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Phoenicids
Leonids 2003
High-altitude meteors
Recollections of IMC 2003

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Front cover photo
Delegates at IMC 2003 discussing the Dutch Meteor Society's cameras. Photograph by Casper ter Kuile.

Cover design
Rainer Arlt

Editorial

Chris Trayner

For the last few years we have been treated to Leonid displays ranging from the excellent to the truly spectacular. This November the rate is expected to be lower, but that is based on theories which need confirming or disproving. In other words, we should not assume that the show is over, although it would be unrealistic to expect the treats of the past few years.

Even if the rates are low, it is important to record them: without data the theories cannot be refined, and the production of such data is the *raison d'être* of the IMO. So please make an effort to observe seriously, not just by wandering out to see a few shooting stars.

To help readers plan their Leonid campaigns, this issue contains a paper (on page 131) with predictions of what we may expect. To aid meteor research worldwide, the IMO is placing this paper on its website (`www.imo.net`) with relaxed copyright restrictions. Anyone may make and distribute as many copies as they like, without charge. This includes both paper copies and the PDF file from the website.

The email address for WGN is `wgn@imo.net`. We use anti-spam filters, and to get past them please include the word meteor in the subject line. Large attachments are also blocked, so if you have one then please send a small email first and we will arrange ways for you to reach us.

Letters

from Marco Langbroek[1]

Dear Editor, and dear Dr. Terentjeva,

I was highly pleased to read Dr. Terentjeva's contribution on my June 15, 1996 observations in WGN 31:4. This observation has always remained enigmatic to me, and it is good to note that someone gives it a follow-up. I might have a few additions to bring in, that align to the ideas as expressed by Terentjeva in her contribution.

First, I think it is very well possible that I overestimated the velocity of the meteors, as I actually find estimating velocities the most difficult part of meteor observations (I now usually use rough categories of slow-medium-fast only). This indeed makes Terentjeva's γ-Draconid stream a candidate, in my opinion.

As part of the discussions following my 1996 report, several people commented on a possible identification with the June Lyrids as observed by Dvorak in 1966. While the reported radiants are off by some 25°, it nevertheless is possible given the similar solar longitude of the observations and general sky area of the proposed radiants, that it does concern the same stream and in fact, I want to propose now that not only 'my' radiant, but also the June Lyrids might perhaps be synonymous with Terentjeva's γ-Draconids. The difference in reported radiant positions need not preclude this, as it is not clear how accurate the reported position by Dvorak is. The history of the 1995 November α-Monocerotids is another case where the true radiant position of a stream was found to be many degrees off from the positions (multiple) it had been previously reported to be.

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from Alastair McBeath[2]

Amendment to the June Boötid prediction in 2004 IMO Meteor Shower Calendar

Owing to a misreading of a source-text, I have accidentally credited David Asher and Vacheslav (not Vasily) Emel'yanenko with a prediction about the 2004 June Boötids they did not actually make, in the *2004 IMO Meteor Shower Calendar*. The prediction of possibly strong activity was in fact suggested by work carried out by IMO President Jürgen Rendtel ('June Bootid Observations in 2002', WGN **30:4**, 2002, pp. 85–86). In the June Boötid text paragraph in the *Calendar*, the sentence beginning 'Work by David Asher ...' should thus read:

> 'Work by Jürgen Rendtel indicates the Earth may encounter potentially substantial June Boötid rates again in 2004 on June 27, around 01$^{\text{h}}$ UT.'

Please amend your Shower Calendar text accordingly.

I apologize unreservedly to all concerned for this mistake.

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Report on IMC 2003: Bollmannsruh, Germany, September 18-21

Margaret Campbell-Brown [1]

Following the tradition of picking on first-time attendees, I have been asked to write a social report on the 2003 International Meteor Conference. Since I thoroughly enjoyed the conference, I'm happy to do so!

We arrived Thursday evening (late Thursday night for some who drove from far away!). The conference location was beautiful: right by a lake, with lovely grounds. The weather couldn't have been better: warm sunshine all four days, and beautiful, dark, clear nights. We filled the time before supper catching up with old friends. Even those of us who were there for the first time met many familiar people: I knew quite a few from other international conferences and Leonid campaigns. Since 2003 was the 15th anniversary of the founding of the IMO, we had several slideshows after dinner showing IMCs of the past. It's amazing how little some people change in 15 years!

The next morning was spent on results from Leonid campaigns over the last five years. Everyone had good Leonid stories to tell, about bright fireballs, high rates, or just trying to escape clouds! In the afternoon we were off to the Berlin Museum of Natural History. We heard a great talk on impact craters on Earth by Thomas Kenkmann, who had the added challenge of giving his talk in English when he had been prepared to give it in German! I was very impressed. After the talk we had private access to the meteorites on display at the museum.

After supper, there were extra talks, and lots more chatting. Getting to bed late is a fine IMC tradition, and Friday evening was no exception for most of the conference delegates.

Saturday morning got started with an interesting variety of talks. I found the poster session particularly interesting: it was a great time to discuss the science in detail and chat with people working on things I was interested in, and those interested in things I was working on! The General Assembly took place after lunch, and went very quickly and smoothly. There was another good set of talks after lunch, including several on my favorite meteor shower, the Geminids. These were followed by an international astropoetry performance, led by Andrei Dorian Gheorghe of Romania. It was enjoyed by all.

Dinner on Saturday night was an excellent barbecue, with plenty of opportunity to chat. Afterwards a great bonfire lasted into the small hours of the morning, with plenty of beer, snacks and conversation for all. Afterward came bed for most (but not all) the delegates.

Sunday morning passed quickly with more talks, covering the π-Puppids (a generally neglected southern shower), the population index of sporadic meteors, and meteorites and impact craters, among other topics. Lunch followed amid last minute exchanging of contact information.

I really enjoyed my first IMC. I have plenty of new ideas for work, I saw lots of old friends and made new ones. Thanks to the organizers for a great conference!

Photographs — Top: Detlef Koschny; Middle: the camp fire, both taken by Jürgen Rendtel. Bottom: Delegates and the Dutch Meteor Society meteor camera arrays, taken by Casper ter Kuile.

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Leonids

The 2003 Leonid shower from different approaches

Jérémie Vaubaillon[1], *Esko Lyytinen*[2], *Markku Nissinen*[3] *and David J. Asher*[4]

Though the Leonid meteor storm period is over now, we provide in this paper predictions for 2003, from three models. It turns out that even if no storm is expected, activity from old trails (14 or more revolutions old) will be observable. In particular the 1499 trail will provide enhanced activity on 2003 November 13 UT with ZHR estimated at about 100. Further minor enhancements are predicted on November 19 at around 07^{h}–08^{h} UT and at other times from November 19 to 22, making the longest expected Leonid meteor shower.

Received 2003 October 22

1 Introduction

These past five years (from 1998 to 2002) have seen some exceptional Leonid activity (for a full review of the observations, see Arlt & Brown 1999, Arlt & Gyssens 2000, Arlt et al. 1999, 2001, 2002, and Jenniskens 2002). For the first time, some accurate predictions have also been possible, thanks to a better knowledge of the dynamics of meteoroids in the Solar System. Following the work of Kondrat'eva & Reznikov (1985) and Kondrat'eva et al. (1997), it was shown (Asher, 1999; McNaught & Asher, 1999) that the orbit of the meteoroids, instead of the orbit of the parent body alone, is relevant to achieve such predictions. At the same time Lyytinen & Van Flandern (2000), from a 'satellite model' of the comet 55P/Tempel-Tuttle, and the consideration of non-gravitational forces, derived a model of the streams. This model has been enhanced (Lyytinen et al., 2001) thanks to the quality of the observations and the Lorentzian profile of a shower deduced by Jenniskens (2002). Recently, Vaubaillon (2002) used the photometry of the comet to make a link between the parent body and the level of the shower encountered.

A meteor storm occurs when the Earth passes close to the center of a trail of material released at a particular perihelion return of the parent comet (Kondrat'eva et al., 1997). Otherwise, a usual meteor shower is expected. Overall, meteor storms are therefore very rare. The last one occurred in 2002 but, from the results of computations, it appears that no other storm is expected for the coming decade. At present, no Leonid storm until at least 2033 has yet been identified. The question arises as to what will be seen in 2003. We shall try to answer that in this paper, by presenting the results of the above different modeling approaches.

2 2003 Leonids predictions

In his first work, Lyytinen (1999) found that the Earth will encounter very old Leonid trails in 2003 Novem-

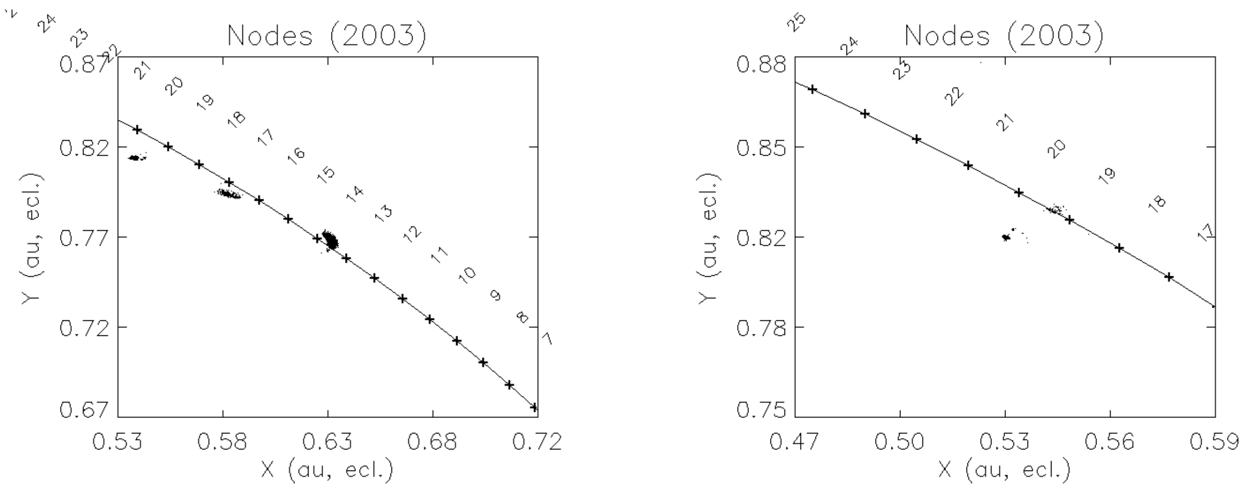

Figure 1 – General circumstances of the encounters in 2003 November with meteoroid streams ejected from 55P/Tempel-Tuttle in 1499 (left) and 1533 (right). Earth's position shown at 1-day intervals.

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ber. Following this result, Asher and Vaubaillon have run their model for various trails, confirming Lyytinen's findings. Figure 1 shows the general circumstances of the two main encounters. Figure 2 is a closer view around each encounter.

Old streams have suffered many planetary perturbations and are split into several parts. This is clearly visible in Figure 1. As old trails are, generally speaking, more dispersed than young ones, one can expect a very low ZHR value for the two expected showers. McNaught & Asher (2002) and Vaubaillon (2002) have independently shown the presence of gaps in meteoroid streams, and their relevance for making meteor shower forecasts. But because of the complexity of gravitational perturbations, there can, in addition to the gaps, be dense parts in a stream, increasing the ZHR. Table 1 provides the timing and the ZHR value from the different approaches of the authors.

There is a lot of fine structure in old trails, and when the original dust trail calculation method is applied to the 1499 trail, multiple encounters are found (Figure 3). The two most significant ones are the first two entries in Table 1; the former is closer to the Earth's orbit although both nominally miss the Earth by well over ten Earth diameters. In reality, material is dispersed over this whole region (Figure 2, left plot), and activity may last half a day (next entry in Table 1). Figure 3 shows a lot of particles compressed into a small range of nodal crossing times, effectively increasing f_M compared to the nominal values. The parameter f_M (McNaught &

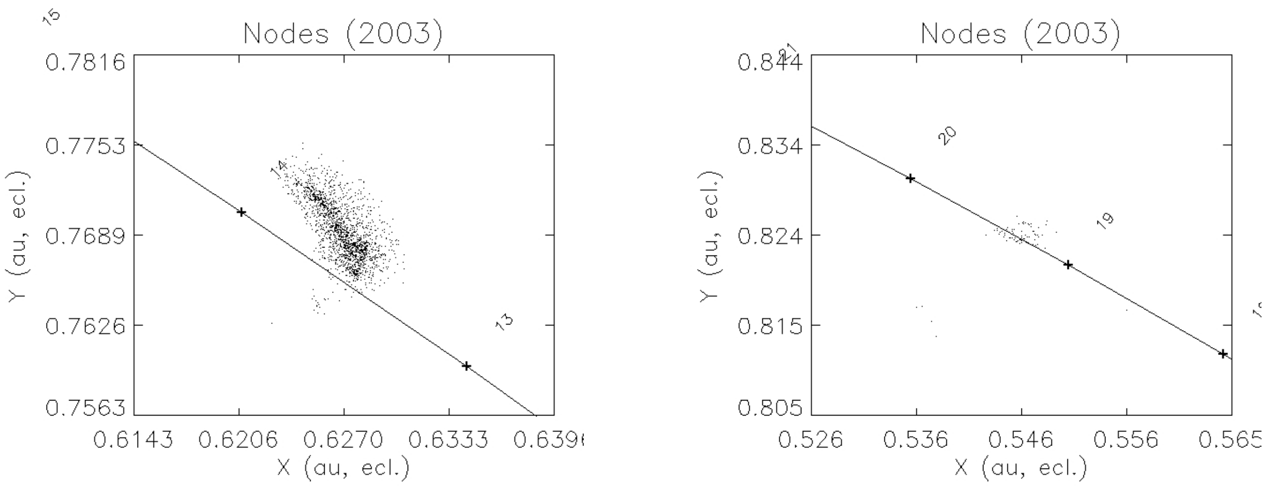

Figure 2 – Closer view of Figure 1.

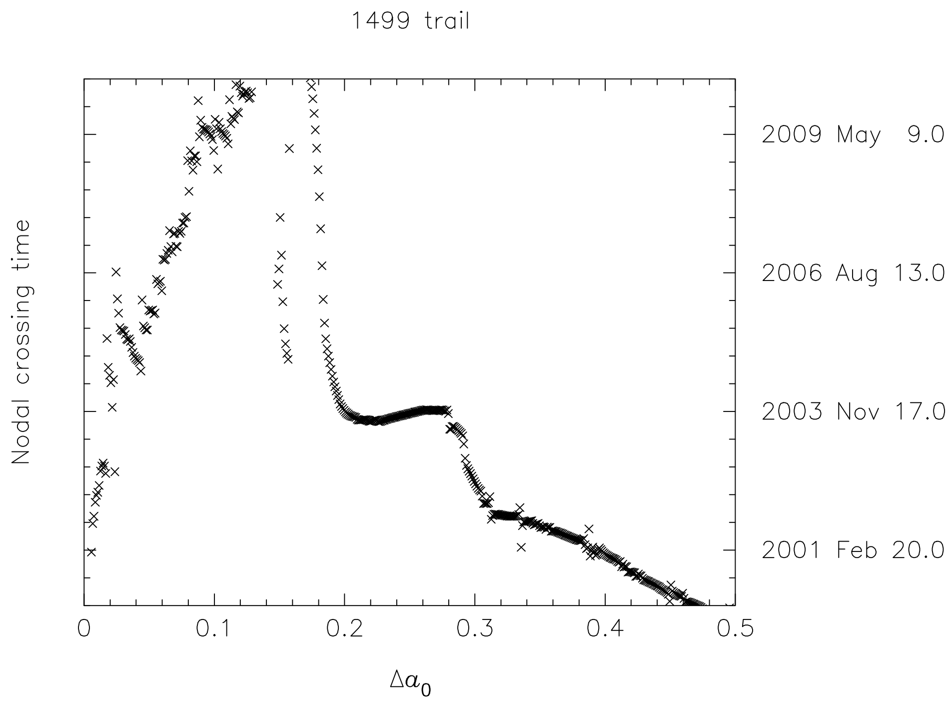

Figure 3 – Nodal crossing time in early 21st century of particles ejected tangentially at perihelion in 1499, as a function of orbital period at ejection time (equivalently $\Delta a_0 \equiv$ difference in semi-major axis from cometary value). Multiple values of Δa_0 allow particles to reach the ecliptic in mid-November of 2003.

Asher, 1999) measures the extent to which a trail has stretched in the along-orbit direction, being 1.0 for a 1-revolution trail and closer to zero for more stretched (lower density) trail sections. We can see from Table 1 that the conditions of the encounter with the 1499 stream are very good, with $f_M > 1$. The high value in Table 1 is somewhat surprising for such an old stream, but again gravitational perturbations have a complicated influence on the streams. Lyytinen (1999) pointed out that the 1499 stream is one revolution late, compared to the parent body, comet 55P/Tempel-Tuttle.

The difference between Lyytinen and Vaubaillon's results for the 1533 stream comes from the very poor number of simulated particles selected by the method (see Vaubaillon, 2002). It is then hard to compute a density that makes sense. The value of 100 for ZHR is thus very uncertain. The Asher & McNaught timing is for the nominal center of the trail, which the Earth misses by only a small distance; $r_E - r_D = -0.0002$ AU (cf. McNaught & Asher, 1999). The miss distance for the 1333 trail is much larger; $r_E - r_D = -0.0017$ AU.

Another consequence visible in Table 1 is that the two main showers are separated by 6 days. During the recent Leonid observations (1998–2002), this has never been observed. This is more surprising since the two streams have only one revolution difference.

3 Discussion and conclusions

The different models agree fairly well overall because they are all based on orbital dynamics. It is worth mentioning that the differences for very old streams seen in these predictions result from different cometary elements at time of ejection. Lyytinen uses the orbit of Nakano (1999), whereas Vaubaillon uses P. Rocher's one (personal communication). Differences in non-gravitational parameters induce, after a long time integration (here more than 1000 years), a very different time of perihelion. The same problem has been encountered with 2003 Perseids between Lyytinen and Vaubaillon's approaches. The orbit of 55P/Tempel-Tuttle is increasingly poorly constrained going back in time from the 1366 return, when the comet was first observed. Although an accurate orbit for the comet is the essential input parameter to the trail encounter calculations, observing the meteors may conversely provide information on the time of perihelion of comet 55P/Tempel-Tuttle a long time ago, by showing which of two possible orbits better matches the observations. If one observation discredits one orbit solution, it does not however definitely prove that the other one is the correct one. Indeed, a negative observation is a necessary condition to refute one solution, but is not sufficient to accept another one. At any rate, as such old streams are very perturbed, the ZHR is expected to be low.

Even if the Leonid meteor storm period (Lyytinen, 1999; McNaught & Asher, 2002) is over now, the year 2003 will provide good conditions to observe some showers. The times in Table 1 correspond to Pacific and east Asian regions being favored for the 1499 trail encounter, and Atlantic and east American regions six days later for the 1533 encounter. We have to emphasize that the last encounter with such old streams was the famous 1998 one. On the other hand, this year is expected to be poor in bright meteors. Although details of the predictions are harder than for younger trails, we encourage everybody to conduct some observations if possible. They will again help to constrain the models of the streams, and also give information on the orbit of the parent body more than 1000 years ago. The encounter with the trail from 1733 is quite a distant (∼0.003 AU) encounter in the nominal solution, but strong non-gravitational effects could bring meteoroids near the Earth's orbit. Even though this

Table 1 – Times (UT) and ZHR forecasts for 2003 Leonids. Larger values of Δa_0 correspond to fainter meteors (see McNaught & Asher, 2002).

Trail	Model	Δa_0	f_M	Time	ZHR
1499	Asher & McNaught	0.28	∼0.03	Nov 13, 13^h15^m	
	Asher & McNaught	0.26	∼0.8	Nov 13, 18^h20^m	
	Lyytinen	0.28	∼1.6	Nov 13, 16^h40^m, half a day	100
	Vaubaillon			Nov 13, 17^h17^m	120
1533	Asher & McNaught	0.30	−0.04 *	Nov 19, 06^h30^m	
	Lyytinen	0.30	∼0.1	Nov 19, 08^h	dozen(s)
	Vaubaillon			Nov 19, 07^h28^m	100
1333	Asher & McNaught	0.12	∼0.02	Nov 20, 00^h50^m	
	Lyytinen		∼0.02	Nov 20, 01^h30^m	20
	Vaubaillon			Nov 20, 01^h26^m	15
736	Lyytinen	−0.008		Nov 22, 21^h	10
	Vaubaillon			Nov 22, 22^h02^m	2
636	Vaubaillon			Nov 23, 02^h56^m	10
1733	Lyytinen	0.11		Nov 19, 00^h25^m	a few dozen?

* Negative values of $f_{\rm M}$ occur when the order of meteoroids is reversed due to planetary perturbations. The degree of dispersal when $f_{\rm M} = -0.04$ is the same as when $f_{\rm M} = +0.04$.

encounter is expected to give only weak rates, observations of this could determine the existence or absence of such a strong non-gravitational effect.

References

Arlt R., Bellot Rubio L., Brown P. and Gyssens M. (1999) "Bulletin 15 of the International Leonid Watch: First Global Analysis of the 1999 Leonid Storm", *WGN*, **27:6**, 286–295.

Arlt R. and Brown P. (1999) "Bulletin 14 of the International Leonid Watch: Visual Results and Modeling of the 1998 Leonids", *WGN*, **27:6**, 267–285.

Arlt R. and Gyssens M. (2000) "Bulletin 16 of the International Leonid Watch: Results of the 2000 Leonid Meteor Shower", *WGN*, **28:6**, 195–208.

Arlt R., Kac J., Krumov V., Buchmann A. and Verbert J. (2001) "Bulletin 17 of the International Leonid Watch: First Global Analysis of the 2001 Leonid Storms", *WGN*, **29:6**, 187–194.

Arlt R., Krumov V., Buchmann A., Kac J. and Verbert J. (2002) "Bulletin 18 of the International Leonid Watch: Preliminary Analysis of the 2002 Leonid Meteor Shower", *WGN*, **30:6**, 205–212.

Asher D.J. (1999) "The Leonid meteor storms of 1833 and 1966", *MNRAS*, **307**, 919–924.

Jenniskens P. (2002) "More on the dust trail of comet 55P/Tempel-Tuttle from the 2001 Leonid shower flux measurements", Proceedings of Asteroids, Comets, Meteors — ACM 2002, International Conference, 29 July – 2 August 2002, Berlin, Germany, 117–120.

