covering May's major shower, the η-Aquarids, since the shower radiant rises barely an hour or two before dawn, and with increasing twilight as May progresses too, lucky observers might spot one or two swift, long-pathed events in a really fine year. Shelagh Godwin was the fortunate one this year, spotting one η-Aquarid on May 4-5. Elsewhere, others were better-placed, including Vasile Micu in Romania (6 shower meteors in early May), but the most useful data came from Jürgen Rendtel and Rainer Arlt in California, USA, Graham Wolf in New Zealand, and Tim Cooper's observers in South Africa. Combined data from California and Spain were published in [2], suggesting that a peak ZHR of 50-60 occurred late in the first week of May, a result supported by data from elsewhere, although η-Aquarid activity was easily detectable by those at suitable locations through until mid-May, and was probably above 15–20, right from almost the start of May.

Two brilliant fireballs also happened near the end of May, one over Scotland, the other over New Zealand. The Scottish event took place at $0^h00^m33^s$ (as recorded by a police surveillance video unit) on May 21, 1995, and probably reached magnitude -10 to -14 or so. Brian Kelly, the *BAA Meteor Section*'s Northern Network coordinator, provided a summary of the eleven sightings that were reported to him, most of which were concentrated around the Firth of Tay, a major sea inlet roughly 1/4 of the way north along the eastern coast of Scotland, although one sighting from the north coast of the Scottish mainland was also received. Unfortunately, the sightings are all from one side of the track, and thus it is difficult to pin down the object's flight at all precisely, but it is probable it moved on a south-south-east to north-north-west line, mostly over the North Sea and Moray Firth, but possibly cutting across the land areas of Grampian and Caithness in north-east Scotland too. Any meteorites would most likely have fallen into the sea off the northern Scottish coast. The object was seen to leave sparks or fragments as it flew by, but there is no consensus on the meteor's color, which ranges from white to red, blue, orange, or green; five observers described it as being blue or green.

On May 25 at 6^h38^m UT, another major fireball fell, this time over North Island New Zealand, and people from twelve sites reported details on it. Graham Wolf, as Director of the *New Zealand Fireball Network*, has provided an abbreviated summary of the sightings, which suggest the meteor reached magnitude -10 to -12 at best, and was generally noted as being blue or white in color. It left a persistent train for some 10–20 seconds, according to most witnesses, and was very slow-moving, with a visible flight duration of around 3–5 seconds.

4. June

June usually produces some of the year's lowest meteor rates, with most shower activity confined to the Sagittarid complex of streams, and certainly observers were not "disappointed" in this respect from data sent to the *SPA Meteor Section*. The bulk of the data submitted came from *AKM* watchers and Graham Wolf, although Martin Plater in Britain also made several short watches on numerous nights in an attempt to beat the all-night twilight that makes noctilucent clouds so easy to see from the UK during the northern hemisphere's summer. Typically, most meteors were sporadics, and the various potential substreams within the Sagittarid complex proved as elusive to pin down as normal, even for our southern hemisphere watchers.

5. Conclusion

The curious near-coincidence in dates for the two bright May fireballs almost diametrically opposed to one another on the surface of the globe and the η-Aquarids helped enliven what can be a relatively quiet time of year for meteor astronomy in 1995. As usual, I wish to express my gratitude to all the observers and correspondents who have helped produce this report, and to wish you all every success in your observing. Clear skies!

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The "New" Peak of the Perseids Is Very Broad

Eisse Pieter Bus

Analysis of radio observations of forward-scattered radio waves at a frequency of 66.89 MHz shows that the "new" peak of the 1994 and 1995 Perseids is very broad and shows periods of lower and higher activity. Probably there are two main peaks. The first peak occurred at $\lambda_\odot = 139\overset{\circ}{.}49$ (equinox 2000.0), almost at the same longitude as visually observed in 1993 and has his origin probably in 1862. The second peak is broad and has periods of lower and higher activity with the highest Perseid rates at $\lambda_\odot = 139\overset{\circ}{.}58$, $139\overset{\circ}{.}64$ and $139\overset{\circ}{.}69$. This second peak has probably not its origin in 1862 but maybe in 1737 and earlier. Bearing in mind that sometimes some of the peaks were missed because of bad observing circumstances (daylight, twilight, radiant low in the sky, moonlight, etc.), all the peaks are probably active since 1993 or even earlier.

