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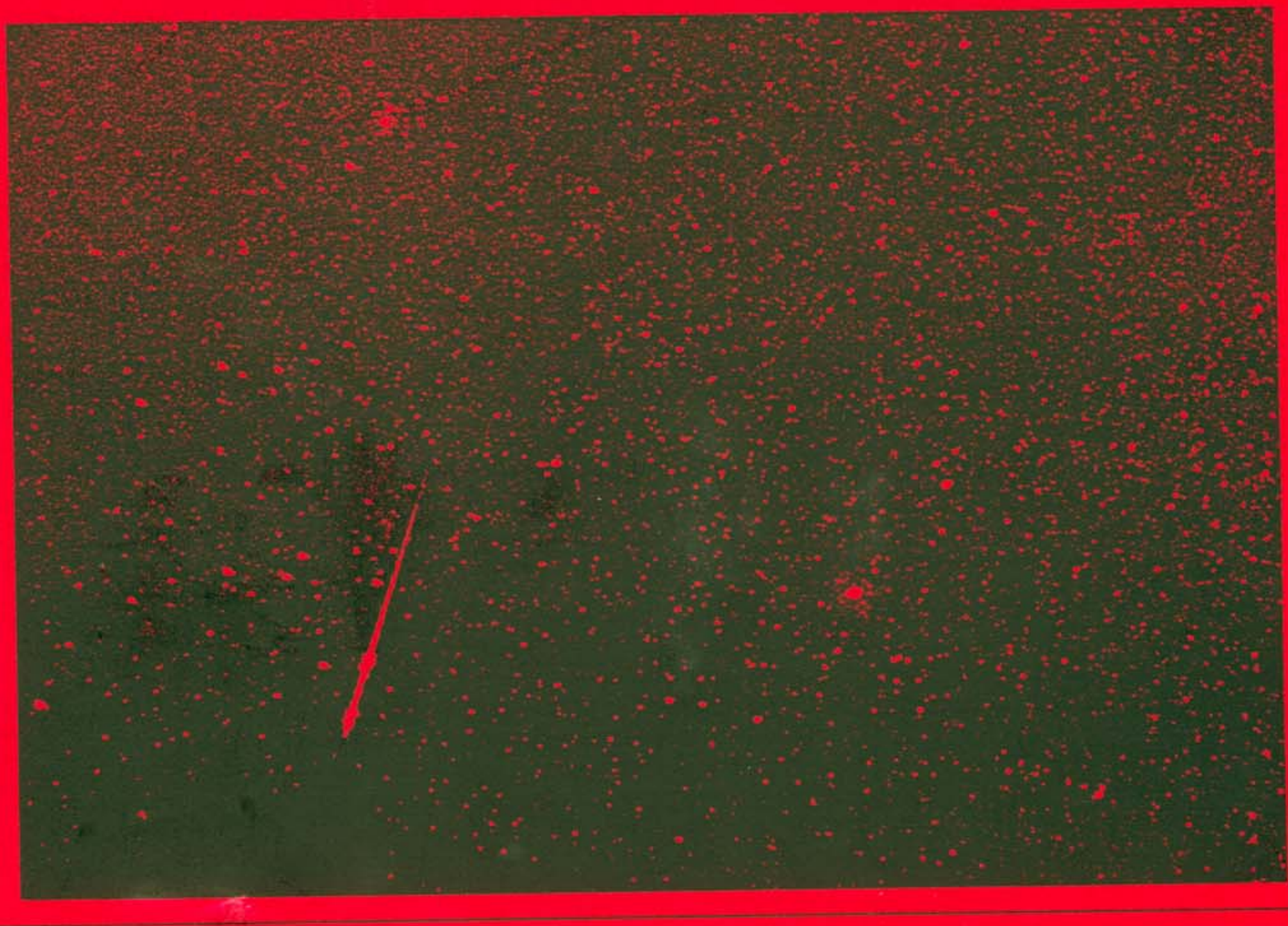

This sporadic meteor of magnitude −2 was photographed by George Zay from Descanso, California, on November 22, 1995, at $9^h15^m30^s$ UT, just a few hours after the outburst of the α-Monocerotid shower. The meteor appeared 6 minutes after the beginning of the 17-minute-exposure with an $f/2.8$, $f = 28$ mm lens on T-Max 3200 film. The bright star to the right is Procyon, and M 4 is clearly visible close to the top.

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

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Useful Information

The August Issue *(WGN 26:4)*

The *August issue* will be mailed around mid-August. Contributions are due on *July 28* at the latest. They should be sent to *Marc Gyssens*.

Administrative Correspondence

Ordering *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to *Ina Rendtel*.

All addresses can be found on the inside of the back cover.

From the Editor-in-Chief

Marc Gyssens

Even in this period, when meteor activity is generally low, when nights are very short, and when students have to spend most of their time in preparing for exams, we received quite a lot of publications, for we which we thank the authors. It means meteor work is alive and well, and people feel the urge to communicate their findings to their colleagues. Keep up the good work!

When the August issue will fall in your mailbox, chances are that the Perseid maximum has already passed. Despite the interference of the Moon, we hope that, this year too, we will receive a lot of observations, not only of the Perseids, of course, but of the entire period. As Rainer Arlt convincingly demonstrated in his analysis in the previous issue, the behavior of the various maxima in the Perseid activity pattern is still not well-understood, so we need more data on how activity will evolve as the parent comet moves farther and farther away from us.

I wish you many clear nights, and, meanwhile, enjoy this issue!

A Meteor Astronomy Workbook—A Piecemeal Approach

Godfrey Baldacchino and Alastair McBeath

Following the somewhat disappointing response to the suggestion that groups around the world might wish to contribute ideas to a *Meteor Astronomy Workbook* [1], an alternative strategy is proposed, encouraging groups and individual observers to participate in projects suggested here. An important aspect of this new approach is the production of follow-up reports for circulation and publication.

1. Introduction

The importance of commissioning a meteor astronomy workbook was more than amply explained by one of us in a previous issue of *WGN* [1]. The idea presented was to take up where the *Visual Handbook for Meteor Observers* [2] leaves off, providing meaningful explanations to standard observational procedures, and which could be used to vindicate some of the practices meteor observers go through in preparing for, executing, or analyzing meteor watches. Concurrently, the project is intended to provide opportunities for meteor groups scattered world-wide to deploy their human and intellectual resources towards providing scientific evidence to back up what have become global routines, thanks to the impact and extensive membership of the *IMO* over the last decade. The workbook, once complete, will be an important addition to the *IMO*-sponsored literature and should provide many interesting and varied suggestions for group activity around meteor astronomy for the myriad meteor groups active here and there.

The invitation, presented to *WGN* readers in February 1997, was to suggest project themes which they would themselves execute. The article was followed up by various e-mail messages by the author to individuals who appeared to have the credentials to serve as national co-ordinators for such a venture; yet, disappointingly, very few responses were received.

2. A new approach

A change of methodology was suggested following various exchanges of correspondence between the current authors. Perhaps it was too ambitious to expect meteor groups to come up with their own project suggestions; and a set of brainstorming letters enabled us to develop a set of 20 distinct meteor project proposals. We present this list below.

The list is by no means exhaustive, but it provides a clear and tangible indication of what we are after. We have broken down the different elements of what constitutes a "normal" meteor watch, and asked ourselves why things are done, and are expected to be done by the *IMO*, in the way that they are done.

The projects fall essentially into two categories [3]. In some cases, they are based on the confirmation of tried and tested proofs in meteor astronomy—but of course, it is always worthwhile testing whether the proof is repeatable in a consistent manner. Are sporadic meteors really distributed evenly around the sky? Is the correction factor for shower meteor radiant altitude really equivalent to simple trigonometry?

In other cases, the projects are more challenging, because no self-evident proof is available. These projects therefore require a serious and imaginative exploration of techniques and procedures to provide a result. For instance, how does a visual meteor observer actually scan a field of view? Do seasoned meteor observers have a larger standard deviation of recorded meteor magnitudes than inexperienced observers observing from the same site?

We would like to ask *WGN* readers—especially those involved with group observations of visual meteors—to volunteer by choosing one project and offer to make it their own. Projects can thus be "booked" and "reserved." We would ask you, if interested, to communicate your choice to us, to enable us to coordinate the efforts. In due course, we would like you to let us have a write-up of what you actually did, step by step, to "prove" the project. There are no set or fixed procedures, and we would emphasize the repeatability of the exercise: the simpler and the least costly, the better, and the more it depends on some form of cooperation by a group of amateur meteor watchers, better still. There will still be scope for people to suggest their own projects, distinct from those on the list, and we would welcome communications on this aspect too.

Providentially, we already have a prototype of a project write-up in a recent issue of *WGN*, where Mihaela Triglav partly tackled project proposal number 16 (see below) [4]. We hope Mihaela herself will be interested in checking and possibly confirming her very original, individual, observations with a Slovenian group in the more normal conditions of non-lunar eclipse. In addition, the Petnica Meteor Observing Group, many of whom will be familiar to those who attended the 1997 *IMC* there, have already expressed interest in tackling project proposal 17.

Finally, we consider that such write-ups, duly edited, would make excellent material to be considered for publication in *WGN*. The eventual *Meteor Workbook* would thus take shape gradually.

If we see that certain projects are not taken up, we may then take the initiative and communicate with a number of individuals who might take up the project challenge with a few words of encouragement on our part.

3. The proposed projects

The following are our 20 project proposals:

1. Recording one's stellar limiting magnitude using averted vision will achieve a different value than if one is recording it using direct vision. How much is the difference and which, if any, of the two techniques should one adopt in making a limiting magnitude estimate? [5]
2. Does a difference of one magnitude in the stellar limiting magnitude result in a reduction/increase of sporadic rates by an approximate factor of 3 (which is assumed in referring to a sporadic magnitude ratio of $r = 3$)?
3. Demonstrate whether, and how, sporadic meteor rates increase from the early evening to a maximum before dawn, under standard sky conditions during an average night.
4. Examine the following three effects of increasing observer experience in visual meteor watching: (*a*) the ability to see and record more meteors, particularly of a fainter magnitude; (*b*) to have a broader magnitude distribution, because of a better capability of assigning correct meteor magnitudes, rather than collapsing them into fewer, central, magnitude categories; and (*c*) to have reduced dead time per meteor.
5. What is a realistic measure for dead time during a visual observation, both in the case of plotting meteor trails and without plotting?
6. What is the size of a "normal" field of view for a visual meteor observer?
7. Are sporadics distributed evenly around the sky? Do they "cluster?"
8. How does an observer actually scan his/her field of view? Is there a tendency to spend more time looking/fixing one's gaze on brighter stars? Would most sporadics observed therefore tend to congregate around such bright stars?
9. How does one measure radiant altitude using simple hand-held tools and/or a simple computer program?
10. How does one measure a meteor's start and end heights from a triangulation exercise?
11. How does one measure a meteor's speed when photographic triangulation is accompanied by a rotating shutter? (As a corollary, what are the requirements for constructing a simple, inexpensive, but effective rotating shutter?)
12. How, and how quickly, does the human eye adapt to darkness? How does the eye's limiting magnitude change with time in the dark? (How do laboratory experiments differ from field tests in tackling this project?)
13. Can we prove that the provided correction factors for radiant altitude are correct? (This task may require collaboration by various observing teams, monitoring the same region of sky at the same time from different latitudes).
14. How can one create laboratory experiments to "prove" the radiant effect?
15. What is the effect of using a red filtered torch on one's limiting magnitude? What happens if the same person is subjected to the same torch without a red filter or with a filter of a different color?
16. What is the effect of moonlight on stellar limiting magnitude? Is it equal across the whole sky? What is the effect of moonlight originating from different lunar phases? (Can we eventually come up with a draft table of expected limiting magnitude extinctions linked to the time in the lunar cycle?)

17. What is the difference in the resulting stellar limiting magnitude determination if one uses the single faintest star method, rather than the *IMO* "area-count" method? (For the faintest-star LM method, see, for instance, [6]).
18. Tiredness/the onset of sleepiness/fatigue will have an effect on meteor rates. What effect?
19. How can one re-create and "explain" a random distribution (as in the case of sporadic meteors) in a laboratory setting (e.g., using Mikado sticks)?
20. How many meteors actually appear to be colored? Does color discrimination exist? (Comparison with reports of seeing color in stars might be undertaken.)

References and notes

[1] G. Baldacchino, "A Meteor Astronomy Workbook", *WGN* 25:1, February 1997, pp. 2–4.
[2] J. Rendtel, R. Arlt, A. McBeath (eds.), "Handbook for Visual Meteor Observers", IMO Monograph No. 2, 1995.
[3] We are grateful to Marc de Lignie for this consideration.
[4] M. Triglav, "Observing Meteors During Moonlight", *WGN* 26:1, February 1998, pp. 39-42.
[5] See, for example, S. Lanfranco, G. Baldacchino, "An Investigation of Limiting Magnitude Determination: A Pilot Study", *WGN* 23:3, June 1995, pp. 87–91.
[6] A. McBeath, "Visual Limiting Magnitude Determination Charts", *Journal of the Brit. Astron. Assoc.* 101:4, 1991, pp. 213–218.

Dark Meteor Database: News from 1996–98

Alastair McBeath

Information from the *Dark Meteor Database* collected during the eighteen months between October 1996 and March 1998 is presented. The proportion of all observers reporting dark meteors remains at about 70%. Two modern sightings of meteor tracks seen passing across the Moon with optical aid are also briefly discussed, along with a historical series of "dark meteor" sightings passing over the Moon's disc reported between 1896 and 1899. A possibly related "earthlight" phenomenon is also commented on.

1. Introduction

As eighteen months have now elapsed since the last update on the *Dark Meteor Database* [1], a fresh review of recent input to the database was felt desirable, which would also allow some further discussion of the topic. As was outlined in [1], the anonymity of all observers reporting dark meteor sightings is again here retained, and this courtesy is extended to all those other individuals who have troubled to contact the author with useful discussions and comments during the intervening period too.

2. Fresh observations

In addition to reports received by earlier correspondents, another three people have submitted dark meteor sightings for the first time. This brings the total number of observers to 39, 11 of whom provided confirmation that they had never knowingly seen a dark meteor (this number remains unchanged), and 28 reported seeing at least one dark meteor event. This increases the proportion of observers reporting positive sightings of dark meteors slightly, to 72%, an insignificant shift from the earlier 69%.

The objects reported remained much as previously described in [2]. One observer reporting two dark meteors also spotted a dark object passing over the skyglow from a nearby city on the same night. It was suggested this might have been an insect. The other dark meteors were well away from this skyglow region, however, and cannot be so easily accounted for.

Although not immediately recent, as the observation was made in the early 1980s, one potentially valuable report was received from an experienced observer. While carrying out a visual meteor watch with another equally experienced colleague at a good, dark-sky site, both observers simultaneously reported seeing the same dark meteor. Both were startled at the object's appearance, and a rapid comparison of experiences showed the object was the same. The location, conditions and time of year made a possible wildlife explanation most unlikely, especially as both were familiar with the appearance of the typical nocturnal flying animals of the locality through their previous observations. Their best description was as if the object had been an anti-meteor, radiating darkness instead of light. Most regrettably, their attempts to report this event were met with hostile criticism from a local "meteor authority," and the original observation notes were discarded as a result of this person's input. This is naturally exceedingly frustrating as we now try to seriously analyze this topic. It might well have helped demonstrate that at least some of the dark meteors do have an objective reality, beyond those that can be accounted for by various known natural creatures or phenomena.

However, it is encouraging that if one pair of observers can achieve this simultaneous sighting, eventually others might also manage to do so.

Naturally, any other observers who have—or have not—seen a dark meteor are encouraged to submit details of their observations to the project. Remember that negative sightings are equally important in order that the percentage of people who have seen such events remains a realistic one. We take this opportunity to again repeat the *Dark Meteor Report Form* with this article, which was previously published in [3].

3. Recent "dark meteors" crossing the Moon

Two sightings of dark meteor trails on the illuminated part of the lunar disc were also received as part of this project.

One was made on a TV monitor linked to a CCD camera attached to a telescope. The Moon was about three days old at the time, and the magnification used was such that only about 25% of the lunar crescent was on-screen at the time. A white light was seen to cross from one corner of the screen, over the illuminated crescent, to end before exiting the screen, on the darkened part of the Moon's disc. The object's speed was comparable with an average meteor velocity. Roughly one second after the object vanished, a dark, shadow-like trail appeared over the illuminated part of the lunar disc, along exactly the track the apparent meteor had taken. This lasted some 3–4 seconds before fading away completely. This darkened trail could be seen extending fractionally beyond the lunar disc, and also just onto the darkened region of the Moon too. The time delay and coloring make it unlikely this was some form of after-image created by the electronics, and it seems instead to have been a type of meteor train dense enough to partially block the light from the lunar crescent. This may simply have been a heat-wake, rather than a true ionization train, however, similar to the shadow effects seen when a light source is shone onto a white card through a candle flame. Such shadow structures, and the possibility of observing those due to meteors on daylight-illuminated clouds is discussed in [4].

The second observation was made visually, using a 6-cm reflector. The Moon was waning gibbous, about a day before Last Quarter. A meteor was seen crossing the Moon's disc, but appeared as a dark trace lasting about half a second as it passed over the illuminated part of the Moon. This appears to have been a different phenomenon to that noted above. Here, the actual meteor streak appeared darkened as it crossed over the lit lunar disc, which may be a contrast effect, or may perhaps have been due to the optical thickness of the meteor's trail being great enough to briefly block the Moon's light.

Neither observation was of a "genuine" dark meteor, but both sightings illustrate that there are meteoric effects which even experienced visual observers are unlikely to have seen before. As always, it is more important to report such events as accurately as possible, and not to dismiss them as "illusory" simply because they do not fit with our own personal paradigm of what events we will "allow" the universe to contain.

4. Historical "dark meteors" crossing the lunar disc

As discussed in [2], the observation of dark objects crossing the illuminated lunar disc was a topic that cropped up in the astronomical literature at various times from the 1890s into the 1920s. One series of notes, articles, and correspondence from the *Journal of the British Astronomical Association* (*JBAA*) between 1896 and 1899 has recently been brought to the author's attention, and of which a brief discussion of some points may usefully illustrate the typical tenor of such past "dark meteor" dealings.

The series begins in 1896 (*JBAA* 7:1, p. 27) with a short anonymous note concerning the observation of a round, dark object, with an apparent diameter "estimated at about one thirtieth of the apparent diameter of the Moon" moving across the lunar disc in about 3–4 s. A subsequent note in the next issue mentions that A.M. du C. Muller's "dark meteor" sightings were the first ever observed (as we discussed earlier in [2]).

The next year (*JBAA* 8:3, pp. 127–129), Frits Hopman prepared a short article, "On Dark Meteors," in which he commented on five observers who all claimed to have been the first observers of these lunar-crossing "cosmic meteors," which usefully republishes various parts of the five claimants' observations (and from which it is informative to see that this current series of notes was merely one of several such in different publications of the day). He goes on to discuss some possible explanations, including birds and *"particles of dust in the eye of the observer,"* but is able to discount these, and comes down very much in favor of the objects being extra-terrestrial objects. One item he mentions concerns a "dark meteor" crossing the Sun, which two observers viewed on a projected image, a curiosity certainly. His concluding paragraph suggests various reasons why these objects had only lately been seen, including *"that the meteors might belong to a swarm which the Earth had only recently captured and which was now rotating round her."* (a suggestion he cites to Th.E.J. Kramers of Schiedam). This is an interesting comment, and brings to mind the possibility that, if the objects were extra-terrestrial small asteroids, the timing between the earliest and latest reported observations (about 1892 to about 1920) would have the Tunguska event of 1908 at its approximate mid-point.

Hopman mentions in passing the statement attributed by Theophrastus to Anaxagoras that *"Lower than the Moon and between her and the Earth there are other dark bodies, which may also produce Moon eclipses."* This is another curiosity, and perhaps implies such *"swarms"* of asteroids may appear in the near-Earth vicinity at variable periods. Naturally, this assumes that such observations are not attributable to other causes.

After this, we find a letter by Edwin Holmes (*JBAA* 8:4, pp. 188–189) commenting on Hopman's paper (which he oddly refers to as being *"Mr. Hoffman's"*), a classic example of the schoolmasterly put-down/criticism letter so familiar to anyone who has come across those who cannot personally believe that some new phenomenon has been found.

Some of his points are worth making, such as the phases of the Moon at the times of the observations, and the physical parameters this implies, but his surprise at a cosmic velocity of perhaps 28 miles per second (approximately 45 km/s) is almost comical from a modern standpoint, while his final point that the apparent rotation possibly noticed by one observer in a "dark meteor" (an intriguing, but regrettably unattributed, observation in itself), was because the object was really an out-of-focus tumbler pigeon is still more amusing!