Kondrat'eva E.D., Murav'eva I.N. and Reznikov E.A. (1997) "On the forthcoming return of the Leonid meteoric swarm", *Solar System Res.*, **31**, 489–492.

Kondrat'eva E.D. and Reznikov E.A. (1985) "Comet Tempel-Tuttle and the Leonid meteor swarm", *Solar System Res.*, **19**, 96–101.

Lyytinen E. (1999) "Leonid predictions for the years 1999–2007 with the satellite model of comet", *Meta Research Bulletin*, **8**, 33–40.

Lyytinen E., Nissinen M. and Van Flandern T. (2001) "Improved 2001 Leonid Storm Predictions from a Refined Model", *WGN*, **29:4**, 110–118.

Lyytinen E. and Van Flandern T. (2000) "Predicting the Strength of Leonid Outbursts", *Earth Moon and Planets*, **82**, 149-166.

McNaught R.H. and Asher D.J. (1999) "Leonid Dust Trails and Meteor Storms", *WGN*, **27:2**, 85–102.

McNaught R.H. and Asher D.J. (2002) "Leonid dust trail structure and predictions for 2002", *WGN*, **30:5**, 132–143.

Nakano S. (1999) "OAA computing section circular, Nakano Note 722", Web page: `http://www.oaa.gr.jp/~oaacs/nk/nk722.htm`.

Vaubaillon, J. (2002) "Activity level prediction for the 2002 Leonids", *WGN*, **30:5**, 144–148.

The Leonid Filament in 2003

Peter Jenniskens [1]

It is shown from Leonid meteor counts that a broad 1-day wide dust component was present in the orbit of Comet 55P/Tempel-Tuttle during the 1998–2002 Leonids. This 'Filament' was first seen in 1994 and was responsible for the 1998 fireball shower. The component may well return in 2003, and perhaps in later years.

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1 Introduction

In 1994, the first Leonid outburst of the new season was observed to be about one day wide and rich in bright meteors (Jenniskens, 1996). This component was seen again in the following years, until it peaked in 1998 into a spectacular shower of fireballs (Arlt, 1998). Asher et al. (1999) calculated that the dust ejected in 1333 into the 5:14 mean-motion resonance was in the Earth's path during the 1998 shower. However, models show that single dust trails do not broaden that much over time (Jenniskens et al., 2002). Indeed, Jenniskens & Betlem (2000) argued that the total mass in the component (10^{12} kg) is much bigger than the amount lost in one return ($\sim 2 \times 10^{10}$ kg) and that the Filament should represent the dust lost in about 50 returns in the past ~1 500 years.

Newer observations of the Leonid showers in 2002 demonstrated that the Filament component continued beyond the 1998 showers. Each year a broad 1-day wide component was present (Figure 1). The narrow 2002 Leonid storms demonstrate that this broad component is not an extention of the younger dust trails.

2 Longevity of the filament

It is unclear, at present, how long the Filament will remain visible in upcoming Leonid showers. Key observations are the sudden onset in 1994 and the whimsical shifts in peak time from a regular pattern. These show that planetary perturbations are important in moving the Filament in and out of Earth's orbit, just as they are for individual dust trails of younger age.

If planetary perturbations are efficient at moving grains from the filament into the annual dust component during encounters with Jupiter, then the Filament will be expected to stop being visible 10–11 years (a little less than 1 orbit of Jupiter) after the first sighting in 1994. In that case, there is a good chance that the Filament will return in 2003 (which would be 10 years after the first sighting). Beyond this maximum range, dust would be less protected from close encounters with Jupiter.

However, Joe Rao pointed out to me that the Filament may have been visible during the previous return in 1965, and as late as 1974 (which is equivalent to 2007 in this return):

- Sky & Telescope, 1972 January, page 57: the 1971 Leonids were described as producing 'moderate' activity with up to 27 meteors per hour for an observer in North Carolina. Others reported a number of bright fireballs.
- Sky & Telescope, 1973 February, page 127: Karl Simmons of Jacksonville, Florida presented a report of the 1972 shower producing 40 Leonids per hour recorded by a team stationed at Ottawa, Ontario.
- Sky & Telescope, 1975 March, page 193: the 1974 Leonids were described as 'startling' by Norman W. McLeod of Punta Gorda, Florida. He observed Leonid rates of up to 40 per hour. About half of the 179 Leonids that he witnessed left trains, in some cases lasting up to 3 minutes, suggesting bright meteors. Another report, from Virginia Beach, reported a blue fireball leaving a train that lasted for up to eight minutes.

3 Prospects for 2003

Except for 1998, the Filament peak rate has remained fairly constant at ZHR = 50 per hour. In 2003, the peak time would be expected around November 19, $05^{h}30^{m}$ UT, with a possible error of a few hours, based on the trend observed in 1995–1997 and 1999–2002. This corresponds to $\lambda_{\odot} = 236.^{\circ}407$ (J2000). Indeed, Jérémie Vaubaillon and colleagues have calculated that one particular trail, from 1533, will peak around $07^{h}27^{m}$ UT, with an expected ZHR of about 20; see also (Vaubillon et al., 2003) in this issue.

If the prediction holds, then the best viewing of this year's Leonid Filament is in the Americas. However, because the component is so broad, bright Leonids will also be seen in other parts of the world in the nights of November 17/18, 18/19, and 19/20. New observations may help decide whether the Filament meteoroids are trapped in orbital resonances.

4 Acknowledgments

I thank Joe Rao for his contribution to this report and the visual observers of the Dutch Meteor Society and IMO for contributions to Figure 1. Leonid MAC is sponsored by NASA's planetary astronomy and astrobiology programs, and flux measurements were supported by Mike Koop, Chris Crawford, Morris Jones and others of the flux measurement team. This paper supports the goals of the ProAmat Working Group of IAU Commission 22.

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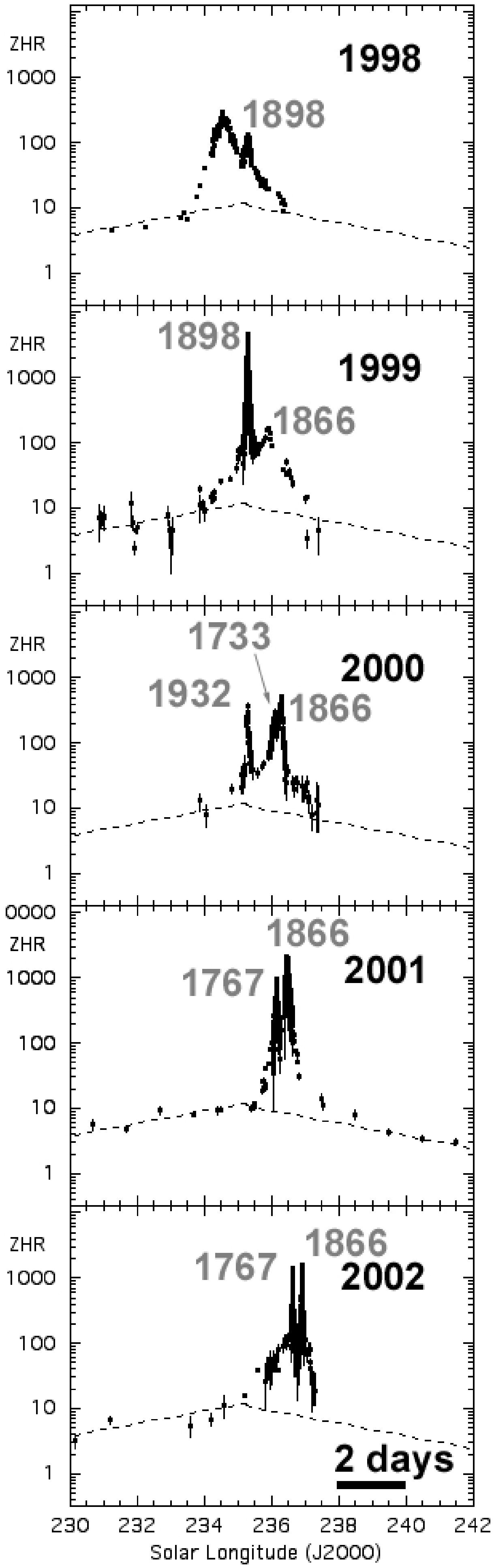

Figure 1 – Leonid shower observations in the period 1998–2002, compiled from data collected during Leonid MAC missions (Jenniskens, 2001) and from visual observations of IMO, e.g. (Arlt, 1998).

References

Arlt, R. (1998) "Leonids Bulletin 13 of the International Leonid Watch: The 1998 Leonid Meteor Shower", *WGN*, **26:6**, 239–248.

Asher D.J., Bailey M.E., Emelyanenko V.V. (1999) *MNRAS*, **304**, L53.

Jenniskens P. (1996) "Meteor stream activity. III. Measurement of the first in a new series of Leonid outburst", *Meteoritics & Planetary Science*, **31**, 177–184.

Jenniskens P. (2001) "Model of a one-revolution comet dust trail from Leonid outburst observations", *WGN*, **29:5**, 165–175.

Jenniskens P., Betlem H. (2000) "Massive remnant of evolved cometary dust trail detected in the orbit of Halley-type comet 55P/Tempel-Tuttle", *Astrophys. Journal*, **531**, 1161–1167.

Jenniskens P., Lyytinen E., de Lignie M.C., Johannink C., Jobse R., Schievink R., Langbroek M., Koop M., Gural P., Wilson M.A., Yrjölä I., Suzuki K., Ogawa H., de Groote P. (2002) "Dust trails of 8P/Tuttle and the unusual outbursts of the Ursid shower", *Icarus*, **159**, 197–209.

Vaubaillon J., Lyytinen E., Nissinen, M. and Asher, D.J. (2003) "The 2003 Leonid shower from different approaches", *WGN*, **31:5**, 131–134.

A bright, high altitude 2002 Leonid

Bernd Gährken[1] *and Jürgen Michelberger*[2]

Two-station observations of a 2002 Leonid are presented. A distinct transition from a diffuse to a drop-like appearance was observed. The results show a starting height of at least 165 km. It is concluded that atmospheric ablation cannot be the cause of the radiation.

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Our group witnessed the 2002 Leonid Storm in Spain, near Calar Alto. To observe the meteors we used a Mintron model MTV-12V1-EX camera. The Mintron was developed to supervise weakly illuminated locations. Combined with an $f = 6$ mm $f/1.2$ video lens it is a good system to detect medium brightness meteors. During the night of the shower, only two fireballs were visible. The first fell more than two hours before the maximum at $01^{\mathrm{h}}36^{\mathrm{m}}$ UT. It passed directly through the Mintron camera's field of view (Figure 1).

A couple of weeks after our return to Germany, we received a picture of this meteor captured near Tarbena at a distance of 274 km. The picture was obtained with an $f = 8$ mm fisheye on chemical film. The great difference in sensitivity between the detecting systems was a problem. Only the end of the meteor is well defined. The calculations show a burnout at 81.9 km. That is a typical value for a Leonid fireball. The calculations for the meteor's entry point led to a surprising result. Normal Leonids begin at a height of 120 km. But the photos from Tarbena and Calar Alto show no possible triangulation point lower than 165 km. The most likely calculation is at a height of 174 km ±5%.

Observations of the Czech Ondřejov Observatory and the Dutch Meteor Society of the Leonid shower of 1998 showed seven fireballs with similar altitudes (Spurný et al, 2000). The radiation higher than 130 km cannot be explained with standard ablation theory. It is possibly an electromagnetic effect which is only detectable in very bright and fast meteors. Such meteors are rare.

Several lucky circumstances came together for our observation. At Calar Alto the meteor appeared near the radiant, so the light was concentrated on a short

Table 1 – Frames of the bright Leonid of 2002 November 11, $01^{\mathrm{h}}36^{\mathrm{m}}$ UT.

Frame number	t_{start} (s)	t_{end} (s)	h_{mid} (km)	m_{V}	Structure	Notes
−1	−0.32	−0.16	> 174	4.6	point	signal not clear (not used)
0	−0.16	0.00	> 174	3.9	diffuse spot	signal weak (not used)
1	0.00	0.16	174	3.5	diffuse spot	first calculated picture
2	0.16	0.32	168	3.5	diffuse spot	
3	0.32	0.48	161	3.3	diffuse spot	
4	0.48	0.64	155	2.9	diffuse spot	
5	0.64	0.80	149	2.6	diffuse spot	
6	0.80	0.96	143	1.9	diffuse spot	
7	0.96	1.12	136	1.3	diffuse spot	
8	1.12	1.28	130	0.7	diffuse spot	drop already visible / mixture
9	1.28	1.44	—	−0.6	drop	rising brightness
10	1.44	1.60	—	−1.6	drop	
11	1.60	1.76	—	−2.4	drop	brightness difficult to estimate
12	1.76	1.92	—	−3.0	drop	brightness difficult to estimate
13	1.92	2.08	—	—	drop	too bright, brightness not estimated
14	2.08	2.24	—	—	—	too bright
15	2.24	2.40	—	—	—	too bright
16	2.40	2.56	—	—	—	too bright
17	2.56	2.72	—	—	drop	too bright
18	2.72	2.88	82	—	drop	height at t_{end}, maximum expansion

Notes

t_{start} and t_{end} are the times of the start and end of each frame.
h_{mid} is the height of the middle of the spot.

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path. Otherwise the weak shine at the starting phase would probably not have been detectable with our system.

Similarly to the fireballs seen by Spuný et al. (2000) in 1998, the meteor structure changes at 130 km. There exists a visible border. The pictures taken when the meteor was higher than 130 km show a weak diffuse spot, but the pictures lower than 130 km show a bright drop. During the first phase we took eight pictures with 0.16 s exposure time (Table 1).

The shutter of the video camera made it possible to calculate the speed. During the first eight clear pictures we measured 70.8 km/sec. This is similar to the speed outside the atmosphere. The result confirms the fact that ablation is not the reason for the new type of radiation.

Further information can be found at `http://www.astrode.de/leo2002f.htm` [including an impressive animation of these frames — *Ed.*].

References

Spurný P., Betlem H., Jobse K., Koten P. and van't Leven J. (2000), "New type of radiation of bright Leonid meteors above 130 km" *Meteoritics & Planetary Science*, **35**, 1109–1115. See also `http://leonid.arc.nasa.gov/leo00.pdf`

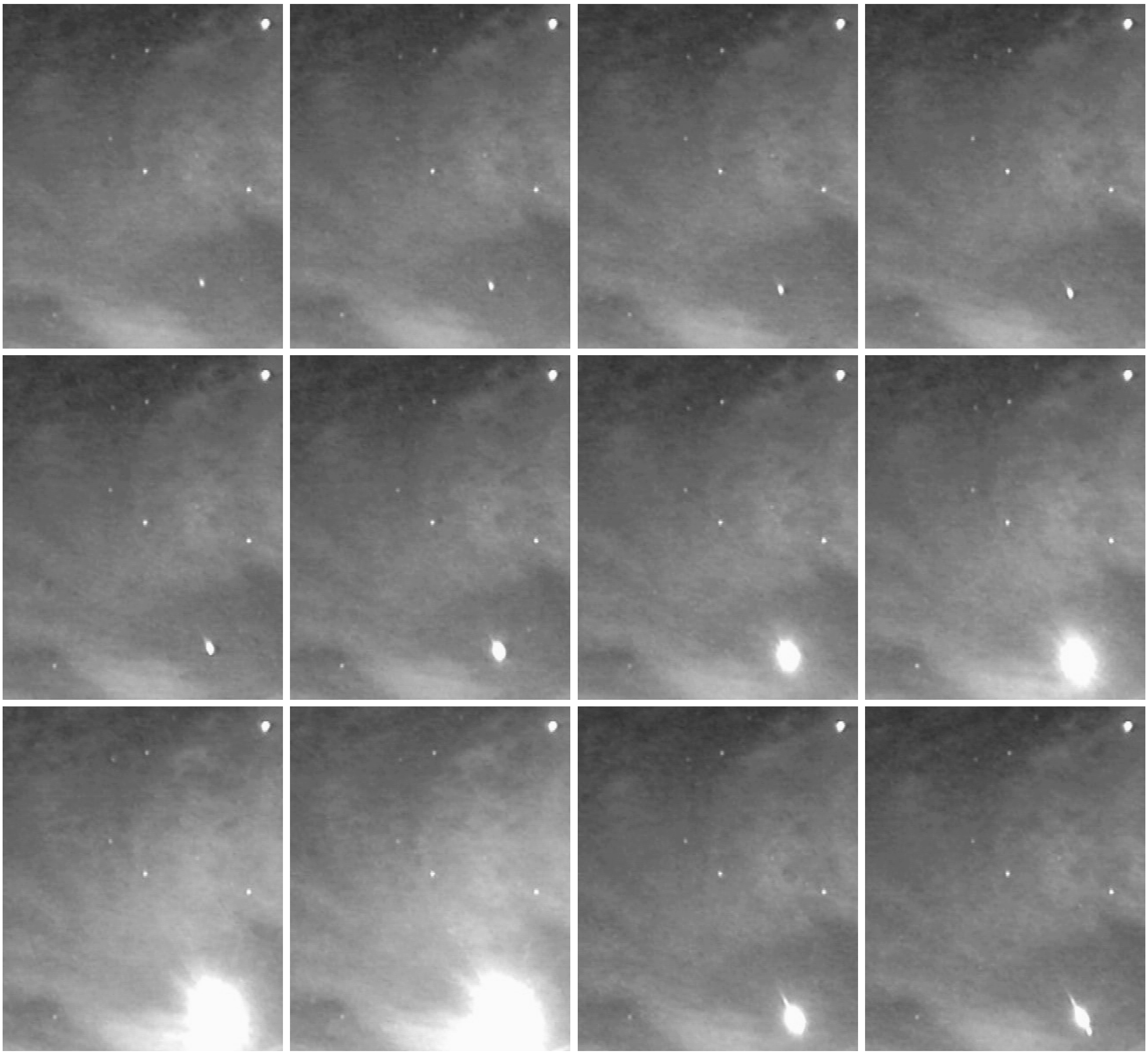

Figure 1 – Frames 7 to 18 as described in Table 1. The top row contains frames 7 to 10 from left to right, the second row 11 to 14 and the third row 15 to 18. Frames 1 to 6, not shown here, are available at `http://www.astrode.de/leo2002f.htm`.

Radio meteors

An automated radio system for recording meteor activity

Antonio Martínez Picar[1]

When meteoroids penetrate the terrestrial atmosphere they generate long and thin trails of ionized particles which have the capacity to reflect or (more accurately) re-radiate radio signals. The technique of forward scatter is based on the fact that these meteor trails, when at an appropriate orientation, can be used to establish long-distance communication links. The present work describes the design and establishment of a system of continuous recording of meteor activity based on this technique.

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1 Introduction

The study of interplanetary matter has become an important topic for understanding the origin and dynamics of the solar system. Within solar system studies, the recording, standardization and analysis of meteor observations is one of the fields which has developed greatly in recent years. Of all the methods of meteor observation available nowadays, radio is one of the most attractive. It is the ideal method for carrying out continuous recording of meteor activity because observations are not affected by presence of clouds, rain, light pollution or daylight.

The history of radar astronomy began in 1925 when E.V. Appleton and M.A.F. Barnett in England published their studies on the reflection of radio waves from ionized layers of the upper atmosphere. The first recordings of meteors using radio techniques were performed in 1928, when R.A. Heising observed brief echoes that indicated transitory increases of the density of electrons in the lower part of the atmosphere. The suggestion of A.M. Skellet that these increases could be due to ionization by meteors was verified by J.P. Schafer and W.M. Goodall in 1931 when the simultaneity of ionization peaks and visible meteors was established (Smith & Carr, 1968) Measurements carried out by E.V. Appleton and J.H. Pidington in 1938 indicated that ionized clouds causing the echoes had very small linear dimensions ($\simeq 30$ m) and that they appeared between 80 and 160 km above the ground with a maximum concentration around 115 km (McKinley, 1961)

The first report of the reflection of a continuous wave signal from meteors was by two Hindu radio engineers in 1941, Chamantal and K. Venkatareman. They heard weak whistles of quickly varying frequency when tuned to a non-modulated carrier signal of a transmitter in Delhi (India) 16 km away. The whistles had a difference (or beat) frequency between the direct signal and that from the ionization near the head of the meteor. The meteoroid motion displaced the reflected signal in frequency due to the Doppler effect (Smith & Carr, 1968).

The first theories of the interaction of electromagnetic waves with meteors were developed between 1948 and 1952 (Foschini, 1999), the time when the study of radio transmission began using the technique of meteor forward scatter. One of the most intriguing aspects of this oblique scatter from meteors is that, when the transmitter is separated by some hundreds of kilometers from the receiver, it is possible to detect meteors that are weaker and at greater heights than when the equipment is at a single point on the ground as with backscatter radar (McKinley, 1961). The development of meteor study through the technique of forward-scatter has received less attention than backscatter radar techniques because the theory and interpretation of the observations are seriously complicated by the more complex geometry (Wislez, 1996). Because of this, more general numerical approaches have been developed to the problem of this type of scatter, such as full-wave theory (Jones & Collins, 1974) and the long wave approximation (Jones & Jones, 1990). An important advantage of forward-scatter lies in this technique using transmitters that are already in operation, freeing researchers from the design and maintenance of the transmitter system, and allowing them to concentrate economic and technical resources on the receiving system.

2 System description

Figure 1 shows a basic system for automatic meteor recording using the forward-scatter technique, based on the proposals of different authors (Doreste, 1993; Richardson, 1999; Yellaiah et al, 2001), which served as a general guide for the development of the Automated System for Meteoric Activity Recording (SARAM).

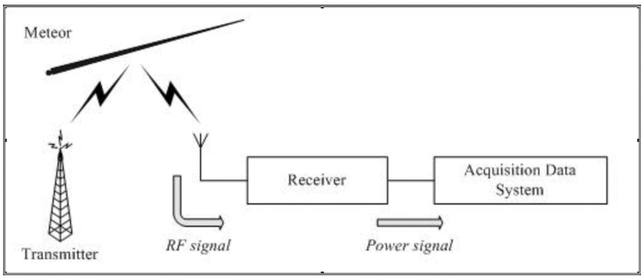

Figure 1 – Basic system diagram for automatic meteor recording using forward scatter.

