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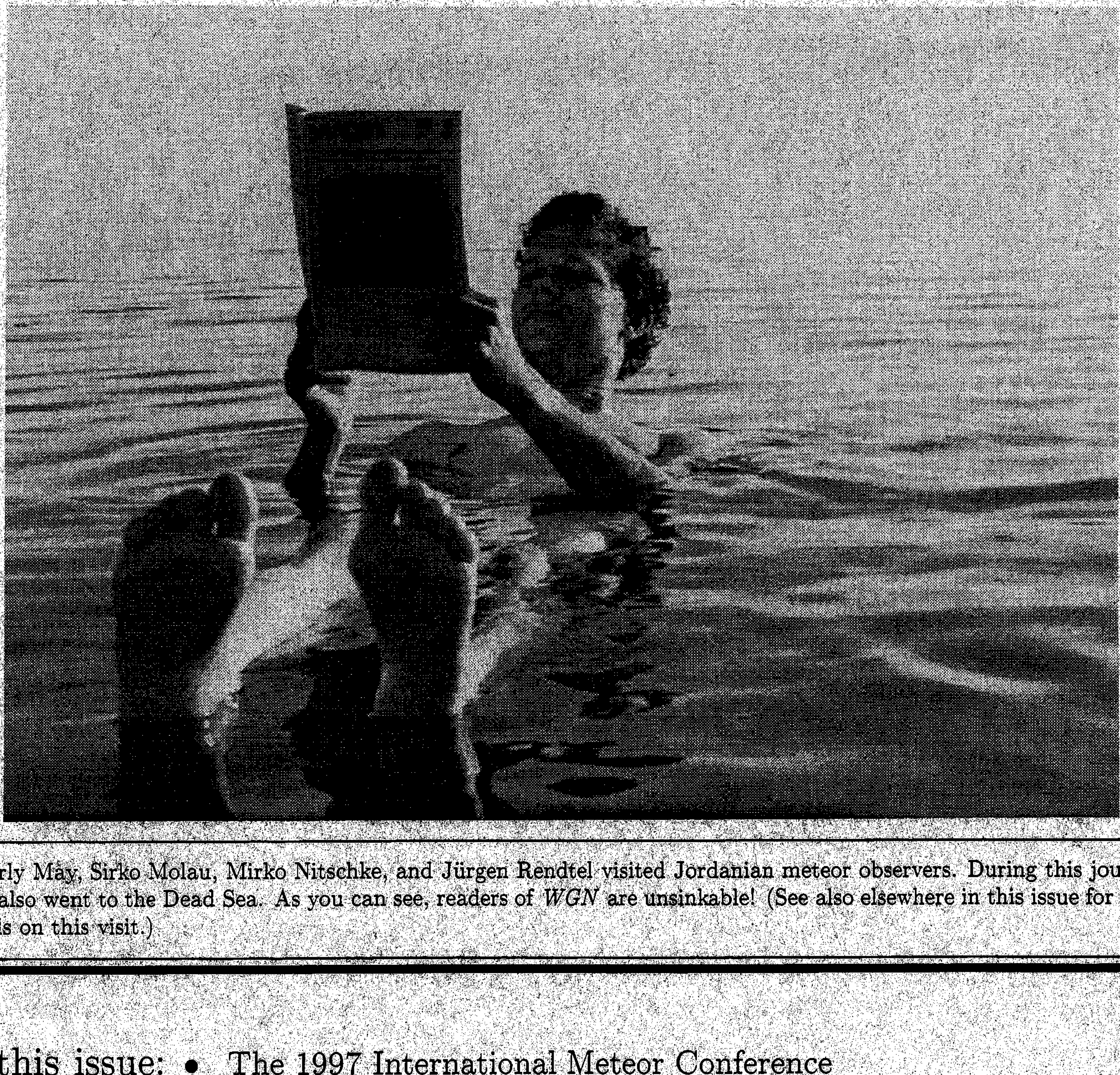

In early May, Sirko Molau, Mirko Nitschke, and Jürgen Rendtel visited Jordanian meteor observers. During this journey, they also went to the Dead Sea. As you can see, readers of *WGN* are unsinkable! (See also elsewhere in this issue for more details on this visit.)

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Contents

Useful Information

The August Issue *(WGN 25:4)*

The *August issue* will be mailed around mid-August. Contributions are due on *July 18* 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 Editor-in-Chief

compiled by Marc Gyssens

By the time you read this, most of you (at least in the northern hemisphere) will be preparing for the summer holiday season. We do hope weather conditions will be favorable, so that a lot of observations can be made. Of course, we are interested in a coverage as continuous as possible—mind that something unexpected can happen at any time—but, as every year, the Perseids deserve special attention. The strong "new" peak, generally attributed to the proximity of parent comet 155/P Swift-Tuttle, now seems to fade away slowly, and therefore it is important to find out how this evolution progresses.

Meanwhile, enjoy this issue!

Letters to WGN

compiled by Marc Gyssens

The Draconids

Alastair McBeath's response (*WGN* 25:2, 1997, p. 69) to my article on the 1998 Draconid prospects (*WGN* 25:1, 1997, pp. 37–39) leaves me puzzled, the point he tries to make in his opening paragraph being not quite clear to me. While, for reasons I do not understand, he seems to take the paper as dismissing the annual calls for observation, I was meant to *add* to raising observational interest—primarily for 1997 and 1998—by pointing out some of the specifics about the upcoming 1998 return. In this sense, I really do not see how this would do a disservice to Alastair or anyone else. I am not dismissing earlier publications in my paper, but merely expanding them by adding a readily accessible discussion of the 1998 encounter geometry circumstances for which some need seems to exist.

My paper on the 1998 prospects originated in the odd combination of questions that arose around the subject among some (Dutch) observers, as well as a genuine ignorance of the possibility of a 1998 event among others. My fear was a little bit that, under such conditions, the Leonid fever would overshadow the event. That some discussion on the topic in fact was useful and might serve a need was underlined, not only by questions among Dutch observers, but also by the fact that request for information on the topic emerged on the *NAMN* news group `meteorobs`, both shortly after I submitted my manuscript to *WGN* as well as before its publication.

In a contact with Peter Bus on the subject of the current 21P/Giacobini-Zinner orbit and the Draconids, his report on radio activity emerged, and I decided to forward his report by including it as a short note, hoping that it might serve in arousing interest to observe the stream as well as hoping that observations aimed specifically at the particular solar longitude might clarify if there is indeed short-lived low-level activity of any kind at this solar longitude or not. These observations are badly needed: the *IMO*'s *VMDB* contains very few recent entries for the relevant restricted solar longitude window, not a single one for 1994–1995, for instance [1]. I am not so much of a radio guy, and as far as the radio observations in question are concerned, Peter Bus and I have agreed that Peter will present his observations in a separate contribution to *WGN* which might serve both Alastair and the reader of *WGN* with some more-to-the-point information than I am able to provide. The only point I want to make is that Peter bases his arguments on data which are corrected for observability (using the model of Hines), unlike Alastair, who discusses raw uncorrected counts in which latent features might be obscured. Yet, I guess this is a discussion for radio buffs, which I am not.

This brings us to the topic of "non-confirmation" of the reported possible activity as stressed by Alastair. I agree with his comment that one should be cautious (hence the use of the word "possible" in the report), but I had wished he had been more cautious himself. Actually, I think he stresses his argument of "non-confirmation" to unacceptable limits. For one thing, he does not seem to acknowledge the clearly stated point that it concerned modest and *short-lived* activity, that is, taking less than 2 hours. Bringing in into the discussion radio data by De Meyere, as Alastair did, really is not to the point and unnecessarily obscures the matter, since De Meyere stopped his observations well before the radio event of Bus took a start! As far as Suzuki's observations are concerned, observability corrections really should be applied before any statement can be made. A radiant, especially one with modest activity, can remain undetected from the sporadic background if it occupies an unfavorable radiant position for the set-up concerned. Contrary to Alastair's remark, it seems to me that a high radiant elevation usually means bad observability for radio set-ups as far as I am able to grasp the subject. For radiant elevations above the 40°–50° optimum, sensitivity dramatically drops [2]. Suzuki's set-up had the radiant at around 70° above the horizon.

Visually, the short-lived character of the possible event, and any short-lived event in general, restricts the area from which observations were possible. This is even more true for the Draconids, since this stream can only be well observed in the early evening. Taking these restrictions into account, circumstances for the possible 1996 event were grim indeed. The event would only have been observable from the Pacific Ocean. At the US West Coast, the radiant was already very low in the sky, certainly making detection of low-level activity impossible. In Japan, strong twilight persisted until the event was as much as over. This leaves only Hawaii, but there the radiant was low in the sky, too, making any activity inconspicuous...

[1] R. Arlt, *personal communications*, late 1995.
[2] P. Bus, *Radiant* 17, 1995, pp. 43–45.

Marco Langbroek, May 10, 1997

The 1997 International Meteor Conference

Petnica, Yugoslavia, September 25–28, 1997

Vladimir Lukić

The 1997 *International Meteor Conference* will be held in Petnica, Yugoslavia, from September 25 to 28, 1997. There is not much time left till the beginning of the *IMC*, and we still have free places available in Petnica, at the same price of 140 DEM. If you would like to participate, use the form provided in recent issues of *WGN*, and return it to treasurer Ina Rendtel, together with 100 DEM pre-payment (or the full amount).

Petnica Science Center is capable to offer special arrangement for people who might have problems with paying the full fee—a reduced fee of only 70 DEM will be applied to the cases where it is necessary. Unfortunately, we can afford only a limited number of these offers. Those searching for discount should contact the organizer immediately!

Participants from certain, mainly West-European countries, may need a visa to enter Yugoslavia. Obtaining a Yugoslav visa is mere formality, but it is necessary. You can get it in one day at any Yugoslav diplomatic mission in your country. We shall supply you with a personal invitation for this matter.

As we expect most of the participants to come by plane or train, meeting points will be at the airport and the railway station in Belgrade, where we shall collect people for transportation to Petnica, a couple of times during a day. The van at the airport will get you downtown: early arrivers will have an opportunity to enjoy a day in Belgrade. A bus will give you a 100 km ride to Petnica, 7 km from the town of Valjevo. Generally speaking, the Petnica Science Center lies in a hilly region, amidst quiet groves and meadows.

The program of the conference begins on Thursday afternoon, as usual. Among the lectures, workshops, and poster sessions, we shall have the *IMO* General Assembly on Friday, and an excursion on Saturday. There is plenty of space in Petnica to present posters, thus you do not need to restrain your creativity. There are enough classrooms (including a computer room) to have several workshops and other group sessions at the same time. What I found that could be the most striking at the *IMC* in Petnica is a large wall VCR projector. Do not forget to bring your "best of" video tapes! As this is an electoral year in the *IMO*, at the General Assembly, the *IMO* officers who will serve the following period will be made known.

The excursion will take us to the mountain region south of Valjevo, where we shall visit some ancient monasteries, the Gradac river canyon, and our standard observing site at Debelo Brdo—a place with a beautiful nature and a remarkable view all the way to Belgrade. If the weather conditions allow us, we shall have an open-air barbecue there, in a traditional way. If not, the huge entrance hall of Petnica cave should be a good substitute. We hope that after departure, on Sunday, you will take home many nice memories.

Weather in late September is still warm, but some rain should not surprise you. The mountains we shall visit during the excursion are not that high that you should be worried about the temperature there. A shirt or light sweater should be warm enough for walks through Petnica village, by the lake, or through the exotic Turkish part of Valjevo.

Participants are accommodated in rooms with three beds. Meals, served in the dining building, will introduce you to the Balkan cuisine (if you have some special diet, you should inform us). As usual, drinks will be served at the bar during the breaks. There is a small, but well-supplied shop within the Science Center. Cars and vans secure non-stop connection with Valjevo. You may stay some days before or after the *IMC* in Petnica, or we can help you arrange a stay in Valjevo or Belgrade. Those who intend to travel by car should contact us for additional information (for your convenience, a meeting point will be arranged in Valjevo).

If you have any questions or some special requirements, or if you need detailed information about traveling to Yugoslavia, accommodation, or anything else please e-mail me at `f2lukicv@afrodita.rcub.bg.ac.yu`, or write to Petnica Science Center/*IMC* 97, P.F. 118, YU-14000 Valjevo, Yugoslavia. Check out our web site at `http://www.yurope.com/org/petnica`. Hope to see you soon, in Petnica (pronounce "Petnitza")!

Observing the η-Aquarids from the Desert

A Visit to the Jordan Astronomical Society

Jürgen Rendtel

The η-Aquarids are normally not a shower for which one organizes an expedition from Central Europe to a remote site in the northern hemisphere. The story, however, started a bit earlier, when Godfrey Baldacchino wrote about one separate outcome of the meteor watchers survey [1]. He mentioned that enthusiastic meteor observers of the *Jordanian Astronomical Society* (*JAS*) were very much interested in direct teaching of observing techniques and data analysis. Independent of the offer mentioned by Godfrey, an exchange of e-mail messages happened with Mohammad Odeh of Jordan about various items related to meteor observations made by members of the *JAS* in 1996. Only later, Sirko Molau and I remembered the letter of Godfrey which was published in *WGN*, and so, in early May, Sirko Molau, Mirko Nitschke, and I visited the *JAS* meteor observers.