Having seen the discussion degenerate to this point, the final commentator in the series, T.W. Craven Jr. (*JBAA* 9:2, 1898–99, pp. 75–76), produces an explanation for his own observation of some "dark meteors" that appeared to curve in their tracks across the bright lunar disc, something not previously noticed. He identified these as being due to loose fragments of the black paint coating the inside of the eyepiece tube drifting through the field of view, which was a useful point to make.

Unfortunately, he then went on to use this as an explanation for some of the previous sightings referred to, for which this does not seem valid compared to his own experiences.

5. "Black" earthlights

Another correspondent made reference to a very brief mention of an unusual form of the so-called earthquake-lights, or "earthlights," which are normally glowing lights, somewhat like another unusual phenomenon, ball-lightning, seen in association with stressed quartz-rich rocks releasing some of their piezo-electric potential by various poorly understood mechanisms. These have been reported before earthquakes for some considerable time, but have only very recently started to be examined with any seriousness. They do not simply occur in connection with earthquakes, but it does seem that the crustal rocks need to be undergoing stress, as at a fault line, for example, to cause them.

The item in question [5] discusses earthlights with particular reference to the possibility they are responsible for many UFO sightings, and the experiences that are claimed to accompany such sightings, but does also provide some useful general information about the phenomenon, and is worth reading by those unfamiliar with it. The aspect of especial note is on p. 31: *"there are pitch-black objects sometime* [sic] *seen by day... which seem to be photon-absorbing instead of light-emitting. These bizarre phenomena... can be round, square, or irregular in form."* Although seen by day, these might perhaps be related to the dark meteors we are interested in here.

Regrettably, although the author of [5] mentioned there that he and a colleague of his had seen examples of these, on contacting him, it transpired that no record of the observations had been made, except for one poor-quality photograph, which he was unable to provide a copy of for examination.

Acknowledgments

I would like to thank all those people who have contacted me in recent times to discuss this phenomenon, whether with observations, suggested references, or comments on what dark meteors may actually be. It is clear there is a great deal of interest in this subject, so please do keep submitting your observations (or non-observations for those who have never witnessed a dark meteor) and ideas.

References

[1] A. McBeath, "Dark Meteor Database—Update", in *Proceedings 1996 IMC*, Apeldoorn, A. Knöfel, P. Roggemans (eds.), IMO, 1997, pp. 19–21.

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

[3] A. McBeath, "A Dark Meteor Database", *WGN* 24:1-2, February-April 1996, pp. 12–15.

[4] Y. Öhman, "On the possibility of observing reflection phenomena in meteor trails", in *Asteroids, Comets, Meteors III*, C.I. Lagerkvist, H. Rickman, B.A. Lindblad, M. Lindgren (eds.), Uppsala University Press, 1990, pp. 599–602.

[5] P. Devereux, "Everything You've Always Wanted to Know about Earth Lights", *Fortean Times* 103, October 1997, pp. 26-31.

IMO DARK METEOR SURVEY REPORT FORM

Once completed, please return this form to:
Alastair McBeath,
12A Prior's Walk, Morpeth,
Northumberland, NE61 2RF, England, U.K.

Date (yy/mm/dd):________ Name:________
Correspondence address:________
Site location (town, country): ________
Longitude:________ Latitude:________ Altitude:________
LM:________ Other sky conditions: ________

Please circle as appropriate to answer:
Observed during meteor watch? Yes No - if "Yes", please give watch start and end times:________

Your fatigue condition: very alert alert normal tired very tired

Were you observing in: glasses contact lenses neither

If you have never reported a dark meteor to this project before, please state:
Your age: ________
Any known eye defects:________
How many years have you been observing meteors for:________
Do you consider yourself a regular occasional casual novice observer?
(Please circle one answer only)

If you did not make this sighting visually, please state equipment used:

____

For each dark meteor, give its appearance time in UT, and describe what you saw:

____

____

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Ongoing Meteor Work

Can Visual Observers Accurately Estimate Meteor Rates in Meteor Storms?

An Approach Using Computer Simulations

Hartwig Lüthen and Sirko Molau

In order to evaluate the capability of meteor observers to correctly estimate high rates of meteor activity during meteor storms, we developed 3 types of computer-controlled self tests. These were then carried out by a number of *IMO* observers in Belgium, the Netherlands, and Germany. Analysis of the results indicates that observers can roughly estimate rates of several tens of meteors per second. It tentatively suggests that the reported high EZHR values during the 1966 meteor storm are realistic.

1. Introduction

On November 17, 1966, one of the greatest Leonid storms ever occurred [1,2]. A team of observers around D. Milon, placed on top of Kitt Peak, had a once-in-a-lifetime experience [3]. At the maximum of activity, they were unable to count individual meteors. Opening their eyes for 1-second intervals and trying to estimate the number of meteors visible, they reported peak activities of 40 meteors per second. Assuming a limiting magnitude of 7.0 (the *Gegenschein* was evident) and a population index of 2.5, this number corresponds to an EZHR (effective ZHR, we use the terminology of Rendtel and Arlt [4] to stress that the hourly rate is derived from time intervals much shorter than one hour) of about 100 000! This value may even be too conservative, since observers at high rates often fail to include faint meteors in their counts.

The reality of this enormous figure has recently been questioned by Jenniskens [5]. The jump in activity to the maximum present in Milon's data was not reflected in radar observations. Jenniskens concluded that the rate must have been in the range of $15\,000 \pm 3000$. This EZHR is nearly one order of magnitude below Milon's!

Langbroek summarized Jenniskens's arguments in a letter to *WGN* [6]. He additionally pointed out that *"it is a well-known phenomenon from psychological research that a normal human being is not able to oversee more than 5 items at an instance and record accurate numbers,"* and on that basis questioned all reports of 40 objects per second. Langbroek's letter triggered a vivid discussion in *Letters to WGN* participants of which re-iterated that (a) one will see a difference between 4 or 40 objects per second [7], and (b) one certainly cannot count more than 5 objects, but possibly quite accurately estimate a much larger number of objects [7–9]. However, no hard data were presented to confirm either side's claims.

The present paper is an attempt to put this discussion on a more quantitative basis. Computer-assisted self tests involving a number of *IMO* meteor observers as test persons were conducted to assess the accuracy of Milon's method. This approach allows an estimate how accurately EZHRs can be quantified visually during massive meteor storms. Results are analyzed and discussed in the present paper. We hope that our results can also be useful to define appropriate observing methods for possible meteor storms in the 1998-99 period.

2. Materials and methods

Streak test (ST)

Test persons, among them meteor observers of different experience, were shown a random number (0 to 50) of streaks, representing the "meteors" on a VGA computer screen for 1-second intervals. The test person then had to enter an estimated number of objects that had just been displayed. The experiments were performed in series of 10–30 estimates. Each observer submitted 2–10 series. In order to avoid training effects, the number of test objects was not displayed to the test person at any time during the tests. The computer stored the simulated (S) and estimated (E) numbers on disk in an ASCII file for further analysis.

Animated meteor test (AMT)

In order to overcome some of the shortcomings of ST, an "animated version" of the software was written. It displayed a random number (0–65) of moving pixels ("meteors") drifting across a field of 100 fixed pixels ("stars") in 1-second intervals. The program was written in a way to ensure a "meteor" velocity independent of computer speed or number of displayed "meteors," since the test software was locally run on different hardware by the individual test persons.

Realistic meteor simulation (RMS)

One of us (Sirko Molau) prepared a more elaborate version of the AMT with advanced features which come much closer to a meteor storm scenario:

- Meteors are displayed as streaks of light fading away to give them a realistic appearance.
- Individual stars and meteors differ in magnitude; for meteors, a population index can be set.
- Some meteors leave a persistent train glowing for some seconds.
- Meteors seem to emanate from a radiant.
- Radiant position and magnitude distribution can be varied.
- The simulation is continuous, and in contrast to AMT and ST, not interrupted after 1 second. Total rates for the test time interval were recorded and compared to the test-person's estimates.
- The number of meteors visible on the screen at a certain time is not constant but scatters around a pre-set value. This resulted in an apparent meteor clustering as often reported by visual observers. The sequence of meteors was determined from an exponential distribution function, to simulate a scenario in which there are no real meteoroid clusters, but a random meteoroid distribution in space. Cluster analysis of video meteors confirmed such a distribution of meteoroids and thus the absence of any real clustering [10].

The public domain program can be freely downloaded from *IMO*'s web site at

`ftp://ftp.imo.net/pub/software/metsim.`

3. Results

General Performance in ST

Figure 1, A, shows individual results of a number of observers from Potsdam in ST. The estimated number (E) is plotted as a function of the simulated number (S). Obviously the data cannot be approximated by a single linear fit. There are 3 distinct regions in the S-E plot:

1. At a number of $0 \leq S < 5$ streaks, observers could normally count the correct number of objects on the screen. We therefore refer to it below as "correct estimate range" (CER).
2. Above 5 "meteors," a significant scatter rapidly builds up, but test persons were still able to approximately estimate the number of streaks (the standard deviation was in the range of 13–30%). In the area $5 \leq S \leq 15$, the slope of the regression line slightly exceeded 1. We therefore refer to this area as the high-slope range (HSR).
3. At $20 \leq S < 60$ meteors, scatter increased with the meteor number, and the slope of the regression line was always below 1, in this case 0.68 (low-slope range, LSR).

Figure 1, B, shows the average relative error computed from many individual estimates as a function of S, which is of course 0 in CER. In HSR, the scatter rises to 15–20%, where it levels off in LSR. Thus at higher rates, the relative error appears to be practically independent of the simulated meteor number.

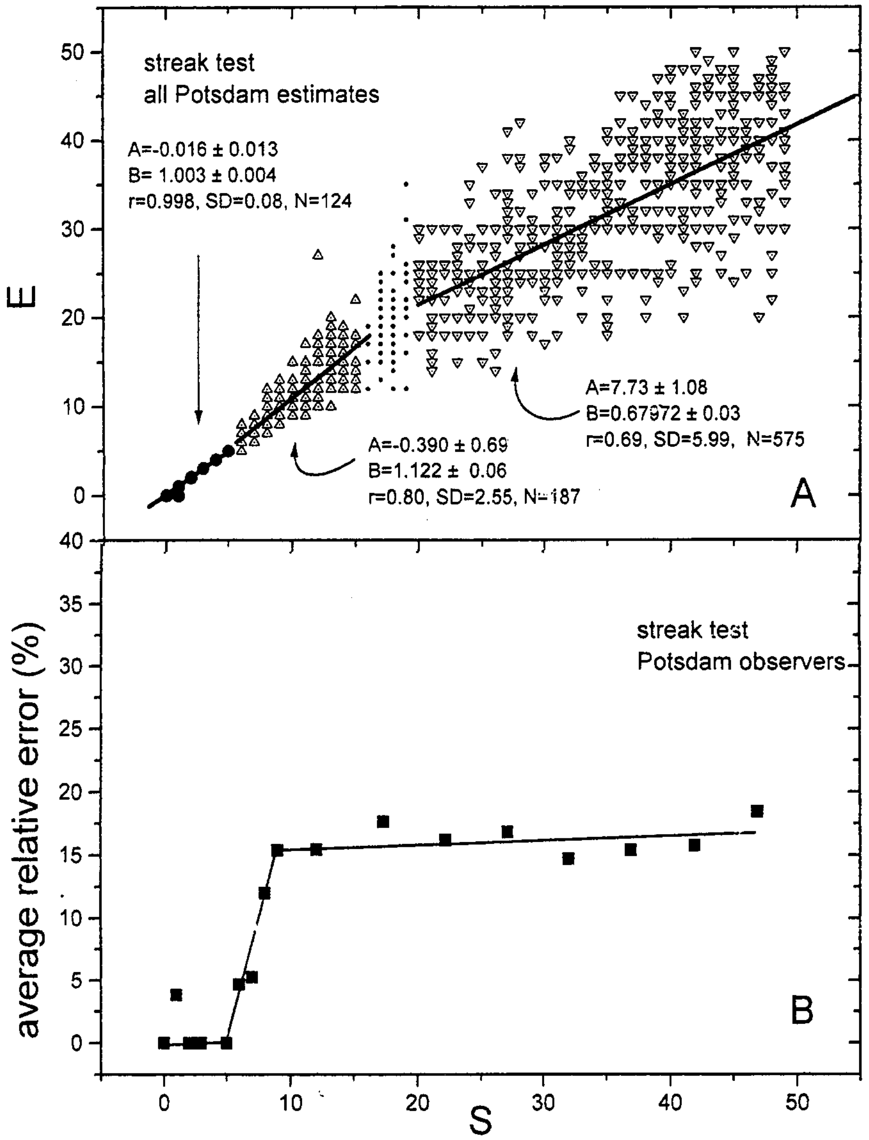

Figure 1 – Results of observers from Potsdam (Germany) in streak test (ST). *Top*: estimated number (E) of streaks as a function of simulated number (S). Linear regressions ($E = BS + A$) for score in CER ($0 \leq S < 5$; circles), HSR ($5 \leq S \leq 15$; up triangles), and LSR ($S \geq 20$; down triangles) are shown separately, along with regression coefficients (A, B, r), standard deviations (SD), and number of individual estimates used for the fit (N). Points indicate estimates that were not used for any regression. Note that in CER, only one of 124 estimates was off. *Bottom*: mean relative error as a function of simulated streak number S. For each data point, 20–40 single estimates were used.

Performance of individual observers

We attempted to compare the performance of "novice" (people who at best once or twice observed the Perseids, Figure 2, A) and "expert" (those with an outstanding observation record, Figure 2, B) observers from the Potsdam team. Some participants were considered neither expert nor novice. The S-E plots from both subgroups were very similar to the general picture shown in Figure 1, A. Apparently, performance in this test does not depend very much on experience in meteor observation, but rather reflects general sense-physiological properties of the eye-brain-system. However, for the "experts," the slope in the LSR area appeared slightly higher. The relevance of these differences has not been further explored.

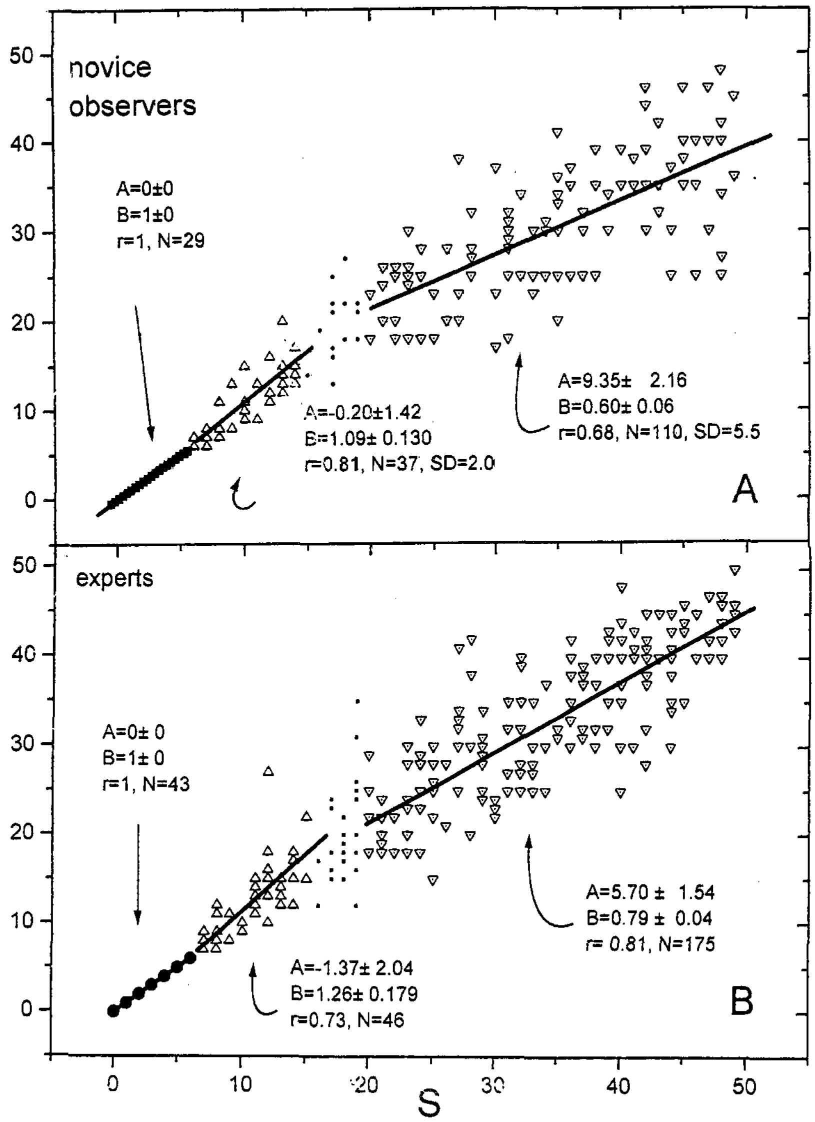

Figure 2 – Performance of novice (*top*) and expert (*bottom*) observers. Symbols and parameters as in Figure 1, A.

Performance in AMT

Figure 3, A, shows results of a number of Belgian and one German observer in AMT. Generally the picture is similar to the results in ST. The differences in slope of the *S*-*E* function in CER, HSR, and LSR stand out even more obviously. There is some scatter even in CER, which is to some extent an artifact from the simulation software. The scatter in LSR appears not to be larger compared to the streak test. The procentual standard deviations from the linear fits shown in Figure 3, A, are of the order of 25% in LSR, CER, and HSR.

Is it legal to combine the estimates of a large number of observers into one single graph? One (experienced) observer submitted a large number of individual estimates. An *S*-*E* plot of her efforts (not shown) is virtually interchangeable with Figure 3, A. Thus, as in streak test, performance in AMT seems to be quite independent of the observer. Figure 3, B, shows that the mean relative error is about 15–30% for the individual observer in much of LSR, and increases only slightly when values from several observers are put together.

Performance in RMS

All observers felt subjectively that RMS was harder to perform than ST and AMT. Confusion was especially brought about by occasional bright and long-lasting persistent trains. In fact, these have also been claimed to have confused observers in 1966 [11].

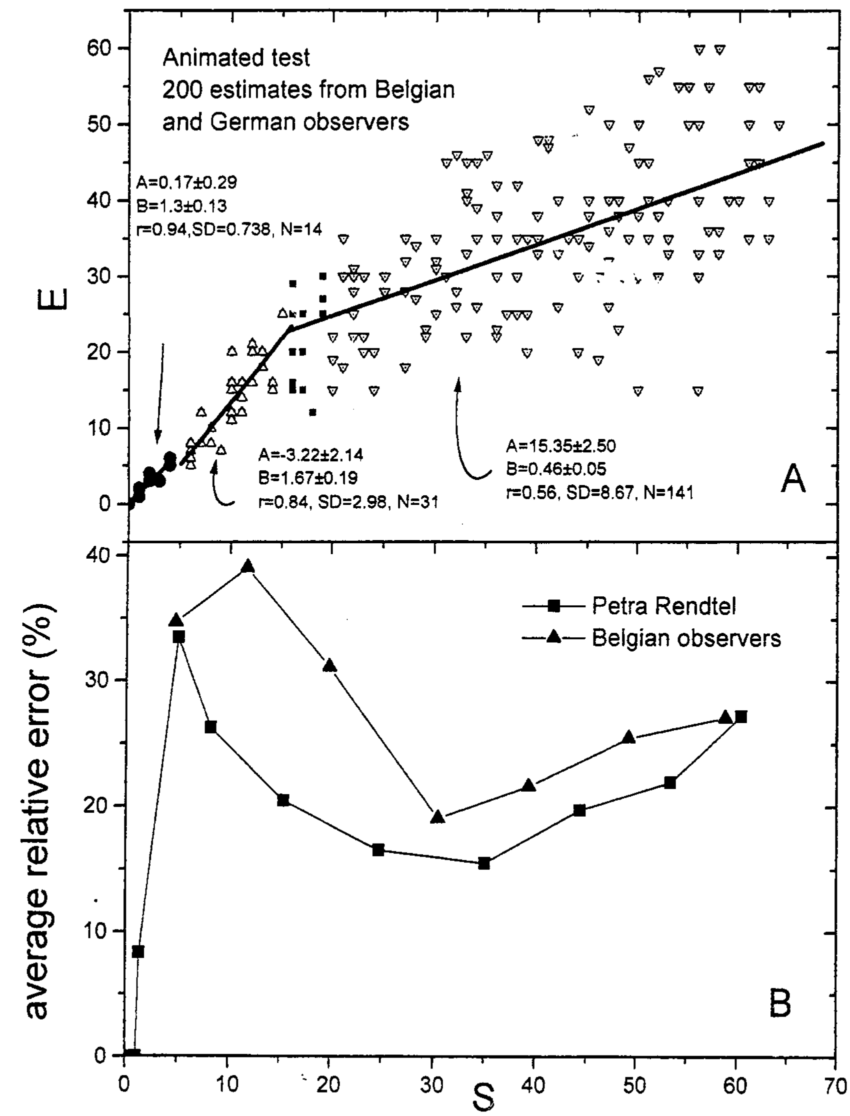

Figure 3 – About 3200 individual estimates submitted by selected observers from Belgium and Germany in the Animated Meteor Test (AMT). *Top*: Estimated number (E) as a function of simulated number of moving objects. For further explanations, see Figure 1, A. *Bottom*: Mean relative error as a function of simulated "meteor" number S. For each data point, 20–40 single estimates were used. Triangles: 200 observations from Belgian observers. Squares: Estimates by one individual observer (Petra Rendtel).

