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This magnitude −4 Geminid was photographed by the *Delphinus* team of the *Dutch Meteor Society* in Camelopardalis/Lynx on December 14, 1996, at $4^h48^m49^s$ UT, from Biddinghuizen, the Netherlands. The photograph was exposed from 4^h47^m till 5^h07^m UT.

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

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Contents

Useful Information

The April Issue *(WGN 25:2)*

The *April issue* will be mailed during the second week of April. Contributions are due on *March 21* 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 should be sent to *Paul Roggemans*. Complaints about not receiving *WGN* should be addressed to *Marc Gyssens*.

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

From the President

Jürgen Rendtel

For most meteor observers, 1996 was another very interesting year. Almost all "considerable" showers could be followed without too much moonlight interference. The persistent appearance of the early Perseid peak seems to become a "regular" feature, but its rates gradually decrease, and we have to find out more about this tendency in 1997. On the other hand, the increase of the Leonid activity and the reported peculiarities indicate that the eagerly awaited activity peaks will occur in 1998 and perhaps 1999.

In 1997, however, the Moon will severely disturb almost all remaining meteor shower maxima. Speaking for optical observers, we should make use of the other periods, then. During the recent years, we have seen quite some unusual events in those "less interesting" periods. This holds for all optical observing techniques—so I would like to encourage more regular observing efforts during all clear, moonless periods.

During the 1996 IMC, *we saw results from established and refined techniques, but also experiments with less known methods and effects. Like in every branch of science, it is important to check "unknown" solutions, and to share negative as well as positive results with other observers as it happened, for example, during the discussions at the* IMC. *It is no secret at all, that the talks and the relaxed atmosphere during the meteor conferences are one of the major sources for new ideas and projects. So I hope to meet many of you also at the 1997* IMC.

However, not only do the observers try out new techniques; the IMO *also has to provide guidance and support in those branches where most results are produced or are to be expected.*

While the start of a new year is an occasion to look forward, it does not harm to reflect on our young history, too. In retrospect, it turns out that the major backbone of the IMO*'s activities has always been the personal correspondence among its members. Do not forget this, particularly because I think almost any form of correspondence is much easier and faster now than a decade ago.*

Last but not least, I would like you to think about giving more feedback to the Council, to the Commission Directors, and to our journal WGN *so that we know better what is regarded useful and what can be improved.*

I wish all members and friends of the IMO *a healthy, peaceful year, and, of course, good luck with all their plans.*

From the Editor-in-Chief

Marc Gyssens

I can only join our President in his wishes to you and in the reflections he makes, and, thus, I am not going to repeat his words. However, I wish to expand a little bit on his suggestion to you to provide more feedback to us.

One of the major weaknesses of the IMO *is that too many tasks rest on too few shoulders. Perhaps, in this respect, the Organization is a victim of its own success. Members have the impression everything runs smoothly, and, therefore, they feel no urge to "interfere." For the sake of continuity, however, this is not a healthy attitude. More members need to get involved in the operational aspects of the* IMO. *One aspect of achieving this goal is that more members should let us know their wishes and opinions, as the President made clear. Another aspect, however, is that more members participate in running the organization, so I want to encourage anyone who wants to help in this respect to make him- or herself known to any one of the Council members!*

As you can see, this is again a thick issue, with a large variety of subjects covered. To two of them, I want to point special attention. One is a contribution by Dr. Sauval on Adolphe Quetelet, a most remarkable and versatile 19th century Belgian scientist, founder of the Royal Observatory of Belgium, who made important contributions to meteor astronomy. The second concerns a platform for video observations within the IMO. *We invite all of you involved or wishing to get involved to react to this article, either through me or directly to the authors. Video observing is such a promising observing technique that the* IMO *cannot afford it to lag behind in this field. In order to be able to provide the full support the video observers are entitled to, the* IMO *first wants to define its priorities with respect to this new observing technique. The article in this issue is a first attempt in this direction, but is by no means definitive; we require your input before we can finalize a program!*

While eagerly awaiting your reactions to the various issues raised by the President and myself, I wish you pleasant reading!

Letters to WGN

compiled by Marc Gyssens

End of an era

Many *IMO* members and *WGN* readers will undoubtedly already be aware that December 1996 saw the sad demise of *The Quarterly Journal of the Royal Astronomical Society.* This splendid journal passed away at the end of its 37th year, having provided a unique outlet for scientific ideas and papers which might perhaps have found publication elsewhere either difficult or unproductive, and which frequently included articles of considerable interest to all meteoricists and atmospheric scientists, amateur or professional. It was perhaps fitting that the Journal's final editor, known to many *IMO* members I am sure, Dr. David Hughes of Sheffield University, England, opened the terminal issue with the Journal's own obituary. Fitting too was that the final issue's contents should include papers on both interstellar and Solar System dust, amongst other things (e.g., a paper on galactic influences on terrestrial periodicities—Taurid Complex, etc.—and an article on the life of Lewis Swift, of Perseid comet fame). In February 1997, a new journal replaces *QJ*, called *Astronomy and Geophysics.* We wish it well, and hope it will continue to publish at least some of the same material that *QJ* became noted for. To paraphrase: The Journal is dead; long live the Journal!

Alastair McBeath, January 4, 1997

1996 Leonids

I enjoyed reading the recent *ILW* Bulletin 9 (Results of the 1996 Leonid Maximum) by Messrs Arlt, Rendtel, and Brown (*WGN* 24:6, December 1996, pp. 203–206).

Is there really evidence for a double maximum as claimed by the authors?

Certainly, Figure 3 of the paper cannot be used to indicate this in a statistical sense. The 1-sigma error bars are all consistent with a roughly constant rate of about 45 meteors per hour over the first 8 points. The dip is not statistically significant at all.

Unless there is other evidence of a double peak, I am not at all convinced that such should be invoked.

George Spalding, December 23, 1996

The authors supplied us with the following reply:

I fully agree with George Spalding that Figure 3 does not show a statistically significant dip in the ZHR graph. We also used other sampling periods for the average profile and got the same dip, but this no proof, of course. The application of other zenith exponents did not alter the shape of the profile nor the error bars distinctly. Actually, the ZHR graph and its interpretation are a little out-dated, because the enhanced value at $\lambda_\odot = 235\overset{\circ}{.}15$ only indicates the short activity peak observed by two Dutch observers [1] and two German observers. The data sample of that period 4^h45^m–5^h00^m UT ($\lambda_\odot = 235\overset{\circ}{.}17$) is very small, and I am concerned about giving an absolute ZHR value here, yet all these four observers reported about doubled rates in that period. Such short periods were not considered in the analysis George refers to.

[1] M. Langbroek, "Observation of a narrow component of faint Leonids in 1996", *WGN* 24:6 (1996), pp. 207–208.

Rainer Arlt, January 31, 1997

A Meteor Astronomy Workbook

Godfrey Baldacchino

1. Why meteor watching?

Let us consider the facts. There may be a hundred reasons why we enjoy observing meteors. Most of us would be able to mention a number of these without much thought. Meteor observation is probably the most democratic, inexpensive, and popular branch of astronomy, both when practiced by individuals as well as by groups. Yet, we know that there is a very high turnover of meteor observers. Very few of those who start observing actually continue to observe for an appreciable length of time [1]. We also know that 99.9% of humanity never even gets the chance to carry out a proper meteor observation... and this percentage is on an upward trend thanks to the onslaught of light pollution. Alas, the most widespread human contact between a meteor and a human being remains the casual or chance glimpse of a "shooting star" (followed by the fanciful act of wish making?), or else a Perseid star party or barbecue every mid-August.

We are here actually referring to two categories of persons. The first, by far the largest, consists of those who still need to be enticed and exposed to the theme, the activity and its ceremonial rigor: map, observing sheet, red filtered torch, dark adaptation, ... They still lack the opportunity to experience the event. The second set consists of that category of persons who do start to observe but soon start slacking: because they need to know more about why it is done and why it is done the way it is done; or, because they consider the activity as an "on-off" event. What is the novelty and challenge left after one's first meteor watch? Are the second and the third not repeats of the first? Such expressions of disillusionment can also be fueled by press reports (often provided by astronomical societies!) which tend to emphasize the prevalence or likelihood of strong meteor displays. The average meteor watcher's fare is, we know, much less dramatic.

2. Role of local societies

With respect to both these sets of persons, it is the local clubs which are in the best position to make a significant difference. These grass-roots organizations can resort to personal contacts and encouragement to rope in friends and associates to meteor watching (see [1]). They can provide the group structure to transform meteor watching into a pleasant social activity, adding that dash of peer pressure to get people out observing. But the local clubs may lack the motivation, creativity, and knowledge to organize anything except the obvious star party, weather permitting, every August 11 (annually) or every November 17 (every 33 years). As a result, many would-be meteor enthusiasts pass by the hobby unaware; and many "on-off"ers fail to get injected with a sense of purpose or adventure—with the result that they very quickly and resolutely move on. They rarely look back.

3. A sense of challenge

From this diagnosis of the situation, one may adopt a complacent attitude and simply accept that this is the way things are. Some people get induced into meteor watching, many others just do not. Perhaps, however, rather than shrugging our shoulders, something can be done to tip the balance. It is clear that well thought out challenges can and need to be developed in order to encourage new observers or else to encourage existing observers to persevere and stay on in this hobby. Meteor astronomy depends on this conservation and widening of observational practice.

How can this be achieved? Already, it is clear that various astronomy associations would like to develop a meteor observing text in their own language. There are already some excellent general texts on the subject, including the *IMO*'s own *Handbook for Visual Meteor Observers* [2]. Yet, most of these publications only provide the theoretical, academic or physical background to the topic. They are therefore likely to appeal only to whoever is already converted and committed to the subject, enough to want to know more and appreciate its technical niceties. Otherwise, such literature is bound to disinterest (or worse, scare) that presumably large majority of persons who are only interested in what they see, and perhaps in how they go about seeing it.

4. Proposal

A verbal proposal was submitted to the *IMO* Council meeting in Apeldoorn in September 1996 and a draft discussion document communicated to all *IMO* Councillors during October. The *IMO* is now pleased to report that it has agreed to commission a workbook or experimental kit for meteor watchers. (The exact format will depend on the outcome of the research work invariably involved in bringing such a project to light).

This publication will include practical hints on what and how to observe, what to record and why. The emphasis will be squarely on the meteor as a light event: what one can see: trails, trains, brightness, radiants, speed, color. It will bring together 101 experiments (perhaps more, perhaps less!) which can be done in relation to meteor watching. These "experiments" will deal with both solitary and group based meteor observations; and they will be amenable for execution not only in the field (during a meteor watch proper) but in a laboratory and/or casual surroundings.

The proposal is not as daunting as it may look at first sight. Firstly, we are not trying to re-create a whole new justification for meteor astronomy. Nor are we trying to depart from the rigor and discipline of standardized observations. Indeed, this exercise will help to make it much clearer to observers what is the explanation behind some of the mysterious behavior patterns insisted upon by such organizations as the *IMO*! Why use a red filtered torch? Why a gnomonic map projection? Why prefer a higher radiant altitude? ...

Secondly, many of the ideas that this publication hopes to bring together already exist out there. I am confident that various meteor societies or individual meteor observers have—like myself—devised original, interesting, and educational experiments and projects which increase the disposition of people to observe; which test out a reasonable hypothesis; which involve the use of statistical, mechanical, electrical, psychological, or other methods of analysis and reduction. The outcome is that no meteor observing project is like any other.

What is therefore important is that these project "what-to-do" ideas are identified, collated, and then printed and distributed. This is a task of daunting coordination which shall be handled by the *IMO*. In this way, the *IMO* hopes to undertake a service of importance and relevance to grass-roots-based organizations. The activity would in itself also serve as an exercise in international coordination and brainstorming.

5. Ideas

Do you need ideas for meteor-related experiments or projects? Well, a number can be organized around the following themes:

- limiting magnitude: averted versus direct vision;
- effect of observer experience on plotting, magnitude estimates;
- effect of alcohol, fatigue, glasses, contact lenses on rates;
- coefficients of perception;
- how to analyze data (different techniques, including simple estimates even for urban "low limiting magnitude" sites), plus worked examples;
- effect of using different film speeds on photos;
- projection of meteor plotting maps;
- random distribution of sporadics;
- workings of the human eye in conditions of darkness;
- radiant perspective effect;
- size and characteristics of the observer's field of view;
- observer's field scanning process;
- effect of moonlight on stellar limiting magnitude;
- effects on rates of individual versus group observations;
- simple trigonometry for meteor start/end height derivation;
- construction and use of a hand-held quadrant;
- introductions to the non-visual realm (especially photography, but also video, radio and binocular/telescopic observation).

6. Procedure

I am calling all *WGN* readers to consider contributing to this original text. Have you thought about a simple, cost effective experiment in connection with meteor watching? Or, better still, have you actually carried out a project, testing out one of the above themes or others not on the list? Have you got yourself and/or others interested in some construction, experiment or data analysis technique you would like to share with others?

All proposals will be seriously considered and appraised by an international panel of referees, whose decision will be final. These will be particularly on the look-out for proposals which are easy to undertake, educational, inexpensive, related to some aspect of meteor astronomy, and lend themselves to repeatability in different settings.

In making your submission, kindly follow this format: *objective; materials needed; procedure; outcome.* Material on IBM-formatted computer diskettes is welcome. Provide any illustrations, photographs, labeled designs, or model specifications where these contribute to the clarity of the proposal. Make sure to write your name, address, telephone, fax, and e-mail address (if any). All submitted material will be considered *IMO* property unless you specifically request this to be returned to you. However, we guarantee that full credit will be given to each of the experiment proponents which get accepted for eventual publication. Kindly submit your proposal in English (the common language within the *IMO*); but if you absolutely cannot do so, we will try and arrange for a translation. Never be deterred from making a contribution because of language problems. Kindly direct all submissions to my home address. Deadline for initial submissions is November 30, 1997.

In the meantime, the proposal shall also be sent out as a separate mailshot to the 28 national coordinators who collaborated so brilliantly and painstakingly in relation to the first world wide survey of meteor watchers. I am indebted to their enormous support and enthusiasm. I am confident that this new initiative will prove just as, if not more, successful, with a tangible outcome of enormous benefit.

References

[1] G. Baldacchino, "A Global Survey of Meteor Observers", *WGN* 24:6, December 1996, pp. 187–200.

[2] J. Rendtel, R. Arlt, A. McBeath, eds., "Handbook for Visual Meteor Observers", IMO Monograph no. 2, 1995.

Practical Meteor Photography
Part VI: Position Measurements of Meteor Photographs

Marc de Lignie

Preface

The *IMO* Photographic Handbook provides a wealth of information, but in some parts additional practical hints would be useful. This series of short articles intends to fill this gap and to support beginning meteor photographers in deciding which materials to use, which methods to apply, etc. The information in this series originates from experienced meteor photographers and has proven its value in practice.

1. Introduction

Meteor pictures have value as educational material, ornaments or as a reminiscence to a succesful observing campaign. However, the eventual goal of regular photographic observations is to perform position measurements of the meteor trails. The resulting positions in terms of equatorial (sky atlas) coordinates can be used for radiant analysis in case of single-station observations and for trajectory and orbit calculations in case of double-station photography.

Apart from its scientific value, making position measurements of meteors is a pleasant pastime. It gives satisfaction to the photographer when he or she participates in the reduction process. Finally, it is something which can easily be shown to newcomers or which can be part of a demonstration at a public observatory.

The process of determining the coordinates of an object in the sky is called astrometry. The idea is to measure the (x, y) positions on the photograph of a number of stars, which have known coordinates, and of some points of the meteor (begin and end point, and shutter breaks). E.g., when on the photograph a meteor point lies exactly in between two reference stars with equatorial coordinates (α_1, δ_1) and (α_2, δ_2), its coordinates are roughly $((\alpha_1+\alpha_2)/2, (\delta_1+\delta_2/2))$. It seems reasonable that with some more precise calculations the equatorial coordinates of the meteor points can be determined from the position measurements of an arbitrary set of reference stars [1].

The goal of the present issue of the series of articles on meteor photography is to provide an overview of methods to perform the position measurements. The next issue will provide a step-by-step description of manual position measurements and introduce a new computer tool.

2. Methods for position measurements

Different tools are available for making position measurements of meteor trails (see Table 1). Two classifications can be made. First, there are tools for measuring prints or for measuring negatives. Secondly, position measurements can be made by hand or by computer, using digitized images.

Table 1 – Different tools for making astrometric measurements.

Method	Prints	Negatives
By hand	Ruler	Coordinate machine
By computer	Scanner	Photo-CD

For meteors photographed from two or more stations, it is preferred to measure the negatives, and thus to obtain the highest accuracy. Traditionally, this has been done with special coordinate machines, which include a microscope and a special mechanism to read accurately calibrated rulers. However, such machines are very expensive and only available within the scientific community. Recently, computer tools, which use digitized negatives on Photo-CD, have become available [2]. In a digitized image you can select the image pixel that best represents the position of a star or meteor point. In practice, it is even possible to show the same image pixel multiple times on the computer monitor (e.g., in a 4×4 matrix), and thus obtain sub-pixel accuracy. Computer tools yield the same accuracy and allow faster reduction than coordinate machines. Further, they are within the reach of any meteor group, because they only require a computer with CD-ROM player. Presently, computer tools are only used for 35 mm film, but reduction of large format negatives will be possible for amateurs in the near future.

For single-station photographs, which do not require the highest accuracy, prints can be used, when this is more convenient to the photographer. Especially in countries where preparing Photo-CDs is a "hard currency" service, making prints yourself might be cheaper. Because of the larger format, position measurements on a print can simply be done by hand with an ordinary ruler (see [1,3]). However, also for prints it is faster to digitize the image and use a computer tool for the position measurements. One of the advantages is that the measurements do not need to be typed, but can be directly stored in a computer file. Digitizing the prints only requires a relatively cheap desk-top scanner (price comparable to a printer).

References

[1] C. Steyaert, "Photographic Astrometry", IMO Monograph no. 1, 1990.

[2] M.C. de Lignie, "Measuring meteor photographs using Photo-CD", *Radiant* 16, 1994, pp. 5–12 (in Dutch), also in *Proc. 1994 IMC*, Belogradchik, pp. 62–66.

[3] J. Rendtel, "Handbook for Photographic Meteor Observations", IMO Monograph no. 3, 1993, pp. 78–82.

Meteor Shower Calendar: April–September 1997

compiled by Alastair McBeath

1. April to June

Meteor activity picks up around the April-May boundary, with showers like the Lyrids, π-Puppids and η-Aquarids, albeit only this latter source is free from moonlight this year. For radio observers, the expected UT maxima for the April showers are as follows: April Piscids (possibly periodic daylight shower)—April 20, 7^h; Lyrids—April 22, 3^h; π-Puppids—April 23, 14^h; δ-Piscids (very short daylight shower)—April 24, 7^h.

During May and June, most of the activity takes place in the daytime sky, with six shower peaks due in this time. Although a few shower members from the o-Cetids and Arietids have been reported from tropical and southern hemisphere sites visually in previous years, sensible activity calculations cannot be carried out from such observations. These daylight showers have the following predicted UT maximum times in 1997: ε-Arietids—May 9, 5^h; May Arietids—May 16, 6^h; o-Cetids—May 20, 5^h; Arietids—June 7, 9^h; ζ-Perseids—June 9, 8^h; β-Taurids—June 28, 8^h.

The ecliptical complexes continue with some late Virginids and the best from the minor Sagittarids in May-June.

η-Aquarids

Active: April 19–May 28; Maximum: May 5, 22^h UT ($\lambda_\odot = 45.^\circ5$); ZHR = 60 (occasionally variable); Radiant: $\alpha = 338^\circ$, $\delta = -01^\circ$; Radiant drift: see Table 2; radius: 4°; $V_\infty = 66$ km/s; $r = 2.7$; TFC: $\alpha = 319^\circ$, $\delta = +10^\circ$ and $\alpha = 321^\circ$, $\delta = -23^\circ$ ($\beta < 20^\circ$ S).

This is a fine, rich stream associated with Comet 1P/Halley, like the Orionids of October, but it is visible for only a few hours before dawn essentially from tropical and southern hemisphere sites. Occasional meteors have been reported from further north, and the shower would benefit from increased observer activity generally.

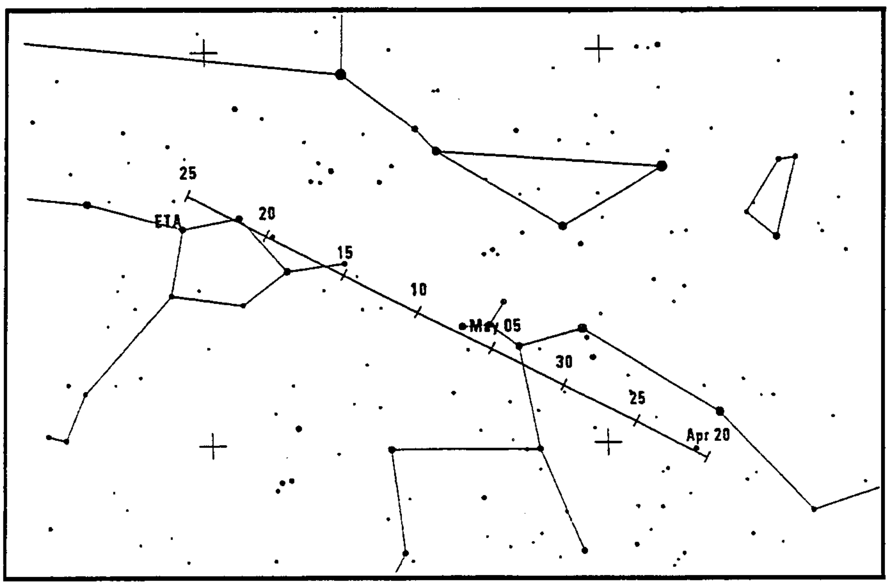

Figure 1 – Radiant positions and drift of the η-Aquarids on Atlas Brno Chart 6.

The fast and often bright meteors make the wait for radiant-rise worthwhile, and many events leave glowing persistent trains after them. A relatively broad maximum—sometimes with a variable number of submaxima — usually occurs in early May, and ZHRs are generally above 30 for almost a week centered on the main maximum, based on *IMO* observations between 1988 and 1995. With New Moon on May 6, the shower is ideally-placed for watchers in 1997. All forms of observing can be used to study it, with radio work allowing activity to be followed even from northern sites throughout the daylight morning hours. The radiant culminates at about 8^h local time.

2. July to September

Minor shower activity continues apace from near-ecliptic sources throughout this quarter, first from the Sagittarids, then the Aquarid and Capricornid showers (discussed below with the Piscis Austrinids; only the Northern ι-Aquarid maximum loses out particularly to moonlight this year), and finally the Piscids into September. Other low activity showers are apparent too, such as the Pegasids and July Phoenicids, but the κ-Cygnids lose out to the near-Full Moon on August 17. Then there are the Aurigid showers from late August through to October. The major northern hemisphere event is always the Perseids in August, of course.

For daylight radio observations, the interest of May–June has waned, but there remains the visually inaccessible γ-Leonids (peak due August 25, 8^h UT), and a tricky visual shower, the Sextantids (maximum expected September 27, 8^h UT). The latter has the waning crescent Moon near its radiant at maximum in 1997, and will rise less than an hour before dawn in either hemisphere.

Pegasids

Active: July 7–13; Maximum: July 10 ($\lambda_\odot = 108°$); ZHR = 3;
Radiant: $\alpha = 340°$, $\delta = +15°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 320°$, $\delta = +10°$ and $\alpha = 332°$, $\delta = +33°$ ($\beta > 40°$ N);
$\alpha = 357°$, $\delta = +02°$ ($\beta < 40°$ N).

Watching this very short-lived minor shower is not easy, as a few cloudy nights mean its loss for visual observers, but with the Moon a waxing crescent for its peak this year, everyone—particularly those in the northern hemisphere—should attempt to cover it. The shower is best-seen in the second half of the night, by when the Moon will have set, though the maximum ZHR is generally low. With its swift, faint meteors, telescopic observers should be in action too.

July Phoenicids

Active: July 10–16; Maximum: July 14 ($\lambda_\odot = 111°$); ZHR: variable, 3–10, usually ≈ 2;
Radiant: $\alpha = 32°$, $\delta = -48°$; Radiant drift: see Table 2; radius: 7°; $V_\infty = 47$ km/s; $r = 3.0$;
TFC: $\alpha = 41°$, $\delta = -39°$ and $\alpha = 66°$, $\delta = -62°$ ($\beta < 10°$ N).

This minor shower can be seen from the southern hemisphere, from where it only attains a reasonable elevation above the horizon after midnight. This means 1997 is a good year to watch it, with the waxing gibbous Moon at maximum setting as the radiant becomes more suitably-placed. Activity can be quite variable visually, and indeed observations show it is a richer radio meteor source (possibly also telescopically too, but more results are needed). Recent years have brought ZHRs of about 2, when the winter weather has allowed any coverage at all. Perhaps 1997 will be a good year for them?

Piscis Austrinids

Active: July 15–August 10; Maximum: July 28 ($\lambda_\odot = 125°$); ZHR = 5;
Radiant: $\alpha = 341°$, $\delta = -30°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 35$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to 360°, $\delta = 0°$ to +15°, choose pairs separated by about 30° in α ($\beta < 30°$ N).

Southern δ-Aquarids

Active: July 12–August 19; Maximum: July 28, 0^h UT ($\lambda_\odot = 125°$); ZHR = 20;
Radiant: $\alpha = 339°$, $\delta = -16°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 41$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to 360°, $\delta = 0°$ to +15°, choose pairs separated by about 30° in α ($\beta < 30°$ N).

α-Capricornids

Active: July 3–August 15; Maximum: July 30 ($\lambda_\odot = 127°$); ZHR = 4;
Radiant: $\alpha = 307°$, $\delta = -10°$; Radiant drift: see Table 2; radius: 8°;
$V_\infty = 23$ km/s; $r = 2.5$;
TFC: $\alpha = 255°$ to $360°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 30°$ N).
PFC: $\alpha = 300°$, $\delta = +10°$ ($\beta > 45°$ N),
$\alpha = 320°$, $\delta = -5°$ ($\beta = 0°$ to $45°$ N), or
$\alpha = 300°$, $\delta = -25°$ ($\beta < 0°$ S).

Southern ι-Aquarids

Active: July 25–August 15; Maximum: August 4 ($\lambda_\odot = 132°$); ZHR = 2;
Radiant: $\alpha = 333°$, $\delta = -15°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 34$ km/s; $r = 2.9$;
TFC: $\alpha = 255°$ to $360°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 30°$ N).

Northern δ-Aquarids

Active: July 15–August 25; Maximum: August 8 ($\lambda_\odot = 136°$); ZHR = 4;
Radiant: $\alpha = 335°$, $\delta = -5°$; Radiant drift: see Table 2; radius: 5°; $V_\infty = 42$ km/s; $r = 3.4$;
TFC: $\alpha = 255°$ to $360°$, $\delta = 0°$ to $+15°$, choose pairs separated by about 30° in α ($\beta < 30°$ N).

The Aquarids and Piscis Austrinids are all rich in faint meteors, making them well-suited to telescopic work, although enough brighter members exist to make visual and photographic observations worth the effort too, primarily from more southerly sites. Radio work can be used to pick up the Southern δ-Aquarids especially, as the most active of these showers. The α-Capricornids are noted for bright—sometimes fireball-class—events, which, combined with their low apparent velocity, can make some of these objects among the most impressive and attractive an observer could wish for. A possible minor enhancement of α-Capricornid ZHRs to about 10 was noted in 1995 by European *IMO* observers, although the Southern δ-Aquarids were the only one of these streams previously suspected of occasional variability.

Such a concentration of radiants in a small area of sky means that familiarity with where all the radiants are is essential for accurate shower association for all nights being observed on. Visual watchers in particular should plot all potential stream members seen in this region of sky rather than trying to make shower associations in the field. The only exception is when the Southern δ-Aquarids are near their peak, when from southern hemisphere sites in particular, rates may become too high for accurate plotting.

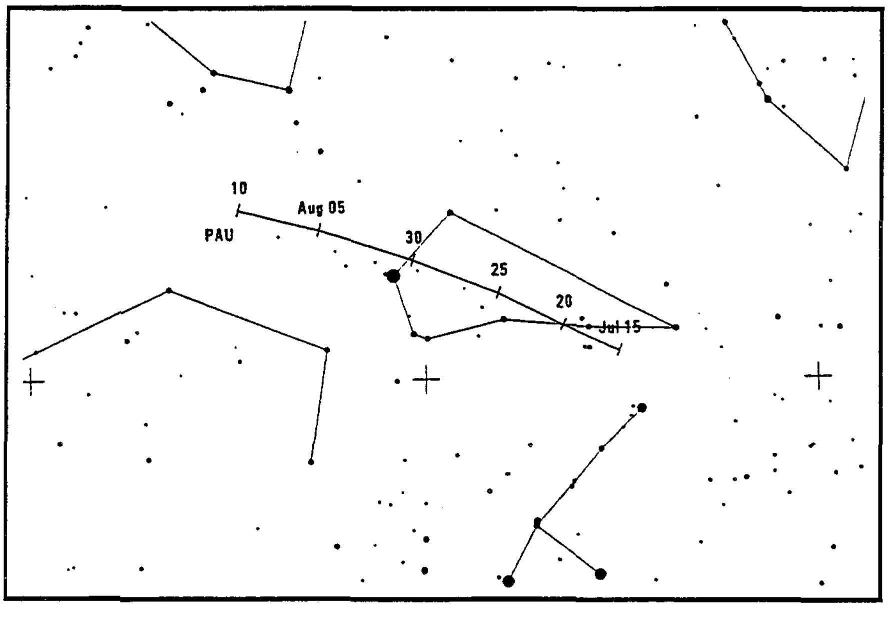

Figure 2 – Radiant positions and drift of the Piscis Austrinids on Atlas Brno Chart 12.

