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Many bright Leonid fireballs occurred around the activity peaks on November 18, 2001. This image was taken by Jürgen Rendtel from Ulaan Baatar, Mongolia, using a fish-eye lens $f/3.5$, $f = 30$ mm and Ilford Delta 3200 film (6 × 6-format). The negative, exposed for 10 min between $18^h00^m$ UT and $18^h10^m$ UT, shows 26 trails. The brightest one is from a magnitude −10 fireball at $18^h08^m$ UT.

In this issue:



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*WGN, Vol. 29, No. 6, December 2001, pp. 185–228*

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# Useful Information

## The February issue *(WGN 30:1)*

The *February issue* will be combined with the April issue of 2002. Contributions should be sent as soon as possible to *Marc Gyssens.*

## Subscriptions and ordering of publications

Volume 30 (2002) of *WGN* is expected to contain at least 240 pages and costs 20 EUR, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to the Treasurer, Ina Rendtel.

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

# The 2002 International Meteor Conference

## Frombork, September 26–29, 2002

*Mariusz Wiśniewski, Arkadiusz Olech, Marcin Gajos, Kamil Złoczewski, and Aleksander Trofimowicz*

We have the great pleasure to invite you to Frombork—the city of Nicolaus Copernicus. The place for the *IMC* 2002 was not chosen accidentally. Frombork is a beautiful small town placed near the Vistula Bay with a nice view on the Vistula Sand-bar. The most important part of the town is the Cathedral Hill with many historical monuments including the Gothic cathedral, the Copernicus Tower, where the great astronomer was making his observations, the Radziejowski Tower with an astronomical planetarium and a 28-meter Foucault pendulum inside.

Other interesting places are Saint Ann Chapel with natural medicine exhibition, the XIV century Water Tower, the nice main city square and a couple of historical canonry buildings.

Frombork is a typical touristic place with many small coffee bars and romantic restaurants. There is also a fishing port and a pier where, each morning, you can buy fresh fish. During the touristic season there is a possibility to sail to Krynica Morska, a town placed at the Vistula Sand-bar just near the open sea and spend free time at the nice sandy beach.

Frombork is surrounded by a village landscape with small areas of wild forests and full of natural beauty estuary of Bałda river. There is an amateur astronomical observatory at Żurawia Hill about 1.5 kilometers to the south of Frombork.

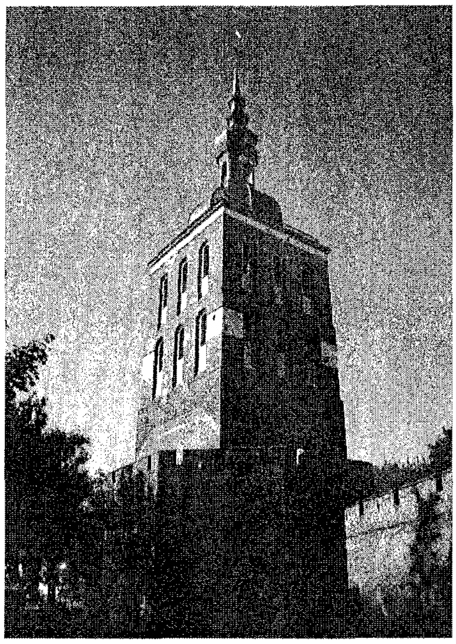

Figure 1 – The Radziejowski Tower on the Cathedral Hill of Frombork

Although we will provide bus transport from Gdańsk to Frombork, we encourage all participants to have a train trip from Frombork to Elbląg. It allows you to admire the great landscapes of the Vistula Bay coast which are sometimes within a few meters from the railroad. Another very interesting trip for people who plan to stay longer is an excursion to Malbork—the biggest middle-age castle in the world—, or visiting Gdańsk and its famous old city center.

The 2002 *IMC* will take place in the days of September 26–29 and will be organized by the Polish *Comets and Meteors Workshop (CMW)*. The *CMW* is an astronomical organization founded in 1987. Its main goal is to coordinate the comet and meteor observations in Poland. Since 1994 the *CMW* is one of the most active group of visual observers in the world.

Detailed information about getting to Frombork, the *IMC* hotel, reduced fees and other important things are available at our web pages: `http://www.astrouw.edu.pl/~olech/pkim/imc2002/imc.html`. The registration fee including lodging, all meals, and the excursion is 100 EUR. If you have any problems, questions, suggestions, or requirements do not hesitate to contact *Mariusz Wiśniewski, ul. Afrykanska 10, 03-966 Warszawa, Poland*, e-mail: `pkim@astrouw.edu.pl`, phone: +48-22-672-38-81, mobile phone: +48-607-49-13-09.

# International Meteor Conference

## Frombork, Poland, September 26–29, 2002

### Registration Form

Each individual participant should fill out a form and return it to *Ina Rendtel, Mehlbeerenweg 5, 14469 Potsdam, Germany*, as soon as possible. Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 50 EUR. If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: ______________________________ Birth date: ______________

Address: ______________________________________________

______________________________________________

______________________________________________

Phone: ______________ Fax: ______________ E-Mail: ______________

- ○ wishes to register for the 2002 *IMC* from September 26 to 29;
- ○ intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by ________, together with ______________________________

Additional requests:

- ○ I need travel information from ______________ to Frombork;
- ○ I wish to stay in Poland before or after the *IMC* and require additional information.

For participants wishing to contribute to the program:

Lecture: ______________________________________________

Duration: ________min. Required equipment: ______________________________

Workshop or discussion: ______________________________________

Poster presentation: ______________________________ Space: ________ $m^2$

Either the entire fee of 100 EUR or a pre-payment of 50 EUR should be sent to the Treasurer, *Ina Rendtel*. Follow the payment instructions below. Participants making a pre-payment only have to pay the remaining 50 EUR in cash upon arrival in Frombork.

Date and signature: ______________________________________

Please send your payment to the Treasurer or one of her assistants as indicated below:

- in Europe: pay in EUR to Ina Rendtel, account number 547234107 at Postbank Berlin, bank code 10010010. No bank checks, please! (Bank checks can only be sent to Robert Lunsford, see below).
- in the UK: proceed as above or pay to Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- in Japan: pay to Masahiro Koseki, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
- all others pay in USD to Robert Lunsford, 161 Vance Street, Chula Vista, California 91910, USA. In case you pay by bank check, make it payable to Robert Lunsford, *not* the *IMO*!

*People wishing to pay in other currencies should contact the appropriate* IMO *contact person for exchange rates.*

The Leonids

# Bulletin 17 of the International Leonid Watch First Global Analysis of the 2001 Leonid Storms

*Rainer Arlt, Javor Kac, Vladimir Krumov, Andreas Buchmann, and Jan Verbert*

Observers in America and Asia have monitored strong peaks of Leonid activity on November 18, 2001. We present a first analysis of global data based on the reports of 177 observers who recorded 137 146 Leonids. Main activity peaks are found for solar longitudes (all J2000.0) $\lambda_{\odot} = 236^{\circ}\!.137 \pm 0^{\circ}\!.003$ (November 18, $10^{h}39^{m} \pm 4^{m}$) and $\lambda_{\odot} = 236^{\circ}\!.458 \pm 0^{\circ}\!.003$ (November 18, $18^{h}16^{m} \pm 4^{m}$). Secondary peaks are found near the main Asian maximum at $\lambda_{\odot} = 236^{\circ}\!.448 \pm 0^{\circ}\!.003$ (November 18, $18^{h}02^{m} \pm 4^{m}$) and $\lambda_{\odot} = 236^{\circ}\!.467 \pm 0^{\circ}\!.003$ (November 18, $18^{h}30^{m} \pm 4^{m}$). The American peak actually exhibits a bimodal structure with two similar maxima at $236^{\circ}\!.137 \pm 0^{\circ}\!.003$ and $236^{\circ}\!.154 \pm 0^{\circ}\!.003$, the second of them being 24 minutes later. The population index shows sharp peaks for the storms, whereas the background level during the interval $\lambda_{\odot} = 235^{\circ}\!.6$–$237^{\circ}\!.0$ is characterized by $r < 1.9$.

## 1. Overview of data and predictions

The theory of the dynamics of the Leonid meteoroid stream has seen an impressive advance during this epoch of the return of the parent comet, 55P/Tempel-Tuttle. We shortly recollect the latest predictions given before the 2001 Leonid peaks and will discuss them together with the observational results in Section 4. The model of Lyytinen et al. assumes that particles leaving the Comet suffer from solar radiation pressure which always increases the semi-major axes of orbits [1]. They predicted major peaks for $10^{h}28^{m}$ UT, $18^{h}03^{m}$ UT, and $18^{h}20^{m}$ UT on November 18. The dust originates from the perihelion passages in 1766 (7 revolutions ago), 1699 (9 revolutions ago), and 1866 (4 revolutions ago), respectively. The refined model of McNaught and Asher resulted in $9^{h}55^{m}$ UT, $17^{h}24^{m}$ UT, and $18^{h}13^{m}$ UT, respectively [2]. The approach of Brown and Cooke [3] may be described as a full stream model with a total of one million particles. Much broader structures result from the stream components suggesting a wide single maximum near $13^{h}$ UT. The contributions from individual perihelion passages are centered near $10^{h}$ (7 revolutions), $12^{h}$ (6 revolutions), and $17^{h}30^{m}$ (4, 5, 9, 10, and 11 revolutions). The 6-revolution-old particles are not considered relevant in [1] and [2].

The process of entering observational data into the *Visual Meteor Database*, thus making them suitable for analysis of the visual activity of the Leonids, is not yet finished. The sample now contains the reports of 177 observers who recorded 137 146 Leonids from from 28 countries in America, the Pacific, Asia, Australia, Europe, and Africa. We have first added the high-resolution reports with details for one-minute or two-minute bins. Since we try to detect features with time differences of the order of 10 minutes, observing reports with 10-minute periods are not applicable. Also 5-minute periods are hardly acceptable, because the time correction for topocentric encounter (see Section 3) will shift observing periods by a few minutes, and the average profile is more "fuzzy" than a real 5-minute-bin profile. We would like to emphasize that *the analysis of meteor storms requires a fine breakdown of observing periods as well as of magnitude distributions* (see Section 5).

## 2. Population index analysis

The increase of meteor numbers with their magnitude is expressed by the population index $r$. We derived average values for $r$ using the average magnitude difference to the limiting magnitude of many observers [4]. Most of the people recorded magnitudes despite the high number of Leonids, as recommended before the storms.

Figure 1 shows the full profile obtained by an adaptive-bin algorithm which tries to keep the number of meteors in each bin roughly constant. The magnification of this profile is shown in Figure 2.

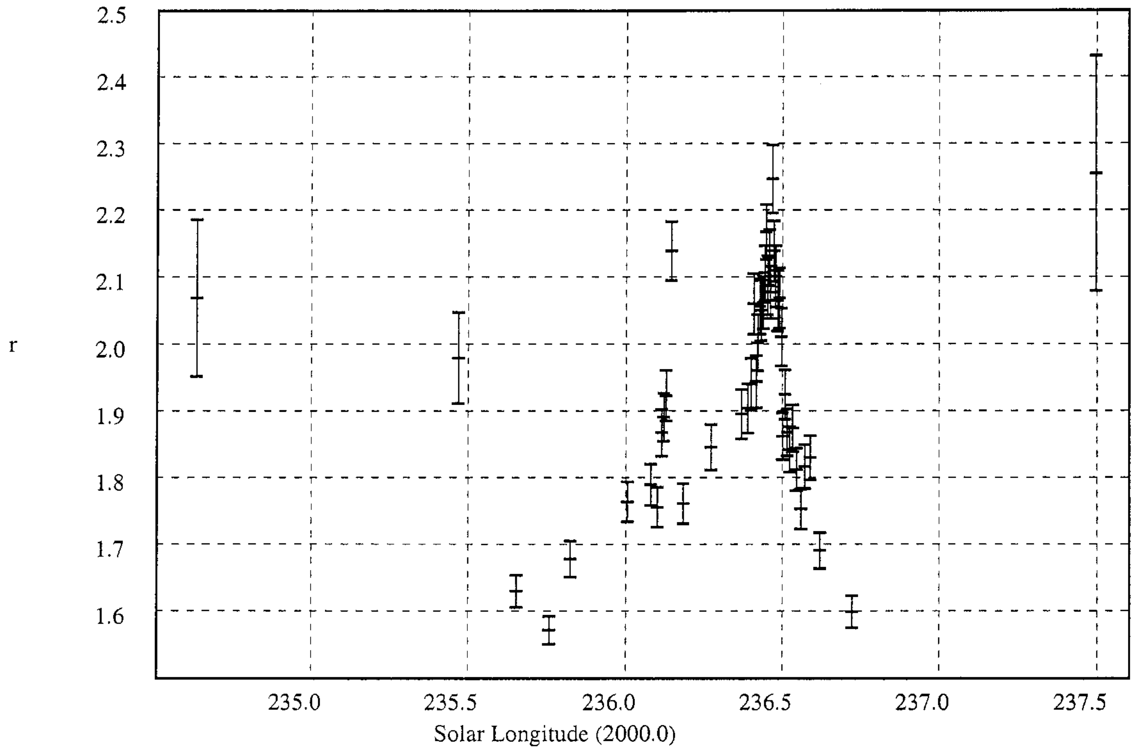


Figure 1 – Profile of the population index of the 2001 Leonids.

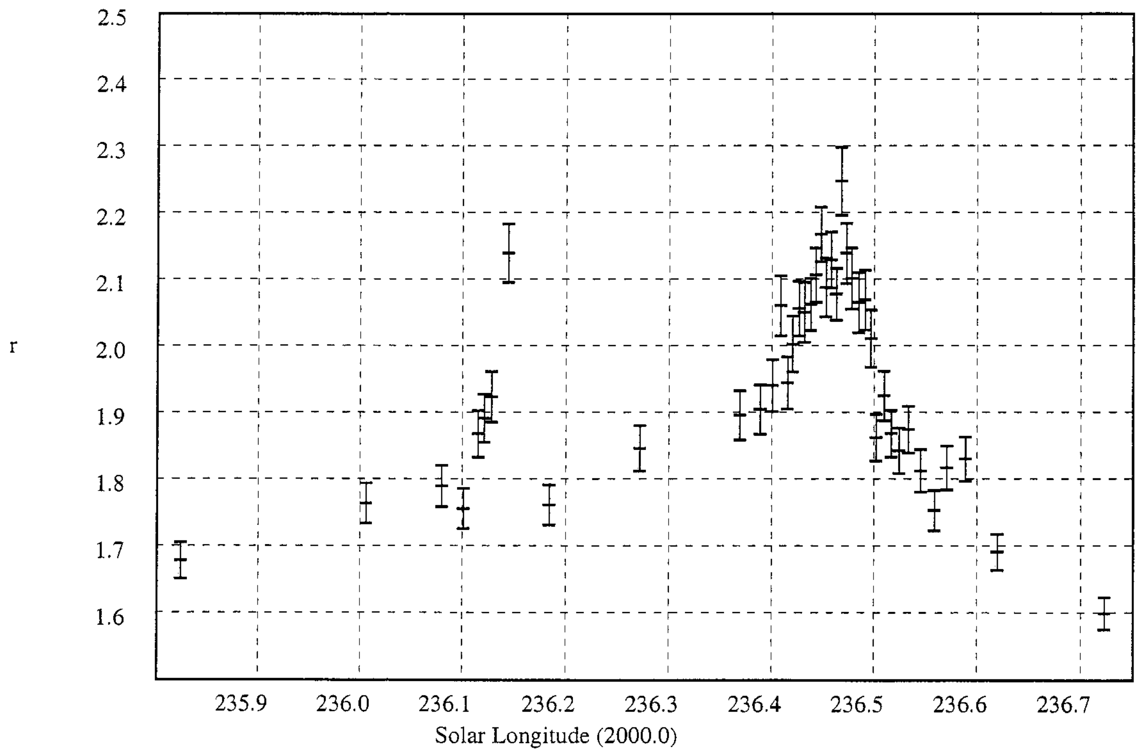


Figure 2 – Magnification of the population index profile near the two main maxima.

The two clear peaks coincide—at first glance—with the activity maxima of the Leonids. It is commonly assumed that we observe an abundance of faint meteors once the Earth is passing through the actual young dust trail. The periods before, in between, and after the peaks show population indices below 1.9, which is lower than typically observed in other major showers ($r \approx 2.0$). An abundance of bright meteors and several fireballs were indeed noted by the observers.

The highest population index of the first $r$-peak is found for $\lambda_\odot = 236.^\circ 14^{+0.03}_{-0.01}$ with $r = 2.14 \pm 0.05$; the second $r$-maximum peaks at $\lambda_\odot = 236.^\circ 465 \pm 0.^\circ 005$ with $r = 2.25 \pm 0.05$. The additional spike at $\lambda_\odot = 236.^\circ 445 \pm 0.^\circ 005$ could be related to the transit through the 9-revolution trail.

## 3. Activity profile analysis

Despite the large number of observations for both storms over America and Asia, the construction of the activity profile was not straightforward. The same averaging as in [4] was used. The analysis routine adapts the bin size according to the data available. In contrast to past attempts, we used the number of observing intervals, instead of the number of meteors, to determine the bin size. The latter would emphasize the results of high-perception observers unless perception correction is applied thoroughly for all the observers participating.