RMS tests soon revealed that, due to the apparent meteor clustering, individual 1-second estimates were not very reliable. Most observers thus developed a successful strategy: performing a sequence of estimates (at a rate of, e.g., 10–15 per minute during a time interval) and from time to time estimating an average rate. This considerably reduced the scatter, since each recorded value is made up of a large number of single estimates. This explains the fair results of many observers: despite the fact that RMS was felt to be more difficult than AMT, the correlations in RMS was in many cases better, especially at higher meteor numbers.

A typical example is shown in Figure 4, A. The general shape of the S-E function remained similar, but the slope of the curve became larger in the LSR-range, in some cases approximating 1 over the whole range tested. Thus in contrast to ST and AMT the plot could be approximated with a single linear fit. The mean relative error is of the order of magnitude of 20%, as can be seen in Figure 4, B.

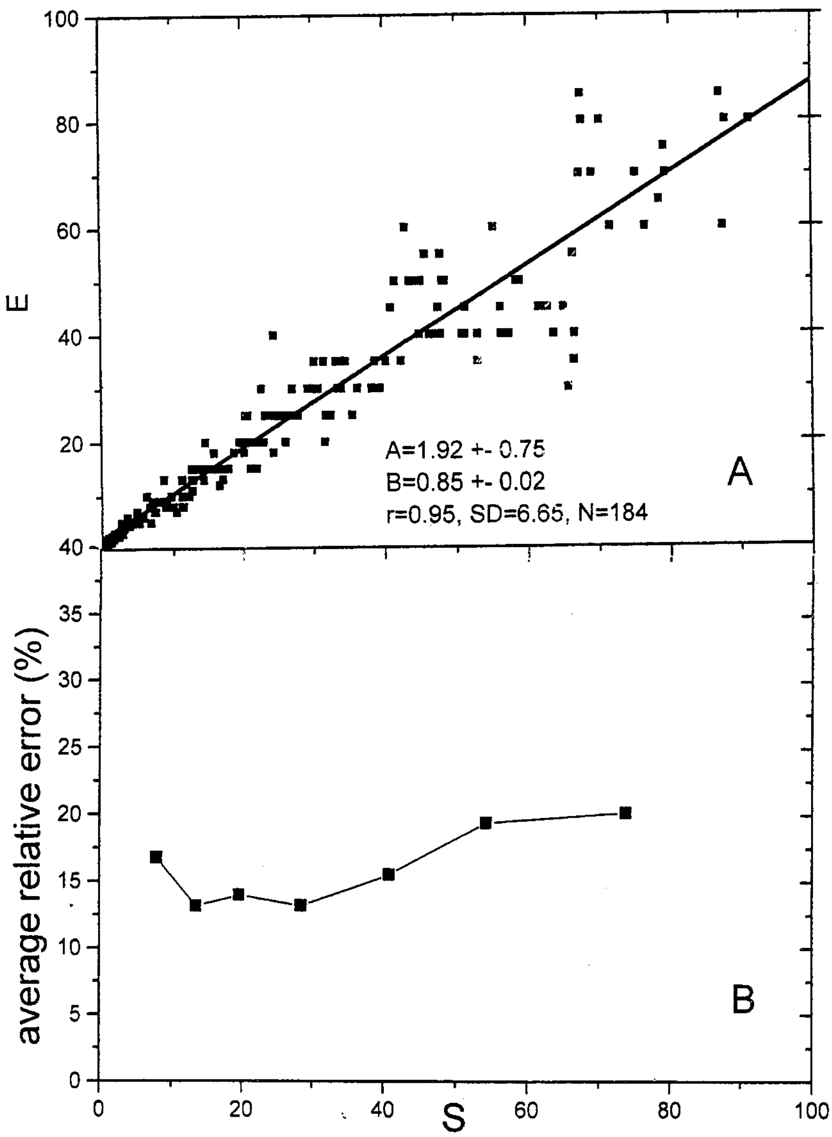

Figure 4 – Performance of one test person (co-author Sirko Molau) in Realistic Meteor Simulation (RMS). *Top*: The *S*-*E* plot can be approximated fairly by a single linear regression. *Bottom*: Mean relative error as a function of simulated streak number *S*. See Figure 1, B, for additional explanation.

All observers submitting this type of data performed the test by estimating the meteors visible in actual 1-second time windows (sometimes by opening their eyes for 1 second). At low meteor rates, most observers counted meteors directly for a time interval of about 30 s and then computed the rates. Some test persons, however, submitted records that were far inferior compared to the same person's performance in AMT and ST (data not shown). The slope of the *S*-*E* curve in the LSR region was extremely low in these cases. All these candidates concentrated on the general impression at high rates and tried—after a while—to express that impression by a number, but not by averaging actual estimates in short time intervals.

Log-log plots

Figure 5 shows the results in ST and RMS in a double-logarithmic presentation. The scatter shown in that graph reflects not the absolute but the relative error. It is shown that in ST, the relative scatter is zero at very low meteor numbers, and fairly constant at simulated meteor numbers above 15 (Figure 5, A). In RMS, the scatter seems to be approximately constant over the whole range of meteor numbers (Figure 5, B). This nicely agrees with the relative errors shown in Figures 1, B, and 4, B, respectively.

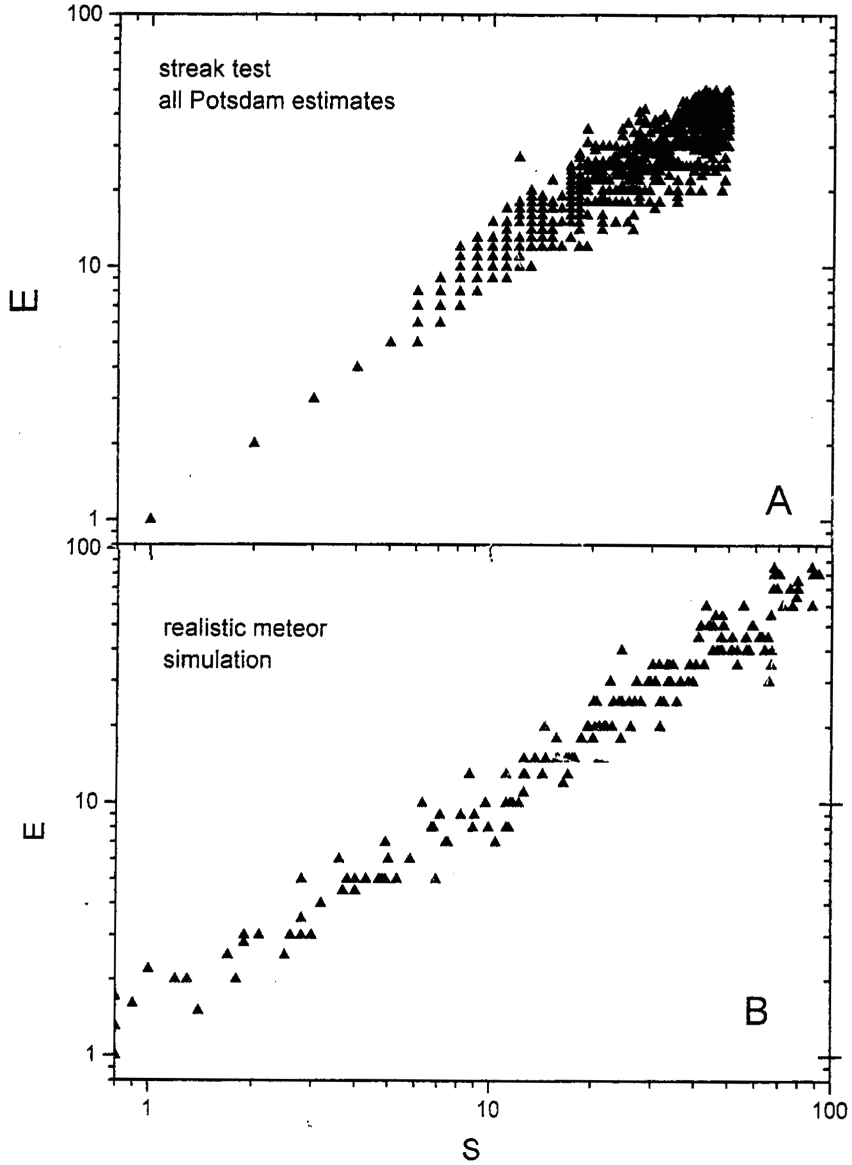

Figure 5 – Double-logarithmic plots of the S-E distribution in ST (*top*, same data as in Figure 1, A) and in RMS (bottom, same data as in Figure 4, A). Especially in RMS, the relative scatter remains fairly constant throughout the whole range of simulated meteor numbers.

4. Discussion

Relevance of ST, AMT, and RMS test results

ST is a very crude test which simply explores the capacity to estimate a large number of objects during a short time interval, without any specific reference to meteor observation. It is not very astonishing that the scatter is slightly larger in AMT, since the rapid movement of objects confuses the observers. Results in RMS appear amazingly reliable, and the estimated numbers of meteors increased almost linearly with the simulated meteor number. Especially the slope in the LSR-area is much higher than in the other tests, but, astonishingly, not far from 1. Obviously, the averaging of various individual estimates over some time interval reduced the scatter in RMS. ST and AMT thus investigate the principal ability of observers to estimate high numbers of shortly displayed objects. RMS, however, additionally explores if this ability is useful in a true meteor storm scenario, especially considering the influence of persistent trains (which may be confused with meteors) and highly variable rates on short time scales. The result is encouraging: number estimates at high rates appear more reliable than sometimes thought before.

Evaluation of the 1966 estimates

Can observers accurately estimate large numbers of objects? In the debate on the reality of the 1966 Leonid EZHR figure, it has been argued that observers can only oversee 4–5 moving objects at one instance [6]. This is clearly supported by our ST data. At numbers above 5–6, all test persons failed to give the precise number of meteors, which they routinely could achieve at lower S. This fact is, however, without much significance for meteor observation: In RMS, observers often overlooked a single meteor at low rates, and these mistakes will introduce large relative errors in EZHR computations. At high rates, the influence of an inaccurate estimate on the relative error is largely compensated by the statistical effect of a much larger data sample. This explains our finding that the relative error is independent of the meteor number (Figures 4, B, and 5, B). In fact, in AMT (Figure 3, B), relative errors at very low rates even exceeded the values found at high rates.

At higher S-numbers, test persons were able to give reliable estimates of the meteor numbers per second. The accuracy of these estimates supports a high EZHR in 1966. If observers reported up to 40 meteors per second, this should be the right order of magnitude. Even if we consider that the programs used in this study cannot simulate all parameters that affect the accuracy, we feel confident that the estimated number should not be off by more than a factor of 2. Our general experience is that, if something goes wrong with these estimates, this will normally lead to underestimates. Provided the 1966 data are not heavily affected by psychological bias ("euphoria factor") and were determined with care they should not be subject to gross overestimate. In summary, our data support a high rate in 1966.

Beside Milon's data, there are other visual reports which are in line with a high EZHR. However, it must be said that most visual counts done in the United States [3] place the maximum rate at a mere 10 meteors a second, corresponding to an EZHR of about 30 000–40 000. That scenario would set the general peak rate only a factor of 2 above (and possibly into the error range of) the radar values. One observer, however, stated that *"in short time intervals, the rate was sometimes 2 to 3 times that value"* (EZHR for this particular observer about 80 000–120 000). The rate in these short-lived bursts of activity is close to the rate in Milon's data and is also compatible with high meteor numbers on shortly exposed photographs. Rendtel estimated that the EZHR during the exposure of the famous "43 meteors in 43 seconds" photograph of 1966 must have been in the range of 60 000–180 000 [7]. The lengths of star trails in the unguided photograph indicate that the given exposure time is correct. Enhanced activity during such a long period cannot be explained by statistical fluctuation only. In Milon's data [3], the maximum activity was sustained for several minutes. Finally it should be noted, that rapid (apparent or real) fluctuations during the peak are also conspicuous in count data of 1866 [12,13]. During that Leonid storm, count rates in England (about 0.5–2 per second) were much lower than in 1966, allowing direct and probably very accurate counting.

Consequences for 1998 and 1999 observing plans

Our data suggest that visual observations of meteor storms can provide at least some useful estimates of EZHRs.

In any case, the method of choice depends on the actual rate. It does not make sense to shift to the 1966 method when the rate is, e.g., 0.5–1 meteor per second as in 1866. In this situation, an observer will be able to record counts online on tape, perhaps even estimating magnitudes. Recording a time signal simultaneously may support the data reduction.

At higher rates, apparent clustering, as simulated in RMS, does not only confuse observers, but renders 1-second activities from possibly unrepresentative samples. A good strategy to handle this problem is to make about 10 estimates in 1 second intervals and compute means from them. In fact, all observers with a good score in RMS used this technique. We therefore urge observers to keep estimating meteor rates in actual short time intervals instead of trying to express a long-term general impression of the rate in terms of numbers. Test results suggest that the latter method yields unreliable results, in most cases underestimates.

Last but not least, much more objective activity figures may be gained by video techniques, which were not available in 1966. These can be used to calibrate visual estimates, too. We hope that in 2032, Leonid observers in their preparation can rely on more accurate figures from the hopefully high EZHRs of the 1998 and 1999 Leonid returns.

Acknowledgments

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Revisiting the Radio Doppler Effect from Forward-scatter Meteor Head Echoes

James Richardson and Werfried Kuneth

Following an introduction to the radio meteor head echo and its historical aspects, a PC-based technique is described whereby the radio Doppler effect from meteor head echoes can be used to make rough meteor range and speed measurements, employing a commercial AM or CW transmitter in a forward-scatter link. The technique is then applied to four known shower meteors, two Leonid and two Geminid, which provided measurable head echoes in addition to specular trail reflections.

1. Introduction

On the night of November 17, 1996, the Leonid meteor shower produced a noteworthy display for both visual and radio meteor observers. While only reaching typical major shower strength as far as rates were concerned, the shower was enjoyably rich in swift, bright meteors and fireballs, some producing enduring visual trains. For the radio observer, the shower produced an abundance of extremely strong, long-duration trail echoes, which occasionally overlapped with each other. It was also noticed by the authors that, while the Leonid radiant was relatively low in the sky, a higher-than-usual number of impressive meteor head echoes could also be heard, occurring just prior to the specular trail reflections. A repeat performance of this unusual radio display in 1997 prompted us to investigate the head echo phenomenon further.

The meteor head echo is a radio wave reflection from an apparent plasma cloud directly around the moving meteoroid as it plows through the upper atmosphere [1,2]. This is a separate phenomenon from the more common specular reflection from the meteor's trail [1,3] Over the 50 or so years of radio meteor research, there have been numerous explanations suggested for this plasma cloud's origin [3–6], but the production and detection mechanism still is uncertain. Investigations of this phenomenon continue today, using sophisticated, high-powered VHF and UHF meteor radars [7,8].

In the conventional back-scatter or forward-scatter system, this dense cloud of free electrons about the meteoroid presents a "moving ball" type of target to the radio waves from the transmitter, creating a very distinct Doppler-shifted signal at the receiver. In a Continuous Wave (CW) receiver, the meteor head echo sounds like a sharp, rapidly descending "whistle," just prior to the specular trail reflection and usually lasting less than half a second. Because significant head echoes are generated only by the brighter meteors having a favorable geometry, they can be rather elusive, occurring in about 0.1% of the trail echo population for a typical system [3]. Nonetheless, their significance as a reflected signal from a rapidly moving target was recognized as early as the late 1930s. This helped to bolster the gathering evidence in support of radio wave reflections from meteors (or their trails—under scientific debate at that time [1]).

McKinley [1] cites one of the first professional studies of this phenomenon:

> *"A novel aspect of the meteoric reflections was described by two Indian radio engineers, Chamanlal and Venkataraman* [9]. *They found that, when listening to a radio receiver tuned to an unmodulated short-wave transmitter, audible whistles could be heard which were short-lived and usually descending in pitch. This "radio Doppler effect" was correctly interpreted as a heterodyne beat between the transmitted wave and the wave reflected from a moving target. However, they assumed that the descending pitch of the beat note was due entirely to rapid retardation of the meteor whereas, as Appleton and Naismith* [10] *have pointed out, the effect should properly be construed as due to the change in apparent radial velocity that is observed when the meteor is moving with a relatively constant linear velocity across the observer's line of sight."*

At Stanford, Manning [11] became the first professional to work out the geometry, interference pattern, and resulting Doppler signal from such a moving ball target for the purpose of obtaining meteor speeds from meteor head echoes [3]. By that time, however, a different range-time method for obtaining meteor speeds had successfully been employed by Hey, Parsons, and Stewart [12] during the great Giacobinid shower of 1946. This became the first professional determination of meteor speeds using radio methods. Due to the rarity of appropriate meteor head echoes and the nearly exclusive use of pulse-type radar instruments by the professionals, the technique of measuring meteor speeds using the CW head echo Doppler shift was quickly abandoned for more practical methods [3]. McKinley [1] does mention the method as a viable and sensitive technique for use with CW systems, and it was this aspect that interested us. The meteor head echo represented a unique opportunity for advancing our amateur efforts in utilizing radio techniques for meteor studies.

2. Equation development

The first step in investigating the meteor head echo is to derive the relationship between the observed Doppler shift and the line-of-sight (radial) speed of the meteor. In the case of the moving target, two separate Doppler shifts occur: the first between the transmitter and the meteor head, and the second between the meteor head and the receiver. Because we choose only to analyze those meteors which also cause a forward-scatter trail reflection, we know that the meteor path must lie within a plane which is orthogonal to the radio signal plane of propagation at the specular reflection point [1]. However, we lack specific information about the orientation of the meteor path within that plane. We therefore need to make the simplifying assumption that the radial speed between meteor and transmitter is the same as the radial speed between meteor and receiver. In essence, this reduces the forward-scatter situation to the back-scatter condition. This assumption is also aided by the observation that if the meteor path is oriented such that one radial speed is increased, it will cause a corresponding decrease in the opposite radial speed, partially canceling the effect of the orientation. Proceeding forward, the first Doppler shift between transmitter and meteor is given by

$$f_1 = \frac{c + v_\ell}{c} f_0,$$

where f_0 is the transmitter frequency (Hz), f_1 the frequency received at the meteor head (Hz), c the speed of light(299 792.458 km/s), and v_ℓ the line-of-sight (radial) speed (km/s). Now, we extend the signal from the meteor head down to the receiver to obtain

$$f_2 = \frac{c}{c - v_\ell} f_1,$$

where f_2 is the frequency received at the receiver (Hz). These are the standard equations first for a moving receiver, and then for a moving transmitter [13]. Combining and simplifying these two equations yields

$$f_2 = \frac{c + v_\ell}{c - v_\ell} f_0$$

or

$$\frac{v_\ell}{c} = \frac{f_2 - f_0}{f_2 + f_0}.$$

For the sum term in the above equation, the received frequency is equal to the transmitter frequency up to four significant digits. This gives us a final Doppler shift equation of

$$\Delta f = f_2 - f_0 = 2\,\frac{v_\ell}{c} f_0$$

or a line-of-sight (radial) speed equation of

$$v_\ell = \frac{\Delta f}{2 f_0} c. \tag{1}$$

Note that if the meteor head is approaching the receiver, the Doppler shift Δf will be positive, and the line-of-sight speed v_ℓ will be positive. If the meteor head is receding from the receiver, the Doppler shift will be negative, and the line-of-sight speed will be negative.

The next step is to investigate the head echo geometry. Figure 1 shows a target moving perpendicularly across the field of view of a receiver. Initially, the line-of-sight distance between target and receiver is large, but decreases as the target approaches. This line-of-sight distance will continue to decrease until it passes through a minimum value at the point of closest approach (PCA) for the target. Note that at the PCA, the line-of-sight is at a right angle to the target's path. Following PCA passage, the line-of-sight distance will begin to increase again as the target recedes.