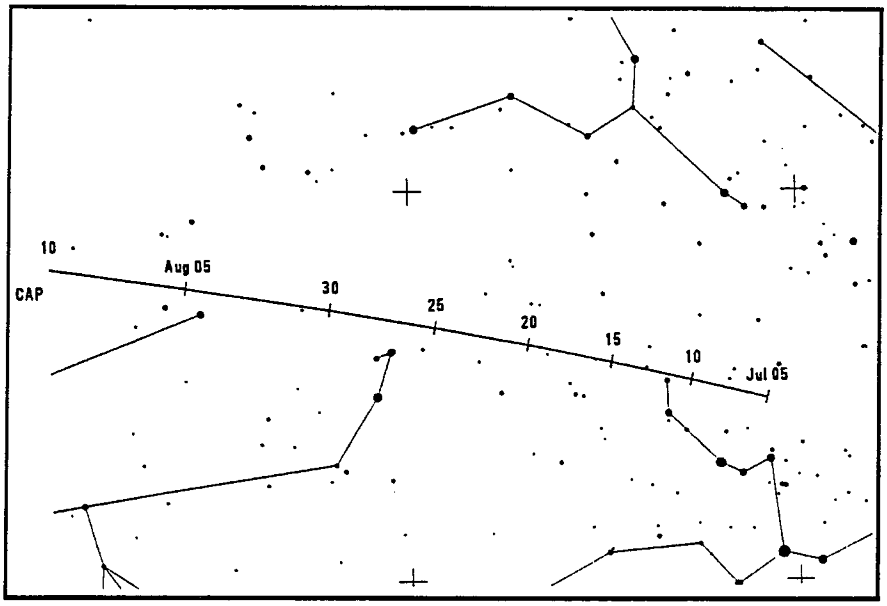

Figure 3 – Radiant positions and drift of the α-Capricornids on Atlas Brno Chart 9.

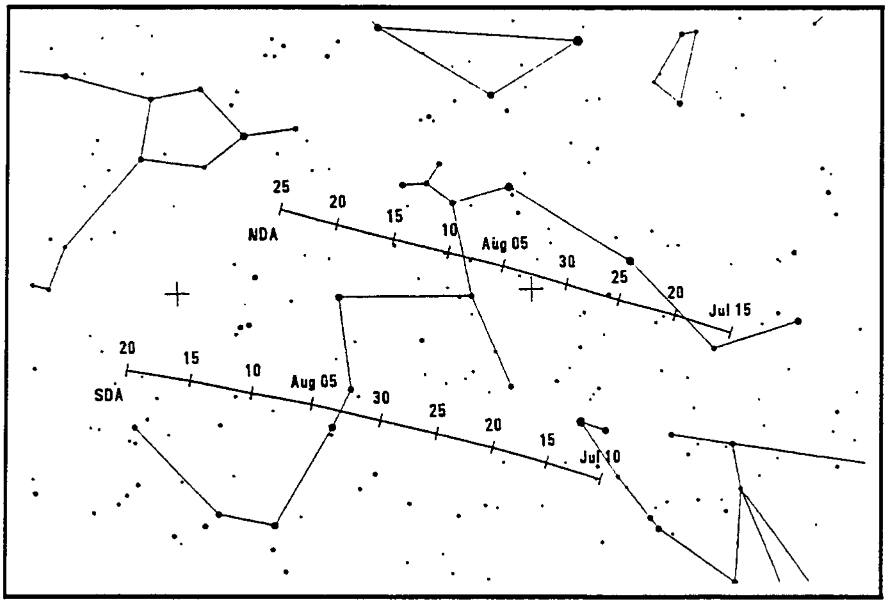

Figure 4 – Radiant positions and drifts of the Northern and Southern δ-Aquarids on Atlas Brno Chart 6.

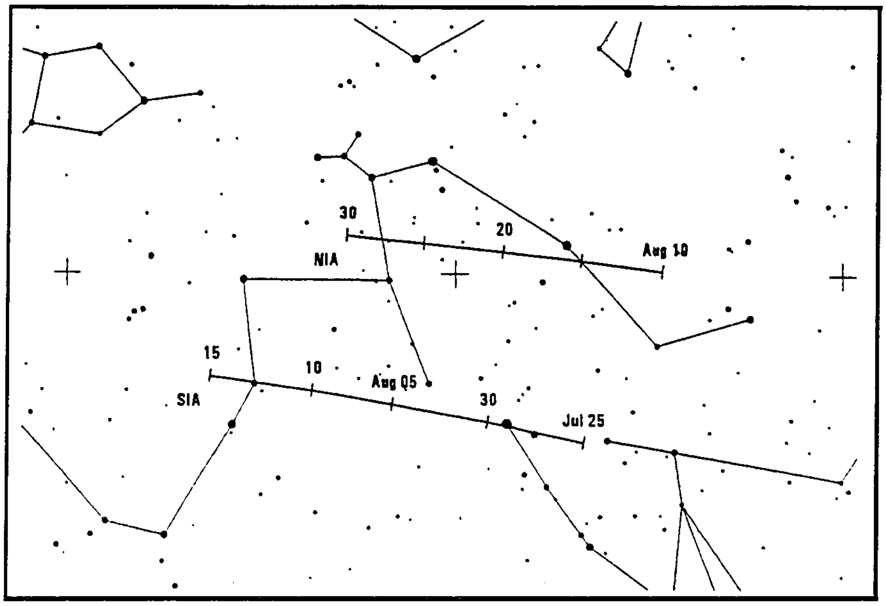

Figure 5 – Radiant positions and drifts of the Northern and Southern ι-Aquarids on Atlas Brno Chart 6.

All the above-listed shower maxima are reasonably free from lunar-light interference in 1997, since all five fall between Last Quarter Moon in late July and First Quarter Moon in mid August.

As the radiants are above the horizon for much of the night, there is ample scope for extended observing sessions.

Perseids

Active: July 17–August 24; Maxima: August 12, 6^h UT ($\lambda_\odot = 139.^\circ6$) and 18^h UT ($\lambda_\odot = 140.^\circ1$)
ZHR: primary peak: variable, 150–400; secondary peak: 100;
Radiant: $\alpha = 46°$, $\delta = +57°$; Radiant drift: see Table 2; radius: 5°;
$V_\infty = 59$ km/s; $r = 2.6$;
TFC: $\alpha = 19°$, $\delta = +38°$ and $\alpha = 348°$, $\delta = +74°$ before 2^h local time;
$\alpha = 43°$, $\delta = +38°$ and $\alpha = 73°$, $\delta = +66°$ after 2^h local time ($\beta > 20°$ N)
PFC: $\alpha = 300°$, $\delta = +40°$, $\alpha = 0°$, $\delta = +20°$, or
$\alpha = 240°$, $\delta = +70°$ ($\beta > 20°$ N).

The Perseids have become the single most exciting and dynamic meteor shower in recent times, with outbursts producing ZHRs over 400 in 1991 and 1992, around 300 in 1993, 220 in 1994 and about 160 in 1995 at the shower's primary maximum, which this year is expected to fall around 6^h UT on August 12. The peak may be encountered up to four hours before this time, however, judging by past variations in the densest stream core.

The return of the Perseids' parent comet 109P/Swift-Tuttle in late 1992 was almost certainly responsible for producing these recent outbursts, although the material was probably laid down at the comet's previous perihelion passage, in 1862.

Observations of the moon-free 1996 Perseid peak have confirmed the decreasing trend in the primary maximum's rates, a trend which of course required continued monitoring. Conditions are reasonable for trying to cover the 1997 event, as the waxing gibbous Moon will set soon after midnight for most northern hemisphere observers on August 12, by when the shower radiant will be at a very healthy elevation. Europe or the eastern seaboards of North America should be the places to be, if the shower's primary peak keeps to time. The "traditional" maximum is expected around 18^h UT on August 12, well-placed for sites in the Far East and eastern Asia particularly.

Visual and photographic observers should need little encouragement to cover this stream, but telescopic watching near the main peak would be valuable in confirming or clarifying the possibly multiple nature of the Perseid radiant, something not detectable visually.

Video observations would be very helpful in this respect, too.

Radio data would naturally enable early confirmation, or detection, of a perhaps otherwise unobserved outburst if the timing proves unsuitable for land-based sites.

The only negative aspect to the shower is the impossibility of covering it from the bulk of the southern hemisphere.

α-Aurigids

Active: August 25–September 5; Maximum: August 31, 23^{h} UT ($\lambda_{\odot} = 158.^{\circ}6$); ZHR = 10;
Radiant: $\alpha = 84^{\circ}$, $\delta = +42^{\circ}$; Radiant drift: see Table 2; radius: 5°;
$V_{\infty} = 66$ km/s; $r = 2.5$;
TFC: $\alpha = 52^{\circ}$, $\delta = +60^{\circ}$, $\alpha = 43^{\circ}$, $\delta = +39^{\circ}$, or
$\alpha = 23^{\circ}$, $\delta = +41^{\circ}$ ($\beta > 10^{\circ}$ S).

δ-Aurigids

Active: September 5–October 10; Maximum: September 8 ($\lambda_{\odot} = 166^{\circ}$); ZHR = 6;
Radiant: $\alpha = 60^{\circ}$, $\delta = +47^{\circ}$; Radiant drift: see Table 2; radius: 5°;
$V_{\infty} = 64$ km/s; $r = 3.0$;
TFC: $\alpha = 52^{\circ}$, $\delta = +60^{\circ}$, $\alpha = 43^{\circ}$, $\delta = +39^{\circ}$, or
$\alpha = 23^{\circ}$, $\delta = +41^{\circ}$ ($\beta > 10^{\circ}$ S).

These are both essentially northern hemisphere showers, and are in need of more observations. Despite occurring close to one another in time, and radiating from the same constellation, they are separate streams. The α-Aurigids are the more active, with short, unusual bursts giving ZHRs of about 30–40 in 1935, 1986, and 1994, although they have not been regularly observed until very recently, so other outbursts may have been missed. The δ-Aurigids produce lower rates of generally fainter meteors, and have yet to be well-seen in more than an occasional year.

The year 1997 provides a fine opportunity to improve our knowledge of the showers, since New Moon on September 2 means dark skies will prevail for much of the night for both maxima. Telescopic data to confirm the radiants—and possibly observe the telescopic β-Cassiopeids simultaneously—would be especially useful, but photographs, video records and visual plotting would be welcomed too. The shower radiants are at a useful elevation from roughly 23^{h}–0^{h} onwards, so protracted watching is distinctly possible.

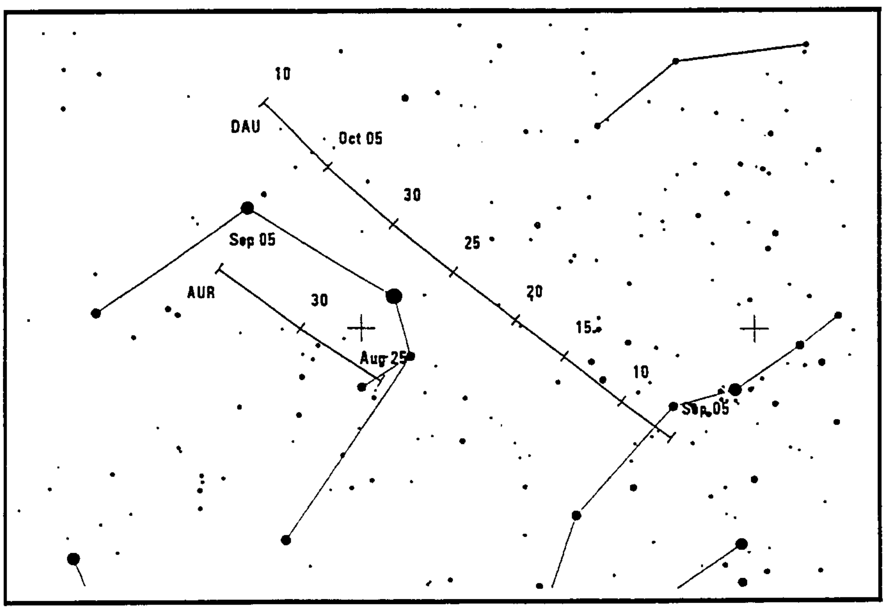

Figure 6 – Radiant positions and drifts of the α- and δ-Aurigids on Atlas Brno Chart 1.

3. Working list of meteor showers

Table 1 – Working list of meteor showers for the period April–September 1997. Streams marked with an asterisk are periodically or occasionally active, and therefore no ZHR is cited. The "maximum" dates cited for the Virginids and the Puppid/Velids should be seen as reference dates rather than true maxima.

Shower	Activity	Maximum		Radiant			V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	Radius	(km/s)		
Virginids (VIR)	Jan 25–Apr 15	Mar 24	4°	195°	−04°	15°/10°	30	3.0	5
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	32°.1	271°	+34°	5°	49	2.9	15
π-Puppids* (PPU)	Apr 15–Apr 28	Apr 23	33°.5	110°	−45°	5°	18	2.0	
η-Aquarids (ETA)	Apr 19–May 28	May 05	45°.5	338°	−01°	4°	66	2.7	60
Pegasids (JPE)	Jul 07–Jul 13	Jul 10	108°	340°	+15°	5°	70	3.0	3
July Phoenicids* (PHE)	Jul 10–Jul 16	Jul 13	111°	32°	−48°	7°	47	3.0	
Piscis Austrinids (PAU)	Jul 15–Aug 10	Jul 28	125°	341°	−30°	5°	35	3.2	5
Southern δ-Aquarids (SDA)	Jul 12–Aug 19	Jul 28	125°	339°	−16°	5°	41	3.2	20
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	8°	23	2.5	4
Southern ι-Aquarids (SIA)	Jul 25–Aug 15	Aug 04	132°	334°	−15°	5°	34	2.9	2
Northern δ-Aquarids (NDA)	Jul 15–Aug 25	Aug 08	136°	335°	−05°	5°	42	3.4	4
Perseids (PER)	Jul 17–Aug 24	Aug 12	139°.6	46°	+58°	5°	59	2.6	200
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 17	145°	286°	+59°	6°	25	3.0	3
Northern ι-Aquarids (NIA)	Aug 11–Aug 31	Aug 19	147°	327°	−06°	5°	31	3.2	3
α-Aurigids (AUR)	Aug 25–Sep 05	Aug 31	158°.6	84°	+42°	5°	66	2.5	10
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 08	166°	60°	+47°	5°	64	3.0	6
Piscids (SPI)	Sep 01–Sep 30	Sep 19	177°	5°	−01°	5°	26	3.0	3

Table 2 – Radiant positions during 1997 in α and δ.

					VIR			
Apr 10	SAG	LYR	PPU		203° −7°			
Apr 15	224° −17°	263° +34°	106° −44°	ETA	205° −8°			
Apr 20	227° −18°	269° +34°	109° −45°	323° −7°				
Apr 25	230° −19°	274° +34°	111° −45°	328° −5°				
Apr 30	233° −19°			332° −4°				
May 5	236° −20°			337° −2°				
May10	240° −21°			341° 0°				
May20	247° −22°			350° +5°				
May30	256° −23°							
Jun 10	265° −23°							
Jun 15	270° −23°							
Jun 20	275° −23°							
Jun 25	280° −23°							
Jun 30	284° −23°	JPE	CAP					
Jul 5	289° −22°	338° +14°	285° −16°	SDA				
Jul 10	293° −22°	341° +15°	289° −15°	325° −19°	NDA	SIA	PER	PAU
Jul 15	298° −21°		294° −14°	329° −19°	316° −10°		12° +51°	330° −34°
Jul 20			299° −12°	333° −18°	319° −9°		18° +52°	334° −33°
Jul 25			303° −11°	337° −17°	323° −9°	322° −17°	23° +54°	338° −31°
Jul 30	KCG		308° −10°	340° −16°	327° −8°	328° −16°	29° +55°	343° −29°
Aug 5	283° +58°	NIA	313° −8°	345° −14°	332° −6°	334° −15°	37° +57°	348° −27°
Aug10	284° +58°	317° −7°	318° −6°	349° −13°	335° −5°	339° −14°	43° +58°	352° −26°
Aug15	285° +59°	322° −7°		352° −12°	339° −4°	345° −13°	50° +59°	
Aug20	286° +59°	327° −6°	AUR	356° −11°	343° −3°		57° +59°	
Aug25	288° +60°	332° −5°	76° +42°		347° −2°		65° +60°	
Aug30	289° +60°	337° −5°	82° +42°	DAU				
Sep 5			88° +42°	55° +46°	SPI			
Sep 10				60° +47°	357° −5°			
Sep 15				66° +48°	1° −3°			
Sep 20				71° +48°	5° −1°			
Sep 25				77° +49°	9° 0°			
Sep 30				83° +49°	13° +2°			

4. Daytime radio meteor streams

Table 3 – Working list of daytime radio meteor streams. The "Best Observed" columns give the approximate local mean times between which a four-element antenna at an elevation of 45° receiving a signal from a 30-kW transmitter 1000 km away should record at least 85% of any suitably positioned radio-reflecting meteor trails for the appropriate latitudes. Note that this is often heavily dependent on the compass direction in which the antenna is pointing, however, and applies only to dates near the shower's maximum.

Shower	Activity	Max	$\lambda_\odot$	Radiant		Best Observed		Rate
		Date	2000.0	α	δ	50° N	35° S	
Piscids (Apr)	Apr 08–Apr 29	Apr 20	30.°3	7°	+07°	07^h–14^h	08^h–13^h	low
δ-Piscids	Apr 24–Apr 24	Apr 24	34.°2	11°	+12°	07^h–14^h	08^h–13^h	low
ε-Arietids	Apr 24–May 27	May 08	48.°7	44°	+21°	08^h–15^h	10^h–14^h	low
Arietids (May)	May 04–Jun 06	May 16	55.°5	37°	+18°	08^h–15^h	09^h–13^h	low
o-Cetids	May 05–Jun 02	May 19	59.°3	28°	−04°	07^h–13^h	07^h–13^h	medium
Arietids	May 22–Jul 02	Jun 07	76.°7	44°	+24°	06^h–14^h	08^h–12^h	high
ζ-Perseids	May 20–Jul 05	Jun 09	78.°6	62°	+23°	07^h–15^h	09^h–13^h	high
β-Taurids	Jun 05–Jul 17	Jun 28	96.°7	86°	+19°	08^h–15^h	09^h–13^h	medium
γ-Leonid	Aug 14–Sep 12	Aug 25	152.°2	155°	+20°	08^h–16^h	10^h–14^h	low
Sextantids	Sep 09–Oct 09	Sep 27	184.°3	152°	00°	06^h–12^h	06^h–13^h	medium

5. Lunar phases

Table 4 – Lunar phases for April–September 1997.

New Moon	Apr 07	May 06	Jun 05	Jul 04	Aug 03	Sep 02
First Quarter	Apr 14	May 14	Jun 13	Jul 12	Aug 11	Sep 10
Full Moon	Apr 22	May 22	Jun 20	Jul 20	Aug 18	Sep 16
Last Quarter	Apr 30	May 29	Jun 27	Jul 26	Aug 25	Sep 23

Solar Longitudes for 1997

compiled by Rainer Arlt

As every year, a conversion table of dates to solar longitudes using [1] is given for planning observations and for the quick reduction of the times of maxima in any analysis to the actual date and time. Remember that the longitudes given are only valid for 1997. I am also repeating the conversion formulae for any time of the day. If you want to calculate the solar longitude $\lambda_\odot$ of a specific time of the day, you may use a linear interpolation between two dates. If you have a certain *Date* and the *Time* in hours (UT), you obtain the corresponding solar longitude from

$$\lambda_\odot = \lambda_{\odot,\mathrm{Date}} + (\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}}) \times \frac{\mathrm{Time}}{24^\mathrm{h}}.$$

Alternatively, if you want to convert a certain solar longitude $\lambda_\odot$ in a time of the day, look up the *Date* with the next-smaller solar longitude in the table and calculate

$$\mathrm{Time} = \frac{(\lambda_\odot - \lambda_{\odot,\mathrm{Date}})}{(\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}})} \times 24^\mathrm{h}.$$

[1] Steyaert, C., "Calculating the Solar Longitude 2000.0", *WGN* 19:2, April 1991, pp. 31–34.

Table 1 – Solar longitudes 1997. Dates refer to 0^h UT.

Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$
Jan 1	280.65	Mar 1	340.48	May 1	40.70	Jul 1	99.24	Sep 1	158.64	Nov 1	218.64
Jan 2	281.67	Mar 2	341.49	May 2	41.67	Jul 2	100.20	Sep 2	159.60	Nov 2	219.64
Jan 3	282.69	Mar 3	342.49	May 3	42.64	Jul 3	101.15	Sep 3	160.57	Nov 3	220.64
Jan 4	283.71	Mar 4	343.49	May 4	43.61	Jul 4	102.10	Sep 4	161.54	Nov 4	221.64
Jan 5	284.73	Mar 5	344.50	May 5	44.58	Jul 5	103.06	Sep 5	162.51	Nov 5	222.64
Jan 6	285.75	Mar 6	345.50	May 6	45.55	Jul 6	104.01	Sep 6	163.48	Nov 6	223.65
Jan 7	286.77	Mar 7	346.50	May 7	46.52	Jul 7	104.96	Sep 7	164.45	Nov 7	224.65
Jan 8	287.79	Mar 8	347.50	May 8	47.49	Jul 8	105.92	Sep 8	165.42	Nov 8	225.65
Jan 9	288.81	Mar 9	348.50	May 9	48.45	Jul 9	106.87	Sep 9	166.39	Nov 9	226.66
Jan 10	289.83	Mar 10	349.50	May 10	49.42	Jul 10	107.83	Sep 10	167.37	Nov 10	227.66
Jan 11	290.85	Mar 11	350.50	May 11	50.39	Jul 11	108.78	Sep 11	168.34	Nov 11	228.67
Jan 12	291.87	Mar 12	351.50	May 12	51.35	Jul 12	109.73	Sep 12	169.31	Nov 12	229.67
Jan 13	292.89	Mar 13	352.50	May 13	52.32	Jul 13	110.69	Sep 13	170.28	Nov 13	230.68
Jan 14	293.90	Mar 14	353.49	May 14	53.28	Jul 14	111.64	Sep 14	171.26	Nov 14	231.68
Jan 15	294.92	Mar 15	354.49	May 15	54.25	Jul 15	112.59	Sep 15	172.23	Nov 15	232.69
Jan 16	295.94	Mar 16	355.49	May 16	55.21	Jul 16	113.55	Sep 16	173.20	Nov 16	233.70
Jan 17	296.96	Mar 17	356.48	May 17	56.18	Jul 17	114.50	Sep 17	174.18	Nov 17	234.71
Jan 18	297.98	Mar 18	357.48	May 18	57.14	Jul 18	115.45	Sep 18	175.15	Nov 18	235.71
Jan 19	299.00	Mar 19	358.47	May 19	58.10	Jul 19	116.41	Sep 19	176.13	Nov 19	236.72
Jan 20	300.01	Mar 20	359.46	May 20	59.06	Jul 20	117.36	Sep 20	177.11	Nov 20	237.73
Jan 21	301.03	Mar 21	0.46	May 21	60.03	Jul 21	118.32	Sep 21	178.08	Nov 21	238.74
Jan 22	302.05	Mar 22	1.45	May 22	60.99	Jul 22	119.27	Sep 22	179.06	Nov 22	239.75
Jan 23	303.07	Mar 23	2.44	May 23	61.95	Jul 23	120.23	Sep 23	180.04	Nov 23	240.76
Jan 24	304.08	Mar 24	3.43	May 24	62.91	Jul 24	121.18	Sep 24	181.02	Nov 24	241.77
Jan 25	305.10	Mar 25	4.42	May 25	63.87	Jul 25	122.13	Sep 25	182.00	Nov 25	242.78
Jan 26	306.11	Mar 26	5.41	May 26	64.83	Jul 26	123.09	Sep 26	182.98	Nov 26	243.79
Jan 27	307.13	Mar 27	6.40	May 27	65.79	Jul 27	124.05	Sep 27	183.96	Nov 27	244.81
Jan 28	308.15	Mar 28	7.39	May 28	66.75	Jul 28	125.00	Sep 28	184.94	Nov 28	245.82
Jan 29	309.16	Mar 29	8.38	May 29	67.71	Jul 29	125.96	Sep 29	185.92	Nov 29	246.83
Jan 30	310.18	Mar 30	9.37	May 30	68.67	Jul 30	126.91	Sep 30	186.91	Nov 30	247.85
Jan 31	311.19	Mar 31	10.36	May 31	69.63	Jul 31	127.87				
Feb 1	312.21	Apr 1	11.34	Jun 1	70.59	Aug 1	128.83	Oct 1	187.89	Dec 1	248.86
Feb 2	313.22	Apr 2	12.33	Jun 2	71.54	Aug 2	129.78	Oct 2	188.87	Dec 2	249.87
Feb 3	314.24	Apr 3	13.32	Jun 3	72.50	Aug 3	130.74	Oct 3	189.86	Dec 3	250.89
Feb 4	315.25	Apr 4	14.30	Jun 4	73.46	Aug 4	131.70	Oct 4	190.84	Dec 4	251.90
Feb 5	316.27	Apr 5	15.29	Jun 5	74.42	Aug 5	132.66	Oct 5	191.83	Dec 5	252.92
Feb 6	317.28	Apr 6	16.27	Jun 6	75.38	Aug 6	133.61	Oct 6	192.81	Dec 6	253.93
Feb 7	318.29	Apr 7	17.26	Jun 7	76.33	Aug 7	134.57	Oct 7	193.80	Dec 7	254.95
Feb 8	319.31	Apr 8	18.24	Jun 8	77.29	Aug 8	135.53	Oct 8	194.79	Dec 8	255.96
Feb 9	320.32	Apr 9	19.22	Jun 9	78.25	Aug 9	136.49	Oct 9	195.77	Dec 9	256.98
Feb 10	321.33	Apr 10	20.21	Jun 10	79.20	Aug 10	137.45	Oct 10	196.76	Dec 10	257.99
Feb 11	322.35	Apr 11	21.19	Jun 11	80.16	Aug 11	138.41	Oct 11	197.75	Dec 11	259.01
Feb 12	323.36	Apr 12	22.17	Jun 12	81.11	Aug 12	139.37	Oct 12	198.74	Dec 12	260.03
Feb 13	324.37	Apr 13	23.15	Jun 13	82.07	Aug 13	140.33	Oct 13	199.73	Dec 13	261.04
Feb 14	325.38	Apr 14	24.13	Jun 14	83.03	Aug 14	141.29	Oct 14	200.72	Dec 14	262.06
Feb 15	326.39	Apr 15	25.11	Jun 15	83.98	Aug 15	142.25	Oct 15	201.71	Dec 15	263.08
Feb 16	327.40	Apr 16	26.09	Jun 16	84.94	Aug 16	143.21	Oct 16	202.70	Dec 16	264.09
Feb 17	328.41	Apr 17	27.07	Jun 17	85.89	Aug 17	144.17	Oct 17	203.69	Dec 17	265.11
Feb 18	329.42	Apr 18	28.04	Jun 18	86.84	Aug 18	145.13	Oct 18	204.68	Dec 18	266.13
Feb 19	330.43	Apr 19	29.02	Jun 19	87.80	Aug 19	146.09	Oct 19	205.68	Dec 19	267.15
Feb 20	331.43	Apr 20	30.00	Jun 20	88.75	Aug 20	147.06	Oct 20	206.67	Dec 20	268.16
Feb 21	332.44	Apr 21	30.97	Jun 21	89.71	Aug 21	148.02	Oct 21	207.66	Dec 21	269.18
Feb 22	333.45	Apr 22	31.95	Jun 22	90.66	Aug 22	148.98	Oct 22	208.66	Dec 22	270.20
Feb 23	334.45	Apr 23	32.92	Jun 23	91.61	Aug 23	149.94	Oct 23	209.65	Dec 23	271.22
Feb 24	335.46	Apr 24	33.90	Jun 24	92.57	Aug 24	150.91	Oct 24	210.65	Dec 24	272.24
Feb 25	336.47	Apr 25	34.87	Jun 25	93.52	Aug 25	151.87	Oct 25	211.65	Dec 25	273.26
Feb 26	337.47	Apr 26	35.84	Jun 26	94.47	Aug 26	152.84	Oct 26	212.64	Dec 26	274.27
Feb 27	338.48	Apr 27	36.82	Jun 27	95.43	Aug 27	153.80	Oct 27	213.64	Dec 27	275.29
Feb 28	339.48	Apr 28	37.79	Jun 28	96.38	Aug 28	154.77	Oct 28	214.64	Dec 28	276.31
		Apr 29	38.76	Jun 29	97.34	Aug 29	155.73	Oct 29	215.64	Dec 29	277.33
		Apr 30	39.73	Jun 30	98.29	Aug 30	156.70	Oct 30	216.64	Dec 30	278.35
						Aug 31	157.67	Oct 31	217.64	Dec 31	279.37

Ongoing Meteor Work

Video Observations of Meteors: History, Current Status, and Future Prospects

S. Molau, M. Nitschke, M. de Lignie, R.L. Hawkes, and J. Rendtel

Video meteor observations have been performed by amateur astronomers for more than 10 years. They enjoy a rapidly increasing interest in the meteor community and will evolve into a powerful tool for amateur observers in the near future. Video meteor observation is the key to a fundamental increase of our knowledge about meteoroid populations and their interaction with the Earth's atmosphere.