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2.1 Receiving system

The first step in system design took into account the fact that, for practical reasons, the receiver station would be located in the Electric Engineering School (EES) of the Central University of Venezuela (CUV) in Caracas. This step was the preparation of a list of possible RF transmitters that fulfilled the requirements of power, polarization, sky cover, frequency and operating schedule suitable for use with a single receiver. The criteria used for elaboration of the above list are based on the geometric and electromagnetic considerations published in (Richardson & Meisel, 1997; Verbeeck, 1995; Verbeeck, 1996; Yrjölä, 2002).

After an initial phase dedicated to location and evaluation of possible transmitters on the list, it was finally decided to utilize a video carrier signal of commercial transmitters that operate in the band of frequencies assigned to TV channel 6 (f = 83.25 MHz, 525-line, NTSC color; see Box 1) located in the towns of La Grita (at a distance of 660 km) and Anzoátegui (at 347 km) and whose transmission powers are 75.9 kW and 94 kW, respectively.

The antenna design of the receiving system was based on a four-element Yagi antenna which was modeled with the IRRADIUM software (Barroso, 1999). The final design (shown in Figure 2) has an input impedance of $Z_{\rm in} = 50.19 + j13.14\,\Omega$, a maximum gain of 9.47 dBi and a front-to-back ratio of 14.71 dB.

The antenna elements were manufactured from hollow aluminum pipes of 10 mm diameter. The support was built with a piece of PolyVinyl Chloride (PVC) tube of 75 mm diameter. Considering that PVC is a dielectric material, the elements did not cross the support on a diagonal, but rather on a chord, which reduced the section 'hidden' by the PVC to 50 mm. The areas where the PVC was drilled obliquely were reinforced with 60 mm wide adhesive tape of high electrical resistance. The two tubular components of the dipole (the active receiving element) are supported by a wooden stick 800 mm long. This is an interference fit inside these two tubes and maintains a separation of 5 mm between their ends. The connection between these tube ends and the coaxial cable was made with adjustable brackets. The antenna was mounted on top of a tower located on the roof of the building. The final mounting of the antenna on the tower used another piece of PVC. Taking advantage of the fact that both tubes of PVC have the same diameter, two cuts at appropriate angles were made in this section to provide the appropriate elevation angle. After a series of measurements with different azimuth and elevation angles had been carried out between 2002 April 22 and 29, the optimum antenna orientation was found to be 250° in azimuth and 60° in elevation. The final position of the antenna on the tower was at an average height of 5.3 m above the roof (1.55λ). The SWR (standing wave ratio, see Box 2) measured on this configuration was 1.23, obtained with a Site Master S332B analyzer. Figure 3 shows the final assembly of the antenna on the tower.

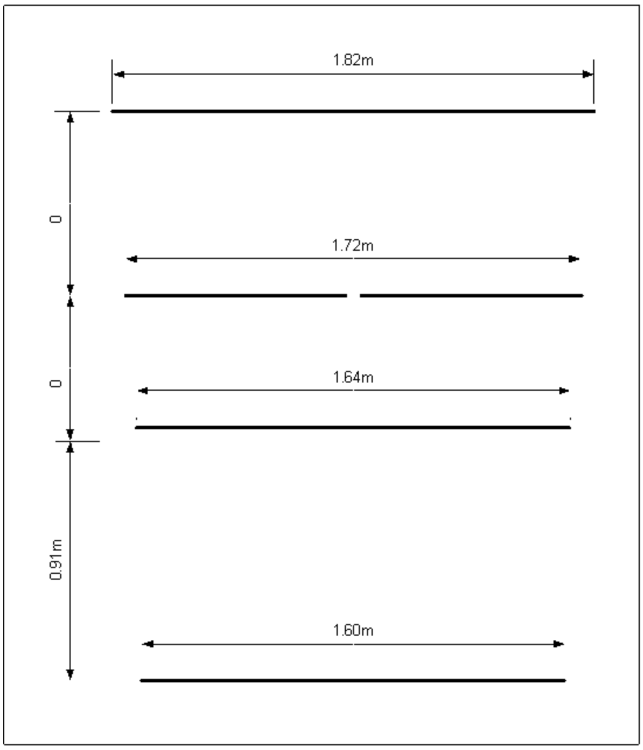

Figure 2 – Four-element Yagi antenna for 83.25 MHz used by the SARAM system.

Box 1 — TV signals

Television transmitters provide convenient high-power signals for back-scatter research. The frequencies transmitted by a TV station cover a wide range, 5.25 MHz in the case of Venezuelan television (which operates on System M). The 83.25 MHz frequency given is a nominal frequency called the carrier frequency. In the case of AM (amplitude modulated) signals such as TV, the variable signal (picture and sound) resides in other frequencies than the carrier: the carrier is of constant amplitude.

System M is 30 frames per second, meaning that the nearest frequency with a variable signal is centred 30 Hz away from the carrier. The use of a 10 Hz receiver bandwidth (described later) means that only the constant carrier will be received, and that changes in TV programme content will not affect the readings.

Readers planning back-scatter observations will need to select a suitable TV transmitter. A standard reference list of these is in the 'World Radio TV Handbook' (published annually), WRTH Publications Ltd., Milton Keynes, UK. — *Ed.*

The antenna is directly connected, through coaxial cables and standard RF connectors, to a Hewlett-Packard model 8564E spectrum analyzer that acts as a receiver, demodulating AM on the stated frequency. The HP 8564E is configured for spot frequency operation (no scanning), 3 kHz resolution bandwidth, 10 Hz video bandwidth, −110 dBm as reference level, 5 dB per division screen display and 10 s for sweep time.

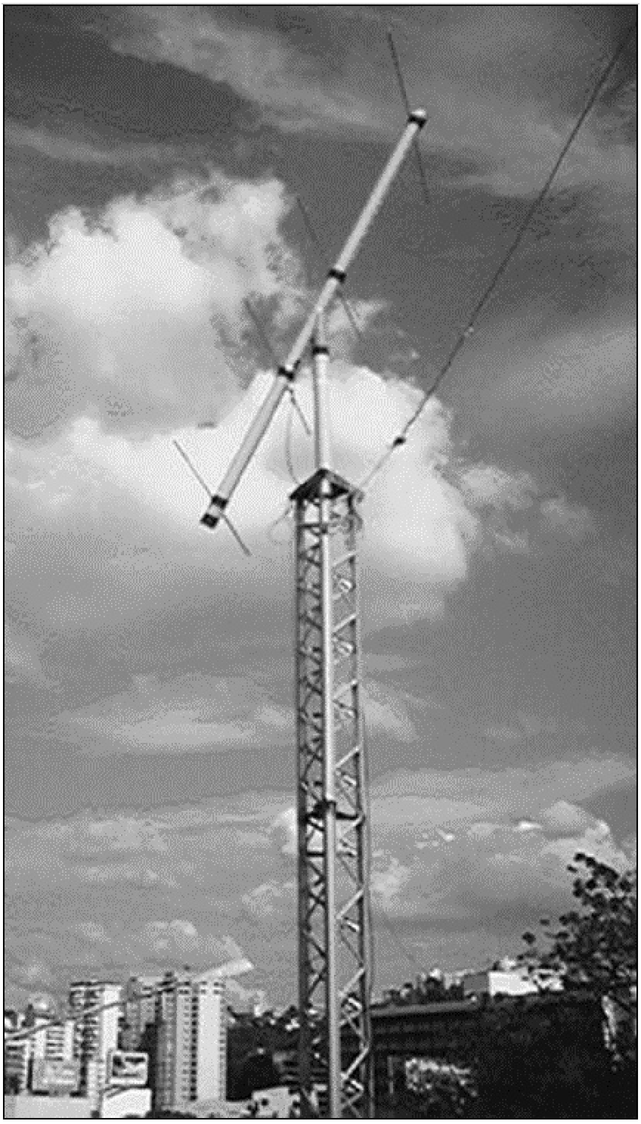

Figure 3 – Final antenna assembly.

2.2 Data acquisition system

To extract and to process the signal produced by the analyzer, the connector J4 it is used (video output) located in the rear panel of HP 8564E, which offers a voltage proportional to the vertical deviation of the signal on screen, and thus to the radio signal strength. This voltage requires an analog-to-digital converter (ADC) as a receiver/computer interface to read the samples into the computer.

A circuit to perform this conversion was developed using the National Semiconductor ADC0831 integrated circuit. Figure 4 shows the circuit diagram. The components of the upper section of diagram concern power supply: they reduce 12V from a commercial 12 V power supply to 5V for the ADC. The potentiometer connected to Vref pin allows the maximum sampling voltage for the ADC0831 to be adjusted.

The ADC0831 chip needs the chip selected signal (CS) and a clock signal – I/O clock – (CLK) to operate; the result of conversion is obtained through the data out pin (DO). It is possible to generate CS and CLK through the corresponding Data Terminal Ready (DTR), Request to Send (RTS) and Clear to Send (CTS) pins of the computer serial port using a simple software routine. The circuit was assembled on a project card which was built into a metal box with the necessary connectors: a DB9 connector to connect it with the computer RS 232 port and a BNC connector for the connection to the HP 8564E.

A personal computer with the following characteristics was used: 150 MHz Pentium processor, 32 MByte RAM, 2 GByte hard disk, communications card (with standard RS232 port), floppy disk drive, CD-ROM, keyboard and monitor. Windows 98 was installed to reduce the disk space used by the operating system. The system clock was synchronized to Venezuelan Legal Time (VLT) using the time signal transmitted by the Cagigal Naval Observatory radio station (5000 kHz, AM).

The computer controls data acquisition and communication with the interface using software written for the purpose, which also handles data storage on hard disk. The CAPTURA program was written in Visual Basic version 6.0 and was developed in different phases that, consequently, became modules and subroutines of the final version. The acquisition and administration module control the receiver/computer interface using instructions that control the DTR and RTS pins of the serial port, as well as detecting the presence or absence of the CTS signal. The information collected is stored in a directory created by CAPTURA and organized in text files whose names represent the date and hour when data acquisition begins. The data obtained are stored sequentially in these files, and a timestamp with the hour and minute is added. At the beginning of every hour of operation, the program closes the current file and creates a new one with the same characteristics; in this manner, a data file for each hour of observation is obtained. A subroutine takes charge of converting the raw data from the interface to physical magnitudes corresponding to the spectrum analyzer's readings.

The CPU load and hard disk access times affect the software timer, making it irregular and unreliable. For this reason the user sets the sampling rate depending on the computer's speed. The precise value of this parameter is calculated by using the timestamps in each

Box 2 — Standing Wave Ratio

Antennas, receivers and the cable connecting them have a characteristic called impedance. For correct performance, the impedances of the antenna, the cable and the receiver should be the same — they are then said to be impedance-matched. Mis-matching results in partial loss of signal. The SWR (standing wave ratio) is a measure of how good this matching is. A perfectly matched system has an SWR of 1, and larger values indicate worse matching. For the frequencies used, the reported SWR of 1.23 indicates a good system.
For further details, see reference works such as chapter 12 of 'Radio Communication Handbook', Bidulph D. (ed.) (6th Edition, 1995), Radio Society of Great Britain, Potters Bar, UK. — *Ed.*

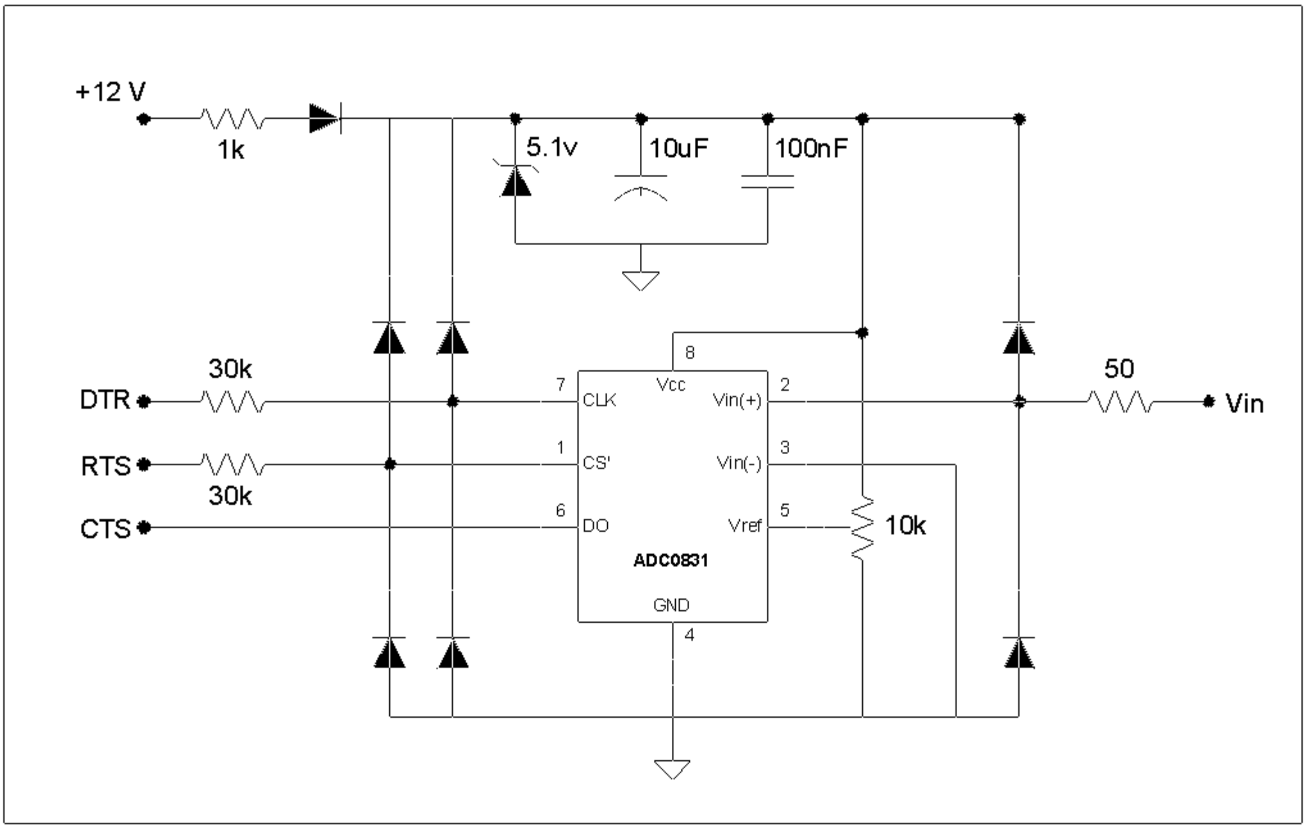

Figure 4 – Circuit diagram for the receiver/computer interface.

data file through the analysis module of the CAPTURA program. This module contains a routine that calculates the average power level of the signal contained in the data file and, using the Maximum and Minimum Threshold values set by the user, counts the meteors recorded. An event will be considered to be a meteor if the signals meet all the following conditions:

- the previous value is smaller than the average plus the Minimum Threshold,
- the present value is bigger than the average plus the Minimum Threshold, and
- the present value is smaller than the average plus the Maximum Threshold.

3 Discussion and results

During the period from 2002 April 22 to 29, the first results of the SARAM receiving system were obtained. At that time the data acquisition system was not complete, but nevertheless the reflections received were observed on the HP 8564E spectrum analyzer's screen. During this period a sky search was carried out varying the antenna orientation to find the position that offered the maximum frequency and greatest signal intensity of meteor events. From these results, it was concluded that the biggest number of reflections, and those of greatest intensity, were recorded with the antenna oriented to 250° azimuth and 60° elevation.

As before, the HP 8564E is configured for spot frequency operation (no scanning), 3 kHz resolution bandwidth, 10 Hz video bandwidth, −110 dBm as reference level, 5 dB per division screen display and 10 s for sweep time. The carrier frequency was 83.25 MHz.

In Figure 5 two power profiles are shown corresponding to two events of low density (left) and high density (right) meteors, obtained with the SARAM system. These images show a resemblance between the profiles obtained by the SARAM system and theoretically expected profiles (Wislez, 1996). The presence of the typical characteristics is confirmed: low density meteors present a strong and abrupt increment in the signal corresponding to the passage of the meteoroid through the first Fresnel zone, which is followed by an exponential decline due to the diffusion of meteor plasma in the atmosphere. For the case of high-density meteors it is seen that, after the typical signal increment, the received power increases and diminishes because the radius of the column first reflects more due to diffusion, but subsequently reflects less as the ionic density becomes very low.

The results obtained from these observations helped to select the threshold values needed by the analysis module of the CAPTURA program, setting the values of Maximum Threshold to 6.5 dB and the Minimum to 4.5 dB for the observations carried out between August 4 and 15, 2002.

During this period, data free from the influence of meteors showers were collected. The graph in Figure 6 shows the activity averages per hour during this period. The average diurnal variation of recorded activity can be seen. The error bars represent the standard deviation of the sample. The curve shown, corresponding to the function $y = 4590.2x^3 + 6491.2x^2 + 2007x + 414.31$,

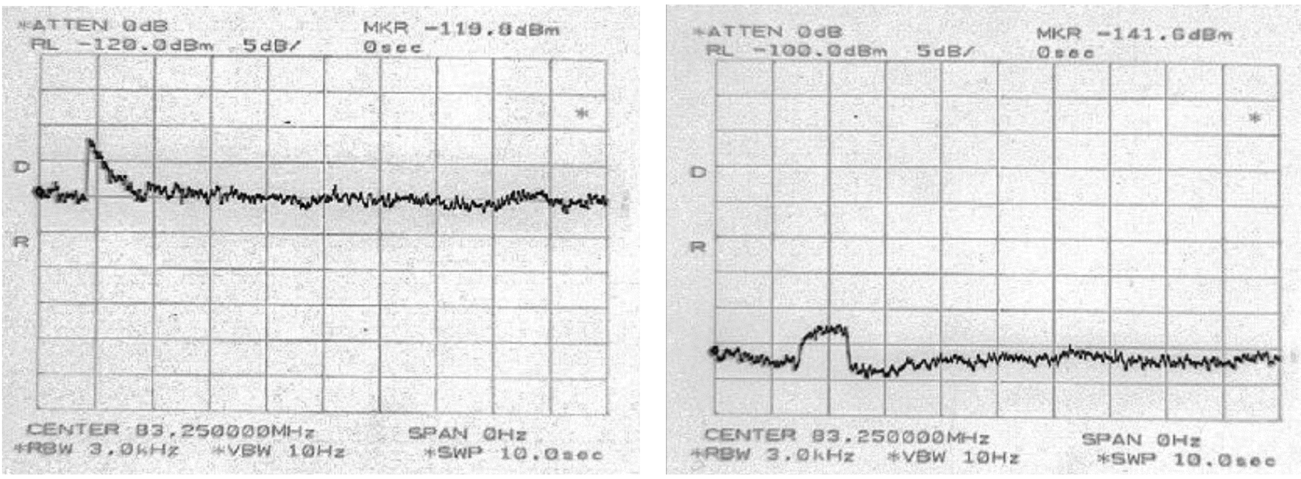

Figure 5 – Two pictures of the HP 8564E screen with low density profiles (2002 April 25, 18:41 UT) on the left and high-density (2002 April 22, 15:07 UT) on the right.

was obtained from a regression analysis carried out on the 44 748 events recorded by the system during the period in question. The correlation between this function and the data is $R = 0.5685$; one must take into account that this graph is based on a small sample. This type of analysis is usually carried out by averaging data over several months, excluding activity periods of major meteor showers (Yrjölä, 2002). Nevertheless, the curve can be seen to approximate the correct one (McKinley, 1961), presenting a minimum toward dusk, between 17^{h} and 19^{h} local time, and a maximum toward dawn, between 04^{h} and 06^{h}.

Observations of the Perseid meteor shower were carried out during the period from 2002 August 9 to 15. The shower's radiant height limited the observation periods to between 00^{h} and 11^{h} VLH (04^{h}–15^{h} UT) due to the geographical location of the system and the time of the year in which this shower occurs. In Figure 7 the Perseid activity recorded by the SARAM system is presented (error bars correspond to sample standard deviation). In 2002 the shower activity maximum could not be observed from Venezuela because the radiant was below the horizon at that time.

It is observed that the activity shows an important increment between 07^{h} and 12^{h} on August 13 (UT), which agrees with Perseid activity recorded by other forward-scatter observation systems worldwide (Ogawa, 2002).

4 Conclusions

With the development and installation of the SARAM system, it has become possible to establish the first Venezuelan radio station for the continuous recording of meteor activity. The work performed becomes one of the first projects carried out in this country related to the study of the reflection of radio signals by meteors. Moreover, the system's capacity to collect standardized information offers the possibility of carrying out studies and analyses that contribute to the international effort to expand knowledge of meteor science.

During the period between 2002 August 4 and 9,

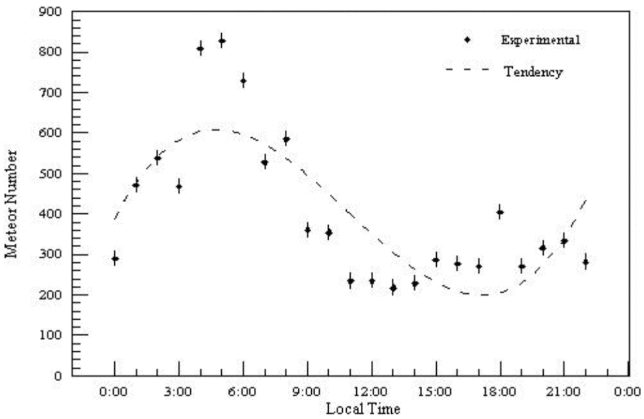

Figure 6 – Daily average variation of meteor activity recorded by the SARAM system, performed on a sample of 44 748 events. The broken line is a polynomial regression of third order fitted to the recorded data (see text).

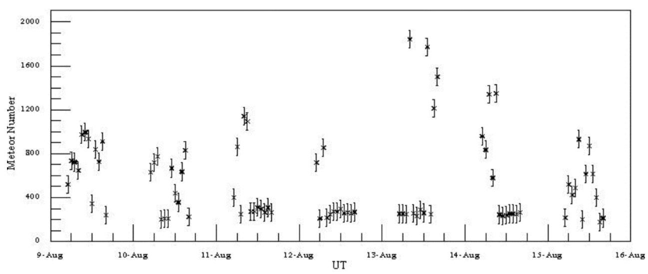

Figure 7 – Perseid activity detected by the SARAM system during 2002 (the periods when the radiant was below the horizon are excluded).

the meteor activity recorded by the SARAM system shows a general minimum towards evening hours (17^h–19^h VLT) and a general maximum maximum towards dawn (04^h–06^h VLT), which indicates the robustness of the system in recording meteors.