1. The equipment

Meteors were detected by receiving forward-scattered VHF radio waves at a frequency of 66.89 MHz. The receiver used was a Bearcat UBC 177XLT scanning radio with a RF sensitivity of 0.3 microvolts for a signal to noise ratio of 12dB and an IF selectivity of 50dB at approximately 25 kHz. The transmitter is located in Krakow, Poland, and the receiver in Groningen, the Netherlands. The path length between the two sites is 1001 km. A three-element Yagi antenna with folded dipole was used at the receiving station. The antenna was directed at an azimuth of 106° (ESE) and elevated at an angle of 9° to the horizontal, directing the main lobe towards the 100 km level, vertically above the mid-point of the transmitter-receiver path. Because the long distance between the transmitter and the receiver, there is no aircraft interference. There is no noticeable interference from other sources like other nearby transmitters or lightning. Sometimes, interference was caused by Sporadic-E, aurora, atmospheric inversion, or nearby computers, but these interferences were easily recognizable.

2. Observational data

"Sporadic" activity was observed by listening and counting in 5-minute intervals in the period July 14–August 7, 1995. For each hour, the sporadic activity was monitored on at least eight different days. The mean of this background level is shown in Figure 1, together with one-sigma error bars. In the same figure the total amount of meteors per hour is given as observed on August 11, 12, 13, and 14, 1995. The numbers are corrected for "dead-time." Dead-time is caused by a certain signal of amplitude that may mask other signals which are of lesser amplitude. The dead-time corrections were applied according to the "Geiger counter method."

3. The normalized observability function

The theory of the variation in the number of shower meteors observed by forward-scattering of radio waves is developed by Hines [1]. In his publication, an expression was derived for the number of shower meteors counted in a given observation period for a given meteor radiant position at the mid-point of transmitter-receiver path lengths over 1000 km. The calculated values of this "observability function" for the radiant of the Perseids were normalized to a value for the given observation period.

The normalized observability function for the apparent Perseid radiant on August 12, 1995, calculated for the mid-point of the given transmitter-receiver path, is plotted in Figure 2.

4. The Perseid rates

The net values of the Perseid meteors were calculated by subtracting the mean "sporadic" meteor counts as observed in the period between July 14 and August 7, 1995. For each period, this net shower count was divided by the value of the normalized observability function to obtain the estimated true Perseid activity. These values are plotted in Figure 3 with their one-sigma errors with the errors of the sporadic activity taken into account. It shows that the new peak is broad and was already active on August 12 at the beginning of the observation period.

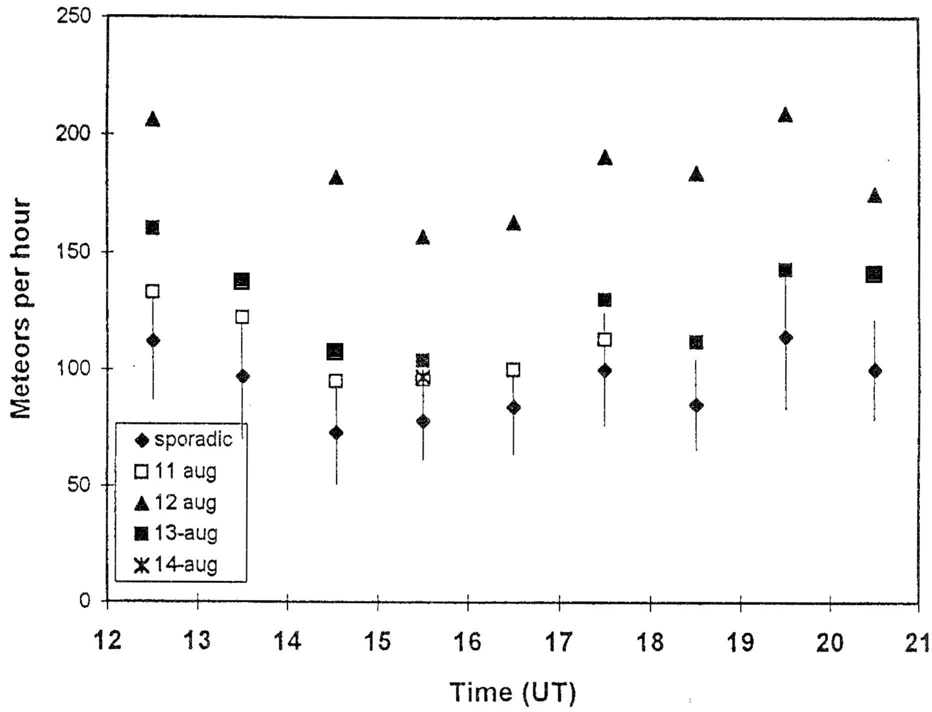

Figure 1 – Raw hourly radio meteor rates as recorded on August 11, 12, 13, and 14, 1995. Also, the mean sporadic activity is given as recorded between July 14 and August 7, 1995. The bars represent one-sigma errors.