In this paper, we want to summarize the history of video meteor observation and describe the current state of affairs. We discuss problems and limitations and propose future projects. The paper is intended to serve as basis for the foundation of appropriate organizational structures within the *International Meteor Organziation.*

1. History and current status

Professional astronomers started to use image intensified systems in connection with film equipment already in the sixties and seventies of our century [1]. Among amateurs, Japanese (1986) and Dutch (1987) observers have been the first using low-light-level video systems [2,3].

At the beginning, there were only XT personal computer and rudimentary frame grabber cards available. Thus, most of the video tape analysis had to be done manually. The main advantage compared to visual observations was the increase in positional accuracy by orders of magnitude. In addition, video systems were much more efficient than photo cameras, since they could record meteors down to magnitude +6 and fainter.

In the beginning of the nineties, new amateur groups started indepently to use that technology in several European countries like Austria, Germany, and the United Kingdom. Thanks to the increasing power of computer hardware, more and more problems could be solved computer aided. First attemps for the automatic video tape inspection were reported in 1993, and the analysis software for video meteors became much more efficient.

However, the major breakthrough did not happen before 1995-1996, when image intensifiers became cheap enough to become affordable for a larger group of amateurs [4].

Scientific results of video observations from several observer groups were published in different journals. So far, video systems have been used for the determination of meteoroid stream orbits, shower radiants, calibration of visual observations, cluster analysis, recording of spectra, and many more research projects.

A major event was the 1995 outburst of the α-Monocerotids, which has been completely recorded by two video teams [5,6]. It was the first time that such an outburst was observed with an appropriate method.

Currently, there are about 40 video systems operated by amateur astronomers around the world. At least 15n systems are in operation in Japan. We know of approximately 10 video systems in Germany and nearly 5 in the Netherlands. Video meteor observations are carried out in the United Kingdom, the United States, and Austria. Besides that, professionals in Canada, the Czech Republic, and Tadjikistan do use this technology.

There are at least three groups who deal with computer-aided meteor detection on video tapes. One of those systems has already proved to work in practice [4]. Several software packages exist for the digital measurement of recorded video meteors [1,2,7]. In the near future it is intended to provide a standard software package containing solutions for all tasks of video observers.

2. Why do video observations?

Video systems combine the advantages of visual and photographic meteor observation and can even compete with telescopic observers.

Current systems allow positional accuracies down to one arc minute. Thus, they are more accurate than visual meteor plottings. When used with wide-angle objective lenses, they can have a field of view of more than 100° in diameter, which is almost comparable to all-sky photography. The limiting magnitude depends strongly on the field of view of the camera, the focal ratio of the lens, and the intensifier's gain. However, modern video systems record on average more meteors in the same time than visual observers. They obtain by some orders of magnitude more meteor recordings than photographic systems.

Video systems achieve a high time resolution (25 or 30 images per second, depending on the video standard used), and record the evolution of a meteor directly. All events can easily be timed down to an accuracy of less than 1 s. The angular speed of meteors can be determined accurately without mechanic shutters due to the short exposure times for each video frame. The brightness of video meteors varies from bright fireballs down to the level of telescopic meteors. Thus, such systems can provide uniform data over a much larger spectrum of meteoroid sizes than any other method. In addition, video systems record the light curve of a meteor, leading to important results about the properties of meteoroids and their interaction with the Earth's atmosphere.

A major disadvantage are the costs, which are still relatively high compared to photographic or visual equipment. In addition, video systems depend on the availability of electrical power.

3. Limitations

A real limitation for video systems is the amount of time needed for data processing compared to the number of events that can be recorded. Currently, the video tapes are inspected visually and meteor positions are then measured with the help of a computer. A working solution for automated meteor search is only a question of time. However, fully autonomous analysis systems seem impossible from the current state of affairs. With the help of specialized computer software the measurement of meteors can be accelerated, but in practice it still requires 5 to 10 minutes for each meteor to be analyzed. Thus, it is impossible to analyse all meteors in detail that can be recorded by video systems. Depending on the actual aim of investigation, one either has to restrict the amount of information to be derived, or the meteors to be analyzed have to be selected.

Video systems are not as portable as photographic equipment. Even though newer cameras are more robust than earlier systems, they still are highly integrated electronic devices with some limits. Most systems are not meant to operate at temperatures far below the freezing point or when dew turns up. This, together with their power dependency, makes them only partly useful under expedition environments.

4. Components and classification of video systems

In general, all video meteor systems consist of a fast lens, an image intensifier and a video camera. It could be shown that image intensifiers are absolutely neccessary for recording faint meteors. Considering the number of photons reaching the photocathode, a charge-coupled device (CCD) alone may in theory be sensitive enough to detect faint objects. However, when operated at video frame rates of 25 or 30 Hz, the read-out noise by far overwhelms the number of electrons generated by the meteor's light.

The least requirement is a first-generation image intensifier with multiple amplification stages. The gain should be at least 1000, and the diameter of the photocathode needs to be larger than 15 mm. First-generation intensifiers with 3 sequential amplification stages can reach a higher gain than other intensifier generations, but suffer significantly from strong image distortion, a variable sensitivity within the field of view, and strong noise. This is why future automatic meteor detection systems will probably not work for those cameras.

Second-generation image intensifiers (micro channel plates or MCPs) do usually contain a single amplification stage. Therefore, they do not reach as a high gain as first generation devices. However, they are prefered for meteor observation because of their high-quality image with less noise, distortion, and sensitivity variations. New MCP devices fulfiling military specifications are still very expensive (above 2000 USD), but nowadays second-hand MCPs are also available at reasonable prices (below 500 USD) from several dealers around the world.

Third-generation image intensifiers are not especially useful for meteor observations, since they reach their maximum sensitivity in the infra-red.

Different video cameras are used to record the intensifier's phosphorous screen: a camcorder has the advantage that it is usually able to automatically record the time. Other systems involve cheaper video cameras. They either mark the time with audio signals or insert it electronically into the video signal. In the analysis process, the video tapes need to be digitized by frame grabbers. Currently, these are available at prices between 200 and 4000 USD. The use of conventional CCD cameras as used for astronomical imaging has been discussed. However, major disadvantages, such as the loss of the high time resolution, have prevented observers so far from using this technology.

In the future, the data stream may be stored digitally. With currently expensive hardware it is possible, to digitize the enormous data amount of a video signal (more than 9 MByte per second or 33 GByte per hour) in real time and save it on a computer's hard disc. This requires good data compression, which is possible for video meteor observations with almost no changes from one video frame to the next. The technology will become cheaper with further technological progress and is an alternative to the use of VCRs and the loss of information caused by that. Also, digital camcorders may help to improve the quality of data storage and transfer in the future.

Today's high end system do not involve any signal conversion between digital image aquisition and storage. They also contain sensors with much higer resolution.

The lens is most important for the recording properties of a video system. Generally it should be as fast as possible (low f ratio) to get best limiting magnitudes. According to the focal length, we can distinguish between 3 types of video cameras:

1. *Wide-angle video systems*: They apply wide-angle photo lenses and have a field of view of more than 40° in diameter. The limiting magnitude of such systems is usually between +5 and +7 for stars. A special type are all-sky video meteor cameras, which use convex mirrors and provide total field coverage.
2. *Standard video systems*: Using standard or moderate tele lenses, those video cameras record a field of view between 10° and 40° in diameter. Their limiting magnitude for stars is usually between +7 and +9. Most currently operated video systems belong to this class.
3. *Tele-video systems*: On application of fast and long focus tele-lenses, a field of view smaller than 10° in diameter is achieved. The limiting magnitude gets better than +9 mag for stars.

All image intensified video meteor detection systems are technically limited in one of 3 ways (see [8] for a more detailed treatment of this topic):

1. *The "quantum limit"*: If too few photons arrive during a video frame's intregration time, a useful meteor image cannot be obtained. For a typical system with a 50 mm diameter lens this would correspond to a magnitude of approximately +12. This is the ultimate detection limit using optical techniques, unless the collecting area of the lens, the integration time or the quantum efficiency of the image intensifier photocathode is increased.
2. *The "background illumination"*: Because of the limited resolution of image-intensified video systems, a variety of faint stars and other sky glow form an unresolved background illumination. There is a simple relationship between the angle subtended by a pixel and the background brightness [8]. Most current video systems are background-limited.

3. *The noise of image intensifiers and video detectors*: Each electronic device involved into the image aquisition process introduces some noise, which will limit the ultimate sensitivity of a typical MCP to magnitude +10 or +11.

5. Video observation projects

From the described properties of video systems we would like to derive the following 3 key projects:

1. *Minor meteor shower radiant determination*: Visual meteor observations reach their limits as soon as the activity of a meteor shower becomes very small. Then, the low plotting accuracy cannot be overcome by a larger statistical sample of recorded meteors. Photographic systems, however, only record very few minor shower meteors. Video systems provide the ultimative solution for that problem: they are able to provide an accurate radiant position from only a few recorded meteors [9]. Thus, they can be used for the investigation of radiants from known minor meteor showers as well as for the search of new showers.

   Radiant positions can be obtained from single-station video observation. Both wide angle and standard video systems have certain advantages for this task. Due to the higher spatial resolution, standard video systems provide more accurate meteor positions. Reliable radiants can be derived from smaller numbers of recorded events. Some meteor showers, however, lack faint meteors. They give impressive displays for visual observers and equivalent wide-angle video systems, but are virtually not detectable in the fainter magnitude range due to their low population indices. For such showers, the ratio of sporadics to shower meteors increases rapidly with the camera's limiting magnitude, favoring video systems with a large field of view.

2. *Determination of meteoroid orbits*: So far, most meteoroid orbits have been computed from double-station meteor photographs. However, with the availability of modern video systems, the orbital database can be extended considerably. Double-station video observations with standard video systems are necessary for that goal [10]. They combine a suitable accuracy with sufficient large fields of view and limiting magnitudes. Typically, the baseline for dual station set-up is of the order of 20 to 100 km. The cameras need to be aligned so that the centers of the field of view aim at a height of 100 km. Accurate time information at both stations and precise alignment of the cameras are vital for the investigation. On average, 50% to 75% of the meteors will be in common between the two stations.

   Again, especially minor meteor shower will be the target of such observations, since their photographic records are naturally very rare. The determination of minor meteoroid stream orbits is probably the biggest challenge for video observers. Depending on the shower's population index, even a double-station video set-up may not be efficient enough to record enough meteors in parallel. Thus, coordinated observations from many video teams may be required. On the other hand, orbit determination is the only task that requires double-station work. All other investigations can be carried out by single station observers!

   A number of double station video observation studies of selected meteor showers has been published so far (e.g., [11–13]). However, each of these studies relied on observations in only a few nights. Especially the period from mid January to early July is poorly covered in that respect.

3. *Derivation of flux densities*: Video systems have the major advantage of being objective regarding the shower association, contrary to visual observers. Much less factors do influence the rate of meteors detected by video systems, so it is possible to directly determine flux rates for major and minor meteor showers. In addition, a much larger variety of meteoroid sizes can be investigated, which extends current visual studies to other particle populations. For that, all types of video systems can be applied. It is not necessary to analyze each meteor in detail, so the flux analysis can be done almost automatically.

Besides those key projects, we suggest a number of other observations to be carried out with video meteor cameras:

- *Observations of very faint meteors*: The possibility to record meteors down to magnitude +9 or even fainter with tele video systems opens the door to a class of particles that has not been observed so far in the telescopic range. The behavior of those very faint meteors needs to be investigated. Is there a minimum brightness for meteors?
- *Observations of exceptional high activity*: Video systems provide the unique possibility of objective observations under meteor storm conditions. Therefore, the study of meteor outbursts should be a major goal for video observers. All types of systems should be involved to enable studies of mass sorting and selection effects as well as meteor cluster analysis.
- *Fireball patrol*: Wide-angle video systems regularly record a large percentage of bright meteors, among them fireballs. Special all-sky video systems can work almost autonomous and obtain valuable information about the rate of very bright meteors. They can fill the gap to routinely working camera networks, like the *European Fireball Network*. For this task, an especially robust video system is required. On the other hand, cheaper equipment of lower power will be sufficient. Even systems without image intensifiers may be useful in this respect. All fireballs capable of producing a meteorite are bright enough to be recorded by an ordinary camcorder. Since the amount of data is enormous compared to the number of events actually recorded, such a system definitely requires an automatic meteor detection system.
- *Observations of wake, persistent trains, light curves, and other meteor characteristics*: Video systems give us the unique chance to study individual meteors in detail (see, e.g., [14,15]). Once the characteristics of a video system are known well enough, reliable measurements of meteor properties and their statistical analysis for different meteor showers can be carried out. They may give insight into physical properties of the meteoroids and their parent bodies.
- *Recording of meteor spectra*: So far, only a handful of good quality meteor spectra have been obtained by professional astronomers [16,17]. With few design modifications, video systems can be used to record spectra of much fainter, and thus, much more meteors regularly.
- *Calibration of visual and radio observations, teaching of new observers*: With the help of wide-angle video systems, which have characteristics similar to visual observers, it is possible to calibrate visual observations [7]. In addition, observers can be trained with the help of video recordings for standard situations as well as exceptionable circumstances. If video systems are used in parallel to radio equipment, they can contribute to the important question of the calibration of radio data.

6. Conclusions and outlook

We have presented a list of projects that can be work on with video systems. This list is certainly not inclusive of all possible projects. We would like to invite other observers to join a discussion about the future of video meteor observation and the focus of our work. We want to call for participation in the projects mentioned above, which will certainly improve our knowledge about small particles in the solar system and their interaction with Earth fundamentally.

We feel that the importantance of this observing technique, which will be the key for new investigations in the future, should be reflected by an own commission within the *IMO*. The main aim of an video commission should be the coordination of activities and the encouragement of further observers to apply this still rarely used observation method. The key to success for many of the proposed projects lies in the coordination between video observers and fruitful cooperation with other techniques like photographic, visual and telescopic observation.

A commission should provide general information on the how and why of video observations, technical hints and construction plans for video cameras, suggestions for observation targets, and support for the data analysis.

Forums like *WGN* and the WWW homepage of the *IMO* could be employed for that function. In addition, the maintenance of a video database and the provision of free access to the stored meteor data should be realized.

Last but not least, a Video Commission could serve as a contact address for everybody who has specific questions or problems. With joint efforts of the currently mostly uncoordinated working video groups, we may approach our scientific tasks more efficient than ever.

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Quetelet and the Discovery of the First Meteor Showers

Jacques Sauval, Royal Observatory, Brussels, Belgium

The contribution of Adolphe Quetelet to meteor astronomy is important. In 1836 he predicted the return of the Perseids and in 1837 he published the first catalogue of meteors. He was also an independent co-discoverer of the Orionids and the Quadrantids in 1839.

1. Introduction

Adolphe Quetelet (1796–1874) was interested in a large variety of subjects: poetry, mathematics, physics, statistics (of which he is the founder), social sciences, meteorology, astronomy, history of science, ... Beside his numerous scientific papers, he also wrote a dozen books, of which the most original ones deal with social sciences, meteorology, and the history of science. In his *Essai de physique sociale–Sur l'homme et le développement de ses facultés* (1835), he applied scientific methods to problems which were previously considered as belonging exclusively to moralists. He also wrote several books on popular astronomy and physics: his *Astronomie populaire* (1827) is a model of scientific popularization at that time (see, e.g., [1]).

Several commemorative events were organized last year in honor of the 200th anniversary of his birth. This provides a good opportunity to point out the role Quetelet played in meteor astronomy, especially in the discovery of the first meteor showers in the decade 1830–1840.

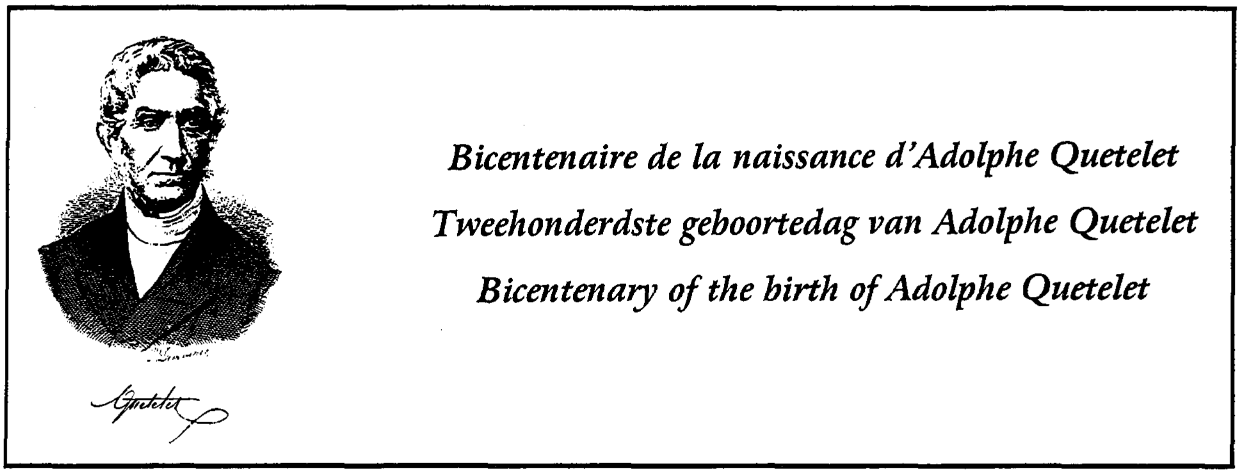


Figure 1 – Adolphe Quetelet (1796–1874)

The contribution of Adolphe Quetelet to meteor astronomy is important. His articles and notes about meteors appeared rather regularly from 1832 till his death: he published a total of about fifty papers about the subject.

His interest in shooting stars began as early as 1824: some years before he became the director of the newly erected Observatory in Brussels, he decided to create a team of a dozen people to make simultaneous observations from different places (Brussels, Liège, and Ghent). Unfortunately, the observations were limited to a few months around 1824–1826, and the results were published only in 1837, when his interest had strongly increased.

His statistical investigations based on his own observations or those of others are by far more important than his theoretical papers. His 1837 paper on the mean number of shooting stars in a normal night [2] was considered as an original study (a standard reference for many years). As another example, we mention his work on the distribution of meteors over different geographical places or over the two parts of the night (before and after midnight). On the other hand, his work on the nature and the origin of shooting stars was not so original and sometimes controversial. He wrongly believed that a correlation could exist between the appearances of shooting stars and other phenomena such as aurorae, earthquakes (and magnetic perturbations), whereas he correctly believed in a correlation with fireballs and aerolites.

He systematically observed and recorded the occurrence of meteors; he also collected reports from everywhere to be published in Belgian scientific periodicals. His main results are the discovery of the Perseids and the co-discovery of two other meteor showers on the basis of his own catalogue of occurrences of meteors in former times. He was the first in 1837 to publish such a catalogue; revised editions appeared in 1839, 1842, and 1861 [3–6] (see also Figure 2). His pioneering work was rapidly followed by catalogues compiled by others (Herrick in the USA, Chasles and Biot in France) [7–9], which proved how useful such catalogues could be.

CATALOGUE

DES

PRINCIPALES APPARITIONS

D'ÉTOILES FILANTES,

PAR A. QUETELET,

DIRECTEUR DE L'OBSERVATOIRE DE BRUXELLES, ETC.

(Mémoire lu à la séance du 8 juin 1839.)

TOM. XII. 1

Ainsi, sur 61 apparitions extraordinaires d'étoiles filantes, 26 appartiennent à des nuits du milieu d'août, et 16 à des nuits du milieu de novembre, tandis que les 19 autres apparitions remarquables appartiennent à différens mois. Il pourrait se faire que, parmi celles-ci, il y en eût aussi de périodiques. Pour pouvoir mieux juger de celles qui, sous ce rapport, mériteraient le plus d'attention, j'ai rangé, dans le tableau suivant, toutes les apparitions remarquables sous le titre des mois auxquels elles appartiennent.

MOIS.	DATES DES APPARITIONS EXTRAORDINAIRES D'ÉTOILES FILANTES.
Janvier	2,1835 — 2,1838.
Février	Pas d'apparition remarquable.
Mars	763 — 18,1811.
Avril	25,1095 — 22,1803.
Mai	Pas d'apparition remarquable.
Juin	17,1777.
Juillet	12,24,26,1784 — 24,1785.
Août	1029 — 9,1779 — 8,1781 — 6,9,1784 — 9,1798 — 9,1799 — 10,1806 — 10,1811 — 11,1813 — 10,1815 — 14,1818 — 6,1819 — 9,1820 — 10 et 15,1823 — 14,1824 — 8,10,14,1826 — 14,1827 — 10,1828 — 14,1829 — 10,1831 — 10,1833 — 10,1834 — 10,1835 — 9,1836 — 10,1837 — 12,1838.
Septembre	2,1820 — 10,1822.
Octobre	902 — 19,1202 — 14,1798 — 23,1805 — 18,1838.
Novembre	25,1741 — 11,1799 — 1812 — 8,1813 — 19,1818 — 12.1820 — 12,1822 — 6,1826 — 13,1831 — 11,13,1832 — 12,1833 — 13,1834 — 13,1835 — 13,1836 — 12,1837 — 13,1838.
Décembre	7,1798 — 7,12,1830 — 6,1838.

Figure 2 – *Left*: Front page of the 1839 edition of Quetelet's catalogue. *Right*: Summary table (Catalogue 1839, p. 20) with the distribution over months for 61 appearances from 763 to 1838.

Among the observers active around 1830–1840 we find (in alphabetical order) François Arago in France, Johann F. Benzenberg and Heinrich W. Brandes in Germany, Edward C. Herrick in the USA, Heinrich W. Olbers in Germany, Denison Olmsted and Alexander C. Twining in the USA, and Louis F. Wartmann in Switzerland in addition to Adolphe Quetelet in Belgium. Already at that time, several amateur astronomers were active observers of shooting stars.

Most of the European observers were in contact with each other; correspondence between American observers was good as well, but little contact existed between the two groups. Quetelet met several observers and kept corresponding with all of them, as can clearly be seen from his Correspondence in the Archives of the Belgian Academy [10]. Most of the American observers published their articles in the *American Journal of Science and Arts* (*AJS*), and so knew all about meteors recorded in America, but most of them were unaware of many European academic publications, or were informed only after some lapse of time. Similarly, most of the European observers ignored many of those American periodicals with a limited circulation. From about 1840 onwards, observers also began to exchange reprints in order to inform each other of their results.

As editor of the *Correspondance Mathématique et Physique* (*CMP*), of which he is the founder in 1825, and of the *Bulletins de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles* (*BARB*), Quetelet published many observational notes from most of the observers mentioned above as well as extracts from their letters. At that time, many original articles were still reprinted (translated and sometimes slightly adapted) in foreign periodicals.

In summary, the group of European observers was were rather well aware of each others results. The same is true for the group of American observers.

2. Criteria for discovering a meteor shower

Even nowadays (150 years later), it still seems difficult to decide impartially who was the discoverer of every shower found between 1834 and 1839. We note that most books about the history of the first discoveries of the meteor streams somewhat disagree as far as the discoverers are concerned: the proposed names differ from one book to another (a selection of books is given in chronological order [11–19]). Furthermore, most of these historical chapters are essentially devoted to the Leonids, the first of the meteor streams to be found, which showed spectacular displays in 1833 and about every 33 years. The history of the other showers is rather limited.

Obviously, any decision about who is the discoverer strongly depends on the adopted criterion. One can choose either

(a) *The discoverer is the first one who announced (suggested or predicted) the annual return, sometimes without any relevant observation, and published his result in a well-known astronomical magazine,* or

(b) *The discoverer is the first one who checked the annual return and who announced the discovery, sometimes in a periodical with a limited circulation or in a non-astronomical book.*

In our opinion, the best criterion to apply should be (a): the discoverer is the one who first announced (generally several months in advance) a date of occurrence of meteors in a scientific periodical, on the basis of certain arguments... even if he was not able to check his prediction himself.

This criterion implies that a critical comparison has to be made between the dates of publication of the original results. Such a search should lead to the first paper which announces the discovery. However, if two results were published within a few weeks or months in distant countries (Europe and the United States, e.g.), we are forced to conclude that there are two independent discoverers, taking into account a delay of at least several months due to the slowness of the information exchange.

We have also to keep in mind that the time elapsed between submission and publication of a manuscript could be exceptionally short for certain authors. Quetelet was the Director of the Observatory and perpetual secretary to the Belgian Academy: therefore his articles in the periodicals edited by these two institutes were published rather rapidly. Similarly, because Herrick was an associate editor of *AJS* and worked on the Yale College campus, his articles appeared more rapidly than those of other American authors.

Quetelet did not contribute at all to the discovery in 1834 of the first meteor stream, the Leonids, but only reported his yearly observations and collected others from around the globe. That explains why we neglect their history here, even if the discovery of the Leonids led to a lot of progress in the interpretation of shooting stars. Details about the discovery of the Leonids can be found in the selection [11–19].

3. The discovery of the Perseids

Several papers about the discovery of the Perseids can also be found in the selection [11–19], as well as in other articles [20,21]. The name of Quetelet is the one most frequently given, but other names (such as Arago, Benzenberg, Forster, Herrick, Locke, and Olbers) are also proposed.

Quetelet's contribution

Starting from November 1835, Quetelet tried to observe the Leonids each year whenever possible. In 1836, Quetelet was already very interested in the observation of periodical natural phenomena of all kinds which were related to plants and animals; and he was really searching for such periodicities in various fields (meteorology, social sciences, geophysics, ...). So it is not surprising that his systematic research in meteor astronomy led to new results about their periodicity.

About the end of 1836 (and not in 1835 as wrongly stated in some books), Quetelet announced that the date of August 9–10 is a very important one for meteors. At a session of the Belgian Academy of December 3, Quetelet draws the attention of physicists to the night of August 10, and in the *AORB* for 1837, Quetelet announces his belief that shooting stars were more numerous from August 8 to 15 (than in other dates) [22] (see also Figure 3). Quetelet reiterated this at later sessions of the Academy in 1837.

ANNUAIRE

DE

L'OBSERVATOIRE DE BRUXELLES,

POUR L'AN 1837,

PAR LE DIRECTEUR A. QUETELET,

Secrétaire perpétuel de l'Académie Royale de Bruxelles, correspondant de l'Institut de France, de la Société Royale astronomique de Londres, des Académies Royales de Berlin, de Turin, de Lisbonne et de Palerme, de la Société Royale d'Edimbourg, de la Société de statistique de Londres, de l'Institut des Pays-Bas, de la Société de physique de Genève, de l'Académie Royale de médecine et de la Société philomatique de Paris, des Sociétés des sciences naturelles de Heidelberg, de Wurzbourg, de Nancy, etc.

Bruxelles,

M. HAYEZ, IMPRIMEUR DE L'ACADÉMIE ROYALE.

SE VEND CHEZ TIRCHER, RUE DE L'ÉTUVE.

1836.

ÉTOILES FILANTES.

5° Quant au *nombre moyen* d'étoiles filantes qu'on peut observer à une époque quelconque de l'année, après avoir examiné spécialement cette question (*Bulletin de l'acad. royale de Bruxelles*, tom. III, p. 404, et suiv.), je suis parvenu à ce résultat qu'un observateur isolé ou plusieurs observateurs dirigés vers une même région du ciel peuvent voir, terme moyen, huit étoiles filantes par heure, et que plusieurs observateurs placés de manière à voir les différentes régions du ciel, peuvent en compter un nombre double.

6° Il semblerait qu'il existe une cause qui produit vers le 8 au 15 novembre, des apparitions plus fréquentes d'étoiles filantes. J'ai cru remarquer aussi une fréquence plus grande de ces météores au mois d'août (du 8 au 15).

Figure 3 – *Left*: Frontispiece of the *Annuaire de l'Observatoire de Bruxelles* (*AORB*) for 1837 (edited in 1836). *Right*: Extract from p. 272 (see particularly Part 6°) [22]

It is clear that his first notes which predicted the annual return of August 9–10 were very short, but very affirmatively worded. It seems to have been the usual style at that time: e.g., Arago also announced the shooting stars of April 20–24, the Lyrids, in one sentence in the *Annuaire du Bureau des Longitudes* (*ABL*) for 1836.

Why was Quetelet so convinced that August 10 was important for meteors?

We can find the reasons for his claim in the introduction to the 1839 edition of his Catalogue [4]:

> *In the process of collecting all available previous occurrences of meteors, I was struck with several events which occurred on August 10: an observation by Brandes in 1823 of a very large number of meteors, another exceptional appearance quoted by Chladni in 1815, and a large number of meteorites or aerolites fallen in August which are listed in Kaemtz.*

By the end of 1836, Quetelet was fully convinced that August 10 was worth drawing attention to, similarly as mid-November. His belief was based on several previous occurrences he collected, some of them being extracted from a new book in meteorology just published in 1836 by Kaemtz [23], with a chronological list of meteorites, and from another by Chladni [24].

Around the end of 1836, Quetelet wrote to other interested observers, such as Arago, Benzenberg, Olbers, and von Humboldt, in order to inform them about his idea (some of these letters and replies were published in *CMP*). Recently, in a search in Quetelet's correspondence at the Royal Academy, we found a 3-page draft letter from Quetelet to Arago dated December 17, 1836 [25].

Quetelet wrote that he was aware of six appearances around mid-August: 1353, 1717, 1815, 1819, 1823, and 1836 (see Figure 4).