Now, an optimum number of 20 observing periods was given for the averaging. The bin size was not allowed to fall below $0.^\circ 0022$ (slightly above 3 min) as well as to exceed $0.^\circ 1$ (2.4 hours). The upper limit helps bridging periods with poor observational coverage. The lower limit is necessary to ensure a fairly constant binning in periods for which very large numbers of intervals are available. If there would be no limit, the routine will reduce the bin size quickly to one minute, but, at the same time, drop almost all of the observing periods, since the length of these periods must not exceed the length of the bin. The behavior of the algorithm without lower bin-size limit would be highly irregular. The application of the lower limit will result in 50–80 observing periods per average (a factor of 3–4 higher than the preset value), as presented in Table 1. Setting the lower limit will include periods of at mos 3 minutes duration, regardless of how much the optimum number of periods (20) is exceeded. No periods longer than 3 minutes are used in the high-resolution part of the activity graph.

Table 1 – Overview of predictions and observed activity of the 2001 Leonids. The two models refer to [2] and [1], respectively. The peak times with exclamation marks are the main maxima, whereas the other times denote slight enhancements of activity with medium significance. Model times in brackets are tentative associations with observed features. The number of individual observing periods is given as "Per."

| Dust trail | Models | | Observations | | | |
|---|---|---|---|---|---|---|
| | McNaught Asher | Lyytinen, Nissinen, van Flandern | $\lambda_\odot$ (J2000.0) | November 18 UT | ZHR | Per. |
| 7-rev | ($09^h10^m$) | – | 236.°082 | $09^h21^m$ (!) | $680 \pm 60$ | 19 |
| 7-rev | $09^h55^m$ | $10^h28^m$ | 236.°137 | $10^h39^m$ (!) | $1620 \pm 40$ | 75 |
| 7-rev | ($11^h00^m$) | – | 236.°154 | $11^h03^m$ (!) | $1610 \pm 60$ | 37 |
| 6-rev | – | ($12^h00^m$) | 236.°179 | $11^h39^m$ | $650 \pm 40$ | 19 |
| 6-rev | – | ($12^h00^m$) | 236.°195 | $12^h01^m$ | $520 \pm 40$ | 19 |
| – | – | – | 236.°262 | $13^h40^m$ | $400 \pm 40$ | 19 |
| 9-rev | $17^h24^m$ | $18^h03^m$ | 236.°448 | $18^h02^m$ | $2830 \pm 70$ | 66 |
| 4-rev | $18^h13^m$ | $18^h20^m$ | 236.°458 | $18^h16^m$ (!) | $3430 \pm 90$ | 39 |
| | – | – | 236.°467 | $18^h30^m$ (!) | $3010 \pm 70$ | 55 |
| 11-rev | $18^h43^m$ | $19^h10^m$ | 236.°491 | $19^h04^m$ | $1840 \pm 60$ | 47 |

General restrictions excluded observing periods where the total correction $r^{(6.5-\mathrm{lm})} F c_\mathrm{p} / \sin h_\mathrm{R}$ is larger than 5. Here, the limiting magnitude is denoted by "lm," the field obstruction correction is $F$, individual perception coefficients are $c_\mathrm{p}$, and $h_\mathrm{R}$ is the radiant elevation. Additionally, the latter was limited to $h_\mathrm{R} > 20°$ to avoid the influence of non-geometrical effects in the radiant altitude correction.

The time correction for the topocentric encounter of the Earth with the Leonid meteoroid stream was applied according to [5]. Since the influx angle of the stream with the ecliptic is small and positive, southern geographic latitudes approach any stream structure significantly earlier than northern latitudes. The results presented in Table 1 refer to the encounter of the Leonids' orbital plane with the center of the Earth. Observers in Australia should thus detect the dust trail 10 minutes earlier than the topocentric encounter; observers in Mongolia had largest delays of 4 minutes shortly after radiant rise.

A very puzzling picture emerged for the first storm over American geographical longitudes. While all observers agreed upon a peak near $10^h40^m$ UT, a secondary maximum was detected near $11^h$ UT, most strikingly by a group of three observers. These amateurs enjoy good meteor perception, but the problem was not the level of their ZHRs, but the presence of a clear structure not obvious from the remaining data set. Only a very detailed—actually oversampled—profile of the American Leonid peak, which does not include the aforementioned observers, revealed a second spike of activity near $11^h$ UT with the same ZHR level as the clear maximum of $10^h40^m$ UT. The structure was just averaged out due too less data available for the northwestern American morning hours. Figure 3 shows the profile omitting the three observers mentioned; note that the bins for the averages are too small, and variations are not necessarily significant.

A look into first results from image-intensified video systems gives more trustworthiness to the second American peak. The video system of the *Arbeitskreis Meteore* operated in New Mexico shows two peaks: one at $10^h39^m \pm 5^m$ UT and the other at $10^h57^m \pm 5^m$ UT. The video camera of Osamu Okamura, who flew from the USA to Japan to record both storms, shows peaks at $10^h45^m \pm 5^m$ UT and $11^h08^m \pm 5^m$ UT, respectively. The route reached geographical latitudes with topocentric correction of about 3 minutes. Since he moved north of the Leonid influx direction, he saw the shower peak later than observers at lower latitudes. This fact makes his times match well with the *AKM*, system which only needs a very small topocentric offset. We cannot give an evaluation of the statistical significance of these data here, and look forward to the activity analysis of the operators of these video systems.

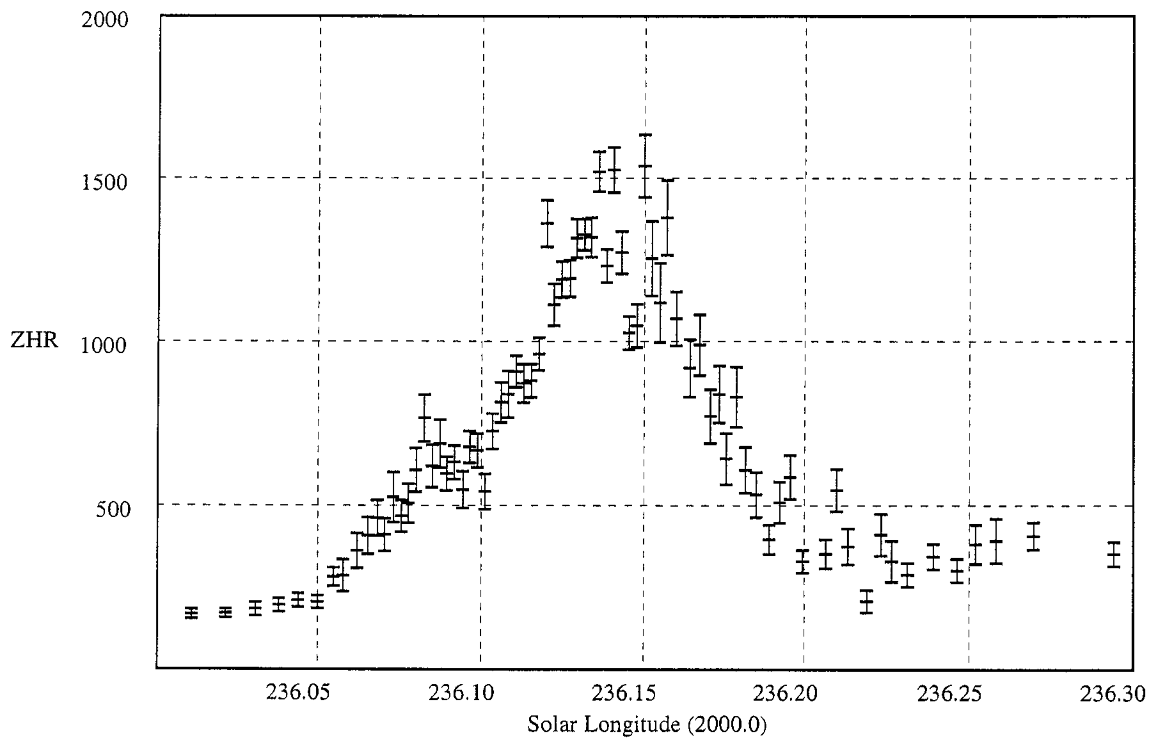


Figure 3 – Oversampled ZHR graph of the first peak as seen from American geographical longitudes. The diagram is intended to reveal a hidden second peak near $11^h$ UT. Variations may suffer from merely statistical fluctuations.

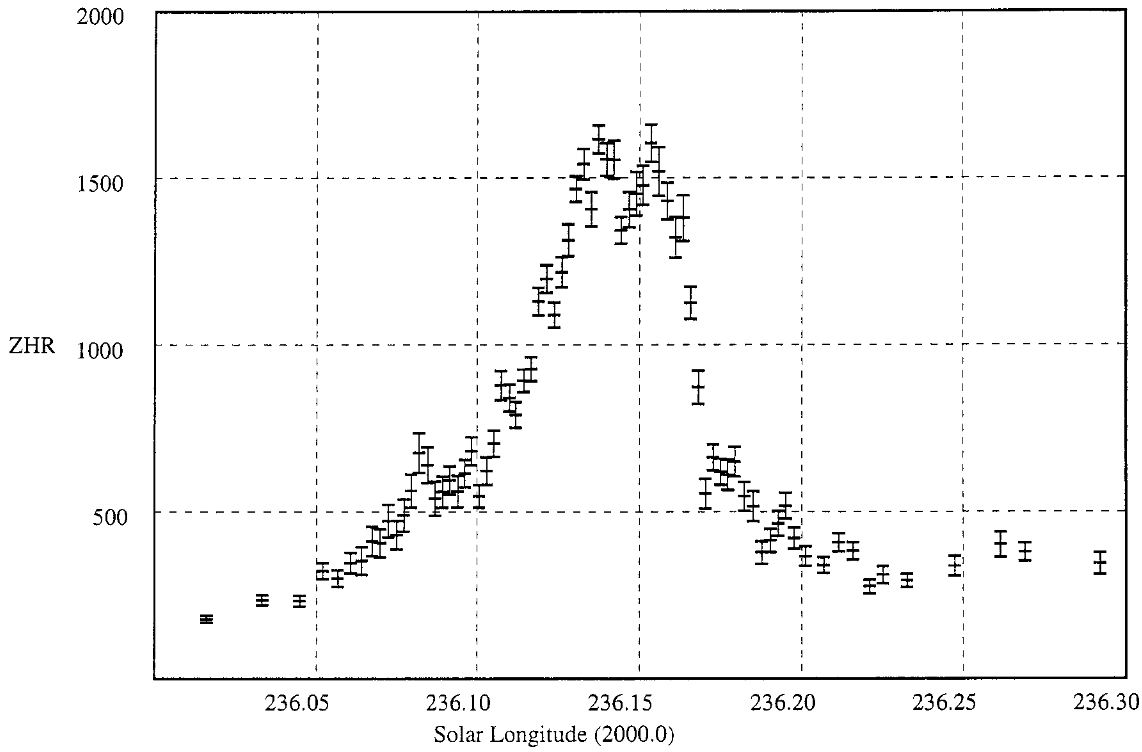


Figure 4 – Final profile of the first 2001 Leonid maximum as seen from American geographical longitudes.

Forward-scatter and radar data are also available, but the temporal resolution usually published is very coarse. The Ondřejov radar shows two peaks at $10^h45^m \pm 5^m$ and $11^h05^m \pm 5^m$, but the actual maximum occurred at $10^h05^m \pm 5^m$ [6]! The topocentric encounter was about 2 minutes ealier, that is, the two spikes in the Ondřejov radar data match the observed peaks very well. Entirely early is the maximum as recorded by the SKiYMET radar at Resolute Bay, Canada. Given the fact that correction for topocentric stream encounter is as high as 10 minutes, we arrive at a main peak time of $10^h20^m \pm 5^m$. The other SKiYMET radars did not record the storm [7].

Finally, a number of perception coefficients were deduced from three periods before and in the first American peak, from the range $\lambda_\odot = 235\overset{\circ}{.}128$–$236\overset{\circ}{.}139$. We have applied the resulting factors which were as high as 2.2–2.6 for the three "double-peakers." A recalculated profile of the entire maximum is shown in Figure 4. We obtain the following quantities from the graph: $\lambda_\odot = 236\overset{\circ}{.}137 \pm 0\overset{\circ}{.}003$ (November 18, $10^h39^m \pm 4^m$ UT) with ZHR $= 1620 \pm 40$ and $\lambda_\odot = 236\overset{\circ}{.}154 \pm 0\overset{\circ}{.}003$ ($11^h03^m \pm 4^m$ UT) with ZHR $= 1610 \pm 60$.

The fine structure of the American peak may also be visible in the profile of the population index. A recalculated graph with higher resolution did not reveal, however, a significant double peak. The scatter in the data becomes too large due to highly reduced meteor numbers in each average.

The Asian Leonid storm is shown in Figure 5. The highest activity level was observed at $\lambda_\odot = 236\overset{\circ}{.}458 \pm 0\overset{\circ}{.}002$ (November 18, $18^h16^m \pm 3^m$ UT) with ZHR $= 3730 \pm 90$. Additional enhancements are found to either side of the highest peak, namely at $\lambda_\odot = 236\overset{\circ}{.}448 \pm 0\overset{\circ}{.}002$ ($18^h02^m \pm 3^m$ UT) and $\lambda_\odot = 236\overset{\circ}{.}467 \pm 0\overset{\circ}{.}002$ ($18^h30^m \pm 3^m$ UT).

It is always good to check the profile on changes when the selection of observers is changed. A second graph of the Asian storm is shown in Figure 6 involving only observing periods with $\mathrm{lm} \geq +5.8$. The times of the three spikes are almost identical, but the level of activity is lower. The average limiting magnitudes for this profile is between +6.2 and +6.4. As the amount of data is still very large, we suggest to consider the results from this profile final.

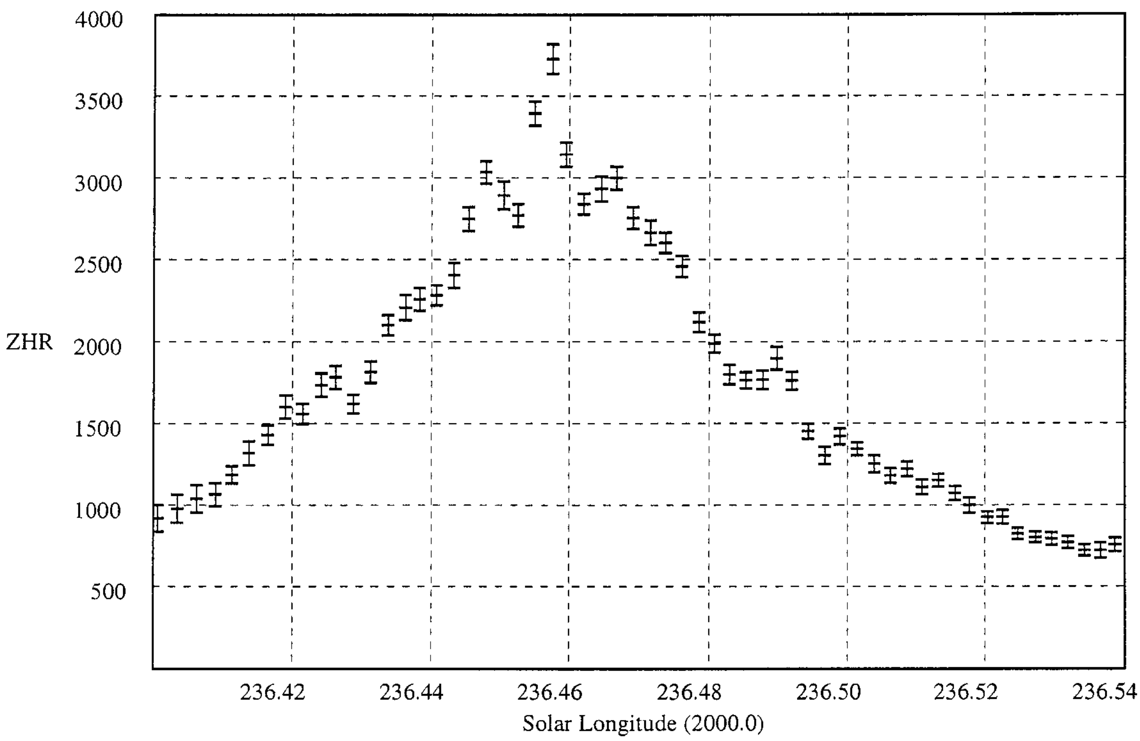


Figure 5 – Magnification of the second set of 2001 Leonid peaks as observed from Asian geographical longitudes.