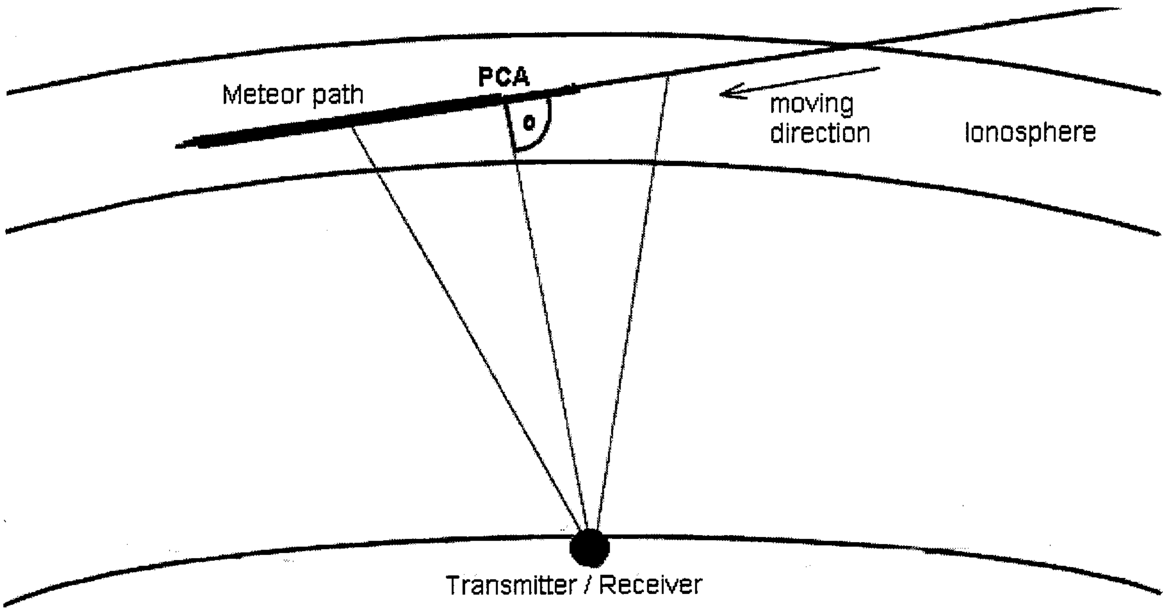


Figure 1 – A target moving across the field of view of a receiver. Radial lines indicate the line-of-sight at various points, including the point of closest approach (PCA).

Still using Figure 1, we next place transmitter and receiver together at the same location (backscatter condition), with the radio signal path to and from the target following a line-of-sight (radial) path. The speed of the target is then split into two components: a radial component and a tangential component. The Doppler shift imparted by the target on the transmitted frequency becomes a function of the target's radial speed. For an approaching target, the radial speed will begin at some high value, with a corresponding high positive Doppler shift. As the target approaches the PCA, its radial speed will continuously decrease, creating a continuously decreasing Doppler shift. At PCA passage, the radial speed will pass through zero, with a corresponding Doppler shift of zero. All of the target's speed will be tangential to the line-of-sight, and the received frequency will equal the transmitted frequency. Following PCA passage, the radial speed will become increasingly negative, with an increasing negative Doppler shift. Thus, as the target approaches, passes through the PCA, and then recedes, the receiver will see a continuously decreasing frequency: first above the base frequency as the target approaches, equal to the base frequency at the PCA, and then below the base frequency as the target recedes.

Figure 2 shows the extension of Figure 1 to the forward-scatter condition, in which a meteor is moving between transmitter and receiver. With respect to the receiver, the meteor head will again display the same behavior as in Figure 1: it will approach the receiver at some radial speed, pass through a point of closest approach (PCA), and then recede. At the PCA, the radio reflection path will be at a right angle to the meteor's flight path, the radial speed will be zero and the Doppler shift will be zero. This allows us to set up a right triangle with the PCA-receiver line as the base (called r_0, for minimum range), the meteor's flight path as the perpendicular (m), and the line-of-sight (ℓ) at some other selected point forms the hypotenuse (all km). This yields the following relationship:

$$\ell^2 = r_0^2 + m^2.$$

If we assume the meteor to be traveling at a constant speed, then the above can be expanded to

$$\ell^2 = r_0^2 + (v_\mathrm{m}\Delta t)^2, \tag{2}$$

where v_m is the meteor speed (km/s), $\Delta t = t - t_0$ (s), t is the time of selected line-of-sight range (s), and t_0 is the time of PCA passage (s).

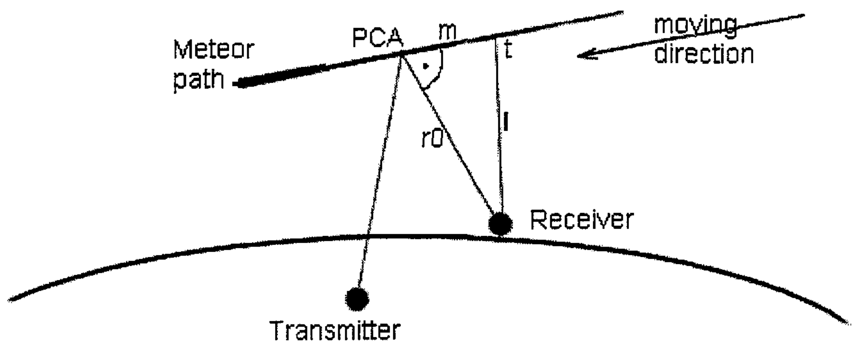


Figure 2 – In a forward-scatter link, a right triangle can be established between the receiver, the meteor's point of closest approach (PCA), and a selected meteor range at time t.

Note that this is the well-known hyperbolic equation used to solve for meteor speed using range-time information from a back-scatter radar [3]. For our purposes we are interested in the related rates for this triangle. Holding r_0 constant and differentiating with respect to time, yields

$$2\ell\frac{d\ell}{dt} = 2m\frac{dm}{dt},$$

or

$$\ell v_\ell = m v_\mathrm{m}.$$

Since $\ell^2 = r_0^2 + m^2$ and $m = v_\mathrm{m}\Delta t$, squaring both sides and expanding the ℓ and m terms yields

$$v_\ell^2 r_0^2 + v_\ell^2 v_\mathrm{m}^2 \Delta t^2 = v_\mathrm{m}^4 \Delta t^2.$$

We can then algebraically solve this equation for each of the desired terms:

- If Δt, v_ℓ, and v_m are known, we can solve for the PCA range r_0 as follows:

$$r_0 = v_\mathrm{m}\Delta t\sqrt{\frac{v_\mathrm{m}^2}{v_\ell^2} - 1}\,. \tag{3}$$

- If Δt, v_ℓ, and r_0 are known, then we can solve for the meteor speed v_m as follows:

$$v_\mathrm{m} = \sqrt{\frac{v_\ell}{2}\left(v_\ell + \sqrt{v_\ell^2 + \frac{4r_0^2}{\Delta t^2}}\right)}\,. \tag{4}$$

- Finally, we can solve for the expected Doppler frequency shift Δf for a given PCA range r_0, meteor speed v_m, and base frequency f_0 by substituting in equation (1) the solution for the line-of-sight (radial) speed v_ℓ:

$$\Delta f = -\,\mathrm{sgn}(\Delta t)\sqrt{\left(\frac{2f_0}{c}\right)^2 \frac{v_\mathrm{m}^2}{\frac{r_0^2}{v_\mathrm{m}^2\Delta t^2} + 1}}\,, \tag{5}$$

where $\mathrm{sgn}(\Delta t) = |\Delta t|/\Delta t$ is used to give the correct algebraic sign to Δf. Prior to the PCA, Δf will be positive, and after PCA, Δf will be negative.

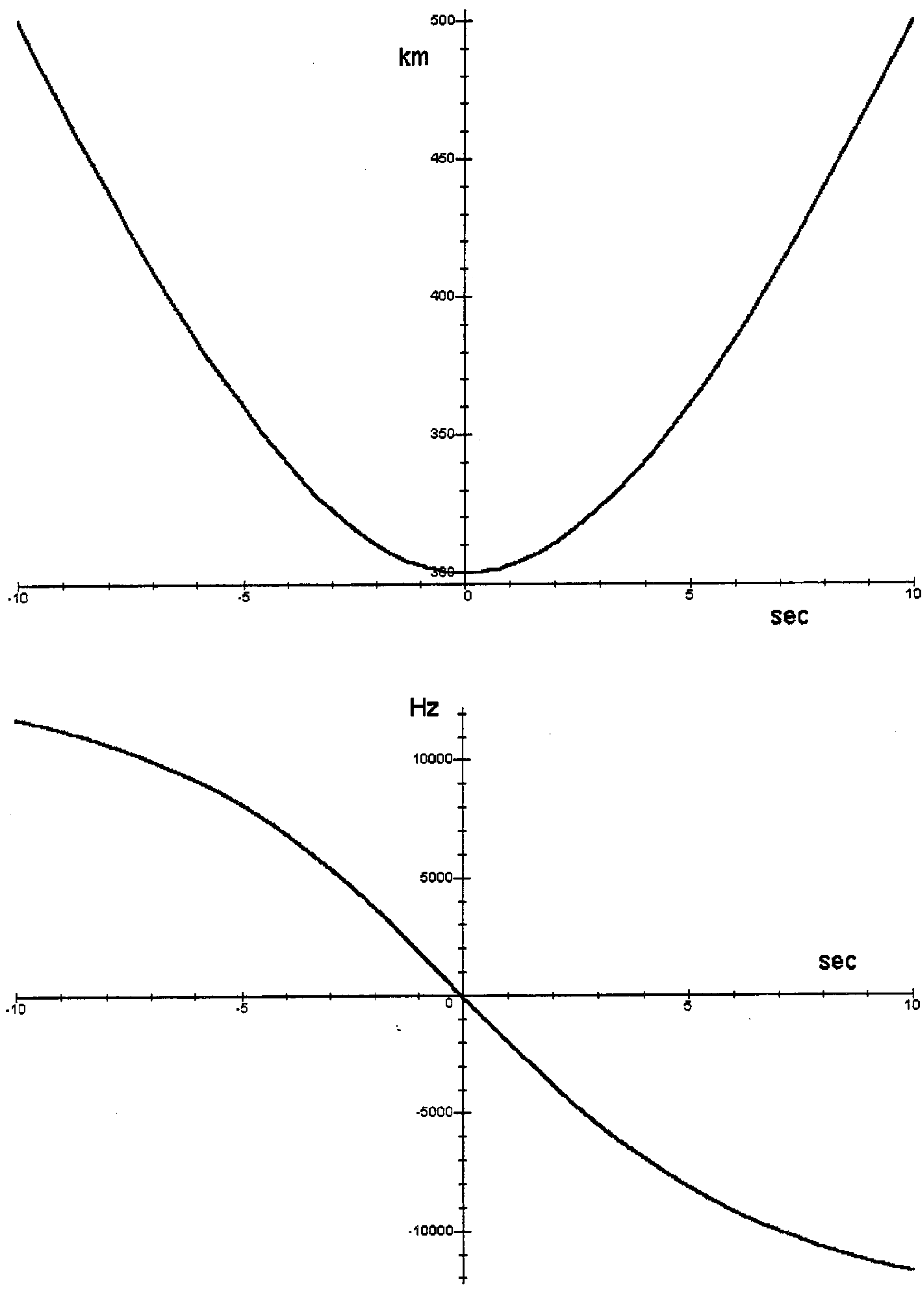
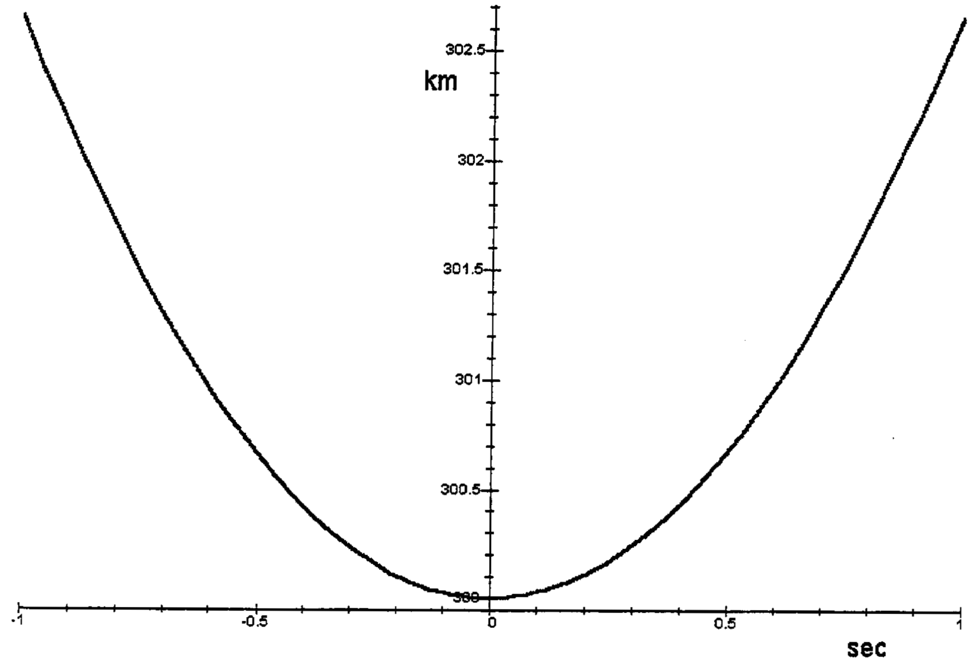


Figure 3 – Within a 10-second time window, the (*top*) hyperbolic range (km) versus time (s) plot, and (*bottom*) Doppler frequency shift Δf (Hz) versus time (s) plot for a "typical" forward scatter meteor head echo are shown. Note the curvilinear nature of the latter.

In order to demonstrate the predicted behavior of a meteor head echo using this last equation, we choose as "typical" values a range of $r_0 = 300$ km, a meteor speed of $v_{\rm m} = 40$ km/s, and a transmitter operating frequency of $f_0 = 55.260$ MHz. Figure 3 shows the (*top*) hyperbolic range versus time plot using equation (2), and the (*bottom*) Doppler frequency shift versus time plot using equation (5). This figure has the relatively large time window of approximately 10 seconds in order to show the curvilinear nature of the frequency shift curve (equation (5)). If the frequency shift plot is extended to either left or right, the curve becomes asymptotic to a maximum frequency shift given by

$$\Delta f = \pm 2 \frac{v_{\rm m}}{c} f_0.$$



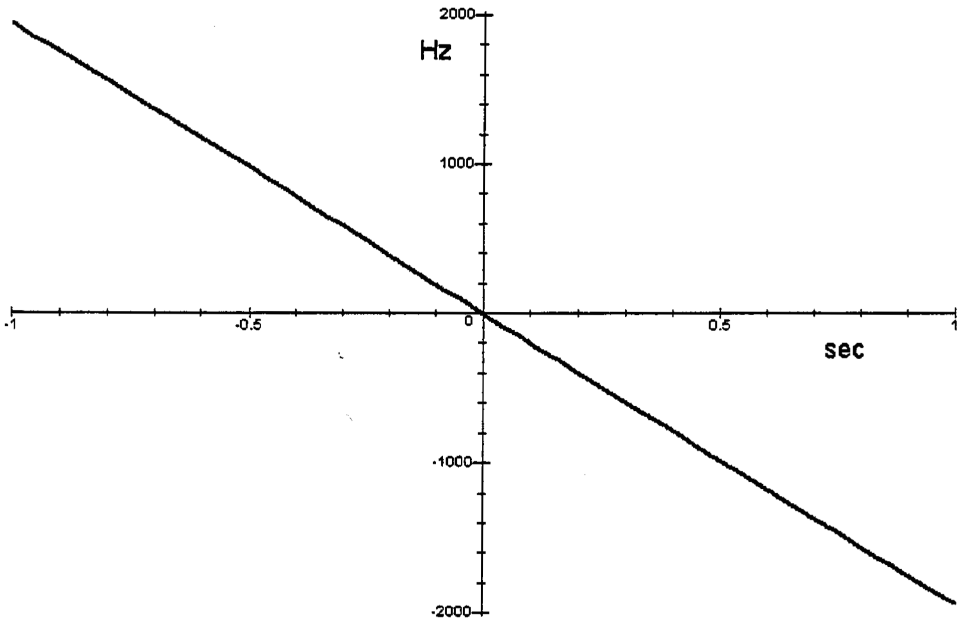


Figure 4 – Within a 1-second time window, the (*top*) hyperbolic range (km) versus time (s) plot, and (*bottom*) Doppler frequency shift Δf (Hz) versus time (s) plot for a "typical" forward scatter meteor head echo are shown. Note the linear nature of the latter over this limited time range.

For our "typical" meteor, the horizontal asymptotes for the frequency shift curve are located at ± 14.75 kHz. In practice, however, these limits are never encountered, since most meteor head echoes occur within half a second or so of the PCA. Figure 4 shows these same two equations over the more useful time range of approximately 1 second. Note that over this time span, the frequency shift curve is essentially linear, has a negative slope, and passes through 0 Hz of frequency shift as the meteor passes through the PCA range of 300 km. Faster meteor speeds will create a steeper slope, while slower meteors will create a shallower slope. In like fashion, meteors at a closer range will create a steeper slope, while meteors at a farther range will create a shallower slope. Of these two variables, the speed term is dominant, having a greater overall effect than the range term.

3. Analysis technique

From the above discussion, it becomes obvious that the most important point in the geometry is the point of closest approach (PCA) for the meteor head. Thus, in order to utilize these equations, proper identification of the PCA becomes paramount in order to solve for the other variables. It is also obvious from Figures 3 and 4 that the Doppler frequency shift versus time curve for a particular head echo cannot be used for this task because the curve passes linearly through the PCA (and base frequency) without inflections. Luckily, however, the base frequency, and hence the PCA, can be identified through another source: the specular reflection from the meteor trail. The meteor trail provides a relatively stationary target, which reflects the transmitter frequency to the receiver with very little to no Doppler shift. Upper-atmospheric winds can cause a trail reflection to have a "body-Doppler" of up to about 10–20 Hz [1], but for our purposes this is near the limits of our measurement accuracy and can be neglected. Hence, the PCA for the head echo is indicated when the head echo frequency matches the trail echo frequency. Using this point in time and frequency as our PCA reference point, our right triangle geometry can be utilized.

The data for this study was collected using the forward-scatter receiving stations located in Poplar Springs, Florida (J. Richardson) [14] and Ferndorf, Austria (W. Kuneth) [15]. Each station utilizes distant commercial television transmitters (AM mode, video carrier signals) as the forward-scatter signal source, within the 52–56 MHz frequency range. Commercial FM transmitters could not be utilized for this study, due to their lack of a frequency stable carrier signal. While both systems feed their receiver outputs to computerized data collection systems, the data collection systems were not used for this study. Instead, good quality audio recordings were made directly at the receivers during periods of known meteor shower activity. Each receiver was placed in CW mode, such that the recorded audio signal became the heterodyne beat frequency between the received frequency and a constant, internal BFO frequency (BFO = Beat Frequency Oscillator). The output frequency is given by

$$f_{\text{audio}} = f_2 - f_{\text{BFO}}.$$

This frequency downshift not only allowed us to monitor, by ear, incoming meteor head and trail echoes, but also to utilize audio recording equipment and analysis software. Because our receiver bandwidths are about 4–6 kHz, the audio signals recorded were generally on the order of 100 to 3000 Hz, depending upon the exact BFO setting in relation to the transmitter frequency.

The audio recordings at Poplar Springs were made using a Sony TCM-4000 mono-channel cassette tape recorder, which has a low noise, and relatively flat frequency response up to 15 kHz using FeO_2 tapes. Selected portions of the audio recordings were then digitized at 22 kHz using a SoundBlaster 16-bit ISA bus card and the Windows 95 sound recorder application, using the PCM format. A similar procedure was followed at Ferndorf.

Once digitized, audio spectrograms for the recordings were produced using the Spectrogram 2.3 software package [16]. This application is available as free-ware from the developer, and can be downloaded at various locations on the Internet. Spectrogram uses a Fast Fourier Transform (FFT) routine to produce an audio frequency versus time display for the recording having audio frequency plotted on the ordinate, time plotted on the abscissa, and signal strength indicated by either a color scale or a grey scale. For our selected audio recordings, a 2048 point FFT generally yielded the best results for the resolution given below:

Sample frequency (f): 22 000 Hz;
Frequency range ($f/2$): 0 Hz to 11 000 Hz;
FFT points (n): 2048;
Frequency divisions in range ($n/2$): 1024;
Frequency resolution: 11 Hz;
Frequency accuracy: ±5.5 Hz;
Time resolution: 4 ms (milliseconds);
Time accuracy: ±2 ms.