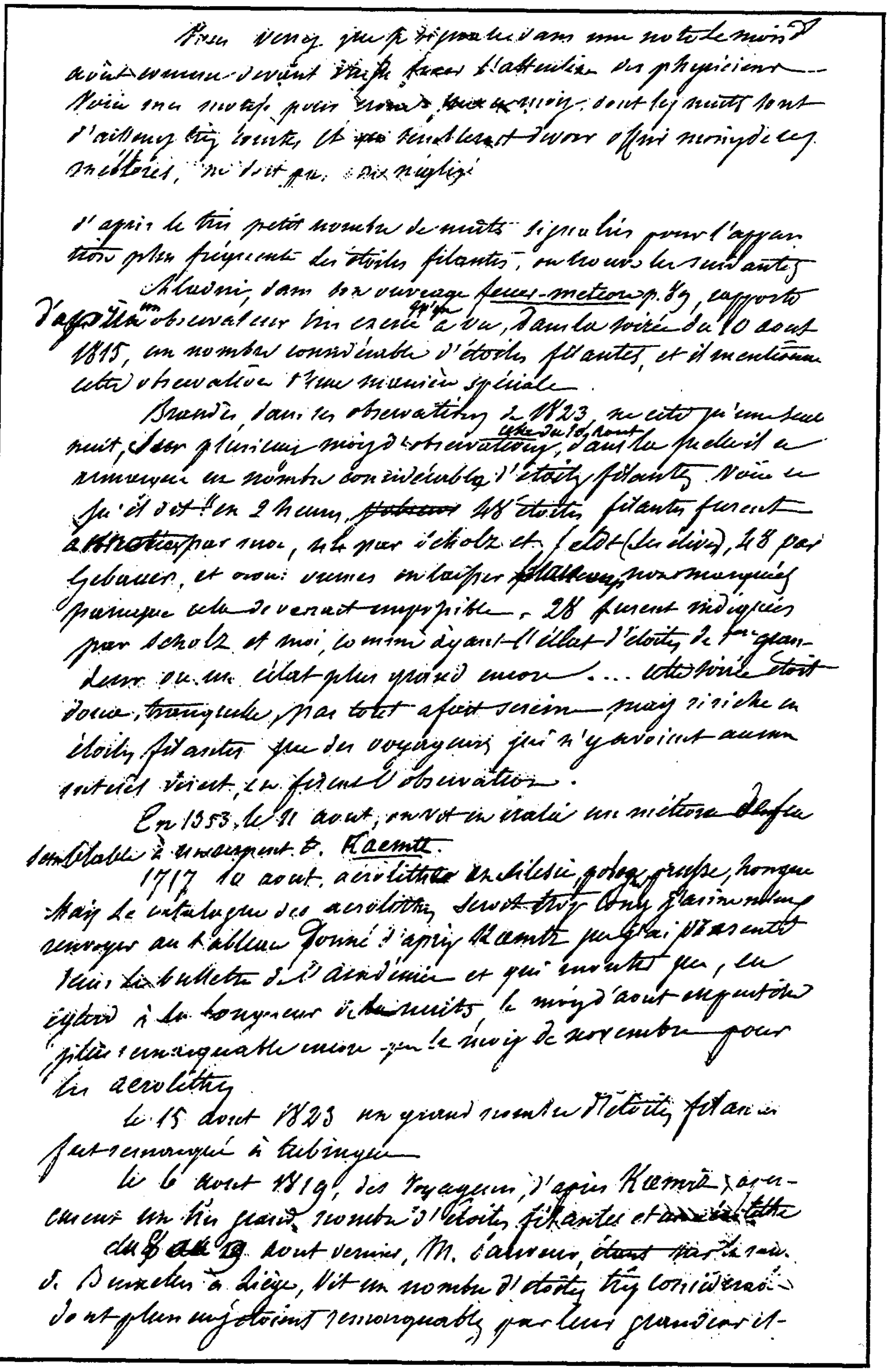


Figure 4 – Extract (2nd page) from a draft letter dated December 17, 1836, from Quetelet to Arago [25] which gives a list of meteor occurrences around mid-August (Archives of the Royal Academy of Belgium).

A surprising fact is that Quetelet forgot to mention two earlier meteor observations in August 1834 and 1835 which were recorded in the register of the Observatory: they were later reported at the Academy [26].

The six listed dates in his letter to Arago of December 1836 [25] are the following:

- August 11, 1353 [23, p. 266];
- August 10, 1717 [23, p. 270];
- August 10, 1815 [23, p. 232, 24, p. 89];
- August 6, 1819 [23, p. 287];
- August 10 and 15, 1823 [23, p. 292]; and
- August 8-9, 1836 (observation by Sauveur in Brussels and quoted by Quetelet [22]).

Now we understand much better why Quetelet was so convinced of the August 10 date. We have to recall that the discovery of the first meteor shower, the Leonids, in 1834 by Olmsted and Twining [27,28], was also based on observations of only a few years (1799, 1832, and 1833). We think that the unusually numerous meteors found in November and in August were by far more significant to these observers than the seeming lack of repeatability.

We have to note that Quetelet's preliminary catalogue of star-showers [3] (probably started end 1836–beginning 1837), which was presented on October 1837 at the Academy, already includes no less than 18 appearances around mid-August, out of a total of 46 [29, p. 466] (see Figure 5).

CORRESPONDANCE

MATHÉMATIQUE ET PHYSIQUE,

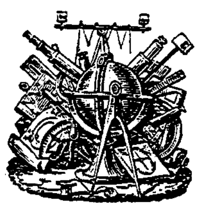
PUBLIEE

Par A. Quetelet,

Directeur de l'observatoire et secrétaire perpétuel de l'académie royale de Bruxelles, chevalier des ordres de Léopold et d'Ernest de Saxe-Cobourg ; membre correspondant de l'institut de France ; de l'institut des Pays-Bas ; des académies royales de Berlin, de Turin, de Lisbonne et de Palerme ; de la société royale astronomique de Londres, de la société royale d'Édimbourg ; des sociétés de Genève, de Heidelberg et de Wurzbourg ; de l'académie américaine de Boston, de l'institut d'Albany, etc.

TOME IX

ET TOME PREMIER DE LA TROISIÈME SÉRIE.



BRUXELLES,

SOCIÉTÉ BELGE DE LIBRAIRIE,

HAUMAN, CATTOIR ET C^{ie}.

PARIS — LEIPZIG

1837

MATHÉMATIQUE ET PHYSIQUE. 463

Extrait d'une lettre de M. Quetelet *à M.* Benzenberg *sur les étoiles filantes, et particulièrement sur le phénomène du* 10 *août.*

J'ai été très-heureux de voir se réaliser mes conjectures relatives à la périodicité des apparitions des étoiles filantes, le 10 août. J'avais eu l'honneur de vous parler de ce phénomène dans ma première lettre ; et vous avez bien voulu, depuis, m'adresser vous-même une note sur ce sujet. Malheureusement, je n'ai pu, cette année, observer ici le phénomène comme en 1834 et 1835. Pendant la nuit du 10 août dernier, contrairement à ce qui semble être arrivé ailleurs, le temps était affreux à Bruxelles. Un violent orage a éclaté au commencement de la soirée, et le tonnerre a grondé jusqu'au delà de minuit. Il a tellement plu qu'on a recueilli le lendemain 26mm,73 d'eau. La nuit qui avait précédé et les suivantes n'ont guère été meilleures.

466 CORRESPONDANCE

	Janvier, aucune nuit remarquable.	
	Février.	»
2	Mars	763, ?.—1811, 18.
2	Avril	1092, 25.—1803, 22
	Mai, aucune nuit remarquable.	
1	Juin	1777, 17.
2	Juillet	1784, 27.—1785, 27.
18	Août	1029, ? —1784, 6 et 9.—1806, 10—1811, 10.—1813, 11.—1815, 10.—1818, 14.—1819, 6 et 13.—1823, 15.—1824, 14.—1826, 14.—1827, 14.—1828, 10.—1829, 14.—1834, 10—1835, 10—1836, 8.—1837, 10.
2	Septembre	1820, 2.—1822, 10.
3	Octobre	902, ?—1202, 19.—1805, 23.
14	Novembre	1799, 11.—1812, ?.—1813, 8. 1818, 19.—1820, 12.—1822, 12.—1826, 6—1830, 12.—1831, 13.—1832, 13—1833, 13.—1834, 13.—1835, 13.—1836, 13.
2	Décembre	1798, 7.—1741, 25.
46	nuits.	

Figure 5 - *Left*: Frontispiece of Volume IX, 1837 of *CMP*. *Right*: Extracts from p. 463 (*top*) about meteors of August 10, 1837, and from p. 466 (*bottom*) showing a table with the distribution over months for 46 appearances [29]

In the night of August 10, 1837, all meteor observers recorded a large number of shooting stars, as predicted by Quetelet. Unfortunately for Quetelet, the weather was very bad that night and the following nights in Brussels: it was awfully bad, rainy, and stormy. Quetelet was not able to observe them... to check his prediction. He had to wait for positive reports from observers of neighboring countries (France, Germany, ...) who all fully confirmed his prediction: meteors had been numerous everywhere indeed. Quetelet was happy to hear their observational reports and so the meteor stream of August 10 was confirmed, one of the most regular showers in fact (later called the Perseids, with its radiant in the constellation of Perseus). In 1866, Schiaparelli identified 109P/Swift-Tuttle (orbital period presently 137 years) as the associated comet.

Several indication of the knowledge of the August meteors were then searched for and found in ancient documents. In the introduction to his preliminary Catalogue in 1837 [3], Quetelet notes that in December 1836 he was unaware of some ancient writings (books, almanacs, journals) which already mention the presence of meteors during the night of August 10. First, in the chapter entitled *De Meteoris Igneis* of a book by van Musschenbroek [30, p. 1061], there is a statement about many *stellae (cadentae)* in August, which should be meteors. In another book, *Ephemerides rerum naturalium*, which was written by a monk at the end of the 18th century, there is a statement that *meteorodes* were frequent on August 10. Thomas Forster, an English physician who lived in Belgium, reproduced this statement in his books (calendars and an encyclopedia) [31–33].

Finally, some popular traditions seem to show that August has long had a reputation for lots of meteors. Let us only quote the "tears of St. Lawrence" whose festival happened to come on August 10; this tradition is especially known among the Catholics in Germany and in England.

Other contributions: Arago, Benzenberg, Forster, Herrick, Locke, and Olbers

The original papers by Olbers, Benzenberg, Forster, Herrick, and others were consulted in order to compare their respective contribution. We also made use of Roggemans's bibliographic catalogue of meteors [34].

T. Forster had grown into the habit of systematically reporting his own meteorological observations in a personal (unpublished) Journal starting from around 1800; he also included his accidental observations of meteors, especially those seen around mid-August from 1806 and was convinced from 1811 (as he stated later) of their annual return. These observations in August 1806, 1811, 1813, 1817, 1824, and 1828 were published only in 1837 [33], after the publication of Quetelet's preliminary catalogue; the latter included them in later editions of his catalogue. Many letters from Forster to Quetelet are also kept [10], but without any mention of this return, which is rather puzzling.

J. Locke should also be mentioned in relation to the discovery of the Perseids. Indeed, in an article in a local newspaper, the *Cincinnati Daily Gazette* of 8 and 10 August 1834, Locke, a physician and headmaster of a school, announced that his observations show the radiant to be near Algol, in Perseus. Locke was aware of the results by Olmsted and others about the Leonids. That very interesting result was, unfortunately, published in a local newspaper only, but it proves that the annual return was already suspected and noted in 1834 by a skilled observer.

Edward C. Herrick, who first worked in a bookstore in New Haven and thereafter became the librarian at Yale College, was a very enthousiastic observer. He was interested in aurorae and in other celestial and natural phenomena of any kind. His interest in meteors started from the display of meteors accidentally observed on August 9, 1837 [35]. He was aware of results about meteors which were published in *AJS*, but not of most of the European observations. His own observations and other facts *appear to me sufficient to render highly probable the periodical occurrence of an unusually large number of shooting stars on or about the 9th of August* [35, p. 177]. He really thought to be the first to announce this new meteor shower, and he was somewhat disappointed when he heard that the discovery has already been made one year before by at least one other person. In his second paper [36], he collected several additional facts which confirmed his opinion of a meteoric shower in August and he quoted Quetelet who independently suspected a meteoric shower in August. In a third note [37], dated December 15, 1837, Herrick added new information about Quetelet's announcement in 1836, and he wrote the following: *At the time when the last number of this Journal was published, I was not aware that any person in Europe, or elsewhere, had ever advanced the idea of a meteoric shower in August.* Note that the article by Littmann [21] gives much information about this contribution. Herrick is in fact an independent co-discoverer of most of the first meteor streams (see later and Table 1). His discoveries were a reward for his careful observations. From 1840, Herrick and Quetelet began to correspond with each other, and this fruitful correspondence continued till Herrick's death in 1861. About 15 letters from Herrick to Quetelet are in the Archives of our Academy [10].

From a search in papers by *F. Arago*, it appears that he cannot be considered as a possible discoverer of the Perseids. The letter dated December 17, 1836, from Quetelet to Arago [25], quoted earlier, clearly shows that Quetelet had first announced his belief to him. In this letter, Quetelet also asked Arago to report his announcement at the next session of the French Academy (this anecdote is also reproduced elsewhere, e.g., in [38, p. 176]). Arago forgot to report Quetelet's announcement, but reported it later, at the session of October 16, 1837 [39]. Arago wrote *your predictions* whenever he addressed Quetelet. In all his later papers and books, without any doubt, Arago attributes this discovery to Quetelet.

According to a report on meteors published in Schumacher's *Jahrbuch* for 1837 (also translated in *CMP* [40]), *Heinrich W. Olbers* wishes that a search be made for meteors around mid-August. One year later, Olbers [41] wrote the following: *The predictions by Quetelet, Benzenberg, and myself about the date of the mid of August have been fully confirmed in August 1837 ... M. Quetelet can thus claim with much confidence a positive prediction.* Therefore, Olbers seems to attribute to Quetelet the whole merit of this discovery.

In 1837, *Johann F. Benzenberg* wrote [42] that he had the idea of this annual return too; in a book published in 1839 [43], he reported his observations of August 1837.

Our conclusion about the discoverers of the Perseids

From a comparison of original results from various observers at that time, we conclude that Quetelet is the first in 1836, among all the known meteor observers, to announce his discovery, especially to inform the astronomical community, with the help of the well-known scientific periodicals. In our opinion, this method is the best way to announce a scientific discovery. At that time, he was unaware of other results (Forster, Locke, and older writings).

Among other "professional" observers, Olbers and Benzenberg seem to have published their results quite independently in European journals, but somewhat later than Quetelet, and so both could be regarded as co-discoverers, too.

With regard to the two "non-professional" observers, Forster and Locke, our conclusion is more difficult. We have to account for their inexperience in publishing a scientific result. Forster could probably claim that he was the first in 1824 to announce this shower through a calendar and in 1827 through a pocket encyclopedia, but he omitted to publish a short note on the subject in a scientific journal. However, we note that his large correspondence (39 letters [10]) from 1833 with Quetelet about meteors never reveals his discovery, which is rather surprising. On the other hand, we have to point out that his discovery was essentially based on his own observations over a period of two decades, which is a remarkable result. J. Locke, as early as August 1834, drew the right conclusion from his careful observations. Unfortunately, he only published his interesting result in a local newspaper with a rather limited circulation. However, we know that he had read the articles by Olmsted in *AJS* [13], and so he could have published it in such a well-known periodical.

Our final opinion is that each of the five observers derived the same correct conclusion: all of them should deserve to be recognized as independent co-discoverers, even if we give Quetelet preference on the basis of rational arguments.

Quetelet's final comments are expressed with a sense of humor in his book on the history of sciences [44, p. 575]:

> *Once the annual return of August 10 announced and reported, some wanted to confiscate it to their benefit; others claimed that it was not new; they found traces of it in all nations and in all times. It was known to the Irish, the Greeks, even to the Chinese. Well, but why did they not say so before?*

4. The discovery of other meteor streams around 1835–1840

The discovery of the first two streams in 1834 (meteors of November 11) and in 1836 (August 10) respectively had probably pushed Quetelet and others to search for other periodical returns. His pioneering catalogue of 1837, based on a historical research of ancient records, enabled Quetelet to predict several other moments in the year when meteors are unusually numerous.

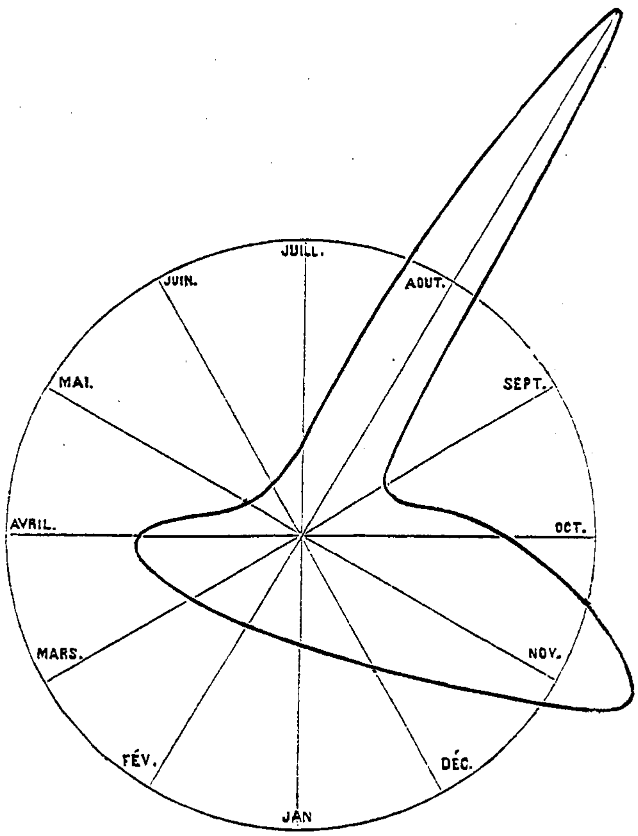


Figure 6 – Figure extracted from the 1861 edition of Quetelet's catalogue [6, p. 318] showing the distribution of meteors over the year. The maxima due to the Perseids in August, the Leonids in November, the Lyrids in April, and the Orionids in October are clearly seen

Already in 1837, just after his preliminary catalogue [3], Quetelet published another note including a summary table with the distribution over months (and days): several appearances do occur at the same dates [29, p. 466]. In his 1839 edition [4, pp. 21–26], Quetelet lists *the nights which deserve the most attention from observers.* In addition to the nights of August 9-10 (26 appearances) and of November 11-12 (16 appearances), Quetelet quotes *four other interesting dates in the year: the nights of April 20–26 (with 2 appearances), the night of December 7 (3 appearances), the night around mid-October (5 appearances) and the night of January 2 (2 appearances).* Next, Quetelet reviews each of these dates and explains his opinion.

In an article, dated December 1838, which appeared the first months of 1839, Herrick also mentioned several dates in one sentence, but without any detailed references [28, p. 366]: *There are other seasons in the year at which meteors may possibly be found unusually numerous: some of these are Oct. 8-15, June 10–20, Jan. 2, Feb. 15, July 28, Sept. 11, Nov. 8. It is not worth while to give the details of the various accounts from which these dates are taken. They are generally vague, and mostly reported by those who had no just ideas concerning the average number of meteors. Of this list, the two first appear the most worthy of attention.* We have to point out that his catalogue of 39 appearances in former times [7] will only appear in 1841. Anyway, the two papers by Herrick and Quetelet were probably published within a few months of each other.

In 1835, Arago [46] also suggested the nights of mid-April (correct) and of the 17th of June as two interesting dates (the latter was based on a single observation by Messier in 1777, but this suggestion was not confirmed).

We would just like to comment here on the four dates quoted by Quetelet, which were all confirmed within the next year(s): they are related to the Andromedids, Lyrids, Orionids, and Quadrantids respectively. The exact references of the original results are given in Table 1.

Table 1 – Discoveries of the first six meteor showers: 1834–1839. The names of our proposed discoverers are written in bold. Abbreviations in the references are explained at the end of the article.

Nights (~ 1835)	Current	Year disc.	Proposed discoverer	Reference (periodical, book)	Associated comet (orbital period)
Nov 11–12	Leonids	1834 1834 1835 1836	**Olmsted** **Twining** **Arago** Olbers	*AJS* 26, 132–174 *AJS* 26, 320–352 *CR* 1, 395; *ABL* 1836, 293 in *Die Sternschnuppen* VII	55P/Tempel-Tuttle (~ 33 years)
Aug 09–10	Perseids	1836 1837 1837 1837 1837 1838	**Quetelet** Forster Arago Olbers Benzenberg Herrick	*BARB* III, 412 *CMP* IX, 448–453; 467–468 *CR* Oct 16 (V, 553) *CMP* IX, 392–419 *CMP* IX, 388–391 *AJS* 33, 176–180	109P/Swift-Tuttle (~ 137 years)
Apr 20–26	Lyrids	1835 1838 1838 1839	**Arago** **Herrick** Benzenberg Quetelet	*ABL* 1836, 297 (footnote) *AJS* 34, 398; 35, 366; 36, 358 *Die Sternschnuppen*, 253 *Catalogue* 1839, 23	C/1861 G1 Thatcher (~ 415 years)
Jan 02	Quadrantids (Bootids)	1839 1839 1841	**Herrick** **Quetelet** Wartmann	*AJS* 35, 366 *Catalogue* 1839, 26 *BARB* VIII, 226	96P/Machholz 1 ? (5.2 years)
Oct 08–15	Orionids	1839 1839 1839	**Benzenberg** **Herrick** **Quetelet**	*Die Sternschnuppen*, 244 *AJS* 35, 366 *Catalogue* 1839, 25	1P/Halley (~ 76 years)
Dec 07	Andromedids (Bielids)	1838 1839 1839	**Benzenberg** **Herrick** Quetelet	*Die Sternschnuppen*, 331 *AJS* 35, 366 *Catalogue* 1839, 25	3D/Biela (6.6 years)

The Quadrantids

On the basis of observations on January 2, 1835 and 1838, by M. Wartmann (*Observatoire de Genève*), Quetelet and Herrick suggest quite independently the night of January 2 for an abundance of meteors. Numerous meteors were recorded in 1839 and in 1840 (especially in Belgium), which fully confirmed this date. In our opinion, Herrick and Quetelet are the two independent co-discoverers as also stated by Lovell and Kronk [19], but Lovell (p. 249) writes that Quetelet claimed first publication. Wartmann announced only in 1841 this annual return, two years after the others, which is unfortunate for him, because he could have been the first if he had correctly interpreted his original observations. This shower, which is called either Quadrantids (after a now obsolete constellation) or Bootids (from Bootes), is rather rich (hourly rate of about 110). Recently, the associated comet might have been discovered: 96P/Machholz 1 (orbital period of about 5 years).

The Orionids

The nights of mid-October are quoted both by Herrick and Quetelet as rich in shooting stars. Quetelet based his suggestion on observations on October 14, 1798, by Brandes and Benzenberg, on October 23, 1805, and on October 18, 1838. Observations by Benzenberg of October 13 to 15, 1837, confirm this date. Kronk [19] writes that Herrick is the discoverer of this shower without any mention of Quetelet. In our opinion, Herrick, Benzenberg, and Quetelet are to be considered as the three independent co-discoverers. Comet 1P/Halley is known from 1911 to be associated with this shower with radiant in Orion.

The Andromedids

The history of this stream has been clearly written by Quetelet in the 1839 edition of his catalogue. From 1838, Herrick was searching if the night of December 7 was rich in meteors. His belief was based on a remarkable observation on December 7, 1798, by Brandes. Herrick hoped also to record many shooting stars in 1838. He succeeded in recording a large number of meteors, whereas other European observers in Belgium (M. Bouvy in Brussels), France, and Italy, recorded many from December 6 to 15. So this meteor stream was confirmed. On the other hand, Benzenberg recorded very few meteors on December 6, 1837 and 1838. Herrick is the discoverer of this shower, but the contribution of Benzenberg is not quite negligible. Comet 3D/Biela, which split in 1846, has the same orbit as this meteor stream and is thus associated with it. Nowadays, very few meteors, if any at all, can be recorded.

The Lyrids

The nights of April 20–24 were first mentioned by Arago in 1835. His suggestion was based on observations made around April 20, 1803, in Virginia. In 1837, Olbers recalled Arago's suggestion, and Benzenberg tried to record meteors from April 20 to 26, 1838, but they were not as numerous as in 1803. Olbers concluded that this return was not exceptional. On the basis of the spectacular display in 1803, Herrick (who was probably unaware of Arago's idea) also suggested in 1838 a new meteor shower in April: *This shower ought to be re-discovered....* He made arrangements for observations around April 20, 1838 and 1839, at several places in the United States. Unfortunately, very few observations were recorded in 1838 (bad weather!); in 1839, he concluded that *no unusual display of meteors was visible in this country on the mornings of the 19th and 20th April, 1839. It is to be regretted that no thorough observation was made on the mornings of the 21st and 22nd.* Benzenberg confirmed the suggestion of Arago, whereas Herrick independently discovered the shower: Arago and Herrick can be considered as co-discoverers. Quetelet did not contribute to this discovery, because his suggestion had already been made four years before by Arago.

5. Conclusion about Quetelet's contribution to meteors

As we showed, most of the discoveries of the first showers have resulted from the work of a small group of observers (Arago, Benzenberg, Herrick, Quetelet, ...), and are generally due to two or more independent co-discoverers.

In 1836, Quetelet discovered the Perseids, a rather well known fact today. In 1837, he had the original idea to publish the first catalogue of occurrences of meteors in former times, which enabled to predict other dates when meteors are numerous. He was also one of the independent co-discoverers of the Orionids and of the Quadrantids in 1839, a fact which is little known nowadays, even in Belgium.

Acknowledgments

We are grateful to the Royal Academy of Sciences of Belgium for permitting us to reproduce a letter in Quetelet's Correspondence and J.-L. De Paepe for his help in the Archives of the Academy. We also thank M. Littmann (Univ. of Tennessee) for his stimulating remarks and R. Blomme (KSB/ORB) for his comments and his careful reading of the manuscript.

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Abbreviations used

AARB: Annuaire de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles
ABL: Annuaire du Bureau des Longitudes (Paris)
AJS: The American Journal of Science and Arts
AORB: Annuaire de l'Observatoire de Bruxelles
BARB: Bulletins de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles
CMP: Correspondance Mathématique et Physique
CR: Comptes Rendus des Séances de l'Académie des Sciences (Paris)
MARB: Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles

Meteoric Dragons

Alastair McBeath

Some notes are presented on the term "dragon" as applied to bright meteors in the past, including a short discussion of meteoric phenomena that may have helped create and strengthen such a link.

1. Introduction

Several references from the past refer to flights of fiery dragons seen in the sky, which were often taken as portents of one sort or another. Many modern commentators have attempted to analyze these dragons as possible astronomical phenomena, including comets, the aurora and meteors. That bright meteors were still being quite commonly called "fiery dragons" as recently as the 1860s, and after (albeit often in an increasingly poetic sense latterly), is a matter of record, and it is these dragons that are examined here, with especial reference to associated phenomena connected with bright fireballs.

2. Sky-dragon meteors and weather phenomena

An early European reference to sky dragons can be found in the *Anglo-Saxon Chronicle* [1,2] from AD 793, regarding portents prior to the destruction of the monastery on the island of Lindisfarne, off the north-east coast of England, including: ... *exceptional flashes of lightning, and fiery dragons ... flying in the air ...* [1, pp. 54–57].

Such comments can occasionally be found in other sources up until relatively recent times, and the full *Oxford English Dictionary* [3] continues to list the terms "dragon" [3, Vol. IV, p. 1012, sense 8.c], "drake" [3, Vol. IV, pp. 1016–1017, sense 2] and "fire-drake" [3, Vol. V, p. 949, sense 2.a] as obsolete terms meaning a fiery meteor or a *shooting star with a luminous train* (reference to dragon, sense 8.c above). Quotations given in [3] illustrating the use of the term under "dragon" begin with one dated 1398, which, like [1], also makes a link between the shooting-star-dragon and lightning.

This dragon-as-meteor to lightning connection is interesting for a number of reasons, not least of which is that mythology going back several thousand years in written form alone, and found right across the world, associates dragons or draconic creatures with thunderstorms, lightning, and rain. The Chinese, for instance, always called upon the dragon to bring the rain essential for their crops in time of drought, and their dragons were always intimately linked with the sky and water (cf. [4,5]). Much of the Chinese dragon mythology may well have originated with the ancient Mesopotamians or their forbears, and pictorial evidence from Mesopotamia going back to at least 2500 BC, if not earlier, supports this concept, where several dragon types were associated with different weather and fertility deities, notably that known as the Mushussu (cf. [6,7]). In addition, dragons have been long associated with tornados and waterspouts (tornados over water) (cf. [5]) which themselves frequently occur near severe thunderstorms.

The derivation of the word "dragon" is commonly traced back to the Greek δερκεσθαι, "to see clearly," but an alternative is δαρκομαι, "to flash or gleam," which ties in very well with the dragon as having a meteoric or storm-cloud origin. We also find that meteorites have enjoyed a long association with storms as well, and indeed "thunder-stone" became a popular term for a meteorite (cf. [8]). The link was further supported in the popular mind by illustrations such as the woodcuts of medieval meteorite falls (e.g., that at Ensisheim, now in France, in 1492—see [8, p. 2], for instance, where the meteorite is shown emerging from a dark stormy cloud accompanied by lightning). There was a common belief that meteorites were formed when lightning struck an earthly rock too. Undoubtedly, the fact that meteoritic fireballs—and even bright fireballs that do not drop meteorites—can create acoustic noises resemblant of thunder in regions they pass over or nearby would merely strengthen such a supposition.