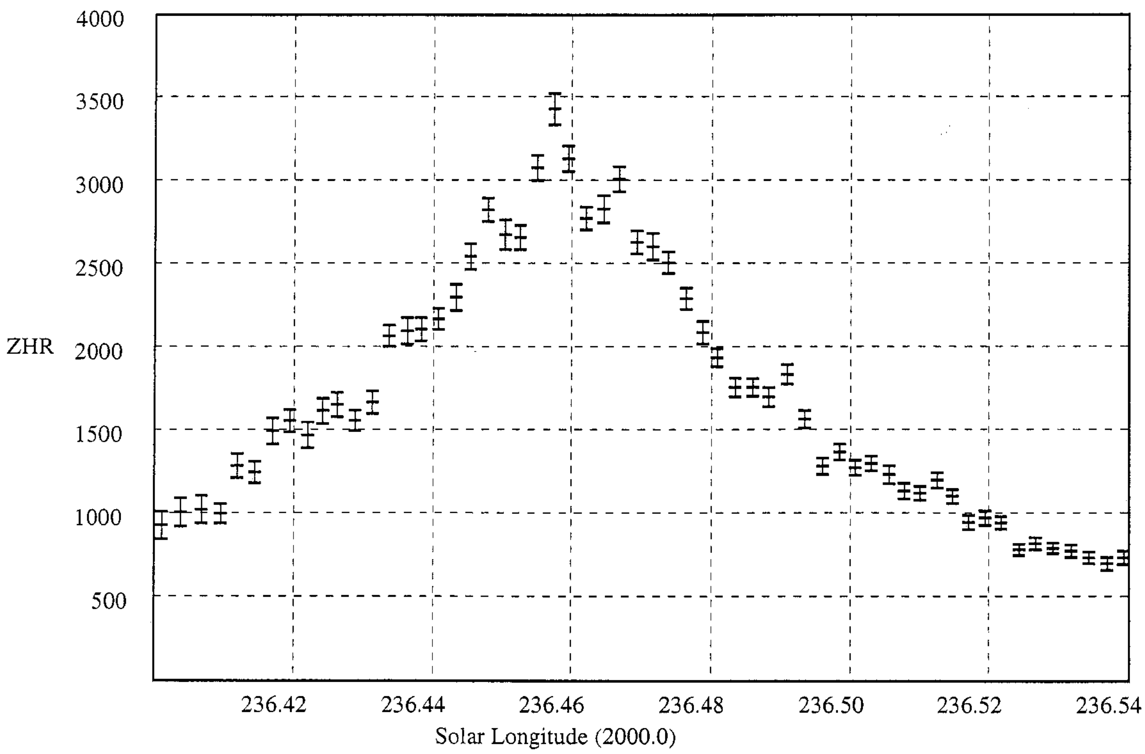


Figure 6 – Final profile of the Asian 2001 Leonid maximum. Observations with lm $\geq +5.8$ were used in the averaging procedure.

Accounting for possible binning effects, we will give error margins for the final peak times which are larger than the actual bin size. These times are $\lambda_\odot = 236\overset{\circ}{.}458 \pm 0\overset{\circ}{.}003$ (November 18, $18^{\text{h}}16^{\text{m}} \pm 4^{\text{m}}$) with secondary enhancements at $\lambda_\odot = 236\overset{\circ}{.}448 \pm 0\overset{\circ}{.}003$ (November 18, $18^{\text{h}}02^{\text{m}} \pm 4^{\text{m}}$) and $\lambda_\odot = 236\overset{\circ}{.}467 \pm 0\overset{\circ}{.}003$ (November 18, $18^{\text{h}}30^{\text{m}} \pm 4^{\text{m}}$).

## 4. Discussion

A first detailed profile of the Leonid meteor storms of 2001 was calculated. The main peaks at $10^h39^m$ UT and $18^h12^m$ UT match the predicted times of the 7-rev. and 4-rev. dust trails well. While the American maximum occured 11 minutes after the prediction of Lyytinen et al., and 44 minutes after the prediction of McNaught and Asher, the Asian peak was quite in time to fall between the $18^h13^m$ UT prediction by the latter and the $18^h20^m$ UT prediction of the model of Lyytinen et al.

The youngest trails up to 4-rev. in age are apparently the easiest to predict with accuracies of a few minutes. The $18^h02^m$ UT peak of the visual graph can be associated with the 9-rev. trail according to the prediction of Lyytinen et al. The result of McNaught and Asher is more than half an hour early, but so is nodal encounter with the trail also in the model of Lyytinen and colleagues! Only the consideration of non-gravitational effects brings the 9-rev. trail to times near $18^h$ UT. The same holds obviously for the 7-rev. trail for which the purely gravitational models result in $10^h05^m$ and $09^h55^m$ UT, in [1] and [2], respectively. See also Table 1.

We conclude that there was a second activity peak seen from American locations after that of the 7-rev. trail. Fatigue and reduced attention after the "fulfilled" prediction of the $10^h40^m$ peak may have resulted in understated Leonid numbers for some observers. The second peak is, however, too early for an association with the 6-rev. trail which was expected after $12^h$ UT.

We would also like to mention the possibility of a hollow stream structure. Such a hollow stream may be observable as a double-peak in the activity. The American maximum would then actually be centered at $10^h52^m$ UT with the two peaks being the two dense regions of the same tube-like structure. The analysis of the 1998 Leonid peak near $\lambda_\odot = 235\overset{\circ}{.}3$ (faint-meteor peak) showed a clearly bimodal population index profile, whereas a double peak in the ZHR profile was much harder to distinguish [8]. The bimodal structure may be associated with the encounters with the relevant 1-rev. and 2-rev. trails in 1998, though [9].

Despite the large number of observations, we found distinct influence of the individual perception of observers on the average activity profiles. This contrasts with earlier findings in global analyses of meteor showers. It is likely that the exceptional situation of a meteor storm results in much stronger scatter of individual data points. The actual ZHR level of both maxima may thus alter in a future full analysis of the 2001 Leonids in which perception coefficients for many observers will be derived.

## 5. Instructions for observers emerging from the analysis

Data input was (and is) a tremendous job, even for eight people. A layperson might wonder why this needs so much time, but each observation looks very different from another, and observations are often not consistent, so that input officers have to ask the observers which of two conflicting pieces of information is correct. In the rest of this section, we would like to stress some points that could further improve the quality of the data and make data input easier:

- *IMO codes for observers and observing site* are fixed by the input officers. Name codes do not always follow the rule "first three letters of the second name plus first two letters of the first name," so do not write codes that have not been fixed yet. New site codes are only fixed if your observing place is not within a radius of about 30 km from an old observing site: this is sufficiently accurate for visual purposes.
- *Limiting magnitudes are crucial.* Each observer should measure his or her own limiting magnitude for each observation (observers under the same sky may differ by up to one magnitude!). At good weather conditions, limiting magnitudes do not change very fast (unless the Moon is rising or twilight begins). The *IMO* standard method for measuring limiting magnitudes is very easy: count stars in three or more standard fields (see `http://www.imo.net/visual`) around your center of field of view and average the corresponding limiting magnitudes given by the tables.

- *Clouds are a severe problem*, if they are moving fast or take more than 20% of your visual field (which is approximately a circle of 50° radius around your center of field of view).
- Make sure that you are *looking at a point higher than* 30° above the horizon, because, otherwise, your field of view is obstructed by the Earth. If the population index is low, this may be balanced by more visible meteors, bute note that the observing situation results in uncertain corrections upon deriving meteoroid stream parameters.
- For a meteor storm, *choose observing periods of about 1 or 2 minutes*. Magnitude distributions can contain two or three such 1-minute periods, but always remember that there may be a loss of information due to a coarse breakdown. Make sure that start and end of an interval for a magnitude distribution always coincide with start respectively end of a smaller interval you give for the rates. A breakdown of magnitude distributions is *also required for other meteor showers.*
- Give effective observing times, $T_{\text{eff}}$, shortened by the time you did not watch the sky (noting down data for example). Caution: $1^{\text{h}}37^{\text{m}}$ to $1^{\text{h}}39^{\text{m}}$ is a 2-minute, period not 3 minutes.
- The *Visual Meteor Database* (*VMDB*) only contains data about rates and magnitudes; information about trains or colors is not stored in it. For meteor storms, you have to report little information on many meteors instead of much information on few meteors. For the rest of the year, however, you can store your data about trains, colors and paths in the *VISDAT* archive. A global *VISDAT* computer archive is planned and would allow even the search for new showers. Input of observations is then distributed to the individual observers, and the *VMDB* can be updated automatically.

**Availability of data**

The full data set of visual Leonid observations are available from Rainer Arlt. Further analysis of the data is most welcome. For enquiries, please refer to the e-mail address below.

**Acknowledgments**

The authors are most grateful to the visual observers who contributed with their data to this analysis. The enormous work of data input and utilization was not only done by the authors, but also by Jürgen Rendtel, Felix Bettonvil, Darja Golikowa, and Orlando Benitez to whom we do express our gratitude. We would also like to thank Sirko Molau and Marc Gyssens for their valuable comments, the former also for providing the video data.

**References**

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# The 2001 Storm from 11 Kilometers Altitude: First Results

*Peter Jenniskens, SETI Institute at NASA Ames Research Center*

A third Leonid MAC airborne campaign was organized to cover the 2001 Leonid meteor storms, with support of NASA's Astrobiology and Planetary Astronomy programs, and executed by the USAF/418th FLTS at Edwards AFB. The mission was flown over the continental United States, from Alabama to California, covering the first 1767-dust trail maximum on November 18, 2001. The shower returned much as predicted with a spectacular display of bright meteors seen all over the United States. Here is a brief first impression of the mission.

## 1. Introduction

The meteor storm that dazzled observers in Northern America was studied from an altitude of 11 kilometers by a team of 18 scientists in a NASA sponsored *Leonid Multi-Instrument Aircraft Campaign* (MAC). Its mission was to study the possible survival of organic matter in the meteors and provide near-real-time flux measurements to satellite operators. This was a follow up on the 1999 airborne campaign and would only be the second storm studied from aircraft [1,2].

Onboard the NKC-135 instrumented tanker *FISTA* (Figure 1), the researchers were able to train a wide array of optical and heat sensors to the rain of meteors. The aircraft departed from Edwards Air Force Base in California on November 18, at $5^h45^m$ UT. The flight commenced East to Alabama, where the plane turned West on a slow trajectory back to cover the anticipated storm peak [3–5]. Soon, numerous bright meteors were detected, sometimes 3 to 4 at a time. On several occasions, the pilots adjusted the heading of the aircraft to help point the instruments towards sudden persistent luminous trains, in one instance by turning the aircraft 180°. Close contact with aircraft operators prevented undue concern from the sudden and irregular aircraft motions. A spectacular sporadic fireball at $12^h52^m$ UT marked the end of the night. Landing occurred around $14^h30^m$ UT in morning twilight.

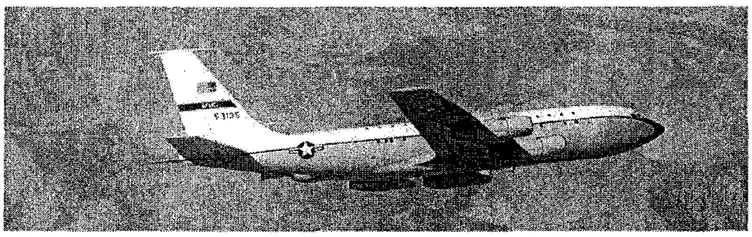

Figure 1 – The NCK-135 "FISTA" aircraft, which features 20 upward-looking windows.

This year's mission involved only one aircraft because of funding restrictions. In northern Arizona, the *Dutch Meteor Society*, in collaboration with Ondřejov Observatory, provided ground-based photography and video for stereoscopic observations. The $12^h52^m$ UT fireball, for example, was detected 5° above the horizon in northwestern direction. Other observers that were active in the region south of St. Louis and Denver and north of Memphis and Albuquerque may help provide additional stereoscopic data.

Because the mission came together only weeks before the shower peaked, it was not possible for international participants to obtain flight authorization. As a result, many observed at ground sited spread throughout the USA, notably Mount Lemmon Observatroy near Tucson, Arizona (Jiří Borovička), Mauna Kea, Hawaii (Hajime Yano, Shinsuke Abe), Poker Flat, Alaska (Hans Stenbaek-Nielsen), and at a site noth of Mojave, California (Ian Murray, Peter Jenniskens). Only Bear Lake was clouded out. Some other sites escaped clouds just barely. For near-real-time flux measurements, two ground stations were established at Mount Lemmon Observatory and near Alice Springs in Australia.

## 2. First results

It is still too early to know what new data were retrieved during the mission. Researchers will spend much of the next year sorting out the gigabytes of data. We do know that, for the first time, the mid-infrared sensor *BASS* was successfully pointed at a persistent train. This will help clarify the role of dust in explaining the mid-IR emission of trains detected during the 1999 campaign and perhaps confirm the presence of surviving organic molecules in the debris [6]. BASS was operated by Drs. Ray Russell and David Lynch of the Aerospace Corporation. We also know at this time that the *MIRIS* spectrometer operated by Drs. George Rossano and Daryl Kim recorded at least several more meteors at mid-IR wavelengths in zero order. Two earlier detections in 1998 suggested that something volatile may be realeased from Leonids around 117 km altitude [7].

A first inspection of the high-resolution optical spectroscopy conducted by former Ames Astrobiology Academy student Emily Schaller of Dartmouth College during the 2001 Leonid MAC mission shows an abundance of Leonid spectra of a quality never seen before. Twenty three spectra and 54 meteors were recorded. Half of the spectra are the garden-variety form, with characteristic lines of oxygen and nitrogen, but many others show yet unidentified emission lines and molecular bands. The reproductions in Figure 2 do not do justice to the hundreds of emission lines visible in the original data.

These data will be used to study the temperature of the meteoric plasma and search for small fragments of organic molecules. Schaller used the SETI Institute slit-less CCD spectrometer.

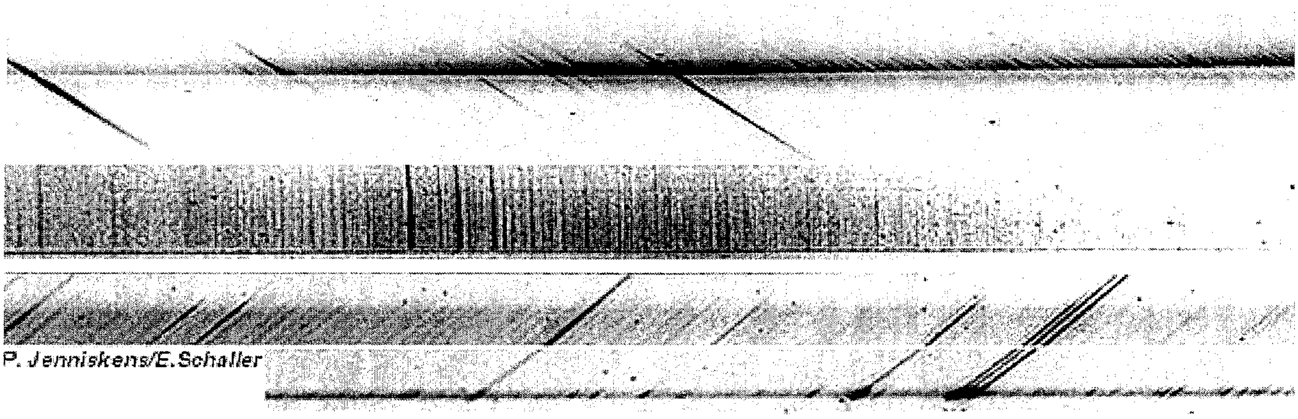


Figure 2 – Examples of optical spectra of Leonid meteors from the 2001 Leonid MAC mission.

Other researchers on FISTA included Rick Rairden of Lockheed, Palo Alto, who reported the detection of several UV spectra that may help put stronger limits on the amount of organic break-up products in the meteor plasma. Also, with the help of the NASA Ames Imaging Technology branch, high-definition TV spectra were taken for studies of meteor composition. This instrument recorded a spectrum of the bright $12^h52^m$ UT fireball in much detail, showing many similar features as the 1999 "Y2K" fireball. This relatively slow meteor left a persistent train, which raises a new perspective on what type of meteor can have such persistent emissions. Bill Smith of Washington University and George Rossano of the Aerospace Corporation obtained high-resolution CCD imaging of the meteors. Finally, persisent trains and airglow measurements were made with a slit-spectrograph operated by Avi Mandell of Penn State University.

Spectacular images of a bright Leonid meteor were obtained by participant Prof. Hans Stenbaek-Nielsen of the University of Alaska at Fairfield from a ground site at Poker Flat, Alaska. He used an unusual intensified high-frame-rate camera, specially designed for observations of thunderstorm-related sprites. This camera records video images at a rate of 1000 frames per second. Nielsen had to continually watch a video screen to catch the meteor in flight.

Figure 3 shows frame number 400 from a 463 millisecond sequence of a bright Leonid meteor at $10^h42^m59^s$ UT on November 18. The horizontal field of view is about 6°.

The meteor is first seen as a very localized ball. Then, it brightens and develops a tail, and one can clearly see a shock set up around the front. The images confirm that most meteor light comes from a bright plasma just behind the meteoroid, and will for the first time provide dimensions of that gas cloud. This will tell us how long organic molecules have to endure a hote plasma before cooling down. Just behind the gas cloud, a wake develops that is thought to be due to green forbidden line emission of O I at 557.2 nm.

The bow shock is larger than anticipated if a consequence of the vapor cloud of ablated material surrounding the meteoroid growing to sizes larger than the mean-free path in air at altitude. This emission may be responsible for some of the emissions of ionized $Mg^+$ and $Ca^+$ that are observed in bright Leonids, more so when the meteoroids are larger. The pictures show for the first time the meteoroid's bow shock and its development.

Figure 3 – The $10^h42^m59^s$ UT Leonid fireball in a 1/1000 s exposure. Courtesy of Hans Stenbaek-Nielsen, University of Alaska.

## 3. Validation of flux models

Near-real-time flux measurements were reported from aircraft (Peter Gural, Mike Koop, et al.) and from two ground stations. The ground sites were at Mount Lemmon Observatory, Arizona (David Holman, Jim Richardson, et al.) and at Alice Springs, Australia (Morris Jones, Jane Houston Jones, et al.).

The Mount Lemmon site was hampered by clouds in the beginning of the night, but cleared up miraculously during the peak of the shower. Alice Springs was partially cloudy the night before and after the peak, but cleared during the storm.