Spectrogram 2.3 provides a direct readout for the frequency and time of a point selected on the display using the mouse cursor. For each meteor head echo analyzed, as many measurements as could be practically taken were made along the line of the head echo, with the identification of the PCA (our reference point) being the most critical. As a general rule, measurements were not usually made within 50 ms of the PCA because such points usually displayed erratic (outlier) behavior due to measurement accuracy affects on the difference terms (Δf and Δt).

Using these measurements, the line-of-sight (radial) speed v_ℓ for the meteor could be calculated using equation (1). This result could also be applied to equations (3) and (4), provided that assumptions were made for one of the unknown variables. This points out the weakest part of this technique: without specific PCA range information, the meteor speed cannot be determined with accuracy, or without specific meteor speed information, the meteor range cannot be determined with accuracy. Despite the lack of accuracy, we nonetheless found it interesting to explore these areas, although the calculated values should be treated with a grain of skepticism.

In order to determine meteor PCA ranges, we purposely selected time periods in which a major meteor shower was at its peak and the radiant for the shower was passing through an altitude of about 20°–45°—biasing the collected recordings strongly toward particular shower members. Observations of previous major showers had also indicated that meteor head echo activity was noticeably enhanced with the shower radiant at low altitudes. We also desired that the shower radiant be as nearly perpendicular in azimuth to the forward-scatter link azimuth as could be achieved, in order to match our derived geometry as closely as possible, and to restrict the meteor reflection area to near the link "hot spot" locations. In the case of the Leonids, the distinctly characteristic head and trail echoes from this shower also helped to ensure a reasonably positive identification. Meteor speed assumptions were then taken from Cook's working list [17], and meteor PCA range assumptions were calculated using a simple forward-scatter "hot spot" model developed by Richardson using Maple (version 4.00C, 1996).

4. Data analysis

We now show the analysis of four recorded meteor head echoes: two Leonid echoes and two Geminid echoes.

Leonid head echo 1

Date: November 17, 1997;
Time: 08^h00^m UT (02^h00^m LT);
Radiant altitude: 35°;
Radiant azimuth: 83°.

Most probable link: Poplar Springs, FL - Baltimore, MD;
Link distance: 1230 km;
Link bearing: 38° (from receiver);
Relative radiant bearing: 45°;
Transmitter frequency (f_0): 55 260 490 Hz.

Figure 5 shows the audio spectrogram for Leonid 1. The meteor head echo is shown by the nearly linear sweep from 878 Hz at 442 ms to 264 Hz at 670 ms (the PCA), for a total sweep of 614 Hz in 228 ms. At this point, the much stronger, horizontal trail reflection begins, extending to the right off the screen and lasting for 5 seconds. With the beginning of the trail echo, the AGC for the receiver was triggered, reducing the gain and swamping out any further signal from the head echo.

Usually, the PCA and the beginning of the trail echo correspond quite close to each other, giving us three types of events: (*i*) if the trail echo begins prior to PCA passage, the head echo will be swamped prior to reaching the base frequency, making this type unusable; (*ii*) most commonly, the PCA and trail echo beginning are coincidental, similar to the back-scatter condition and matching our desired geometry most closely; and (*iii*) if the trail echo begins after PCA passage, the head echo can be followed below the base frequency. This last happens only rarely, however.

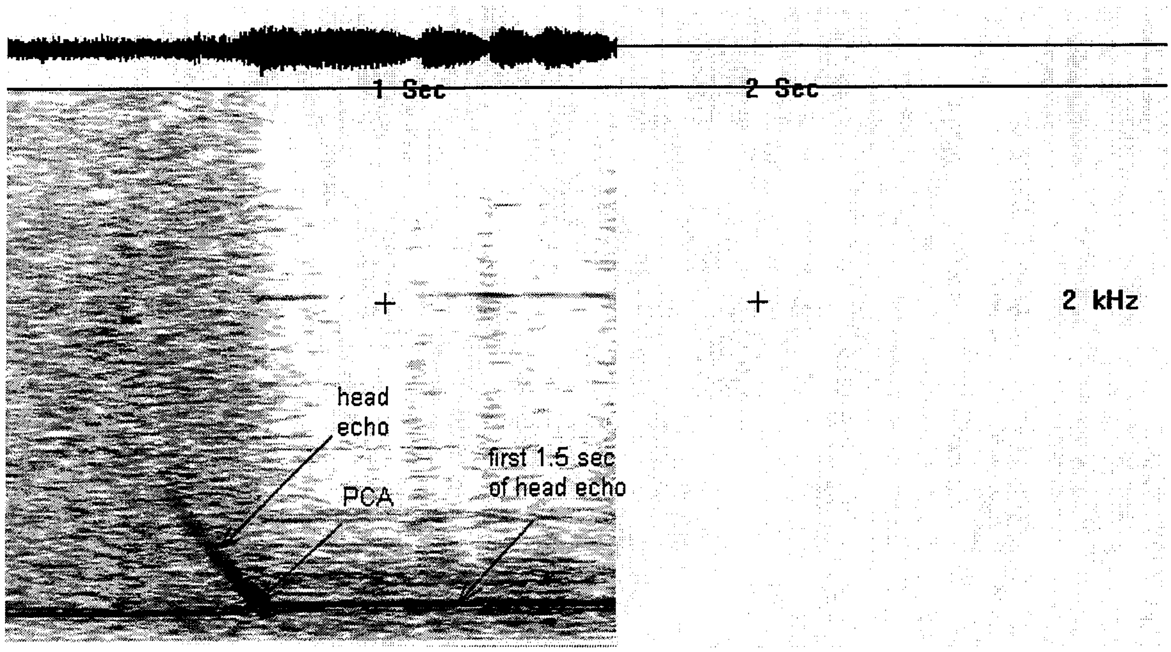


Figure 5 – Audio spectrogram for Leonid meteor recorded at Poplar Springs, Florida, on November 17, 1997, at 8^h00^m UT.

Table 1 – Data table for Leonid 1

Data point	Δf ±11 Hz	Δt ±4 ms	Slope Hz/ms	v_ℓ km/s	r_0 km	v_m km/s
1	614	−228	−3.58	1.67	684	68.3
2	571	−216	−3.25	1.55	697	67.6
3	506	−196	−3.07	1.37	714	66.8
4	420	−168	−2.67	1.14	737	65.8
5	356	−144	−2.32	0.966	745	65.4
6	291	−116	−2.69	0.789	734	65.9
7	205	− 84	−2.21	0.556	755	65.0
8	130	− 50	−2.60	0.353	709	67.1

PCA point: 264 Hz at 670 ms.

Using an assumed meteor speed of 70.7 km/s:

$\overline{r_0} = 722$ km;
SD = 24.8 km;
Final PCA range: (722 ± 50) km (confidence interval = 2 × SD).

Using an assumed PCA range of (638 ± 200) km:

$\overline{v_m} = 66.5$ km/s;
SD = 1.2 km/s;
Final v_m: (66.5 ± 10.8) km/s (confidence interval based upon high/low method for a range assumption accuracy of ±200 km. The selection of this accuracy is rather arbitrary, but is based upon encompassing the majority of the primary reflection area for the link).

An interesting facet of the data table is the apparent deceleration of the meteor over its flight path (m) of about 16 km. This can also be seen as a small change in the slope of the head echo line in Figure 5, making it slightly concave upward. Whether this is a true indication of meteor deceleration, or simply an effect of geometry not adequately covered in our assumptions, we cannot say at this point.

It should also be remembered that the two final results above cannot be used together, because each depends upon an assumption made in the other variable. These simply represent two possible fits to the same data, and of the two, we have more confidence in the range determination (based upon the classical Leonid speed) than in the meteor speed determination.

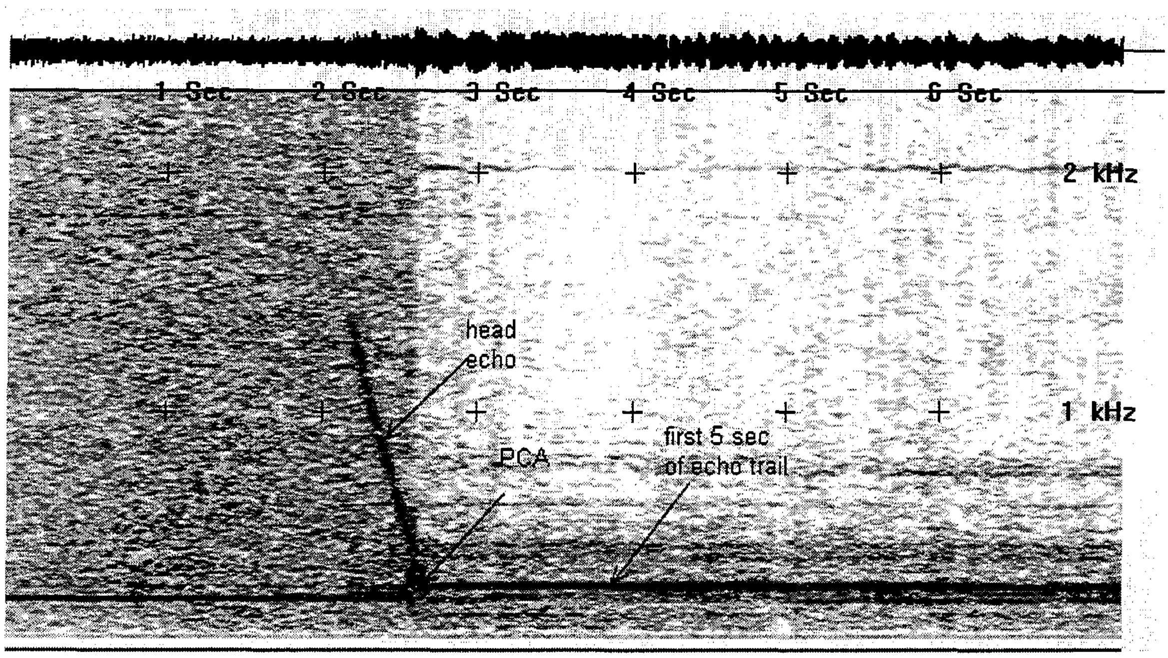


Figure 6 – Audio spectrogram for Leonid meteor recorded at Poplar Springs, Florida, on November 17, 1997, at 8^h30^m UT.

Leonid head echo 2

Date: November 17, 1997;
Time: 08^h30^m UT (02^h30^m LT);
Radiant altitude: 41°;
Radiant azimuth: 87°.

Most probable link: Poplar Springs, FL - Baltimore, MD;
Link distance: 1230 km;
Link bearing: 38° (from receiver);
Relative radiant bearing: 49°;
Transmitter frequency (f_0): 55 260 490 Hz.

Figure 6 shows the audio spectrogram for Leonid 2. The meteor head echo is shown by the nearly linear sweep from 1348 Hz at 2188 ms to 348 Hz at 2611 ms (the PCA), for a total sweep of 1000 Hz in 423 ms. At this point, the much stronger, horizontal trail reflection begins, extending to the right off the screen. This echo is very similar to Leonid 1, except that the slope of the sweep is somewhat less than in the former example. This is most likely indicative of a farther range, or perhaps a slower speed. While this sweep is more linear than for Leonid 1, a slightly concave upward shape is present, along with a slight apparent meteor deceleration. The total meteor path length (m) in this case is an impressive 30 km from first indication to the PCA, and the overdense trail echo lasted for 26 seconds following the head echo.

Table 2 – Data table for Leonid 2.

Data point	Δf ± 11 Hz	Δt ± 4 ms	Slope Hz/ms	v_ℓ km/s	r_0 km	v_m km/s
1	1000	−423	−2.83	2.71	779	64.0
2	898	−387	−2.79	2.44	794	63.4
3	750	−334	−2.36	2.03	820	62.4
4	625	−281	−2.21	1.70	828	62.1
5	508	−228	−2.14	1.38	827	62.1
6	461	−206	−2.46	1.25	823	62.2
7	429	−193	−2.20	1.16	829	62.0
8	242	−108	−2.24	0.656	822	62.3

PCA point: 348 Hz at 2611 ms. (Note that the BFO frequency had been adjusted slightly since Leonid 1.)

Using an assumed meteor speed of 70.7 km/s:

$\overline{r_0}$ = 815 km;
SD = 18.5 km;
Final PCA range: (815 ± 37) km.

Using an assumed PCA range of (638 ± 200) km:

$\overline{v_m}$ = 62.6 km/s;
SD = 0.73 km/s;
Final v_m: (62.6 ± 10.2) km/s.

Geminid head echo 1

Date: December 13, 1997;
Time: 07^h27^m UT (08^h27^m LT);
Radiant altitude: 20°;
Radiant azimuth: 298°.

Most probable link: Ferndorf, Austria - Bari, Italy
Link distance: 673 km;
Link bearing: 161° (from receiver);
Relative radiant bearing: 137°;
Transmitter frequency (f_0): 53 760 000 Hz.

Figure 7 shows the audio spectrogram for Geminid 1. Although similar to the previous Leonid head echoes, the head echo curve's slope is much shallower than in the previous examples: moving from 684 Hz at 507 ms to 480 Hz at 729 ms, for a total sweep of 204 Hz in 222 ms (compare to Leonid 1). The slope is about 1/3 the magnitude of the two Leonids, despite a much shorter link distance, and is indicative of a much slower meteor speed. The total path length of the meteor head is about 8 km during this echo.

Table 3 – Data table for Geminid 1

Data point	Δf ± 11 Hz	Δt ± 4 ms	Slope Hz/ms	v_ℓ km/s	r_0 km	v_m km/s
1	204	−222	−0.88	0.569	462	30.7

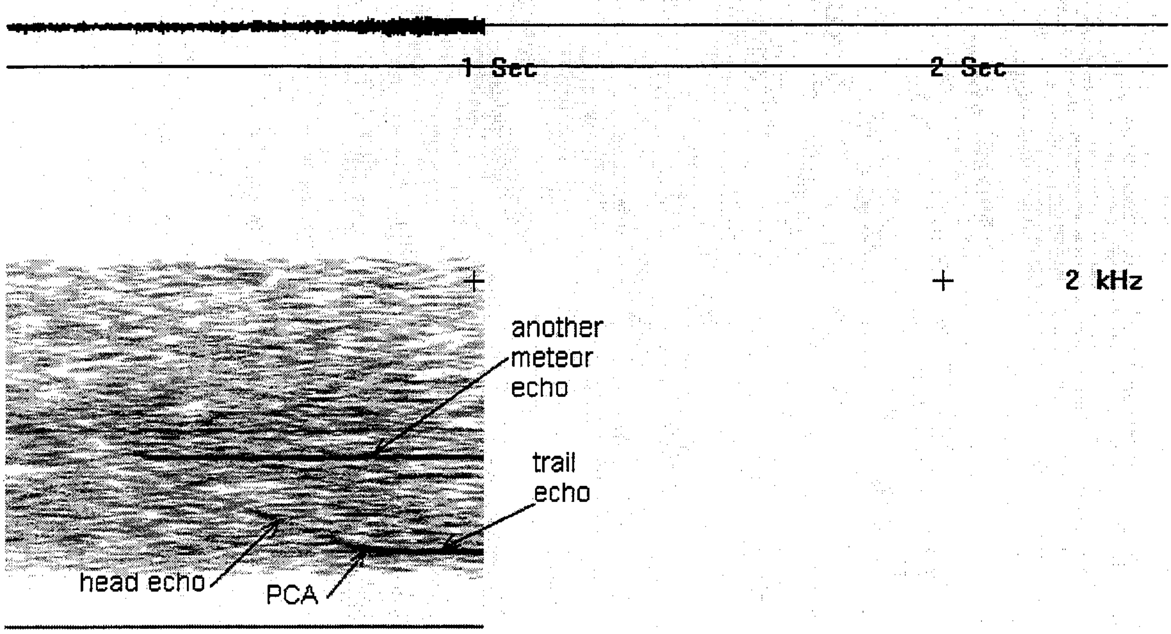


Figure 7 – Audio spectrogram for Geminid meteor recorded at Ferndorf, Austria, on December 13, 1997, at 7^h27^m UT.

PCA point: 480 Hz at 729 ms.

Using an assumed meteor speed of 34.4 km/s:

PCA range: (462 ± 52) km (confidence interval based upon $2 \times$ fractional error derived from instrument errors).

Using an assumed PCA range of (367 ± 200) km:

Meteor speed $v_{\rm m}$: (30.7 ± 8.7) km/s.

Geminid head echo 2

Date: December 13, 1997;
Time: $07^{\rm h}28^{\rm m}$ UT ($08^{\rm h}28^{\rm m}$ LT);
Radiant altitude: 20°;
Radiant azimuth: 298°.

Most probable link: Ferndorf, Austria - Bari, Italy
Link distance: 673 km;
Link bearing: 161° (from receiver);
Relative radiant bearing: 137°;
Transmitter frequency (f_0): 53 760 000 Hz.

Figure 8 shows the audio spectrogram for Geminid 2. This example represents the shortest sweep we attempted to measure: moving from 641 Hz at 585 ms to 490 Hz at 693 ms, for a total sweep of only 151 Hz in 108 ms. The total path length of the meteor (m) is also only about 4 km during this echo.

Table 4 – Data table for Geminid 2

Data point	Δf ± 11 Hz	Δt ± 4 ms	Slope Hz/ms	v_ℓ km/s	r_0 km	$v_{\rm m}$ km/s
1	151	−108	−1.40	0.421	304	37.8

PCA point: 490 Hz at 693 ms.

Using an assumed meteor speed of 34.4 km/s:

PCA range: (304 ± 50) km

Using an assumed PCA range of (367 ± 200) km:

Meteor speed $v_{\rm m}$: (37.8 ± 10.8) km/s.

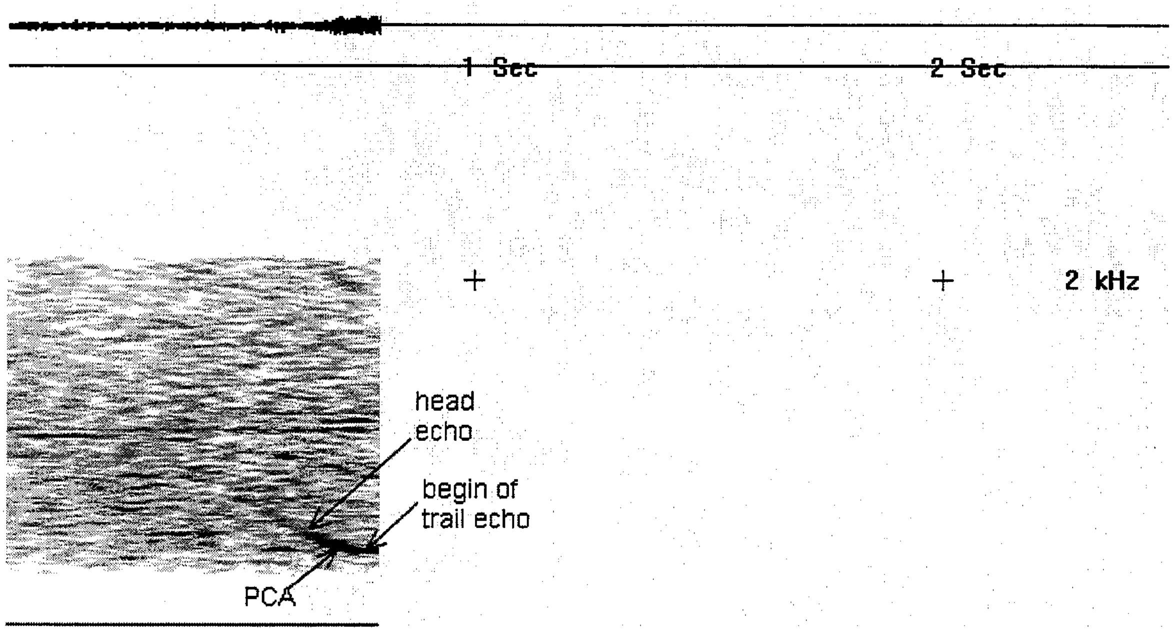


Figure 8 – Audio spectrogram for Geminid meteor recorded at Ferndorf, Austria, on December 13, 1997, at $7^{\rm h}28^{\rm m}$ UT.