In many respects, this is perfectly reasonable, and no more outlandish than some of the currently accepted scientific hypotheses. Indeed, we should remember it were the scientists of their day during the 18th and early 19th centuries who refused to accept the evidence that such meteoritic rocks could fall from the sky at all.

One final point concerning dragons in this regard is that, in some myths, a dragon is killed for a precious stone which grows inside its head, called a draconite stone. The possible connection here with a meteorite fall is too obvious to labor over, suffice to comment on the reverence with which meteoritic material has long been held throughout the world, with many attested meteorites being worshiped as deities or their avatars in places [8].

3. Other draconic features of bright meteors

Anyone with even a modest level of meteor observing experience will probably have realized already that there are other features of meteoric activity that could be interpreted as draconic, or at the very least serpentine. Firstly, there are particularly persistent trains left hanging in the sky on occasion where especially bright, and generally swift-moving, meteors have passed. During recent Leonid returns especially, observers have detected meteor trains with durations between 2 to 6 minutes, for instance, and there are other similar, or longer, trains on record.

As many observers reading this will hopefully have seen for themselves, when such a long-lived meteor train appears, winds in the high atmosphere can blow it away from the meteor's straight line path within a matter of a few tens of seconds, winds which often blow in very different directions only a few vertical kilometers from each another. This means there is a strong tendency for trains like this to generally form into an "S" shape, sometimes curling into what looks like a ring (but is probably a helix in three-dimensions), or, at the very least, develop kinks in the train. At times, the motion can appear to be dynamic, as if the train were alive, while variations in the ionized train's gas can even make the train seem to glint or sparkle, or infrequently to brighten as well as fade. Such a ring, spiral or "S" form, is often described as "serpentine", and it is easy to visualize why a train of this type could be described as "draconic."

The train need not simply be of ionized gas, but can also be what has become called a dust train, and which has been reported notably with daylight fireballs that have dropped meteorites. A particularly fine painting of one such dust train, belonging to the Sikhote-Alin meteorite of 1947 is reproduced in black-and-white as Figure 2 in [9], for example. Dust trains are probably composed of smoke, dust, and, possibly, some ionized gas emitted by a meteoroid capable of penetrating to deep levels in the atmosphere, and which often results in a meteorite fall. Such a column of dusty material will tend to behave rather like a volcanic plume under the action of atmospheric winds and its own internal energies (heat and motion, chiefly), and will tend to assume an outer surface not unlike that of cumulus clouds over a matter of minutes, if it does not dissipate too rapidly. The appearance would thus be very reminiscent of the archetypal knobbly reptilian skin often portrayed in artistic representations of dragons. Dragons are commonly shown as elongated creatures as well, none more so than the oriental types, which again adds to the similarity between them and either a dust or an ionization train. Dust trains, especially in their early stages, when the upper parts will tend to have spread further from their original path faster than the lower ones, will also look quite comparable with the long cone-shape of a tornado or waterspout, perhaps even extending down from any tropospheric cloud sheet which is present at the time.

Apart from this, there are also VLF/ELF sounds heard simultaneously with the occurrence of, primarily, the brightest meteors, by witnesses not far from the projected ground tracks of such objects. Sounds of this kind have been detected throughout recorded human history, and as the most common electrophonic noises reported appear to be of a serpent-like hissing type (hissing, rustling, swishing = 48% [10]) or similar to thunder (bang, boom, rumbling = 29% [10]), this ties in precisely with a draconic affiliation, as we have earlier established.

4. Conclusion

This short article should not be seen as an attempt to suggest that only such bright meteors account for the widespread nature of draconic creatures, their lore and mythology, to be found around the world, although it seems quite plausible that it has helped the power of the dragon as a symbol to survive into the present day.

Other aspects of dragon myths show the dragon is not something that can be explained easily, and it is almost certain that a great deal of celestial mythology can be traced back to an ancestral dragon.

As an example in closing, the Moon's path through the sky as seen from the Earth, possibly including the Moon itself, can also be called "The Dragon," since the draconic month is a period defined as the time between successive lunar ascending node crossings of the ecliptic. This is further borne out by the actual ascending node being called "the dragon's head," while "the dragon's tail" is the descending node. The node symbols themselves—which are also now used for the nodes of any orbiting body—appear to be highly stylized serpentine dragons, and the part of the Moon's orbital path which lies south of the ecliptic is known as "the dragon's belly." "The dragon's back" is naturally the part of the apparent lunar track that currently lies north of the ecliptic. It is this which gives rise to the concept of eclipses (which can only occur when the Sun, Moon, and Earth are in alignment, and the Moon is near one its nodes) being times when the Sun or Moon is being eaten by a dragon or some equally huge monstrous creature [11].

These myths too are found across the globe, an understanding of which strongly suggests that they were never merely some sort of fantasy created by superstitious peasants who knew no better, that some supposed scientists might like us to believe!

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1998 October Draconid Prospects?

Marco Langbroek

The possibility of a Draconid revival around perihelion passage of the parent comet 21P/Giacobini-Zinner in 1998 is discussed. In addition, it is reported that 1996 radio meteor scatter observations suggest short-lived (annual?) Draconid activity around nodal passage. A visual watch around nodal passage in 1997 is called for.

1. Introduction

During the 1996 *IMC* at Apeldoorn, the Netherlands, a workshop was devoted to the organization of activities on the 1998 and 1999 Leonid displays. Due to all attention and high expectations for the Leonids, it might easily be forgotten that yet another stream could provide the opportunity of observing impressive rates, though not comparable to the rates expected for the Leonids.

In November 1998, periodic comet 21P/Giacobini-Zinner, the parent comet of the October Draconids, will pass through perihelion, and this might produce a conspicuous short-lived revival of the currently dormant Draconid stream. Interestingly, some possible first signs of a stream coming to life were detected by radio meteor scatter last October.

2. A slight touch of history

On December 20, 1900, M. Giacobini at the observatory of Nice discovered a faint comet. Only a limited amount of observations was gathered following the discovery, resulting in an orbit with rather large uncertainties. On October 23, 1913, Ernst Zinner in Bamberg rediscovered the comet and its orbital period was determined at only 6½ years. The comet proved to be under serious perturbations by Jupiter.

In the first half of this century, perturbations brought the orbit of the comet extremely close to that of the Earth, resulting in conspicuous meteor activity in the years of perihelion passage caused by the encounter with the debris of the comet. In 1926, Prentice observed the stream, now known as the Draconids or Giacobinids, with a ZHR of about 14.

In 1933, the distance between Earth and comet orbit was only 0.0054 AU. The Earth passed the cometary node only some 80 days after the comet went through its node. In the early local evening of October 9, thousands of Europeans, among them the late and now legendary J.H. Oort (at that time still a young and rather unknown astronomer), witnessed a spectacular meteor storm rivaling with the famous Leonid storms.

Two orbital periods later, in 1946, European and American observers again witnessed an intense display—moonlit, but not less impressive because of that unfavorable circumstance. That year, the distance between Earth and cometary orbit had decreased to only 0.0015 AU, and the Earth encountered the debris at the cometary node only 15 days after the comet had passed this point. In the best traditions of this field of research, the absolute as well as relative strengths of the 1933 and 1946 peaks are debatted. A summary of different opinions is given by Jenniskens [1], who himself provides the figures of $10\,000 \pm 2000$ for 1933 and $12\,000 \pm 3000$ for 1946 based on a reduction of original raw data.

In 1952, the cometary orbit had shifted such that the node became located inside the orbit of the Earth, but the distance remained small: 0.0057 AU. The Earth crossed the cometary node 196 days before the comet encountered this point. Radar observations from Jodrell Bank (UK) showed that conspicuous activity was present in the late afternoon, though evidently the rates remained rather modest compared to the incredible 1933 and 1946 events. In 1953, no activity was detected.

The interplanetary play of pinball between Jupiter and the comet then took a negative twist.

The next years, the distance between Earth and comet orbit increased considerably and the Draconids vanished from the scene until a new round of push and pull hurled the comet to an extremely close encounter in 1972: 0.0007 AU, with the Earth passing outside the cometary orbit, only 58 days after the comet passed its node. Surprisingly, and disappointingly, only very modest activity was detected that year.

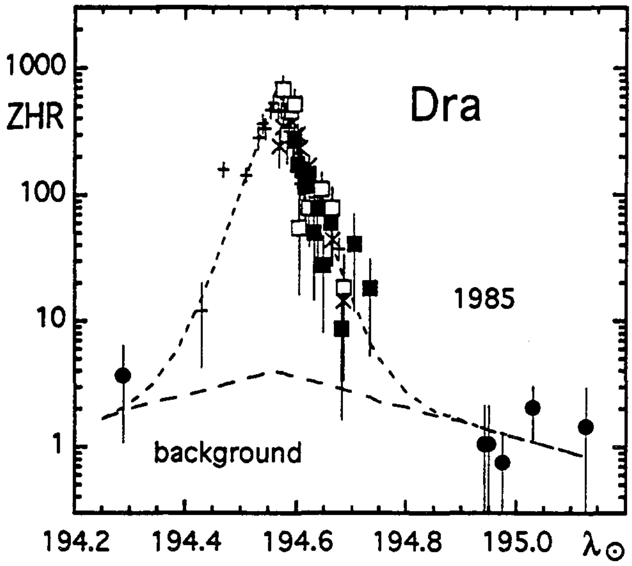

Figure 1 – Activity curve of the Draconid outburst of October 8, 1985, based on visual NMS-data and radar data by Lindblad (ref. [1]).

By 1985, the orbit had changed again. This time, the cometary orbit remained rather far from that of the Earth at a distance of 0.0329 AU, but the node had shifted outside the Earth orbit again. On October 8, only 27 days after the comet had passed its node, Japanese observers witnessed an impressive outburst with a peak ZHR of 700 ± 100 [1]: nothing compared to the 1933 and 1946 events, but still a rather remarkable event. Besides the strong main peak, a very low level background activity with a ZHR in the order of 2–4 seems to have been present for several hours before and after the main peak that year. In the following years, little or no activity of the stream was detected. The stream seems to be absent except for a short period around perihelion passage of the parent comet [1]. In non-perihelion years, the stream is virtually undetectable [1–3].

3. 1996 activity?

In 1996, Draconid observational attempts were spoiled by cloudy weather in the western part of the Netherlands, where the author is living. Koen Miskotte, on a more eastward location, observed 1 (one) possible Draconid in 3 hours observational time on the evening of October 8, with limiting magnitude near +6.1, and this might well have been a chance alignment of a sporadic. Interestingly, radio observer Peter Bus detected modest but clear activity (up to a factor about 1.5 above the "sporadic" background in proceeding and following days), which might be attributed to the Draconids in 1994 and 1996 [4]. In 1996, the activity was restricted to a 2-hour period with highest rates around $8^{\rm h}40^{\rm m}$ UT on October 8, which interestingly almost exactly coincides with the passage of the 21P/Giacobini-Zinner node. A visual watch from western Asia around approximately $13^{\rm h}$–$17^{\rm h}$ UT on October 8, 1997, is called for.

4. The 1998 encounter conditions

At the occasion of the 1998 perihelion passage of P/Giacobini-Zinner, the Earth and the comet will pass the cometary node with a time difference of only 50 days according to the latest orbital predictions [4,5]. The distance between the cometary orbit and the Earth orbit at the cometary node is only slightly larger than in 1985: 0.0383 AU (against 0.0329 AU in 1985). At first glance, this would suggest that, judging from the 1985 experience, the conditions for 1998 are favorable and we could expect a conspicuous 1985-like event again.

Yet, there is some reason for caution. In 1985, the comet passed its node 27 days before the Earth passed near this point. In 1998, the comet will pass 50 days after the Earth. It is very difficult to asses what effect this difference will have, but it might well be the difference between all or nothing. On the other hand, both the Leonid and Perseid parent comets have shown to cause outbursts before nodal passage too—but then, these have orbits passing closer to Earth and are less disturbed.

Table 1 – Encounter geometry of historic Draconid events and the 1998 perihelion passage of 21P/Giacobini-Zinner. Listed are (from left to right) date, approximate peak ZHR, the peak location (eq. 1950), the time difference (in degrees of solar longitude) between the peak location and the passing of the node, the distance between Earth and comet orbit (in AU: cometary node inside (−) or outside (+) the orbit of the Earth) and the number of days that the Earth leads (+) or follows (−) the comet at passing the node. All data are from [1], except for the 1998 data [4,5].

Date	ZHR_{max}	$\lambda_{\odot,max}$	Δt-Ω	ΔE-C	Δdays
Oct 9, 1933	10000 ± 2000	196°302	+0°059	+0.0054	+ 80
Oct 9, 1946	12000 ± 3000	196°292	+0°001	+0.0015	+ 15
Oct 9, 1952	(~ 250?)	196°241	+0°001	−0.0057	−196
Oct 8, 1985	700 ± 100	194°565	−0°147	+0.0329	+ 27
Oct 8, 1998				+0.0383	− 50

5. Observational conditions

As difficult as to asses if there will be an outburst, is to asses when it will occur. The node of the 1998 orbit of 21P/Giacobini-Zinner, predicted at 195°39847 (eq. 2000.0) [5], will be passed in the evening of October 8, 1998, around 21^h UT. Kresák has predicted 17^h UT as the possible peak location some years ago [6]. If the time difference between peak location and passing of the node is similar to 1985, we might expect it near 17^h45^m UT. Give or take a few hours, the event might be expected to occur in the early evening for Europe. The most favorable locations to observe the possible event might be the eastern Mediterranean, the Balkans, and western Asia. Though the actual peak might drown in evening twilight, observers in western Europe might still be able to catch a considerable part of the descending slope of the outburst from late twilight onwards if the event roughly mimics the 1985 event in general strength and Δt-Ω of the peak and the B-value [1] of the slopes (the last condition is very likely in case of a positive event [1]).

The possible 1998 recurrence is not so favorable with regard to interference of the Moon. Full Moon will occur on October 5, 1998, only three days before the possible event: the Moon has a phase of 0.87 on October 8. Yet, the first hour (depending a little bit on the latitude) after the end of astronomical twilight will be void of Moon, and it is during this early part of the evening that the radiant is located highest in the sky and observing conditions are perfect for eastern Europe and the Balkans.

Acknowledgments

I thank Peter Bus (*Dutch Comet Section*) for providing information on the 1998 orbit and encounter geometry of 21P/Giacobini-Zinner and his 1996 radio observations, and Koen Miskotte for communicating visual observations.

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A New Device to Investigate Meteors in Japan

Hironori Okauchi, Hiroaki Motoki, and Norihito Kawamura

The authors investigated meteor scatter with the MU-radar.

1. What is the MU-radar?

The authors have investigated meteor scatter with a new device: a MU-radar (MU stands for Medium-Upper atmosphere). The MU-radar of the Kyoto University is located in Shigaraki-cho, Shiga Prefecture, in Japan, and can emit pulsed radio waves at 46.5 MHz (VHF). The MU-radar is generally used to measure the condition of the atmosphere. Plenty of astronomers and researchers have their investigations depend on the MU-radar.

The distance between Shigaraki-cho and Takamatsu-city is about 150 kilometers. Around the survey spot at Takamatsu-city, there are a lot of obstacles, such as tall buildings, that can prevent the conveyance of radio waves from the MU-radar. On the other hand, around 46.5 MHz, no radio stations are admitted except for some investigations transmitters such as the MU-radar, so we can receive its waves rather clearly. The MU-radar is a famous radar among professional astronomers, but not among amateur investigators, and still much less among high school-students. In spite of this, we dared to deal with it since there is little jamming around 46.5 MHz. Along with bistatic-way, we decided to use the SSB (Single Side Band) receiving mode because the S/N ratio (Signal to Noise ratio) seemed to be better than when using the DSB (Double Side Band) mode, judging from our preparatory survey test. We also investigated the characteristics of the meteor echo and considered the possibility of the use of the MU-radar signal for meteor surveys, and evaluated its limits.

2. Observations

As a matter of fact, there are some modes used by the MU-radar. Using the "phased array antenna," the beam pattern can be changed and the lobe structure can be aimed toward different directions. Among the available beam patterns we think that the "ionosphere mode" is best to observe meteor scatter because more meteor echoes can be expected to be recorded, for the power is then high (1 MW).

The MU-radar could be a high-performance device and very efficient for meteor scatter observations, but there are some troubles. First of all, the MU-radar is not always on the air, but is only used when researchers survey the ionosphere. The radar wave is stopped around the hour and around quarter past the hour to save the data, so we cannot keep surveying any time we want to and cannot collect continuous data. When it comes to the survey of meteor activity, continuous data may be very useful.

The following is a description of the way our experiment was carried out.

First of all, we shall describe our survey system. Our apparatus consists of three parts: a $\lambda/2$ dipole antenna, a radio receiver, and a pen recorder. Between the antenna and radio receiver, we have put an adaptor circuit unit (ACU), which transforms the received radio waves to a frequency suited for the receiver. Extracting the audio-signal from the earphone terminal, a line conveys the signal toward the recorder. The system is an "AF device" (Audio Frequency). A $\lambda/2$ dipole antenna has a torus-like radiation pattern and is nearly omnidirectional, which is more suitable for the survey of meteors.

The basic method for echo counting is the following: if the voltage of the AF output signal is high enough to reach 300 mV, we decided to make it available, and, if not, we did not count it for fear that it might just be an unidentified noise. This way, we could have credible data.

We shall now discuss the reliability of our survey. There are some risk factors that might affect our data, such as atmospherics or unusual conveyance by sporadic-E ionospheric scatter. We took these phenomena into consideration and decided that these "pseudo-meteor echoes" could be distinguished from the chart (data-recording paper for the pen recorder) if the radar is active. In our research, the average number of "pseudo-echoes" is about 6.25 per hour—the median value is 1.5 per hour—ranging from 0 to 44 per hour. By the way, if sporadic-E remains too long, we cannot have good data. If so, we calculate an HR (hourly rate). To have credible data, we ignored some echoes if they yielded a signal level below 300 mV. Additionally, if two echoes appear too shortly after each other, we had difficulty counting them.

3. Results

Are our data reliable? The following is a discussion of some evidence.

1. Echoes could be found at random, and the graph of the echoes shows a Poisson distribution. In space, the distribution of the meteor dust is considered to be random. Therefore, the occurrence of the echoes should follow a Poisson distribution.
2. Underdense echoes appear often.
3. Sometimes, we came across noise, but we could distinguish it using meteorological information afterwards.

We thus can conclude that the signals received in Takamatsu-city are meteor echoes from the MU-radar. This means that there can be a possibility of what we call a "meteor-burst interactive communication." However, the signal levels are quite low and the durations short. These two demerits are expected to be conquered by means of computers, etc. Though we do not have enough equipment and money, we shall carry on these experiments, dreaming that a "meteor burst communication" system will become possible some day. If you have opinions or questions, please contact us. Any criticism is welcome.

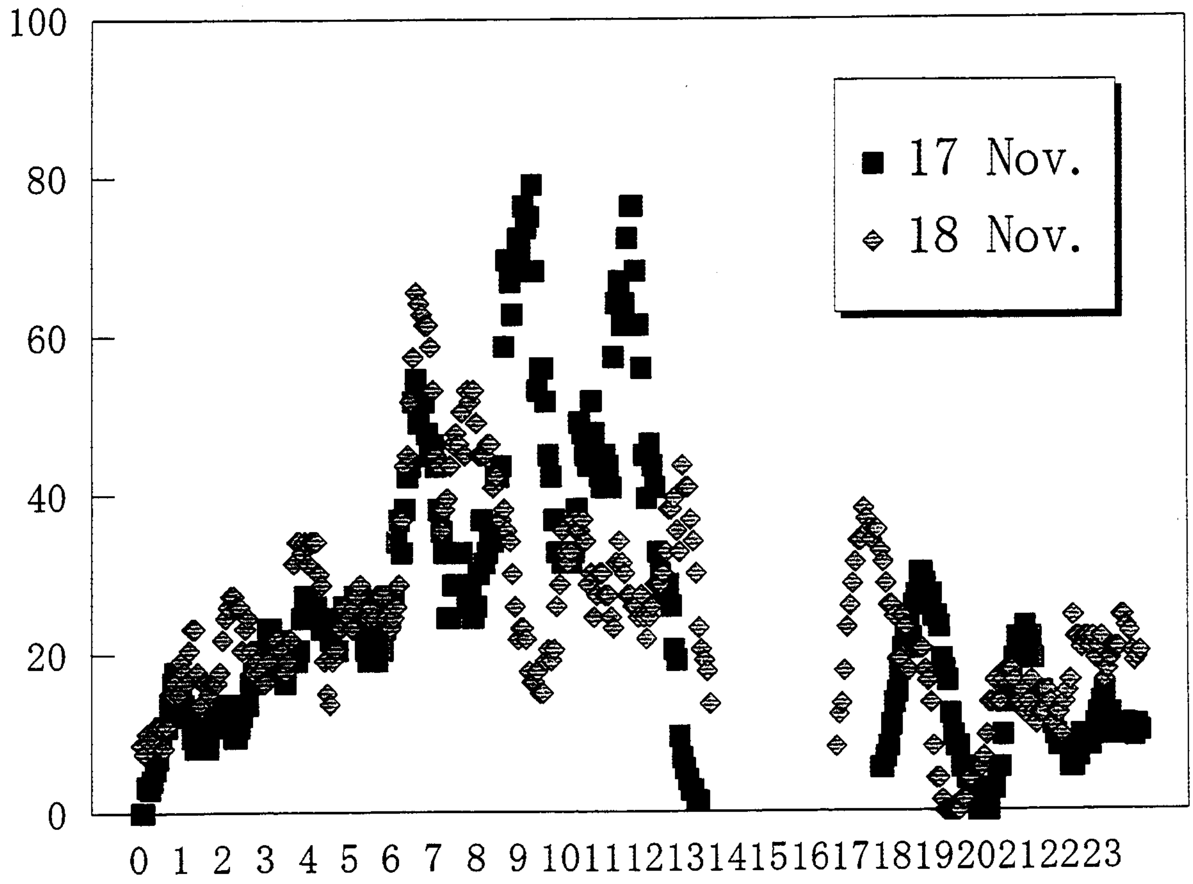

Figure 1 – MU-radar meteor observations of the Leonids (hourly rates versus local time).

The 1996 Leonids

The Leonid Maximum of 1996 from Radar Observations in Italy

Giuliano Trivellone, Luigi Foschini, and Giordano Cevolani, FISBAT/CNR

Continuous radar observations of Leonids during November 15–25, 1996, were carried out by using the FS (forward scatter) facility in Italy. Enhanced activity was observed in the interval from 0^h to 9^h UT on November 17, with a prominent peak at 7^h corresponding to solar longitude $\lambda_\odot = 235^\circ\!.29$ (eq. 2000.0). Even though lower levels of transmitted power were utilized in comparison to the 1995 recording (0.25 kW instead of 1kW), the radar observations of the 1996 Leonids in Italy show clear evidence of a general increase in rates as compared to previous years (1994 and 1995).

Radar observations were performed continuously between November 15 and 25, 1995, utilizing the FS radar with the transmitter in Budrio, near Bologna ($\varphi = 44^\circ\!.6$ N) and the receiver in Lecce ($\varphi = 40^\circ\!.3$ N) over a baseline of 700 km. The bistatic radar system utilizes a 42.7 MHz continuous wave with a fixed modulation tone at 1 kHz and 0.25 kW mean power.

The radio echoes from overdense meteor trains were divided in class durations of 1–2, 3–4, 5–8, 17–32, 33–63, 64–128, and > 128 seconds. The shower started to give signs of activity on November 15 with a consistent number of long-duration echoes of at least 30 seconds (18 echoes at 7^h UT). The real *show* occurred on November 17 between 0^h and 9^h UT, when during 10 hours of observations 214 exceptionally enduring echoes were registered, with 97 fireballs of durations T = 1–2 minutes, 50 with T = 30 seconds–1 minute, and 67 with T = 16–30 seconds. This number is almost the double of the number registered on the morning of November 18, 1995, when, during the same interval of 10 hours centered around the peak activity, 116 long-enduring echoes were recorded (29, 37, and 50 echoes in the corresponding class durations, see Table 1). Even the occurrence of the peak activity of the 1996 Leonids was in accordance with the expected time. In fact, in 1996, the maximum of very long-enduring echoes having $T \geq 16$ seconds occurred at 7^h UT on November 17, corresponding to $\lambda_\odot = 235^\circ\!.29$ (eq. 2000.0) with 36 very bright meteors (expected time for the maximum: November 17, 7^h20^m UT). In 1995 conversely, the maximum was observed with 18 fireballs, 1–2 hours later than expected, at 3^h UT on November 18 (expected time for the maximum: November 18, 1^h15^m UT).

Table 1 – A comparison of hourly rates of Leonids during the maximum activity in 1996 and 1995 for 16–30 seconds, 30 seconds–1 minute, and 1–2 minute class durations, utilizing two different levels of transmitted power (0.25 kW and 1 kW respectively in 1996 and 1995).

Time	November 17, 1996			November 18, 1995		
(UT)	16–30 s	30–60 s	1–2 min	16–30 s	30–60 s	1–2 min
0^h	4	6	4	7	2	0
1^h	6	5	4	4	3	2
2^h	9	7	8	6	8	3
3^h	3	3	11	7	5	6
4^h	8	5	8	5	6	4
5^h	7	5	18	5	3	6
6^h	8	4	18	7	4	3
7^h	14	7	15	3	0	0
8^h	7	8	7	6	6	5
9^h	1	0	4	0	0	0

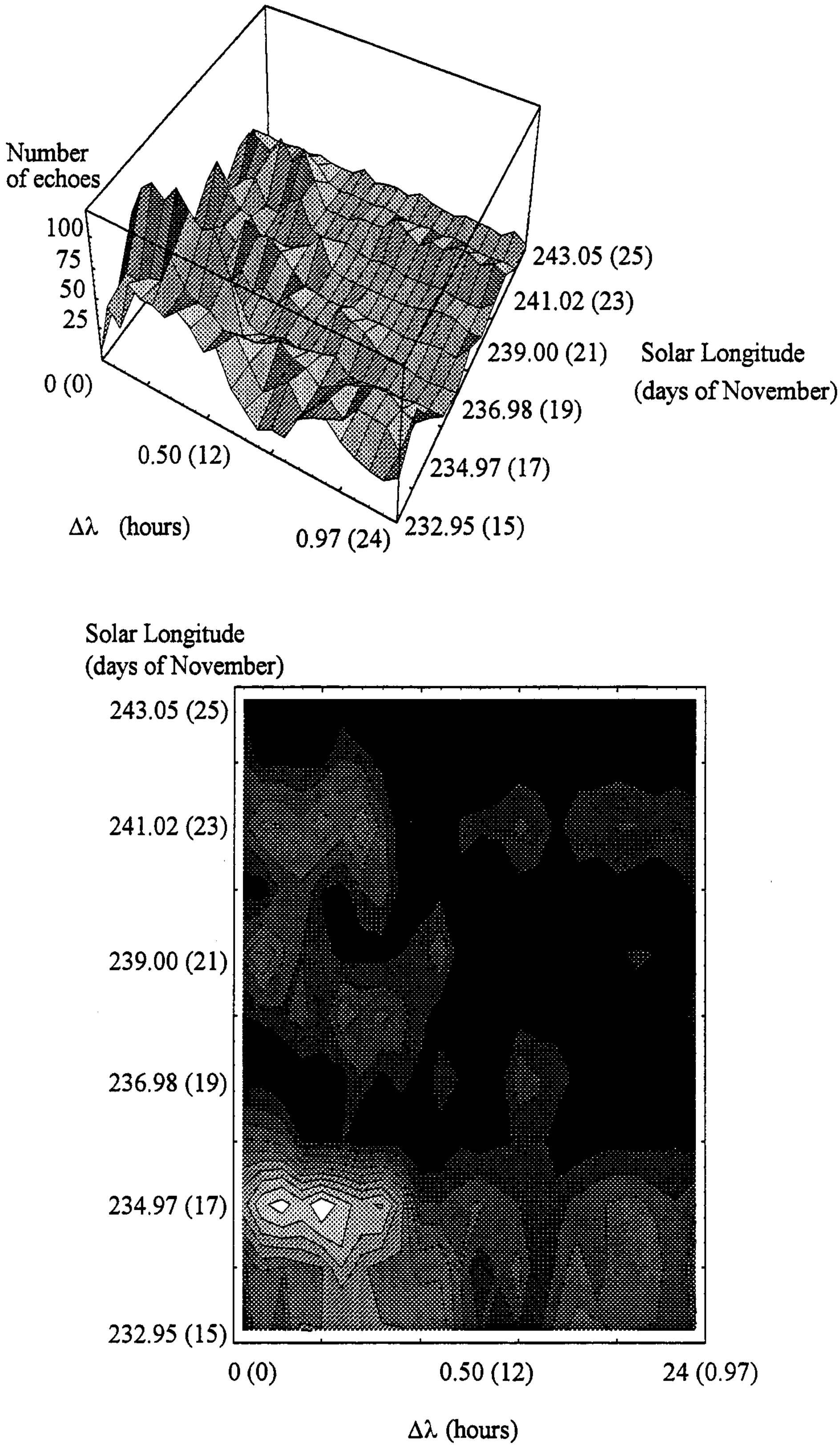

Figure 1 – This figure shows the three-dimensional (top) variations and the relative section (bottom) of the hourly flux of overdense meteors with durations $T \geq 2$ seconds, observed in the period November 15–25, 1996.