There are not too many choices for observations of major meteor showers under moonless conditions in 1997. Only the η-Aquarids, the Perseids, and the Ursids are on this list. The η-Aquarids were not only the first target, but they also offered a chance to see something of this southern shower which is in fact not observable from our mid-European latitudes. So, we made arrangements about the time and the program of our visit, and on May 3 we went to Amman. In our luggage, we had a lot of lecture stuff but also one of the intensified meteor video cameras and photographic equipment.

At the airport Khalil Konsul, the President of the *JAS*, and Mohammad Odeh waited for us. A colleague of Khalil helped with the visa procedures, and we arrived in a hotel after midnight. On the next day, preparations for the expedition into the Jordanian desert were made. All the equipment necessary for a meteor camp was put somehow in a bus and a car, including food, a power generator, an overhead projector, and all the bags with personal items. We went towards Azraq, a small settlement at a cross-road between Syria, Saudi Arabia, and Iraq. Here, some final purchases were made, and, after a few kilometers, we left the main road and went right into the desert for about 20 kilometers. In the early evening, we all arrived at a camp which was once used for an oil pumping station. Still, the houses and some of the installation was there and partly intact, and soon all was set for the first observing night. Before that, we had a meal, and we started with a first lecture, or better, seminar about the visual meteor work. After a break to have some rest, all observers prepared their watch.

Figure 1 – The main purpose of our visit to the Jordanian Astronomical Society (JAS) was the instruction of their meteor observers during a joint observing campaign. As printed on their banner for the group photo, it was the 17th astronomical camp of the JAS, and most of these were organized for meteor observations.

Before this camp, they used to carry out group observations. Soon, they realized that observing individually requires much more concentration. For example, no one takes over if an observer wants to have a break. Unfortunately, it became quite cold in the morning, and most observers were not prepared for such conditions.

So, breaks were necessary to warm up just when the η-Aquarids became significant in the last two hours before the twilight ended our watch. Nevertheless, it was the first step towards *IMO* standard observations.

Other topics of talks we gave were photographic and video meteor work. We set up the video equipment in the second night. In the evening, we obtained some recordings of the still impressive C/1995 O1 (Hale-Bopp) and the bright clouds of the Milky Way. Later, in the night of May 5-6, the next regular meteor observation went on, using visual, photographic, and video techniques. This was the maximum night of the η-Aquarids, but with a radiant elevation reaching 30° towards the end of the night, the observable number of shower meteors remained low. A typical number of η-Aquarids seen during the last hour was about 15 under very good skies with limiting magnitude around 6.5. Sirko's video meteor camera AVIS recorded 36 η-Aquarids within about two hours of operation in that night.

We used the daytime for a few excursions to nearby desert castles which appeared as described in many of the famous oriental tales. The increasing temperatures also caused interesting atmospheric mirror phenomena and miraculous lakes within the desert. Some of these phenomena were so "convincing," that they mislead even the native people. But we also had enough time to do the raw data analysis together with the observers. So we got a large number of their reports ready before the camp ended.

The last night in the camp became very clear. Since most parts of the desert are covered with stones, there is little dust in the air. Shortly after sunset we found Venus in the twilight. The zodiacal light was easy to recognize, and a bit later the central portions of our galaxy gave the impression of clouds lit by nearby lights. Due to the better conditions, the number of η-Aquarids was as high as in the previous night. While we introduced the counting method in the beginning, now the first Jordanian observer started to plot meteors. We together analyzed the plots the next day, also explaining all sorts of plotting errors and problems of shower association using a real observation.

Unfortunately, the observing camp was already over. We went back to Amman, where we had a meeting with all observers in the evening. Another talk was given by Sirko about meteor observing techniques and some results, and we were given plaquettes to remember the η-Aquarid camp. For the next days, a touristic program was established, and we were accompanied to some of the most famous places in Jordan. First of all we have to mention Petra, the Nabatean city with its marvelous facades worked directly out of the rocks. In the mainly Roman city of Jerash, north of Amman, we enjoyed an extra song and dance performance given by a group of school girls in the ancient amphitheatre. We also liked our guided walks through downtown Amman with its markets and historic places. And last but not least we experienced swimming in the Dead Sea—reading *WGN*, of course.

This list is certainly not complete since you cannot describe a marvelous week in a few sentences. We wish to thank all our hosts for their hospitality and enthusiastic support during our stay. The last day was filled with a visit and another lecture on meteor astronomy in the Jordanian Geographical Institute and a final meeting in the Haya Cultural Center with most of the participants of the η-Aquarid camp, before we went back home with a lot of new impressions and friendly feelings for the *JAS* meteor observers. I think we will hear more from them in the future. Perhaps the contacts to the *JAS* will extend to meteor observers in other countries in that region. Hope we meet again at an *IMC* or at another meeting in the Middle East.

Reference

[1] G. Baldacchino, "Results of Meteor Watchers Survey", *WGN* 24:5, August 1996, p. 131.

Second Arab Astronomical Conference

Amman, Jordan, September 8–10, 1997

communicated by Jürgen Rendtel

The *Jordanian Astronomical Society* and the *Royal Jordanian Geographic Center* organize the *Second Arab Astronomical Conference* in cooperation with the *Al al-Bayt University*. The conference will be held at the *Royal Jordanian Geographic Center* from September 8 to 10, 1997.

The scientific fields covered are amateur astronomy and astronomical culture, astrophysics, radio astronomy, atmospheric physics and cosmology, ancient astronomy in the Arabo-Islamic civilization, astronomical applications in Islamic affairs, astronomy and space sciences in education, remote sensing and image analysis, modern discoveries in the Solar System, and space science and technology.

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Observers' Notes for the 1997 Perseids

Rainer Arlt, Sirko Molau, and Marc de Lignie

1. Prospects

Another interesting return of the Perseid meteor shower is expected for this year. Unfortunately, it is not the expectation of heightened activity that makes the 1997 Perseids worth observing; the scientific interest is rather focussed on the possible vanishing of the short-lived peak occurring several hours before the traditional maximum.

When looking at the Perseid analyses from 1988 to 1996, we notice a gradual decrease of the peak time of that new maximum until 1992, and an increase of solar longitude after 1992 until the last year [1]. The orbital node of the parent comet 109P/Swift-Tuttle is located at $\Omega = 139\overset{\circ}{.}44$ (all values are eq. 2000.0) [2], and the smallest solar longitude of the new peak was $\lambda_\odot = 139\overset{\circ}{.}48$ whereas the traditional maximum is located at about $\lambda_\odot = 140\overset{\circ}{.}0$. Theoretical calculations suggest that the new peak mainly represents the particles ejected at the 1862 return of the parent comet and is still bound to the comet's perihelion passage in 1992. Now the peak heads towards larger solar longitudes and reached a value in 1996, which lies between the peak times of 1989 and 1988. What will we see in 1997?

First, we can estimate the peak time when assuming that the solar longitude is still increasing gradually by $0\overset{\circ}{.}05$ per year on average. This results in $\lambda_\odot = 139\overset{\circ}{.}71$ or August 12, 8^h30^m UT. The traditional maximum is much broader, and we cannot pick a certain hour as the peak time. Highest rates will occur between August 12, 13^h and 18^h UT (solar longitude $139\overset{\circ}{.}9$–$140\overset{\circ}{.}1$).

The ZHRs of the first peak in 1996 were significantly higher than the peaks with comparable solar longitudes in 1989 and 1988. Hence, we may assume that it will not be as difficult to detect the peak as in 1988 when it did not even exceed the activity of the traditional maximum. However, the decrease of activity was much faster during the last four years than the increase from 1988 to 1990. Combining both facts, we may suggest peak ZHRs of 80–100, i.e., rates comparable to the traditional maximum.

2. Visual observations

A 60% illuminated Moon disturbs observations only in the first half of the maximum night. Observers in eastern North America will witness the sharp peak with the radiant highest in the sky, but miss the descending branch (if any still exists) in the dawn. Observers on the West Coast have good circumstances to see the first peak and may see the ascending branch of the traditional maximum. Meteor amateurs on Hawaii and in eastern Asia are encouraged to cover their dark hours with observations on August 11-12 or August 12-13 respectively.

If a meteor report contains the periods above mentioned as the maxima, it should give 15-minute periods for the first and 30-minute periods for the traditional maximum. Simultaneous observations in eastern Asia, the Near East and eastern Europe between 19^h and 20^h UT may allow an estimate of the zenithal correction exponent, as was possible during the Leonid maximum in 1996.

3. Video observations

For video observers, the 1997 Perseids are especially interesting for the following reasons.

Earlier observations have shown that meteors from the fresh meteoroid filament have a more compact radiant and very similar orbital elements. It is worth to support this finding by 1997 data as we may witness the pre-maximum peak for the last time.

The Perseids in general are one of the showers that give high numbers of meteors for both visual observers and video systems. This makes them especially useful for calibration of visual observations, investigations of systematic differences between the observing techniques, and special analyses like meteor cluster search.

It is suggested to use two or more standard video systems in a multi-station set-up to obtain meteoroid orbits from the fresh filament. For the location of the different stations and the fields of view the same rules as for multi-station meteor photography apply.

Calibration of visual observations is done preferably with wide-angle video recordings obtained at the same time and place. The limiting magnitude of the system should be about $6\overset{m}{.}5$ with the field-of-view diameter as large as possible. Additionally, visual observers accompanying the video set-ups should record the accurate time of each meteor to permit direct meteor assignment in the following analysis process.

Last but not least, we should remember that the expected 1998 Leonid outburst is approaching quickly. Observers who intend to record this event should use their video system in the same set-up as planned for 1998. This enables them to analyze the efficiency of their system and to determine the relation between visual ZHRs and the flux densities obtained from video observations.

4. Photographic observations

Photographs of Perseid meteors are particularly welcomed. The fact that already many Perseid photographs are available, makes it attractive to add new ones to the analysis and obtain a statistically more significant result. To optimize the number of photographed Perseids it is best to aim your camera not too far from the radiant, e.g., at azimuths of 200° or 250° to the north-east, just left or right of the radiant. People with very clear and dark skies can aim their camera(s) at a rather low elevation (e.g., 35°) to further improve their chances. Others better choose a higher elevation (e.g., 70°).

References

[1] J. Rendtel, R. Arlt, "Perseids 1995 and 1996—An Analysis of Global Data", *WGN* 24:5, October 1996, p. 141.

[2] B.G. Marsden, G. Williams, "Catalogue of Cometary Orbits", Cambridge, Massachusetts, 1995.

Ongoing Meteor Work

Public Perception, Meteor Astronomy, and Leonid Storms

Martin Beech, Campion College, University of Regina

Meteor astronomers have failed on more than one occasion to predict the behavior of the Leonid meteor shower. Some of these failures have occurred under the gaze of the public eye. It is argued here that historically the success or failure of publicly promoted predictions has had little to no impact on the practices of the meteor astronomy community.

1. The kraken wakes

Like it or not, the Leonid meteor shower is on the verge of stardom. As meteor astronomers, there is very little we can do about this, even if we so desired. During the next several years the Leonid shower will be front and center on the media stage. And indeed, why should it (and meteor astronomy) not wallow in the limelight given the predictions for storm activity in 1999 and 2000?

Celebrity status is not a new Leonid shower attribute. It has been famous many times before now, although most people—the great unwitting public—will not be aware of this. Indeed, the public as of the present time hardly knows what it is in for. The great juggernaut that will become Leonid storm hype is barely perceptible at the present time, but its bloated form is stirring. Future historians will be able to debate the consequences, good or bad, of the forthcoming Leonid hype on meteor astronomy. My guess, and I emphasize the word *guess*, is that meteor astronomy, no matter what happens towards the end of this century, will end up neither better nor worse off in the public eye. This is not to say, of course, that we, as people passionate about meteors, should not try to educate and inform the public about the Leonid shower.

My claim is that, no matter what happens with the Leonids in 1999 or 2000, meteor astronomy as an amateur pastime and as a professional activity will change but very little. Certainly, we shall learn a lot more about the Leonids, but I do not foresee the emergence of a massive ground swell of public support for meteor research. We should not be disheartened by this fact, but should simply accept it for what it is—the public and the media are only interested in easy to see spectaculars.

2. What does history tell us?

In general, one can make three predictions about the Leonids. If the stream's parent comet 55P/Tempel-Tuttle is not near perihelion, then the annual shower will be marginal in the sense of hourly meteor rates, and consequently the shower will be of no interest to the media or the general public. This is the normal state of affairs. If, on the other hand 55P/Tempel-Tuttle is near perihelion, then two predictions are possible. One can either predict a veritable rain of meteors (a storm), or one can predict that nothing untoward will happen. It is the very fact that two predictions are possible, with two crucially different outcomes, that will fuel media and public uncertainty. It will not, of course, inhibit the claims of the media juggernaut which will (I have no doubt) promote the storm predictions. And, why not? Meteor storms are, for so I read, amazing visual spectacles. Public interest will be running high and the media has a story to sell.

In the past century, the Leonids have twice badly frustrated the expectations of meteor astronomers. This essay is not, however, concerned with how or why various Leonid predictions failed. Rather, I am interested in the public perception question and the workings of meteor astronomy. Irrespective of what happens in 1999 or 2000, how will meteor astronomy fair once the media has switched attention to some new approaching spectacular? This is the question I am interested in here.