A note of caution should be added here about the use of apparently very low frequency sweep, short-duration head echoes. Within about 2–3 km (about 50 ms) of the primary point of trail formation (the first Fresnel zone), the effects of trail formation can impart its own apparent Doppler shift to the reflected signal, interfering with the reflection from the true head echo [1]. Indeed, Manning was criticized for applying his head echo technique to reflections where no true head echo existed—only the Doppler "whistle" from underdense trail formation [3]. Therefore, care should be used in identifying true meteor head echoes, with the sweep extending for at least 100 ms prior to the identified PCA. Also, with the exception of identifying the PCA itself, measurement points should be avoided within about 50 ms of PCA passage because of interference effects due to trail formation [3]. As was mentioned previously, measurement accuracy at such low differences is poor, and such points tend to display outlier behavior.

5. Conclusion

The forward-scatter meteor head echo is a novel and fascinating aspect of the radio meteor phenomenon. It also presents a unique opportunity for amateur radiometeor enthusiasts to make rough meteor range and speed determinations through radio methods. However, without "hard" PCA range information from a separate source, such measurements should be treated with caution and skepticism. In multiple link systems using commercial AM or CW transmitters, measurements are currently limited to the survey of reasonably known shower members only—still with poor accuracy. Despite the low scientific value of the measurements made at this stage, the technique does, nonetheless, open up an interesting new vein for amateur meteor workers to explore. The study has also been an enjoyable foray into the history of the science, adopting an older technique to modern PC based methods.

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Fireballs and Meteorites

Seismograms: a Useful Tool to Understand Meteoroid Airbursts

Luigi Foschini, CNR, FISBAT

The explosion of large meteoroids in the Earth's atmosphere generates shock waves that can be detected by seimographs on the ground. These data are of extreme importance for a detailed study of the original cosmic body. Some notes on the amplitude-yield relation are presented, with particular attention to the "Lugo" airburst of January 19, 1993 (14 kton).

During the last months, there was a wide debate around asteroids and comets impact hazard, caused by two false—even if with several differences—alarms of asteroid impact. Moreover, the release of two movies on this argument has drawn the attention of mass media.

However, in despite of this sensationalism, the impact hazard is a well-known reality. Large meteoroids enter periodically in the Earth's atmosphere: between 1975 and 1992, infrared sensors of the US Department of Defense detected 136 impacts in the Earth's atmosphere with energy in excess of 1 kton of TNT [1]. Sometimes, there can be dramatically spectacular events, such as the 1908 Tunguska explosion, or catastrophic impacts, such as the impact on the Cretaceous-Tertiary boundary, which may have caused the dinosaurs' extinction.

The study of meteoroid airbursts can be our main tool to improve the knowledge of large meteoroid flux, the near-Earth environment, and the meteoroids aerodynamics. Moreover, these studies are important also with respect to the *Comprehensive Test Ban Treaty*, because meteoroid airbursts or meteorite impacts are difficult to distinguish from explosions potentially due to terrorist activity or treaty violations [2].

It is worth to note that during such spectacular events, witnesses' surprise can play an important role. So, visual observations must be handled with extreme care. But dynamic explosive fragmentation of large meteoroids causes also low frequency shock waves, that can be detected by seismic sensors on the ground. For example, seismograms allowed to find, with a good experimental error, the source parameters of the Tunguska explosion [3].

The theoretical background on seismic effects due to airbursts is represented by studies on nuclear tests carried out after the Second World War. However, relations are expressed with empirical formulas, and then the problem is how to reduce formulas to the case of a meteoroid airburst. The problem is very complex, because several random factors, such as local geological conditions, soil characteristics, and atmospheric conditions, must be taken into account.

For sufficiently large meteoroids, up to several meters, ablation at high heights is negligible, so bodies can reach lower heights, with negligible changes in size. When the meteoroid reaches the low atmosphere, the dynamic pressure can be so high to cause an explosive fragmentation [4]. There are several doubts around the interaction of large meteoroids with the Earth's atmosphere, but, here, we want to deal with the ground detection of an airburst.

So we consider an explosion that expands in the surrounding atmosphere with spherical shape. We can consider the source as a radially expanding distribution of vertical forces caused by the overpressure loading of the ground [3].

For an estimate of the explosion energy, we can use the relation for maximum velocity of the displacement of the solid rocks, obtained from studies on underground nuclear explosions [5].

We can then rearrange the equation in order to calculate the energy, when the distance and the displacement velocity are known:

$$E = kD^3 \left(\frac{v}{240}\right)^{12/7}, \tag{1}$$

where E is the explosion energy in kiloton TNT; D is the distance of the sensor from explosion in km; v is the displacement velocity in mm/s. The coefficient k is introduced to take into account that, in order to produce rock displacement, an airburst is less effective than a nuclear undergroud explosion (at least 100 times). Moreover, there also is an energy difference because the explosion of a meteoroid in the Earth's atmosphere does not involve nuclear fission: then we should have an explosion 10 times less powerful. Finally, a little increase of the wave amplitude with the height of the burst up to 40 km must be considered [6]. Taking into account a wave amplitude increase of a little more than 2 times, we can consider a power increase of about 5. So we have that $k = 100 \times 10 \times 1/5 = 200$. Comparable results, with obvious differences, because they deal with meteorite impacts, are obtained by Chyba et al. [2].

Taking into account these data, we have recently re-analyzed the powerful explosion over Lugo (Italy), that can be a useful example for testing these theories [7]. On January 19, 1993, at $0^h33^m29^s$ UT, a large meteoroid impacted over Italy at $\varphi = 44.^\circ48$ N and $\lambda = 11.^\circ91$ E, approximately over the town of Lugo [8–10]. We have data from six seismic stations, located at distances lower than 70 km (a complete set of graphics and other informations are published elsewhere, see [9]). Really, it should be noted that the formula (1) is valid for $D < 100$ km.

We must calculate the frequency spectrum of the seismic signal, mainly because seismographs have transductors in order to convert a mechanical signal into an electric one. Transduction is frequency dependent so, before selecting the correct transduction factor, it is necessary to know the main frequency of the shock wave. However, we have transfer functions only for three stations, belonging to the *Microseismic Network of Ferrara*. Moreover, one station (Fiorile d'Albero) showed a strong background noise coupled to the shock wave, and we can not perform a reliable spectral analysis. Two stations remain, Pontisette and Cà Fornasina. We performed a Fourier analysis of the waveform in order to find the frequency spectrum, and we found a peak located at 1.4 Hz, which corresponds to the airburst (see, for example, Figure 1).

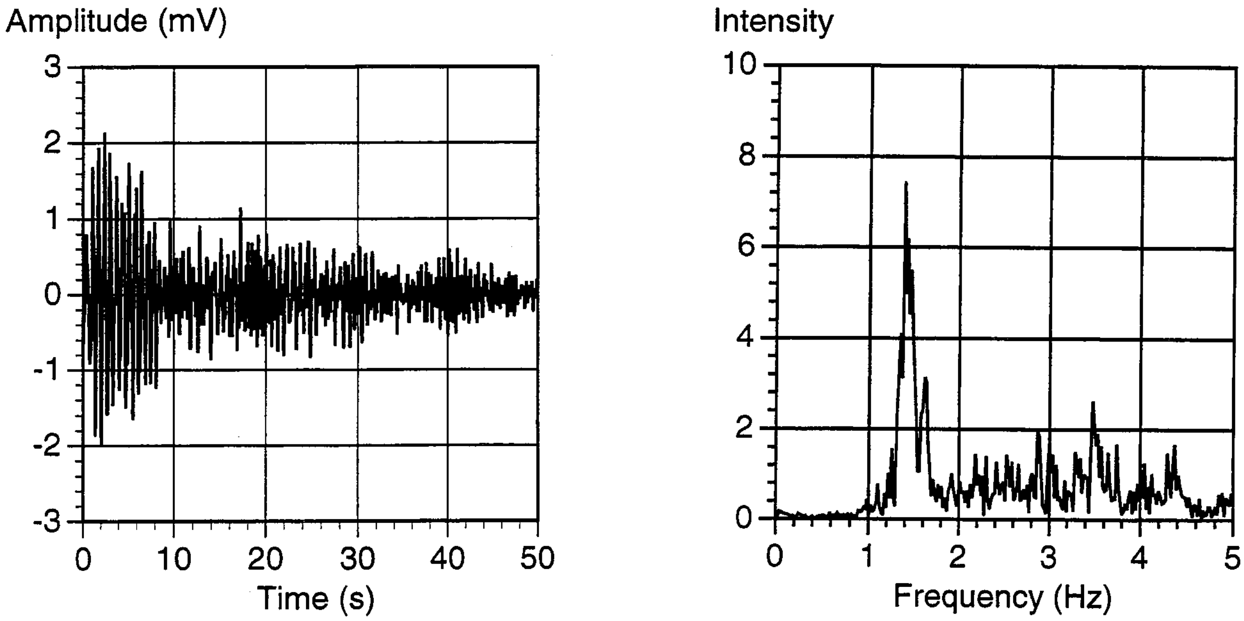

Figure 1 – *Left*: Seismic plot recorded at the Pontisette station. Time starts from $0^h36^m37.^s3$ UT. Further plots can be found in [9]. *Right*: Fourier analysis of Pontisette plot.

The greater the distance from the explosion, the smaller is the fraction of high frequency component remaining in the spectrum. So we can consider the main peak only.

The presence of a main peak, with negligible higher frequencies components, is due to the fact that the attenuation during atmospheric and ground path is frequency dependent: there is a sort of "filtering", but the fundamental frequency is scarcely attenuated [11]. Now, it is possible to calculate the explosion energy with equation (1). Results are shown in Table 1.

Table 1 – Explosion energy calculated from seismic data.

Station	D (km)	v (μm/s)	E (kton)
Pontisette	59 ± 3	41.040 ± 0.002	14 ± 2
Cà Fornasina	63 ± 3	35.369 ± 0.002	13 ± 2

Almost all countries have a national, or local, network of seismic sensors. So, after an airburst, it is useful to record visual observations, but it is better to search for seismic data.

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Meteorite Craters Discovered by Means of Examining X-SAR Images—Part II

Roberto Gorelli

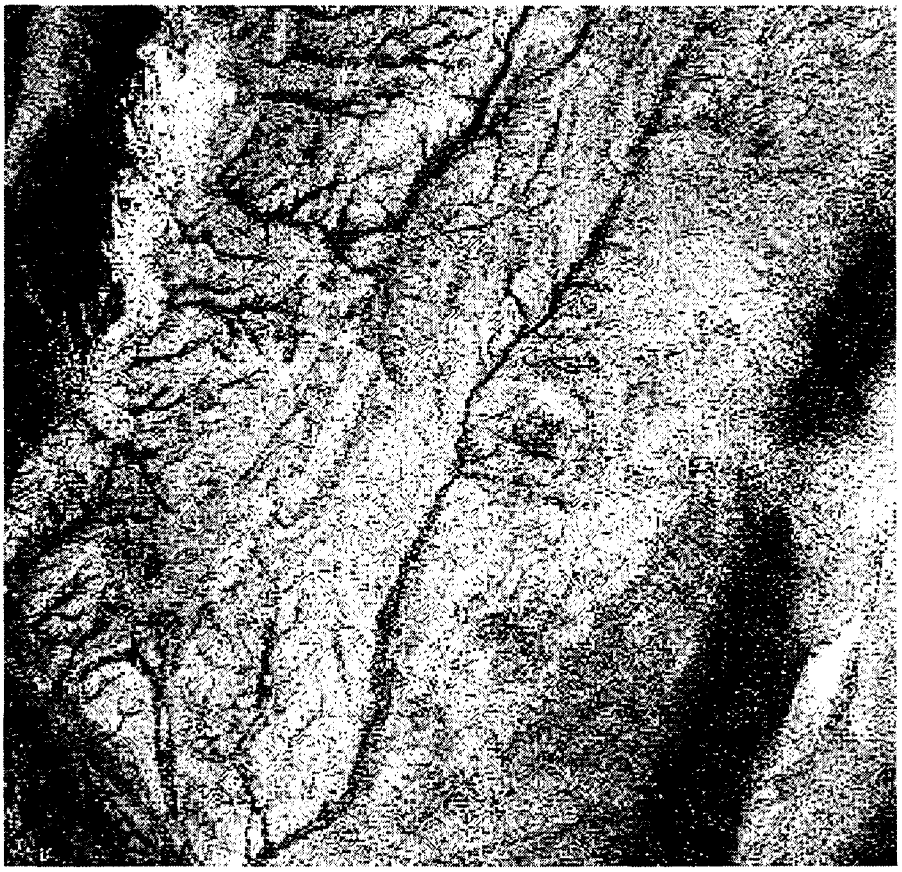

Figure 1 – Craters 7, A (*right*) and B (*left*).

15. *Crater coordinates*: $\lambda = 92^\circ\!.06$ E, $\varphi = 21^\circ\!.48$ N (Bangladesh).

    Diameter: 4.142 km.

    Presumed age: less than 50 million years,

    Reliability: possible.

    Notes: The crater has a very sharp rim which suggests a young age. In the neighborhood, there are three more structures, one with the same size to the south and two smaller, that could be other craters, but some details make the author think that probably their origin is not extraterrestrial. Detached from this group, there is another crater; if this is an impact crater, it must have originated during an other event.

16. *Crater coordinates*: $\lambda = 103^\circ\!.96$ W, $\varphi = 56^\circ\!.42$ N (Saskatchewan, Canada).

    Diameter: 10.264 km.

    Presumed age: 250 million years,

    Reliability: possible.

    Notes: This is perhaps the most problematic structure among the ones presented in this study. Really, there is no evidence of a meteoric origin of this structure, consisiting of an approximately circular lake, with an irregular shape.

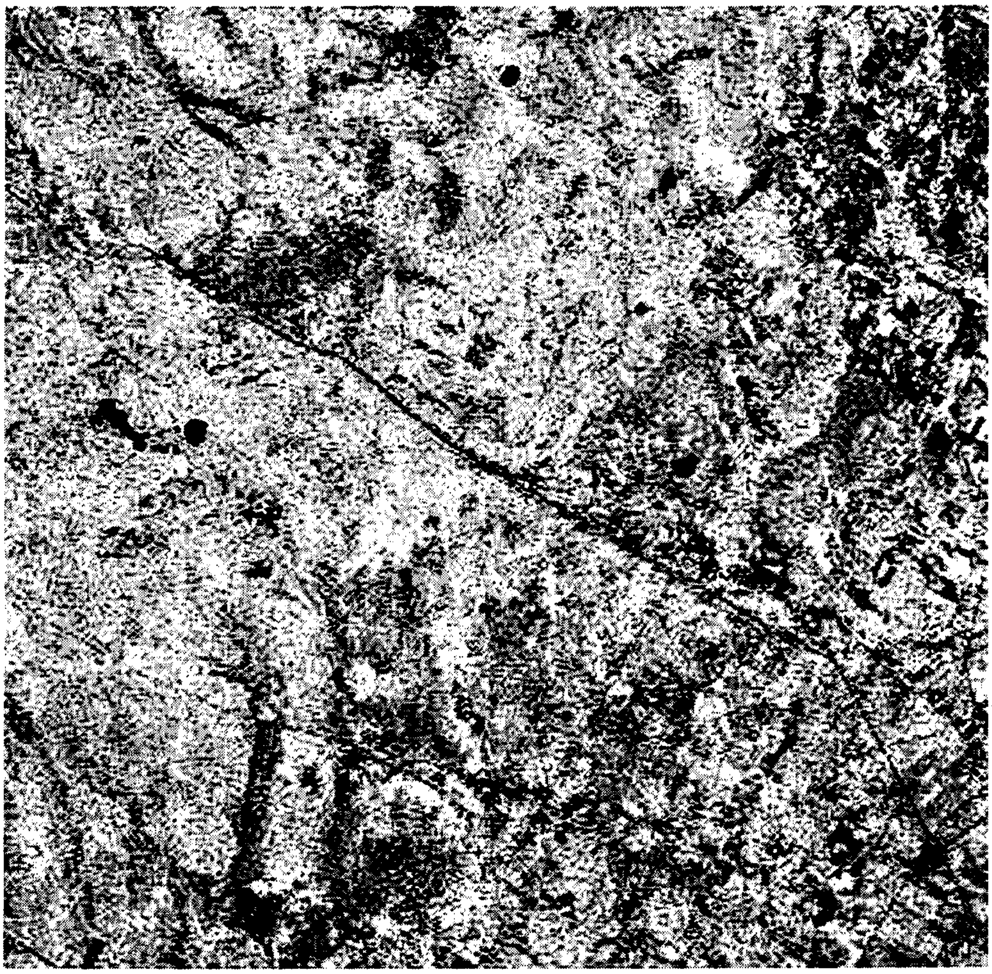

Figure 2 – Crater 13.

The only reason for which it has been included in the present work is because, apparently, it seems to have a remarkable depth—it is deeper than many surrounding lakes in a radius of hundreds of kilometers—and an explanation of its origin does not seem to exist (ablation from part of the glacial cap, tectonic ground subsidence, karst phenomena, etc.). Possibly, Canadian geologists know more about the origin of this lake.

17. *Crater coordinates*: $\lambda = 97^\circ\!.72$ W, $\varphi = 59^\circ\!.05$ N (Manitoba, Canada).

    Diameter: 1.304 km.

    Presumed age: less than 50 million years,

    Reliability: possible.

    Notes: Its size is comparable with that of Meteor Crater in Arizona; apparently it seems to have a remarkable depth with regard to its size. Its origin preceeds the last glacial age, because it shows changes due to at least one glaciation.

18. *Crater coordinates*: $\lambda = 99^\circ\!.65$ W, $\varphi = 54^\circ\!.76$ N (Manitoba, Canada).

    Diameter: 0.95 km.

    Presumed age: less than 10 million years,

    Reliability: possible.

    Notes: Perfectly round crater, though its age can go up to one hundred million years, the author thinks that its age is not exceeding some million years.

Figure 3 – Craters 14, A (*left*), B (*center*), and Rotter Kamm Crater (*right*).

19. *Crater coordinates*: $\lambda = 99.^\circ 94$ W, $\varphi = 54.^\circ 56$ N (Manitoba, Canada).
    Diameter: 1.237 km.
    Presumed age: less than 10 million years,
    Reliability: possible.
    Notes: Same considerations as for Crater 18.
20. *Crater coordinates*: $\lambda = 107.^\circ 79$ W, $\varphi = 55.^\circ 87$ N (Saskatchewan, Canada).
    Diameter: 0.575 km.
    Presumed age: less than 10 million years,
    Reliability: possible.
    Notes: Same considerations as for Crater 18.
21. *Crater coordinates*: $\lambda = 107.^\circ 98$ W, $\varphi = 55.^\circ 85$ N (Saskatchewan, Canada).
    Diameter: 1.341 km.
    Presumed age: less than 10 million years,
    Reliability: possible.
    Notes: Same considerations as for Crater 18. This crater is probably older than the three previous ones, because its origin must be before the last glacial epoch as it has been eroded by ice during the last glaciation.
22. *Crater coordinates*: $\lambda = 95.^\circ 65$ W, $\varphi = 49.^\circ 83$ N (Manitoba, Canada).
    Diameter: 5.741 km.
    Presumed age: less than 50 million years,
    Reliability: possible.
    Notes: Nearly completely filled-up crater, practically invisible from the ground. It can only be perceived because of its slightly elevated rim.

23. *Crater coordinates*: $\lambda = 101^\circ\!.45$ W, $\varphi = 58^\circ\!.60$ N (Manitoba, Canada).

    Diameter: 2.121 km.

    Presumed age: less than 250 million years,

    Reliability: possible.

    Notes: The crater is below the surface, only a chain of lakes can be seen at the surface, showing the round incomplete shape of the crater rim: probably, the crater was created during the formation of the Canadian Shield.

24. *Crater coordinates*: (Crater A) $\lambda = 67^\circ\!.925$ W, $\varphi = 42^\circ\!.29$ S;
    (Crater B) $\lambda = 67^\circ\!.98$ W, $\varphi = 42^\circ\!.28$ S (Chubut, Argentina).

    Diameter: (Crater A) 3.657 km; (Crater B) 2.063 km.

    Presumed age: less than 25 million years.

    Reliability: (Crater A) probable; (Crater B) probable.

    Notes: Crater A shows a flat floor. Its nordwest rim shows considerable erosion. Crater B is a nearly completely filled-up, only its rim is visible.