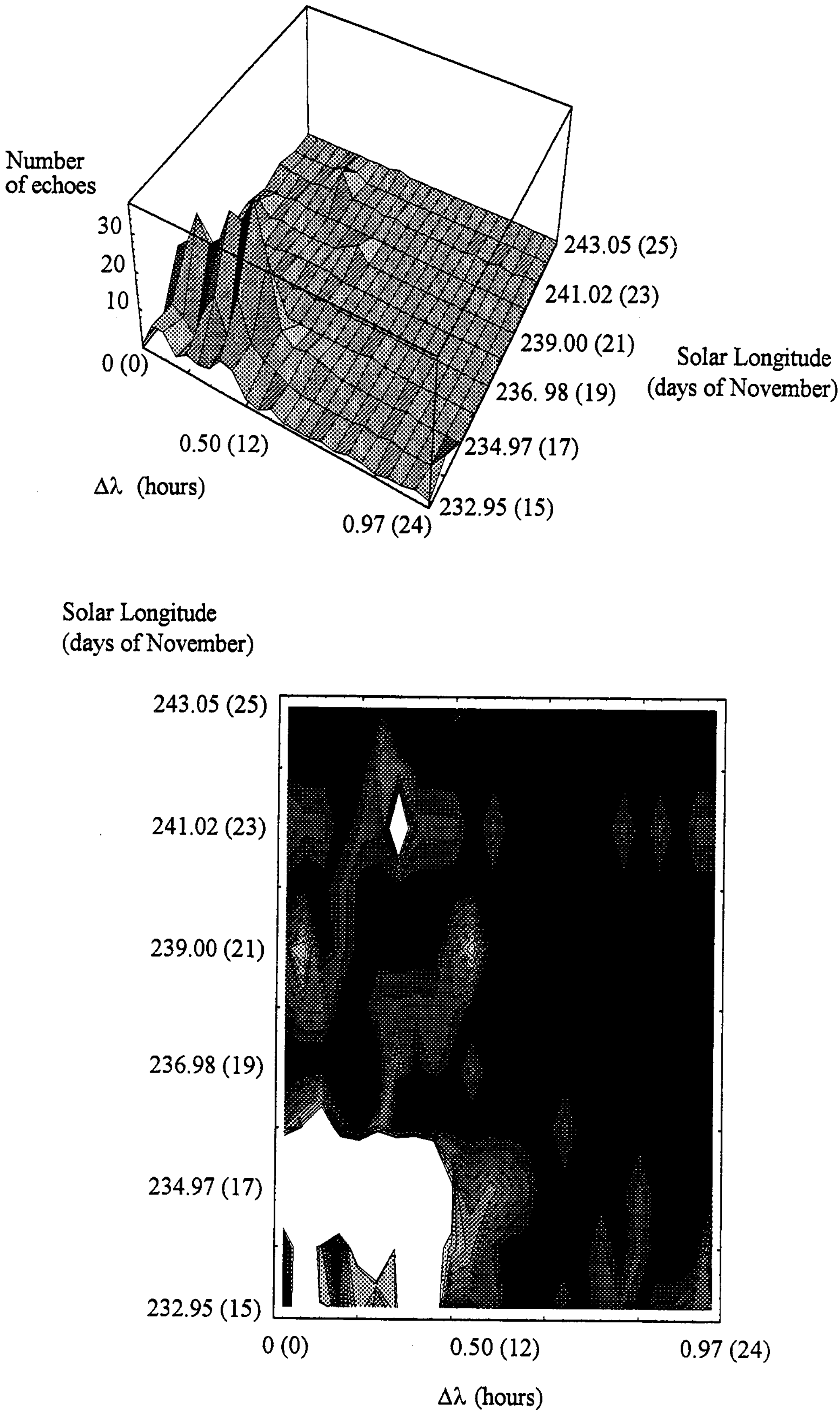

Figure 2 – This figure shows the three-dimensional (top) variations and the relative section (bottom) of the hourly flux of overdense meteors with durations $T \geq 32$ seconds, observed in the period November 15–25, 1996.

The results of the radar observations of the 1996 Leonids in Italy are particularly important when considering that the November campaign was carried out utilizing only a fourth of the power (0.25 kW) employed in the 1995 observations. Since, for a radar system, the number of echoes is proportional to the square root of the variation of transmitted power, this means that a reduction of a factor 2 in our hourly rates should be expected. The performance of the 1996 Leonids at the radar station in Italy was thus really exciting, and the future Leonid observational campaigns before and after the next perihelion passage of P/Temple-Tuttle appear therefore to be particularly promising.

As a first conclusion, the analysis of the data presented in Table 1 and in general of all the overdense data with $T \geq 1$ second recorded at the Bologna-Lecce radar in November 15–25, 1996, reveals that the activity of the Leonids in 1996 increased significantly with at least a factor 2 with respect to the corresponding data of 1995.

SPA Meteor Section Preliminary Radio Results: 1996 Leonids

Alastair McBeath

A preliminary overview of Leonid radio results submitted to the *SPA Meteor Section* from November 1996 is given. A spectacularly high peak occurred in echo counts over European sites, with perhaps three or four subphases within the maximum itself. Overall activity was significantly above normal from around 2^h–10^h UT on November 17, ($\lambda_\odot$ = 235°.0–235°.39, eq. 2000.0). By contrast, Japanese observers recorded only a minor enhancement in echo counts on November 16–17 and 17–18. A component noted in both data sets was a large increase in long-duration echoes (more than 10 s) coincident with the Leonid radiant's observability on November 16-17 and 17-18. Observations and comments by European radio operators also suggest an effect reminiscent of Sporadic-E may have accompanied, or closely followed, the Leonid radio maximum. Such an event has been recorded previously, most recently after the very high Perseid return of 1991. Some problems this may cause in interpreting radio observations where no other data is available for comparison are outlined. A brief discussion of other interpretational factors and problems for radio data is given too, along with some comparisons with 1994 and 1995 Leonid results.

1. Introduction

Following the increased ZHRs shown by the 1994 and 1995 Leonid returns, interest was again generated by the moonless Leonid epoch in 1996. Unfortunately, many visual observers across Europe and the United States found their view of the event blocked by clouds at the shower's expected peak, judging by correspondence to the *SPA Meteor Section*, where observers complaining about poor skies were almost more numerous than those with positive Leonid sightings! A separate summary of the *SPAMS* visual and photographic observations, together with additional radio details from other parts of November, is in preparation for *WGN*, but the radio data submitted from various sources for the time around the Leonid maximum was deemed of sufficient interest to warrant a swifter publication, and to encourage any outstanding radio data on the shower to be presented without further delay.

To date, reports on 2747 hours of radio operation have been received from 1996 November, the work of nine observers, with in excess of 120 000 meteor echoes detected. The observers, all of whom were active across the Leonid maximum, included the following people:

> Peter Bus (Spain, RMOB), Maurice de Meyere (Belgium, RMOB), Werfried Küneth (Austria, RMOB), Kimio Maegawa (Japan, RMOB), Ton Schoenmaker (Netherlands, RMOB), Chikara Shimoda (Japan, RMOB), Kazuhiro Suzuki (Japan, RMOB), Robert S. White (England), Ilkka Yrjölä (Finland, RMOB and via RSGB).

I am particularly grateful to Christian Steyaert for providing the information from the *Radio Meteor Observation Bulletin* observers [1], and to Norman Fitch of the *Radio Society of Great Britain* for part of the above data and for other notes [2], as well as all the contributing observers themselves. In addition, Maurice de Meyere included some notes from three other European radio amateurs (non-meteor observers) in his RMOB report, which confirmed the general opinion that the Leonid peak was exceptionally good for radio workers there in 1996. Specific equipment set-up details for individual RMOB observers can be found in [1].

2. Observational considerations

As usual in these reports, the radio data used are almost all raw counts over specified time-intervals. This is mainly due to the inaccuracies caused by applying the parameters of one or other of the published sets of Observability Function equations to the raw data, although the time, effort, and complexity involved in setting such a system up to run workably on a PC spreadsheet is a further deterrent at present, especially as the end product will often not be significantly more valid than the unprocessed echo counts. This is not to criticize all those who have worked long and hard to create these Functions in the first place, nor to belittle the splendid efforts of those who are still working on the problem of generating a good, workable, and accurate Observability Function for radio observations. The problems in doing so are regrettably legion, and it seems very probable that in the foreseeable future, all such Functions may well have to involve making assumptions and using correction factors which are known very poorly, or in some cases, not at all. This is naturally frustrating for radio workers, whose data has to a large extent remained virtually unexamined and unknown, because we are unable to refine their raw data with the same accuracy that we can a visual ZHR, for instance. Although the raw counts do not tell the full story, when sets of data from several locations relatively near one another geographically are available, it is possible to reduce the problems such uncorrected data creates, by comparisons of the shape and character in the graphs produced by individual observers and their radio equipment. The actual echo-count numbers, and their relation between different radio set-ups, are in this case of little real interest, and should only be dealt with for comparisons between different dates and times using the same equipment, to enable variations in relative activity levels to be seen, although even here, a degree of caution must be employed.

In using this raw data, it is important to establish which shower radiants the radio activity may have been coming from. Fortunately, to a large extent this follows exactly the same geometrical conditions as for visual observing, in that a low radiant elevation will generally produce barely detectable activity, except in unusual circumstances, and where the radiant is well below the local horizon, no meteors from that source can be expected. The highest recorded activity does not necessarily coincide with when the radiant is highest above the horizon, but is influenced by the angle the radio aerial is set to at the receiving station, compared to where most meteors from the shower at that time are likely to appear in the sky, and where the transmitter or transmitters lie, amongst other factors. It is true to say, though, that a higher radiant elevation is normally just as preferable for radio meteor detection as for visual work.

Where only a single shower radiant is active and above the horizon, interpreting the results is relatively straightforward, but complexities occur as soon as several radiants are active above the horizon simultaneously, and as it is at present not possible to use forward-scatter methods to determine which shower any given meteor echo resulted from, an element of educated guesswork is needed to derive meaningful data from the raw reports in such a case. It is also vital to have monitoring data using the same equipment for several days both before and after a hoped-for shower peak, ideally recorded for 24 hours a day, but at least for 12 hours a day, at the same time of day, in order that the activity detected can be sensibly calibrated, and unusual events seen more clearly. With modern PCs, such a virtually automated set-up is perfectly feasible. Short run times make it impossible to derive useful data, and the best that can be hoped for in such cases is to compare the relative activity level with that produced by a more complete set of radio results, or with similar results produced at the same time in previous years. Neither of these options is likely to yield information of much more than academic interest, however.

In the case of the Leonids, especially at their maximum, there are no other major showers active simultaneously, so the interpretation of the data becomes somewhat easier, providing calibration data from days around their peak are also on-hand, to allow for the sporadic and minor shower element in the overall activity. Geometrical considerations mean that the Leonids are effectively radio-observable from a given mid-latitude northern hemisphere site (such as the majority of radio data in this report were recorded at) from about 22^h-23^h to 14^h-15^h local time each day around November 17, although few meteors are liable to be detected during the first and last two to three hours the radiant is above the horizon, unless meteor activity itself is abnormally high at those times. The radiant culminates at around 6^h30^m local time.

3. Leonid maximum results and discussion

Five of the observers listed above provided data from at least part of the day during the whole of November, while the remainder concentrated their efforts around November 17. The three graphs presented here are given as useful examples of what was achieved, and to give an overall view of Leonid activity. Their accuracy is generally confirmed by the data from other observers, much of which will be discussed in a later paper.

Figures 1 and 2 illustrate the difference in rates detected from Japan and Europe respectively around November 17.

The Japanese data as a whole show only a very minor enhancement around the date of Leonid maximum. Indeed, the daily meteor echo count data set from Kazuhiro Suzuki (not illustrated here) actually shows lower activity on November 16-17 and 17-18 than at any other time in November. His system was effectively saturated for part of this time, however, with effective "dead time" of up to 12.4 minutes per hour on both dates, due to persistent meteor echoes.

The Leonid activity becomes more obvious in the Japanese data by looking only at these long-duration meteor echoes (those of at least 15–20 s length). This information was provided by Kimio Maegawa and Kazuhiro Suzuki, and shows significantly enhanced numbers of such echoes from 17^h UT on November 16 continuously until 2^h UT on November 17, with an especial concentration from about 21^h UT until about 2^h UT (see Table 1).

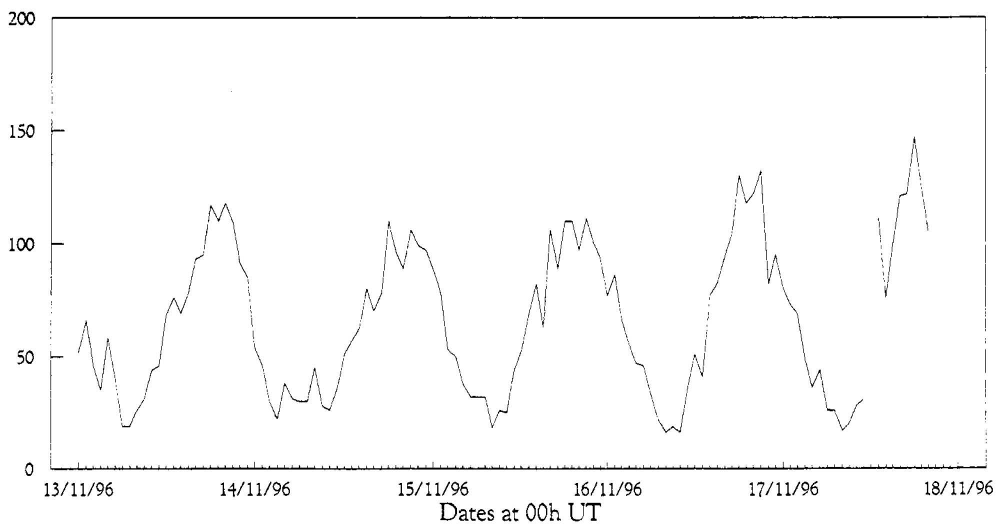

Figure 1 – Raw hourly radio meteor echo counts from data collected by Kimio Maegawa in Japan around the 1996 Leonid epoch. The gaps on November 17 were when his radio equipment was not operating. Japanese local time equals UT + 9 hours.

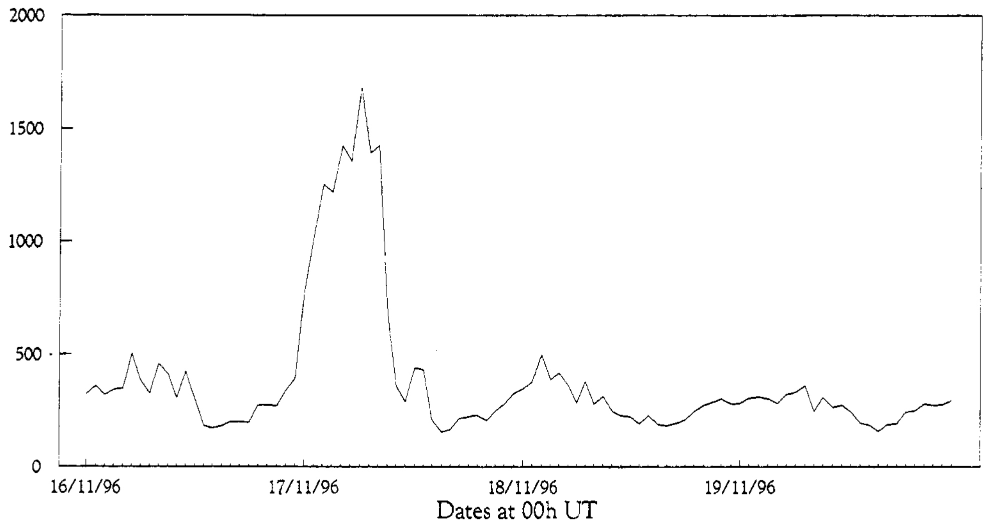

Figure 2 – Raw hourly radio meteor echo counts from data collected by Ilkka Yrjölä in Finland over the 1996 Leonid epoch. Note that this covers only part of the time shown on the graph in Figure 1, and that the vertical scale is very different, and loses much of the diurnal peak-to-trough curve as a result. This is primarily due to the variation in sporadic activity. Local time is UT + 1 hour.

The first period coincides with the approximate time the Leonid radiant is at a useful elevation above the horizon from Japanese sites, but the highest concentration period coincides with the hours effectively after the radiant culminates at about $21^{h}30^{m}$ UT. With two different radio set-ups, including slightly different antenna directions, this is perhaps indicative of the early part of the rising branch of the Leonid peak. A further, if more patchy, enhancement in long-duration echoes was also recorded on November 17-18, around 16^{h}–21^{h} UT (Maegawa) or around 18^{h}, 21^{h} and 23^{h}–2^{h} UT (Suzuki). The last of these three periods detected by Kazuhiro Suzuki is again coincident with the period some time after the radiant's culmination, but without confirming data from elsewhere, it is difficult to know if this might be significant.

In the European data, the Leonid maximum is incredibly obvious, with activity on November 17 dwarfing that on any other date in November, for those who recorded data throughout the month. Looking at the numerical rate counts from individual observers suggests the enhancement was at least three to four times above the best other peak detected in November away from the days around the Leonid maximum itself. As stated previously, however, such direct comparisons of the raw numerical values must be treated with due caution. Most observers recorded either three or four activity spikes, with "peaks" around 2^{h}–3^{h}, 4^{h}–5^{h}, and 6^{h}–8^{h} (which most observers concur was the single most active period). Approximate solar longitudes (eq. 2000.0) for these "peaks" are $\lambda_\odot \approx 235.^\circ06$–$235.^\circ10$, $\lambda_\odot \approx 235.^\circ14$–$235.^\circ18$, and $\lambda_\odot \approx 235.^\circ22$–$235.^\circ31$, respectively. Two observers, Peter Bus (who corrected his own data before publication using an Observability Function attributed by him to Hines) and Robert White (raw data), provided results suggesting the highest activity occurred around $7^{h}25^{m}$ UT (Bus: $\lambda_\odot \approx 235.^\circ28$) or around $7^{h}40^{m}$–$07^{h}50^{m}$ UT (White: $\lambda_\odot \approx 235.^\circ29$–$235.^\circ30$).

High echo counts occurred on November 17 between 2^{h} and 10^{h} UT ($\lambda_\odot \approx 235.^\circ06$–$235.^\circ39$) as a whole, and the profile looks distinctly skewed in all the European data sets, with a slow ascending branch, and a more rapid descending one. Part of this may result from a decreasing radiant elevation as time passes, after the radiant has culminated at around $5^{h}30^{m}$–$6^{h}30^{m}$ UT, coupled with a less-favorable geometry for receiving signals from transmitters which are primarily to the east of sites in Western Europe, but it is quite probable the effect is largely a real one, since it appears at a comparable time in all the European data sets available. As an example, Figure 3 illustrates Robert White's raw ten-minute counts for November 17. This gives an idea of the variations in detected activity on shorter time scales.

Table 1 – Long-duration raw echo numbers per hour recorded by Kimio Maegawa (echoes of at least 15 s duration), Kazuhiro Suzuki (echoes of at least 20 s duration) and Werfried Küneth (echoes of at least 10 s duration) for the given dates and times. Note that no long-duration echo counts higher than 3 per hour were recorded by either Maegawa nor Suzuki during the remainder of their run-time in November. For Küneth, the same figure was 7, although that was only one isolated case at 7^h UT on November 16, a day marred by a series of thunderstorms, preventing monitoring of activity at various times prior to 21^h UT. A dash (–) indicates the observer was not operating his system at that time, while an asterisk (*) shows the system was not operating for a full hour. For Suzuki only, the amount of "dead time" in each hour due to system saturation from long-duration echoes is also given in parentheses, in minutes, where this was not zero.

Time (UT)	Maegawa Nov 16-17	Suzuki Nov 16-17	Küneth Nov 16-17	Maegawa Nov 17-18	Suzuki Nov 17-18	Küneth Nov 17-18
12^h	0	0	0*	–	0	2
13^h	0	–	1*	1	0	0
14^h	0	0	0	0	0	0
15^h	0	0 (0.1)	0*	0	1 (0.7)	–
16^h	1	1 (1.1)	–	3	1 (0.7)	–
17^h	6	7 (4.0)	–	5	2 (1.3)	–
18^h	6	4 (2.6)	–	5	3 (2.2)	–
19^h	6	5 (3.4)	–	7	0	–
20^h	9*	3 (2.3)	–	7	1 (0.7)	–
21^h	13	8 (8.0)	0	–	5 (5.1)	1
22^h	11	11 (11.6)	0	–	1 (0.3)	0
23^h	12	12 (12.4)	2	–	3 (1.9)	0
00^h	12	14 (11.2)	8	–	5 (3.0)	3
01^h	6	8 (7.7)	14	–	3 (2.5)	2
02^h	3	4 (4.4)	22	–	1 (0.3)	0
03^h	1	1 (2.1)	21	–	0	2
04^h	0	0	21	–	0	9
05^h	0	0	20	–	0	7
06^h	0	0	23	–	0	7
07^h	1	0	22	–	0	7
08^h	0	0	22	–	0	1
09^h	0	0	15	–	0	3
10^h	0	0	10	–	0	2
11^h	0*	0	4	–	0	–

Werfried Küneth was the only European observer to provide details on echo durations to date, and his information from around the Leonid maximum is presented in Table 1.

In the absence of other confirmatory data, it is wise to proceed with caution, but long-duration echoes are clearly present in his observations in enhanced numbers from about 0^h–11^h UT on November 17, and can also be seen, but with less conviction, from the same period on November 18. These times are again roughly coincident with the best Leonid radiant elevations, as we found with the Japanese data, but this time, there is a better-fit to a degree of symmetry about the expected culmination time, around 5^h30^m UT, although long-duration echo numbers appear to be slightly higher after culmination than before, a skew which fits the overall activity profile established above too. This perhaps gives more weight to the idea of the Japanese long-echo results having detected the rising branch of the stream's best activity.

A greatly enhanced count of long-duration echoes above the norm may be a useful diagnostic tool for all radio meteor workers to examine in showers such as the Leonids in future, and perhaps other high-velocity meteor showers, like the Perseids.

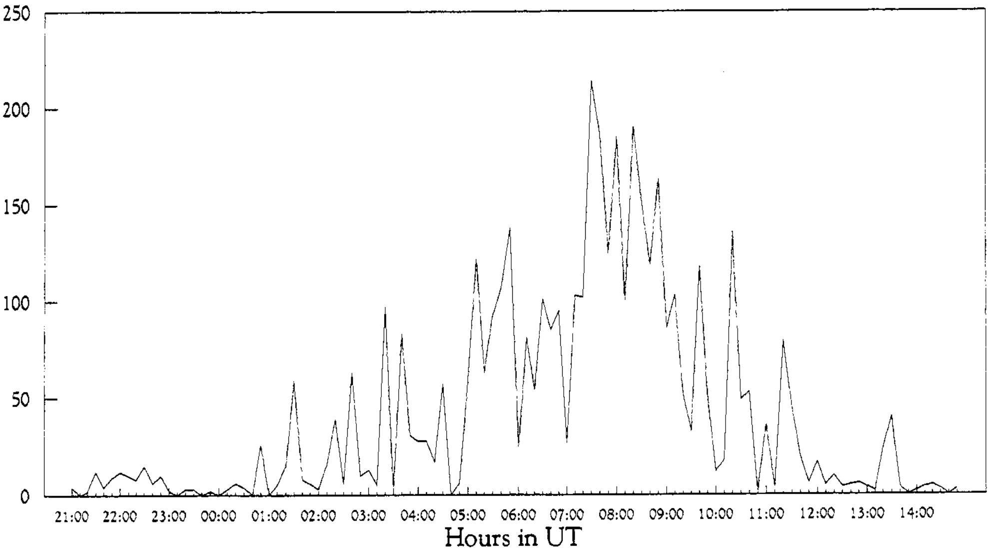

Figure 3 – Raw ten-minute radio meteor echo counts from data collected by Robert S. White from November 16-17, 1996, giving an overall impression of the radio Leonid maximum. Activity from 21^h–0^h and after 14^h UT indicates what "normal" ten-minute echo counts look like, with no major shower rates present. Local time = UT.

In this case, it has provided virtually the only means Japanese radio observers had of detecting anything especially significant from the Leonids in 1996, whose peak occurred after radiant-set from their sites, and this is something all radio meteor workers should bear in mind for the future. This is especially so where nothing unusual initially appears to have been detected from a known shower maximum, looking at only the raw echo count numbers alone.

Comparing the radio data with the preliminary global visual ones [3] shows a broad level of agreement in the peak timings of both. It is unfortunate that no radio results have yet been forwarded from sites in North America, which would have helped continue the shower coverage beyond about 12^h–14^h UT on November 17 ($\lambda_\odot \approx 235\overset{\circ}{.}48$–$235\overset{\circ}{.}56$: low radiant to radiant-set times from Europe), even though the European data indicate that radio Leonid activity was well into decline by this stage. A double or multiple peak is shown by both visual and radio results, the first visual peak ($\lambda_\odot = 235\overset{\circ}{.}15$) coinciding well with the second radio one at $\lambda_\odot \approx 235\overset{\circ}{.}14$–$235\overset{\circ}{.}18$, but the main radio peak does not seem to have occurred at quite the same time as the second visual one (radio: $\lambda_\odot \approx 235\overset{\circ}{.}22$–$235\overset{\circ}{.}31$, with a probable center at $\lambda_\odot \approx 235\overset{\circ}{.}28$–$235\overset{\circ}{.}30$; visual: $\lambda_\odot = 235\overset{\circ}{.}37$). It is interesting that the earlier visual maximum's r-value is higher than the second one's ($r = 1.91$ and 1.66, respectively), suggesting a greater relative proportion of fainter meteors at that earlier stage, perhaps indicative of more events suitable for radio detection then. The gap in r data from the visual results between $\lambda_\odot = 235\overset{\circ}{.}19$ and $\lambda_\odot = 235\overset{\circ}{.}32$ is thus particularly unfortunate, as this coincides with the probable primary phase of the radio activity. The dip in visual ZHRs around this period might be attributed to an increased flux of faint meteors, perhaps with many invisible to the unaided eye. With the uncertainties in the radio data, albeit reduced because of the overall consensus between different sets of observations, this is probably pushing the radio data to the limit of its usefulness however.

4. Possible Sporadic-E event associated with the Leonid peak

One radio amateur's notes from the Netherlands given in Maurice de Meyere's report in [1], and several other comments passed directly to the author, or via Norman Fitch [2], from similar sources suggest that the Sporadic-E (Es) radio propagation mode may have been triggered by the 1996 Leonid activity. Indeed, Norman Fitch was prompted to suggest that the radio Leonids were apparently "at storm levels" in [4] and that "Es-like propagation" had occurred during the morning hours (UK local time, about 7^h–10^h UT) of November 17, based on initial reports reaching him just after the shower's peak.

Leonid meteors are known to be capable of producing a great deal of ionization on entry into the Earth's atmosphere, due to their high atmospheric velocity. Their relative brightness is also partly due to their high-speed approach vector. Visually, this gives rise to occasionally brilliant meteors with often magnificently long-lasting trains, sometimes many bright meteors, and a high proportion of trained Leonids. Recent *SPAMS* results have shown over 50% of Leonids leaving trains, with the longest persisting for several minutes [5]. An early examination of the 1996 data suggests the train proportion then may have been closer to 60%, with the longest-lasting train thus far reported being of 12 minutes duration. The shower's r-value at maximum, particularly in 1996 [3], also indicates that many bright Leonids were present in the recent returns.

Such meteoric ionization probably forms the major part of typical Es sheets, although these usually occur from around April to September over northern hemisphere sites. While there is a link between meteor showers and Es formation, the processes appear to be quite complex, and although Es can probably be generated immediately due to meteoric input, other processes also operate to allow Es ions to survive and re-form into sheets in the upper atmosphere over periods which may extend to several weeks during the Es "season." There are, however, occasions when Es sheets have been recorded simultaneously or near-simultaneously with unusual meteor shower maxima, the most recent of which was due to the unexpectedly high return at the primary peak of the 1991 Perseids, when an extremely impressive Es event immediately followed the meteor shower's outburst [6].

It is not always possible to differentiate between the various atmospheric radio propagation modes, but with no auroral reports on-hand for mid-November, the Auroral-E mode can be effectively eliminated, along with possible atmospheric interference, which no observers reported, leaving two possibilities. Either the 1996 Leonids did generate a short-lived Es sheet, perhaps only over Europe (the Japanese reports do not support any unexpected propagation coincident with their observed radio Leonid activity, while the absence of American reports makes establishing the maximum westwards extent of any Es sheet impossible), or the meteors were appearing in large enough numbers and generating sufficient ionization in their wakes to make it appear as if such an Es sheet had appeared. In a sense, a dense enough meteor shower maximum of high-velocity meteoroids like the Leonids will effectively generate an Es sheet simply by its own maximum rates, and the consequent ionization generated, without a "true" Es event necessarily happening. This will naturally make deciding what type of propagation was present exceptionally difficult, if not impossible, under such circumstances.

In the case of the 1996 event, where visual ZHRs showed Leonid rates to be quite modest compared to their potential storm ones, we need to consider the possibility that a small number of bright meteors producing very persistent trains (of duration, say, about 0.02 to 0.2+ hours) could also give rise to seeming Es-type propagation, at least for a short time. Meteor trains visible to the naked-eye will almost certainly have a sufficient electron line-density to be readily detected by typical forward-scatter meteor radio set-ups as overdense trails, providing they occur in a suitable orientation to the transmitter-receiver line. *SPAMS* visual Leonid observations from 1995 and 1996 suggest that at best, an observer might see between 0.3 to 1 such trains per hour near the shower's peak, but a visual observer is covering only a fraction of the potential radio-meteor volume of the atmosphere, perhaps around 1/10 to around 1/20, so that the rates of possible radio meteors in this class could lie between 3 and 20, using this very crude and imprecise estimate. This is in the area of long-duration echo numbers shown in Table 1, certainly. Whether it is possible for radio operators to differentiate between "genuine" Es and such long-duration echoes is not easy to determine, but from the comments made about the 1996 radio Leonids, the implication is that in many cases, especially with radio amateurs as opposed to specific radio meteor observers, it is not.