The meteor activity recorded by the SARAM system during the period between 2002 August 9 and 15 shows a maximum toward 07^h of August 13 (UT).

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References

Smith A.Y. and Carr T. (1968) "Radioexploración del sistema planetario", Editorial Reverte Mexicana S.A., Mexico.

McKinley D.W.R. (1961) "Meteor Science and Engineering", McGraw-Hill, New York.

Foschini L. (1999) "On the interaction of radio waves with meteoric plasma", *Astron. Astrophys.*, **341** 2, 634–639.

Wislez J.-M. (1996) "Forward scattering of radio waves off meteor trails.", *In: Roggemans P., Knöfel A. (Eds.) Proceedings of the International Meteor Conference 1995*, Brandenburg, 99–117.

Jones J.Y., Collins G. (1974) "The mass distribution of radio meteors and the full-wave scattering theory", *Mon. Not. Roy. Astr. Soc.*, **166**, 529–542.

Jones W.Y., Jones J. (1990) "Oblique scattering of radio waves from meteor trains: long wave approximation", *Planet. Space Sci.*, **38** 7, 925–932.

Doreste D. (1993) "Fundamentos para el análisis digital de reflexiones meteóricas", *Meteors*, **25**, 14–29.

Richardson J. (1999) "The AMS radio meteor project, The Poplar Springs radiometeor station, [on line]. Philadelphia: American meteor society. Available in: `http://www.amsmeteors.org` [2002, May 7th]."

Yellaiah G., Suresh K.Y. and Raghavender (2001) "Study of Es occurrences during meteor shower periods at Hyderabad by using FM radio signals", *Bull. Astr. Soc. India*, **29**, 251–257.

Verbeeck C. (1995) "The spatial distribution of potential forward scatter reflection points", *WGN*, **23:6**, 236–243.

Verbeeck C. (1996) "The first Fresnel zone and the power profile throughout the forward scatter reflection surface, In: Roggemans P., Knöfel A. (Eds.), Proceedings of the International Meteor Conference 1995" Brandenburg, 83–98.

Yrjölä I. (2002) "Meteor scatter observation with VHF radio and computer, [on line]. Kuusankoski, Finlandia. Available in: `http://www.sci.fi/~oh5iy/msobs` [2002, August 15th]."

Richardson J.Y., Meisel D. (1997) "The AMS radiometeor project", *AMS Bulletin*, **No. 203 (revised)**, The American Meteor Society, State University of New York.

Barroso R. (1999) "Desarrollo de un programa usando el método de los momentos para alambres delgados, para calcular los parámetros principales de un arreglo de antenas", Grade Thesis, Central University of Venezuela (in Spanish).

Ogawa H. (2002) "The international project for radio meteor observation – Perseids 2002", [on line]. Nippon Meteor Society. Available in: `http://homepage2.nifty.com/~baron/per02p.htm` [2002, August 28th].

History

Meteor Beliefs Project: Meteoric references in Ovid's *Metamorphoses*

Andrei Dorian Gheorghe[1] *and Alastair McBeath*[2]

Three sections of Ovid's *Metamorphoses* are examined, providing further information on meteoric beliefs in ancient Roman times. These include meteoric imagery among the portents associated with the death of Julius Caesar, which we mentioned previously from the works of William Shakespeare (McBeath & Gheorghe, 2003b).

1 Introduction

The ancient Roman poet Publius Ovidius Naso, more commonly known as Ovid (43 BC to 18 AD), wrote perhaps the greatest of his surviving works, the *Metamorphoses*, around 2–7 AD, shortly before Augustus Caesar banished him to Tomi in 8 AD. Tomi is said to be named from the Greek 'temio', 'to cut', as this is where, in some versions of the Argo myth, Medea is supposed to have murdered her brother Apsyrtis, cut up his body, and cast it into the water to delay the pursuing Colchians as she, Jason and the Argonauts were returning to Greece with the golden fleece. Tomi is modernly Constanţa, Romania's second city, on the Black Sea some 120 km south of the delta of the River Ister (today the Danube).

Ovid, perhaps influenced by such tales, described Tomi in ghastly terms, as having a harsh climate, unlovely scenery, and being home to an uncultured, savage people (although he wrote at least one poem in the local Geto-Dacian language, and since the 19th century, Ovid has been thought of as the first Romanian poet; a statue of him by Ettore Ferrari was set up in Tomi in 1887). Indeed, he was so distraught at the thought of his banishment, that he burned his original manuscript of the *Metamorphoses*. Luckily, copies survived with some of his friends, and these have been passed down in various other recopied forms to us today.

The poem is a handbook of classical mythology, the single most important source of such material for all subsequent writers. The English authors Chaucer, Milton and Shakespeare are known to have drawn extensively upon it. Although much ancient Greek and Roman mythology survives in the works of others before Ovid, texts which he himself also used, Ovid brings a freshness and vivacity to the retelling of the tales.

We discuss three sections from the *Metamorphoses* here, each taken from two separate translations, one in prose including a full Latin text (Miller, 1977) and (Miller, 1984), the other a free-verse translation which is more of a reinterpretation of Ovid's text in parts, but which has its own fascination (Slavitt, 1994). As in some of our earlier comments in these articles, this helps give a flavour for how the same material may be approached and translated differently by different modern authors.

2 Phaethon

The myth of Phaethon taking his Sun-god father's chariot on a disastrous career across the sky, scorching Earth and heavens, is well-known. Some modern meteor/comet science writers have tried to see in it an ancient close cometary approach to the Earth, actually causing the devastation of the myth.

Unfortunately, much of this work has been carried out with little appreciation of the difficulties in interpreting myths, and in dealing with not one, but many, variants of the same tale, not all extant. Until more rigour is employed, reworkings of this nature should be treated with caution. They do show the power of myths to still capture and manipulate the human imagination, millennia after they were first written down, however, creating an entirely new meteoric belief system.

In his retelling of the Phaethon story, Ovid adds ideas, including the bringing to life of some of the constellations the calamitous journey passes, such as the two Bears, Ursa Major and Minor. The Serpent Draco is heated into frenzy from its normal icy torpor near the boreal pole, while Boötes lumbers off in terror, with his clumsy ox-cart in tow (Book II, lines 171–177; (Miller, 1977, pp. 72–73)). This most likely provided some inspiration for Piers Anthony's living constellations which we looked at in our first Meteor Beliefs Project article (McBeath & Gheorghe, 2003a).

Eventually Jupiter, father of the gods, is forced to intercede, and kills Phaethon with a hurled, fiery, thunderbolt. So we reach the meteoric section:

> But Phaëthon, fire ravaging his ruddy hair, is hurled headlong and falls with a long trail through the air; as sometimes a star falls from the clear heavens, although it does not fall, still seems to fall. Him far from his native land, in another quarter of the globe, Eridanus receives and bathes his steaming face. The Naiads in that western land consign his body, still smoking with the flames of that forked bolt, to the tomb and carve this epitaph upon his stone: HERE PHAËTHON LIES: IN PHOEBUS' CAR HE FARED, AND THOUGH HE GREATLY FAILED, MORE GREATLY DARED.
>
> *Book II, lines 319–328 (Miller, 1977, pp. 82–83).*

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Phaëthon,/ his hair ablaze, is thrown free, plummets down through the air,/ leaving a neat contrail of fire and smoke behind him./ As a shooting star that seems sometimes to fall from a clear/ sky and makes its momentary punctuation,/ so Phaëthon fell, and fell, and landed at last,/ far from his native place, in the river Eridanus,/ which received his broken corpse and bathed the ruined face./ The nymphs thereupon performed the solemn rites of interment/ for the charred flesh, which was all that remained of the handsome lad/ after the thunderbolt's devastation. They carved on a stone/ an epitaph to mark the site and note the life:/ IN . THIS . PLACE . PHAËTHON . LIES . WHO . ROSE . IN . HIS . FATHER'S . CAR/ WITH . A . DARING . BEYOND . HIS . STRENGTH . OR . WISDOM — AND . FELL . FAR.
Book II, lines 317–330 (Slavitt, 1994, p. 29).

3 Hersilia, wife of Romulus

After the death of Romulus (legendary father of the Roman people), now referred to by his deified post-mortem Roman name of Quirinus, his grieving widow is brought to the top of Romulus' hill in Rome by Iris, goddess of the rainbow:

> There a star from high heaven came gliding down to earth, and Hersilia, her hair bursting into flame from its light, goes up together with the star into thin air. Her with dear, familiar hands Rome's founder receives, and changes her mortal body and her old-time name. He calls her Hora, and now as a goddess is she joined once more to her Quirinus.
> *Book XIV, lines 846–851 (Miller, 1984, pp. 360–361).*

> Rainbow's daughter then took the queen by the hand and led her/ to the top of Romulus' hill, where a bright star from the heavens/ came down to earth. Hersilia's hair at once caught fire,/ burst into flames so she was transformed, was a star, and ascended/ herself into the air, climbing the firmament, rising/ until the founder of Rome could receive her in his embrace./ She felt the familiar arms enclose her and change her body/ from the mortal that it had been to something new and immortal,/ just as her name changed from Hersilia to Hora -/ the goddess of time and seasons - joined to her husband Quirinus./
> *Book XIV, lines 842–851 (Slavitt, 1994, p. 306).*

This piece of mythology records a Roman tradition regarding the deification of their legendary originator, who could scarcely be expected to enjoy his deification without his beloved spouse. Her main claim to fame was as his wife, so the employment of the meteor as both the agent of her death and her means of transportation to the living afterlife of deification, adds the necessary magical or otherworldly twist to help raise her to greatness. Despite Slavitt's added comment, it is not clear if her new name Hora equates her as one of the Horae (note this is plural), the Hours, goddesses of time, and attendants of the Sun-god.

4 Caesar

As we discussed last time (McBeath & Gheorghe, 2003b), Shakespeare reused and reworked Ovid's information about the portents seen before Julius Caesar's death. Finally for this time, we look at the original versions of those, as well as the comet Caesar was said to have become after dying.

Julius Caesar was assassinated in 44 BC, the year before Ovid was born, so it is likely Ovid grew up with tales of events surrounding Caesar's death recounted to him at first-hand, tempered further by his having the benefit of viewing subsequent events with hindsight when he wrote. He first uses meteoric imagery in this regard in Book XV, lines 749–750, already discussing events after Caesar's death.

Caesar was:

> ...changed to a new heavenly body, a flaming star; but still more his offspring deified him.
> *(Miller, 1984, pp. 416–417.)*

> Caesar, splendid in war and peace as well, achieved/ great things for us all, and his glory, so well-observed, showed bright/ in the new star in the sky that he became. His godhood/ his son declared and proved...
> *Book XV, lines 744–747 (Slavitt, 1994, p. 327).*

Then, in-keeping with the apocalyptic beliefs of his time (on which in this regard see (McBeath, 1999)), Ovid gives the portents associated with Caesar's murder (Book XV, lines 782–790):

> They say that the clashing of arms amid the dark storm-clouds and fear-inspiring trumpets and horns heard in the sky forewarned men of the crime; also the darkened face of the sun shone with lurid light upon the troubled lands. Often firebrands were seen to flash among the stars; often drops of blood fell down from the clouds; the morning-star was of dusky hue and his face was blotched with dark red spots, and Luna's chariot was stained with blood.
> *(Miller, 1984, pp. 420–421)*

> Lightning flashed in the sky, and battle horns resounded/ in baleful bellows, which came from nowhere to charge the air/ with shivers of awe. The Sun's bright face turned dim and sickly,/ as if the ills of earth had infected his golden light./ The skies at night were aglow with ominous flashes. At dawn/ the morning star was spotted and blotchy. Strange dark clouds/ drifted above, and it rained, not water but drops of blood./ The moon at night shone red as a wound...
> *Book XV, lines 783–790 (Slavitt, 1994, p. 328).*

After Caesar's death, his patron deity or mother goddess Venus:

> ...caught up the passing soul of her Caesar from his body, and not suffering it to vanish into air, she bore it towards the stars of heaven. And as she bore it she felt it glow and burn, and released it from her bosom. Higher than the moon it mounted up and, leaving behind it a fiery train, gleamed as a star.
> *Book XV, lines 845–850 (Miller, 1984, pp. 424–425).*

> ...Venus sped to the Senate chamber/ to catch up Caesar's soul and carry it into the heavens./ She felt its fiery heat as she clutched it tight to her bosom,/ and she let it go. She watched as it rose on its own to the heights/ above the moon. It mounted higher and left a blazing / comet's tail in its wake as it reached its assigned position,/ where it shines now as a star and beams in paternal approval/ of what his son and heir is achieving.
> *Book XV, lines 845–852 (Slavitt, 1994, p. 330).*

Interestingly, Miller's translation, more strictly accurate to the Latin text, seems to be describing what other sources give as a comet, as a very bright meteor, or perhaps is describing a comet in very meteoric terms. Slavitt clearly shows influence by other ancient authors in his more closely cometary interpretation.

5 Conclusion

We hope you will agree both versions of our chosen translations have their own merits and, as ever, would encourage anyone interested to read the full texts, not merely our meteoric extracts. While Ovid reflects beliefs about meteors and death, he also pulls in the idea that meteors are linked to deification, and the transformation between mortal life and a deified afterlife ('metamorphoses' means 'changes' after all!), as well as touching on the fiery nature of meteors. Perhaps with the description of Phaethon's fall, we see some early influential ideas about burning hot meteoritic objects falling from the sky, concepts which still persists to this day, no matter how generally incorrect we believe them to be, at least for normal small meteorites. With so great a poet, it was inevitable that even such minor aspects as these few lines of meteoric imagery should be carefully reworked and interwoven with multiple layers of meaning.

References

McBeath A. (1999) "Meteors, Comets, and Millennialism", *WGN* **27:6**, 318–326.

McBeath A., Gheorghe A. D. (2003a) "Meteor Beliefs Project: Introduction", *WGN* **31:2**, 55–58.

McBeath A., Gheorghe A. D. (2003b) "Meteor Beliefs Project: Some Meteoric Imagery in the Works of William Shakespeare", *WGN* **31:4**, 121–123.

Miller F. J. (translator; revised by G. P. Goold) (1977) "Ovid, Metamorphoses, Books I-VIII (3rd edition)" Harvard University Press (Loeb Classical Library)

Miller F. J. (translator; revised by G. P. Goold) (1984) "Ovid, Metamorphoses, Books IX-XV (2nd edition)" Harvard University Press (Loeb Classical Library)

Slavitt D. R. (translator) (1994) "The *Metamorphoses* of Ovid, Translated Freely into Verse" Johns Hopkins University Press

Ongoing meteor work

A re-evaluation of the Phoenicid outburst in December 1956

Alastair McBeath[1]

The 1956 Phoenicid outburst has been used as a standard for suggesting low-velocity meteor showers may be less readily observed by backscatter radar and forward-scatter radio observing methods. This derives from a single paper, (Weiss, 1958), in which a radar rate of 30 meteors per hour was claimed as unexpectedly low for the Phoenicids early in their outburst on 1956 December 5. In a re-examination of Weiss's paper, problems were found both in terms of what data were not recorded by radar during the outburst, and the supposed rate of 30 meteors per hour, which latter could not be confirmed. Instead an observed Phoenicid hourly radar rate of between $\simeq$ 35–50 was revealed, possibly peaking between $\simeq 10^{\rm h}20^{\rm m}$ and $11^{\rm h}10^{\rm m}$ UT, coincident with a potential first maximum of up to three suggested by the visual reports.

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1 Introduction

During discussions while preparing an analysis of the radio π-Puppids in 2003 (McBeath, 2003), the possible problems came up associated with slow-moving meteors producing relatively little radio-reflecting ionization, and thus being poorly detected by radio observing techniques. This was first raised by A.A. Weiss as an explanation for why the 1956 December 5 Phoenicid outburst, which was detected strongly by visual observers (best EZHRs $\simeq$ 100–140, discussed in section 3 below), was recorded apparently weakly by the Adelaide meteor radar (Weiss, 1958). Such an explanation fits poorly with how well the 1998 June Boötid outburst (ZHRs $\simeq$ 50–100 (Rendtel et al., 1998)) was recorded by radio observers around the world (cf. McBeath, 1998; Maegawa et al., 1999), as the June Boötids have a similarly slow atmospheric velocity, $\simeq$ 18 km/s, to that estimated for the Phoenicids. This is especially curious, as the modern radio systems typically collected rather fewer echo numbers overall than the 1956 Adelaide radar equipment. It was decided to re-examine the Phoenicid outburst, to see if some other explanation for Weiss's findings might be possible.

2 The present Phoenicids

In common with many southern hemisphere showers, little detailed observation of the Phoenicids (PHO) has been carried out since the mid 1980s. Kronk (1988, pp. 261–263) briefly summarized the results published during the 1970s and 1980s, although the few reports from 1972–1977 must be treated with caution. Peak ZHRs from more reliable sources between 1977 and 1986 were available for only six years, but ranged from $\simeq$ 3–8, averaging 5. The details in (Rendtel et al., 1995, pp. 250–251) extended this period to 1988, but the maximum rate was below the visual detection threshold (ZHR < 3) in 1988. The shower's elements, as currently delimited in the annual *IMO Meteor Shower Calendar*, were derived chiefly from the more reliable Australian data produced since 1977. For clarity, these are repeated in Table 1.

The proposed connection between Comet D/1819 W1 Blanpain and the PHO was heavily criticized, and ultimately disproven, by Steel (1995). Thus the shower does not presently have an associated parent body. Indeed, the PHO stream's orbital elements are not known with any accuracy; the details in (Rendtel et al., 1995) are to be preferred to those in (Kronk, 1988) in this regard.

3 The 1956 Phoenicid outburst

As is obvious from the preceding section, no strong PHO outburst has been reported since the shower's discovery in 1956 although, given the often very patchy coverage, other outbursts could have passed unobserved. The main published papers containing observations of the 1956 outburst consist of (Anonymous, 1956; Shain, 1957; Weiss, 1958; Ridley, 1962). Ridley's paper précised the information in the other sources, as well as report summaries provided directly to him. The other papers, all Australian, are important, however, as they gave details Ridley did not mention. The anonymous piece in the 1956 December issue of the *Journal of the Astronomical Society of Victoria* had near-verbatim visual data accounts from T.B. Tregaskis (and his wife, who continued counting meteors while he briefly tele-

Table 1 – The current PHO details from (McBeath, 2004, p. 16).

Activity dates	Maximum date	Radiant $\lambda_\odot$	α	δ	V_∞ km/s	r	ZHR
Nov 28 – Dec 09	Dec 06	$254\overset{\circ}{.}25$	18°	−53°	18	2.8	variable

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phoned an alert to another observer reported there, J P Hamilton). They and L.R. Whitby were all in Melbourne, from where the sky was noted as 'unusually clear' in the early part of the night, when the watches were carried out. Shain reported his own visual data from near Sydney, and preliminary comments on the radar data by Weiss, while Weiss covered the Adelaide meteor radar results.

By modern standards, a lot of information is lacking in the published visual data especially. This missing detail includes:

- No LMs, and little information on sky conditions generally.
- Commonly no T_{eff} stated.
- Sometimes roughly estimated or uncertain meteor numbers cited.
- Often little indication given regarding the accuracy of the shower association involved.
- The previous problem compounded by a large variation in the estimated radiant positions. The outlying values are $\alpha \simeq 10°$ to $70°$, $\delta \simeq -58°$ to $+10°$, with no common agreement between observers.
- Few quantitative meteor magnitude estimates.

Rendtel (1996) attempted to overcome part of these problems by using two assumed LM values of +5.5 and +6.5, with $r = 2.5$, and a radiant position at $\alpha = 15°$, $\delta = -45°$ (note this is different to the currently accepted position), to compute estimated ZHRs.

The visual observations do not fit to a simple pattern of activity, as shown most clearly by Rendtel (1996, Figure 1), which graph suggested perhaps three ZHR maxima, at around 10^h35^m, 13^h15^m and 19^h00^m UT on 1956 December 5. There is a significant problem in interpreting the results due to a gap in the data between 13^h30^m and 18^h UT, however. This can be partly filled qualitatively from the comments in Table 1 of (Ridley, 1962), narrowing the gap to between $\simeq 14^h$ and 17^h UT, but this material is not detailed enough to allow even an estimate of potential ZHRs.

Observed PHO rates tabulated in (Ridley, 1962) ranged at best from roughly one every five minutes up to about one or two a minute, while the EZHRs in (Rendtel, 1996) lay between 8 and 275. Using Rendtel's suggested EZHR averages gives a reduced range of $\simeq$ 15–195. The mean of these two ranges indicates that rough limits of $\simeq$ 100–140 may give a guide to the nature of the peak EZHRs. These figures should not be regarded as anything other than very approximate measures for the activity, but point to the probable order of magnitude involved. Confusingly, a rate of 100 meteors per hour is the most commonly cited value for the outburst in the meteor literature, typically without making clear that this is actually an observed rate, not a computed one. In fact, this value is based on just one report of 102 meteors in a T_{eff} of 60 minutes spread over two hours between 18^h and 20^h UT, by G. Bebink in South Africa (Ridley, 1962, Table 1).

The most objective view of the 1956 PHO outburst was that of the Adelaide meteor radar. According to Ridley (1962), the other southern hemisphere meteor radar of the time, at Christchurch in New Zealand, was not operating during the critical interval, unfortunately. Shain (1957) cited a personal communication from Weiss thus: 'During routine operation of the 67 Mc/s [MHz] meteor radiant equipment at Adelaide, a strong shower was recorded on the nights of 1956 December 5 and 6. The shower was of short duration, no activity being detected before or after these dates.' Weiss was cited further by Shain as adding a preliminary radiant position for the meteors, and said that nothing of such a shower was found in results from 1952–1954.