Meteor astronomers widely predicted that Leonid storms would occur in 1898 and 1899. The many newspapers and journals (the mass media of the era) that then existed carried numerous letters about the expected displays. The public could hardly fail to notice that something was up. Judging from the Times newspaper [1] the hype started as early as 1896. It is interesting to note that astronomers were in fact predicting that two meteor storms might occur in 1898—a Leonid storm and an Andromedid storm. Writing in 1894, for example, the doyen of meteor astronomers, W.F. Denning wrote [2],

> *"It is a curious circumstance that on November 1898 (or 1899), two fine meteoric displays may come nearly together. There ought to be a plentiful return of the Leonids... while the Andromedids should re-appear... 8 days afterwards. Thirteen years elapsed between the great Andromedid showers of 1872 and 1885, and a similar interval brings us to 1898. If the two systems fulfil expectation meteoric observers will find their hands full to attractive work, and no doubt the general public will take advantage of the opportunity, to witness two of the most attractive spectacles which it is possible for the heavens to afford."*

Denning's claims for the appearance of an Andromedid storm are purely empirical and were offered in a manner seemingly oblivious to the already established idea that meteor storms only occur when a stream's parent comet is near perihelion. However, the claim is entirely consistent with Denning's outlook. There were no clear theories of meteoroid stream structure and evolution, he would reason, and consequently one should be guided by the patterns that exist within the observational data. The problem with this approach, however, is that one can not be sure that all of the potential shower variations have been observed.

And what did the public get for all the advanced billing and conjecture? A mere drizzle of meteors. Not only did the Leonids fail to deliver a meteor storm, so too did the Andromedids. Writing of the Leonids in 1899, W.W. Payne commented [3]

> *"To say that any one interested in, or having knowledge of, the expected shower of the Leonids for this year was disappointed in what was observed, is to put the matter mildly... It is probable that more has been said about the return of the Leonids in 1899 during the past few years, than about any other astronomical theme in a score of years."*

Likewise, W.F. Denning wrote [4]

> *"It may be safely said that no meteoric display was ever so generally looked for and awaited with so much interest as the one which has just occurred. That the character of*

it should have proved so disappointing is to be regretted... The astronomical world had been eagerly anticipating the event for many months and the curiosity of the general public had been excited by articles in the newspapers pointing out, perhaps too confidently, that the meteors would appear in such amazing numbers that the event would form one of the most striking spectacles of a lifetime..."

Clearly, public expectation was running high in 1898 and 1899, and basically meteor astronomy failed to deliver a reliable prediction. In a second article about the 1899 Leonids, Denning attempted some damage control and indeed, tried to shift some of the blame away from meteor astronomy [5],

"The long-looked-for time when a repetition of historic meteor displays was expected has come and gone, leaving behind it a feeling of disappointment; a disappointment perhaps more felt by the general public than by astronomers... The daily newspapers and the magazines had created a popular interest in the subject, without adequate cautions as to the uncertainty of the event, and as a result many thousand persons assembled in open spaces in London... for observations of the shower which did not appear."

Denning's comments about the media are somewhat unfair, especially since he was one of the prime sources of their information. However, his complaint has a very familiar, even modern day ring to it. Denning also appears to be hinting that if people were disappointed it was their own fault.

In 1966, the greatest meteor storm of recorded history (in the sense of reduced zenithal hourly rate at maximum) materialized. And yet, few astronomers were aware of the possibility that such an event might take place. As for the public, most were completely unaware that anything was going on. Even the popular and widely read *Sky and Telescope* magazine hardly dared mention the shower. The November 1966 issue of the magazine carried an editorial note that suggested some "interesting" activity might be seen, but also noted that C.P. Olivier felt *that no certain prediction is possible*. Olivier had every reason to be cautious, but he essentially failed to realize the implications of the enhanced Leonid rates that had been observed since the outburst of 1961.

In the public eye a non-prediction of a spectacular event is just as bad as the non-appearance of a predicted one. And it seems to me that the public has every reason to view it so. In a now famous out-poring of emotion, C.P. Olivier commented of the 1899 Leonids [6] (and it may have been these feelings that held him back in 1966)

"The failure of the Leonids to return in 1899 was the worst blow ever suffered by astronomy in the eyes of the general public, and has indirectly done immense harm to the spread of science among our citizens."

A number of comments can, I feel, be attached to Olivier's comments. Firstly, I do not believe that Olivier's concerns about the "harm" done to the spread of science were realized or even realistic. The general public, as has been found on numerous occasions throughout history (see, e.g., [7,8]), shows very little understanding of even very basic science. Furthermore, I am not convinced that the general public is so highly preoccupied with meteor astronomy that the failure of one, or indeed several, predictions will influence collective opinions on science one way or the other. I would further note, for example, that the Draconid meteor storms of 1933 and 1946 arrived unpredicted and unbeknown to the general public and yet there was no backlash against meteor astronomy. Indeed, one could safely argue that the 1950s and 1960s were the most productive decades of modern meteor astronomy. Fear of failure does not mean that meteor astronomers have no social responsibility to proffer predictions when there are good grounds for doing so. And, even though it is highly probable that the mass media and the public will completely miss the point, it is also incumbent upon meteor astronomers to highlight the uncertainties in their predictions. And remember, in science there is nothing wrong in being wrong. It is, after all, the ability of science to correct its own failings that makes it the power that it is.

From the view point of meteor astronomy the interesting consequence of the failure of the Leonids in 1899 was that it promoted great debate and innovation within the meteor science community. Closer attention, for example, was directed towards the understanding of orbital perturbations. Indeed meteor astronomy flourished for many years after the so-called Leonid failure of 1899 [9]. Meteor astronomy did not "suffer" as a result of the failed prediction. The public may have been disappointed, but meteor astronomers were inspired—and so they should have been. Predictions that do not hold true indicate that more work needs to be done. Similarly, the failed storm prediction of 1966 did not result in a revival of public interest in meteor astronomy, and it did not reverse the trend away from a declining "professional" interest in meteor physics. In other words, I would suggest, failed "public" predictions do not adversely effect the underlying trends that are already present within a science.

The end result, it seems to me, is that, in the "public eye," science (in general) will only very rarely win much long-term attention, and a corollary to this is that public opinion has little to no impact on what scientists (such as meteor astronomers) do, or don't do. Comet Hale-Bopp was a recent success in the public eye, and for more obscure reasons, so was the Jupiter impact of Shoemaker-Levy-9[1]. I am not convinced, however, that these two events will result in a public outcry for greater funding of cometary research.

If there are Leonid storms in 1999 and 2000, all will be well. The media will no doubt feel happy that they carried the event off in a grand fashion, and meteor astronomers will have gathered vast quantities of data. I am not convinced, however, that the appearance of any storms will result in a vast influx of *IMO* memberships and/or result in large sums of research money being granted to meteor projects. I would, I hasten to add, be very happy to be proved wrong on these points. Time will tell. If there are no Leonid storms, then meteor astronomy will blame the media for unjustified hype (in similar fashion to Denning's comments in 1900 [5]). The end result for meteor astronomy, however, I would wager, will be the same: no long-term increase in public interest and no great influx of long-term research funding. There will no doubt be a few special interest groups that will profit from Leonid storm mania—and more power to them.

3. Closing thoughts

The most recent parallel to the approaching Leonid display was that of the 1993 Perseids. I imagine we all have some vivid memories of this event. Certainly there was a lot of media attention, certainly the public was continually warned that nothing interesting might happen, and yet, large numbers of the public were disappointed when a storm did not materialize. Having said this, I still meet to this day people who remember the event. They explain how they drove out into the country side, and how, even though they did not see hundreds of bright meteors, they were still amazed by the few tens of bright shooting stars they did see. The outcome, as far as I can judge, is that meteor astronomy was not adversely affected by the non-appearance of a Perseid storm[2]. There has been no "backlash" of public scorn. Likewise, meteor astronomy has changed very little since then. We still do the same things that we did before, we still publish *WGN* and we still put out press releases. No mass resignations from *IMO*, or from the Meteor Section of the *BAA* occurred, and no calls for the abandonment of meteor research were circulated. In spite of what we might like to think from within meteor astronomy, the public

[1] I say "more obscure" because the Shoemaker-Levy 9 crash was not really a public viewing event. You could not actually "see" the crash, but rather one experienced it second hand through television or the internet. It was a true media event—just like the Gulf War. Comet Hale-Bopp, on the other hand, was there for even the simplest tyro to find. On this point, however, I note that I received more calls from the public and the media concerning the UFO supposedly stalking the comet than I did for information about the comet's location and history.

[2] On a personal note, it has been wrongly suggested, on more than one occasion, that Peter Brown and I actually predicted that a Perseid storm would occur in 1993 (*Monthly Notices of the Royal Astronomical Society*, 262, L35, 1993). The article that we wrote was in fact concerned with the satellite impact probabilities that might arise if the Perseid rates were high. We did not predict a Perseid storm. This footnote is not a cry of self-pity, but rather is offered as an example of how easy it is for misrepresentations to arise.

is not very interested in what we do, unless there is a spectacle to see. And, if the promised spectacle does not show, well, there is always the memory of the anticipation and the memory of the night itself. It seems to me that history tells us that failures of predictions do not stir the general public to despair or anger, and that they do not adversely affect the "internal" workings of meteor astronomy and/or science.

As to the 1999 Leonids, we shall see what we shall see. I for one will be watching both the celestial show and the media. I will be watching the Leonids because I am truly fascinated by meteors—it is what I do, irrespective of public opinion. I will also be watching the media in the hope that I can pick up the threads to this story circa 2002.

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Stones from Heaven: Some Meteoric Fossil Folklore

Alastair McBeath

A short review of several elements of folklore connecting certain fossils with the heavens is given, indicating the widespread belief in stones coming from the skies in earlier times.

1. Introduction

The folkloric connection between meteorites and dragons, including how earthly stones struck by lightning were often regarded as examples of how meteorites could be formed, was discussed in an earlier article [1]. Here, we broaden the discussion to include examples of "star-stone" folklore associating fossils with the heavens. An excellent, brief commentary covering this topic and other items of fossil folklore, and the original inspiration for this present paper, can be found in [2].

In the late 17th century, the Englishman Dr. Robert Plot, perhaps most notable for being the first Keeper of the Oxford Ashmolean Museum, wrote two books: *The Natural History of Oxfordshire* (1677) and *The Natural History of Staffordshire* (1686). His work is now considered important less for his scientific conclusions, which have almost all been superseded by later thinking, but for the fact that he troubled to record so much information concerning contemporary thought and colloquial beliefs about the subjects he discussed. Of particular relevance here are his comments on the "formed stones," what we now call fossils. He does not appear to have favored the organic origin theories concerning these, which existed in his own day, and which we now know to have been chiefly correct, but believed that they were created by some natural processes within the Earth or the Heavens. It is largely because of his efforts that we are still able to trace the items discussed in this article, and to pin down the long-held opinions concerning them.

2. Star-stones

Plot defined two chief classes of fossil Asteriae or "star-stones," those whose entire form was that of a five-pointed star, and those which he called Astroites, which as he put it, ... *in the whole are irregular, but adorned as it were with a Constellation*... Both forms he suggested belonged ... *to the Heavenly Bodies or Air*...

From his descriptions and drawings of the former type, it is clear he was referring to the plates comprising the stems of crinoids, vaguely tree-like marine organisms with hard exoskeletons, part of the large Echinodermata phylum of animals [3, pp. 104–142; 4, pp. 189–237]. Although the vast majority of the echinoderms show pentameral or five-fold symmetry, and thus many other forms might be taken as star-related (e.g., the modern star-fish), these crinoid stems seem particularly appropriate choices for the popular imagination to catch upon, especially the Jurassic genus Pentacrinites, which is exactly the type he illustrated in his *Oxfordshire* text. Individual crinoid stem plates perhaps half a centimeter across are sometimes found, along with more common complete sections of stem, where several plates are still held together in the life position as a column. Presumably, the popular conception would be that these were the remains of fallen stars, solidified once they had landed on Earth, the more complete stems being either large (bright?) *shooting stars*, or groups of stars seen to fall together in a shower, perhaps. Unfortunately, Plot does not enlighten us on this point, but the implication is clear from his earlier comments that he saw these *formed stones* as originating in the heavens.

The Astroites or starry-stones primarily appear to be fossilized coral skeletons, at least two genera of which can be identified from Plot's *Oxfordshire* volume as Isastrea and Cyathopora, both scleractinian corals, which commonly form small (a few millimeters across) pentagonal or hexagonal shapes all across the surface of the rock they create. These have linear structures within them called septa, which appear to radiate from almost the center of each individual coral skeleton in a star-like pattern. Many fossil specimens do look uncommonly like a large cluster of different-sized stars, and the eye tends to pick out patterns based on this, just as with the stars, hence Plot's comment about the whole looking like a constellation, at least in a loose sense. From the Jurassic-age Portland beds near Tisbury in Wiltshire, England, very fine specimens of *Isastrea oblonga* are often found. The corals are preserved as silica in this, which polishes up beautifully, and makes handsome decorative stones. The rock is commonly called Tisbury starstone or starry agate because of this. Again, from Plot's discussion, one assumes the stars fell to Earth and collected to form such fossils, or perhaps fell in a meteor storm.

Further details on the scleractinian corals can be found in [3, pp. 171–176] or [4, pp. 82–87].