The saturation of radio receivers by a "meteoric Es" event of the types described creates additional problems other than the simple semantic one of what we should call it. In particular, it makes identifying individual meteor echoes very difficult, and could well lead to an artificial reduction in rates. This is most obvious in Kazuhiro Suzuki's observations, where radio activity over the two main Leonid activity dates was lower than at any other point in November, as mentioned above. In such cases, it will be necessary to look at other facets of the recorded activity, such as the numbers of long-duration echoes and the amount of effective "dead time" the system is suffering from. The alternative is to employ some form of artificial cut-off mechanism, so that the monitoring system recognizes signals as being of a maximum fixed length, as for instance in Robert White's set-up [7], and so prevents the system from becoming saturated. This does introduce an element of inaccuracy as well, however, since the system is not necessarily monitoring just individual meteor echoes any longer.

That this "meteoric Es" event should have occurred in 1996, when visual Leonid activity was well below what we hope for in the next few years, is of some concern. If such an event were to be recorded only by radio methods, as could happen, for example, with the daylight showers, or even for the Leonids if their maximum, brief, storm rates took place over the Pacific Ocean or an area of land shrouded by a complete cloud blanket, we could well have no means of calibrating what took place at all, and be left trying to draw conclusions from far too little reliable information. It is difficult to see how this can be overcome easily, other than by encouraging more radio meteor observers into activity and reporting their data regularly. Even that would only allow a relative calibration, but which would be better than nothing. It would also permit correlation between observers, as has been done in this present paper.

5. Comparison with 1994 and 1995 Leonid results

Radio observations from [5,8–10] allowed comparisons with observations made during the 1995 Leonid epoch. In particular, Maurice de Meyere, Robert S. White and Ilkka Yrjölä all produced results in a directly compatible format for both years. Using data from [11,12] allowed a further approximate comparison using results from these same three observers, although all have made changes to their equipment during the intervening years.

Robert White's data showed a maximum hourly radio activity level about 2.6 times higher for the Leonids in 1996 than in 1995, compared to levels of 1.43 and 1.29 times higher for Maurice de Meyere and Ilkka Yrjölä respectively over the same period. Robert's data from 1994 showed a marginally lower level of activity compared to 1996 (1.01 times), whereas both Maurice's and Ilkka's results showed that rates in 1994 had been higher than their 1996 level by 1.37 and 1.34 times respectively. Robert's results from 1994 November did suffer in their later stages from atmospheric interference, and so it is probably sensible not to read too much into his results from that year in particular.

Maurice's and Ilkka's data show remarkably similar activity level changes between the two years, and curiously, their mean level of change, both between 1995 and 1996 and between 1996 and 1994 was 1.36 times. As an exercise, the 1995 ZHR level from [13], 34, was multiplied by this factor of 1.36 twice, yielding effective "ZHR equivalents" of 46 for 1996 and 63 for 1994. The peak Leonid ZHR value from [3] for 1996 was given as 46, while thanks to moonlight in 1994, a value of "100 or perhaps slightly less" was assigned to it in [14]. The values for 1995 and 1996 are thus very oddly coincidental, and perhaps indicate a slight reduction of the 1994 maximum ZHR might be in order, although it would be unwise to use just these few data to derive definitive statements on this matter. It does suggest, though, that relative radio echo rates, using comparisons with identical set-ups only, might be tools for assisting in calibrating visual ZHR levels, albeit approximately, in future, and are at least worth more investigation as the amount of available radio data increases.

6. Conclusion

Radio meteor observations have been somewhat underplayed in recent years, often because of the problems in setting up reliable automated recording equipment, but also because it is very difficult to derive corrected numerical data of sufficient reliability to compare with, for example, visual analyses. The first point has been overcome by the increasing use of PCs, but the second one is still a serious difficulty in bringing to fruition our hopes for radio work. In this paper, an attempt has been made to show that when sufficient radio observers are prepared to pool their data, in the way that visual observers around the world now routinely do, even the raw, unprocessed echo counts can be used to derive useful information on meteor showers, helping to confirm features suggested by other analyses, as well as potentially revealing fresh aspects of shower maxima in particular. Some of the problem areas in such raw data interpretation have also been highlighted, but in many respects, these are challenges to be faced, as we try to understand features such as Sporadic-E better, something radio operators are uniquely able to attempt. Radio work clearly remains a valuable tool in modern meteor astronomy.

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Spanish Observations of the 1996 Leonids

Josep M. Trigo

An overview is given of the author's observations of November 18, 1996.

The following observations were made by the present author from Benicassim ($\lambda = 0°$, $\varphi = +40°$, near Castelló) show a moderate hourly activity from the Leonid radiant in the morning of November 18.

Table 1 – Observational data.

Interval (UT)	$T_{\rm eff}$	Lm	F	LEO	AMO	Other
2^h38^m–3^h40^m	$0\overset{h}{.}94$	6.00	1.17	9	1	4
3^h40^m–4^h42^m	$0\overset{h}{.}98$	6.20	1.00	10	1	2
4^h42^m–5^h51^m	$1\overset{h}{.}05$	5.70	1.05	16	1	1

Table 2 – Magnitude distribution.

Magnitude	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	Trained
Leonids	1	1	1	2	3	0.5	7.5	11.5	6.5	1	5

The data in Table 1 and a population index of approximately $r = 2.5$ yield the following Leonid ZHRs: 31 ± 10 (1st interval), 20 ± 6 (2nd interval), and 38 ± 10 (3rd interval).

The magnitude data of the Leonids are shown in Table 2. Of the Monocerotids, 2.5 were of magnitude 3, and 0.5 of magnitude 4; of the sporadics, 1 was of magnitude 2, 2 were of magnitude 3, and 3 of magnitude 4.

Fireballs and Meteorites

Spectacular Leonid Fireball

Sirko Molau and Volker Gerhardt

Some photographs are presented of a spectacular Leonid fireball on November 17-18, 1996, photographed at Tenerife.

On November 17, 1996, Volker Gerhardt from the public Wilhelm-Förster-Observatory Berlin spent a night near Pico del Teide at Tenerife, on the Canary Islands.

Around 1^h40^m UT, when he was photographing different astronomical objects, he suddenly witnessed a spectacular Leonid fireball.

The bolide had approximately Full Moon brightness, showed two flashes and finally broke into several pieces. Then it left a persistent train, which was visible with naked eyes for more than half an hour. On photographs, it could be traced for almost one hour!

Here, we want to present three pictures of the amazing event. The photographer used a camera with a 50 mm $f/1.2$ objective and Fujichrome Provia 1600 film. Figure 1 was taken at 1^h45^m UT. The exposure time was approximately 5 minutes. Figures 2 and 3 show the persistent train at 1^h50^m UT and 2^h30^m UT, respectively. Here the exposure times were roughly 10 minutes.

In addition, some Leonids could be photographed that night, too. Figure 4 shows one of them, which was captured at 3^h00^m UT using a 28 mm $f/2.8$ lens.

The color pictures and more comments on the event (in German) are available on the WWW at `http://www.be.schule.de/schulen/wfs/PotW/96_50/PotW.html`.

Figure 1

Figure 2

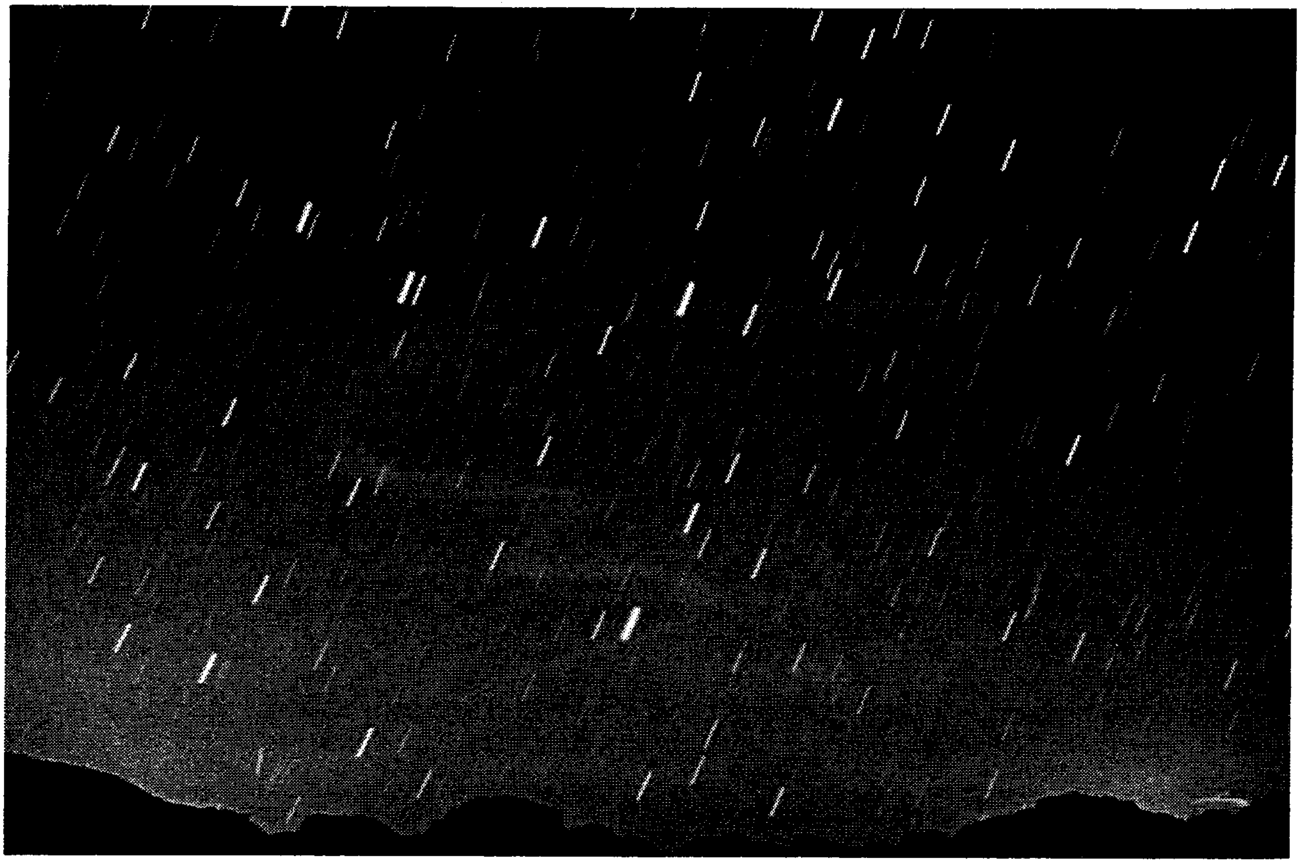

Figure 3

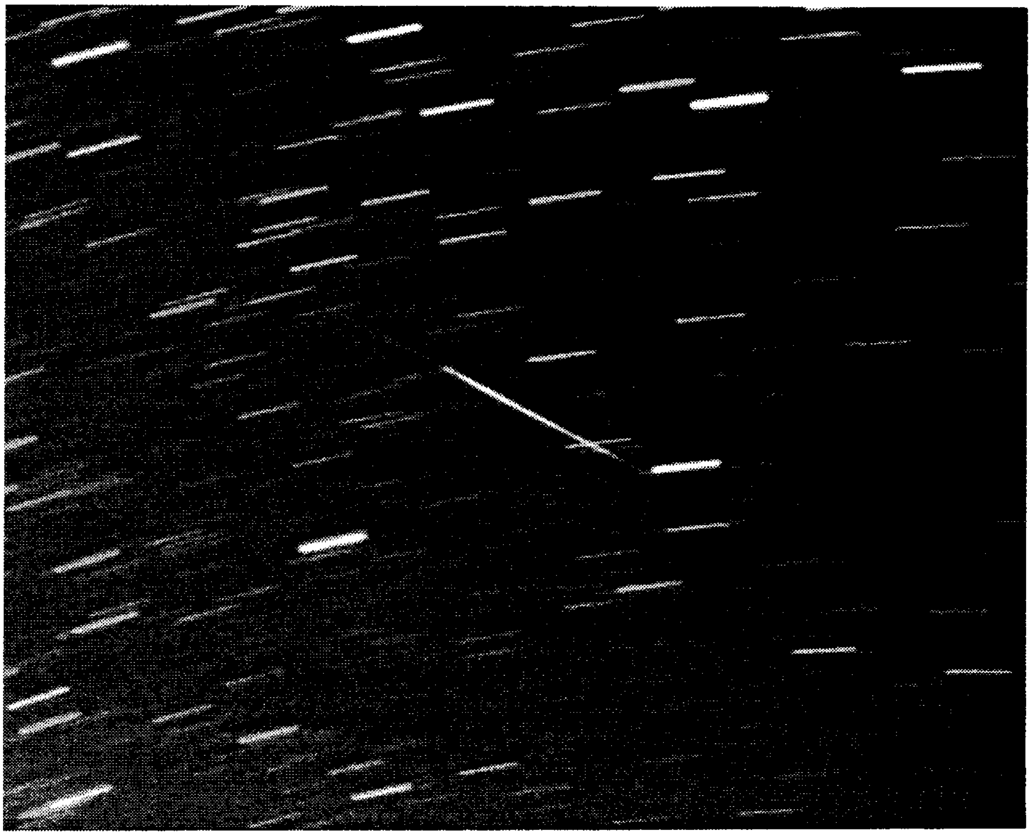

Figure 4

Real Frequency of Meteoritical Events of Megatonic Class

Roberto Gorelli

The author has attempted to determine the real frequency of meteoritical events of megatonic class through a bibliographic search for events that occurred during the last two centuries. The outcome of this search was unexpected: (*i*) megatonic events seem to occur once every ten years; and (*ii*) the discovery of some presently unknown events. A list of possible or certain megatonic events is presented.

Until some years ago, astronomers figured that events such as Tunguska can occur once every few centuries [1]. The occurrence of some events of this type in the present century and the discovery that the number of objects that can cause these events is much higher than was assumed [2] impose upon science the duty to verify what the real frequency is of these events. Although no verified casualties of meteorite impacts have been recorded yet, they can potentially cause catastrophes much worse than, e.g., the earthquake of Tagshan on July 28, 1976, one of the biggest recorded natural catastrophes ever, which seems to have caused the death of about one million persons.

A method for determining the real frequency of these impacts is to identify such events in the past. Our search was restricted to the two last centuries, because this period is characterized by a large number of scientific and historical records, and because only since the beginning of the 19th century, scientists have accepted the reality of meteorite falls and registered meteoritical phenomena in a systematic way. Later work can then extend this search to preceding centuries or even millennia; of course, the more we go in the past, the scarcer the records will be and the harder it will be to distinguish facts from myths.

Six possible or certain events of the Tunguska type were found; one more event happened over sea. All these events, some of which need further investigation, are listed in Appendix A. The principal criteria utilized to select the listed events are the release of big quantities of dust and/or disturbance of the terrestrial or marine surface requiring an energy in the megatonic range.

If the reality and the released energy of all the listed events can be confirmed, and if it is conjectured that their number is the average for a period of two centuries, the real frequency of megatonic impacts can be estimated. A simple calculation taking into account that 70% of the Earth's surface is covered by water and that 6 events have happened over land yields an average frequency of one megatonic impact every 10 years somewhere on Earth, and one every 30–35 years over land. This values are almost certainly underestimated, because some events have no witnesses or were reported in documents that still await discovery or were not recognized as such. In this respect, it must be observed that only one of the 14 events expected over sea was recorded. In the absence of witnesses, megatonic impacts over sea will only manifest themselves by the tsunamis they cause, which in most cases will be ascribed to seismic activity.

The author also searched further in the past, but only to demonstrate that is possible to obtain records for remote periods, too; only an infinitesimally small fraction of all the historical reports of all peoples of the world was examined; the result was the discovery of 3 other possible events during the last millennium, reported in Appendix B.

Since the Tunguska event is certainly no longer unique, the author suggests to call this type of event an impact of megatonic class, thus using a denomination according to the order of magnitude of energy released (megatonic, kilotonic, etc.), which is more rational and scientific.

The author invites the readers to study and to verify the presented events and to look for others. This search can be done, for example, by going to reading rooms of local newspapers, by examining scientific journals and reviews, or by searching for evidence of impacts in sections of trees, sediments, magnetic or barometric records, seismograms, etc.

Appendix A

List of megatonic impact events of the last two centuries

1. *April 5, 1800, North America*: Fall of a big meteorite with an earthquake and destruction of a forest. Released energy unknown. Source: E. Howard in *Transactions Philosoph. Ann.*, 1802, 23, Chapter 338 [3].
2. *November 9 or 19, 1819, Canada and Northern United States*: Black rain accompanied by bolids, shaking as of an earthquake, and obscuration of the sky, Released energy unknown. Sources: (1) Zurcher, *Meteors*, p. 238; (2) *Edinburgh Philosophical Journal* 2-381; (3) F.G. Plummer in *U.S. Forest Service Bulletin* no. 117 [4].
3. *February 24, 1885, Pacific Ocean*, $\lambda = 170°$ E, $\varphi = 37°$ N: Red inflamed sky, blinding mass fell on the ocean and lifted a big mass of water. Released energy unknown. Source: report of Mr. Innerwich transmitted to the Hydrographic Office in Washington by the San Francisco branch and published in *Science*, 5-242 [4].
4. *May 3, 1892, Sweden, Norway, Denmark, and surrounding locations*: Fall of 500 tons of dust. Released energy unknown.
5. *June 30, 1908, Tunguska, Siberia, Russia*: Released energy: 12.5 megatons [5].
6. *August 13, 1930, Rio Curuça, Amazonia, Brazil*: Released energy: 0.1–1 megaton [6].
7. *December 11, 1935, West Marudi Mountain, British Guyana*, $\lambda = 59°10'$ W, $\varphi = 2°10'$ N: Released energy: more than 10 megatons? Source: *The Sky*, september 1939, from a report of S.A. Korff of Bartol Research Foundation, Franklin Institute (Delaware, USA). Additional sources: W.H. Holden and D. Holdridge [7].

Appendix B

List of of other megatonic impact events in the last millennium

1. *12th century, South side of South Island, New Zealand*: Released energy unknown. Source: P. Snow (Tapanui, New Zealand) [8].
2. *September 2, 1311, England*: Gleam lasting many hours, trees burned, church burned. Released energy unknown. Source: *Abr. Bzou. Eccl. An.*, 1311, no. 23 [9].
3. *1338, Aquileia, Northern Italy*: Lands burned by fire that fell from the sky. Released energy unknown [10].

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Obsservational Results

Photographic Observation of the 1995 Perseids in Japan

H. Murayama, K. Ohtsuka, and Y. Taguchi

By analyzing an activity profile of photographic Perseids obtained in the night of August 12, 1995, we found that the new peak of the 1995 Perseids for photographic size meteoroids (a mass of more than about 10^{-2} g) occurred at $\lambda_\odot \approx 139\overset{\circ}{.}63$ (eq. 2000.0). This is quite identical with those obtained by Japanese radar data and of visual data analysis. We tentatively estimated an influx rate for such photographic meteoroids as 3×10^{-7} ($\mathrm{km}^{-2}\ \mathrm{s}^{-1}$) during the new peak of the 1995 Perseid shower. This is probably half or less the scale of the 1991 Perseids.

A possibility of an encounter with the Perseids' new peak was promised in the night of August 12, 1995, in Japan. Although three years had passed since the latest return of the parent comet, 109P/Swift-Tuttle, an enhanced activity of the new peak due to the swarm around the comet was still expected that year. However, the observing conditions were rather poor because of interference of the near Full Moon. Despite these conditions, four *Tokyo Meteor Network* (*TMN*) teams went on a Perseids' observing expedition to the southern-Tohoku district in order to obtain precise multi-station photographic meteor data.

Unfortunately, three teams suffered cloudy and rainy weathers and could not observe. It was a pity that no multi-station Perseids were obtained by the *TMN* that year. However, one *TMN* team, H. Murayama and Y. Taguchi, successfully observed at Jododaira that night. They enjoyed clear skies all night long, above a sea of clouds. Jododaira is one of the best observing sites in Japan, located at 1660 m above sea level.

The Jododaira team operated a set of four Canon T70 cameras on which new FD 85 mm $f/1.2$ lenses were installed, along with Kodak High Speed Infrared Film 2481 and Kenko R60 (red) filters. This set-up in common in the *TMN*'s photographic observations [1], because it is very effective for photographing meteors, even in the presence of light pollution or moonlight. It is also advantageous for recording high-velocity meteors, such as the Perseids (V_∞ = 60 km/s), because some strong spectral emissions exist in the near-infrared region of high-velocity meteors, e.g., O I (1) at 777 nm, N I (1) at 868 nm, etc. [2]. The camera system can cover an area of $6.8 \times 10^3\ \mathrm{km}^2$ at 105 km above sea level. We expected to detect Perseid meteors with absolute magnitudes up to +1 with this optical system on a moonlit night. A magnitude +1 Perseid corresponds to a meteoroid of about 10^{-2} g.

The Jododaira team carried out the photographic observation from 15^h till 19^h UT in the night of August 12. During the interval 15^h–18^h UT, no Perseids were captured. However, around 18^h UT, the meteor activity rate was rapidly increasing, and 8 Perseids were photographed in one hour, until 19^h UT (see Figure 1). In particular, 6 of them were captured during 30 minutes in the interval 18^h–$18^\mathrm{h}30^\mathrm{m}$, most of which were brighter than magnitude −1 (see Figures 2 and 3).

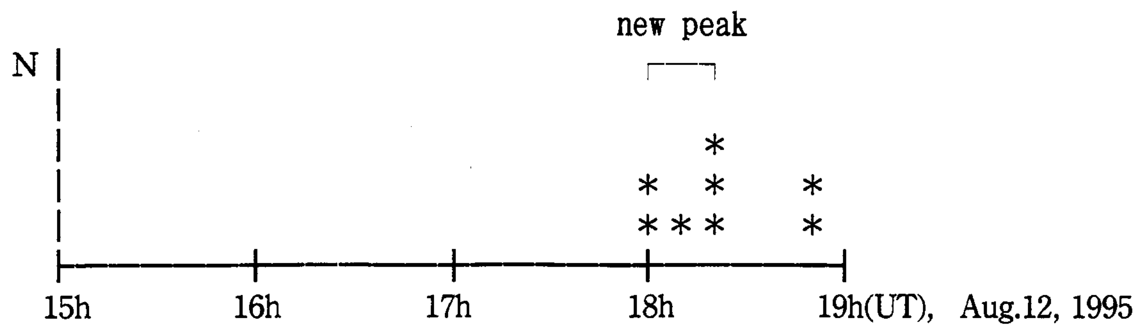

Figure 1 – Number of the photographed Perseids every 10 minutes' exposure.

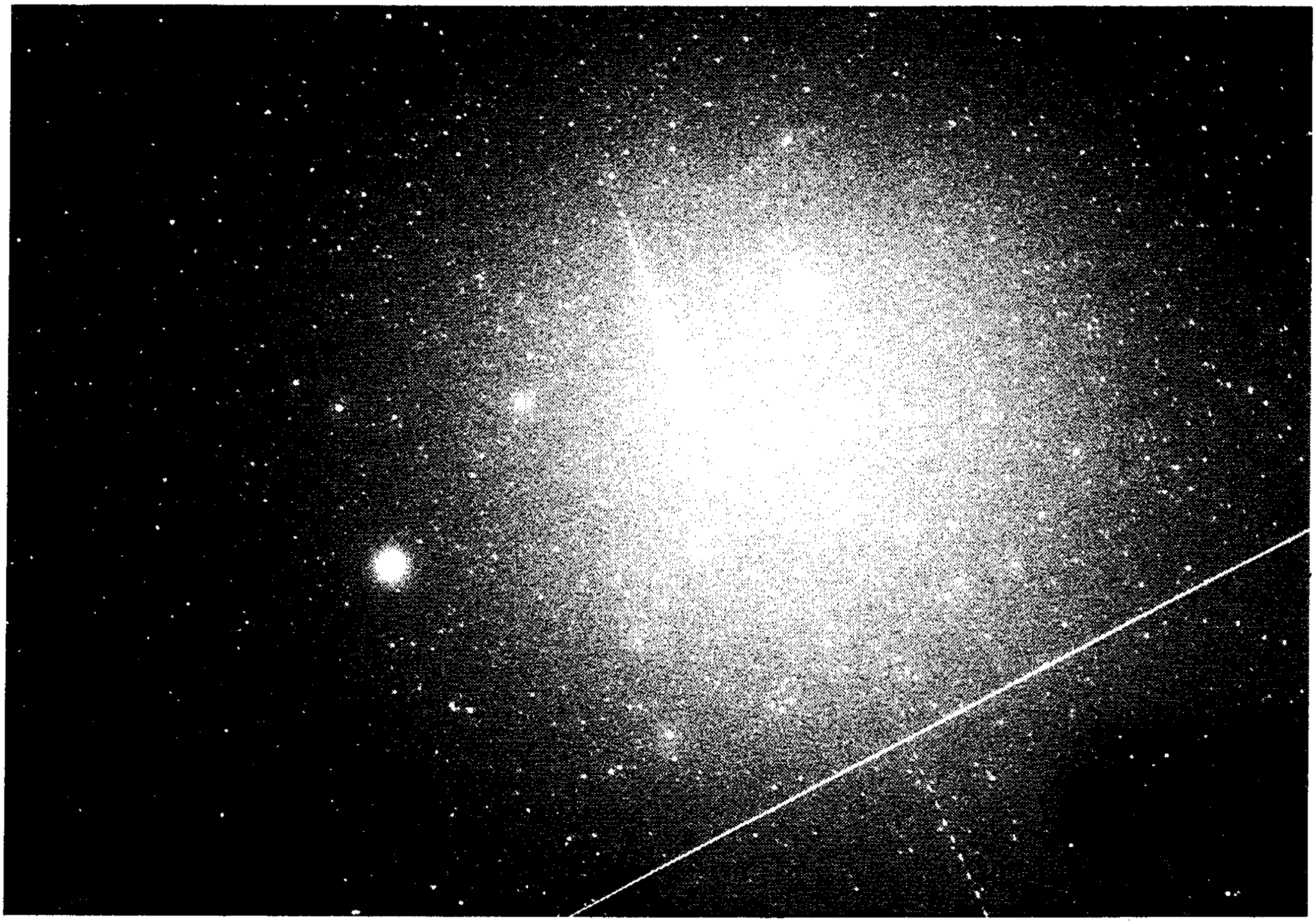

Figure 2 – The Perseid in the center appeared at $18^h20^m14^s$ UT and was of magnitude −1.5. Another Perseid at the bottom of the photograph appeared at $18^h23^m15^s$ UT and was of magnitude −1. The photograph also shows the track of an artificial satellite.

Therefore, we deduce that the new peak for photographic-size meteoroids (a mass of more than 10^{-2} g) occurred in that 30-minute interval, which corresponds to $\lambda_\odot = 139\overset{\circ}{.}63$ (eq. 2000.0). This was quite identical with the results obtained by Japanese radar data [3] and from visual data analysis [4]. The radiant is about 60° above the horizon then. Taking into account the photographic area and the radiant elevation, we can tentatively estimate an influx rate for such photographic meteors as 3×10^{-7} ($\mathrm{km}^{-2}\ \mathrm{s}^{-1}$) during the new peak of the 1995 Perseid shower. This is probably at most half of the magnitude of the 1991 Perseid display [5,6].

If the 1995 stream consists of rather new cometary particles, the radiant area should be smaller than that of the regular Perseids [7,8]. We will next analyze whether the radiant area in 1995 was as small as that of 1991.