By the following year, Weiss had revised his preliminary opinions quite considerably. Weiss (1958) has the shower detected for a short time ($<$ 2h) on just one night, and there is no longer any mention of strong activity. Instead, from his abstract: 'The radio rate of 30/hr measured on an equipment of high sensitivity is much lower than expected from the visual rates of from 20 to 100/hr reported from 1 to 9 hr later.' Surprisingly, Weiss also managed to write his paper without once mentioning the date of the observations, though by inference, it must have been December 5. It is not unusual that preliminary findings might be amended when a final analysis has been completed of course, but such a radical reassessment without comment is less commonplace, assuming Shain had accurately reported Weiss's earlier remarks. Certainly, there is no reason to think he had not. Weiss made no corrections to his attributed quotes in Shain's letter, for example, though he did refer to it.

4 Weiss's 1958 Phoenicid paper re-examined

Weiss (1958) mentioned a whole series of tasks the Adelaide meteor radar was unable to accomplish during the 1956 PHO outburst. Observing of the radiant was only possible between $\simeq 09^h40^m$ to 12^h20^m UT (19^h40^m to 22^h20^m local time), as just one recording channel and one aerial were functioning. This also meant the radiant position could not be accurately measured, and had to be estimated using a computed method to fit an envelope of probability to the recorded range-time meteor echo plots, taking an assumed mean PHO meteor height of 90 km. A radiant was thus suggested at $\alpha = 15° \pm 2°$, $\delta = -55° \pm 3°$. Decreasing the mean meteor height, because slower-moving meteors would be expected to ablate lower in the atmosphere than this mean of 90 km, would further increase these uncertainty limits, although Weiss did not comment on what the change would be, other than to dismiss it as 'small'. No velocity measurements could be made using the type of radar system in operation, nor were any echo duration and amplitude data secured, making it much more difficult to estimate the probable meteor brightnesses/meteoroid sizes. An attempt was made to compare equal numbers of PHO and sporadic meteors, using the rather crude method of subjectively assigning the spot intensities of the echoes recorded on photographic film (the standard recording medium for radar meteor data at the time) into four bins, from 'weak' to 'strong'. This suggested the PHO meteors during the observed part of the outburst were very similar to the sporadics seen well before and after the PHO event, implying a relatively faint magnitude range for the observed PHO meteors.

With so many problems, Weiss's Figure 1, a range-time plot of all the radar echoes recorded during the observed period, thus comprised the most useful hard data the Adelaide radar collected during the outburst. Even so, the numbers of PHO meteors shown on it were estimates, albeit reasonably accurate ones, due to having to use the range-time envelope, rather than a direct identification of each meteor's radiant. In addition, the range-time envelope could only be applied between $\simeq 20^{\rm h}$ and $21^{\rm h}45^{\rm m}$ local time ($\simeq 10^{\rm h}$ to $11^{\rm h}45^{\rm m}$ UT). The numbers of echoes represented by this Figure are given in Table 2 here.

The non-PHO meteors recorded during the observation, hourly rates of 9, 15 and an extrapolated 18 (as the third period was only 40 minutes long), are reasonable for the anticipated sporadic numbers during the mid evening hours, as Weiss indicated radar sporadic rates in early December 1956 away from the PHO outburst were $\simeq 600$ per day (an average of 25 per hour). It is less clear what effect the selectivity of the aerial's direction-sensitivity may have had in terms of the PHO numbers. Weiss made no comment concerning this, perhaps because he did not consider it significant.

In his Table 2, Weiss gave an hourly radar rate of 30 for the PHO, although where this value came from was not stated. It is not apparent from his Figure 1, where there was no uniformity in PHO numbers over time. With a total of 59 PHO recorded as falling within the range-time envelope between $10^{\rm h}00^{\rm m}$ and $11^{\rm h}45^{\rm m}$ UT, this would equate with an observed hourly rate average of $\simeq 34$, although as these PHO meteors actually occurred between $10^{\rm h}06^{\rm m}$ and $11^{\rm h}36^{\rm m}$ UT (as estimated by eye from Weiss's Figure 1), this average hourly number should be $\simeq 39$. Taking only the best hour, between $10^{\rm h}20^{\rm m}$ and $11^{\rm h}20^{\rm m}$ UT, the number rises to 49, with the three 20 minute periods in that hour extrapolating out to observed hourly rates of 54, 51 and 42, respectively.

On page 116 of his paper, Weiss commented that the Adelaide observations 'extended from 11 to 12.30 hr U.T.'. (Weiss gave clock times throughout using this style of notation, '12.30', to indicate hours and minutes. It does not indicate decimal fractions of an hour.) This tallies very poorly with the times from his Figure 1, as noted above. Rather worryingly, taking the total number of all radar echoes after $11^{\rm h}$ UT (43) and dividing by 1.5, for the supposed observing interval's length, gives a total of $\simeq 29$. If this is where the radar rate of 30 has come from, it has nothing to do with the PHO meteors as detected by the radar system.

Allowing that the better PHO rates observed by radar at Adelaide were really between 1.33 and 1.8 times higher than Weiss stated, this still seems less impressive than a comparison with the visual rates might imply, based on statistics in Weiss's Table 2. It is unfortunate that the radar system was operating at far from its peak efficiency, thus failing to provide much data which would have been of great interest. The suspicion is that with so many problems in collecting the results, the relatively low PHO rates may have had more to do with those problems than the overall detected meteor rates. Although Weiss provided comparison Adelaide radar rates, and visual data from other sources, for the maxima of the δ-Aquarids and Geminids (in his Table 2), because he failed to comment on whether those rates were obtained under the same problematic observing circumstances as the PHO data, it is most unclear if such a direct comparison was viable. If the observing circumstances were different, that could invalidate his argument that the PHO radar rates were unusually low.

Regardless of the actual or relative radar rate numbers, the contribution by the PHO meteors is very clear. Even in the absence of any shower identification, it remains obvious that something unusual was happening in at least the best hour, from the raw total echo counts alone (Table 2 here).

5 Evidence for multiple peaks within the Phoenicid outburst

As mentioned in section 3 above, the visual EZHRs examined by Rendtel (1996) suggested more than one peak may have happened during the PHO event on 1956 December 5, despite their limitations. Intriguingly, the pattern in visual rates around the first of these peaks seems very similar to that seen in the radar data. The visual datapoints and EZHRs are given in Table 3 here, together with some short-interval EZHRs in Table 4, to compare with Table 2. The first strong peak, visually around $10^{\rm h}35^{\rm m}$, ending perhaps around $11^{\rm h}10^{\rm m}$ UT, ties in with the stronger radar rates from $\simeq 10^{\rm h}20^{\rm m}$–$11^{\rm h}$ UT, which fell over the next twenty minutes, to be relatively

Table 2 – Numbers of radar meteor echoes detected by the Adelaide system on 1956 December 5 during the indicated 20-minute-long UT intervals. Extracted from Figure 1 of (Weiss, 1958).

Interval beginning at:	$09^{\rm h}40^{\rm m}$	$10^{\rm h}00^{\rm m}$	$10^{\rm h}20^{\rm m}$	$10^{\rm h}40^{\rm m}$	$11^{\rm h}00^{\rm m}$	$11^{\rm h}20^{\rm m}$	$11^{\rm h}40^{\rm m}$	$12^{\rm h}00^{\rm m}$
PHO echoes	0	6	18	17	14	4	0	0
Non-PHO echoes	3	5	1	2	5	8	3	9
Total echoes	3	11	19	19	19	12	3	9

low by 11^h20^m–11^h40^m UT, rather as the visual data suggests. This general pattern is supported by the less numerical data around the same times in (Ridley, 1962). It is interesting that the observers' comments listed by Ridley start to mention notably bright or brilliant meteors only after $\simeq 12^h30^m$ UT, which might imply there were more normal to faint magnitude PHO meteors before this time. T.B. Tregaskis in (Anonymous, 1956) noted a magnitude range from brighter than +1 to +5 or fainter, but implied few bright events, and said the brightest one was roughly comparable to Venus, thus magnitude $-4/-5$. J.P. Hamilton (*ibid*) commented on only one of his six meteors being brighter than Sirius. The radar data would seem to support this idea too, as noted before. This interpretation should be approached with caution, because the radar pattern may relate more to the aerial's sensitivity than the real meteor rates, though the fact the visual and radar activities do seem comparable in character during this interval could be taken as an unlikely chance coincidence.

Table 3 – Visual PHO EZHRs between 10^h and 12^h UT on 1956 December 5, from (Rendtel, 1996). The EZHRs are averages of those calculated for LM = +6.5 and +5.5, using the two limiting magnitude values as the lower and upper limits respectively (given as a single ± error here for simplicity). All were computed assuming $r = 2.5$.

Central UT of observing interval	Average EZHR	± error
10^h35^m	175	75
11^h38^m	59	26
11^h41^m	28	12

Table 4 – Visual PHO short-interval EZHR averages for the indicated observers, computed as for Table 3, but using data from (Anonymous, 1956) and Tregaskis' estimated radiant position at $\alpha = 60°$, $\delta = -38°$. Hamilton's observing interval has been reduced just to the approximate time he noted meteors in. His full claimed interval was 11^h30^m–11^h53^m UT, but he had left a lit building, and was under time pressure to return indoors as soon as possible.

UT interval	$T_{\rm eff}$ (h)	No. PHO	EZHR (Ave.)	± error
T.B. Tregaskis*:				
11^h08^m–11^h11^m	0.05	9	340	146
11^h11^m–11^h34^m	0.38	8	40	17
11^h34^m–11^h44^m	0.17	5	55	23
11^h44^m–11^h54^m	0.17	4	43	18
11^h54^m–12^h08^m	0.23	6	47	20
J.P. Hamilton:				
$\simeq 11^h35^m$–11^h50^m	0.25	6	43	18

* Tregaskis' wife observed briefly, in the second listed interval.

The lack of radar data after 12^h20^m UT makes it impossible to attempt confirmation of the other two potential visual maxima implied by Rendtel's findings. If the suggestion here is correct for the possible first peak, they may have been genuine features too. This could mean the 1956 PHO outburst may have resulted from a series of meteoroid filaments, perhaps similar to some of the Leonid events witnessed in recent years. The apparently coincident radar-visual data for a possible first peak, and the likelihood that the main (here second) peak at least was recorded over South Africa, gives a moderate case for suggesting any future PHO outbursts may also show a complex pattern of maxima.

6 Conclusion

The observing problems with the Adelaide meteor radar during the 1956 PHO outburst have been largely ignored over the intervening half century, and Weiss's conclusions on it have been generally accepted without much questioning. It seems clear now that this has led to an inaccurate assessment of how the PHO were perceived by radar. It has not proven possible to determine how Weiss arrived at his hourly radar rate of only 30, nor why he failed to comment on what effect the problematic observing circumstances may have had on the observed PHO numbers. It seems more likely that the relatively low observed radar rate of $\simeq$ 35–50 an hour resulted from these difficulties, rather than because of any putative problems due to low-velocity meteors producing too little radio-reflecting ionization to be detected properly, as Weiss supposed. This is particularly so as the low-velocity 1998 June Boötid outburst, with visual ZHRs apparently comparable to or lower than the 1956 PHOs, produced a readily-detectable signature for modern radio observers, whose equipment typically recorded somewhat lower general echo counts than the 1956 Adelaide meteor radar.

However, the radar data do seem to confirm the tentative visual findings of an early first peak in the PHO outburst, most likely in the period between 10^h20^m and 11^h10^m UT on 1956 December 5, something which has not been remarked upon previously. This may imply a filamentary structure within the PHO stream segment encountered in 1956.

Attempts are underway to try to establish if any more of the original visual observations from 1956 have survived and, if so, whether additional details beyond those extracted from the summaries Ridley had access to might be recovered. If anyone reading this knows of such material from Australia, New Zealand or other southern Pacific islands, the southern Indian Ocean, South Africa; or especially if there are any newly-discovered, previously unreported observations of the outburst from South or Central America, please contact the author with details. There are huge gaps in coverage before 10^h10^m, between 14^h and 17^h, and after 21^h UT on December 5. Any data to try to help fill these, or confirm the other observations, would be most welcome.

References

Anonymous (1956) "The December 5 Meteors", *Journal of the Astronomical Society of Victoria*, **9**, 93–94.

Kronk G.W. (1988) "Meteor Showers: A Descriptive Catalog", Enslow Publishers Inc., Hillside, NJ, USA..

Maegawa K., Ueda M., and Minagawa Y. (1999) "HRO Caught Outburst on June 27, 1998", *WGN*, **27:1**, 76–80.

McBeath A. (1998) "SPA Meteor Section Preliminary Radio Results: 1998 June Bootid Outburst", *WGN*, **26:4**, 173–176.

McBeath A. (2003) "SPA Meteor Section Results: Preliminary Report from 2003 April 20–26" *WGN*, **31:4**, 111–116.

McBeath A. (2004) "2004 Meteor Shower Calendar", IMO.

Rendtel J. (1996) "Meteors, literature — what to believe?" Proceedings IMC Brandenburg 1995, Roggemans P. and Knöfel A. (eds.), IMO, 72–75.

Rendtel J., Arlt R., McBeath A. (eds.) (1995) "Handbook for Visual Meteor Observers", IMO.

Rendtel J., Arlt R., Velkov V. (1998) "Surprising Activity of the 1998 June Bootids", *WGN*, **26:4**, 165–172.

Ridley H.B. (1962) "The Phoenicid Meteor Shower of 1956 December 5", *Journal of the British Astronomical Association*, **72:6**, 266–272.

Shain C.A. (1957) "A Remarkable Southern Meteor Shower (letter)", *The Observatory*, **77**, 896, 27–28.

Steel, D. (1995) "Foreword" in: (Rendtel et al., 1995), 9–13.

Weiss A.A. (1958) "The 1956 Phoenicid Meteor Shower", *Australian Journal of Physics*, **11**, 113–117.

SPA Meteor Section results: 2002 Leonids I - visual, radio and imaging data

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An analysis of results submitted to the SPA Meteor Section from the 2002 Leonid epoch, particularly on November 18/19, is presented and discussed. Visual maxima were identified on November 19 at $4^{\mathrm{h}}05^{\mathrm{m}} \pm 5^{\mathrm{m}}$ UT ($\lambda_\odot$ (eq. 2000.0) $= 236\overset{\circ}{.}61 \pm 0\overset{\circ}{.}003$, ZHR $= 3180 \pm 80$) and $10^{\mathrm{h}}45^{\mathrm{m}} \pm 5^{\mathrm{m}}$ UT ($\lambda_\odot = 236\overset{\circ}{.}89 \pm 0\overset{\circ}{.}003$, ZHR $= 2640 \pm 110$). Video data showed a peak coincident with the first visual maximum. Radio results suggested a first maximum in the 10-minute interval between $04^{\mathrm{h}}10^{\mathrm{m}}$–$04^{\mathrm{h}}20^{\mathrm{m}}$ UT, a close coincidence to the visual peak given the binning interval size. The second peak was less clear-cut in the 10-minute-interval radio data, with a main maximum sometime between $10^{\mathrm{h}}50^{\mathrm{m}}$ and $11^{\mathrm{h}}10^{\mathrm{m}}$ UT, both times $\pm 10^{\mathrm{m}}$. There were clear indications in the visual and radio data that the first peak was relatively rich in brighter meteors than the second. Imaging results allowed the determination of the Leonid radiant on November 18/19 near the first storm maximum from UK results alone (at $\alpha = 153° \pm 2\overset{\circ}{.}5$, $\delta = +20° \pm 3°$) and from video data from Spain (at $\alpha = 152\overset{\circ}{.}8 \pm 0\overset{\circ}{.}2$, $\delta = +21\overset{\circ}{.}7 \pm 0\overset{\circ}{.}2$).

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1 Introduction

Up to two storm-strength maxima were predicted for the badly moonlit Leonids in 2002 and, as with the 2001 double-peaked storm, the shower did not disappoint the fortunate watchers with clearer skies who reported to us. Unlike in 2001 though, British observers were not only favourably placed to catch one of the storm peaks under night-time skies, but also were luckier with the weather, and many people were able to see something near the shower's best. This report provides details on the visual, radio and imaging results. A second article will give a series of personal recollections of observing near the storms. Moonlight and poor weather meant too few visual and video datasets were available from nights other than November 18/19 during the Leonids to make a sensible analysis of them practical, so attention here is centred on data from close to the peaks only.

As usual in the SPAMS reports, the essential element is the numerous dedicated meteor watchers and casual witnesses, who troubled to observe and provide data from the 2002 Leonid epoch, November 16/17 to 20/21, including those who were unlucky with their sky conditions. Very many most grateful thanks go the list of people below for their work during this period. Additional thanks for provision of often extensive data summaries go to: Bob Lunsford of the *American Meteor Society* (AMS — website: `www.amsmeteors.org`) via the AMS's journal *Meteor Trails* No.18 (March 2003); Ina Rendtel of the German *Arbeitskreis Meteore* group (AKM; data in their journal *Meteoros* **5:12** (2002) and **6:1** (2003) — website: `www.meteoros.de`); and Chris Steyaert, editor of the *Radio Meteor Observation Bulletins* (RMOBs — website: `www.rmob.org`), with data from numbers 112 and 113, November and December 2002 respectively. In the listing, observers whose data was taken chiefly from the one of these sources are credited with the appropriate abbreviation. Other letters indicate the type of observing undertaken, including 'P' = photographic results, 'R' = radio observations, 'Vi' = video data, and '+ V' = 'and visual results'. Those not otherwise noted provided visual reports.

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2 Visual results

The problems in computing ZHRs from times of very high meteor activity have been discussed several times in recent years in this journal, chiefly in regard to the Leonid storms since 1999. A particular difficulty is where observers may struggle to give accurate magnitude distributions during phases of very high to storm level activity, in turn leading to the calculation of less accurate estimated ZHRs than normal. This year, although more SPAMS observers were able to provide magnitude details, even during the storm peak heights, an additional problem was moonlight seriously affecting the LMs. In order to keep reasonable numbers of meteors in the magnitude and ZHR analyses, the usual strictures regarding LMs were relaxed from +5.5 or better, to +4.0 or better. In addition, wherever possible, the ZHRs were derived using 5–15 minute intervals on November 18/19 to help give a better picture of any briefer changes in activity, and the main maxima timings. Consequently, the ZHRs should be treated as still giving a useful guide to the general character and relative strengths of the activity seen at different times, but may be less reliable for the specific numbers involved.

An assumed population index, $r = 2.5$, was decided for the ZHR calculations. This is the long-term mean value for the Leonids used in the annual *IMO Meteor Shower Calendar*. It is also close to the mean values on November 18/19 during the time most SPAMS observations were obtained, according to IMO results: (Arlt et al, 2002) mean $r = 2.46$; (Arlt, 2003) mean $r = 2.41$. There are strong indications in (Arlt, 2003) that before the first peak the population index may have been nearer 1.9–2.1 (meaning more bright meteors were present), and shortly before the second maximum it may have been about 3.1–3.4 (indicating a lot more faint meteors), improving to 2.7–2.8 during the second peak itself. Although much of the SPAMS ZHR and magnitude analyses were carried out before (Arlt, 2003) was published, colloquial reports and the findings of (Arlt et al, 2002) had already suggested some variation in r across the storm maxima was probable. An attempt was made to examine the magnitude distributions from skies with LM = +5.0 or better only. While this gave a reasonable meteor tally overall, when attempting a shorter-interval breakdown to examine these possibilities, the meteor numbers, especially during the second maximum, were reduced too far to be especially useful.

These potential different meteor populations were examined instead using three intervals on November 18/19, from $23^{h}30^{m}$ to $03^{h}30^{m}$ UT, $03^{h}30^{m}$ to $05^{h}00^{m}$, and $05^{h}00^{m}$ to $12^{h}35^{m}$ UT. Figure 1 shows these values as percentage magnitude distributions, along with the overall Leonid and sporadic distributions. The Leonid meteors available for the magnitude analysis in each interval were 296, 480 and 154 respectively, and the mean LMs per interval were +5.05, +4.72 and +4.33.

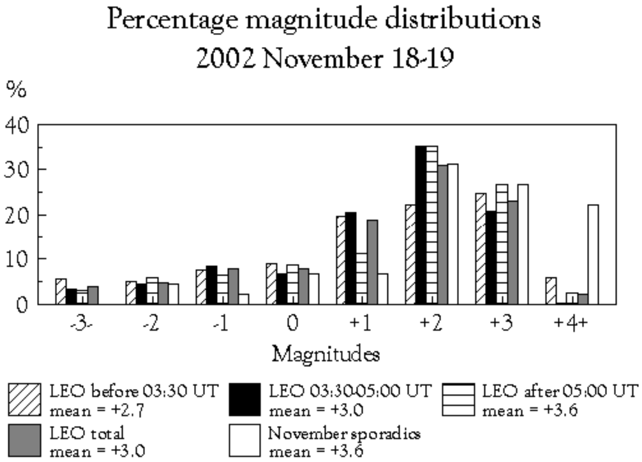

Figure 1 – Percentage magnitude distributions for the Leonids overall and during three main intervals on 2002 November 18/19, before, during to soon after the main European peak, and in the period after this, covering the main North American maximum. Values for the sporadics are also shown, along with the corrected mean magnitude values for all these intervals and sources. In total 930 Leonids, but just 45 sporadics, are represented.

Most meteors were reasonably bright (or they would not have survived the moonlight!), so the distributions are not quite what we would expect. For instance, in 2001 with no Moon (McBeath, 2002) 50% of the Leonids were magnitude +2 or brighter, and about 25% of the sporadics. In 2002, the respective values were nearer 75% and 50%. The Leonid mean magnitudes grew fainter over time on November 18/19, and there is an indication that somewhat more fireballs were seen before the first maximum than subsequently. The faintest mean magnitude covering the second storm maximum is in line with the IMO findings of many more faint meteors near and during that later peak. The small number of sporadic magnitude estimates gives their details less reliability, although the overall character of the distribution graph is fairly typical of what we would expect under the circumstances.

Figures 2 and 3 show Leonid ZHRs for November 18/19 as a whole. The short, sharp nature of both maxima compared to the lower activity away from the peaks is clear from Figure 2, while Figure 3 allows some detail in the activity away from the main peaks to be appreciated. This includes the fact that the typical Leonid ZHRs of around 10–15, seen for many years prior to the late 1990s, would scarcely have registered this time! The steep outer curves in the approach to the first storm peak and in the departure from the second are quite striking, while the inner curves are somewhat more gentle. ZHRs were above 100 virtually throughout the whole interval these graphs represent, although parts of the dip between roughly $06^{h}00^{m}$ and $08^{h}30^{m}$ UT were not well covered, due to a 'North Atlantic gap' between the last European observations near dawn and the majority of North American watchers starting to enjoy a useful Leonid radiant elevation.