3. Thunderbolts and stones from Heaven

Fossil objects that look rather like rounded spear-points or cigars have long been commonly called "thunderbolts." Robert Plot's comments on them run as follows. They have ... *the form of arrow heads... thought by the vulgar to be indeed darts of Heaven: which... I have placed among the stones related to the Heavens*...

We now know these as belemnites (from the Greek belemnon, a dart), and we have found them to be the fossilized guards, the solid internal skeletons, of an extinct group of small squid-like molluscs, which are also called belemnites or belemnoids. The soft tissues of the animals very rarely survive in the fossil record, but the dart-like guards occur in great profusion in some rocks from the Carboniferous to the Cretaceous periods, with a few surviving into the Eocene. More information can be found in [3, pp. 98–101] and [4, pp. 184–186].

Folklore in many places has interpreted these belemnites as being objects flung from heaven during thunderstorms, something perhaps given further credence by their occasionally translucent appearance, quite often with a yellowish or bluish tinge to their coloring. As we saw in [1], stones flung from the skies in thunderstorms are also often interpretations of meteorite falls.

A final type of fossil, widely perceived as stones from heaven, are the echinoids, which still exist today and which are commonly known as sea urchins, another branch of the Echinodermata (see above for references). As with the crinoids that we examined earlier, they have a five-fold symmetry too. Plot mentions that in Oxfordshire, these normally rounded objects, generally a few centimeters in size, are sometimes called "thunderbolts" or "stones from Heaven," their submarine existence in life perhaps making them look equally streamlined for a rapid descent through the air, like the belemnites. As Bassett comments [2, p. 16], the surface of some echinoids can be very rough, rather like the iron sulfide mineral iron pyrites (whose common name is "fool's gold"). Iron pyrites' lumps have also long been regarded as stones from Heaven too, probably because of their metallic nature and considerable density, rather like an iron meteorite. Bassett also notes (ibid.) that this belief in echinoids being thunderstones is especially strong in Denmark, where they are still placed in houses to ward off lightning strikes and as charms against witchcraft.

4. Conclusion

This has been only the briefest of surveys of some of the common beliefs about "meteoric" fossils, primarily from England. Many of these had been known "time out of mind" when Plot recorded them, and suggest that in the common mind at least, there was no reason why all manner of stony or metallic objects should not fall from the sky. Barely a century after Plot's death in 1696, the learned men of their day were happily denying the extraterrestrial origin of even genuine meteorites, spurred on perhaps by confusions in the public mind concerning the star stones, thunderbolts and stones from Heaven.

If anyone is aware of other folklore tales or myths concerning meteors or meteorites from their own countries, the author would be very interested in learning of them.

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Meteor Shower Activity after the Perseid Maximum

Marc de Lignie and Klaas Jobse

Because of their selectivity, double-station video observations provide an excellent means to distinguish between sporadic background and shower activity. Eight hours of observations around solar longitude $\lambda_\odot = 144°$ (August 16) confirm the clear presence of the κ-Cygnid and Perseid showers and the weak presence of the Capricornid, Southern and Northern δ-Aquarid showers. The results on the activity of the Northern ι-Aquarid shower are inconclusive. Three possible showers were detected at $\alpha = 1°$, $\delta = -17°$, $V_g = 44$ km/s (Aquarid Complex), $\alpha = 46°$, $\delta = +45°$, $V_g = 64$ km/s (Aurigid Complex), and $\alpha = 274°$, $\delta = -09°$, $V_g = 8$ km/s (eq. 2000.0). The world total of high-precision κ-Cygnid orbits was increased from 9 tot 14 orbits.

1. Introduction

The period after the Perseid maximum is not very popular among meteor observers. Perseid rates drop sharply, the rates from the Aquarid Complex dropped long before, and the Aurigid rates are still near detection level. The only silver linings are the κ-Cygnid and Northern ι-Aquarid showers which both have their peaks near August 18, but with maximum ZHRs of only about 3. With so many meteor showers present with such low activity, visual observers can easily become paranoid about which showers are real and which meteors are merely chance alignments with radiants active in other periods. Such an obscure situation asks for a more selective way of observing: double station video observations. At two stations, Puimichel (λ = 6°01′ E, φ = 43°59′ N) and Tourves (λ = 5°59′ E, φ = 43°25′ N), intensified video systems were operated for double-station observations.

2. Observations

Many Dutch observers traveled to Southern France to observe the 1993 outburst of the Perseids. Some of them stayed after the maximum to observe the κ-Cygnids.

Table 1 – Orbital data (eq. 2000.0) of 60 meteors recorded by video cameras between August 15 and 18, 1993. "Mv" means visual absolute magnitude, "w" means length of perihelion, "node" means ascending node. The "tol" values are standard deviations

code	day	stream	Mv	q	tol	a	1/a	tol	e	tol	i	tol	w	tol	node	pi	tol
93109	15.9146	ND-Aqr	4	0.138	0.003	2.40	0.42	0.03	0.943	0.005	11.2	1.4	321.2	0.3	143.15	104.4	0.3
93158	16.9799	SD-Aqr	4	0.146	0.012	4.95	0.20	0.04	0.971	0.005	15.2	2.8	137.5	2.1	324.18	101.7	2.1
93165	17.9194	NI-Aqr	6	0.376	0.014	1.54	0.65	0.05	0.755	0.028	8.0	1.7	297.5	0.8	145.08	82.6	0.8
93169	17.9514	NI-Aqr	3	0.252	0.008	2.10	0.48	0.03	0.880	0.008	8.3	2.6	307.2	1.4	145.11	92.3	1.4
93130	16.0035	??-Aqr	4	0.110	0.021	5.33	0.19	0.06	0.979	0.005	59.5	1.9	143.2	4.0	323.24	106.4	4.0
93176	17.9785	??-Aqr	5	0.134	0.047	4.66	0.21	0.11	0.971	0.009	50.5	3.5	139.5	8.5	325.14	104.6	8.5
93119	15.9611	??-Aur	4	1.011	0.001	4.85	0.21	0.09	0.792	0.095	134.6	0.6	175.2	0.9	143.20	318.4	0.9
93133	16.0194	??-Aur	3	0.992	0.002	5.00	0.20	0.06	0.802	0.058	134.3	0.4	162.5	1.2	143.25	305.7	1.2
93131	16.0035	Cap	5	0.605	0.012	2.44	0.41	0.03	0.752	0.018	2.2	0.9	266.4	1.7	143.23	49.6	1.7
93115	15.9250	K-Cyg	5	0.981	0.003	2.74	0.37	0.04	0.642	0.043	32.9	0.9	203.2	1.3	143.16	346.3	1.3
93121	15.9688	K-Cyg	4	0.977	0.002	3.36	0.30	0.02	0.709	0.020	34.5	0.4	203.9	0.6	143.20	347.1	0.6
93135	16.0208	K-Cyg	5	0.981	0.004	3.37	0.30	0.04	0.709	0.039	36.3	0.8	202.3	1.4	143.25	345.5	1.4
93143	16.8792	K-Cyg	0	0.973	0.001	3.49	0.29	0.02	0.721	0.020	33.7	0.4	204.9	0.4	144.08	349.0	0.4
93145	16.8931	K-Cyg	4	0.968	0.002	3.34	0.30	0.06	0.710	0.057	36.5	1.1	206.6	0.9	144.09	350.7	0.9
93103	15.8896	Per	4	0.973	0.010	-5.21	-0.19	0.10	1.187	0.102	117.3	0.7	158.2	2.8	143.13	301.3	2.8
93111	15.9153	Per	4	0.933	0.014	-6.05	-0.17	0.08	1.154	0.079	109.7	0.7	148.6	2.9	143.15	291.7	2.9
93116	15.9403	Per	3	0.973	0.006	-5.66	-0.18	0.16	1.172	0.160	117.7	1.0	157.9	2.1	143.18	301.1	2.1
93157	16.9694	Per	4	0.946	0.004	-3.32	-0.30	0.07	1.285	0.062	114.1	0.4	152.0	1.0	144.17	296.2	1.0
93162	17.0049	Per	3	0.980	0.003	26.55	0.04	0.12	0.963	0.116	111.6	1.0	159.3	1.6	144.20	303.5	1.6
93179	17.9875	Per	4	0.925	0.005	-55.15	-0.02	0.08	1.017	0.072	110.7	0.6	146.0	1.6	145.15	291.2	1.6
93183	18.0056	Per	3	0.925	0.007	16.61	0.06	0.12	0.944	0.109	114.4	1.0	145.4	2.5	145.16	290.6	2.5
93101	15.8868	Spo	4	0.899	0.003	2.42	0.41	0.03	0.629	0.025	51.1	0.6	224.8	1.0	143.13	7.9	1.0
93102	15.8889	Spo	3	1.007	0.000	3.15	0.32	0.02	0.680	0.023	31.1	0.4	170.1	0.4	143.13	313.2	0.4
93104	15.8896	Spo	5	1.012	0.000	3.81	0.26	0.04	0.734	0.039	27.2	0.7	181.8	0.8	143.13	325.0	0.8
93105	15.8958	Spo	5	0.975	0.005	2.07	0.48	0.03	0.529	0.034	3.4	0.6	206.7	1.7	143.13	349.8	1.7
93108	15.9139	Spo	4	0.949	0.013	1.07	0.94	0.03	0.110	0.020	36.8	1.9	248.8	13.1	143.15	31.9	13.1
93112	15.9167	Spo	5	0.508	0.023	1.12	0.89	0.04	0.547	0.035	4.0	1.3	114.2	1.8	323.16	77.3	1.8
93114	15.9243	Spo	6	0.833	0.009	3.13	0.32	0.04	0.734	0.038	2.2	0.5	54.5	1.3	323.17	17.7	1.3
93120	15.9632	Spo	4	0.808	0.011	49.38	0.02	0.09	0.984	0.072	117.6	0.8	233.7	2.5	143.20	16.9	2.5
93124	15.9799	Spo	5	0.161	0.002	0.60	1.67	0.00	0.732	0.003	40.7	1.2	7.8	0.2	143.21	151.0	0.2
93127	15.9819	Spo	4	0.404	0.010	3.41	0.29	0.04	0.882	0.015	36.6	0.9	286.4	1.5	143.22	69.6	1.5
93136	16.0208	Spo	4	0.344	0.026	0.77	1.30	0.02	0.552	0.029	0.0	1.6	148.3	2.0	323.99	112.3	1.9
93138	16.0236	Spo	5	0.833	0.005	10.39	0.10	0.05	0.920	0.038	50.4	0.7	231.0	1.1	143.26	14.2	1.1
93139	16.0250	Spo	2	0.430	0.010	2.29	0.44	0.03	0.812	0.013	14.9	0.6	286.5	1.4	143.26	69.8	1.4
93141	16.8764	Spo	5	0.861	0.007	2.71	0.37	0.05	0.683	0.040	9.1	0.8	230.9	1.3	144.07	15.0	1.3
93142	16.8792	Spo	5	0.978	0.006	1.86	0.54	0.09	0.474	0.086	3.1	1.0	206.7	1.5	144.07	350.8	1.5
93144	16.8882	Spo	5	0.986	0.003	5.53	0.18	0.05	0.822	0.049	68.8	0.7	160.4	1.1	144.09	304.4	1.1
93146	16.8951	Spo	5	1.011	0.001	2.78	0.36	0.03	0.637	0.029	25.5	0.6	174.5	0.7	144.09	318.6	0.7
93147	16.8965	Spo	5	0.990	0.004	2.31	0.43	0.04	0.572	0.038	19.3	0.7	200.3	1.8	144.10	344.4	1.8
93148	16.9000	Spo	4	0.791	0.090	0.91	1.09	0.04	0.136	0.068	6.1	5.5	326.3	6.5	144.10	110.4	6.5
93149	16.9021	Spo	4	0.534	0.017	13.51	0.07	0.08	0.960	0.040	130.6	1.0	92.1	3.1	144.10	236.2	3.1
93150	16.9021	Spo	5	1.012	0.001	2.30	0.43	0.22	0.560	0.218	102.3	2.6	178.1	3.7	144.10	322.2	3.7
93151	16.9028	Spo	3	0.803	0.009	2.63	0.38	0.03	0.695	0.021	2.7	0.7	240.4	1.7	144.09	24.5	1.7
93152	16.9194	Spo	4	0.947	0.005	1.08	0.92	0.02	0.127	0.014	18.6	1.2	244.8	4.8	144.12	28.9	4.8
93153	16.9194	Spo	2	1.008	0.000	4.35	0.23	0.02	0.768	0.022	37.1	0.4	188.5	0.3	144.12	332.6	0.3
93154	16.9271	Spo	5	0.989	0.003	1.94	0.51	0.04	0.491	0.034	75.7	0.7	201.5	1.6	144.13	345.6	1.6
93155	16.9500	Spo	5	0.711	0.012	-4.74	-0.21	0.10	1.150	0.070	127.3	0.7	243.7	2.4	144.15	27.9	2.4
93160	16.9938	Spo	4	1.008	0.001	2.53	0.40	0.02	0.602	0.019	23.8	0.4	189.0	0.6	144.19	333.2	0.6
93163	17.0069	Spo	5	0.938	0.010	1.29	0.77	0.02	0.276	0.030	2.2	0.5	228.8	1.6	144.19	13.0	1.6
93164	17.0083	Spo	4	0.068	0.009	1.25	0.80	0.06	0.946	0.008	55.4	4.6	336.9	1.7	144.20	121.1	1.7
93168	17.9396	Spo	5	1.012	0.000	-31.89	-0.03	0.07	1.032	0.075	149.9	0.5	177.3	1.1	145.10	322.4	1.1
93170	17.9535	Spo	5	1.007	0.001	-13.74	-0.07	0.07	1.073	0.072	171.1	0.5	8.0	1.1	325.11	333.1	1.1
93172	17.9674	Spo	4	0.803	0.008	-14.83	-0.07	0.06	1.054	0.051	142.2	0.5	233.3	1.7	145.13	18.5	1.7
93173	17.9701	Spo	5	0.079	0.006	0.96	1.04	0.02	0.918	0.006	28.8	1.5	158.0	0.8	325.13	123.1	0.8
93174	17.9708	Spo	5	0.843	0.026	0.99	1.01	0.02	0.147	0.036	13.5	4.0	287.7	7.1	145.13	72.8	7.1
93175	17.9778	Spo	4	0.929	0.009	2.03	0.49	0.07	0.543	0.065	11.5	1.3	220.1	1.0	145.13	5.2	1.0
93180	17.9917	Spo	5	0.969	0.005	1.20	0.84	0.02	0.190	0.018	9.8	0.9	222.9	1.9	145.15	8.1	1.9
93181	17.9965	Spo	6	0.592	0.028	2.53	0.40	0.09	0.766	0.059	2.4	1.6	87.5	3.4	325.16	52.7	3.4
93182	17.9972	Spo	4	0.983	0.003	8.91	0.11	0.15	0.890	0.148	105.2	1.4	200.1	2.0	145.16	345.2	2.0
93184	18.0056	Spo	4	0.993	0.003	-4.59	-0.22	0.26	1.217	0.262	121.9	1.4	195.0	1.8	145.16	340.1	1.8

In three nights, from August 15 to 18, 84 events were recorded during 8 hours of observing, 60 of which were suitable for measurement and triangulation. Unfortunately, video observations during the Perseid maximum itself were not successful.