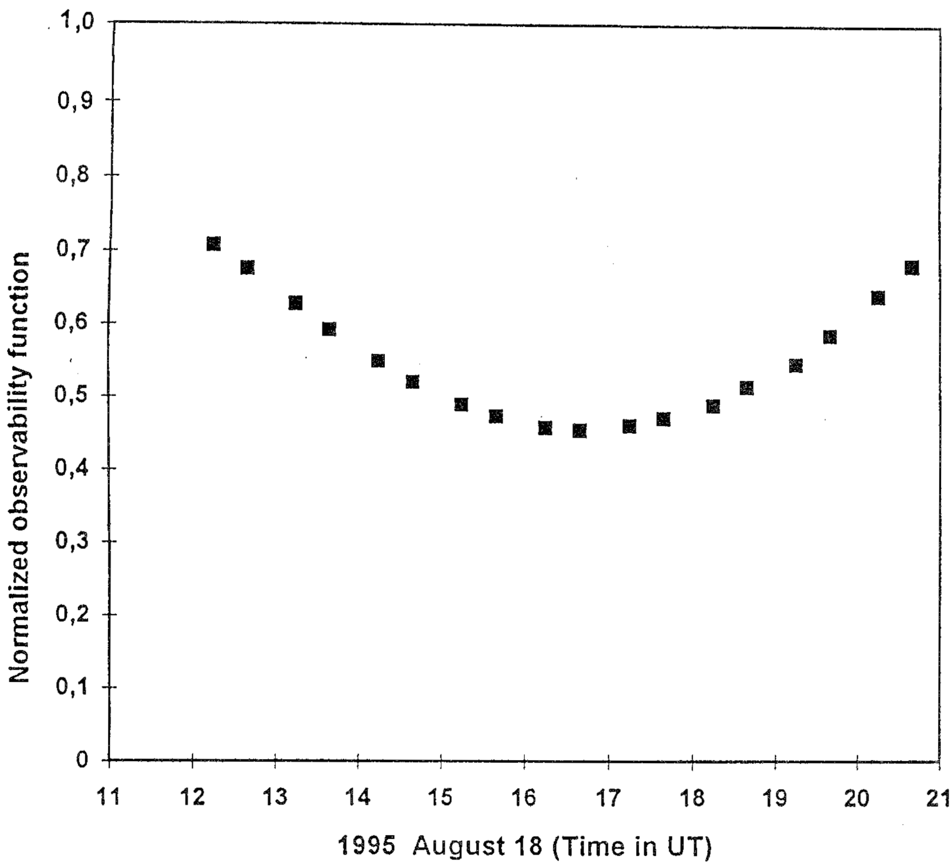

Figure 2 – The normalized observability function for the apparent Perseid radiant on August 12, 1995, calculated for the mid-point of the transmitter-receiver path.