Figures 4 and 5 close in on the two storm maxima. The first peak reached its highest ZHR of 3180 ± 80 at $04^{h}05^{m} \pm 5^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}61 \pm 0.^{\circ}003$), with a Full Width Half Maximum, FWHM, time of $44^{m} \pm 5^{m}$ from $3^{h}52^{m}$–$4^{h}36^{m}$ UT. This compares with the IMO data (Arlt et al, 2002), which indicated a peak at $4^{h}08^{m} \pm 1^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}615 \pm 0.^{\circ}0007$), ZHR = 2505 ± 55, FWHM = $39^{m} \pm 3^{m}$. The second peak in SPAMS data was achieved at $10^{h}45^{m} \pm 5^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}89 \pm 0.^{\circ}003$, ZHR = 2640 ± 110, FWHM = $35^{m} \pm 5^{m}$ from $10^{h}27^{m}$–$11^{h}02^{m}$ UT), although near-peak rates appear to have been sustained at only slightly reduced levels until $10^{h}55^{m}$ UT (ZHRs $\simeq 2300 - 2450$). IMO results (*ibid.*) for this second peak were: time = $10^{h}46^{m} \pm 1^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}8933 \pm 0.^{\circ}0007$); ZHR = 2940 ± 210; FWHM = $25^{m} \pm 3^{m}$. The IMO's second peak was of course computed assuming a fainter r than in the SPAMS analysis. It also did not show the extended nature suggested by the SPAMS rates nearly as well, although IMO ZHRs were still 2250 ± 160 by $10^{h}50^{m}$ UT.

It is difficult to be sure if the 'shoulder' of near-constant rates seen both after the first maximum, between roughly $04^{h}15^{m}$ and $04^{h}30^{m}$ UT, and before the second around $10^{h}30^{m}$–$10^{h}40^{m}$ UT, were real effects in the shower or simply artefacts in the analysis. The number of observations available during these times gives some confidence that they were genuine features however.

The relative strengths of the two maxima remain open for debate, and were very probably r-dependent. This analysis, using a constant r-value throughout, implied the European peak was the stronger; while the IMO data, using the estimated probable changes in r over time, indicated the North American peak was stronger. Judging by some of the observers' comments from North America, whatever the actuality, the impression was that the Leonid peak there was not as impressive a storm as seen there in 2001. This would be the case if meteor rates were actually lower, or if they only seemed lower because many meteors during the storm were too faint to be seen in the bright moonlight. This point is discussed further in relation to the radio results in the next section.

Echoing the 2001 results once more, relatively few Leonid train reports were secured. Part of the reason was that observers rightly concentrated on getting accurate magnitude distributions during the storm, but part was down to the poor sky conditions. Faint trains, like faint meteors, do not show up well on a moonlit night. An LM criterion of +5.0 or better was used for the train analysis attempt, as the train results from skies worse than this were extremely few and variable in character. Thus in 2002 only about 58% of Leonids from the magnitude distributions had the presence or absence of trains noted, compared with 78% of sporadics (but remember that few sporadics were seen anyway), yielding train populations of 29% (158/537) and 6% (2/35) respectively. While the sporadic value is typical for them overall, the lower Leonid one reflects the expected problems. Too few train reports were received during the North American maximum to say if the potentially greater numbers of faint meteors then might have reduced the train proportion still further. No further details could be derived with any reliability, but the general paucity of fireballs seems to have reduced the number of very long-duration trains, and no train lasting more than 20s was reported from the visual observations within the LM strictures outlined already. Some longer trains than this were casually recorded, however.

3 Radio results

Figure 6 gives a representative sample of six sets of radio observations received from various geographic regions around the world across the Leonid peak. The normal procedures for analysing raw radio data were followed, as described in (McBeath, 2001). As I have discussed before in this journal, in earlier Leonid reports and other SPAMS results articles, the interpretation of radio data is not easy, but it can be less difficult during very strong meteor activity such as a Leonid storm. Leonid activity was good enough in 2002 to produce at least one very clear radio peak for most of the observers

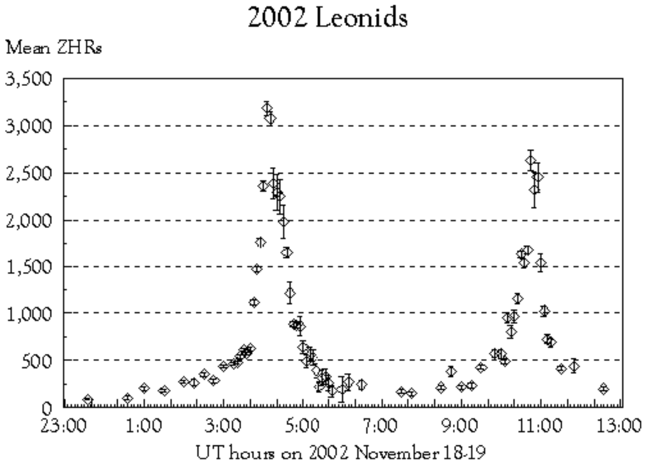

Figure 2 – Leonid mean ZHRs on November 18/19, from a total of 27 585 Leonids seen in almost 348 hours of watching.

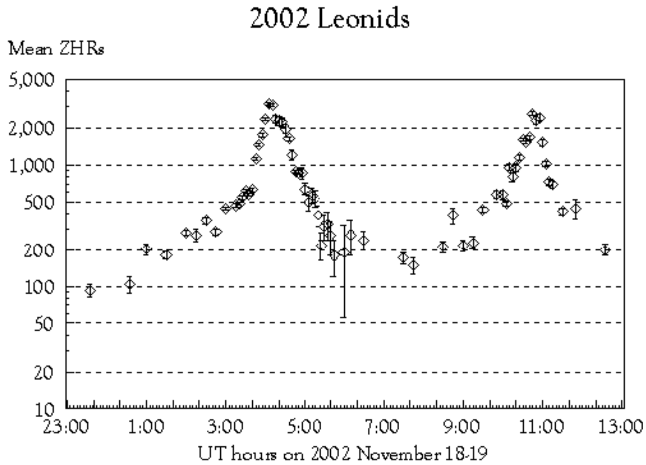

Figure 3 – As Figure 2, but now using a logarithmic y-axis.

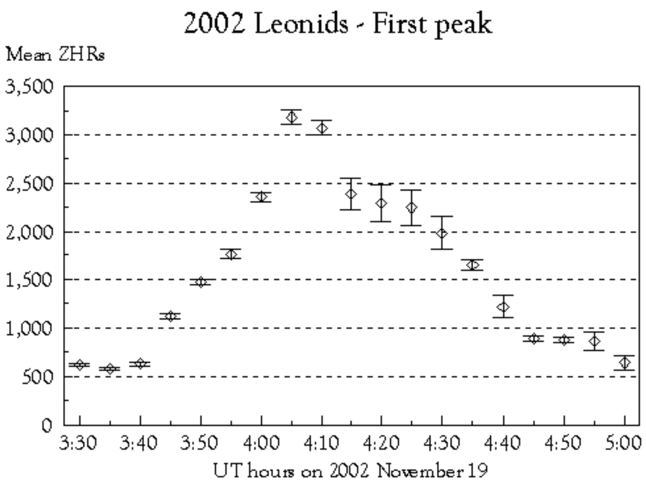

Figure 4 – Detail from Figure 1 for 90^{m} over the first storm maximum.

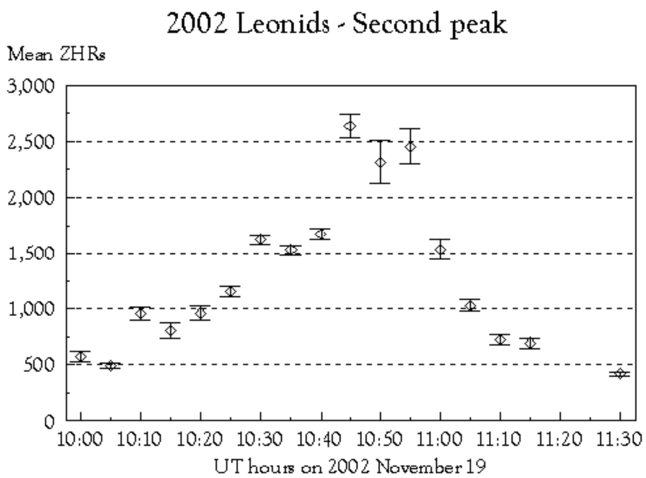

Figure 5 – Detail from Figure 1 for 90^{m} over the second storm maximum.

reporting to us, dependent on their location, either in the hours shortly before midnight UT on November 18/19 or during the UT day of November 19, as Figure 6 demonstrates. Even where neither storm maximum was radio-visible, such as in Japan and Australia, the build-up towards the best activity is very obvious. Europe was almost ideally located to catch both storm peaks under similar radiant elevation conditions, allowing a comparison of the relative appearances of both in the same observer's data in some cases. Over the Americas,

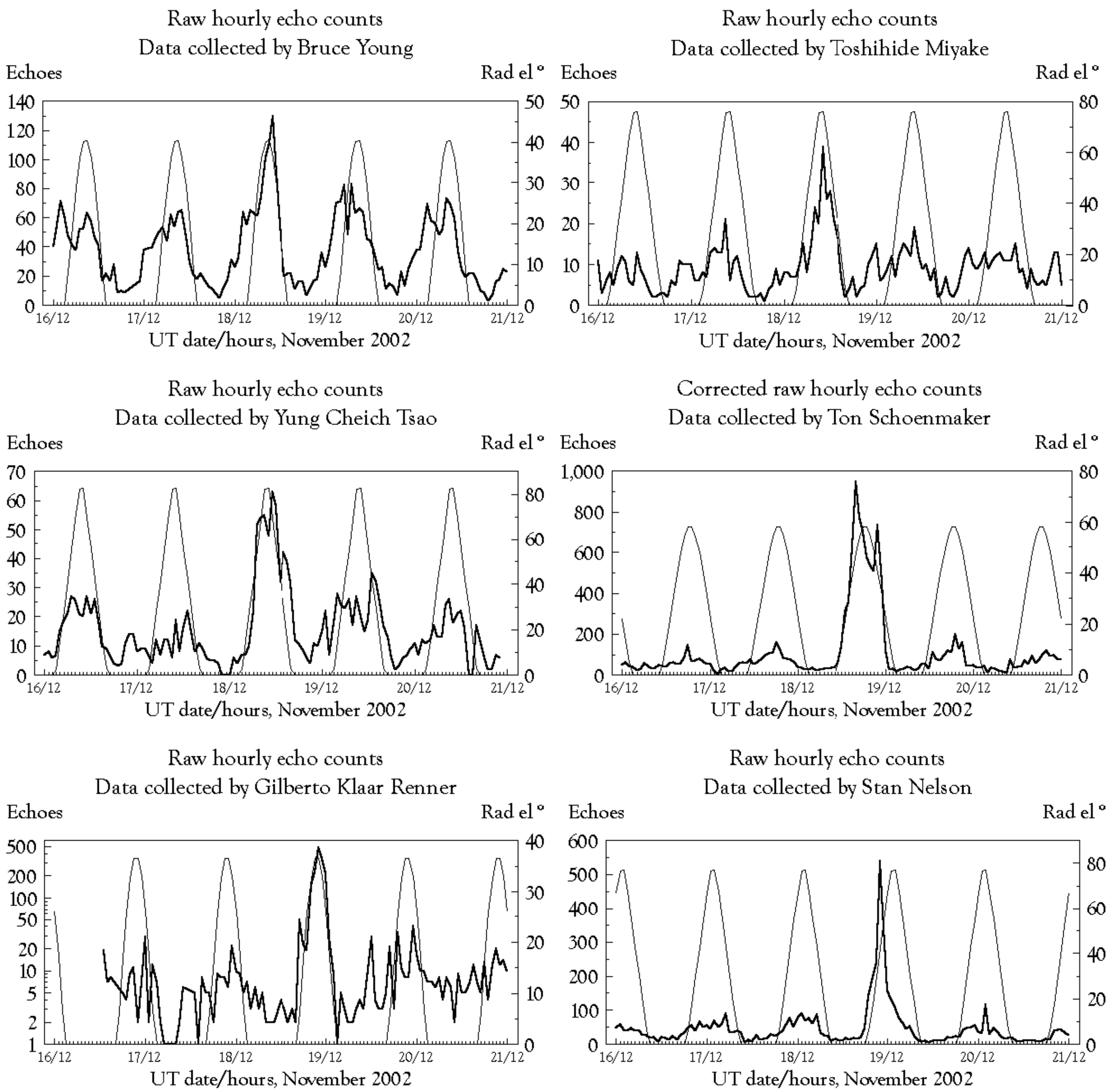

Figure 6 – Six graphs giving hourly counts of radio meteor echoes reported between November 16, $12^{\rm h}$ UT and November 19, $12^{\rm h}$ UT. Echo counts are shown as the thicker, irregular line on each graph, which is keyed to the left-hand y-axis. The thinner, daily-symmetrical curves describe the Leonid radiant's elevation above the horizon for each site, values keyed to the right-hand y-axis. In general, times when interference intervened, preventing accurate data collection, are shown by the count line dropping to zero. The data was collected by Bruce Young (Australia), Toshihide Miyake (Far East), Yung Cheich Tsao (Far East, see Note 1), Ton Schoenmaker (Europe, see Note 2), Gilberto Klar Renner (South America, see Note 3) and Stan Nelson (North America).

Notes: (1) Yung Cheich Tsao was the most westerly of the Far Eastern observers, and was just able to catch something of the first storm peak as the radiant was getting ready to set for him. (2) Ton Schoenmaker's echo counts were corrected for dead time due to system-saturation during the higher activities. Such saturation seems to occur both when there are many meteors present and when higher rates of brighter meteors are happening, as this is found too during the major shower maxima through the year, even without rates coming close to storm levels. (3) Gilberto Klar Renner's graph has a log y-axis scale has been used in order not to lose the lesser detail in the lower count times away from the Leonid storm. His system was only operational from November 17, $00^{\rm h}$ UT.

the second storm peak was well caught.

A consensus in most of the available radio results suggests Leonid rates began rising strongly from about 21^{h}–22^{h} UT onwards on November 18, over the Far East and Australia. The actual start of the rise was probably a few hours before this, possibly as early as 18^{h}–19^{h} UT. The Leonid radiant set around the time of the first storm maximum from most of these sites — except for Yung Cheich Tsao on Taiwan, as noted in Figure 6's caption — so it was left to Europe to enjoy the best of this peak, as the radiant had yet to rise across the Americas. A possible minor pre-maximum peak, relatively rich in longer-duration echoes (normally taken to be produced by brighter meteors) seems to have happened around 03^{h}–04^{h} UT on November 19, perhaps centred around $03^{h}30^{m}$–$03^{h}40^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}585$–$236.^{\circ}592$), though this is not certain because of the small number of available radio datasets giving 10^{m} count tallies, as opposed to the typical hourly time-bins. It would largely tally with the visually brighter magnitudes before $03^{h}30^{m}$ UT, certainly, and also with some of the marginally lower population indices in (Arlt 2003), although still lower values of r were found in the IMO data between 00^{h}–02^{h} UT.

The first radio maximum fell in the one-hour interval between 04^{h} and 05^{h} UT, unsurprisingly. The few datasets with 10^{m} counts indicated the best activity occurred from $04^{h}10^{m}$–$04^{h}20^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}613$–$236.^{\circ}62$). Given the reporting intervals, uncertainty levels, and possible slight timing variations, this is very close to the visual results. The Czech Ondřejov meteor radar results on *IMO-News* for November 19 indicated a peak time of $04^{h}06^{m}$ UT, conveniently very close to the SPAMS visual maximum timing! The Ondřejov radar data detected a different meteoroid size population generally than either visual or radio observers; most radio observations seem to detect a comparable range of meteor sizes and brightnesses to visual watchers. However, these radar data on the Ondřejov website indicated that most echoes were well defined and of longer durations, suggesting they were significantly brighter than the system's limiting magnitude of about +9.

As activity declined after the first maximum, another possible minor radio peak was found around 05^{h}–06^{h} UT, most likely between $05^{h}00^{m}$ and $05^{h}10^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}648$–$236.^{\circ}655$). The Ondřejov radar also showed a small, short peak at about $05^{h}06^{m}$ UT, which gives some support for this feature, as does a brief small drop in r around $05^{h}10^{m}$ UT in IMO results (Arlt, 2003) together with a small rise in ZHRs at the $05^{h}07^{m}$ UT datapoint in (Arlt et al, 2002).

After this, radio activity trundled along in a somewhat irregularly elevated, but non-peak, state for several hours, until a potential longer-duration echo minor maximum cropped up in the 09^{h}–10^{h} UT interval, perhaps around $09^{h}00^{m}$–$9^{h}10^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}816$–$236.^{\circ}823$). This does not show up clearly in the visual data, though only two observers were active during the critical ten minute interval anyway, and there is no Ondřejov radar or IMO visual data covering this short period at all.

The second maximum was clearly defined in the 10^{h}–11^{h} UT spell, when there may have been two phases of longer-duration echo counts, around $10^{h}40^{m}$–$10^{h}50^{m}$ and $11^{h}00^{m}$–$11^{h}20^{m}$ UT ($\lambda_{\odot} = 236.^{\circ}886$–$236.^{\circ}893$ and $236.^{\circ}9$–$236.^{\circ}914$ respectively). However, these did not appear especially strongly, nor coincidentally, in all the available longer-duration data. There is little to support them in the visual findings, although the first did coincide with the main peak's timing, while after 11^{h} UT very few visual observers were able to remain active in North America as dawn approached. The storm peak in radio data probably occurred between $10^{h}50^{m}$ and $11^{h}10^{m}$ UT, both times $\pm 10^{m}$.

As noted above, European observers were almost ideally sited to cover both maxima. On the whole, the second storm peak was recorded less strongly than the first in such data. There are a number of reasons why this might be so, dependent on things like transmitter-receiver geometries and the elevation and direction of the Leonid radiant at the time, although the number of results which show the same feature mean these reasons probably played a relatively minor role. It may be the second storm peak produced fewer meteors than the first, as our visual results suggest, but the picture appears more complex than this. Figures 7 and 8 show hourly radio echo counts collected by two European observers throughout November 19, compared to the Leonid radiant elevation.

Looking at Figures 7 and 8, the first Leonid maximum is obvious enough, along with the second maximum at a lower level in the all-echo count lines. (The drop around 05^{h} UT in David Entwistle's results was due to an uncertain cause; it does not recur so obviously in the other European data.) The swift rise to, and slower decline after, the first peak, and the relatively slow rise and sharper fall around the second maximum helpfully reflect the visual findings too. However, looking at David's longer duration counts, and Ton's lost-time percentages, the second maximum does not appear at all. This strongly suggests the second maximum was indeed significantly lacking in brighter meteors, as the IMO visual data suggested, and the SPAMS data plus colloquial reports from North America hinted. Consequently, recomputing the SPAMS second peak value at $10^{h}45^{m}$ UT, using the IMO $r = 2.8$ suggested for near that time, would bring this visual ZHR up to 3460 ± 140, making the second peak now slightly higher than the first. Although somewhat conjectural, this value may well be closer to the true rate. More discussion of the two peaks is given in the next section.

In sum, the radio data support the visual findings of two main peaks, similar in character and at coincident times for the two techniques, the first one of which was richer in brighter meteors, the second apparently deficient in these brighter events. Several lesser items found in the radio analysis may have analogues in a close inspection of the visual results as well, though not necessarily all.

4 Imaging results and all-method peak comparisons

Photographic and video observations were submitted by only a few people. Drawing on data from four UK observers, Russell Cockman in Scotland, David Entwistle, Robin Leadbeater and Cliff Meredith all in England, it has been possible to determine a surprisingly accurate Leonid radiant position for November 19 during and near the storm peak. A total of 52 Leonid trails were available, of which only 37 were suitable for the radiant derivation, and yielded a position centred at $\alpha = 153° \pm 2{}^{\circ}\!\!.5$, $\delta = +20° \pm 3°$. This is an impressive result given the often poor sky conditions the British imaging was carried out under, and compares very favourably with the theoretical Leonid radiant position for November 19 at $\alpha = 153°$, $\delta = +21{}^{\circ}\!\!.3$. Using 202 Leonid trails, part of his own video data collected on November 18/19 from southern Spain, Steve Evans computed a radiant position at $\alpha = 152{}^{\circ}\!\!.8 \pm 0{}^{\circ}\!\!.2$, $\delta = +21{}^{\circ}\!\!.7 \pm 0{}^{\circ}\!\!.2$, again an excellent result for the observing circumstances. A selection of Leonid images are available on and via the 2002 Leonids webpage on the SPA site (`www.popastro.com`).

The video trail numbers recorded by Steve Evans and Robin Leadbeater showed closely similar patterns across the European storm maximum. These combined raw video trail numbers are compared with the visual and the 10^{m} radio counts made at the same time in Figure 9, while Figure 10 shows a comparison between the visual and available 10^{m} radio data for the North American storm peak (from which regrettably no video results were available).

The first maximum shows a simple pattern, with the video and visual peak times coincident with one another, and in general these lines show similar trends throughout the 90 minutes of the graph. The radio peak timings all coincide with one another too, but seem to fall slightly later than the video-visual peak. This may be due to the fact that the radio data are given in ten-minute bins, rather than the five-minute ones for the other techniques, or may be a genuine aspect of the shower. The shift of $+5^{\mathrm{m}}$ in the radio peak time is in line with the expected difference allowing for the geocentric corrections given by McNaught (1999), although such a shift should apply equally to the visual and video data too, as it was all collected from the same general area, Europe. All the radio curves are generally comparable to one another in shape and character, and to the video-visual activities, however, which may imply more of an artefact in the analysis than a real effect.