Results from a preliminary analysis after normalizing and scaling of all available counts are shown in Figure 4. The ZHR graphs are very similar to the early results reported by the *International Meteor Organization* [8], but provide more detail. These 5-minute counts are not smoothed. The ZHR profiles show no significant filamentary structure.

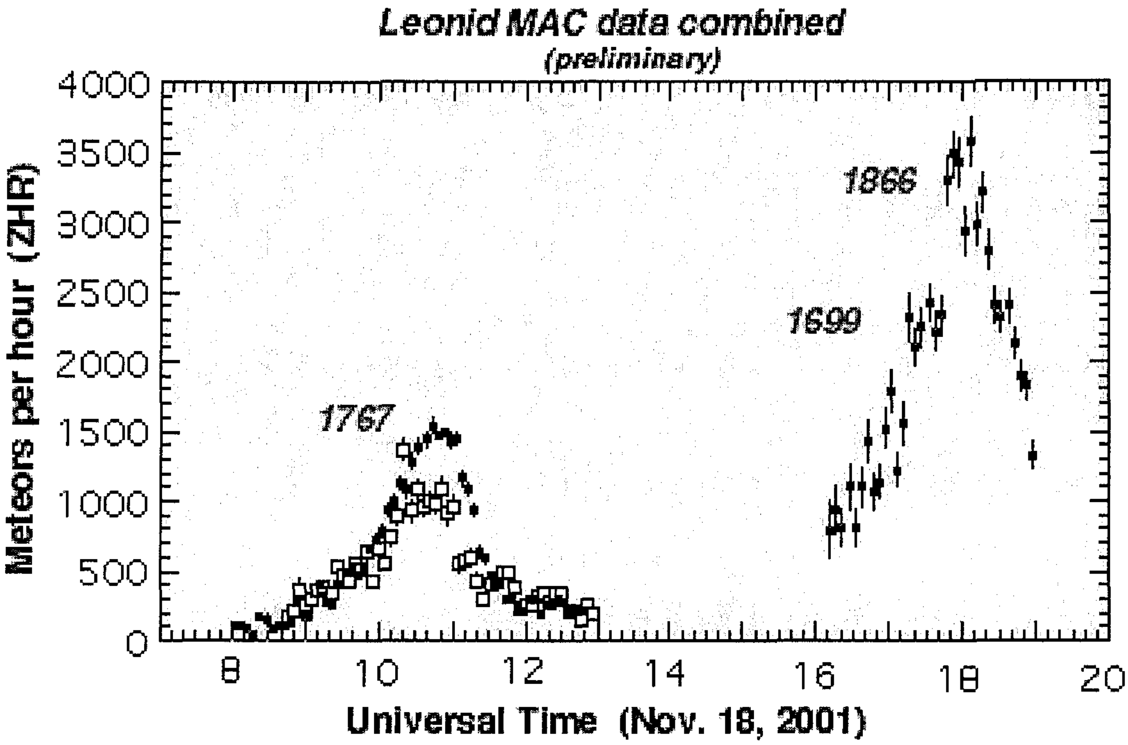


Figure 4 – Near-real-time flux measurements from the FISTA aircraft (○), and from ground locations at Mount Lemmon ($8^h$–$13^h$ UT) and Alice Springs ($16^h$–$19^h$ UT).

The FISTA results (○), which represent only a small subset of the available video data, provide the following preliminary results for the first maximum (with $r \approx 1.8$):

- *1767 trail*: peak at $10^h40^m \pm 3^m$ UT, FWHM = 1.5 h, peak ZHR = 1000.

The general shape and amplitude agree well with the early *IMO* data. However, at Mount Lemmon Observatory, that same peak was measured to be sharper and occur later:

- *1767 trail*: peak at $10^h45^m \pm 5^m$ UT, FWHM = 1.3 h, peak ZHR = 1500.

Closer inspection of the video records may clarify the reason for these differences. Other observers have reported peak ZHRs as high as 2200 and as low as 800.

The second peak occurred at $18^h05^m \pm 5^m$ UT, close to the predicted times. The present data do not enable an accurate decomposition. A single Lorentz profile fit gives

- *1866/1699 trails*: peak at $18^h05^m \pm 5^m$ UT, FWHM = 1.5 h, peak ZHR = 3500.

Scaling of the data to account for observer perception and atmospheric conditions may have introduced an error in the relative activity of the US and Australian peaks. Comparison of the videotapes taken in Australia and at Mt. Lemmon will help establish the precise relative intensity of the 1767 and 1866/1699 dust peaks.

The peaks are readily identified with the 1767 and 1699/1866 dust trails that were predicted to be encountered by McNaught and Asher [3] and Lyytinen, Nissinen, and Van Flandern [4]. The model by Brown and Cook [9], on the other hand, predicted that the 1799 dust trail encounter at approximately $13^h$ UT would be the dominant event and that the showers would be much broader than observed. Lyytinen et al. [4] made the most precise calculations of the shape and position of the 1767 dust trail under planetary perturbation and radiation pressure effects and obtained the most accurate prediction of the peak time for an "A2 parameter" of 4–6. Their latest model also predicted the 1866 peak time correctly. The peak rates were overestimated by a factor of 2–3 in both cases. If the rates can be taken at face value, it appears that the 1866 dust trail was further from the Earth's orbit than in the models by Asher and Lyytinen, as predicted in my description of a one-revolution dust trail [5]. However, the peak rates for the 1767 dust trail were not as high as I expected. Also, the 1767 dust trail was a factor of 2 wider than I had calculated and the peak time 31 minutes later [5]. Those discrepancies are unusually large. Therefore, I suspect that the results from the 1767 dust trail are affected by the uncertain trail position from distortions by planetary perturbations, as pointed out by McNaught and Asher [3]. The new observations will help improve the variation of the nodal displacement with the epoch of ejection and the variation of the size distribution index along the stream, adding further results to a very successful Leonid observing campaign. We hope that these results inspire others to take part in the final 2002 campaign.

## Acknowledgments

We are grateful to all that made this Astrobiology mission a reality. The mission was funded by NASA's Astrobiology program, with additional support by NASA's Planetary Astronomy program and ESA. The US Air Force supported the mission as part of the USAF sponsored MOIE program of the Aerospace Corporation. NASA Ames and the SETI Institute provided support with outreach and logistic matters. The Air Force Research Laboratory at Hanscom AFB made optical windows and struts available to provide the researchers with a clear view on the sky. The 418th Flight Test Squadron at Edwards Air Force Base was able to execute the mission despite the many challenges imposed by the nation's war on terrorism. Special thanks go to those that made the near-real-time flux measurements possible: Morris Jones and Mike Koop, for software and hardware development; David Holman and Jim Richardson and their team of visual observers, for operating the system at Mount Lemmon Observatory; Morris Jones and Jane Houston, for bringing a team together at Alice Springs in Australia; Peter Gural and Mike Koop, for running the system onboard the Leonid MAC mission; webmaster Joshua Kitchener of `NearEarth.net`, with support of Mike Wilson and Carrie Gembicki, for updating the Leonid MAC website at the Ames mission Head Quarters; and Glenn Deardorf, for making the applets that showed the evolving counts to hundreds of thousands of web surfers on mission night.

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# SSFA 2001 Leonid Fireball Observations

*Martin Beech and Alison Illingworth*

We present a set of Leonid fireball observations gathered by the Southern Saskatchewan Fireball Array. In the time interval November 18.08 to 18.30 UT, a total of 251 Leonid and 2 sporadic meteors brighter than magnitude −2 were detected by an all-sky video camera system operated at Regina, Saskatchewan, Canada. The peak fireball rate occurred between $10^h15^m$ and $10^h30^m$ UT on November 18. We deduce a population index of $r = 1.8 \pm 0.4$ for the entire time interval of our observations, indicative of there being a relatively large proportion of bright meteors. We also present a set of 13 high-time resolution (data spacing at 1/120 s) light curves recorded with an all-sky radiometer.

## 1. The Southern Saskatchewan Fireball Array (SSFA)

The all-sky camera system used in this study forms part of the *Southern Saskatchewan Fireball Array* (SSFA) located in the southernmost prairie region of Saskatchewan, Canada. The camera systems have been designed and supplied by Sandia National Laboratories, New Mexico, and each system consists of a 45-cm diameter spherical mirror combined with a centrally mounted and downward-looking video camera. The camera systems afford all-sky monitoring to a limiting magnitude of about −1 [1].

In addition to the camera system, the Regina site houses a radiometer, also supplied by Sandia National Laboratories [2], which is used to monitor and log the times of optical transients. The radiometer returns, and stores directly to a PC hard drive, 1200 sky brightness samples per second, and these data are later analyzed for the times of optical transients and are used to reconstruct high-time resolution light curves. The limiting magnitude for achieving good light curve reconstruction with the radiometer data is estimated to be about magnitude −7.

## 2. Observations

In spite of light rain in the late afternoon of November 17 and total cloud cover during most of the evening, the conditions from $8^h00^m$ UT, November 18, to sunrise were perfect from Regina. We had zero cloud interference and good seeing during the entire time interval that the data discussed in this article were collected. At the commencement of data logging, the radiant altitude was some 22° and the Leonid shower was already at a high level of activity.

Figure 1 shows the fireball activity as recorded by the all-sky video system at Regina in 15-minute time intervals.

The videotapes were reviewed manually and eye-estimates of fireball brightness were made according to achieved observations of the Moon at various phases, the planets Venus, Mars and Jupiter, and iridium satellite flares. A peak rate of some two fireballs per minute was recorded in the time interval $10^h15^m$ to $10^h30^m$ UT. The fireball peak occurred in the same time interval as the visual peak reported by *IMO* observers, and the activity profile is non-symmetric about the time of maximum.

Table 1 gives the observed distribution of Leonid meteors in the magnitude range of −2 to −6. We feel less certain of our magnitude estimates for fireballs brighter than magnitude −6, and, consequently, have not used them in the population index derivation. We estimated that eleven of the observed fireballs were brighter than magnitude −6 at maximum, with the brightest pair observed being set at magnitude −10.

We deduce a population index of $1.8 \pm 0.4$ (corresponding to a mass distribution index of about 1.4) over the entire time interval that our observations were collected. The population index was reported to be nearer $r = 2.0$ at the time of the second maximum at $18^h20^m$ UT. The population index we derive is similar to that deduced for the time of maximum of the fireball-rich 1998 Leonid return for which a population index of $r \approx 1.5$ was found [3].

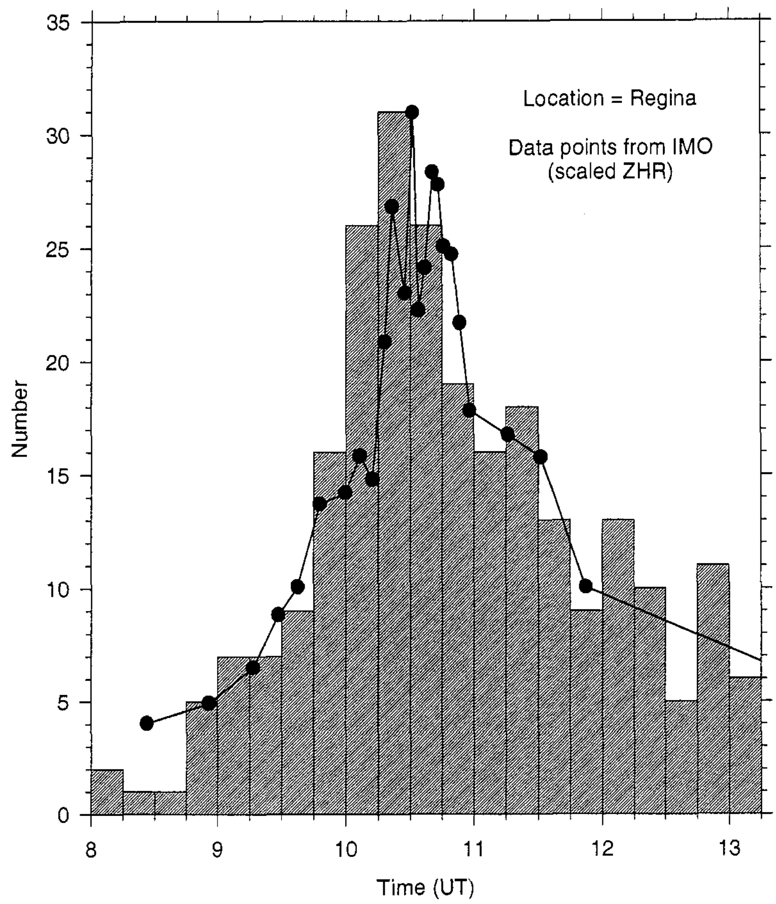


Figure 1 – Leonid fireball activity as recorded by the Regina all-sky camera system. The data is presented in counts per 15-minute time interval. The scaled *IMO*-derived activity profile is superimposed upon the fireball histogram to illustrate the common peak times and the asymmetric activity profile.

Table 1 – Magnitude distribution of Leonid fireballs observed between $8^h00^m$ and $13^h15^m$ UT on November 18, 2001.

| Magnitude | −2 | −3 | −4 | −5 | −6 |
|---|---|---|---|---|---|
| Leonids | 95 | 70 | 43 | 22 | 10 |

Traveling at 71 km/s, a meteoroid of mass $10^{-4}$ kg will produce a Leonid meteor of peak magnitude −2 (for a zenith angle of 45° [4]). Further, if we assume that the ablation height of Leonid fireballs is 100 km, then the sky area monitored by the camera system amounts to some $3.6 \times 10^5$ km$^2$. Using this estimate of the collecting area, we determine a Leonid fluence of $3.7 \times 10^{-9}$ meteoroids of mass greater than $10^{-4}$ kg per square meter between $8^h00^m$ and $13^h15^m$ UT on November 18. The peak fireball flux amounted to $9.6 \times 10^{-14}$ meteoroids of mass greater than $10^{-4}$ kg per square meter and per second.

## 3. The light curves

The thirteen reconstructed radiometer light curves, for the fireballs listed in Table 2, are shown in Figures 2, 3, and 4. The light curves show the irradiance (radiant flux energy) against time relative to the time of maximum brightness.

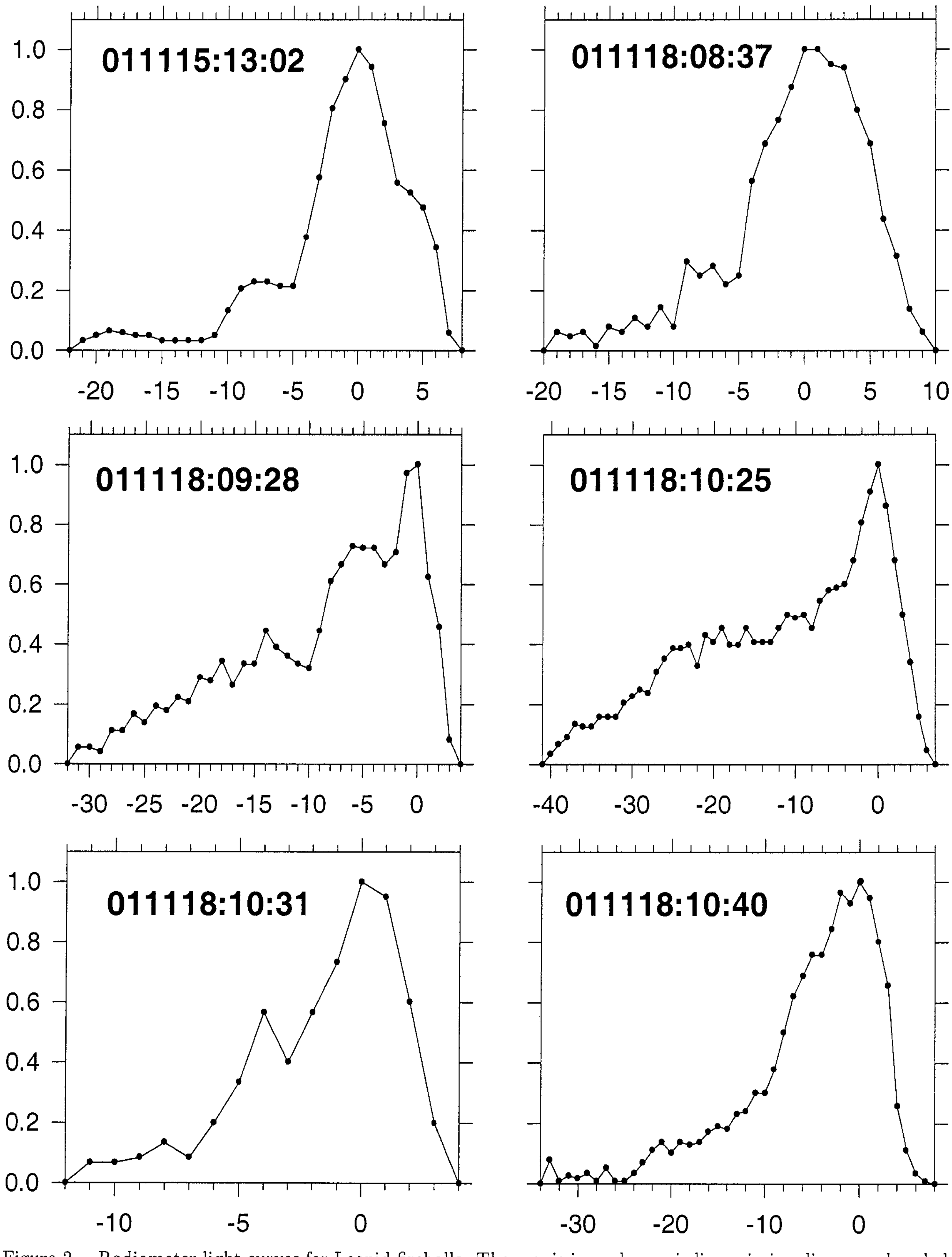


Figure 2 – Radiometer light curves for Leonid fireballs. The $y$-axis in each case is linear in irradiance and scaled to unity at maximum. The time intervals are spaced at 1/120 s and are given relative to the time of maximum ($t = 0$). Individual fireball details are given in Table 2. Each light curve is identified according to year/month/day/UT time.