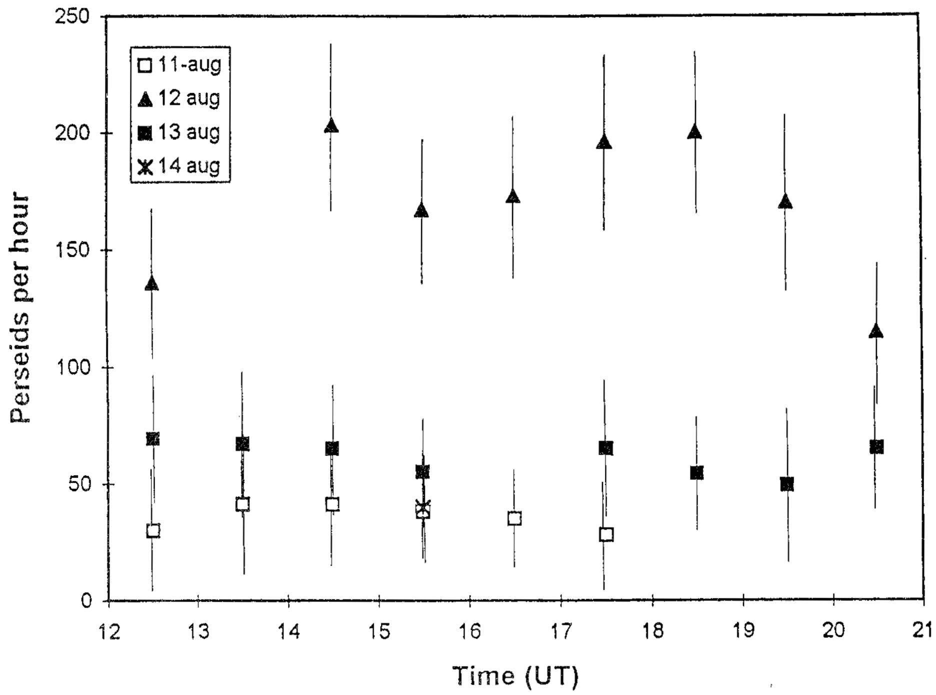

Figure 3 – Hourly Perseid radio rates on August 11, 12, 13, and 14, 1995, corrected for dead-time, sporadics, and observability function. The bars are one-sigma errors with the errors of sporadic activity taken into account.

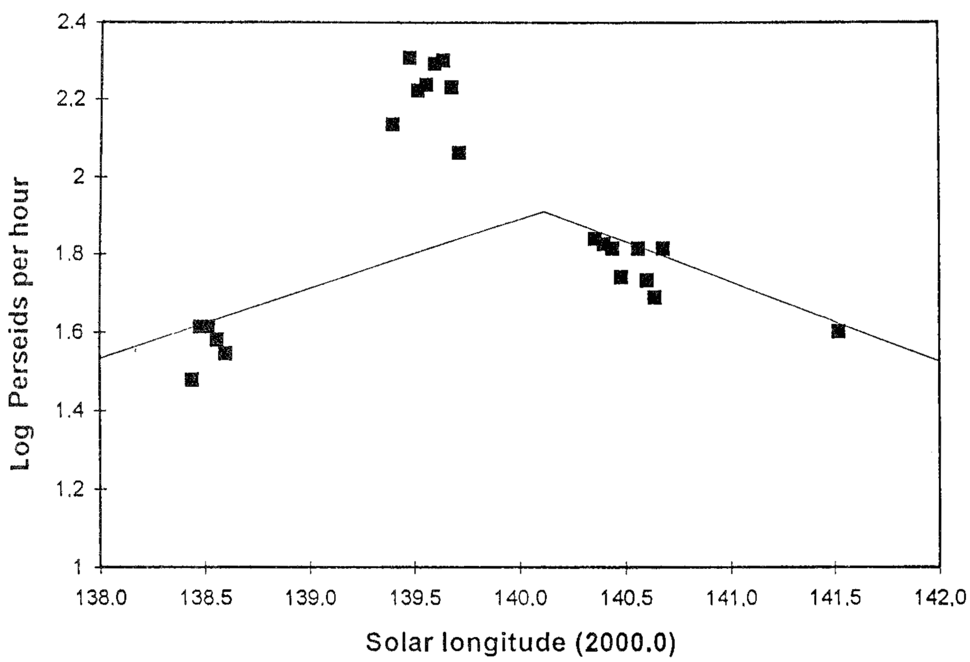

Figure 4 – Corrected Radio Hourly Rates of the 1995 Perseids. The high "new" peak is clearly present. Note that the "old" peak is not observed because of bad antenna geometry for detecting Perseids in the period the "old" peak was active. The drawn line gives the theoretical annual visual activity of the Perseids after [2]. Solar longitudes refer to equinox 2000.0.

Note that on August 12 between 13^{h} and 14^{h} UT no observations are plotted because of some atmospheric interferences. Figure 4 shows the corrected Hourly Radio Rates of the Perseids. The line gives the theoretical annual visual activity of the Perseids after Jenniskens [2].

The theoretical visual limiting magnitude for radio meteors at a frequency of 70 MHz is about magnitude 4.5 for Perseids [3]. By simultaneous observations in Puimichel, France, in 1994, visually by Paul Roggemans and by radio by the author, a limiting magnitude of 4.3 was found. In Figure 4, the "old" peak is not present, because of bad antenna geometry at the moment the "old" peak was active.