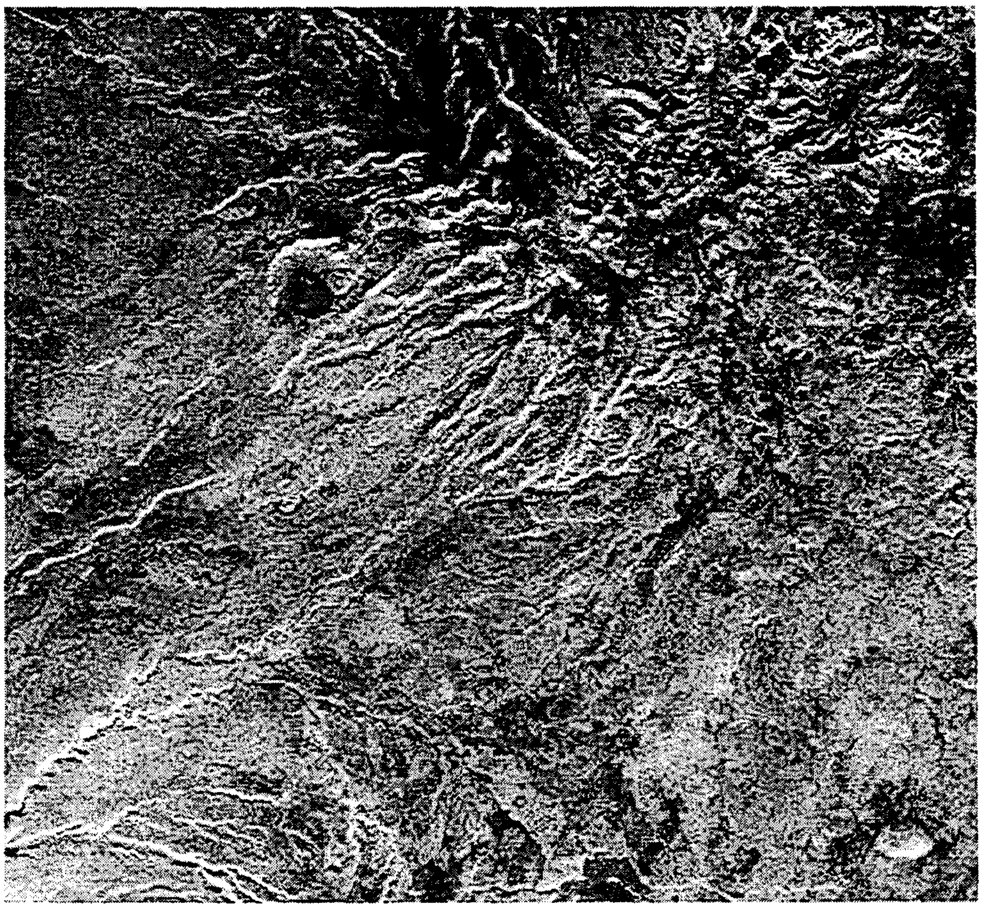

Figure 4 – Craters 24, A (*right*) and B (*left*).

The author reminds the readers that all the craters presented are yet to be identified as such, so it is expected that part of them will turn out to be of terrestrial origin. The author invites the readers capable of doing so to check these craters, because even non-professional researchers can provide valuable help.

The images used in this study have been taken from the Internet site of DLR:

`http://isis.dir.de/XSAR/catalog.html.`

The identification data of the images containing these craters are shown in Table 1. If the reader wants to see a quicklook, he must enter the above site and follow directions using the number of the quicklook, or directly use the address

`http://isis.dlr.de/XSAR/jpeg/qlxxxxx.jpg,`

replacing `xxxxx` by the number of the selected quicklook. Table 2, finally, is a listing of images containing craters of known meteoritic origin.

Table 1 – Identification of the images containing the craters discussed in this study. Notice that image 8 also shows the Al Umchaimin Crater and that image 14 also contains the Rotter Kamm Crater.

Nr.	Quicklook	Time (UT)	Orbit	Coordinates
1	ql00218	Apr 10, 1994, $04^h57^m55^s$	X1 013.00	010°–020° E /30°–40° N
2	ql03574	Apr 13, 1994, $11^h55^m08^s$	X1 066.05	030°–040° E /10°–20° N
3	ql03571	Apr 13, 1994, $11^h54^m34^s$	X1 066.05	030°–040° E /10°–20° N
4	ql10936	Oct 02, 1994, $00^h08^m04^s$	X2 025.50	040°–050° E /20°–30° S
5	ql10936	Oct 02, 1994, $00^h08^m04^s$	X2 025.50	040°–050° E /20°–30° S
6	ql22693	Oct 10, 1994, $02^h23^m46^s$	X2 157.20	100°–110° E /40°–50° S
7	ql19374	Oct 08, 1994, $13^h40^m23^s$	X2 132.30	010°–020° W/10°–20° N
8	ql05737	Apr 15, 1994, $09^h41^m05^s$	X1 097.06	030°–040° E /30°–40° N
9	ql19289	Oct 08, 1994, $13^h22^m17^s$	X2 132.10	090°–100° W/50°–60° N
10	ql02772	Apr 12, 1994, $14^h52^m43^s$	X1 052.03	100°–110° W/50°–60° N
11	ql06122	Apr 15, 1994, $20^h02^m44^s$	X1 104.05	110°–120° W/30°–40° N
12	ql02235	Apr 12, 1994, $02^h49^m09^s$	X1 044.11	020°–030° E /20°–30° N
13	ql02677	Apr 12, 1994, $13^h20^m46^s$	X1 051.32	090°–100° W/40°–50° N
14	ql01690	Apr 11, 1994, $15^h43^m54^s$	X1 036.08	040°–050° E /20°–30° S
15	ql07603	Apr 17, 1994, $06^h05^m29^s$	X1 127.62	090°–100° E /20°–30° N
16	ql04906	Apr 14, 1994, $15^h45^m20^s$	X1 085.01	100°–110° W/50°–60° N
17	ql19291	Oct 10, 1994, $13^h22^m29^s$	X2 132.10	090°–100° W/50°–60° N
18	ql12544	Oct 10, 1994, $15^h03^m30^s$	X2 052.30	090°–100° W/50°–60° N
19	ql12544	Oct 10, 1994, $15^h03^m30^s$	X2 052.30	090°–100° W/50°–60° N
20	ql08022	Apr 17, 1994, $16^h14^m18^s$	X1 134.03	100°–110° W/50°–60° N
21	ql08022	Apr 17, 1994, $16^h14^m18^s$	X1 134.03	100°–110° W/50°–60° N
22	ql02677	Apr 12, 1994, $13^h20^s46^s$	X1 051.32	090°–100° W/40°–50° N
23	ql19286	Oct 08, 1994, $13^h21^m59^s$	X2 132.10	100°–110° W/50°–60° N
24	ql24119	Oct 10, 1994, $19^h06^m30^s$	X2 168.80	060°–070° W/40°–50° N

Table 2 – Identification of images containing craters of known meteoritic origin.

Nr.	Quicklook	Time (UT)	Orbit	Coordinates
Henbury craters, Australia	ql00898	Apr 10, 1994, $18^h00^m26^s$	X1 021.08	130°–140° E/20°–30° S
Munsan, South Corea	ql02306	Apr 12, 1994, $04^h43^m28^s$	X1 045.03	120°–130° E/30°–40° N
Aorounga chain, Chad	ql08374	Apr 18, 1994, $00^h46^m08^s$	X1 140.01	010°–020° E/10°–20° N
Wolf Creek, Australia	ql09285	Apr 18, 1994, $15^h20^m49^s$	X1 149.41	120°–130° E/10°–20° S
BP, Libya	ql12978	Oct 04, 1994, $02^h41^m10^s$	X2 060.10	020°–030° E/20°–30° N
Oasis, Libya	ql16068	Oct 07, 1994, $01^h42^m00^s$	X2 108.10	020°–030° E/20°–30° N

Acknowledgment

The author gives his thanks to Mr. Andrea Pelloni of the *Associazione Romana Astrofili* (Roman Amateur Astronomers Association) for the precious advice given during the preparation of this paper, and for the English translation of the text, originally in Italian, and to the DLR for the authorization to publish some images of its catalogue.

Observational Results

SPA Meteor Section Results: September–October 1997

Alastair McBeath

Information provided to the *SPA Meteor Section* for September and October, 1997, are summarized. Weak Aurigid activity was detected during September, and a widely-seen fireball was observed from sites across northern England and Scotland on September 23. Early October brought possible indications of weak Draconid activity, and some Orionids were apparent from a few sites. Radio observing continued to provide useful details throughout both months.

1. Introduction

The Moon presented serious difficulties for observers throughout the fall of 1997 for the major showers, although even so, some observers were not deterred by this, or the sometimes difficult weather conditions, notably near the Orionid peak in October. No photographers have so far reported any details from either month to us, a reflection of the generally poor sky conditions during October. Our overall observing totals are shown in Table 1.

Table 1 – Visual and radio hours' totals, visual meteor numbers, recorded in each month, including a partial breakdown of visual meteor types.

Month	Visual	DAU	SPI	AUR	TAU	Meteors	Radio
September	$115^{h}_{.}1$	76	107	–	–	1199	3022^{h}
October	$194^{h}_{.}5$	8	–	325	220	1832	3465^{h}

Forward-scatter radio results were extracted from *Radio Meteor Observation Bulletins* (*RMOB*s) 50–52 (October–December 1997, inclusive), thoughtfully provided by Chris Steyaert. The observers included Enric Fraile Algeciras (Spain), Maurice de Meyere (Belgium), Ghent University (Belgium), Werfried Kuneth (Austria), Sadao Okamoto (Japan), Chikara Shimoda (Japan), and Ilkka Yrjölä (Finland). As normal, our standard practice for examining raw forward-scatter data was followed. The graphs selected for display here are representative of those available.

Visual data were received from the following observers:

> *AKM* members Rainer Arlt, Robert Gehlhaar, Matthias Growe, Wolfgang Hinz (Czech Republic), André Knöfel, Sylvio Lachmann (Czech Republic), Hans-Jörg Mettig (Czech Republic), Sirko Molau, Sven Näther, Jürgen Rendtel, Petra Rendtel, Janko Richter (Czech Republic), Thomas Schreyer (Czech Republic), Harald Seifert (Czech Republic), Manuela Trenn, Oliver Wusk, Hans-Georg Zaunick (Czech Republic); all in Germany only, except where noted; details taken from *Mitteilungen des Arbeitskreises Meteore* 11 and 12 (1997), kindly submitted by Ina Rendtel, *Astroclub Canopus* members Nikolay Dobrev, Ivo Genchev, Katja Koleva, Maria Koleva, and Valentin Velkov; all in Bulgaria; full details provided by observer Eva Bojurova, Jay Brausch (North Dakota, USA), Shelagh Godwin (England), Chris Hall (England), Alastair McBeath (England), the Petnica Meteor Observing Group (Yugoslavia; data summarized by observer Vesna Slavkovic), and Graham Wolf (New Zealand).

2. September

Low visual rates of α- and δ-Aurigids were noted in early September, but there was no longer any clear sign of the possible minor "Arietid" radiant in the plotted meteor data available, found in late August [1]. Poor weather in the opening days of the month did nothing to assist observers trying to cover the expected Aurigid maxima, and only the radio results give indications of these around $\lambda_{\odot} = 159°–160°$ and $\lambda_{\odot} = 163°–165°$ (see Figures 1 and 2; all solar longitudes used here are for eq. 2000.0). Further weak Aurigid rates were seen into October after this. Jay Brausch reported several casual δ-Aurigids during his auroral observations on September 27, for example.

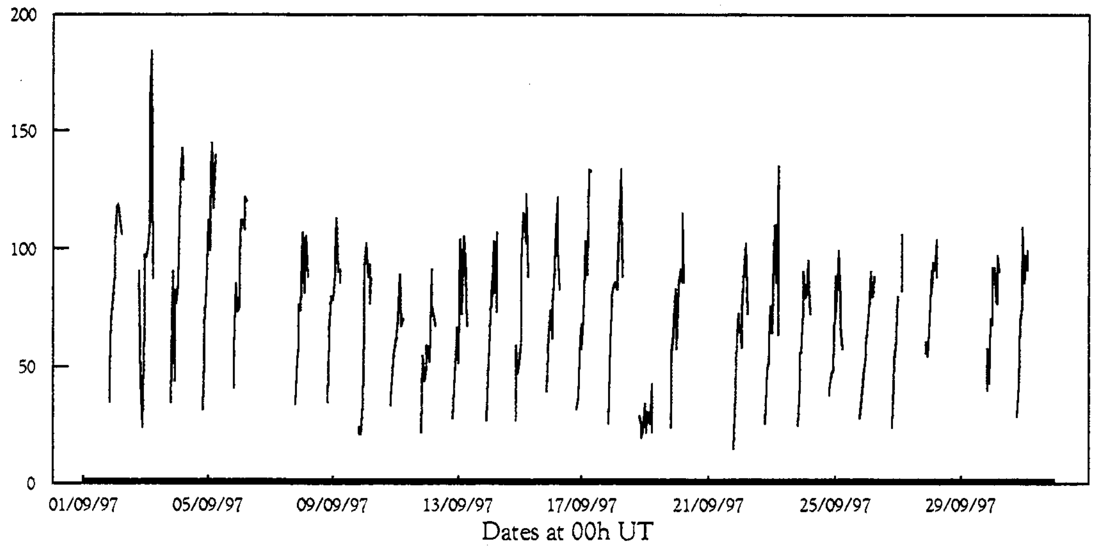

Figure 1 – Raw hourly radio meteor echo counts from September 1997, from data collected by Maurice de Meyere. Maurice's set-up was generally operated for around 11 hours a day, between 20^h and 6^h UT. Gaps are largely due to non-operation of equipment, but a few minor breaks in late September are because of Sporadic-E (Es). A main peak at $\lambda_\odot = 159°–160°$ was seen in almost all datasets for this month, along with the wave-like "roll" in activity around mid-month. Note that x- and y-axis scales vary between the graphs shown here.

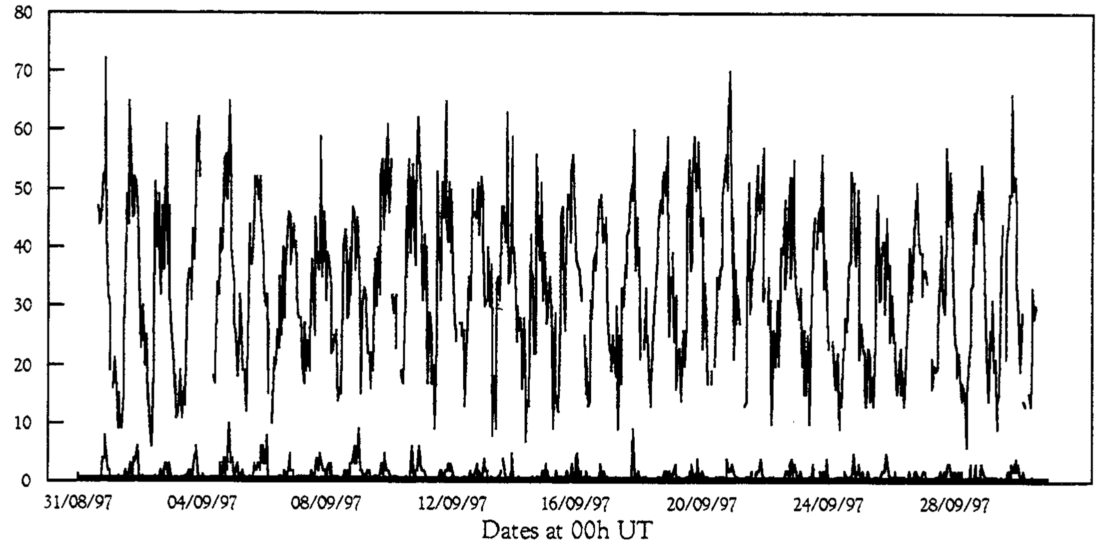

Figure 2 – Raw hourly radio meteor echo counts from 1997 September, recorded by Sadao Okamoto. Sadao's set-up was continuously active, thus all breaks result from either atmospheric phenomena or equipment failure (almost all in the former category). The upper line illustrates all echoes detected, while the lower one shows just echoes whose duration was at least 5 s. Similar trends to those in Figure 1 are obvious, with more long-duration echoes apparent during the first eleven days of September.

Although full Moon accounted for much of the best from the Piscids, the total lunar eclipse on September 16 afforded two observers in Germany—Sven Näther and Oliver Wusk—a chance to see what was happening meteorically during the darkest phase of totality, at least for a short while.

Several fireballs were reported during the month, the most widely-seen being that of September 23, which occurred around 7^h56^m UT, in daylight. It was reported from numerous sites across Scotland and Northern England, and was clearly a brilliant object which most witnesses suggested was yellow-orange in color. The reports received were often vague and contradictory, but the most likely trajectory was from roughly east to west across northern Scotland, perhaps near latitude 57° North. Many thanks are due to all the correspondents who provided reports, summaries and news cuttings of this event, including Brian Kelly, John Lambert, Tony Markham, and Don Simpson.

Minor radio peaks found in [2] confirmed again in 1997, and not already mentioned, included those at $\lambda_\odot = 168°$–$169°$ (weak), $\lambda_\odot \approx 170°$ (weak, and possibly extended to $\lambda_\odot \approx 171°$), $\lambda_\odot = 172°$–$173°$, $\lambda_\odot = 176°$–$177°$ (extending to $\lambda_\odot \approx 178°$ in most datasets available), $\lambda_\odot = 180°$–$181°$ (but noted only by European observers), $\lambda_\odot \approx 183°$ (not confirmed by all observers), and $\lambda_\odot = 185°$–$187°$.

3. October

Early October saw several groups and individuals out hunting for any Draconids that might appear. Unfortunately, most were disappointed. Weak possible rates of visual Draconids were seen in the Netherlands (comments from Marco Langbroek on his own observations and those of Koen Miskotte), Germany, and Bulgaria, perhaps comparable to the combined Taurid rates at the time (ZHRs of 5 ± 3) at very best on October 6–7 and 8–9. However, the vast majority of radio data (see Figures 3 and 4) showed virtually no confirmation of the potential very weak maximum found in [2] around $\lambda_\odot = 195°$–$196°$. By contrast, the minor peak at $\lambda_\odot = 190°$–$192°$ was detected again by most radio observers. It seems likely that most of the "Draconids" in 1997 were simply sporadics lining up with the radiant area by chance. Low Taurid rates continued to be seen during the remainder of October, but without any significant fireballs reported from late month.

The Orionids proved difficult to quell, even with strong moonlight, although this reduced the number of meteors available for accurate analysis significantly. Despite this, we have managed to construct a global magnitude distribution from those meteors seen under better skies, as shown in Table 2.

A train distribution for the shower proved less practical, as many observers did not submit complete train details, but from those that did, 30.9% of Orionids and 3.1% of October sporadics left persistent trains.

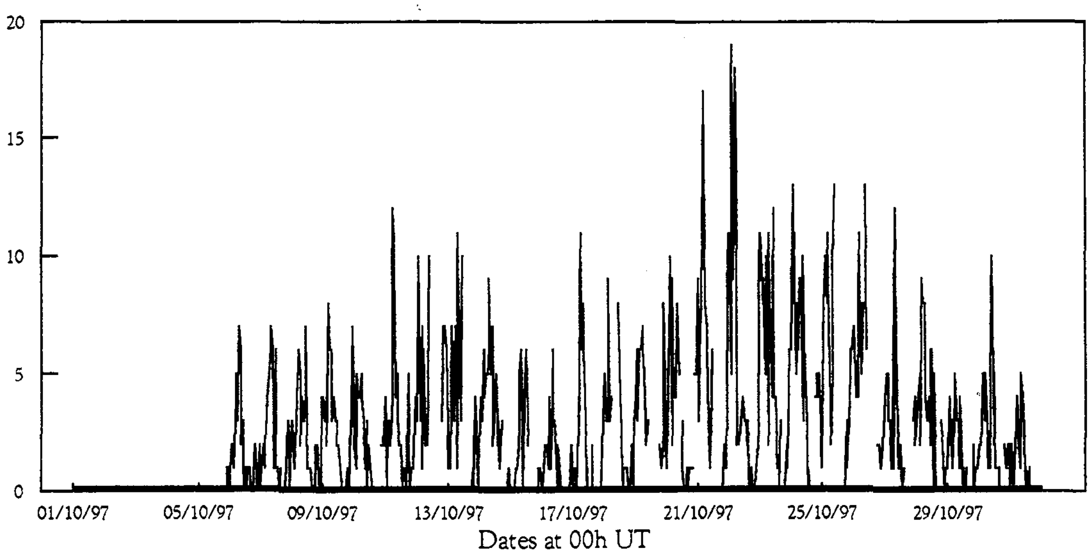

Figure 3 – Raw hourly long-duration radio meteor echo counts (duration of more than $6^{s}.5$) from October 1997, as reported by Werfried Kuneth. Werfried endeavored to operate his set-up almost continuously after 20^{h} UT on October 5. Some gaps due to Es and other atmospheric interference are apparent, but the longer gaps are generally because of equipment down-time. The Orionid "bulge" is nicely shown by these long-duration echo counts, though the mild enhancement around October 11–13 is not seen in all datasets.