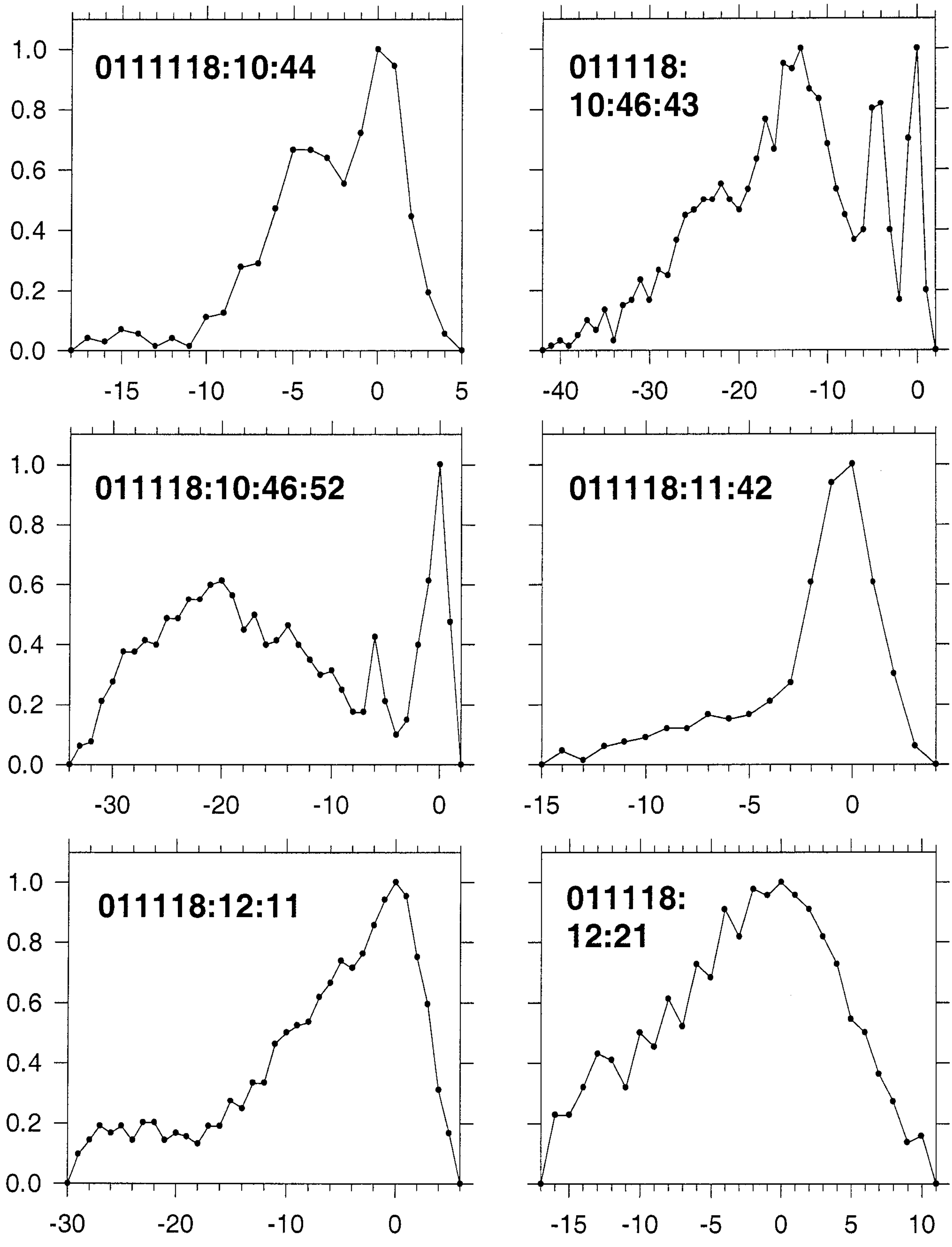


Figure 3 – Radiometer light curves for Leonid fireballs. Details are the same as for Figure 2.

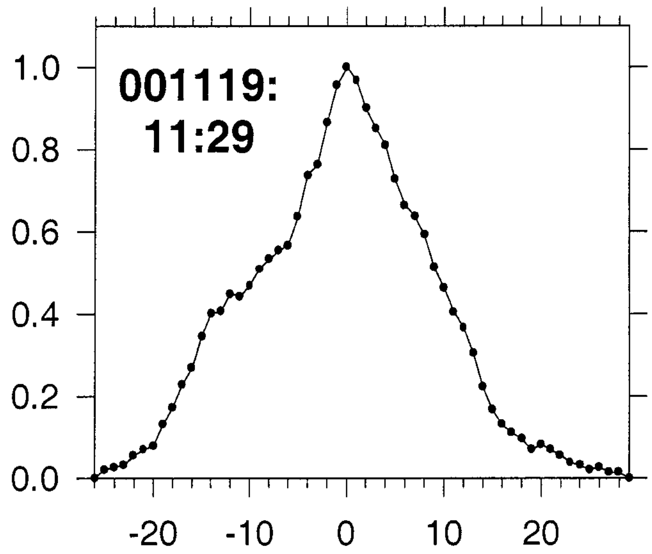


Figure 4 – Radiometer light curve for the Leonid fireball observed on November 19, 2000. Details are the same as for Figure 2.

Table 2 – Radiometer light curve data. The first two columns identify the time of the fireball (note the first entry is for the year 2000—the only Leonid recorded from Regina in that year). Column 3 gives the estimated magnitude at maximum. An "F" in column 3 indicates that distinctive flares were observed (see Figure 3). The total duration of the meteor as recorded by the radiometer is given in column 4, with the rise-to-fall time ratio about maximum being given in column 5. The radiant altitude is given in column 6. The light curve type as advocated by Spurný et al. [5] is given in column 7—see text for further discussion on light curve morphology.

| Date | Time (UT) | $m$ | $D$ (s) | Rise/Fall | $h$ | Type |
|---|---|---|---|---|---|---|
| 2000 Nov 19 | $11^h29^m29^s$ | −10 | 0.46 | 0.9 | 54°0 | I |
| 2001 Nov 15 | $13^h02^m02^s$ | −12 | 0.25 | 2.8 | 60°7 | II |
| 2001 Nov 18 | $08^h37^m48^s$ | − 8 | 0.25 | 2.0 | 28°0 | Int. (II?) |
| | $09^h28^m17^s$ | − 8 | 0.30 | 8.0 | 36°0 | II |
| | $10^h25^m38^s$ | − 8 | 0.40 | 5.9 | 44°8 | II |
| | $10^h31^m58^s$ | − 8 | 0.13 | 3.0 | 45°7 | II |
| | $10^h40^m22^s$ | −10 | 0.35 | 4.3 | 47°0 | II |
| | $10^h44^m16^s$ | − 8 | 0.19 | 3.6 | 47°5 | II |
| | $10^h46^m43^s$ | −10 F | 0.37 | 21.0 | 47°9 | Int. (I?) |
| | $10^h46^m52^s$ | − 8 F | 0.30 | 17.0 | 47°9 | Int. (I?) |
| | $11^h42^m09^s$ | − 8 | 0.16 | 3.8 | 55°0 | II |
| | $12^h11^m04^s$ | − 8 | 0.30 | 5.0 | 58°0 | II |
| | $12^h21^m05^s$ | − 7 | 0.23 | 1.5 | 58°8 | I |

The light curves have been reconstructed from the radiometer data at time intervals corresponding to 1/120 s. The light curves therefore sample the radiant energy of the fireball over successive spatial distances of about 600 m. Two of the fireballs observed ($10^h46^m43^s$ UT and $10^h46^m52^s$ UT) showed distinct flares, while two were essentially symmetric light curves (the November 19, 2000 fireball, and the November 18, $12^h21^m$ UT fireball). The remainder are "late peaked" with the rise time to maximum typically being some 4.5 times longer than the decay time (see column 5 of Table 2). A number of the light curves show an interesting early phase in which the irradiance increases linearly with time to a symmetric profile about maximum brightness. Virtually all of the light curves show a "flickering" effect (particularly prominent in the $8^h37^m48^s$, $9^h28^m17^s$, $10^h46^m43^s$, and $12^h21^m05^s$ fireballs). This phenomenon was also present in the 1998 Leonid fireball light curves studied by Spurný et al. [5]. Since Leonid meteors belong to the most fragile IIIB fireball group, it is clear that the flickering can not be due to rotation (as invoked under other circumstances [6]), but must be an intrinsic phenomenon of the meteoroid fragmentation (crumbling?) process. We shall present a more detailed study of this phenomenon and a model for Leonid fireball light curves at a later date.

In their study of 1998 fireballs, Spurný et al. [5] suggested that the Leonid light curves could be sorted according to three morphological types. The Type I light curves were those that were essentially symmetrical in shape with rapid rise and fall times to a maximum, sometimes plateaued, brightness. The Type II light curves were those that were non-symmetric about the maximum, and which showed a much greater rise time to maximum than decay. An intermediate none-designated light curve type between those of I and II was also recognized. We find the same morphological types as those outlined by Spurný et al. (see column 7 of Table 2) but we do not find supporting evidence to their suggestion that light curve morphology is determined by the entry angle of the meteoroid into the Earth's atmosphere. It was suggested by Spurný et al. that Type I light curves are produced for entry angles less than 30°, while Type II light curves are produced for entry angles in excess of 45°, with intermediate morphologies arising for entry angles between 30° and 45°. We have found, however, two Type I light curves (the November 18, 2001, $12^h21^m$ UT fireball and the November 19, 2000, $11^h29^m$ UT fireball) for Leonids with entry angles of 54° and 59°, respectively. While we certainly agree that entry angle is an important factor in the ablation process, we would suggest that the morphological type is more likely determined by a meteoroid's constituent grain mass distribution and its binding matrix material. Murray et al. [7] have found, for example, that "ordinary" Leonid light curve morphologies vary according to space exposure age (i.e., with respect to dust trail sampled) and the mass distribution of fundamental grains contained within the meteoroid. They also find "composite" light curves that mimic the Type II fireball morphology of Spurný et al. [5]. We would suggest at this time that there is really a continuum of possible Leonid (and other meteor) light curve morphologies and that establishing a president for ascribing just two main types and an intermediate is unnecessarily restrictive.

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# The 2001 Leonids Meteor Storm 2001 over Japan

*Hiroshi Ogawa and Shigeo Uchiyama*

In 2001, many Japanese observers saw a Leonids meteor storm on November 18 UT. During this event, although the parent comet (55P/Tempel-Tuttle) had passed three years ago, many fireballs, trains, and meteors were observed. The maximum of Leonids activity was a HR of 2300 and a ZHR of 4500 around $18^h10^m$ UT on November 18. The Leonids peak in 2001 was very flat. Therefore, the high activity lasted for a long time. We also analyzed ZHRs per magnitude class. We found that the ZHR for fireballs of magnitude $-2$ or brighter was nearly constant. So, no increase of fireballs was seen because of the encounter of the various dust trails.

## 1. Introduction

In 2001, the Leonid meteor stream was expected to show us its most impressive appearance of this epoch thusfar. Many researchers published predictions. Robert McNaught and David Asher predicted that the Earth encountered three main dust trails [1]. Other researchers, Esko Lyytinen and Van Flandern scrutinized seven dust trails [2]. Both researchers predicted the main peak to occur around $18^h00^m$–$18^h20^m$ UT on November 18. Hence, the best observational sites were in East Asia and Australia. Japan was one of the best places, geographically. The ZHR prediction of ZHR was about 7600–8000 [3,4].

First, the Earth would encounter the 1766 dust trail in North and South America, and then the 1699 and 1866 dust trails in East Asia and Australia.

In Japan, many observers prepared for the Leonids big appearance. We searched for the best place taking into account the weather, light pollution, etc. On the maximum night (November 18 UT), we saw a Leonids meteor storm. Members of the general public saw the storm, too. Also, several projects were set up for the 2001 Leonids (visual, radio, video, photo, etc.). We observed by each observational method. Many useful data could be obtained. These data are being collected and analyzed now. Actually, some of the visual and radio meteor observations have already been analyzed.

## 2. Observations

Many observers prepared themselves in order to catch the Leonid meteor storm. Observational projects or networks were set up and all observational methods were used.

Visual observation is the major observational method. The *Nippon Meteor Society* (*NMS*) recommended a standard format for the Leonid reports. This format required date, start time, end time, effective observational time, the number of Leonid meteors seen, limiting magnitude, cloudiness, observational site, field of view, and name of observer. The time interval was not decided upon, but we recommended 5-minute intervals. Some observers reported 1-minute intervals. We collected information about meteor magnitudes every 30 minutes.

Via the *Nippon Meteor Society*, 72 observers reported flash data. The total number of observations up to now is 2145, but more observational data will be reported. Besides, about 2000 high school students in Japan observed the Leonids during the same night. This project is called Astro-Classroom for High-School Students of the World (Astro-HS) [5].

Also, about 80 radio meteor observers registered Leonids since November 1 (Leonids 2001 Project by Radio Meteor Observation, coordinated by Hiroshi Ogawa) [6]. Mr. Daiyu Ito and Mr. Yasuo Shiba set up the network for photographic observation, and Mr. Masayuki Toda and Mr. Masayuki Yamamoto set up the meteor train observing campaign. Besides these efforts, video observations were made. In the "Astro-Classroom for High School Student of the World" project, high-school students observed visually, by radio, and by video observation. In particular, video observation by high-school students were carried out at 40 sites.

## 3. Results

*HR and ZHR curve of the 2001 Leonids from visual observations*

Visual observational data were reported by 72 members (2145 entries). For the period November 10–24, they are summarized in Table 1 and Figure 1. the ZHRs are calculated by the usual formula, taking $r = 2.2$ and $\gamma = 1$. The total observing time amounts to 14 788 minutes, or more than 246 hours, and the total number of Leonids seen to 131 957.

Table 1 – Daily Leonid result from visual observations. $N_{\mathrm{data}}$ is the number of data entries; the ZHR was calculated with $r = 2.2$ and $\gamma = 1.0$.

| Time (UT) | $N_{\mathrm{data}}$ | LEO | $T_{\mathrm{eff}}$ | $\overline{\mathrm{HR}}$ | $\overline{\mathrm{ZHR}}$ |
|---|---|---|---|---|---|
| Nov 10, $18^h00^m$ | 11 | 60 | $558^m$ | 6 | 10 |
| Nov 11, $18^h00^m$ | 1 | 3 | $60^m$ | 3 | 19 |
| Nov 12, $18^h00^m$ | 2 | 24 | $100^m$ | 15 | 22 |
| Nov 13, $18^h00^m$ | 3 | 33 | $180^m$ | 11 | 23 |
| Nov 14, $18^h00^m$ | 6 | 71 | $360^m$ | 12 | 19 |
| Nov 15, $18^h00^m$ | 4 | 72 | $223^m$ | 20 | 37 |
| Nov 16, $18^h00^m$ | 22 | 157 | $993^m$ | 9 | 31 |
| Nov 17, $18^h00^m$ | 70 | 521 | $2098^m$ | 17 | 73 |
| Nov 18, $18^h00^m$ | 1774 | 130562 | $8576^m$ | 1191 | 2478 |
| Nov 19, $18^h00^m$ | 14 | 97 | $180^m$ | 20 | 65 |
| Nov 20, $18^h00^m$ | 2 | 41 | $120^m$ | 21 | 33 |
| Nov 21, $18^h00^m$ | 6 | 112 | $360^m$ | 19 | 17 |
| Nov 22, $18^h00^m$ | 4 | 57 | $240^m$ | 11 | 14 |
| Nov 23, $18^h00^m$ | 6 | 80 | $360^m$ | 10 | 12 |
| Nov 24, $18^h00^m$ | 7 | 67 | $380^m$ | 11 | 12 |

The observers were as follows:

Atsushi Kisanuki, Akemi Oono, Daisuke Ishikawa, Daiyu Ito, Hidekatsu Mizoguchi, Hideki Yasui, Hirokazu Fukushima, Hiromichi Yoshidome, Hiroshi Ogawa, Hiroshi Yamamoto, Hirotaka Serizawa, Hiroyuki Katoh, Hiroyuki Kodama, Hiroyuki Nishimoto, Hiroyuki Okayasu, Hiroyuki Shioi, Hitoshi Izumi, Ikuko Yamamoto, Karimu Kuragaki, Katsuhiko Nozaki, Katsuhiro Yoshizaki, Kazuaki Shiotani, Kazuhiro Osada, Kazuhiro Sumie, Kazumi Terakubo, Keiko Higuchi, Ken-Ichi Fushimi, Kenya Kawabata, Kiyohide Nakamura, Koetsu Sato, Kouji Naniwada, Masaaki Yoshimura, Masafumi Suzuki, Masahide Nishihashi, Masumi Shimizu, Mikiya Sato, Minoru Shimizu, Mitsuaki Kato, Mitsue Sasaoka, Misaki Kanetaka, Miyuki Ozawa, Naoto Mawatari, Norihiro Nishitani, Noriko Yoshimura, Risa Fujimoto, Ryousuke Morita, Sachiko Akiyama, Seiichi Yoshida, Seishiro Jin, Shigeo Uchiyama, Shin-ichiro Izuhara, Shinichiro Yanagi, Shoichi Tanaka, Shouhei Usui, Takashi Sekiguchi, Takuya Kashiki, Takuya Maruyama, Tatsuya Yamane, Tetsuya Nakamura, Tomoko Sato, Tomomi Jin, Tooru Nishino, Tsukoukou Tenmonbu, Wakaba Kobayashi, Yasuhiro Tonomura, Yasuko Toya, Yasuo Hayami, Yasushi Inagaki, Yoko Yamanami, Yuiko Watamoto, Yukichi Hattori, and Yumi Izuhara.