In Figure 10 for the second peak, the patterns are not as straightforward. The main visual and two of the radio count lines coincide to within the same 5^{m} time difference as in Figure 9, for the peak time. However, the two longer-duration time peaks from Gilberto Klar Renner's data bracket the visual and all the radio maxima, without correlating to features shown by the other methods. Intriguingly, David Entwistle's longer-duration and all-echo count lines peak together just before the second of these South American longer-duration ones. Some of these problems may be due to the time interval lengths, although even more likely are problems with the radio observing technique overall, and the different systems detecting slightly different aspects of the shower peak to one another. From (McNaught, 1999), the geocentric corrections should be about -9^{m} for Gilberto's data, and roughly $+9^{\mathrm{m}}$ for the European results, and while this might help resolve part of the peak timing discrepancies, it does not resolve all of them. Overall, there remains a suggestion here that the second peak was rather more complex in nature than the first one, perhaps with overlapping sub-streams within the Leonid stream as a whole, each with varying meteoroid size-mass populations.

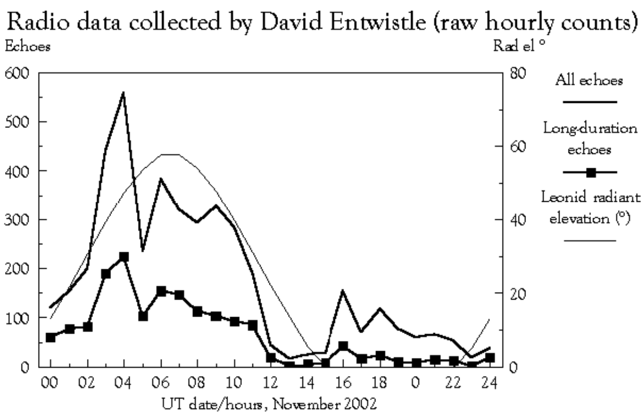

Figure 7 – Raw hourly radio echo counts collected by David Entwistle in England, comprising all echoes and longer-duration echoes, compared to the Leonid radiant's elevation on 2002 November 19. Echo counts are keyed to the left-hand y-axis, radiant elevations to the right-hand one.

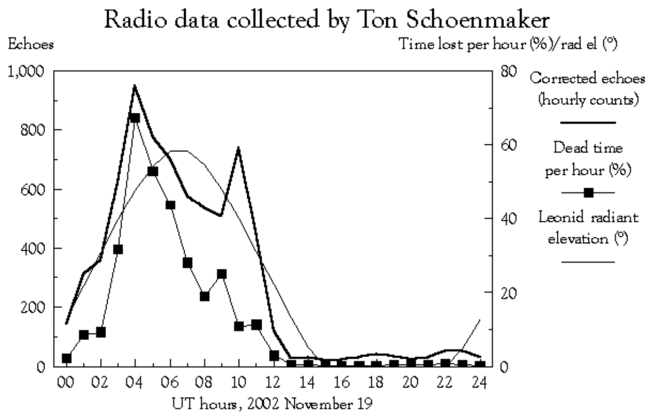

Figure 8 – As Figure 7, but from data collected by Ton Schoenmaker in the Netherlands. This gives corrected hourly echo counts allowing for system-saturation (keyed to the left-hand y-axis), and the percentage of such dead time per hour (keyed to the right-hand y-axis, along with the Leonid radiant's elevation).

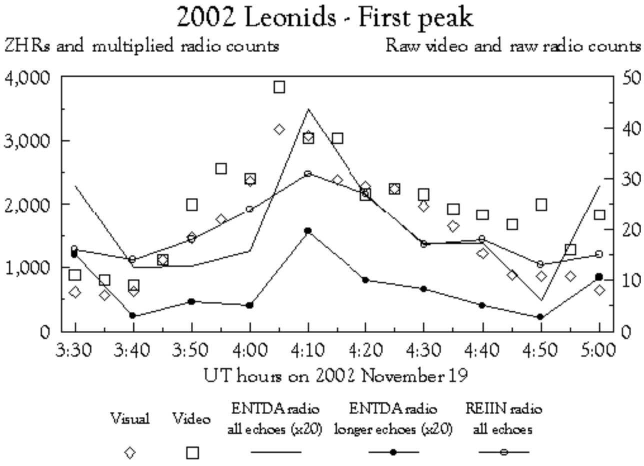

Figure 9 – A comparison of the appearance of the first storm maximum in visual ZHRs, combined raw video counts by Steve Evans and Robin Leadbeater, and two radio datasets, collected by observers David Entwistle (ENTDA) and Ingo Reimann (REIIN). David Entwistle's radio counts have been multiplied by 20 to allow them to use the same y-axis as the ZHRs, while Ingo Reimann's raw echo counts are keyed to the right-hand y-axis, along with the raw video counts.

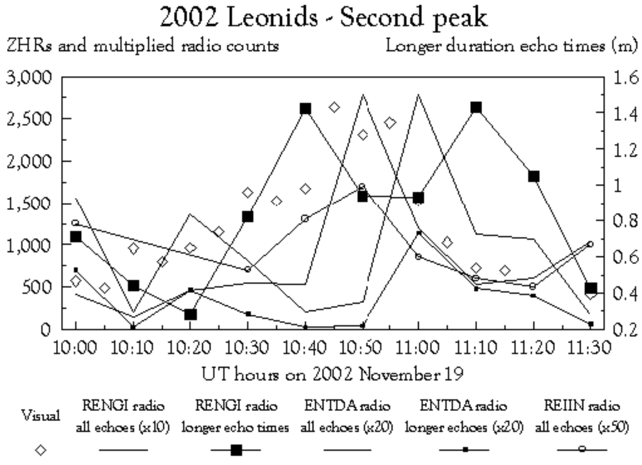

Figure 10 – A similar graph to Figure 9, but for the second storm peak, comparing visual and various radio datasets. RENGI is Gilberto Klar Renner, who provided information on the amount of time per 10^{m} interval his system recorded longer duration echoes, which information has also been plotted, using the right-hand y-axis.

5 Conclusion

Results submitted to the SPA Meteor Section allowed an excellent and detailed examination of the period over the two Leonid storm maxima in 2002, another in a very fortunate run right through the strong Leonid epochs seen since 1998. The radio and imaging data enabled independent confirmation of several aspects of the peaks, including useful radiant determinations by imaging techniques, while the radio results also suggested a few new times when stronger or brighter meteor activity may have been taking place, not all of which have yet been found in any of the published visual results. The first maximum was apparently a more clear-cut affair than the second, and the possible complexity around the second peak in the radio information was certainly fascinating. Radio data also confirmed the visual view that the second peak had far fewer brighter meteors than the first. Many congratulations and grateful thanks are as always extended to all the contributors to this report.

References

Arlt R. (2003) "Bulletin 19 of the International Leonid Watch: Population index study of the 2002 Leonid meteors", *WGN* **31:3**, 77–87.

Arlt R., Krumov V., Buchmann A., Kac J. and Verbert J. (2002) "Bulletin 18 of the International Leonid Watch: Preliminary Analysis of the 2002 Leonid Meteor Shower", *WGN* **30:6**, 205–212.

McBeath A. (2001) "The Forward Scatter Meteor Year: 2001 Update", *WGN* **29:3**, 85–92.

McBeath A. (2002) "SPA Meteor Section Results: 2001 Leonids", *WGN* **30:3**, 59–70.

McNaught R.H. (1999) "Visibility of Leonid Showers in 1999-2006 and 2034", *WGN* **27:3/4**, 164–171.

SPA Meteor Section results: 2002 Leonids II - personal recollections

Alastair McBeath[1]

Personal recollections from observers of the 2002 Leonid epoch, particularly November 18/19, are presented, extracted from correspondence and comments provided to the SPA Meteor Section. The numbers of UK reports enabled a useful general overview to be gained of how different British locations fared on November 18/19.

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1 Introduction

Following the pattern set in previous SPAMS Leonid reports, in addition to discussing the data analyses in a first paper on the shower in 2002 (McBeath, 2003), this second article gives some ideas of how the observers reacted to what they saw — or sometimes missed seeing — on the maximum night. This is based on correspondence and comments received in the weeks after the event. The full list of observers involved was given in the first of these two results papers and is not repeated here. Details on the individual cited observers' locations are given again here however, in order to place them in their proper geographic context. Most of the comments were from UK observers. As a result, it was possible to get a good idea of just what the weather conditions across the country were like on November 18/19. All times cited in this article are in local time. For the UK only, this is the same as UT in November.

2 Media comments

Before beginning a commentary on what actually happened, it is worth noting that the British media had decided in advance that the event was going to be clouded out across the country. This seemed to be based on some of the weather forecasts on November 18, which, despite a considerable degree of inconsistency and vagueness in parts, seemed to suggest that in general a poor night might be in prospect for many of the more heavily populated places. The inconsistent and vague forecasting was often reflected in the variable conditions actually experienced, although the variations often failed to marry up with the forecasts for any given site!

For instance, the national broadsheet newspaper, The Independent, dated November 19, but written the evening before, had a small editorial item on how 'the weather was expected to be cloudy enough to obscure the Leonids', while their leading article, entitled 'Damp squib', was more definite, with phrases like 'Trust the British weather to spoil it', 'And what happens? The usual cloud and rain, that's what', as if the event had already passed. Yet as the sketch map in Figure 1 illustrates, some observers barely 30 km away from the newspaper's registered office in East London enjoyed the Leonids under partly clear skies, and many people away from the southern one-third of the mainland UK had an even better view!

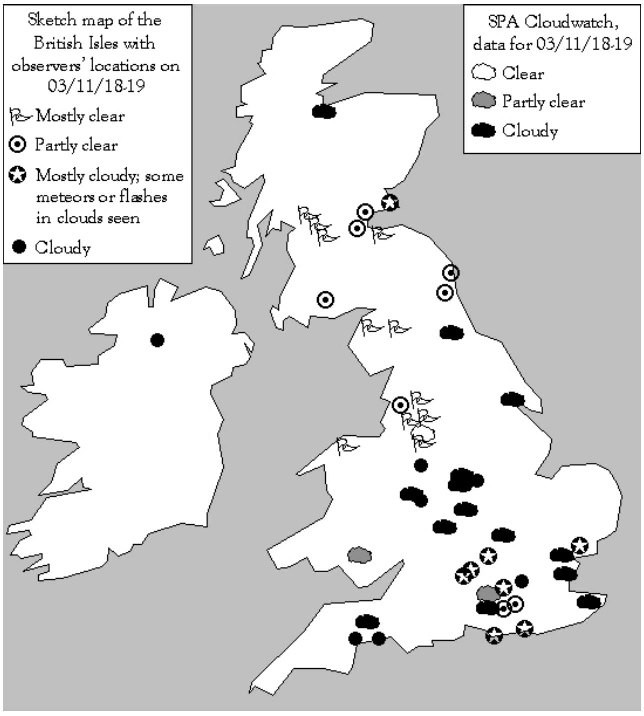

Figure 1 – A sketch map of the British Isles, showing the locations of observers whose data was received by the SPA Meteor Section, and on SPA Cloudwatch Project data, from 2002 November 18–19. This gives a view of how the UK fared on the critical Leonid storm night. One symbol may represent more than one individual and, in some cases, may indicate a number of people at the same site, or ones too close together to show separately at this scale. The SPA Cloudwatch Project exists to collect information from observers on their general sky conditions overnight, especially the presence and quantity of clouds, using a simple clear – partly clear – cloudy scale. Most, but not all, of the Cloudwatch data was collected from the hours up to midnight UT, even so, providing consistent support for what other observers active after midnight UT found.

3 British observers' comments

Figure 1 indicates roughly where the following watchers were located. The map's Cloudwatch results were kindly provided by Project coordinator **Terry Holmes**. Terry tried to observe from his home site, in the West Midlands of England, but was unlucky: 'I didn't see anything of the Leonids. After sunset ... the sky was clearing and I prepared my equipment. But the weather forecast predicted cloud to increase, and this is what happened ... By midnight there was the first fog of the autumn.' However, just 70km north in Cheshire, skies

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were clear right through the storm maximum. Such was the fickle nature of the UK's weather on November 18/19, as the remarks below help demonstrate.

Conditions were at their poorest in the post-midnight hours across parts of southern and central England. On the south-west coast, for **Guy Ottewell** in Dorset, '. . . the sky at 11 pm was almost covered with beautiful clouds like ice-floes, moonlit so that I could see the gaps between them and hope to see a few meteors . . . but from midnight onward the cloud had solidified.' Further east in Sussex, **Mike Feist**, '. . . saw just one Leonid — at 2:27 am — in a small hole in the clouds . . . That was it, as the clouds got worse and worse, and then nothing was visible by the magical 4 am'. **Pete Lawrence** near Selsey Bill, also in Sussex, struggled with occasionally broken clouds, finally giving up at $04^{h}40^{m}$ after solid clouds since $03^{h}00^{m}$. He rose again at $06^{h}00^{m}$ for work: 'Popping outside while I was getting ready for a 7 am meeting, the area around Leo was covered by a large clear patch . . . I did 10 minutes of sight-seeing and saw 5 Leonids . . . ' As Pete noted, a frustrating night, but at least he saw a few Leonids.

A little way north, in Surrey, skies were also trying, but rather less frustrating. Assistant SPAMS Director **Shelagh Godwin** at Godalming: 'When I got up at 1:30 am and saw cloud, I really thought "Am I going to be cheated yet again of the chance of a Leonid storm?" and went back to bed. However, encouraged by a bird singing an hour later, I did get up and go outside to find the clouds had melted away. For a blissful 45 minutes I watched Leonids coming at a rate of 2 or 3 every 10 minutes, and mostly bright. Then, at 3:20, just as the rates appeared to be increasing, thick clouds started rolling in from the south east. However they often had a few holes in them, and as the critical time of 3:50 approached, these holes got larger. Then I started seeing bright Leonids in the clouds and through the holes. It was obvious that the rates were much, much higher. Then amazingly, just after 4 am, the clouds parted like the Red Sea leaving a crystal clear sky full of meteors, and I had a wonderful 20 minutes or so. At 4:15 the clouds came back and stayed persistently for the next half hour. After they cleared at 4:45, there was still a good show of meteors, about 6 every 10 minutes. I finally went inside at 5:15 when the clouds came in again. But what a night. I was so pleased to have seen a Leonid storm at last.'

Nearby, **Paul Wolstenholme** had been fogged out on Epsom Downs, so moved to Box Hill, Surrey, observing between $03^{h}20^{m}$ and $04^{h}50^{m}$, spotting 190 Leonids. His feeling was that the shower, 'reached maximum as predicted, at around 4 am, when I would estimate there were as many as 10 per minute . . . An excellent show.' Slightly north in and near London, things were hopeless. **Nigel Knighton**, West London: 'Well, I went out at 0, 2, 3, 4 hours only to find cloud. Could not even see the Moon.' **Dave Campbell**, Middlesex: 'Broken clouds at 10 pm. Misty and nearly overcast at midnight. And very misty with just a faint glimmer of Jupiter at 4 am . . . I did see one very faint flash that might have been a Leonid at about 4:20 am, but altogether a very disappointing night.'

Further north-west, in Oxfordshire, former Meteor Section Director **George Spalding** had a difficult night too with fog lifting into low clouds from midnight till 3:40 am, when a breeze picked up and a few gaps appeared. 'I was able to cover 4:00-4:30 and 4:45-5:15 am, though cloud cover was usually about 99% and rarely better than 95%, LM was at the very best, about 4, and more often I could see little except Jupiter.' George spotted 18 Leonids, as he said, merely a tantalising glimpse of what lay above the near-overcast. Yet just a few kilometres away, **Chris Holt** had a better time, with a gap from Ursa Major to Leo and about as far south again of Leo from $04^{h}00^{m}$–$04^{h}50^{m}$, sometimes with several Leonids a minute visible in the first half hour. 'All meteors seen were bright — they needed to be . . . bright enough to be seen through tenuous cloud', or at times even while still in thicker patches of cloud.

Over in Essex, southern East Anglia, **Si Clarke** discovered thick fog and clouds at $03^{h}00^{m}$, but a second check at $03^{h}30^{m}$ revealed a clearer area to the east, still leaving 75–85% of the sky obscured: 'From 3:45 to 4 am I saw 8 Leonids, which is an 800% increase on all previous attempts to witness them . . . The clouds rolled back in at 4 am and didn't break again, with the rain starting at 4:55 am. At which point I went back in — I know when I'm beaten.'

As mentioned, central England had very poor conditions all night. Former SPA President **Heather Couper** with Nigel Henbest in Buckinghamshire spotted a combined tally of just five Leonids beneath cloudy, foggy, and very damp skies between $03^{h}30^{m}$–$04^{h}30^{m}$, while SPA Secretary **Guy Fennimore** in Nottinghamshire 'enjoyed' only thick fog all night.

North-west of here were the best skies in England, over Cheshire, Manchester, Lancashire and Cumbria, extending west to include parts of North Wales. **Meredic Hallett** in Conwy had generally only a little thin, wispy cloud to contend with, and observed from $03^{h}16^{m}$–$05^{h}05^{m}$. His best spell brought 54 Leonids in eight minutes from $04^{h}04^{m}$–$04^{h}12^{m}$. 'Some of the meteors came in bursts of 3 to 5 and were difficult to count they were so quick.'

Paul Brierley, Cheshire: 'Fortunately we did have clear skies for the peak at 4 am, when the sky lit up; it was a truly amazing spectacle . . . there were too many Leonids to record — I gave up trying at 3:51 and just enjoyed the view . . . One thing that struck me was how brief the peak was. It appeared to last for only a number of minutes.' **Paul Clark**, Cheshire: 'We saw 10–15 a minute around 4:00-4:10 am, including several groups of three through the "bowl" and "handle" of the Plough. Too many to count at 4:00. Once in a lifetime? I hope not.' Former SPA Planetary Section Director **Cliff Meredith**, Manchester: 'To my surprise the sky stayed clear, though milky . . . and it turned out to be one of those special astronomical occasions . . . which I will particularly remember.' Long-standing observer **Ian Rigney**, Manchester: 'As the night went on there was a slow but steady build up of meteors as the Leonid radiant climbed higher. At 3 am it was as if someone had turned on a switch, as meteors started to come at one a minute and more ... Just after 3:40 am the Leonids stepped up another gear and meteors were coming so often that I could only keep a count; meteors were coming at 3–4 a second at times ... the spell from 4:00-4:10 being particularly busy.'

Paul Richardson, Lancashire: 'Can't believe that just for once, the Manchester area seems to have been exceptionally clear for an astronomical event! I was very poorly prepared, having expected cloud cover from the west during the night ... but the display was certainly the best I have ever seen'. **David Entwistle**, Lancashire, observing 2-5:30 am: 'During the Leonids I concentrated on trying to get a decent photograph [succeeded! — see Figure 2 — *AM*], and didn't attempt to count rates ... Generally, activity seemed to come in bursts, with several meteors in the space of a few seconds followed by a brief lull. However, during the peak, you'd seldom have to wait more than a few seconds for a meteor ... Bright meteors seemed more common early on ... Those arriving later, at the predicted peak, generally seemed fainter.' **Peter Duffy**, Lancashire, having driven over from Yorkshire seeking better skies: 'At first [about $01^{h}30^{m}$] I was only seeing about one every ten minutes, but things suddenly picked up at 3:40, until at about 3:55 there were two breathtaking short bursts during which I lost count of the number of meteors visible. I really have never seen anything like it. At about 4:20, things were slowing down again, the clouds were thickening, and the cold and chattering teeth finally won! ... A memorable night.'

Robin Leadbeater, Cumbria: '... we were blessed with 9/10 clear skies (at least from 3:30 to 4:30 am when I was looking skyward). I was concentrating on imaging, so did not keep any accurate records of visual activity, but ... I spotted perhaps 2 or 3 per minute on average through the hour, with a couple of periods of higher activity around 4:00-4:15 where the rate was significantly higher, perhaps 7–10 a minute ... mostly bright ones but almost all with short trails and no fireballs.' **Anita Evans**, Cumbria: 'I set my alarm for 3:55 am and was out in the garden a few minutes after ... I saw one quite bright one and wondered if that was the lot, then they started coming thick and fast. I suppose at about 4:10 it quietened down a bit ... Then there was enough to keep me thinking "wow" until just after 4:30 when it started to get quiet again ... half an hour on the sun-lounger (more action than it saw all summer) ... rewarded by quite a display.'

Westward in Northern Ireland, as has seemed often the case during the Leonids, skies were useless. **Peter Phillips**, County Tyrone: 'I'm afraid I was clouded out AGAIN! for the Leonids (5th year in a row, would you believe it?)' Meanwhile well east of Cumbria, Northumberland's skies did allow something of the Leonids to be seen at their best, both for myself and a group elsewhere from the Northumberland Astronomical Society, as **Adrian Janetta** relates: 'Against the odds, we had a fairly clear spell from about 3:35 to 4:25 am. Activity seemed to be most intense for a few minutes either side of 4:10 am ... Sometimes there would be a flurry of meteors streaking across different parts of the sky at the same time. I wonder how many we weren't seeing?'

Southern to central Scotland was a splendid place to be for the Leonids, especially further west, but even in the east some better views were had. **Mike Holmes**, Edinburgh: 'We went up Blackford Glen around 1 am ... There was sporadic misty cloud which seemed quite high ... We saw a couple of dozen Leonids up to 3:45. After that there were two times when we saw 5 in a minute, and things took off at 4:00; we saw 26 between then and 4:10. We saw 19 in the next ten minutes and 5 in the ten minutes after that ... Things petered out from 4:30 though we stayed until Castor and Pollux were lost in twilight around 7:00, with only an occasional meteor visible.' **Mike Dale** of Royal Observatory Edinburgh: 'On entering the garden at 3:10 am my first impression was of a beautifully clear sky, but I soon realised that there was a thin haze over most of it. The Moon was yellowish and very murky-looking ... However I quickly realised that there was a fairly steady stream of Leonids coming in. They were mainly faint with the odd one a little brighter. They were mainly single but with occa-

Figure 2 – A superb Leonid fireball caught crossing through the seven-star asterism of the Plough in Ursa Major, and perfectly in-shot (a great rarity as most meteor photographers will know only too well!), by David Entwistle at $02^{h}56^{m}$ UT on 2002 November 19, from Accrington, Lancashire. The visual magnitude was estimated at about −6. Conditions were bright moonlight and slight haze, as the image suggests. Taken using a Pentax MV with a 50 mm lens, $f/1.7$, 30 s exposure, on Fuji Superia ISO 800 colour film. David managed to photograph two further images showing this meteor's train (not shown here), which lasted for approximately one minute. On the first of these, another, but notably fainter, Leonid crosses that image.

sionally two or three in spurts ... Overall I was quite delighted.' **Tom McEwan** (with Nick Martin), Perth & Kinross: 'It was raining here in North Ayrshire on the evening of the 19th ... so, we drove through to Powmill, Perth and Kinross, and managed 90 minutes of observing, catching the peak. Conditions were not however ideal — there was a patchy veil of thin cloud and drifting cumulus ... but we did see some striking activity.'