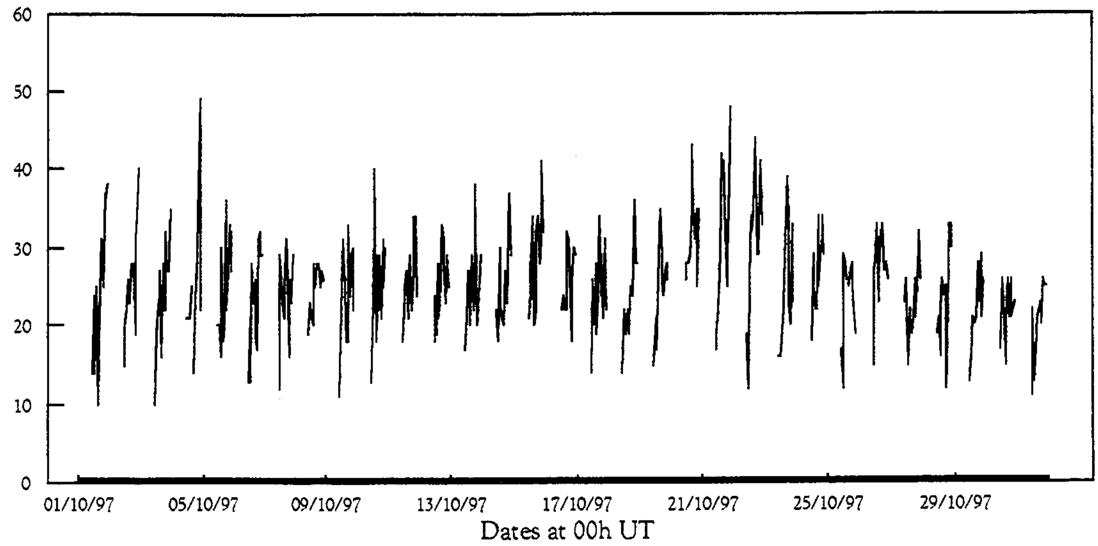

Figure 4 – Raw hourly forward-scatter echo counts during October 1997, in data collected by Chikara Shimoda. Chikara's observations were carried out normally for 12 hours a day, between 11^h and 22^h UT. An enhancement around $\lambda_\odot = 191°$–$192°$ was seen in most radio data from early October, though this graph shows the feature most obviously. The Orionids gave a relatively weaker showing from Japanese radio sites, but still produced a noticeable "hump" around October 21.

Table 2 – Global magnitude distributions, including mean limiting magnitudes and corrected mean magnitudes for the Orionids and October sporadics seen in good sky conditions.

Shower	-3^-	-2	-1	0	$+1$	$+2$	$+3$	$+4$	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
ORI	0.5	0.5	8	25	16.5	42	50	9	1.5	153	5.87	2.51
SPO	16	5	30	41.5	48	113.5	122.5	42.5	7	426	5.76	2.49

Best estimates of the peak Orionid ZHRs on October 21 came from the Petnica observers, and were around 20–30. At Petnica, during the Orionid observing camp, a superb, complete 22° lunar halo was seen in hazy clouds that otherwise prevented observing one night, which was at least some reward for the observers then—and a reflection of the often poor weather.

From the radio data, the Orionids were certainly clear enough, and the entire $\lambda_\odot = 201°$–$212°$ period found previously to show significant enhancements in echo counts was again very noticeable. The weak $\lambda_\odot \approx 199°$ peak was confirmed in several datasets, but seemed spread over $\lambda_\odot = 198°$–$199°$ on this occasion.

Acknowledgments

Naturally, my grateful thanks are extended to all contributors during these two months. It is always in such difficult times that we find out who the really dedicated observers are. Good luck with your next observations!

References

[1] A. McBeath, "SPA Meteor Section results: July–August 1997", *WGN* 26:2, April 1997, pp. 97–102.

[2] A. McBeath, "The Forward Scatter Meteor Year", in *IMC Proceedings* 1997, Petnica, Yugoslavia, A. Knöfel and A. McBeath (eds.), IMO, 1998, pp. 39–54.

SPA Meteor Section Results: November–December 1997

Alastair McBeath

News and observing details sent to the *SPA Meteor Section* for November and December, 1997, are presented. Poor weather and moonlight created severe problems in both months, and other than bright fireballs on December 1 (UK) and 9 (Greenland), the most useful reports were from radio observers. A radio Leonid maximum around $\lambda_\odot = 235\overset{\circ}{.}13$–$235\overset{\circ}{.}17$ (eq.2000.0, 10^h–11^h UT on November 17) can probably be inferred, and a Geminid peak at about its expected time on December 13 was probably detected, too. The Ursids produced only a weak radio signature in the received data, so most likely produced no unusual rates this year.

1. Introduction

Some dismal weather, combined with Full Moon for the major shower maxima, held visual observing well in-check during both months, and the bulk of data received was from the radio observers. Table 1 illustrates the observing totals achieved. Unfortunately, even the radio data collection was not without problems, with various atmospheric effects making monitoring the Leonids exceptionally difficult in November. As for photography, just one photographer has reported any details as yet, Valentin Grigore in Romania, who secured one probable Taurid fireball trail during an eleven-minute exposure of the morning zodiacal light in Leo on November 2.

Table 1 – Visual and radio hours' totals, visual meteor numbers, recorded in each month, including a partial breakdown of visual meteor types.

Month	Visual	TAU	LEO	GEM	URS	Meteors	Radio
November	$30\overset{h}{.}4$	38	25	–	–	281	3982^h
December	$37\overset{h}{.}1$	–	–	51	23	330	3970^h

A large part of the forward-scatter radio results were obtained from *Radio Meteor Observation Bulletins* (*RMOB*s) 52–54 (December 1997 to February 1998, inclusive), kindly submitted by Chris Steyaert. The observers included the following:

> Enric Fraile Algeciras (Spain, *RMOB*), Michael Boschat (Canada, *RMOB*), Giorgio Bressan (Italy, *RMOB*), Eisse Pieter Bus (the Netherlands, *RMOB*), Norman Davis (California, USA, *RMOB*), Maurice de Meyere (Belgium, *RMOB*), Ghent University (Belgium, *RMOB*), Werfried Kuneth (Austria, *RMOB*), Kimio Maegawa (Japan, *RMOB*), Sadao Okamoto (Japan, *RMOB*), Chikara Shimoda (Japan, *RMOB*), Robert S. White (UK), Ilkka Yrjölä (Finland, *RMOB*), Wim T. Zanstra (the Netherlands, *RMOB*).

Normal practices for examining raw forward-scatter data were followed, as usual, and graphs selected for display representative of those available. Visual data were received from the following observers:

> *AKM* members Rainer Arlt, Matthias Growe, Sylvio Lachmann, Sirko Molau, Sven Näther, Jürgen Rendtel, Petra Rendtel, Janko Richter, Thomas Schreyer, Harald Seifert, Manuela Trenn, Björn Vob, Oliver Wusk; all in Germany; details extracted from *Meteoros* 1 (1998), thoughtfully provided by Ina Rendtel, Jay Brausch (North Dakota, USA), Alastair McBeath (England).

2. November

Visually, the month was a near-disaster, with some very poor skies preventing watchers from properly monitoring the Taurids or Leonids. Indeed, if it had not been for the efforts of Sirko Molau in Germany, working under difficult conditions on November 16-17 and 17-18, no visual Leonids would have been reported to us at all! Some compensation for the Bulgarian observers at Avren Village during their clouded-out Leonid observing camp was the sighting of a wonderful 22° lunar halo on November 14. Valentin Velkov managed to take some excellent photos of this, which show just the slightest hint of colors.

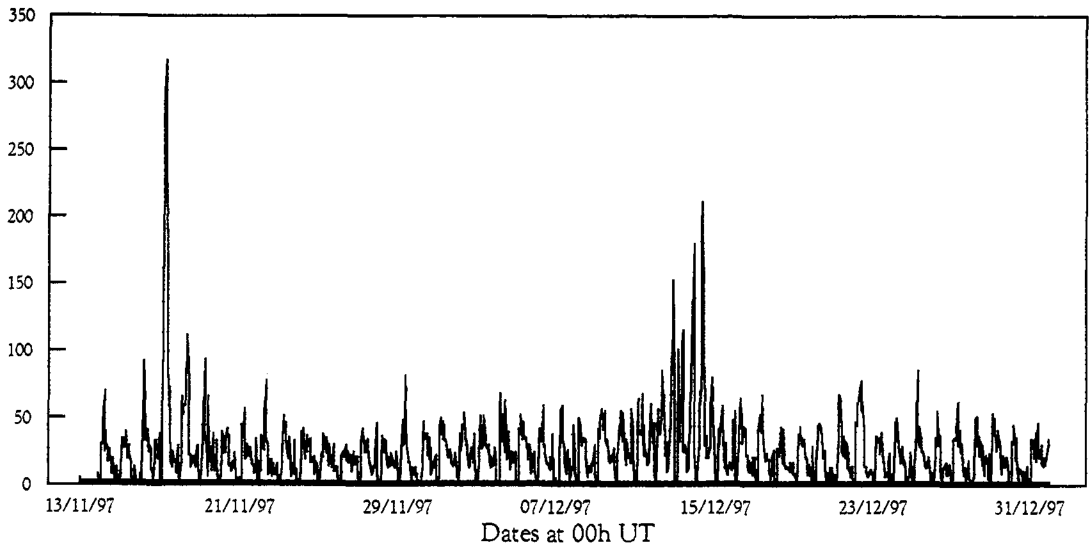

Figure 1 – Raw hourly radio meteor echo counts from November and December, 1997, from data collected by Robert S. White. Robert operated his equipment continuously throughout this time, from $21^{h}00^{m}$ UT on November 13. Robert's data are among the very few from November not affected by atmospheric interference. The Leonid, Geminid, and, to a lesser extent, Ursid, maxima can all be clearly seen.

One curious Leonid report was forwarded by Jürgen Rendtel. This suggested that Masao Kinoshita had caught a two-second outburst of Leonids on video from Hawaii, between $13^{h}31^{m}51^{s}$ to $13^{h}31^{m}53^{s}$ UT on November 17. The e-mail notes mention that over 100-150 meteors had appeared in a very small area of the field of view (less than 10°) for those two seconds, with meteors between magnitudes -2 to $+4$. Unfortunately, attempts to find confirmatory reports, or even to view or analyze the video tape, have so far met with no response, so the report should be treated with due caution.

Consequently, the vast majority of useful data came from the radio observers. Regrettably, atmospheric and equipment problems for many have meant the detailed analysis that was possible last year [1] cannot be repeated for 1997. The overall trends in radio activity from mid-November through December can be seen in Figure 1.

The Leonids were extremely obvious in most datasets that cover the shower's expected peak date, and the majority show a single clear maximum, which is generally coincident (to within $\pm 1^{h}$–2^{h}) with the time of the radiant's culmination for any given location. Those European and North-American observations continued throughout the day on November 17 show suggestions of two or more echo-count maxima during the Leonid radiant's visibility, while the Japanese data give just a single peak during the equivalent period. Breaks in the data and the fact that the lesser maxima are often only weakly apparent, have made pinning down a possible time quite difficult. However, the American and European data all suggest a non-culmination maximum around 10^{h}–$11^{h} \pm 1\overset{h}{.}5$ UT on November 17 ($\lambda_{\odot} = 235\overset{\circ}{.}13$–$235\overset{\circ}{.}17 \pm 0\overset{\circ}{.}06$). Although this result is close to the expected peak around 11^{h} UT on November 17 [2], it should not be treated as anything more than a probable maximum time. All datasets that covered sufficiently beyond the Leonid maximum found the $\lambda_{\odot} = 233°$–$235°$ peak from [3] extended to at least $\lambda_{\odot} \approx 236°$ in 1997, and a few were still showing marginally enhanced counts at $\lambda_{\odot} \approx 237°$.

Concerning the other minor radio meteor peaks that recurred compared to those in [3], caution must again be exercised owing to the sometimes patchy nature of the radio coverage possible this November. However, some confirmation was possible for the following solar longitude peaks: $\lambda_{\odot} \approx 219°$ (weak), $\lambda_{\odot} \approx 224°$, $\lambda_{\odot} \approx 227°$ (strongest in Japanese data), $\lambda_{\odot} \approx 230°$ (nothing unusual was found at $\lambda_{\odot} \approx 229°$; this perhaps represents a slight shift, or may be due to the rounding-off procedures used in calculating the solar longitude), $\lambda_{\odot} \approx 238°$ (some datasets show a minor peak at $\lambda_{\odot} \approx 239°$ instead), and $\lambda_{\odot} = 240°$–$248°$ (very weak, except in Japanese data).

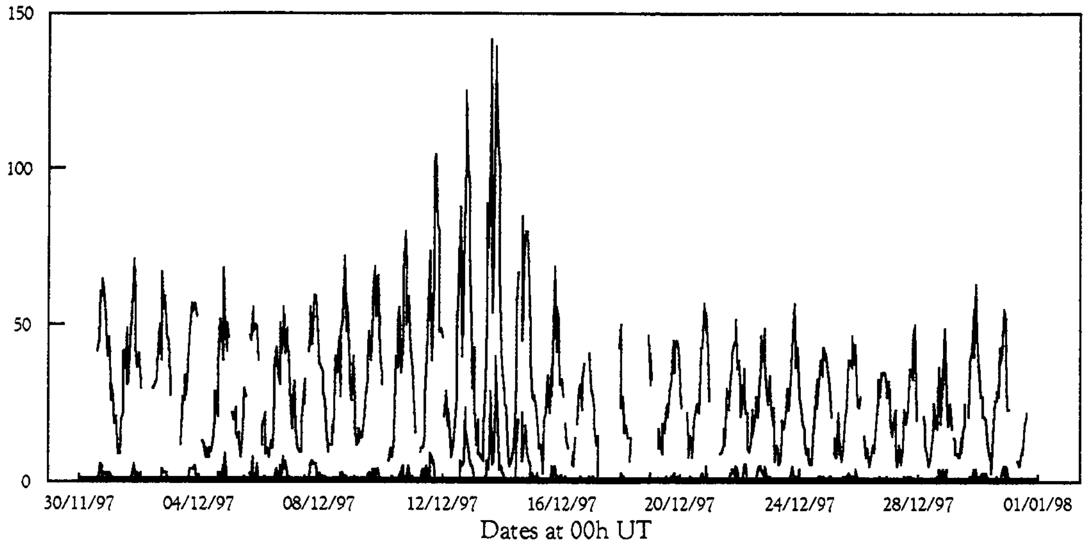

Figure 2 – Raw hourly radio meteor echo counts from December 1997, recorded by Sadao Okamoto. Sadao's set-up was continuously active, thus all breaks result from either atmospheric phenomena or equipment failure (almost all in the former category). The upper line illustrates all echoes detected, while the lower one shows just echoes whose duration was at least 5 s. Note the almost identical appearance of the Geminids in the "all echoes" trace, compared to Figure 1. The Ursids were only recorded very weakly from Japan, though the longer-duration echoes show a very small enhancement on December 22 and 23.

3. December

The majority of visual reports came from the opening ten days or the closing five of December, with the bulk of the Geminid epoch completely lost to bright moonlight. A few Ursids were seen, but observing was hampered, as so often, by the weather. Only Jay Brausch managed any watching on December 22 for this shower, taking advantage of some very mild conditions at his site (temperatures were $-5°$ C to $-8°$ C then; more usually, they are $-20°$ C or below).

The major visual events were two fireballs. The first was on December 1 at around $20^{\mathrm{h}}25^{\mathrm{m}}$ UT, and was seen from at least five sites across northern England. It was of perhaps magnitude -7 to -10 or more (in one instance, it was seen from a floodlit football stadium, although no stars could be seen from there), and was almost certainly out over the North Sea, heading roughly south to north. It left a trail of glowing fragments, and broke up completely late in its flight.

The second event was a brilliant bolide over Greenland around $8^{\mathrm{h}}11^{\mathrm{m}}$ UT on December 9. Many people will doubtless have seen some of the, in places highly speculative, items on this that appeared in the media and on the Internet within days of the object's occurrence. Looking through the various reports kindly submitted by Section correspondents (especial thanks are due to Jack Keiser, John Lambert, Peter McBeath, and Dave Newton for their time and trouble), it seems the initial description of the event as an impact of supposedly Tunguskan proportions was wildly inaccurate. Indeed, it is highly probable that no impact of any significance took place at all, judging by the available evidence. A useful summary of this evidence is given in [4], although even this reference indulges in speculation about the event being an impactor, not simply a meteor, as well as whether it was due to the "annual Geminid meteor storm" (sic).

Passing on to the radio results, both the Geminid and Ursid epochs were reasonably well-covered (see Figures 1 and 2), but still with some problems from atmospheric interference. The Geminid maximum time has not been easy to exactly identify, as there is no clear consensus between European observers, but a peak sometime between 20^{h} and 2^{h} UT on December 13-14 is most likely. The radiant's culmination at about 2^{h} UT from Europe then has not made matters easier, certainly, but a maximum about as expected is implied. The effect of the Geminids on the observed echo counts was clear in all the appropriate datasets between $\lambda_\odot = 258°$ and $\lambda_\odot = 263°$, much as usual.

A minor peak is also apparent in echo counts in time to the Ursids on December 22 and 23 in the available data ($\lambda_\odot = 269°$–$270°$), which perhaps suggests the shower did not produce anything unusual this year. Other minor radio peaks from [3], confirmed this year, included those at $\lambda_\odot = 249°$–$250°$ (weak, and chiefly in the Japanese data), $\lambda_\odot \approx 254°$ (one dataset only), $\lambda_\odot \approx 257°$ (but not at $\lambda_\odot \approx 256°$ as previously found), $\lambda_\odot = 265°$–$267°$ (very weak, and not all datasets show this), $\lambda_\odot = 272°$–$275°$ (especially $\lambda_\odot \approx 273°$), and $\lambda_\odot \approx 278°$ (weak). In addition, three (possibly four) of the active six observers reported a minor peak around $\lambda_\odot = 252°$ not found earlier.

Acknowledgments

As always, I am happy to send many thanks to all observers and other contributors to this report. Good luck and clear skies for next time!

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Conferences and Events

Perseide '98, July 21–August 15, 1998

Valentin Grigore

The Romanian Society for Meteors and Astronomy (*SARM*) will organize between July 21 and August 15 the sixth edition of the international astronomical event entitled *Perseide* (Perseids). This event touches upon astronomy, culture, art, education, and society in general, and has meteor work as its focus. This edition is very important for those persons wishing to prepare for observing the total solar eclipse op August 11, 1999, in Romania.

The program is divided in three parts. The first part is centered around Targoviste, 80 Km north of Bucharest, and consists of the National Camp of Meteors and General Astronomy, July 21–August 3 (summer school, observations, cultural and touristic activities, program for the general public) and Astro-Art '98, July 30–31 (colloquium, workshop on the eclipse, cosmopoetry festival, astro-art exhibition). The second part consists of an expedition to the totality line of the 1999 total solar eclipse (August 3–7). The third part, finally, is an expedition to the Carpathian Mountains to observe the Perseid maximum, August 8–14.

The *SARM* will support a part of the organizational costs, so the fee will be only

- 180 USD per person for the first part (July 2–August 3);
- 250 USD per person for the second part (August 3–7); and
- 180 USD per person for the third part (August 8–14).

For people interested in the first two parts only, there is a package deal of 350 USD. Special arrangements can be made for participants on a very tight budget.

Any contribution for the *Perseide '98* is welcomed. Such contribution could consist of courses during the camp (epecially meteors, eclipses, CCD, techniques, etc.), lectures at the colloquium, exchanges of experiences, information, and various materials regariding your activity or association, etc. We also welcome artistic initiatives: photographs, poetry, posters, music, publications, proposals, greetings, etc.

Interesting people can contact Valentin Grigore, CP 14, OP 1, Targoviste, R-0200, Dambovita, Romania, phone +40-45612573, e-mail: `sarm@minisat.canad.ro`.

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Addresses of authors not mentioned above

J. Richardson, Route 2, Box 118, Graceville, *Florida, USA*
L. Foschini, FISBAT/CNR, via Gobetti 101, I-40129, Bologna, *Italy*
R. Gorelli, Via di Val Favara n. 72, Pal. B, I-00168 Roma, *Italy*
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