On November 15 UT (the morning of November 16 in Japan), HR and ZHR increased. But next morning, although there were many observers, the HR and ZHR were smaller again. Also, there were more bright meteors on November 15 than on November 16.

Table 2 and Figure 2 contain data for every 5 minutes.

From these results, the maximum of the Leonids in 2001 occurred on November 18, $18^h10^m$ UT, $\lambda_\odot = 236\overset{\circ}{.}457$ (J2000.0). The trend towards maximum had already begun when the radiant rose (around $14^h$ UT). When the radiant was very low, many long Leonids meteors were observed. Then, the number of meteors steadily increased. Around $17^h25^m$ UT, the value of the HR arrived at 1000. The activity stayed above that threshold until $19^h50^m$ UT, i.e., for two and a half hours. An HR of 2000 or more was observerd from $18^h00^m$ UT until $18^h25^m$ UT, i.e., for about 25 minutes. After maximum, high activity kept continued with ZHR-levels around 1700. From $19^h50^m$ onward, twilight began in Japan, but many observers still saw a lot of meteors during twilight.

Table 2 – Visual Leonid results for five-minute intervals (see also Table 1).

| Time (UT) | $\lambda_\odot$ (J2000.0) | $N_{data}$ | LEO | $T_{eff}$ | $\overline{HR}$ | $\overline{ZHR}$ |
|---|---|---|---|---|---|---|
| Nov 18, $16^h00^m$ | 236°366 | 16 | 170 | $63^m$ | 192 | 663 |
| Nov 18, $16^h05^m$ | 236°369 | 24 | 381 | $114^m$ | 264 | 862 |
| Nov 18, $16^h10^m$ | 236°373 | 23 | 408 | $113^m$ | 297 | 837 |
| Nov 18, $16^h15^m$ | 236°376 | 29 | 561 | $164^m$ | 313 | 949 |
| Nov 18, $16^h20^m$ | 236°380 | 24 | 423 | $96^m$ | 338 | 916 |
| Nov 18, $16^h25^m$ | 236°383 | 27 | 576 | $135^m$ | 358 | 963 |
| Nov 18, $16^h30^m$ | 236°387 | 28 | 785 | $172^m$ | 373 | 1018 |
| Nov 18, $16^h35^m$ | 236°390 | 30 | 794 | $158^m$ | 408 | 1183 |
| Nov 18, $16^h40^m$ | 236°394 | 29 | 666 | $122^m$ | 411 | 1116 |
| Nov 18, $16^h45^m$ | 236°397 | 31 | 959 | $155^m$ | 495 | 1352 |
| Nov 18, $16^h50^m$ | 236°401 | 26 | 730 | $110^m$ | 538 | 1278 |
| Nov 18, $16^h55^m$ | 236°404 | 30 | 1100 | $142^m$ | 613 | 1569 |
| Nov 18, $17^h00^m$ | 236°407 | 34 | 1123 | $129^m$ | 646 | 1628 |
| Nov 18, $17^h05^m$ | 236°411 | 47 | 1661 | $245^m$ | 551 | 1376 |
| Nov 18, $17^h10^m$ | 236°415 | 38 | 1674 | $168^m$ | 793 | 1796 |
| Nov 18, $17^h15^m$ | 236°418 | 42 | 2099 | $215^m$ | 878 | 1946 |
| Nov 18, $17^h20^m$ | 236°422 | 40 | 2231 | $199^m$ | 974 | 2134 |
| Nov 18, $17^h25^m$ | 236°425 | 51 | 3230 | $280^m$ | 1002 | 2222 |
| Nov 18, $17^h30^m$ | 236°429 | 41 | 2575 | $161^m$ | 1266 | 2744 |
| Nov 18, $17^h35^m$ | 236°432 | 48 | 3772 | $238^m$ | 1319 | 3060 |
| Nov 18, $17^h40^m$ | 236°436 | 42 | 3409 | $177^m$ | 1442 | 3174 |
| Nov 18, $17^h45^m$ | 236°439 | 44 | 3815 | $210^m$ | 1463 | 3205 |
| Nov 18, $17^h50^m$ | 236°443 | 38 | 4266 | $194^m$ | 1732 | 3645 |
| Nov 18, $17^h55^m$ | 236°446 | 39 | 4805 | $209^m$ | 1884 | 4150 |
| Nov 18, $18^h00^m$ | 236°450 | 40 | 4890 | $183^m$ | 2018 | 3908 |
| Nov 18, $18^h05^m$ | 236°453 | 51 | 7840 | $384^m$ | 1837 | 3819 |
| Nov 18, $18^h10^m$ | 236°457 | 49 | 6709 | $213^m$ | 2278 | 4520 |
| Nov 18, $18^h15^m$ | 236°460 | 54 | 7428 | $257^m$ | 2119 | 4499 |
| Nov 18, $18^h20^m$ | 236°464 | 49 | 6630 | $222^m$ | 2131 | 4281 |
| Nov 18, $18^h25^m$ | 236°467 | 55 | 7715 | $280^m$ | 1976 | 4083 |
| Nov 18, $18^h30^m$ | 236°471 | 49 | 5202 | $220^m$ | 1714 | 3444 |
| Nov 18, $18^h35^m$ | 236°474 | 47 | 4909 | $219^m$ | 1626 | 3266 |
| Nov 18, $18^h40^m$ | 236°478 | 46 | 4315 | $189^m$ | 1651 | 3150 |
| Nov 18, $18^h45^m$ | 236°481 | 54 | 5540 | $278^m$ | 1506 | 2992 |
| Nov 18, $18^h50^m$ | 236°485 | 36 | 3211 | $164^m$ | 1431 | 2619 |
| Nov 18, $18^h55^m$ | 236°488 | 39 | 2956 | $203^m$ | 1149 | 2098 |
| Nov 18, $19^h00^m$ | 236°492 | 25 | 1939 | $116^m$ | 1371 | 2275 |
| Nov 18, $19^h05^m$ | 236°495 | 33 | 2325 | $163^m$ | 1182 | 2138 |
| Nov 18, $19^h10^m$ | 236°499 | 30 | 1621 | $122^m$ | 1093 | 1798 |
| Nov 18, $19^h15^m$ | 236°502 | 28 | 1573 | $133^m$ | 1090 | 1608 |
| Nov 18, $19^h20^m$ | 236°506 | 29 | 1677 | $126^m$ | 1135 | 1862 |
| Nov 18, $19^h25^m$ | 236°509 | 31 | 1798 | $145^m$ | 1097 | 1666 |
| Nov 18, $19^h30^m$ | 236°513 | 26 | 1445 | $104^m$ | 1179 | 1768 |
| Nov 18, $19^h35^m$ | 236°516 | 27 | 1629 | $125^m$ | 1188 | 1753 |
| Nov 18, $19^h40^m$ | 236°520 | 23 | 1194 | $96^m$ | 1186 | 1806 |
| Nov 18, $19^h45^m$ | 236°523 | 26 | 1431 | $115^m$ | 1157 | 1821 |
| Nov 18, $19^h50^m$ | 236°527 | 17 | 794 | $99^m$ | 547 | 1684 |
| Nov 18, $19^h55^m$ | 236°530 | 17 | 714 | $92^m$ | 484 | 1357 |
| Nov 18, $20^h00^m$ | 236°534 | 8 | 680 | $40^m$ | 907 | 2116 |
| Nov 18, $20^h05^m$ | 236°537 | 9 | 635 | $45^m$ | 847 | 1966 |
| Nov 18, $20^h10^m$ | 236°541 | 9 | 567 | $45^m$ | 756 | 1907 |
| Nov 18, $20^h15^m$ | 236°544 | 8 | 407 | $40^m$ | 611 | 1757 |
| Nov 18, $20^h20^m$ | 236°548 | 6 | 254 | $30^m$ | 508 | 1350 |
| Nov 18, $20^h25^m$ | 236°551 | 6 | 135 | $30^m$ | 270 | 1082 |
| Nov 18, $20^h30^m$ | 236°555 | 4 | 46 | $20^m$ | 138 | 681 |
| Nov 18, $20^h35^m$ | 236°558 | 4 | 39 | $20^m$ | 117 | 827 |
| Nov 18, $20^h40^m$ | 236°562 | 3 | 12 | $15^m$ | 48 | 802 |
| Nov 18, $20^h45^m$ | 236°565 | 3 | 17 | $15^m$ | 68 | 1277 |
| Nov 18, $20^h50^m$ | 236°569 | 3 | 14 | $15^m$ | 56 | 1223 |
| Nov 18, $20^h55^m$ | 236°572 | 2 | 12 | $10^m$ | 72 | 1274 |

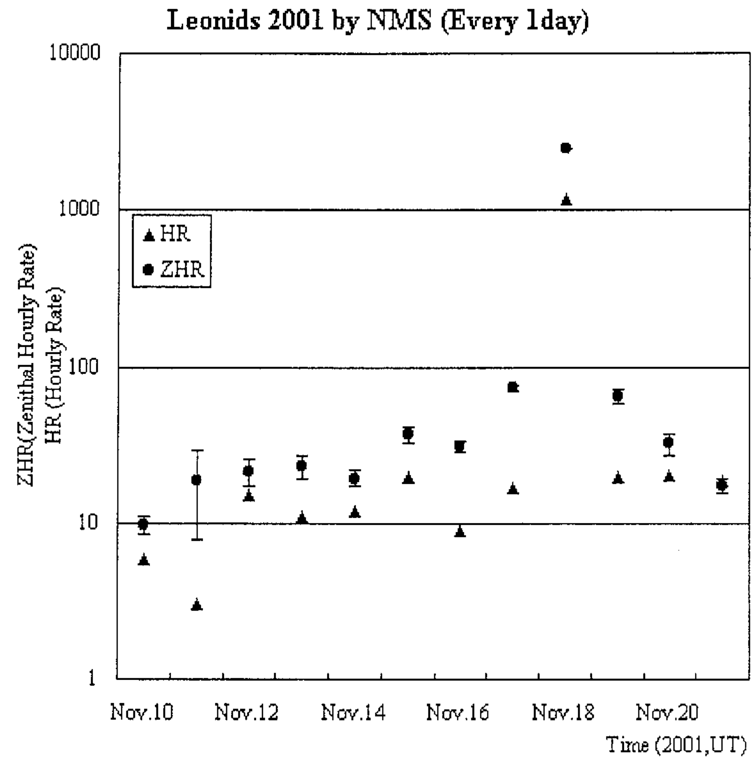


Figure 1 – HR and ZHR curve of the 20001 Leonids from visual observations. The vertical axis is logarithmic.

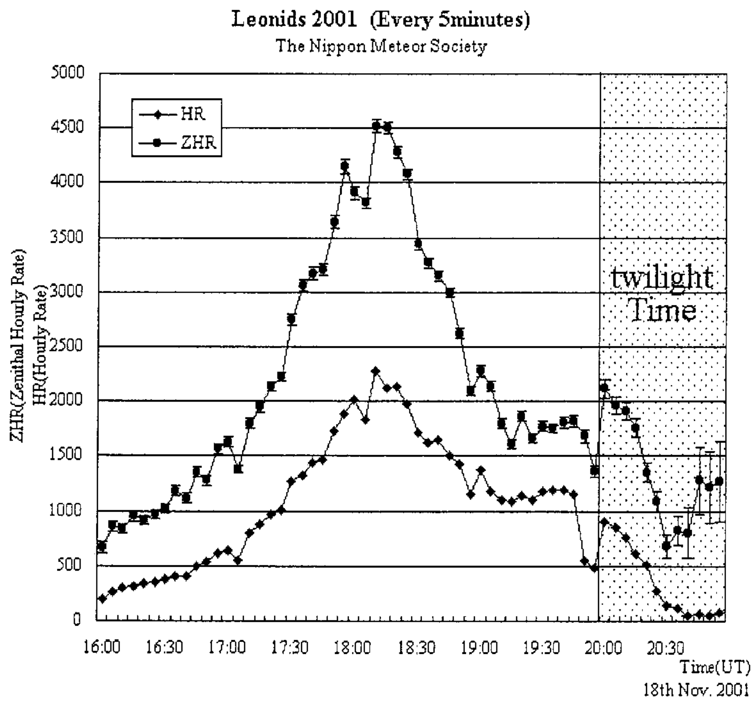


Figure 2 – HR and ZHR curve of the 2001 Leonids every five minutes from visual observations. The right side is the twilight time.

There are two clear peaks. One is the main peak, at $18^h10^m$ UT. The other peak is at $17^h50^m$ UT. The main peak is most probably related to the 1866 (4-rev.) dust trail. Other peaks of more dust trails are not clear. However, some results by some observers from one-minute interval graphs indicate another peak around $17^h35^m$ UT. Perhaps, this peak is caused by the 1699 (7-rev.) dust trail (9-rev.).

The $17^h50^m$ UT peak may be due to another dust trail or may be part of main peak. Lyytinen and Van Flandern predicted the 1699 (9-rev.) dust trail encounter at $18^h08^m$ UT. Therefore, it is possible that this peak is the 1699 dust trail. Like these, predictions of Leonids 2001 by many researchers resemble observational results.

*ZHRs per magnitude class*

Many observers reported remarkably more bright meteors between $15^h$ and $17^h$ UT than between $18^h$ and $19^h$ on the Leonid storm night of November 18. Therefore, we analyzed magnitude distribution data reported from Japanese observers, and calculated ZHRs per magnitude class, using the formulae ZHR $= NC/T_{\text{eff}}$ and $C = KF/\sin h$, with $N$ the number of meteors in the magnitude class under consideration, $T_{\text{eff}}$ the effective observing time, $F$ the possible field obstruction factor, $h$ the radiant elevation, and $K = P_{6.5}/P_{\text{lm}}$, with $P_{6.5}$ and $P_{\text{lm}}$ are the perception probability for the magnitude class under consideration when the limiting magnitude is 6.5 and the observed limiting magnitude, respectively [8]. These ZHRs are then averaged using a weight factor of $T_{\text{eff}}/C$.

The following persons contributed to this analysis:

Kazuhiro Osada, Takema Hashimoto, Kenya Kawabata, Koetsu Sato, Minoru Shimizu, Masumi Shimizu, Hiroyuki Okayasu, Masayuki Oka, Daiyu Ito, Syoichi Tanaka, and Shigeo Uchiyama.

Koetsu Sato and Masumi Shimizu observed from China. Others were in Japan. Because Kazuhiro Osada has a wide field of view, he counts exceptional many meteors, not only faint ones but also brighter ons. He was even not able to record magnitudes between $18^h00^m$ and $19^h00^m$ UT, because he counted so many meteors (126 in one minute at maximum). So, we used individual perception correction for him only.

Results are shown in Tables 3 and 4 and in Figure 3.