The cameras used and the reduction methods applied were the same as described in [1]. The results are listed in Tables 1 and 2.

The absolute visual magnitudes are merely rough estimates, because our reduction software does not include photometry. The height of maximum intensity, `Hmax`, is only available for part of the meteors, because the feature to indicate the brightest part of the meteor during the measurements was introduced during the months in which the reduction process was carried out.

Table 2 – Trajectory data (eq. 2000.0) of 60 meteors recorded by video cameras between August 15 and 18, 1993. Velocities are in km/s and heights are in km. "`Hmax`" is the height of the maximum intensity. "`RAG`" and "`DEG`" are the geocentric right ascension and declination of the radiant. "`Z`" is the zenith distance of the radiant. "`Qmax`" is the parallax angle between the trails.

code	VG	VH	VINF	<V>	tol	HB	Hmax	HE	RA	tol	DE	tol	RAG	DEG	cos Z	Qmax
93109	36.7	37.2	38.6	38.3	0.4	104.3	0.0	86.6	345.25	0.08	0.09	0.58	345.73	-1.07	0.510	12.8
93158	39.0	39.7	40.7	40.4	0.4	105.7	97.8	94.4	349.21	0.31	-10.03	1.39	349.21	-11.24	0.522	5.9
93165	25.1	34.3	27.7	27.3	1.2	94.0	90.3	87.5	336.63	0.18	0.88	1.43	337.26	-1.30	0.615	12.3
93169	31.6	36.5	33.7	33.3	0.4	102.7	96.0	88.5	341.72	0.50	-0.49	1.63	341.84	-1.93	0.639	4.2
93130	44.9	39.8	46.4	46.2	0.5	102.5	0.0	90.8	1.10	0.56	-15.15	1.62	1.15	-16.21	0.425	4.9
93176	42.9	39.5	44.5	44.2	0.7	99.8	98.6	92.9	0.59	1.15	-15.72	3.52	0.80	-16.93	0.374	8.0
93119	63.8	39.6	65.0	64.8	1.1	113.3	0.0	105.2	43.54	0.32	44.29	0.20	44.08	44.23	0.519	53.3
93133	63.7	39.7	64.9	64.7	0.7	117.5	0.0	102.0	48.52	0.34	45.27	0.18	48.88	45.30	0.665	78.8
93131	21.4	37.3	24.1	23.7	0.5	97.0	0.0	87.8	323.67	0.83	-8.16	1.21	322.34	-11.53	0.601	10.7
93115	21.1	37.8	23.8	23.5	0.8	90.0	0.0	83.4	287.50	1.35	51.85	0.32	284.93	52.04	0.972	37.6
93121	22.5	38.6	25.0	24.7	0.3	100.4	0.0	87.2	289.36	0.64	51.76	0.16	286.28	51.59	0.929	43.4
93135	23.3	38.6	25.7	25.3	0.6	93.3	0.0	85.8	290.52	1.48	54.62	0.87	286.68	54.03	0.844	28.3
93143	22.3	38.7	24.9	24.5	0.3	117.6	85.4	76.0	288.00	0.41	49.85	0.14	286.66	50.18	0.995	56.5
93145	23.6	38.6	26.1	25.7	1.0	100.2	93.4	88.6	292.14	0.67	51.95	0.29	290.75	52.33	0.991	35.3
93103	62.9	43.8	64.0	63.8	1.1	120.2	0.0	104.4	48.73	1.85	57.39	0.27	49.74	57.20	0.406	10.6
93111	60.0	43.6	61.2	61.0	0.9	117.2	0.0	106.8	54.96	2.26	62.08	0.28	56.16	61.94	0.476	9.4
93116	62.9	43.7	64.0	63.8	1.8	114.0	0.0	102.2	49.16	0.88	56.91	0.10	50.01	56.88	0.522	19.5
93157	62.7	44.9	63.9	63.7	0.7	115.5	110.4	104.2	55.42	0.58	60.02	0.12	56.28	60.06	0.577	41.0
93162	58.9	41.5	60.2	60.0	1.4	106.7	96.7	91.8	47.47	0.41	59.62	0.22	48.10	59.78	0.705	66.7
93179	59.0	42.1	60.2	60.0	0.9	116.0	106.1	99.9	58.52	0.55	61.01	0.14	59.45	61.08	0.609	37.7
93183	59.5	41.2	60.7	60.5	1.4	114.7	106.8	99.8	58.05	0.41	58.40	0.21	58.80	58.50	0.642	81.3
93101	30.5	37.2	32.6	32.2	0.5	104.7	0.0	89.0	317.35	0.30	55.09	0.25	317.47	55.56	0.936	77.1
93102	20.2	38.3	23.0	22.6	0.4	102.0	0.0	82.1	248.59	0.52	61.42	0.17	243.05	61.33	0.864	43.0
93104	18.6	39.0	21.6	21.2	0.6	95.9	0.0	86.2	259.18	1.11	52.20	0.40	254.95	51.97	0.921	30.7
93105	8.7	36.4	14.1	13.7	0.5	83.5	0.0	79.3	278.20	1.83	1.60	1.71	273.46	-9.20	0.710	18.0
93108	19.0	30.3	22.1	21.7	1.1	88.0	0.0	83.6	317.59	0.88	66.14	0.52	317.74	67.96	0.913	80.4
93112	16.9	31.0	20.5	20.1	1.2	96.9	0.0	88.8	336.86	0.19	-9.87	1.99	339.09	-15.50	0.457	12.7
93114	15.7	38.3	19.3	18.9	0.7	87.0	0.0	75.9	305.51	0.97	-17.87	1.04	304.48	-24.86	0.470	8.2
93120	60.0	41.6	61.3	61.1	1.0	112.2	0.0	95.0	14.34	0.35	42.73	0.27	14.54	42.78	0.766	25.4
93124	21.2	16.5	24.2	23.8	0.3	101.5	0.0	89.0	59.06	0.47	52.03	0.08	64.43	50.36	0.508	34.8
93127	33.6	38.6	35.4	35.1	0.5	92.9	0.0	83.4	331.93	0.60	18.06	0.48	331.49	17.39	0.894	24.2
93136	13.8	24.4	17.9	17.4	0.9	90.1	0.0	78.1	357.80	1.33	4.58	2.47	358.59	-0.67	0.732	4.5
93138	33.6	40.8	35.3	35.0	0.7	105.9	0.0	95.1	317.05	0.73	46.27	0.23	315.68	46.11	0.960	36.9
93139	27.2	36.9	29.3	29.0	0.5	90.3	0.0	81.5	330.63	0.61	4.40	0.48	329.64	2.77	0.760	20.6
93141	15.0	37.8	18.8	18.4	0.7	88.7	87.0	82.1	298.45	0.94	5.73	1.36	298.30	1.38	0.773	11.6
93142	7.9	35.7	13.6	13.2	1.4	83.0	82.9	80.3	278.39	1.53	2.41	1.48	274.40	-9.27	0.738	22.5
93144	40.3	39.9	41.9	41.6	0.7	107.0	103.2	98.4	355.69	1.40	84.08	0.55	2.23	84.76	0.722	25.9
93146	17.0	37.9	20.3	19.8	0.5	97.4	92.4	89.8	251.13	0.99	54.77	0.46	245.17	54.19	0.868	30.4
93147	13.9	37.0	17.8	17.4	0.6	87.0	85.2	84.0	276.30	1.86	38.46	0.95	272.75	37.32	0.966	36.3
93148	4.0	28.0	12.0	9.3	3.2	80.9	80.9	77.4	327.32	0.76	45.47	0.98	339.09	44.69	0.926	81.4
93149	61.0	41.1	62.2	62.0	0.9	119.0	115.5	113.7	81.30	0.38	45.94	0.41	82.17	45.28	0.090	11.3
93150	51.9	37.0	53.3	53.0	3.0	106.9	94.0	92.8	31.65	2.10	60.85	0.30	32.93	60.84	0.578	8.0
93151	15.9	37.6	19.5	19.1	0.3	90.8	83.5	81.3	307.38	1.09	-7.51	1.32	307.22	-13.03	0.612	8.9
93152	10.2	30.6	15.1	14.7	0.7	82.3	80.0	75.9	302.17	0.98	53.87	0.28	299.19	55.75	0.986	46.1
93153	23.8	39.3	26.3	25.9	0.4	108.8	85.8	79.7	276.43	0.47	59.43	0.18	273.16	59.68	0.926	35.9
93154	40.5	36.0	42.1	41.8	0.6	107.3	100.4	92.1	356.64	0.26	67.15	0.36	357.55	67.65	0.819	78.6
93155	63.9	44.0	65.1	65.0	1.0	105.2	94.8	92.9	14.98	0.32	35.86	0.16	15.20	35.83	0.693	64.4
93160	15.9	37.4	19.3	18.9	0.3	98.3	93.7	92.2	270.05	0.68	50.10	0.43	263.10	48.07	0.764	33.0
93163	6.1	32.7	12.6	12.1	0.7	83.8	81.4	79.6	306.62	0.64	5.79	0.54	296.82	-9.07	0.703	30.7
93164	39.1	32.3	40.8	40.5	1.0	95.2	89.4	85.1	356.73	0.85	13.28	1.12	356.60	12.67	0.811	9.8
93168	69.2	42.2	70.4	70.3	0.8	113.6	110.9	107.8	48.32	0.41	36.73	0.26	48.85	36.56	0.349	39.6
93170	71.8	42.6	73.0	72.9	0.7	124.8	120.8	120.8	51.40	0.33	13.80	0.31	51.88	13.43	0.102	28.4
93172	66.5	42.6	67.7	67.5	0.7	121.3	109.6	105.9	26.73	0.24	33.06	0.23	26.97	32.99	0.629	51.4
93173	33.0	28.8	35.0	34.7	0.5	99.0	94.0	88.8	4.88	0.14	-6.44	0.68	5.51	-8.10	0.448	11.8
93174	7.9	29.2	13.7	13.3	2.3	81.9	81.0	79.0	319.86	1.32	45.94	0.48	316.44	46.39	0.999	57.1
93175	12.1	36.3	16.3	15.9	1.4	93.6	89.9	87.3	294.64	0.70	18.68	0.56	289.77	13.94	0.811	32.2
93180	6.5	31.8	12.8	12.4	0.6	81.4	78.9	77.5	299.30	0.97	38.34	0.72	288.34	33.98	0.915	34.3
93181	22.0	37.4	24.7	24.3	1.7	92.9	90.6	88.5	328.09	1.61	-13.24	2.08	327.00	-16.81	0.537	9.6
93182	56.0	40.7	57.2	57.0	1.9	111.4	99.4	93.7	21.84	0.29	57.09	0.26	22.05	57.32	0.838	78.1
93184	64.6	44.1	65.7	65.5	2.9	116.2	101.1	98.9	31.64	0.44	50.35	0.11	31.83	50.48	0.788	87.8

3. Shower activity

In Tables 1 and 2, many meteor streams can be recognized. Table 3 summarizes the numbers of stream members. Table 3 als includes a "Video ZHR" (VZHR). To calculate this value, the shower hourly rates were normalized by dividing by the sporadic background ($N = 39$) and multiplying by an assumed HR of 10. The rates were corrected for the radiant height in the usual way. In addition, a limiting magnitude correction was applied, assuming Lm = 7.5, $r = 3.4$ for sporadic meteors, and $r = 2.3$ for shower meteors. The values calculated in this way still somewhat underestimate the shower rates as seen by a visual observer, because video cameras have the same field of view for sporadics and shower members, while visual observers tend to have a wider field of view for the brighter shower members. Because of the small number of shower meteors, it was not attempted to correct for this effect.