5. The "new" peak shows periods of higher and lower activity

Using 5-, 10-, 20-, or 30-minute intervals of meteor counts in the observing period shows four peaks of high activity in the Perseid rates. The solar longitudes for the four peaks are $\lambda_\odot = 139^\circ\!.49$, $139^\circ\!.58$, $139^\circ\!.64$, and $139^\circ\!.69$ (2000.0). Probably, there are two peaks, the first at $\lambda_\odot = 139^\circ\!.49$ and the second, very broad, around $\lambda_\odot = 139^\circ\!.64$. The second one is split up into periods of lower and higher activity. Figure 5 show the data for 30-minute intervals.

This result confirms the 1994 radio observations of the Perseids at a frequency of 72.11 MHz with a folded dipole antenna directed at NE at Puimichel. In 1994, the first peak had a maximum at solar Longitude $\lambda_\odot = 139^\circ\!.49$ and the second at $\lambda_\odot = 139^\circ\!.60$.

Ton Schoenmaker at Roden, the Netherlands, observed the Perseids in 1994 on a frequency 144.965 MHz with a 10-elements Yagi-antenna directed at NW. His first peak occurred before solar longitude $\lambda_\odot = 139^\circ\!.50$ and the second at $\lambda_\odot = 139^\circ\!.58$, and a possible third peak around $\lambda_\odot = 139^\circ\!.65$.

Wim Zanstra observed in 1995 at the "Jura-Sternwarte," Switzerland, on a frequency of 72.11 MHz with a 5-elements Yagi antenna directed at NE. Because his observation period was too short, he only observed the first peak at a solar longitude around $\lambda_\odot = 139^\circ\!.45$.

The observations of Schoenmaker and Zanstra are plotted in Figure 6. Both show also the double structure of the "new" peak and are in good agreement with the peaks in Figure 5.

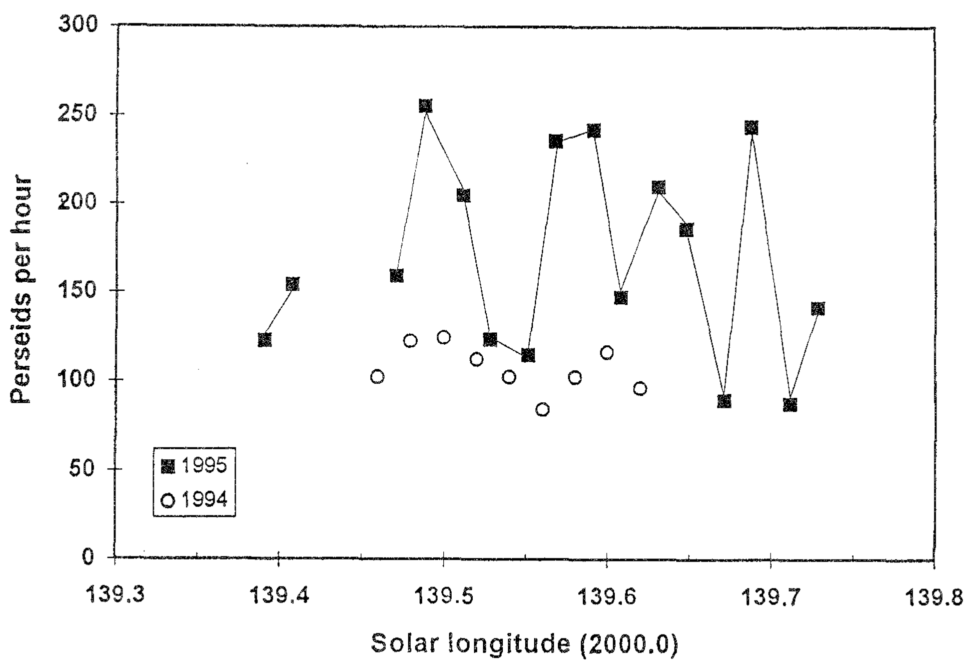

Figure 5 – The corrected counts for 30-minute periods show the observed peaks for the 1995 Perseids (filled squares) detected by receiving forward-scattered VHF radio waves at a frequency of 66.89 Mhz. The 1994 Perseids detected at a frequency of 77.11 MHz show two peaks (open circles). Solar longitudes refer to equinox 2000.0.