Table 3 – Numbers of Leonids in each magnitude class on November 18.

| Time (UT) | Obs | $-3^-$ | $-2$ | $-1$ | 0 | +1 | +2 | +3 | $\overline{\text{Lm}}$ | $\bar{h}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $15^h45^m$ | 6 | 14 | 17 | 18 | 33 | 48 | 77 | 77 | 5.60 | 19°9 |
| $16^h15^m$ | 10 | 62 | 58 | 75 | 88 | 124 | 187 | 253 | 5.71 | 24°5 |
| $16^h45^m$ | 10 | 86 | 78 | 96 | 122 | 234 | 281 | 281 | 5.66 | 29°0 |
| $17^h15^m$ | 10 | 88 | 83 | 170 | 302 | 481 | 640 | 758 | 5.65 | 35°2 |
| $17^h45^m$ | 9 | 60 | 100 | 205 | 358 | 640 | 951 | 1252 | 5.68 | 42°1 |
| $18^h15^m$ | 9 | 50 | 66 | 134 | 264 | 584 | 1057 | 1049 | 5.49 | 46°7 |
| $18^h45^m$ | 8 | 40 | 78 | 119 | 223 | 407 | 861 | 904 | 5.50 | 52°4 |
| $19^h15^m$ | 10 | 105 | 115 | 201 | 326 | 480 | 758 | 876 | 5.57 | 58°5 |
| $19^h45^m$ | 11 | 73 | 109 | 167 | 249 | 408 | 583 | 609 | 5.56 | 63°5 |

Table 4 – Average 2001 Leonid ZHRs per magnitude class on November 18. Solar longitudes refer to J2000.0

| Time (UT) | $\lambda_\odot$ | $-3^-$ | $-2$ | $-1$ | 0 | +1 | +2 | +3 |
|---|---|---|---|---|---|---|---|---|
| $15^h45^m$ | 236°354 | 12 | 15 | 16 | 34 | 54 | 115 | 112 |
| $16^h15^m$ | 236°375 | 22 | 25 | 36 | 42 | 64 | 124 | 184 |
| $16^h45^m$ | 236°396 | 23 | 29 | 36 | 55 | 117 | 177 | 183 |
| $17^h15^m$ | 236°417 | 18 | 18 | 42 | 89 | 162 | 303 | 386 |
| $17^h45^m$ | 236°438 | 9 | 21 | 47 | 101 | 218 | 531 | 642 |
| $18^h15^m$ | 236°459 | 19 | 25 | 55 | 111 | 272 | 652 | 825 |
| $18^h45^m$ | 236°480 | 14 | 27 | 44 | 86 | 175 | 494 | 658 |
| $19^h15^m$ | 236°501 | 19 | 21 | 43 | 74 | 122 | 283 | 361 |
| $19^h45^m$ | 236°522 | 14 | 24 | 39 | 61 | 117 | 245 | 293 |

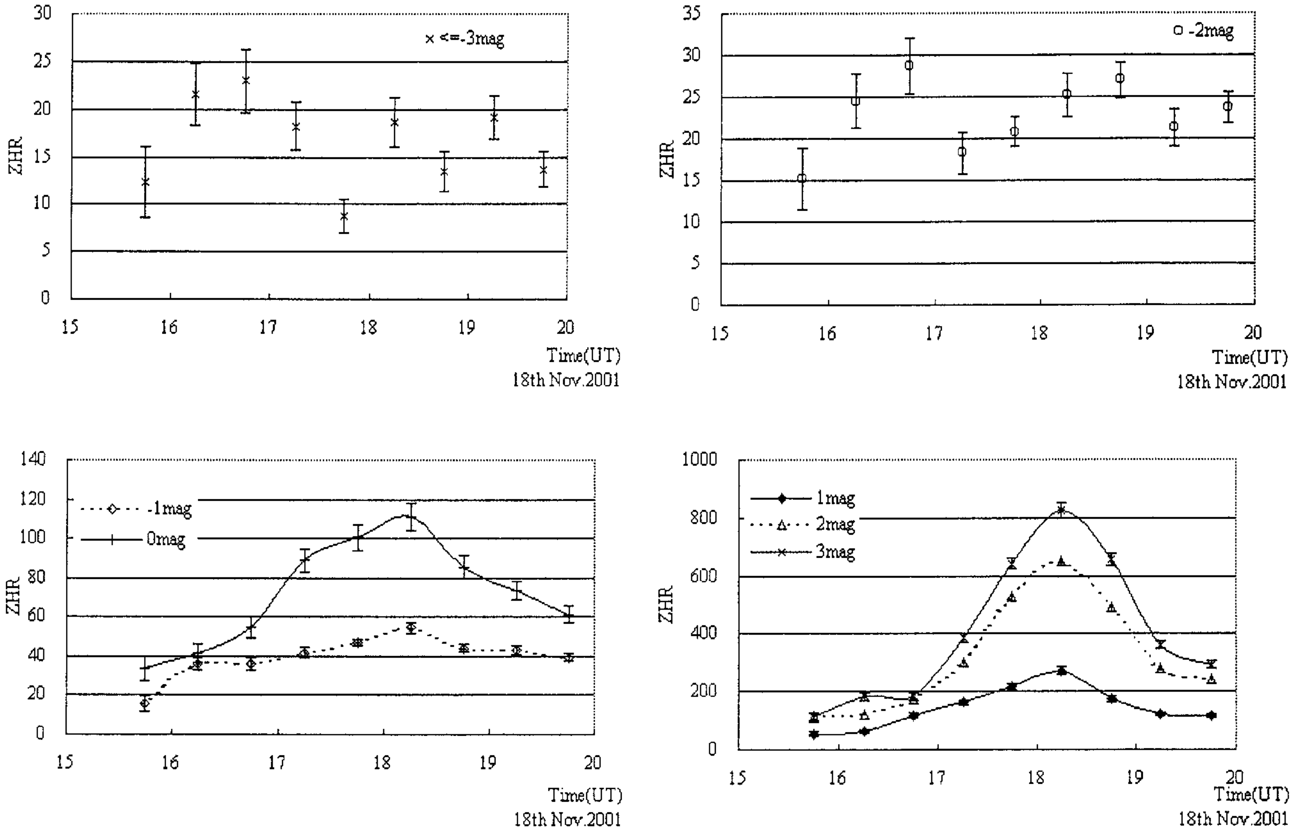


Figure 3 – ZHR profiles for Leonids of magnitude −3 or brighter (*left top*), magnitude −2 (*right top*), magnitude −1 and 0 (*bottom left*), and magnitude +1 to +3 (*bottom right*).

We only used data with radiant elevation over 15°. Also, we made no calculate for meteors of magnitude +4 or fainter, because they are strongly affected by limiting magnitude and individual perception. Figure 3, *bottom left* and *bottom right*, show the rise, peak, and fall of activity for meteors between magnitudes −1 to +3. The peak around $18^h15^m$ UT was caused by the 1866 and 1699 dust trails [1,4]. Figure 3, *top left* and *top right*, however, show that the activity of meteors of magnitude −2 or brighter appears to be nearly constant. It is difficult to assume that bigger meteoroids were diffused more widely than smaller one. Magnitude estimation errors are unlikely, as Sirius (−1.5) and Jupiter(−2.5) were in the sky. We therefore conclude that meteors of magnitude −2 or brighter meteors were caused by the background and that the 1866 and 1699 trails contain almost no meteoroids resulting in meteors of magnitude −2 or brighter.

As mentioned above, fainter meteors show a clear rise, peak, and fall. Now, we compare their rise and fall ratio. Therefore, we normalized the ZHR graphs for each magnitude class by reducing the average ZHR to 1. (Figure 4). The result of this procedure shows that rise and fall rates for meteors of magnitudes +1 to +3 are almost the same and steeper than for meteors of magnitude −1 or 0. The Earth encountered the 1866 and 1699 dust trails simultaneously, so we cannot guess how these trails affected the ZHRs for each magnitude class separately. However, our result indicates that these trails consist of mainly of meteoroids producing meteors of magnitude +1 or fainter.

*Radio meteor observations*

In the context of the Leonids 2001 project by radio meteor observation, many data were reported. The number of observing sites is about 80 in 13 countries. In Japan only, the number of radio meteor observer sites is already about 65. Most of the Japanese observers use the 53.750 MHz frequency. Starting on November 15 UT, some long echoes were observed. On the evening on November 17 UT, many long echoes were observed. After that, around $8^h00^m$ UT on November 18, the number of echoes in the USA increased, indicating the approach of the the first peak, which occurred around $10^h30^m$–$11^h00^m$ UT.

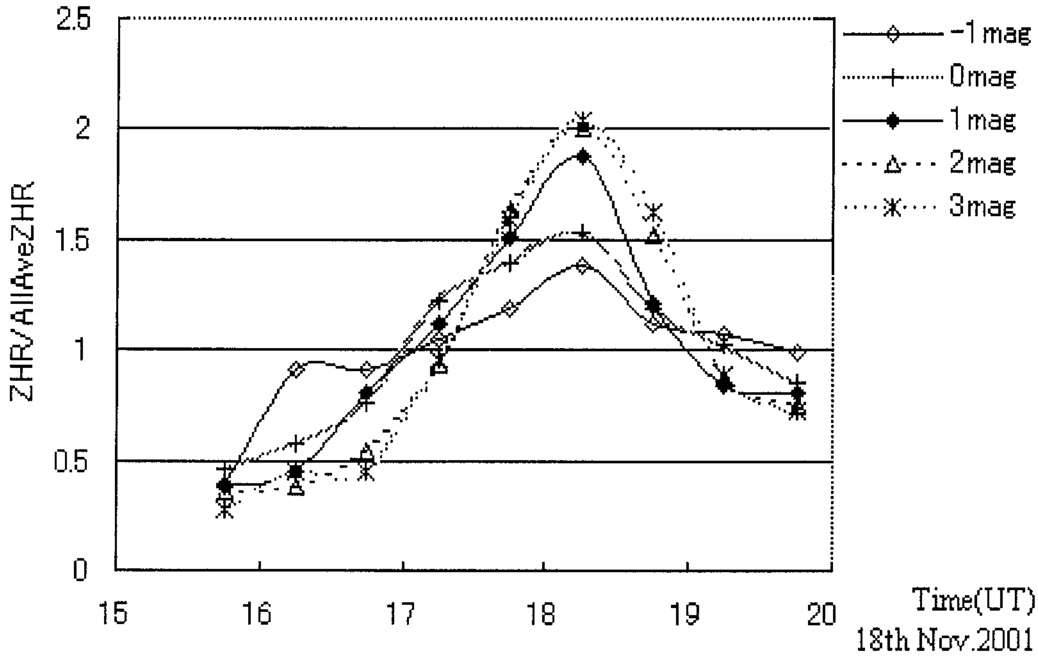


Figure 4 – Relative ZHR profiles for meteors of magnitudes between −1 and +3. Average ZHRs of each class were normalized to the value 1.

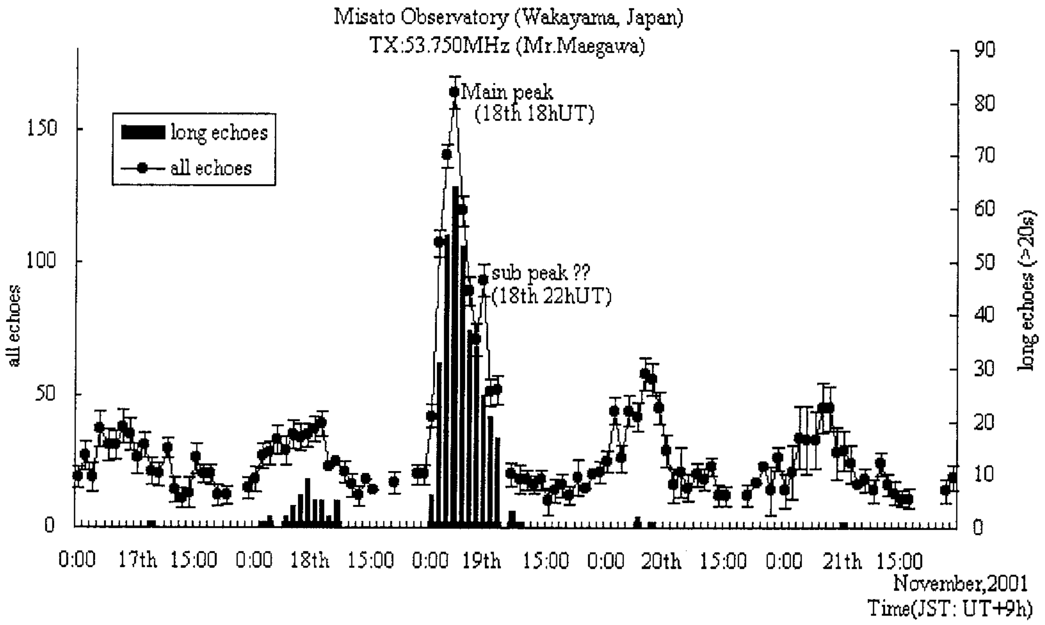


Figure 5 – Result of radio meteor observations of the 2001 Leonids by the Misato Observatory.

Around $14^{h}00^{m}$ UT, the number of echoes increased clearly in Japan. Then, from $15^{h}30^{m}$ UT onward, many long echoes were observed. One hour later, around $16^{h}30^{m}$ UT, most radio meteor observers could no longer count the number of echoes because of intermittent long echoes. Figure 5 is the graph by Misato Observatory (Wakayama, Japan). Notice there is an additional peak at $22^{h}$ UT. Also, Miss Kayo Miyao found this unexpected peak. Tetsuharu Sasaki, Seiji Fukushima, Toshihiko Masaoka, and Okayama-Asahi High School observed this peak, too. Other observers could not count the number of echoes because too many long echoes were observed. Exactly the fact that until around $21^{h}00^{m}$ UT, almost none of the observers could count the number of echoes, and that counting resumed around $22^{h}00^{m}$ UT could have caused this additional peak. We are now discussing the reality of this peak.

## 4. Discussion

At this time, the 2001 Leonids leave many questions.

First, the activity of the 2001 Leonids remained high for al long time. Generally speaking, the peak of the Leonids is supposed to be sharp, because this is a young meteor stream. At this occasion, however, we saw that high activity (ZHRs of 1000 and more) persisted for more than three hours (from $17^h30^m$ UT on November 18). In Japan, morning twilight began at $20^h00^m$ UT, so from our visual observations only, it is hard to tell how long exactly high activity lasted.

Radio meteor observations indicate that high activity lasted from $16^h30^m$ UT of November 18 to $0^h00^m$ UT on November 19 (i.e., for seven and a half hours). Why was this high activity seen? Also, the results of the *Nippon Meteor Society* clearly show the main peak. This peak was probably caused by the 1866 dust trail. Other dust trail peaks were not clear, however, such as the 1699 dust trail peak. Where there any sub-peaks?

Next, the parent comet passed three years ago. Therefore, big particles that can give rise to fireballs were gone with the parent comet. However, many fireballs and meteor trains were observed. There is the possibility of a resonance phenomenon. There are 14 resonance areas on the orbit of Tempel-Tuttle. In 1998, we encountered one of them. The next resonance area was supposed to be encountered in 2001 [7].

Besides, many strange meteors and phenomenon were observed. For example, about 50 meteors were observed at the same time; a meteor faded and brightened again (or were this two meteors?), wide radiant, etc. We are discussing many questions now.

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# Ongoing Meteor Work

# Polish Visual Meteor Database 1996–1998

*A. Olech, M. Wiśniewski, and M. Gajos*

The summary of 1996–1998 visual observations collected by the Polish *Comets and Meteors Workshop* is presented. In total, during 2328.12 effective observing hours, 14 085 meteors were seen and plotted onto gnomonic starmaps by 41 observers. The date, time, magnitude, angular velocity, and equatorial coordinates for each observed event are given. The full data for 1996–1998 in the *Polish Visual Meteor Database* (PVMDB) are accessible via Internet.

## 1. Introduction

Since 1994, the Polish *Comets and Meteors Workshop* (CMW) has been cooperating with the *International Meteor Organization*. During the first two years, we made mostly visual observations of major showers without plotting the meteors onto the gnomonic star maps. Over time, the experience of our observers grew and, in 1996, we decided to start visual observations with plotting.

Every year, a complete set of our observation reports was sent to the *IMO*, and our results were included in the *IMO Visual Meteor Database* (VMDB) (see, for example, [1]). However, we would like to point out that the *VMDB* contains only the information about hourly rates and magnitude distributions of the observed meteors. Thus, an error in classification of a meteor made by the observer while filling out the report form is included also in the *VMDB*.

Additionally, the *VMDB* contains only data about meteor showers from the *IMO Working List of the Meteor Showers*. Thus it is impossible to get the information about other small or poorly known streams from the *VMDB*.

The solution to the problem is to publish a full database containing all quantities describing a meteor event including its equatorial coordinates and angular velocity. Such a database can be searched for the presence of any shower at any moment of time.

The database of Polish telescopic observations made during the years 1996–1998 was already published by Olech and Jurek [2]. Following this approach, we decided to publish in the same format our visual results from the years 1996–1998. Table 1 summarizes our visual work during this period of time. In total, 14 085 meteors were seen by 41 observers during $2328^{h}.12$ effective observing hours.

Table 1 – *Polish Visual Meteor Database* (PVMDB) grand totals for 1996–1998.

| Year | Observers | $T_{\text{eff}}$ | Meteors |
|---|---|---|---|
| 1996 | 18 | $247^{h}.86$ | 1508 |
| 1997 | 25 | $849^{h}.41$ | 5269 |
| 1998 | 31 | $1230^{h}.85$ | 7308 |
| Total | 41 | $2328^{h}.12$ | 14085 |

Table 2 shows a list of the *CMW* observers with their effective observing time and number of meteors plotted in each of the years 1996–1998.