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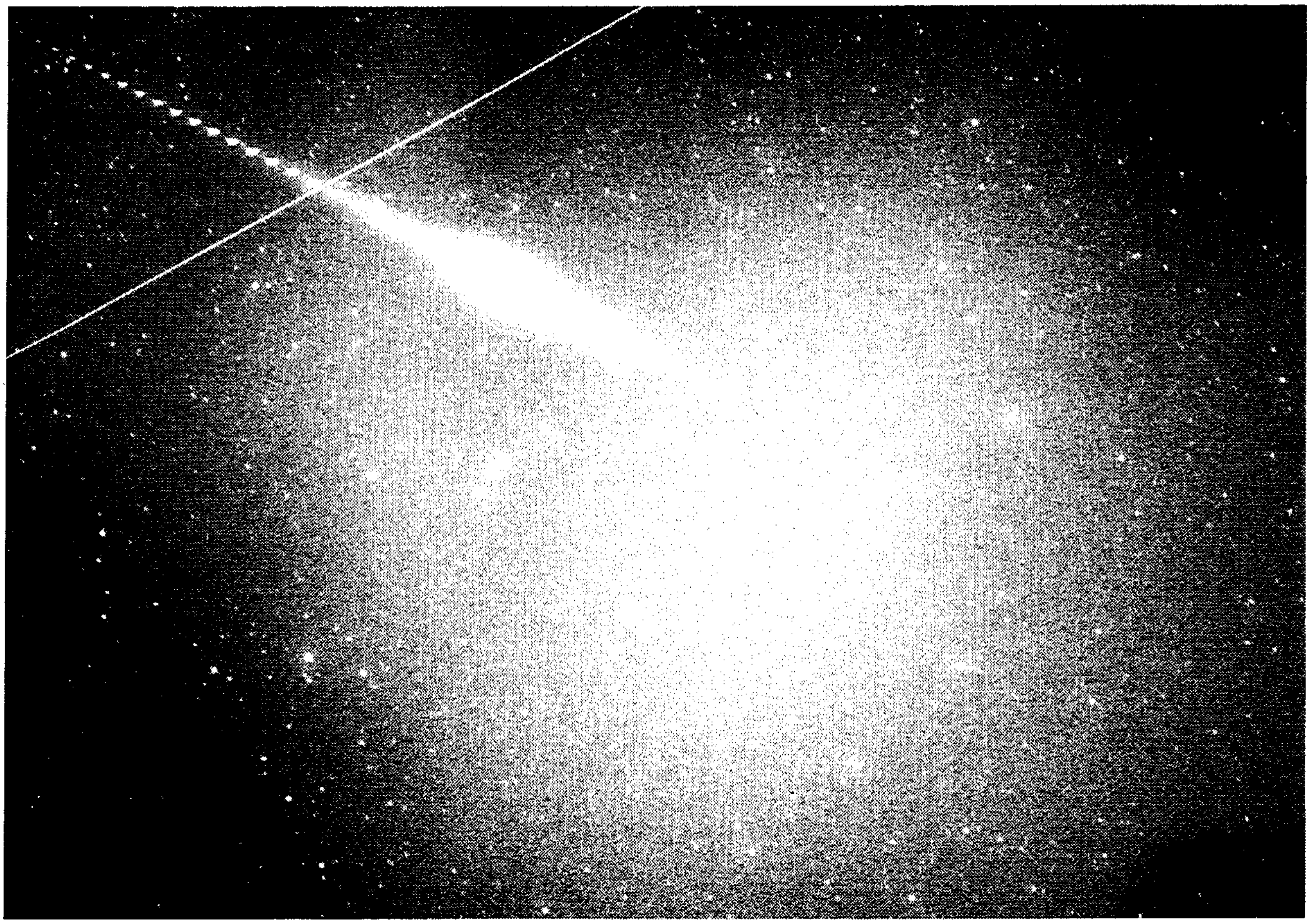

Figure 3 – This Perseid fireball appeared at $18^h25^m20^s$ UT and was of magnitude −4. The photograph also shows the track of an artificial satellite.

Normal Activity of the 1996 Lyrids in Poland

Arkadiusz Olech, Warsaw University Observatory

The results of the Polish observations of the 1996 Lyrids are presented. These observations do not indicate enhanced activity of this stream. The moment of the maximum occurred slightly later (solar longitude $\lambda_\odot$ = 32°15, eq. 2000.0) than was expected ($\lambda_\odot$ = 32°1).

1. Introduction

The Lyrids are one of the few major showers which are active in the first half of the year. Meteors belonging to that shower are typically visible from April 16 to 25, with a one or two hour maximum around April 21 ($\lambda_\odot$ = 32°1). During the maximum, hourly rates usually reach a level of 15 per hour. It is worthwhile to note that there have been a few returns when the Lyrids showed more spectacular behavior. For example, in 1803, the hourly rates exceeded 700 meteors per hour, and more recent outbursts were observed in 1946 and 1982 when Zenithal Hourly Rates (ZHRs) were higher than 100 [1]. I also mention that the Lyrids shower is one of the oldest meteor showers. The first observations of Lyrid meteors came from China more than 2000 years ago. In spite of its considerable age, the Lyrids activity is compared with young showers' behavior. This is caused by the highly inclined orbit, which protects the Lyrids particles from gravitational perturbations of other bodies of the Solar System.

The short period of activity and poor weather conditions in central Europe make it sometimes difficult to obtain reliable results for this shower. A few cloudy nights suffice to make any observational actions impossible. On the other hand, the good predictions concerning the time of the maximum strongly encouraged all observers to watch for Lyrids. In 1996, the maximal ZHRs were expected around April 21 at 21^{h} UT. This time was favoring Asian sites, but a small delay of this moment resulting from variations in the stream would also favor observers in Eastern Europe. Additionally, the Moon phase was almost ideal with New Moon on April 17.

Fortunately, the weather conditions during the second half of April 1996 did not disappoint the meteor observers in Poland and gave us the opportunity to watch this shower under clear skies. They allowed us to collect several good observations, which are discussed below.

2. Observations and data reduction

From April 15 to 25, a group of 18 observers from the *Comets and Meteors Workshop* (*CMW*) obtained $112^{\mathrm{h}}13^{\mathrm{m}}$ of effective observing time. During this period, 230 Lyrids and 249 sporadic meteors were recorded. The list of our observers with effective time of observation for each observer is given below:

> Maciej Reszelski ($20^{\mathrm{h}}18^{\mathrm{m}}$), Arkadiusz Olech ($15^{\mathrm{h}}00^{\mathrm{m}}$), Rafał Kopacki ($10^{\mathrm{h}}15^{\mathrm{m}}$), Tomasz Dziubiński ($8^{\mathrm{h}}36^{\mathrm{m}}$), Tomasz Fajfer ($8^{\mathrm{h}}15^{\mathrm{m}}$), Michał Jurek ($7^{\mathrm{h}}00^{\mathrm{m}}$), Krzysztof Wtorek ($7^{\mathrm{h}}00^{\mathrm{m}}$), Kamila Ruta ($6^{\mathrm{h}}33^{\mathrm{m}}$), Monika Fidor ($6^{\mathrm{h}}31^{\mathrm{m}}$), Robert Olech ($6^{\mathrm{h}}30^{\mathrm{m}}$), Robert Szczerba ($4^{\mathrm{h}}23^{\mathrm{m}}$), Marcin Gajos ($3^{\mathrm{h}}00^{\mathrm{m}}$), Michał Kopczak ($3^{\mathrm{h}}00^{\mathrm{m}}$), Maciej Kwinta ($2^{\mathrm{h}}00^{\mathrm{m}}$), Wojciech Jonderko ($1^{\mathrm{h}}00^{\mathrm{m}}$), Łukasz Sanocki ($1^{\mathrm{h}}00^{\mathrm{m}}$), Michał Antonik ($56^{\mathrm{m}}$), Małgorzata Reszelska (56^{m}).

As usual, before calculating of ZHR, we selected our data according to the following rules:

- the mean limiting magnitude in the center of the observed field should be at least 5.0;
- the effective time of observation should be equal or longer than 30 minutes;
- the sky obstruction by clouds should be smaller than 20%; and
- the radiant of the shower should be at least 20° above the horizon.

After this operation, we obtained $99^{\mathrm{h}}13^{\mathrm{m}}$ of observations satisfying these conditions. In our ZHR calculations, we adopted a population index $r = 2.9$ and a zenith exponent $\gamma = 1.0$.

3. Results

The activity profile of the 1996 Lyrids obtained from *CMW* observations is given in Figure 1.

There were over 20 ZHR estimates during the night of the maximum, so we divided these observations into three parts. The highest point of the graph of activity with ZHR $= 14.5 \pm 2.5$ corresponds to $22^{\mathrm{h}}40^{\mathrm{m}}$ UT ($\lambda_{\odot} = 32\overset{\circ}{.}15$). It suggests that the maximum occurred slightly later than was expected, and had a normal ZHR.

On the other hand, the preliminary results based on data of the *International Meteor Organization* (*IMO*) and two *CMW* observers, presented by Rainer Arlt [2], showed high Lyrids activity from $17^{\mathrm{h}}20^{\mathrm{m}}$ UT to $10^{\mathrm{h}}50^{\mathrm{m}}$ UT during the night from April 21 to 22. During this period, ZHRs were in the range 15–20, and the peak occurred at $2^{\mathrm{h}}40^{\mathrm{m}}$ UT on April 22 with ZHR $= 28 \pm 12$. Clearly, accuracy of these figures is very low, and we can only say that normal activity of the 1996 Lyrids was observed. However, the possibility of slightly higher activity cannot be excluded. The problem should be solved when *IMO* will publish its final results.

The *CMW* observers also estimated the brightness, angular velocity, and color of the meteor events. The brightness of the Lyrids meteors was estimated for 230 events. The distribution of this quantity is given in Table 1.

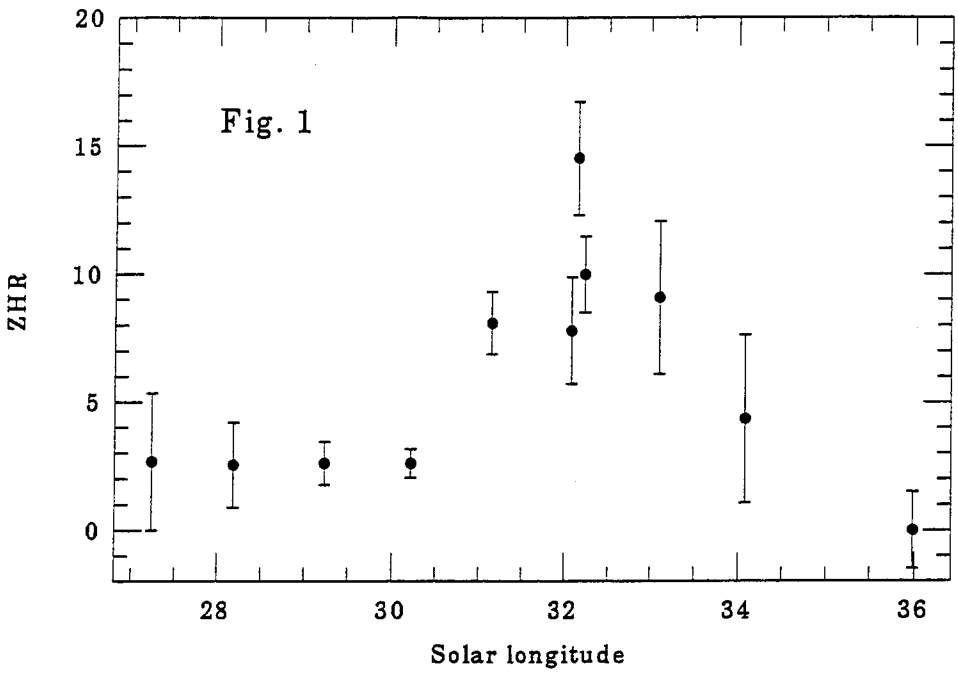

Figure 1 – Rate data of the Polish observations of the 1996 Lyrids.

For comparison, a similar distribution for sporadic meteors is also presented. The average brightness of the 1996 Lyrids was 2.0. The majority of 1996 Lyrids were white (86%); the other colors are yellow (8%) and red (3%). Trains were detected in 11 events.

Table 1 – Magnitude data of the Polish observations of the 1996 Lyrids.

Shower	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot
Lyrids	2	2	1	11.5	24.5	36.5	62.5	49.5	22	17.5	1	230
Sporadics	2	0	1	4	14	30	44	61.5	56.5	31	3	248

4. Summary

We presented the visual observations of 1996 Lyrids made by Polish amateurs of *CMW*. Our observations indicate that only the normal activity of this stream with ZHR around 15 was observed. This value corresponds to a spatial density equal to about 10 particles per 10^9 km^3. The number of observed meteors is too small to derive any valuable conclusions concerning the mass distribution in the stream.

Acknowledgments

I am grateful to Prof. Jerzy Madej for helpful discussions, reading, and commenting on the manuscript. I also would like to thank all the observers who sent me their observations.

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The 1996 Lyrids from Slovakia

Pavol Rapavý and Jaroslav Gerboš

An overview is given of Slovak observations of the 1996 Lyrids.

The Lyrid shower is active from April 16 to 25, sometimes with a high ZHR (1982: 90, 1945: 112, 1922: 100) [1,2]. The Lyrid shower was observed by groups of observers during a gathering in Rimavská Sobota, from April 19 to April 22.

The complete list of 32 observers (in effective observing time order) is given below:

> Pavol Rapavý ($12^{h}.63$), Vratislav Čillik ($10^{h}.55$), Jaroslav Gerboš ($10^{h}.54$), Dušan Hübner ($10^{h}.26$), František Erben ($10^{h}.17$), Milan Uhlár ($10^{h}.10$), Peter Sedlák ($10^{h}.03$), Peter Harmady ($9^{h}.85$), Roman Mikušinec ($9^{h}.45$), Emil Štefánik ($9^{h}.44$), Ivan Vincenc ($9^{h}.31$), Peter Socháň ($9^{h}.3$), Miroslav Blaho ($9^{h}.21$), Pavol Chladný ($9^{h}.08$), Matej Korec ($8^{h}.88$), Miloš Socháň ($8^{h}.7$), Lucia Tomášiková ($8^{h}.29$), Lukáš Červený ($8^{h}.18$), Ján Mäsiar ($8^{h}.01$), Miroslav Znášik ($7^{h}.87$), Ivan Mišeje ($7^{h}.82$), Eva Uliczaiová ($7^{h}.31$), Henrieta Takáčová ($6^{h}.68$), Adrián Pápista ($6^{h}.12$), Marián Hudák ($5^{\circ}.85$), Jaroslav Ambróz ($5^{h}.73$), Zdeněk Komárek ($5^{h}.16$), Miroslav Vyravec ($5^{h}.16$), Peter Kaňuk ($5^{h}.11$), Ivana Lukáčová ($4^{h}.75$), Anna Beňová ($4^{h}.38$), and Luboslav Dobrovoda ($4^{h}.26$).

There were also 4 writers:

> Marta Svacárová, Eva Šušková, Peter Zimnikoval, and Beata Zimnikovalová.

In total, 1666 individual meteor records were obtained under average observing conditions (Table 1) during 258.18 hours of effective observing time. Of those 1666 meteors, 657 were Lyrids, 140 were α-Bootids, and 959 were sporadics.

The evolution of the Lyrid ZHR is given in Figure 1, the maximum took place at $\lambda_\odot = 32^{\circ}.2$ (2000.0) (April 21.99 UT) with a top ZHR of 24.4 ± 5.46 and a mean magnitude of about 3.

The α-Bootids had a relatively stable ZHR of about 4.

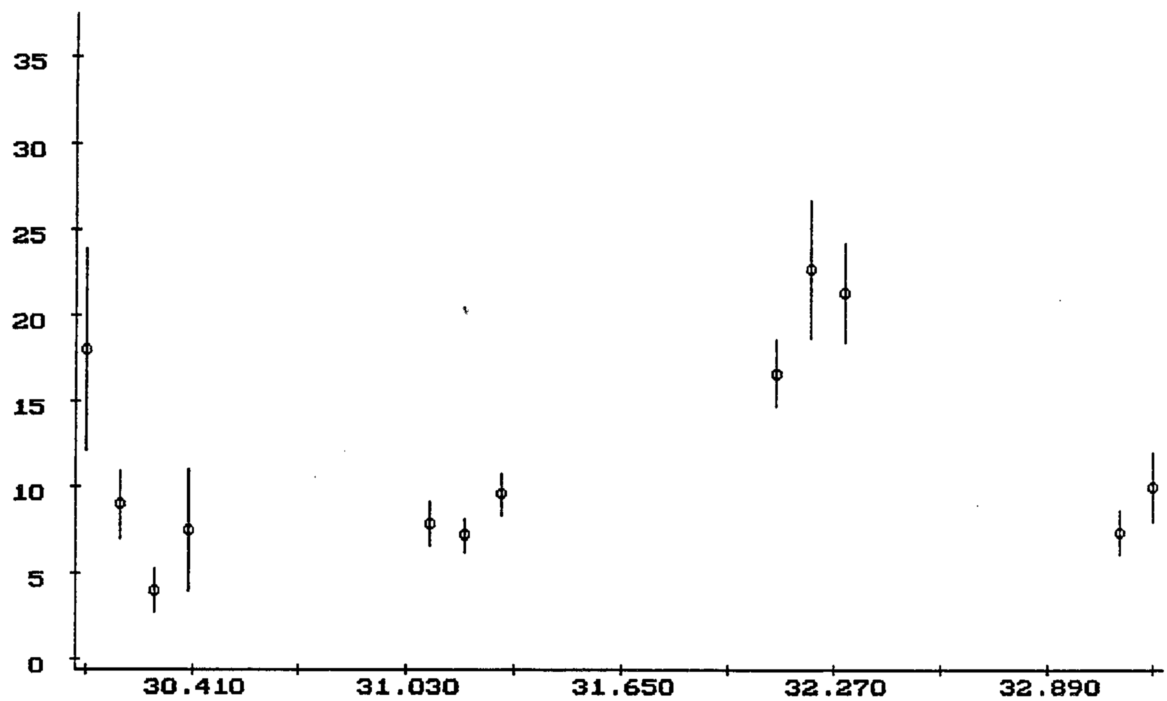

Figure 1 – Activity profile of the 1996 Lyrid observations from Slovakia.

Table 1 – The Slovak observations of the magnitude distribution of the Lyrids in April 1996 (all the observers).

Date	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}$	Lm
19-20		2.5	10.5	4.5	8	2	19.5	14.5	9	6	0.5		77	−0.44	5.35
20-21						3	6	25	29	18.5	7.5	1	90	+1.89	5.41
21-22	7	5.5	2.5	1		1	24.5	55.5	99	103	52	5	356	+2.00	5.47
22-23						2.5	1.5	12	10	12.5	4.5	1	44	+2.05	5.68

References

[1] A. McBeath (comp.), "Meteor Shower Calendar", *WGN* 24:1-2, February–April 1996, p. 15.

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SPA Meteor Section Results: May–June 1996

Alastair McBeath

A short report on results submitted to the *SPA Meteor Section* from May and June 1996 is presented. Weather conditions and northern midsummer twilight prevented much visual observing, but some useful radio data were received in both months.

1. Introduction

Neither May nor June provided many usable nights for our visual observers, and observing tallies were generally cut short as a result, as illustrated by Table 1.

All the photographic data were achieved by the *Arbeitskreis Meteore* (*AKM*) observers of the all-sky *European Fireball Network*, but no trails have been found on their films as yet. Radio results totaling some 288 hours of monitoring were received from Ilkka Yrjölä in Finland via Norman Fitch of the *Radio Society of Great Britain.* He operated his set-up for two sessions, between May 3–6 and June 5–12, inclusive.

Visual reports were received from four members of the *AKM* (chiefly Jürgen Rendtel in Germany), Shelagh Godwin, and Alastair McBeath (both in England), while three May fireballs were reported from the *New Zealand Fireball Network* through Graham Wolf.

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

Month	Visual	SAG	Meteors	Photo
May	$15^{\rm h}.87$	23	104	$55^{\rm h}.32$
June	$16^{\rm h}.70$	12	75	$164^{\rm h}.65$

2. May

Visual observations concentrated in the first fortnight or in the closing days of the month. Activity from all sources was generally low, and watches were kept short by poor weather and increasing amounts of strong twilight, especially in the latter part of the month.

Ilkka's radio data gave a probable enhancement due to the η-Aquarids' main peak in the morning hours of May 5. Visually, just "one" meteor from this source was seen, comprising two "possible" η-Aquarids seen by one observer on separate nights (noted as 0.5 η-Aquarid, 0.5 sporadic on each occasion)!

3. June

An even worse month than May, weak Sagittarid activity continued to be reported, mainly during the second week of the month.

While noctilucent cloud sightings were very prevalent across the UK during June, many such observations were made with ordinary tropospheric cloud interfering, a clear indication of how poor skies were generally. In central Europe, the situation was less favorable, even for noctilucent cloud sightings, with several regular observers commenting on having seen almost nothing of them all month.

A few fireballs were reported, the only one from more than one site was over Germany at $0^h48^m17^s$ UT on June 15, a magnitude -5 event.

Of greater interest was Ilkka Yrjölä's radio results over the expected maxima of the daylight Arietids and ζ-Perseids (June 7 and June 9, respectively). What radio enhancements could be detected occurred on June 5 and 7, which may indicate a shift in the maxima, or, more likely, is the result of Sporadic-E problems. Activity levels showed only a very marginal change from day to day, and as Robert White's results indicated from 1995 [1], the daylight showers of June and July are not easy to distinguish from this other type of radio propagation with automatic monitoring equipment. Nevertheless, it is important that radio monitoring of such showers should continue, in order to give us a better idea of just what is happening with the streams in more modern times.

Acknowledgment

Once again, I am indebted to the correspondents and observers who have provided their support, comments, and data during this particularly difficult spell, and I wish all continued success in their forthcoming efforts.

Reference

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BAA Observations of the 1996 Perseids: A Preliminary Report

Neil Bone

An overview is given of *BAA* observations of the 1996 Perseids

In common with much of North West Europe, the British isles were badly affected by cloud around the 1996 Perseid maximum.

Observers in the south of England endured, for the fourth successive favorable Perseid return, cloud and rain which proved slow to clear away.

BAA members in Scotland, Ireland, and the north of England were more fortunate, providing some excellent coverage around the Perseids' early peak on August 11-12.

Up to the beginning of October, the 63 individual observers and four groups listed below had contributed 141.1 hours of visual reports, totaling 2500 meteors (465 sporadics, 1881 Perseids, and 154 others) for the interval from August 3-4 to 20-21, inclusive. August 11-12 accounts for about a quarter of the watch time and 43% of the meteors seen. The observers were as follows:

> D. Baker, R. Baxter, S. Beaumont, P. Bispham (Germany), N. Bone, G. Boots, W. Bradford, A. Bridson, P. Brierley, E. Britton (Ireland), R. Bruce, H. Bruce, J. Burns, T. Burns, D. Callister, H. Callister, L. Entwisle, S. Evans, M. Gainsford, D. Gavine, J. Glover, C. Hall, B. Hardie, E. Hardie, S. Hardie (Croatia), M. Hanson, M. Harris, A. Heath, A. Hopwood, S. Hudson, R. Johnson, T. Kaneen, A. Kelley, B. Kelley, R. Livingstone, A. McBeath, T. McEwan, T. Markham, J. Martin (London), J. Martin (Peel), N. Martin, I. Merritt, S. Moore, T. Moseley, C. Newman, J. Olesen (Denmark), R. Pitaluga (Gibraltar), N. Quinn, N. Rayner, R. Schmude (USA), J. Shanklin, J. Shepherd, J. Smith (Canada), G. Spalding, D. Storey, S. Sullivan (Canada), M. Taylor, A. Vincent, C. Watson, P. Yates, J. Young, Ayrshire AS, Isle of Man AS, Macclesfield AS, Worthing AS.

Sky- and radiant altitude-corrected Perseid Zenithal Hourly Rates have been derived from the best-quality data as previously [1], using population index $r = 2.35$ for Perseids; sporadic CHRs from the same watch intervals are based on $r = 3.42$. Calculated ZHRs are given in Table 1.

The Perseids showed their usual slow rise in activity through early August, reaching ZHR of the order of 30 by August 10-11. Naturally, great interest centered on the possibility of a continuation of recent years' enhanced activity [2,3] associated with the 1992 perihelion of 109P/Swift-Tuttle.

Clear skies over Scotland favored some of our most experienced observers on the night of maximum. Up to about midnight UT, Perseid ZHR of the order 60—much in line with a "normal" return some 10 hours from maximum—was found. Around 01^{h} UT, however, activity was markedly higher, reaching ZHR=89.1 ± 6.5. Several observers commented on the sharp rise in activity.

Assigning an absolute value to the early maximum ZHR is difficult due to differences in reported rates: for instance, one observer reported almost double the rates seen by others of equal experience under similar conditions at the same time. What is obvious, however, is that the early peak, while still present, was much less marked than in 1993 or 1994. Also, there was no indication of the 2–3 hour "plateau" of enhanced activity seen around the sharp maximum in those years. Clearly, with the parent comet having passed perihelion over four years ago, there must be some doubt whether this feature will remain in 1997.

Activity on August 11-12 fell back noticeably before dawn. The "regular" Perseid maximum was expected around August 12, 09^{h} UT, during daylight from UK longitudes. Observations from Canadian observer James N. Smith in New Brunswick show Perseid activity well on course for this peak up to 07^{h} UT.

The clear skies began, finally, to make southward progress over the UK overnight on August 12-13, by which time Perseid rates were dropping. Observers in the southern UK were able to follow the Perseids' steady decline thereafter up to August 20-21.

As usual, the Perseids proved a good crop of bright events. Mean Perseid magnitude overall was +1.71, compared with +2.64 for sporadics. There is little in the magnitude data to suggest an abundance of bright Perseids close to the early maximum; respective means for Perseids and sporadics on August 11-12 were +1.57 and +2.46—not significantly different from those at other times. Some noteworthy Perseids were reported on August 11-12, including a magnitude -4 at $22^{h}46^{m}$ UT and a spectacular event (estimated to be magnitude -2 to -8 depending on observer location) with a persistent train lasting for over a minute at $23^{h}34^{m}$ UT. A very bright, green sporadic fireball was seen in the southern UK at $02^{h}16^{m}$ UT on August 12-13.

Persistent trains were shown by 35.9 % of Perseids, compared with 6.0 % of sporadics.

Table 1 – Perseid data from members of the BAA in August 1996. The columns list the date in August 1996 (D), the solar longitude ($\lambda_\odot$), the observing time (T), the limiting magnitude (Lm), the cloud correction factor (F), the number of sporadics (Spor) and Perseids (Per), the CHR of the sporadics, the radiant altitude (rad.), and the ZHR of the Perseids.

D	UT	$\lambda_\odot$	T	Lm	F	Spor	Per	CHR	rad.	ZHR
3	22^h30^m	131°89	2h00	6.00		3	3	2.8 ± 1.6	31°1	4.7 ± 2.7
4	22^h21^m	132°84	3h50	5.50		12	7	11.7 ± 3.4	26°7	10.5 ± 4.0
7	22^h24^m	135°72	4h00	5.38	1.01	4	32	4.0 ± 2.0	31°8	39.9 ± 7.1
7	23^h48^m	135°78	1h67	6.25		4	12	3.2 ± 1.6	41°0	13.6 ± 3.9
10	22^h01^m	138°58	2h00	6.22	1.04	2	24	1.5 ± 1.0	31°7	30.2 ± 4.2
10	22^h57^m	138°62	3h00	5.67		13	28	12.0 ± 3.3	38°4	30.5 ± 5.8
11	00^h01^m	138°66	4h00	5.90		7	53	3.7 ± 1.4	46°4	30.6 ± 4.2
11	01^h02^m	138°70	2h77	6.50		5	42	1.8 ± 0.8	53°2	18.9 ± 2.9
11	02^h00^m	138°74	3h00	6.50		5	40	1.7 ± 0.8	60°2	15.4 ± 2.4
11	22^h05^m	139°54	4h67	5.24	1.05	16	55	16.9 ± 4.2	34°0	64.9 ± 8.8
11	23^h13^m	139°58	8h50	5.86	1.02	36	182	10.8 ± 1.8	41°1	57.4 ± 4.3
12	00^h20^m	139°63	8h31	6.06	1.02	44	252	10.1 ± 1.5	48°9	59.8 ± 3.8
12	01^h12^m	139°67	4h45	5.90	1.02	24	189	11.3 ± 2.3	54°3	89.1 ± 6.5
12	02^h06^m	139°71	6h30	6.00	1.01	24	195	7.1 ± 1.4	61°5	42.2 ± 3.0
12	03^h30^m	139°76	1h00	7.00		12	45	12.0 ± 3.5	33°2	82.2 ± 12.3
12	04^h30^m	139°80	1h00	7.00		4	54	4.0 ± 2.0	40°2	83.7 ± 11.4
12	05^h30^m	139°84	1h00	7.00		5	59	5.0 ± 2.2	47°7	79.8 ± 10.4
12	06^h30^m	139°88	1h00	7.00		9	72	9.0 ± 3.3	55°5	87.4 ± 10.3
12	23^h26^m	140°56	3h00	5.53	1.14	4	52	6.6 ± 3.3	41°4	68.4 ± 9.5
13	00^h21^m	140°59	4h00	5.63	1.04	12	75	9.1 ± 2.6	48°2	55.0 ± 6.4
13	01^h00^m	140°62	3h00	5.45	1.09	9	62	17.8 ± 5.9	51°6	70.5 ± 9.0
13	02^h07^m	140°66	1h00	5.63	1.08	6	19	21.4 ± 8.7	59°6	54.5 ± 12.5
13	22^h18^m	141°47	4h77	5.46	1.06	21	43	16.8 ± 3.7	34°2	41.3 ± 6.3
13	23^h20^m	141°51	2h75	5.40	1.04	9	14	13.2 ± 4.4	40°5	20.9 ± 5.6
14	01^h25^m	141°59	3h00	6.03	1.02	24	53	14.3 ± 2.9	52°3	33.4 ± 4.6
14	22^h54^m	142°46	8h46	5.21		21	35	12.1 ± 2.6	38°2	20.1 ± 3.4
15	23^h51^m	143°46	2h00	5.70		4	7	5.3 ± 2.7	44°8	9.8 ± 3.7
16	22^h37^m	144°37	3h00	5.43	1.12	12	13	13.3 ± 3.8	38°0	15.6 ± 4.3
17	00^h36^m	144°45	2h00	5.90		7	8	7.3 ± 2.8	50°6	8.6 ± 3.0
17	22^h45^m	145°34	2h00	6.30		4	3	2.6 ± 1.3	38°5	2.9 ± 1.7
18	22^h12^m	146°28	5h00	5.99		15	6	5.6 ± 1.4	34°8	3.3 ± 1.3
19	22^h32^m	147°25	3h17	5.90		14	5	9.2 ± 2.5	37°2	4.4 ± 2.0
20	22^h53^m	148°23	1h75	6.50		6	2	3.4 ± 1.4	40°5	3.1 ± 2.2

Acknowledgment

As always, thanks are expressed to all observers who made the effort to collect the data under less than ideal conditions. For many in the UK, a clear major shower maximum is long overdue!

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