Table 3 – Video ZHRs assuming HR = 10, Lm = 7.5, $r_{spor} = 3.4$, and $r_{sh} = 2.3$.

Shower	Cap	S δ-Aqr	N δ-Aqr	N ι-Aqr	Per	κ – Cyg
N	1	1	1	2	7	5
$\langle \cos Z \rangle$	0.6	0.5	0.5	0.6	0.55	0.95
VZHR	1	1	1	1	5	2

The VZHR values of Table 3 agree well with the known visual ZHRs [2,3]. Although the figures in Table 3 seem to suffer from poor statistics, it should be realized that they are based on 8 hours of observations. For instance, when the uncorrected hourly rate is 1, the probability to observe not more than 1 meteor during 8 hours is a mere 0.5%. This calculation shows that the shower rates cannot be much higher than indicated in Table 3. Therefore, the table shows that only the Perseids and κ-Cygnids are sufficiently active to be visible to visual observers.

The latter conclusion needs some comment for the case of the Northern ι-Aquarid shower. Here, both members of the shower were observed very close to the end of the entire observation period ($143^\circ\!.1 < \lambda_\odot < 145^\circ\!.2$). This could indicate that the shower is narrower than believed [2] and that the last observing night near solar longitude $\lambda_\odot = 145^\circ$ was close to the maximum. If this were true, the actual activity would be higher than listed in Table 3.

4. Perseids

The ephemeris of the Perseid radiant as derived from 592 photographic meteors were reviewed in [4]. It seems that a mere 7 new video Perseids can add little to this. However, the video sample becomes more significant once it is realized that the photographic sample contains only 20 meteors after solar longitude $\lambda_\odot = 143^\circ$.

The average radiant of the new Perseid meteors observed by video does not significantly deviate from the photographic ephemeris. Figure 1, though, shows that 3 out of 7 of the observed video radiants fall outside the photographic radiant area. This suggests that the radiant area of the Perseid shower at video magnitudes and near solar longitude $\lambda_\odot = 146^\circ$ is larger than the photographic average. This provides some additional evidence for the trend of increasing radiant area size for less brighter Perseids and for observations outside the maximum period [4].

5. κ-Cygnids

The κ-Cygnids were the actual target of the observations. Therefore, it is satisfying to note that the number of 5 observed stream members is a significant increase of the world total of 9 high-precision orbits known to date [5].

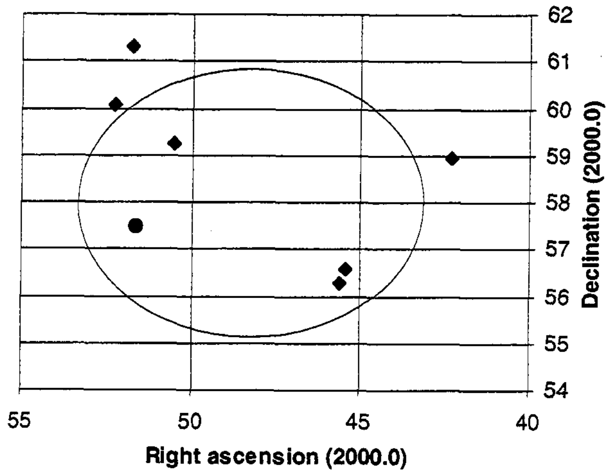

Figure 1 – Perseid radiants determined from the double-station video observations between solar longitudes $\lambda = 143.^{\circ}1$ and $\lambda = 145.^{\circ}2$. The radiant points were moved to solar longitude $\lambda = 140.^{\circ}00$, using the ephemeris of [4]. The ellipse is the radiant area which contains 97% of all photographic Perseid observations.

In Table 4, the average photographic and video orbits are listed, as well as a new overall average. The photographic and video observations agree reasonably well, with the exception of the declination of the radiant. There, the video observations yield a systematically lower value ($\delta = 52°$ instead of 55°). This difference is quite remarkable, because for the Quadrantids, which have similar orbital characteristics as the κ-Cygnids, essentially no difference between photographic and video observations was found [1,6]. It would be interesting to see whether model calculations can account for the different behavior of these streams in terms of age and encounter geometry. Note that both streams suffer from perturbations of Jupiter, because their aphelia lie close to the orbit of Jupiter.

During the period of observations, also the ζ-Draconid shower was active [5]. In the photographic magnitude range, it has a similar activity as the κ-Cygnids. The results of the video observations, however, include only one possible member (meteor no. 93153).

Table 4 – Average κ-Cygnid geocentric radiants and orbits from existing photographic observations and from the present video observations (eq. 2000.0).

Method	N	α	δ	V_g	q	a	e	i	ω	Ω
Video	5	287.°1	+52.°0	22.6	0.976	3.26	0.698	34.°8	204.°2	143.°6
Photo	9	286.°6	+55.°1	23.7	0.983	3.72	0.731	36.°8	200.°5	145.°7
Overall	14	286.°8	+54.°0	23.3	0.980	3.56	0.719	36.°1	201.°8	144.°9

6. Other showers

For the remaining streams, the number of meteoroid orbits added by the current observations is so small that they contribute little to the existing knowledge. In three cases, however, two similar orbits were found of unknown or ill-established streams.

The first case is provided by meteors 93130 and 93176 which have been listed in Table 1 as an unknown branch of the Aquarid Complex. Their orbits have a strong resemblance to that of the Southern δ-Aquarids, including the characteristic small perihelion distance of 0.13 AU. However, the inclination of these orbits is much higher, making an association with the Southern δ-Aquarid stream very unlikely. The *IAU* database of photographic meteors does not contain other members of this branch, nor do other publications with video orbits. So, more observations are needed to acknowledge the existence of this stream.

The results of Tables 1 and 2 also include a few members of the Aquarid Complex, two of which have very similar orbits and have been listed as an unknown branch (meteors 93119 and 93133).

From an earlier analysis of meteors plotted by visual observers in early September, Rendtel concluded [7] that the δ-Aurigids are active in late September and early October, while activity in early September is due to the September Perseids present in Hoffmeister's radiant list. The *IMO*'s Shower Calendar does not distinguish between the two showers and lists September 5 as the start of the interval in which the aggregate shower is observable. In [8], Jenniskens provides an overview of Aurigid radiants reported in August and September. The currently listed video radiants do not match with any of the reported Aurigid radiants except with the δ-Aurigid ephemeris; however, this shower is not supposed to be active in mid-August, and the association was not made.

Meteors 93155, 93168, and 93172 can also be regarded as members of the Aurigid Complex. Meteor 93172 fits the average September Perseid orbit listed in [7] quite well.

Finally, meteors 93105 and 93142, which have very similar radiants and a characteristic extremely low velocity, are noteworthy. The *IAU* database (1990 edition) contains one additional meteor with similar characteristics. However, as for the Aquarid and Aurigid branches mentioned above, it is too early to start looking for the nearest star in the sky atlas.

7. Conclusions

Double-station video observations can yield several tens of orbits in a single night. One year of continuous observations would result in more than 20 000 precise orbits, much more than presently known. Therefore, only a few consecutive nights can provide a picture of meteor activity not known before. The present observations prove mid-August to be particularly rich in shower activity.

The κ-Cygnids seem to display a shift in radiant position of 3° when moving from the photographic to the video magnitude range.

Acknowledgments

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An Operational Autonomous Meteor Detector: Development Issues and Early Results

Peter S. Gural

A real-time computer based meteor detector has been in operation by the author in the United States since February 1997. Operating in a completely autonomous mode it has successfully detected several meteors, numerous artificial satellites, and aircraft since its inception. Since the computer system is based on an Intel 486 microprocessor and operates at half the pixel resolution available from a CCD camera, it is believed with the faster computers on the market today, a full resolution system is realizable. A proposal to fund the building of such a system is in the works at this time.

1. Project Goals

This project began over two years ago when it was realized that intensified CCD imagery of meteors required many tedious hours of reviewing videotapes and that an automated system of identifying meteors would be beneficial. Thoughts on the concept were presented in an article by Gural [1] and over the last year and a half the necessary components were acquired and software written until the first "live" computer meteor detection was made on April 15-16, 1997. At the start of this project, my goals were somewhat different than other workers in the video meteor field. Other operators of intensified video cameras had also identified a need for automated scanning of videotapes by computer. One of the pioneers in automated methods, Molau and Nitschke [2], recently reported on an operational system called MOVIE that uses a multipass approach, scanning for meteors on a different region of the video field each pass. My goal was to work directly off the CCD camera output, thus bypassing the recording on tape completely. In this way, a detector could be left running autonomously all night long without the need for changing tapes every few hours and in addition, reducing any imagery noise induced by the recording/playback process.

One of the requirements that flow down from this mode of operation is that the software must not only detect meteors in real-time, but also archive the detection images to disk for later analysis before the next sequence of images are digitized and overwrite memory. Without the benefits of playing back videotape, one has only a single opportunity at detecting and saving the image field at as high a resolution as the computer system can support in real-time. This meant that, rather than keeping only the last frame, a means had to be found to save the integrated or summed image. However, in order to check the validity of a meteor detection, an alternating difference image is also required to determine angular velocity and cull out satellites and aircraft.

2. Constraints

The stated goals collided head-on with several operational constraints encountered with the computer and operating system available at the time. The software was developed on an Intel 486/100 MHz VESA local bus based computer using a Control Vision Corp. frame grabber and a 16-bit version of Microsoft Visual C (v1.52). Initial attempts at using Windows 3.1 as the operating system failed since the OS would decide to go off and do its own thing periodically, interfering with the timing of the real-time processing. Because the start of image processing for each frame was triggered by detection of vertical blanking, if the vertical blank signal was missed, then an entire frame would be skipped. Randomly dropped frames from the summed images can make discerning angular velocity of a meteor in later post-detection processing difficult. Running under MS-DOS rather than Windows 3.1 eased this problem considerably, but placed a memory constraint of 640 Kbytes on immediately accessible data memory. Additional memory was available via the virtual memory manager, but at the cost of transferring blocks of data in/out of the 640 Kbytes of working memory, a time hog of only limited use in a real-time system. (Current 32-bit compilers and operating systems use a flat memory model and no longer suffer from this problem.)

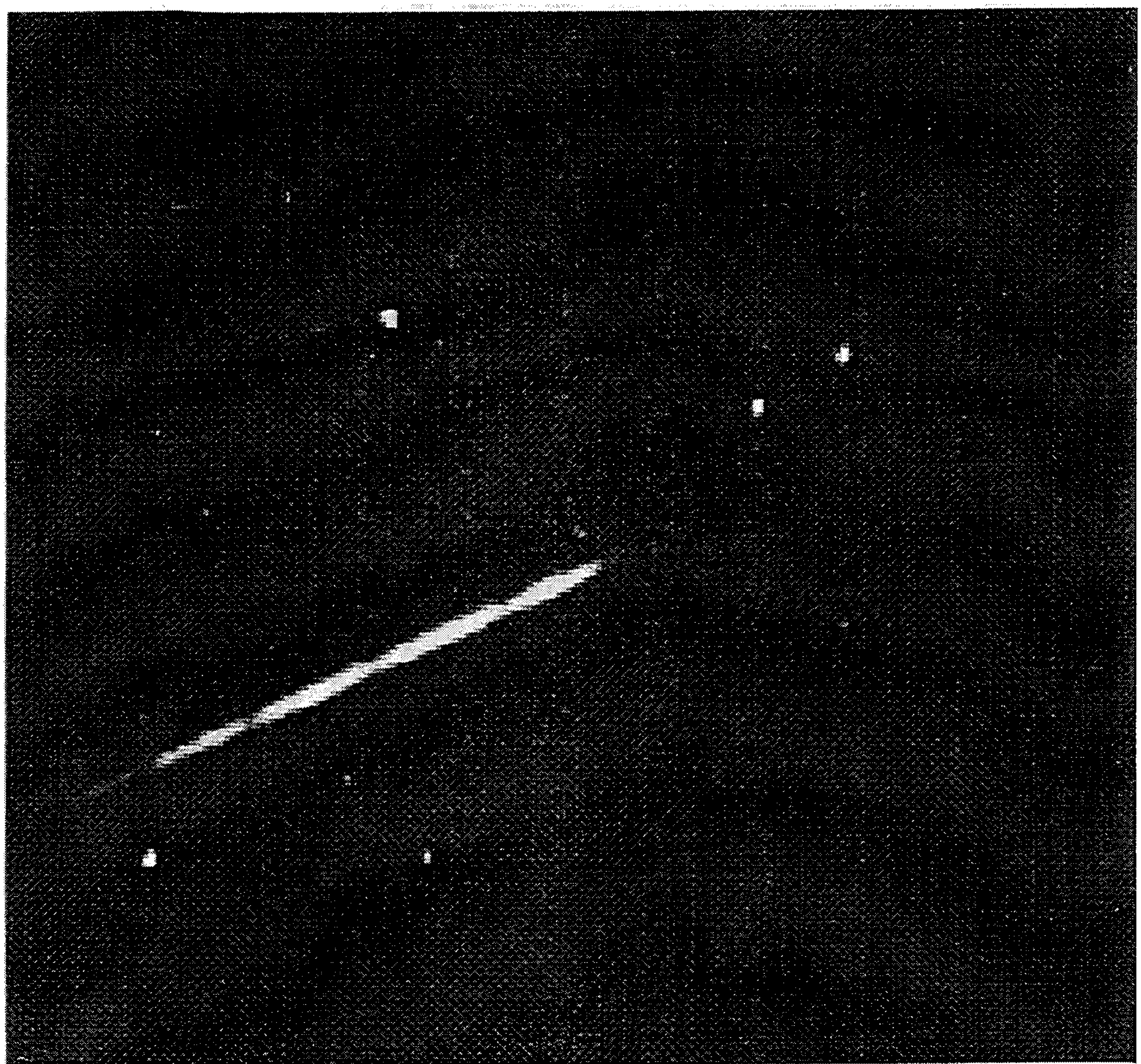

Figure 1 – First meteor detected (Lyrid) with an autonomous meteor detection system on April 15-16, 1997 at $4^h32^m36^s$ UT in Sterling, Virginia, USA. Imager system comprised of 28 mm $f/1.8$ with an MCP generation 2.5 intensifier and an Electrophysics WAT-902 CCD. North is up, ι Draconis is in the lower left corner, α Draconis is the second star in from the right edge.