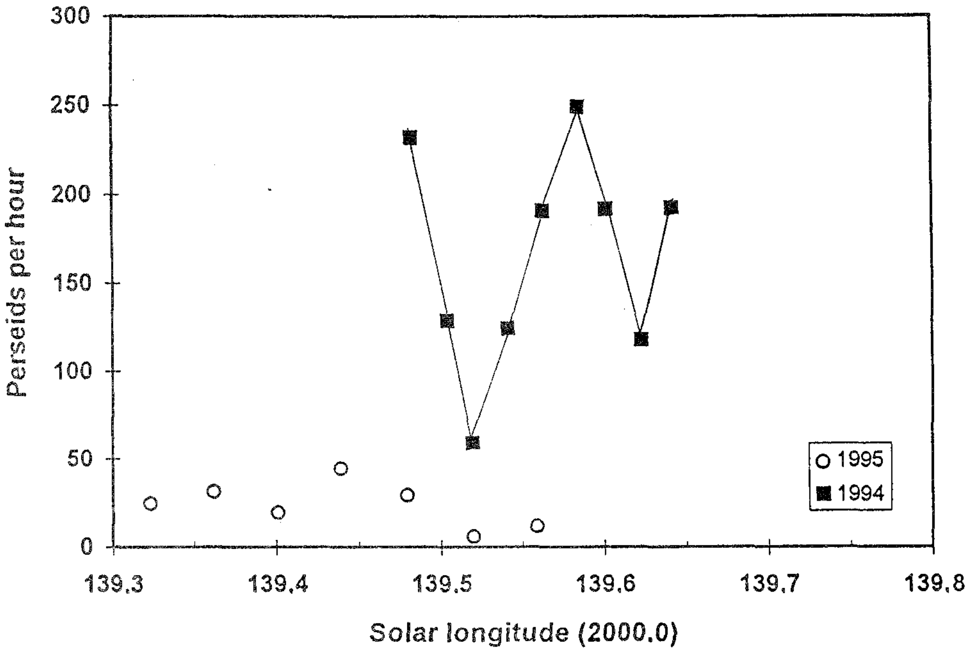

Figure 6 – The corrected counts for the 1994 Perseids as observed by Ton Schoenmaker (filled squares) and for the 1995 Perseids as observed by Wim Zanstra (open circles).

6. Conclusion

The "new" peak does not show a simple structure. It is complex with periods of higher and lower activity. Probably, there are two main peaks: a short one after the Earth has passed the point of the descending node of comet Swift-Tuttle and another one with lower and higher activity starting around $\lambda_\odot = 139\overset{\circ}{.}56$ (2000.0). The "new" peak is broad and is possibly already active around $\lambda_\odot = 139\overset{\circ}{.}3$, or even earlier. Bearing in mind that visual observation counts of shower meteors depends on observational circumstances such as twilight, moonlight, clouds, radiant elevation and above all, the global distribution of meteor observers mainly centered in Japan, Europe, and the USA [4], one of the peaks could have been missed easily. It is interesting to note that the simulation model of the new peak by Williams and Wu [5] is in very good agreement with our observations of the first peak. This peak is about $0\overset{\circ}{.}1$ smaller than the second peak and it is on the right place. The second peak probably has its origin not in 1862, but maybe in 1737 or even earlier. Both peaks are probably active since 1993 or even earlier.

7. Future observational prospects of the peaks in the "new" peak

The first peak can been observed in Europe in the early evening of August 11, 1996, around 20^h45^m UT, the second around 23^h15^m UT with lower activity around 22^h00^m UT. Lower activity could also occur on August 12 around 0^h00 UT, higher activity around 0^h45^m UT, lower activity around 1^h15^m UT, and again higher activity around 2^h00^m UT.

Acknowledgments

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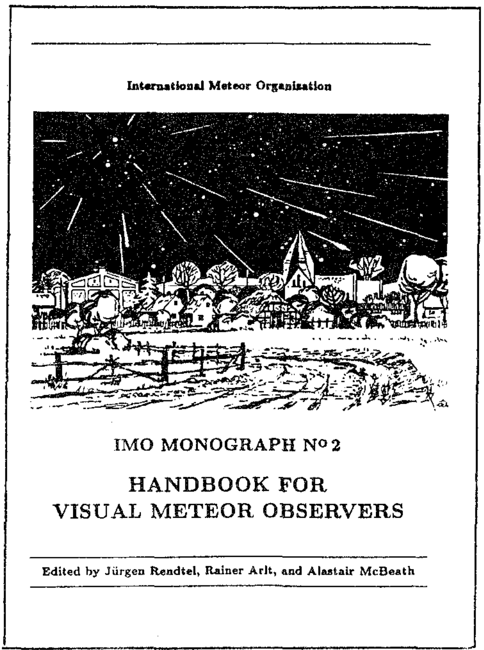

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