Russell Cockman (with Walter Scott Jr.), Dumfries & Galloway, south-west Scotland: 'There were many bright (mag 0 and brighter) events ... Observation of the radiant around the time of the predicted maximum showed very brief bursts of activity with several meteors appearing simultaneously, then nothing. Overall impressions either side of the maximum were of meteor rates of several per minute. Even as dawn twilight intervened, meteors continued to be observed ... The display was very entertaining despite the almost full Moon, patchy cloud cover and the cold.' **Roy Watson**, East Dunbartonshire, near Glasgow: 'In spite of the negative weather predictions, I was able to observe the shower, cloud-free, from 3:22 until 6:25 am ... it was a truly awesome and memorable display. The bulk of the Leonids were very bright, and there was much activity around 4:00.' **Colin Begg** (with Craig Stobo, Sarah Watson and Chris Wilson), in Stirlingshire not far from Loch Lomond: 'The peak for us clearly happened at 4:00-4:15 am. We were treated to a good display of meteors ... Many — indeed a sizeable minority — left good trains and several easily outshone Jupiter.'

4 Overseas observers' comments

European reports suggest conditions on November 18/19 were patchy across the Continent too. Clearer skies were available for parts of Italy, southern France, Spain, Romania (especially for Transylvania; Moldavia was very poor, but Wallachia good in parts) and Morocco, but only overcast conditions were apparent in Belgium, the northern Netherlands, Slovenia and Croatia. Further afield, positive reports were received from large tracts of North America, especially in the eastern half of the USA, but the best view of all our regular overseas correspondents was IMO Sceretary-General **Bob Lunsford**'s, who had been invited to observe with the NASA MAC Leonid team in two high-altitude aircraft. On the maximum night, the pair of aircraft flew across the Atlantic from Spain to Kansas in the USA, far above the clouds, so Bob was treated to a superb view of BOTH storm maxima — aside from the distraction of an aurora filling almost the entire sky at times over the USA! Comments from others of our overseas correspondents follow.

Ton Schoenmaker, Netherlands: 'Visually, I saw almost nothing, 99% moonlit clouds most of the time.' **Hendrik Vandenbruaene**, leader of the Belgian VVS meteor observing group, Belgium: 'Leonids were terrible in Belgium ... Most observers only saw a handful of meteors, if they were lucky ... BUT, some other colleagues went to southern Spain and southern France, where they could make observations of the complete event.' SPA Comet Section Director, **Jonathan Shanklin**, southern France: '... one of the first meteors was a bright, fragmenting Taurid, followed by a long-trailed Leonid. Rates were initially slow, with a meteor every few minutes ... until half an hour before the predicted maximum ... Rates then rapidly escalated, and at maximum, rose to about a dozen a minute, with some meteors appearing simultaneously ... The three brightest meteors with long-lasting trains (about 30 seconds) occurred during the decline, and were bright enough to light up the ground. Even as dawn brightened the sky, rates were still around one a minute ... a *fantastique pluie des étoiles*!' SPA Vice-President **Robin Scagell** (with his wife Sally and SPA Webmaster Paul Sutherland), southern France: 'Around the peak, Sally counted 100 Leonids in just 10 minutes. There were few fireballs, but there were large numbers of fainter ones ... As dawn began to break, the peak had passed, but meteors could still be seen falling at a rate of one or more a minute.'

IMO Council member **Mihaela Triglav**, Slovenia: '... we were clouded and rained out ... I went to sleep with the alarm set for 3 am, but it rained then, so I changed it to 4 am — it rained again. At 5 it didn't rain any more, but there were low clouds everywhere, so I missed the maximum ... I was a little bit disappointed not to see any Leonids, but I saw them three times in recent years, so I got my part of them already.' **Steve Evans**, southern Spain: 'I travelled to Spain with the DMS and Ondřejov observers again ... as in 2000 ...

Figure 3 – Steve Evans had travelled from his home in England to Andalucia in Spain, joining teams from the Dutch Meteor Society and the Ondrejov observatory, in the hopes of catching the Leonid storm under better skies than in Britain. In that, he was right, as his normal UK locations were overcast all night. Unfortunately, even Spain managed to provide more moonlit cloud than he'd hoped. Steve had borrowed Andrew Elliott's video system 'Elli' for the trip, which uses a 25 mm second-generation MCP image intensifier and an $f/2.8$ 16 mm lens, giving a field of view of 90°, and a stellar limiting magnitude under normal conditions of about +3.5. This image was taken as datestamped, the night before the maximum, and just about at moonset, showing how good the sky in Andalucia can be. The Plough and the brighter stars of Ursa Minor are obvious in the centre and centre-left of the image, as is the bright Leonid.

The expedition was very enjoyable, and conditions on November 17/18 were superb ... Leonid activity was low, but did seem to pick up a bit towards dawn. The maximum night started in promising fashion, with very clear skies, but thin cloud started to roll-in from the SW just after midnight, and was troublesome for the rest of the night ... because of the clouds/Moon it was difficult to be completely objective about activity, but ... the elevated activity was short-lived — starting around 3:30 am, peaking around 4:00 and tailing-off very rapidly after 4:30.' Figures 3 and 4 show two of Steve's composite video images.

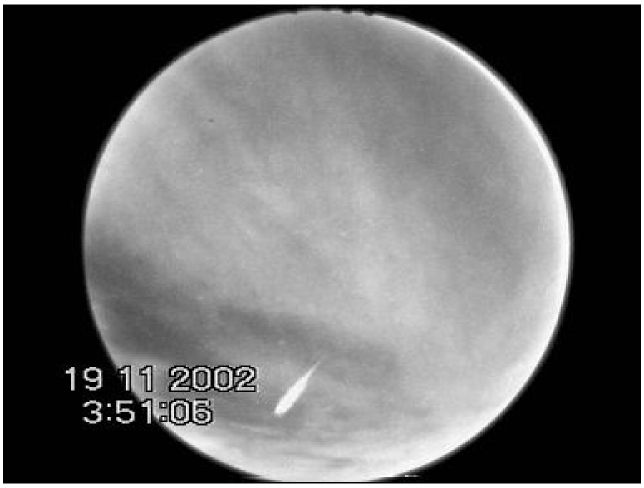

Figure 4 – Another image by Steve Evans (camera and site details as captioned for Figure 3). This field of view at $03^{h}51^{m}$ UT on November 19 is the same as in Figure 3, but now the effects of the moonlit thin cloud sheet blot out virtually all the stars. Luckily, not all the meteors met the same fate, as another splendid Leonid slips down into where Hercules should be!

Rich Taibi, North Carolina, USA: '... forecasts suggested that travelling to North Carolina would help ensure clearer skies. The good news is that for the 2nd peak period, the sky was cloudless. The bad news was that tape problems distracted me, and I [accidentally] recorded over about two hours' data [thankfully not from the most critical time! — *AM*] ... Like others who have commented on the 2nd peak, I saw mostly fainter meteors.' **Jay Brausch**, North Dakota, USA: 'I figured because the Moon was all full this year that my sky would finally be clear for the Leonids, and it was after 1:30 am ... when I went out at 3:10, I was "lured" to my observing site by the activity. So, this strong shower ... literally rose to the occasion ... At best [in the hour after 3 am] I was seeing 2-3 meteors per minute.'

5 Two brief obituaries

Completing these recollections on a sombre note, brief obituaries to two good friends who died in March 2003, Stanley Toyn of Exmouth, Devon, and Kath Hodges of Manchester. Neither were SPA members, nor even amateur astronomers, but both had provided notes and cuttings to the Section in the past, notably in recent years regarding the Leonids. Stanley had confirmed how poor his skies were for the 2002 Leonids, for instance. He was 79, and many years retired from his business in Manchester producing geological microscope slides and specimens. His interest in microscopy and his friendship with my father was how I came to know him. Although partly disabled by illness for a long time, he died unexpectedly of a heart attack on March 2. Kath worked in bioscience publishing, having a PhD in Fungal Genetics, and was just 39. Having successfully battled against breast cancer in the late 1990s, it was a dreadful blow when she was diagnosed with terminal liver cancer in November 2002. Given at least a year to live, she died unexpectedly early on March 29/30. Both are greatly missed by their families and many friends.

6 Conclusion

Many and fulsome thanks go to all of our contributors in what was a wonderfully-observed and successful Leonid campaign in 2002. Good luck and clear skies for your next observing.

References

McBeath A (2003) "SPA Meteor Section Results: 2002 Leonids I - Visual, Radio and Imaging Data", *WGN*, **31:5**, 153–160.

Other organizations

IAU C22 Working Group on Professional/Amateur Cooperation in Meteor Studies
Progress report for August 2003 (IAU General Assembly, Sidney)

Peter Jenniskens[1]

The 'Pro-Amat Working Group' of Commission 22 (Meteors and Interplanetary Dust) of the International Astronomical Union consists of leading amateur meteor astronomers worldwide, who help provide support for international observing campaigns and facilitate contacts between professional and amateur astronomers. The working group also consists of professional meteor astronomers who recognize the importance of the amateur astronomy community for the future of our field.

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1 Brief history

The ProAmat Working Group (WG) was established under Colin Keay (then president of Commission 22, C22) at the 1988 General Assembly held in Baltimore, Maryland. The activities were aimed to improve cooperation between professionals and amateurs in meteor research. There were only professionals. The first chairman was David Meisel (1988-1990), as a professional observer also active within the American Meteor Society. Amateurs were first included at the next working group established at the 21st General Assembly of the IAU in Argentina. Vladimir Porubčan was chair from 1991-1994. The WG consisted of twelve members, six members of Commission 22 (I. Hasegawa, R.L. Hawkes, J. Mason, V. Porubčan, D. Steel and A. Terentieva) and six representatives of amateurs (P. Brown, D. Očenáš, K. Ohtsuka, J. Rendtel, G. Spalding and J. Wood) of whom three represented the IMO. Under Vladimir Porubčan, the ProAmat WG encouraged amateur collaboration within IMO. The WG provided reprints of recent articles to IMO, from which summaries were published. A list of amateur meteor organizations and their contact persons was made. The Working group was re-installed at the 22nd General Assembly in Rio de Janeiro, Brasil, in 1994. The chair was Robert Hawkes, who worked to encourage the use of video techniques and made the IAU C22 accessible by means of a web site.

Peter Jenniskens has chaired the working group since the 23rd General Assembly in Kyoto in 1997. The 1998–1999 Leonid meteor storms were a strong rally for meteor observers worldwide. There were initially six professionals (P. Jenniskens, J. Baggaley, I. Hasegawa, X. Pinxin, R.L. Hawkes and P. Brown) and seven amateurs (H. Betlem, N. Bone, T. Cooper, G. Klar Renner, J. Rendtel, J. Richardson and T. Yoshida), representing the various continents and leading meteor organizations. The working group was continued at the 24th General Assembly in Manchester in 2000, again chaired by Peter Jenniskens: (P. Jenniskens, J.-I. Watanabe, V. Porubčan, J. Zhu, M. Gyssens, L. Bellot, T. Yoshida, H. Betlem, N. Bone, G. Klar Renner, J. Richardson and T. Cooper). The activities over this period focused on involving amateur observers in professional observing activities and motivating the publication of observing results by amateurs in the professional literature. During this period, the significance of amateurs in the study of meteor outbursts has become clear and the use of the internet has taken off. In July of this year, at the latest General Assembly in Sidney, Australia, Commission 22 decided to reinstall the ProAmat Working Group, in a continued commitment to integrate amateur and professional efforts in the field of meteor research.

2 Report of the previous working group

The previous working group formed at the 24th General Assembly in Manchester consisted of the members listed in Table 1 and report the following activities over the past three years:

2.1 2000-2002 Leonids

Facilitate the participation of US amateur astronomers in the 'flux team' during the NASA-sponsored 2001 and 2002 Leonid Multi-Instrument Aircraft Campaigns. Include the result of global visual meteor observations (gathered by IMO) in ongoing studies of Leonid storm prediction models.

Japanese amateur astronomers participated in and presented at the Leonid MAC Workshop in Tokyo, Japan, and were a major factor in its success (J.-I. Watanabe and H. Yano). Amateur observers participated in the ESA- and USAF-sponsored ground campaigns during the Leonids. ESA used the MetRec software (by Sirko Molau) for data analysis. Jin Zhu facilitated the Sino-Dutch Leonid campaign in 2001 and took an active role in reporting on Chinese meteor observations.

Hans Betlem organized ground-based observing efforts in Spain (2000, 2002) and the USA (2001), with participation of astronomers from Ondřejov Observa-

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Table 1 – Membership of the previous Working Group

Peter Jenniskens	Chair	USA	pjenniskens@mail.arc.nasa.gov
Jun-Ichi Watanabe		Japan	watanabe@pub.mtk.nao.ac.jp
Vladimir Porubčan	President of Commission C22	Slovak Republic	astropor@savba.savba.sk
Jin Zhu		China	zj@bac.pku.edu.cn
Marc Gyssens	IMO (Editor, WGN)	Belgium	gyssens@charlie.luc.ac.be
Luis Bellot		Spain	lbellot@ll.iac.es
Takatsugu Yoshida		Japan	LMJ53851@biglobe.ne.jp
Hans Betlem		Netherlands	betlem@strw.LeidenUniv.nl
Neil Bone		UK	bafb4@central.sussex.ac.uk
Gilberto Klar Renner		Brasil	klar@plug-in.com.br
Jim Richardson		USA	Richardson@DigitalExp.com
Tim Cooper		South Africa	tpcooper@ilink.nis.za
Robert Lunsford	IMO (Secretary-General)	USA	lunro.imo.usa@prodigy.com

tory. Contacts between Ondřejov Observatory and the Dutch Meteor Society were further enhanced. Jim Richardson coordinated the near-real time flux measurement effort at Mount Lemmon Observatory in 2001 and 2002, with the help of an international team of amateur observers.

In collaboration with other IMO officers, Marc Gyssens set up a network for rapid dissemination of information on the past Leonid outbursts. The purpose was to provide within a few hours after the event a preliminary ZHR profile and a tentative interpretation to professionals and amateurs as well as the interested press, based on observations sent in via personal email, mailing lists, telephone and fax.

2.2 Other events

- Circulars were issued to warn about upcoming meteor outbursts.
- Support was given to establish a new real-time reporting of radio forward meteor scatter observations via the internet (H. Ogawa).
- Gilberto Klar Renner established a 24-hour radio station in support of meteor outburst monitoring in support of Global-MS-Net (P. Jenniskens of NASA Ames and H. Ogawa of Tsukuba University). Visual campaigns were organized in support of the IMO by Rainer Arlt.
- Tim Cooper coordinated a β-Tucanid observing campaign in South Africa in support of research by Esko Lyytinen and Peter Jenniskens.
- The Dutch Meteor Society supported an Ursid outburst campaign in 2000 in support of research by Peter Jenniskens and Esko Lyytinen. NASA Ames issued a press released based on a WGN paper on the issue.
- Internet discussion groups were monitored and contributed to, and interesting observations were followed up on.
- Robert Lunsford created monthly overviews of meteor shower activity for the AMS and NAMN, which were used by amateurs and professionals.
- Numerous inquiries on the internet were answered.
- Marc Gyssens served as editor of WGN, the Journal of IMO, and maintained a high standard by providing many internal and external reviews of manuscripts.
- Numerous professionals published in WGN, the Journal of IMO. Authors who gave their institute addresses included Martin Beech, Giovanni Imponente, Costantino Sigismondi, Peter Jenniskens, Robert McNaught, David Asher, Arkadiusz Olech, Bo Gustafson, Mark Kidger, Detlef Koschny, Josep Maria Trigo-Rodriguez, and Nilakshi Dingra.
- Results published in WGN, the Journal of IMO, and Radiant, the Journal of DMS, were included in discussions in the peer-reviewed scientific literature.
- Amateur journals were included in the Bibliography of Leonid Storm Research (Peter Jenniskens).
- In organized meetings, special efforts were taken to include amateur observers.
- Professional astronomers participated in the International Meteor Conferences organized by the International Meteor Organization.
- Numerous lectures and talks were given by amateur and professional participants that helped increase popular interest in the field of meteor astronomy.

3 The newly installed working group (2003-2006)

The ProAmat working group will continue to further observing activities during upcoming meteor outbursts of such showers as the Leonids, Perseids and Ursids. The working group also intends to further other observations of interplanetary dust, now the Leonid showers

Table 2 – Membership of the current Working Group

Peter Jenniskens	Chair	USA	pjenniskens@mail.arc.nasa.gov
Ingrid Mann	President of Commission C22	Germany	imann@uni-muenster.de
Jin Zhu		China	jinzhu@bao.ac.cn
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Bob Lunsford	IMO (Secretary-General)	USA	lunro.imo.usa@prodigy.com
Hans Betlem		Netherlands	betlem@strw.LeidenUniv.nl
Neil Bone		UK	bafb4@central.sussex.ac.uk
Tim Cooper		S. Africa	tim@chemfit.co.za

are behind us. For the next three years, the ProAmat working group will consist of the representatives listed in Table 2.

Chris Trayner has taken over from Marc Gyssens as editor of WGN, the Journal of the IMO. Marc has served from many years as chief editor and has done an amazing job. In the spring of 2003, Hans Betlem resigned as editor of Radiant, the Journal of the Dutch Meteor Society after heading the journal for 24 years. Radiant played an important role in raising the quality of meteor observations in the Netherlands, resulting in many scientific publications. The DMS has decided to continue its reporting via the internet. Shinsuke Abe, who has long been active in involving Japanese amateur observers in professional observing activities, will step into the shoes of Jun-Ichi Watanabe. Hiroshi Ogawa, who will replace T. Yoshida, has recently been very active in bringing the amateur astronomy community together by providing near-real-time flux data on meteor showers from radio forward scatter observations. Robert Lunsford will continue to work closely with former Working Group member Jim Richardson, who did an excellent job in the past years. Jim is completing a PhD program to become a professional astronomer.

The International Meteor Organization

web site http://www.imo.net

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WGN

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Other publications		
Photographic Meteor Database (1986)	4	4
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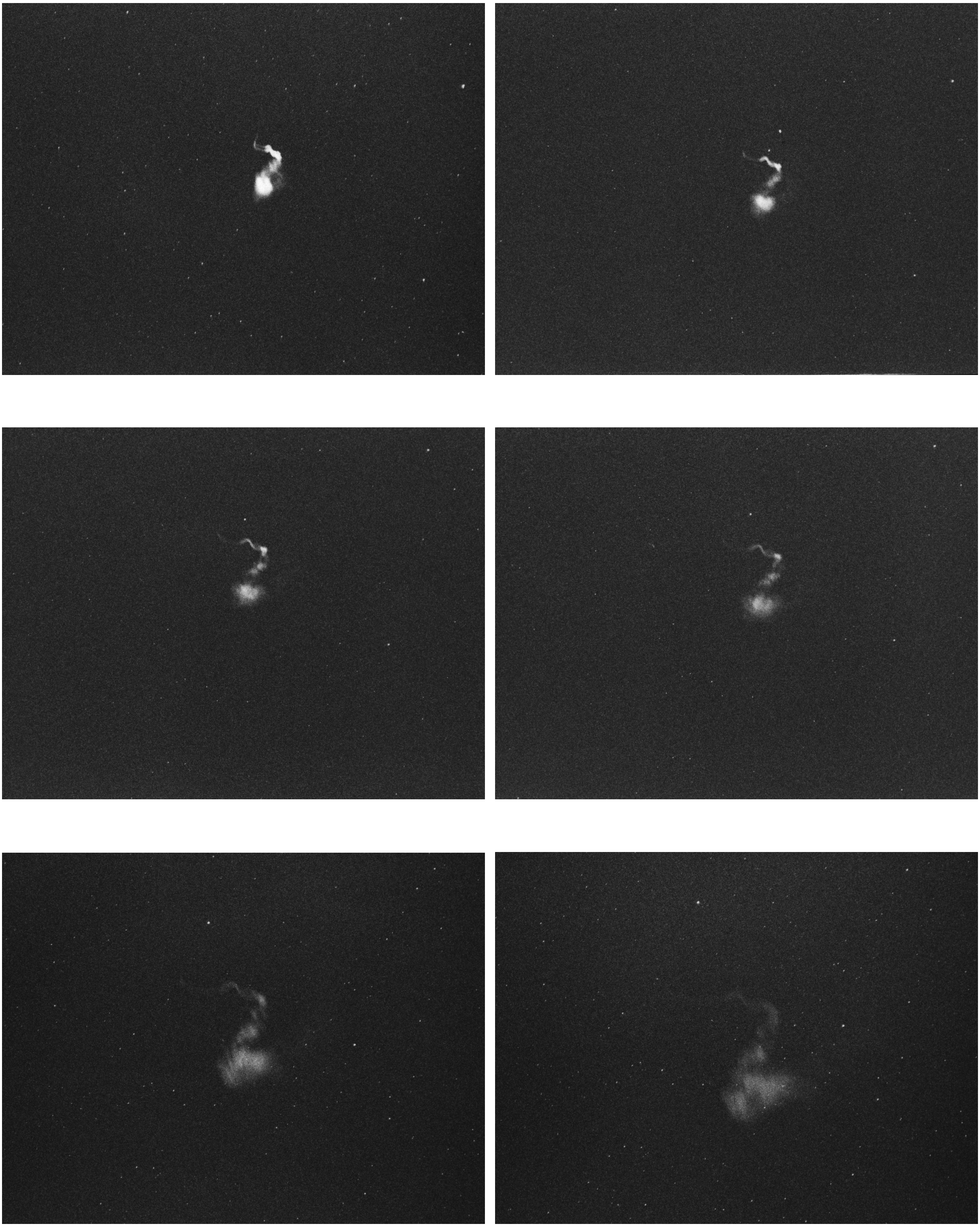
Photographic Astrometry + diskette	7	7

Persistent trains



Six images of a persistent train from a 2002 Leonid photographed in Avren village, Bulgaria.
Photographs from Valentin Velkov. Further details of this will appear in the Proceedings of IMC 2003.
Image sequence: top row left then right, then middle row, then bottom row.