Since the software design needed more than the 640 Kbytes and the CPU was tied up at nearly full throughput capacity doing image processing, something had to go. The virtual memory transfer time was made available by not image processing every 3rd frame pair to allow memory block moves with time left over for image processing. This introduced the feature of placing an electronic shutter break in the integrated image sum as seen in Figure 1. It was necessary to size the virtual memory blocks so that they could be moved in under 32 ms so no disruption of the real-time synchronization occurred.

3. Processing

With the higher speed of the VESA local bus over an EISA or ISA bus, much of the image processing time was evenly divided between being data transfer bus limited and CPU limited. This did require extensive in-line assembly language programming to squeeze the most out of every compute cycle. An excellent book on ways to do this optimally for the 386/486 has been published by Gulutzan and Pelzer [3]. Working with the frame grabber in half resolution mode (240×256 pixels), typical compute speeds that were achieved for two frame image summation was 10.4 ms which is 70% loaded at the frame-rate of 60 Hz (16.7 ms/frame).

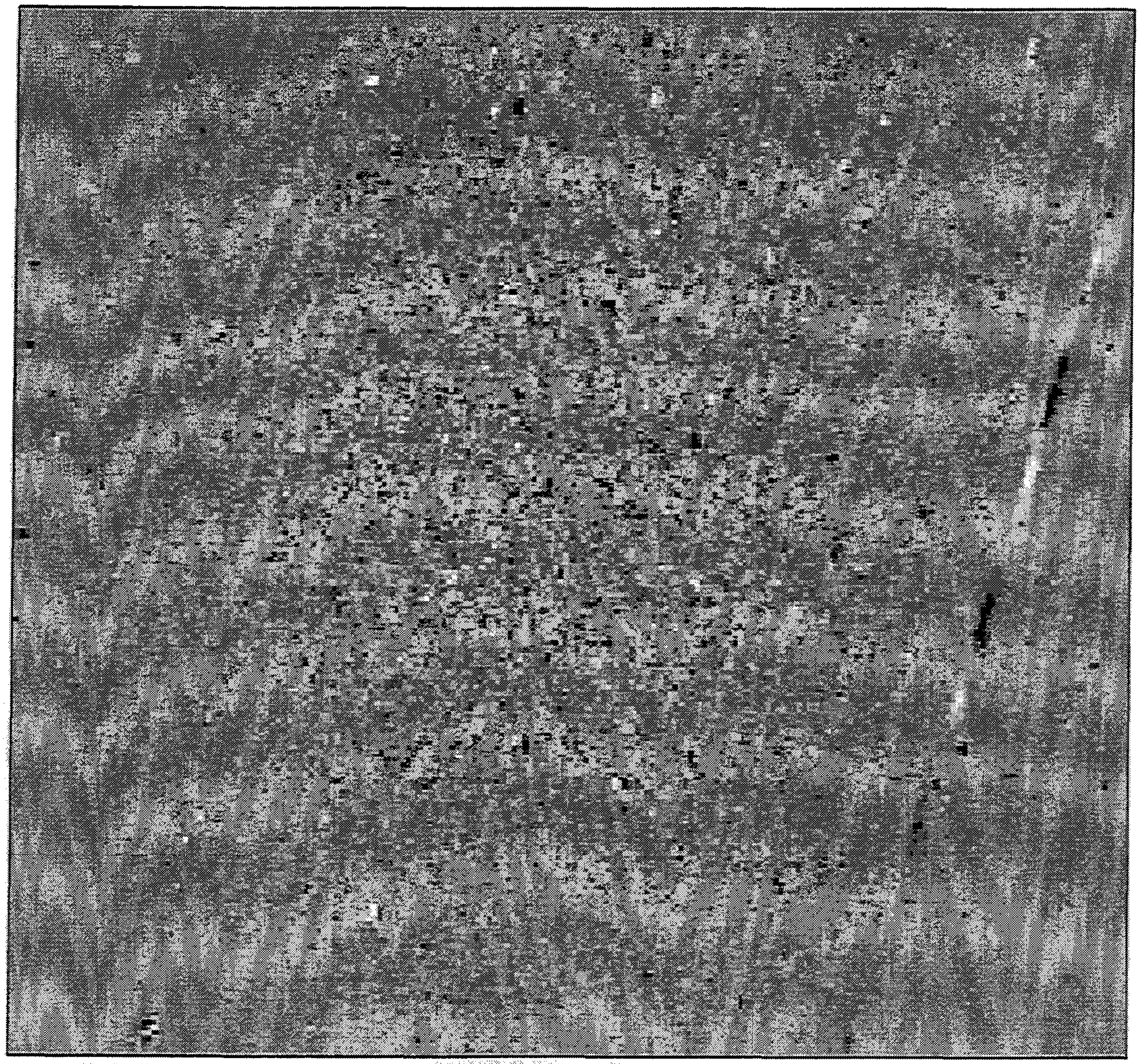

Figure 2 – Example of a meteor displayed in the differenced-sum mode showing the direction of the meteor's travel.

The image summation is the most computationally intensive part of the processing. By maintaining two separate sum images on alternating frames (not counting the electronic break shutter frames), the software can form both an integrated sum image, equivalent to a photo of a meteor track, and a differenced sum image to run the detection algorithms upon and assess track validity in post-processing. With the algorithm below, only one summation per frame is required with the final integrated sum and difference processed at a leisurely 1 Hz rate. (Note: sums are grouped in image pairs due to interleaving of video frames in the 60 Hz mode)

$$S_A = f_0 + f_1 + f_6 + f_7 + \cdots + f_{n-2} \qquad \text{Integrated Sum} = S_A + S_B$$
$$S_B = f_2 + f_3 + f_8 + f_9 + \cdots + f_n \qquad \text{Differenced Sum} = S_A - S_B$$
$$\text{Blanked}: \ f_4, f_5, f_{10}, f_{11}, \ldots$$

Since time history is lost when forming the summed image frames, a means needed to be found to determine a meteor's direction. By the introduction of a blank every third pair and the alternating sign on the differenced sum, the direction of a meteor's travel is revealed as you pass from negative amplitude through the blank into a positive return ($+ + - -$ `blank blank` $+ + - - \cdots$). This can be seen in Figure 2 as a change in the meteor's appearance of black to gray to white to black to gray...

A serious drawback of working with integrated sum frames is that the noise rejection thresholds had to be set much higher since noise spikes are integrated up over several frames. A few spikes per difference frame pair appear as a larger number of pixels with noise threshold crossings in a multi-frame differenced sum. This degrades the limiting magnitude performance of the detection phase which can only be resolved by thresholding on the individual paired difference frames or averaging groups of pixels. Neither approach was considered feasible under the memory/time constraints and operating goals stated earlier to save the highest resolution image.

For detection, a two-dimensional Hough transform [4] was used for locating collinear positioned pixels. This is an algorithm that maps pixels in Cartesian image space (x, y) into Hough space where the coordinates (ρ, φ) represent a parametrized formulation of a straight line:

$$\rho = x \cos\varphi + y \sin\varphi.$$

Peaks in Hough space are formed by a linear alignment of "detected" pixels. An issue encountered here involves the production of false peaks in Hough space that chance linear alignments of the pixel threshold crossings may create leading to false detections. A simulation was developed using Gaussian distributed random noise to determine the Hough detection threshold as a function of the number of pixels passed through the Hough transform. The empirically derived result forms the basis of the detection threshold algorithm. (A study of the Hough transform and false alarm issues could take up a nice graduate level career and thesis.) A means was also developed to track the variance in the differenced sum noise by using a first order response filter tracking an approximation to the noise standard deviation. This was derived so that only integer arithmetic was required and no square roots were taken.

How was all this processing done in real-time? Basically, there are three main processes running at different rates through the computer. The first is the continuous digitization of the imagery by the frame grabber at 60 Hz which runs independently of the computer's CPU (asynchronous operation). The second process, also running at 60 Hz, is the summation of the last fully digitized frame, completed in the time to digitize the next frame. It is vitally important to have the digitized frames be directly addressable by the computer on the frame grabber board to avoid time consuming moves to CPU memory. The third process is the detection processing and archival to disk. This last process operates at a 1 Hz effective rate and is interwoven with the available time left over from the second process. The third process includes the final combination of the odd-frame/even-frame running sum fields, virtual memory block moves, thresholding for brighter than average pixels, screening for adjacent pixel groups, Hough transforming, and if no detection, updating the noise tracking filter, else writing the integrated sum, differenced sum, and tracking filter coefficients to a file. A post-detection program is run later in an interactive mode with a human operator to screen out false detections caused by artificial satellites, aircraft lights, and camera noise.

4. Operation

The system has been in operation since February 1997 with only 9 nights of clear weather through the end of April and has logged 6 meteor detections thus far. An image of the first meteor detected on April 15-16, 1997, is shown in Figure 1. It was one of three captured just after midnight local time and may be an early Lyrid. One explanation for the low frequency of meteor detection (6 meteors in 9 nights) is that the camera is operated on the roof of the author's home in a fairly light polluted region near Washington DC, USA. With limiting magnitudes rarely better than +4.5, the intensifier system gains must be turned down to avoid too many false alarms. An additional constraint has been to operate the system only after $22^{\rm h}$ local time to avoid aircraft detection due to the proximity of Dulles Airport nearby.

This raises the issue of operating an automated meteor detector directly off of a camera out in the field in that the computer system must travel with the imager system. Power must be available in a relatively benign environment that a computer can withstand at a remote observing site. Thus the author chooses to leave the computer end of the system at home and uses an 8 mm camcorder for recording imagery from the intensified video system when out at a dark field site. Later, the tape is fed back through the same computer system to scan an evening's set of tapes. Nevertheless, it is felt that demonstration of fully autonomous meteor detection has been achieved for those nights when one cannot get away to observe.

Items that will be addressed in the near future are to demonstrate a full resolution capability with current off-the-shelf computers.

Today's 32-bit operating systems and C compilers have flat memory models, no longer requiring memory block moves or limiting available memory. The Windows NT operating system gives one options to lower the priority of its housekeeping tasks, thus causing minimal interference with real-time processing. The PCI data bus has burst transfer rates of 45 Mb per second which is plenty of bandwidth to cover the 9 Mb per second pouring out of the frame grabber. CPU speeds are better than twice as fast as the 486/100 MHz system reported on here, so that processing full frames at 30 Hz is easily achievable.

With more available memory, retaining every digitized frame opens up the choices on the possible detection algorithms to include time domain approaches. To this end, the author has formulated a three-dimensional Hough transform which is comprised of two spatial and one temporal dimension for detecting time evolving linear tracks.

5. Conclusion

In conclusion, progress in the field of video meteor imagery has been phenomenal having tracked closely with the lower costs and higher performance of components that make up the systems.

With more meteorists entering the realm of video meteor operation, it will be necessary to develop algorithms and standardize approaches to meteor detection to get the best performance from any given system.

Hopefully, this article has given a flavor for the issues one may encounter in this rapidly evolving field. Thoughts and ideas on novel or alternative methods to working this problem are most welcome.

Acknowledgments

The author would like to thank Sirko Molau for sharing his algorithmic approaches he has implemented in the `movie` program which spawned the seeds of some new techniques used in this work. In addition, Mike Palermiti has been an invaluable aid in providing the imager hardware and in hashing out numerous camera hardware configurations and interfacing issues. Finally, I would like to thank my children for bearing with me during the months of software trial and error when they could only battle Tie fighters and the Star Wars evil galactic empire on a severely reduced computer schedule. May the force be with you all.

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The Global Meteor-Scatter Network

P. Jenniskens, NASA/Ames Research Center,
I. Yrjölä, P. Sears, W. Kuneth, and T. Rice

The Global Meteor-Scatter Network consists of 3 stations, in Finland, Hawaii, and Austria, coordinated at NASA/Ames Research Center and is aimed at detecting meteor outbursts. Radio meteor amateurs are encouraged to participate in the Network.

1. Introduction

The *Global Meteor-Scatter Network* (*Global-MS-Net*) is a global network of automatic meteor counting stations, which use the technique of forward meteor scatter to monitor the level of meteor activity. The network is made possible by a consortium of amateur radio meteor observers.

The purpose of the network is to detect meteor outbursts, which are defined as short enhancements of meteor rates that typically last 0.5–2 hours. Special effort is put into detecting meteor outbursts caused by the dust trails of Earth-threatening long-period comets. An example is the outburst of α-Monocerotids in November of 1995. The detection of such an outburst by the radio meteor-scatter technique can direct future observations by visual, video, and photographic techniques, which can provide the orbit of the meteoroids and the amount of dust in the stream.

The project is funded by NASA's "Research in Planetary Astronomy and Planetary Atmospheres" program.

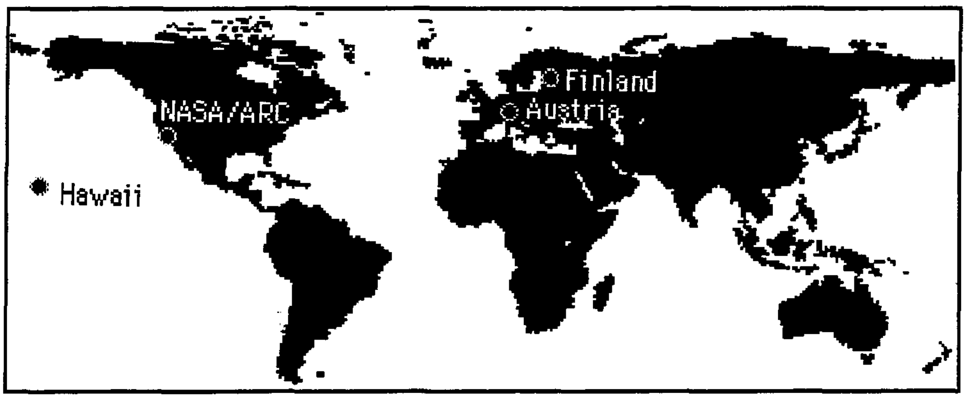

Figure 1 – Current locations of Global-MS-Net stations.

2. Current participants

At the time of this writing in April of 1997, the Network consists of three operating stations in Finland, Hawaii, and Austria.

The Finnish station is run by Ilkka Yrjölä (OH5IY). His receiver works at 87.360 MHz, with a bandwidth of 15 kHz. The receiver is located in Kuusankoski, Finland ($\lambda = 26°.4$ E, $\varphi = 60°.9$ N). Ilkka monitors a network of transmitters of Eurosignal, most notably the transmitter near Hamburg (5 kW, vertically polarized), at 1300 km in a south-western direction from Kuusankoski. The station has been in continuous operation since December 1993.

The technique used by Ilkka was transferred to Hawaii, where Paul Sears (NH6LH) has operated a similar station since November 1996. The receiver is located in Naalehu on Big Island, Hawaii. Local transmitters set the operating frequency at 96.9 MHz (15 kHz bandwidth). The transmitter is an FM radio station on Kauai (100 kW ERP) at 515 km distance in direction NNW.

The Austrian station was developed and built by Werfried Kuneth. Presently, he works at an operating frequency of 48.2493 MHz, covering 40 Hz with a bandwidth of 2 Hz. The receiver is located in Villach, Austria ($\lambda = 13°.9$ E, $\varphi = 46°.6$ N). The transmitter emits horizontally polarized radio waves and is at 400 km distance in southern direction.

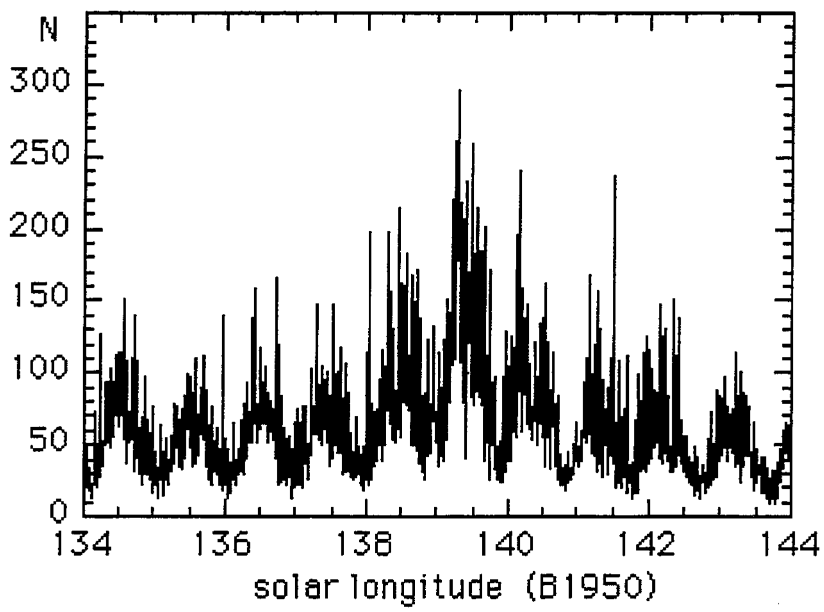

Figure 2 – Daily counts of meteor reflections from a remote transmitter [1].

3. Preliminary results

Here, we shall present some results from the counting system of Ilkka Yrjölä. Figure 2 shows the daily counts of meteor reflections between August 7 and 16, 1995 (from [1]).

The daily variation is due to the changing altitude of the Earth's apex: early in the morning, there are more meteors in the sky than late in the evening. The increase of rates around solar longitude $\lambda_\odot = 139\overset{\circ}{.}4$ is due to the Perseid meteor stream.

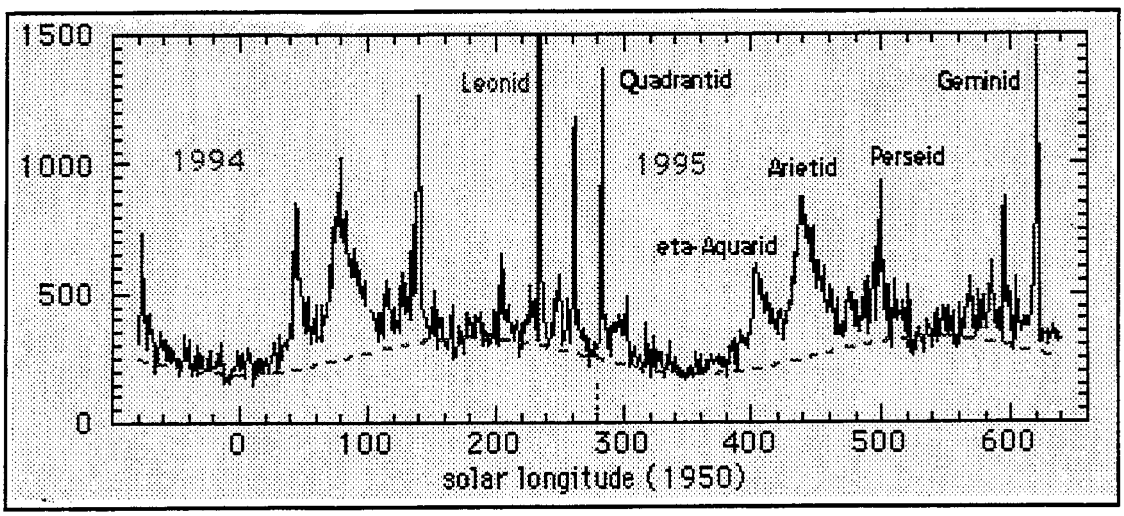

Figure 3 – Annual variation of meteor rates at a given time of the night [1].

Figure 3 shows the meteor count in 10-minute intervals at 5^h UT for different days during the year.

The first part of the graph shows the counts from 1994, and the second part the counts from 1995. Note that the annual meteor streams show up much the same in both years. The 1994 Leonid meteor outburst is indicated [2].

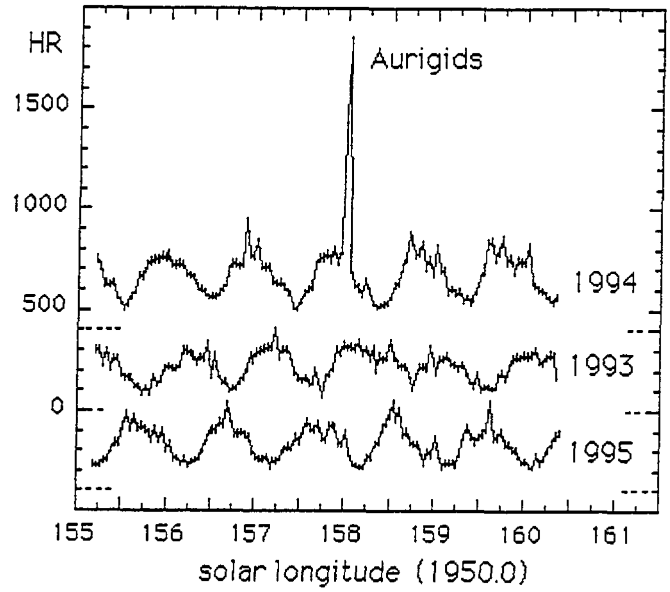

Figure 4 – Detection of a meteor outburst of an Earth-threatening comet [3].

Figure 4 shows the detection of a meteor outburst of the kind that we are most interested in: those caused by the dust trail of long-period comets. It shows the 1994 Aurigid outburst [3], caused by the dust trail of Comet P/Kiess 1911 II.

Comet Kiess has a period of 2000 years, and was last seen in 1911, when it passed the Earth's orbit within less than twice the distance Earth-Moon.

Note that the short outburst of meteors in 1994 did not occur in 1993 and 1995, when it should have been detected from Ilkka's location. These outbursts are due to the trails of dust in the orbit of the comet that intercept the Earth's orbit only in those years when the major planets are appropriately positioned [3,4].

Because the comet is far from the Earth when the outbursts occur, we call these events "far-comet type meteor outbursts."

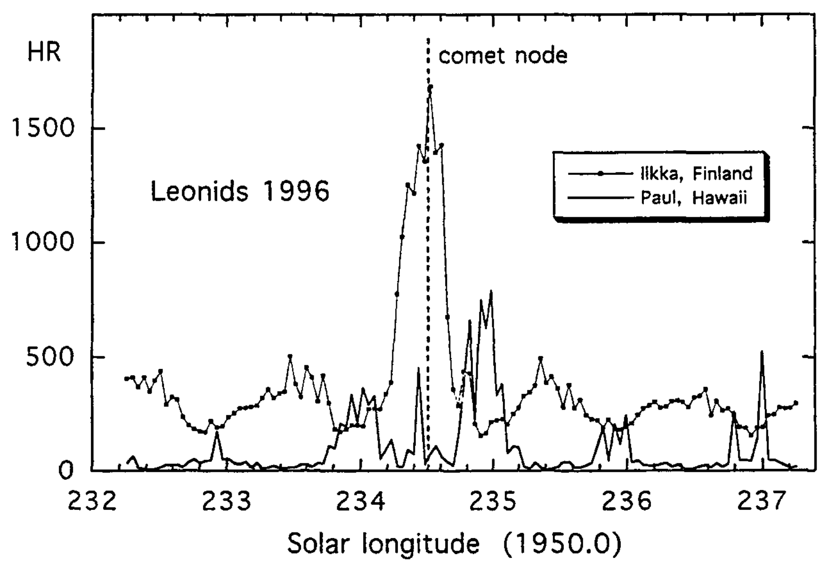

Figure 5 – Detection of the Leonid shower from Hawaii and Finland.

Table 1 – Detected outbursts.

Year	Stream	Date	Outburst type	Ref.
1994	Perseids	August 12	near-comet	
1994	Aurigids	September 1	far-comet	[3]
1994	Leonids	November 18	near-comet	[2]
1994	Ursids	December 23	near-comet	
1995	Leonids	November 18	near-comet	[5]
1995	α-Monocerotids	November 22	far-comet	[4]
1995	Ursids	December 23	near-comet	
1996	Perseids	August 12	near-comet	
1996	Leonids	November 17	near-comet	
1996	Ursids	December 23	near-comet	

Figure 5 shows the strength of a Global Meteor-Scatter Network. The stations in Hawaii and Finland detected the Leonid meteor outburst of November 1996. The different locations of the stations allow an almost continuous monitoring of the stream. In order to cover all possible radiants at all times of the year, it is necessary to have an additional station in eastern Asia, and at least three stations in the southern hemisphere. Our goal is to expand the network to include stations in Japan, South Africa, Brazil, and New Zealand within the next two years.

In order to find all possible comet dust trails in the Earth's neighborhood, a complete Global-MS-Net must operate continuously for a period of at least 60 years. This is because the various planetary configurations of Jupiter and Saturn, which influence the comet dust trail positions relative to the Earth's orbit, repeat only after this period of time.

4. Data archiving

Monthly, the counts are collected via electronic mail and archived at NASA/Ames Research Center, Moffett Field, California, by Peter Jenniskens. The data are available to participants upon request.

An electronic bulletin has been prepared by Ilkka Yrjölä that gives an instruction on how to use and operate a continuously monitoring station like his. The participating amateurs offer help to those who also want to participate in the Global-MS-Network.

For further information, contact Peter Jenniskens at `peter@max.arc.nasa.gov`, or visit our web site at `http://prometheus.arc.nasa.gov/division/ssx/ssx_indiv_pages/pjenniskens/Global-MS-Net/GlobalMSNet.html`.

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