Table 2 – Total effective observing time in hours ($T_{\rm eff}$) and number of meteors plotted ($N$) per observer during the years 1996–1998.

| Observer | Code | 1996 | | 1997 | | 1998 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_{\rm eff}$ | $N$ | $T_{\rm eff}$ | $N$ | $T_{\rm eff}$ | $N$ | $T_{\rm eff}$ | $N$ |
| Jarosław Dygos | `DYGJA` | | | $44^h.99$ | 181 | $308^h.98$ | 1324 | $353^h.97$ | 1505 |
| Tomasz Fajfer | `FAJTO` | $84^h.50$ | 382 | $185^h.50$ | 862 | $22^h.50$ | 115 | $292^h.50$ | 1359 |
| Konrad Szaruga | `SZAKO` | $26^h.14$ | 144 | $108^h.15$ | 659 | $88^h.35$ | 437 | $222^h.64$ | 1240 |
| Krzysztof Socha | `SOCKR` | $17^h.31$ | 102 | $87^h.47$ | 616 | $105^h.11$ | 769 | $209^h.89$ | 1487 |
| Maciej Kwinta | `KWIMA` | $4^h.67$ | 19 | $71^h.24$ | 438 | $68^h.08$ | 540 | $143^h.99$ | 997 |
| Gracjan Maciejewski | `MACGR` | | | $49^h.17$ | 219 | $81^h.17$ | 394 | $130^h.34$ | 613 |
| Marcin Konopka | `KONMA` | | | $36^h.39$ | 349 | $81^h.59$ | 450 | 117.98 | 799 |
| Arkadiusz Olech | `OLEAR` | $20^h.92$ | 248 | $42^h.88$ | 540 | $49^h.75$ | 463 | $113^h.55$ | 1251 |
| Andrzej Skoczewski | `SKOAN` | | | $46^h.68$ | 276 | $56^h.84$ | 380 | $103^h.52$ | 656 |
| Paweł Trybus | `TRYPA` | | | $2^h.17$ | 8 | $90^h.55$ | 587 | $92^h.72$ | 595 |
| Wojciech Jonderko | `JONWO` | $2^h.20$ | 5 | $22^h.17$ | 137 | $39^h.12$ | 155 | $63^h.49$ | 297 |
| Marcin Gajos | `GAJMR` | $6^h.29$ | 37 | $35^h.17$ | 248 | $17^h.63$ | 104 | $59^h.09$ | 389 |
| Albert Krzyśków | `KRZAL` | | | $11^h.83$ | 76 | $43^h.49$ | 282 | $55^h.32$ | 358 |
| Aleksander Trofimowicz | `TROAL` | | | | | $38^h.47$ | 229 | $38^h.47$ | 229 |
| Krzysztof Wtorek | `WTOKR` | $23^h.00$ | 140 | $11^h.99$ | 78 | | | $34^h.99$ | 218 |
| Łukasz Raurowicz | `RAULU` | | | $23^h.62$ | 163 | $6^h.09$ | 41 | $29^h.71$ | 204 |
| Michał Jurek | `JURMC` | $8^h.52$ | 43 | $14^h.66$ | 93 | $6^h.00$ | 53 | $29^h.18$ | 189 |
| Cezary Gałan | `GALCE` | | | | | $28^h.85$ | 204 | $28^h.85$ | 204 |
| Łukasz Pospieszny | `POSLU` | $20^h.68$ | 158 | $6^h.91$ | 30 | | | $27^h.59$ | 188 |
| Luiza Wojciechowska | `WOJLU` | | | | | $25^h.32$ | 168 | $25^h.32$ | 168 |
| Mariusz Wiśniewski | `WISMA` | | | | | $20^h.86$ | 342 | $20^h.86$ | 342 |
| Maciej Reszelski | `RESMA` | $7^h.86$ | 89 | $8^h.77$ | 99 | | | $16^h.63$ | 188 |
| Paweł Brewczak | `BREPA` | | | | | $16^h.52$ | 81 | $16^h.52$ | 81 |
| Łukasz Sanocki | `SANLU` | $5^h.77$ | 39 | $4^h.34$ | 40 | $6^h.17$ | 28 | $16^h.28$ | 107 |
| Tomasz Ramza | `RAMTO` | $7^h.00$ | 32 | $5^h.98$ | 19 | | | $12^h.98$ | 51 |
| Artur Szaruga | `SZAAR` | | | $10^h.17$ | 37 | $2^h.12$ | 8 | $12^h.29$ | 45 |
| Tomasz Dziubiński | `DZITO` | $3^h.50$ | 21 | $8^h.00$ | 42 | | | $11^h.50$ | 63 |
| Krzysztof Kamiński | `KAMKR` | | | $7^h.60$ | 45 | $1^h.35$ | 8 | $8^h.95$ | 53 |
| Jarosław Nocoń | `NOCJA` | | | | | $6^h.53$ | 21 | $6^h.53$ | 21 |
| Waldemar Drozdowski | `DROWA` | | | $1^h.00$ | 3 | $5^h.40$ | 19 | $6^h.40$ | 22 |
| Rafał Kopacki | `KOPRA` | $5^h.50$ | 30 | | | | | $5^h.50$ | 30 |
| Krzysztof Mularczyk | `MULKR` | | | | | $4^h.00$ | 17 | $4^h.00$ | 17 |
| Mariola Czubaszek | `CZUMA` | | | | | $2^h.80$ | 40 | $2^h.80$ | 40 |
| Adam Pisarek | `PISAD` | | | | | $2^h.71$ | 8 | $2^h.71$ | 8 |
| Marek Piotrowski | `PIOMA` | | | $2^h.56$ | 11 | | | $2^h.56$ | 11 |
| Jacek Kluczewski | `KLUJA` | | | | | $2^h.00$ | 21 | $2^h.00$ | 21 |
| Sylwia Chełmoniak | `CHESY` | | | | | $1^h.50$ | 11 | $1^h.50$ | 11 |
| Krzysztof Gdula | `GDUKR` | $1^h.50$ | 4 | | | | | $1^h.50$ | 4 |
| Paweł Musialski | `MUSPA` | $1^h.50$ | 11 | | | | | $1^h.50$ | 11 |
| Sylwia Hołowacz | `HOLSY` | | | | | $1^h.00$ | 9 | $1^h.00$ | 9 |
| Robert Sołtys | `SOLRO` | $1^h.00$ | 4 | | | | | $1^h.00$ | 4 |
| Total | | $247^h.86$ | 1508 | $849^h.41$ | 5269 | $1230^h.85$ | 7308 | $2328^h.12$ | 14085 |

## 2. Coordinate files

The files `coor96.txt`, `coor97.txt`, and `coor98.txt` contain data for each observed meteor such as the date of appearance, serial number of meteor, its magnitude, its angular velocity (in scale from $A$ to $F$), time of appearance, equatorial coordinates of beginning and end, *IMO* code of the observer and three-letter code.

Below, we show a small sample of such a file:

```
1998 01 01/02  1   4.5 C 00:47 219.20  76.42 237.00  72.38 SKOAN ABZ
1998 01 01/02  2   2.0 B 00:47 321.66  66.76 005.76  59.44 SKOAN ABZ
1998 01 01/02  3   1.5 C 00:47 216.55  52.21 236.21  56.24 SKOAN ABZ
1998 01 01/02  4   1.5 C 00:47 257.92  50.32 266.80  48.49 SKOAN ABZ
1998 01 01/02  5   4.0 D 00:47 211.86  50.55 206.85  51.73 SKOAN ABZ
1998 01 01/02  6  -2.0 B 00:47 097.50  87.00 312.50  81.00 SKOAN ABZ
1998 01 01/02  7   2.0 B 01:37 206.19  78.68 251.99  65.72 SKOAN ACA
1998 01 01/02  8   4.0 C 01:37 181.14  73.42 171.16  74.95 SKOAN ACA
1998 01 01/02 10   4.0 D 01:37 273.52  52.78 269.18  49.60 SKOAN ACA
1998 01 02/03  1   4.5 D 17:01 028.60  43.07 017.24  43.14 OLEAR ACB
```

In Table 3, we give byte-by-byte description of these files.

Table 3 – Byte-by-byte description of `coor9?.txt` files. Right ascension and declination are in degrees.

| Bytes | Format | Explanations |
|---|---|---|
| 1– 4 | I4 | Year |
| 6– 7 | I2 | Month |
| 9–13 | A5 | Day/Day |
| 15–17 | I3 | Number of meteor in report |
| 19–21 | F5.1 | Meteor magnitude |
| 25 | I1 | Velocity in scale from $A$ to $F$ |
| 27–31 | A5 | Time of meteor (UT) |
| 33–38 | F6.2 | RA of beginning of meteor (J2000) |
| 40–45 | F6.2 | Decl. of beginning of meteor (J2000) |
| 47–52 | F6.2 | RA of end of meteor (J2000) |
| 54–59 | F6.2 | Decl. of end of meteor (J2000) |
| 61–65 | A5 | *IMO* code of observer |
| 67–69 | A3 | Three-letter code |

The three-letter code shown in the last column of `coor9?.txt` file is used for connecting each meteor with the information about the observation stored in the `head9?.txt` file. The time of appearance of a meteor, when it is not given exactly in the report form, is assumed as the middle time of each observing period. All equatorial coordinates were entered using the CooReader software [3].

## 3. Header files

The files `head96.txt`, `head97.txt`, and `head98.txt` contain information about each observing run, such as three-letter code allowing to connect each observation with data on meteors presented in coordinate files, *IMO* code of observer, longitude and latitude of place of observation, date, UT time of begin and end of observation, solar longitude (J2000) of middle time of each run, equatorial coordinates of observed field, effective time of observation, cloud correction factor $F$, stellar limiting magnitude estimated by the naked eye and the *IMO* code of the place of observation.

Below we show a small sample of such a file:

```
ABZ SKOAN  21.0 E 50.0 N 02 01 98 0016 0118 281.444 210  75 1.00 1.00 5.80 34029
ACA SKOAN  21.0 E 50.0 N 02 01 98 0118 0156 281.479 210  75 0.60 1.00 5.72 34029
ACB OLEAR  23.5 E 51.1 N 02 01 98 1630 1732 282.133 000  70 1.00 1.00 5.42 34012
ACC OLEAR  23.5 E 51.1 N 02 01 98 2026 2134 282.302 000  70 1.00 1.00 5.70 34012
ACD OLEAR  23.5 E 51.1 N 03 01 98 0005 0108 282.456 000  70 1.00 1.00 6.18 34012
ACE OLEAR  23.5 E 51.1 N 03 01 98 0110 0214 282.502 000  70 1.00 1.00 6.13 34012
ACF OLEAR  23.5 E 51.1 N 03 01 98 0214 0305 282.543 000  70 0.75 1.00 6.15 34012
ACG SZAKO  23.2 E 50.5 N 02 01 98 2003 2124 282.291 181  53 1.30 1.00 6.40 34040
```

Table 4 gives a byte-by-byte description of the header files.

Table 4 – Byte-by-byte description of `head9?.txt` files. Solar longitude, right ascension, and declination are in degrees; effective observing time in hours.

| Bytes | Format | Explanations |
|---|---|---|
| 1– 3 | A3 | Three-letter code |
| 5– 9 | A5 | *IMO* code of observer |
| 11–15 | F5.1 | Longitude of observing site |
| 17 | A1 | Hemisphere designation |
| 19–22 | F4.1 | Latitude of observing site |
| 24 | A1 | Hemisphere designation |
| 26–27 | I2 | Day |
| 29–30 | I2 | Month |
| 32–33 | I2 | Year |
| 35–38 | I4 | Begin time of observation (UT) |
| 40–43 | I4 | End time of observation (UT) |
| 45–51 | F7.3 | Solar longitude of middle time of observation (J2000) |
| 53–55 | I3 | RA of center of field of view (J2000) |
| 57–59 | I3 | Decl. of center of field of view (J2000) |
| 61–64 | F4.2 | Effective observing time |
| 66–69 | F4.2 | Cloud correction factor $F$ |
| 71–74 | F4.2 | Limiting magnitude estimated in field of view |
| 76–80 | I5 | *IMO* code of observing site |

## 4. Summary

We have presented the summary of the 1996–1998 visual observations made by the Polish *Comets and Meteors Workshop*. In total, 14 085 meteors were observed during $2328^{\rm h}_{\cdot}12$ effective observing hours collected by 41 observers. The date, time, magnitude, angular velocity, and equatorial coordinates for each observed event is given. The full 1996–1998 *Polish Visual Meteor Database* (PVMDB) is accessible via Internet at `http://www.astrouw.edu.pl/~olech/VIS/`.

The 1999–2000 data are still under review, but they will be available to the astronomical community as soon as possible.

## Acknowledgments

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# Counting Meteors Using a Handheld Computer

*Hartwig Lüthen*

Data analysis is still the bottleneck of meteor observing. The advantage potentially taken from the available data analysis software is limited, since raw meteor data on tape or paper roll do not readily come in a digital format. In light of this situation, the author has written an easy-to-use meteor counting program for the Palm handheld computer. It is possible to enter magnitudes and stream associations directly under the skies, and each meteor is recorded with a precise timing. Data can be transferred to a PC for analysis and for the preparation of *IMO* report forms. This technique has been tested during the last Lyrids, Perseids, and Geminds, and during the 2001 Leonid meteor storm. A complete software package is available for free download through the Internet.

## 1. Introduction

Meteor observers normally record their counting data on paper rolls or on tape [1]. Both techniques share the advantage of avoiding dead time. In analyzing the data, tape recordings have to be played back and transferred to a written list. This and the following data analysis can be a tedious, time-consuming process, especially when several thousands of meteor data on a meteor storm have been recorded. The analysis itself can be facilitated considerably by computer programs like METEOR COMPANION or VISDAT. However, since the original data do not come in a digital format, meteors still have to be entered manually into a computer, which may be a laborious procedure.

It has been repeatedly suggested to enter the observations into a computer directly under the sky. A decade ago, such an approach was taken by Sirko Molau [2]. He used a specially designed handbox linked to a PC to enter magnitudes and stream associations and provided software for rapid data analysis. However, this method never gained widespread popularity among observers, mainly because micro cassette recorders are so much more portable than desktop or even notebook PCs.

By now, a new breed of small computers has arrived, the so-called handheld organizers or personal digital assistants (PDAs). They are typically used as digital notebook, address book, and date planner. Data are entered via a touch screen display or through a small numbers of keys. These devices can be synchronized ("hot-synced") with a desktop PC at home to transfer data from the organizer to the PC and vice-versa.

This paper on an attempt to evaluate the suitability of a handheld organizer to record meteor counting data.

## 2. Choice of the handheld

Two major types of handhelds are currently available: one group runs on Windows CE , whereas the other uses the Palm operating system (OS). Windows CE PDAs cannot run Palm programs and vice versa. Palm OS handles hardware resources very economically, which makes the devices less expensive. The cheapest Palms with monochrome displays also have a very low power drain and can run for several nights (e.g., 30 hours of continuous use, cf. [3]) on two AAA cells. Other Palms offer more memory (e.g., 8 MB) and larger displays, which may be convenient. Clones using the Palm OS (like the Handspring Visor) are also available and will most probably do the job. Palms featuring color display are more expensive and have a much higher power consumption which probably makes them less suitable for meteor work. The same is probably true for many Windows CE PDAs with color displays. (A color Palm or a color Windows CE handheld will operate typically 5–10 hours on one charge of the accumulator at room temperature, cf. [3]).

I therefore decided to use a Palm M100, with monochrome display and 2MB of memory for this study, running Palm OS 3.5.1. This Palm is smaller and lighter than a typical micro tape recorder (140 g, including batteries).

### 3. Meteor counting software

The meteor counting program (MeteorCount) was written in Hot Paw BASIC. This shareware BASIC interpreter (Version 1.3.1) runs small BASIC programs from Memo files. After a trial period of 30 days, the shareware version of the interpreter will be restricted to run in "demo mode." This essentially means that no more than four BASIC programs are simultaneously displayed in the "file menu." The interpreter will, however, still perfectly run MeteorCount. Regular users should consider buying the registered version for 20 USD. In any case, the meteor counting program MeteorCount is freeware.

Once MeteorCount is started, the observer can enter the names of the active streams and indicate which stream is the most important. Then, a message `click 'ok' to begin observing appears`. The user can do all this before the observation and switch the Palm and click on the "ok" field when the observation is actually going to begin.


Figure 1 – A Palm M100 handheld computer running MeteorCount. Explanations are in the text. A Leonid of magnitude +4 has been entered at $23^h31^m04^s$ by simply hitting field (F) 4. The keys A, B, C, D, and E allow more complicated entries, as explained in the text.

Then, the user interface shown in Figure 1 will show up.

There are seven labeled fields ("F" in Figure 1) on the touch screen, corresponding to magnitudes 0 to 6. Clicking on one of these fields will enter a meteor of the most important stream of the indicated magnitude. If Leonids are the most important stream and the user hits field 4, this will enter a 4th magnitude Leonid (Figure 1). Entering a meteor of the most important stream thus will require only one click. This is crucial when observing at high rates, e.g., during a meteor storm.

The keys A, B, C and D (shown in Figure 1) allow more complicated entries:

- *Key A*:

  Enter a half magnitude interval. Example: Consider `LEO` to be the most important stream. Hitting [A] and Field 1 will enter a Leonid of magnitude +1.5.
- *Key B*:

  Delete the last entry ("oops" key).
- *Key C*:

  Enter negative magnitudes. Example: Hitting [C] and Field 1 will enter a Leonid of magnitude −1.0.
- *Key D*:

  Enter another stream: hit [D] once for a sporadic meteor, and more than once for the other active streams. Example: Consider Taurids (`TAU`) the second and $\alpha$-Monocerotids (`AMO`) the third active stream. Hitting [D] once and Field 2 enters a sporadic of magnitude +2; hitting [D] twice and Field 3 will enter a Taurid of magnitude +3; hitting [D] three times and Field 4 will enter an $\alpha$-Monocerotid of magnitude +4.
- *Key E*:

  Enter other things (clouds, star field counts, breaks).

Keys A, C, and D can be freely combined: hitting [A], [C] and twice [D] plus Field 3 enters a Taurid of magnitude −3.5.

Hitting the fields and keys triggers beeps which are intended to give some interactive feedback. For instance, the frequency of the sound corresponds to the magnitude entered. Thus, it is easy to recognize wrong entries and correct them on the spot using key B.

MeteorCount stores the data to a so-called memo, which is a small ASCII file. The format is not designed to report data to the *IMO*, but, rather, to transfer them to a PC for a more complete analysis and to prepare proper *IMO* report forms. The file name of a memo is its first line of text. MeteorCount automatically designates the memo with the date and time stamp of the beginning of the observation. Memos in Palm OS are limited to 4 kBytes, corresponding to 270–300 meteors. If the memo is full, MeteorCount will automatically create a new one.

Entries consists of a line of 4 strings separated by commas as delimiters, the first one being a time stamp (to a second). For example,

```
183612,leo,1,
```

means a Leonid of magnitude +1 entered at $18^{\rm h}36^{\rm m}12^{\rm s}$, or

```
183917,lm,3,12
```

means that the observer entered at $18^{\rm h}39^{\rm m}17^{s}$ that he or she saw 12 stars in *IMO* field 3;

```
183959,cl,20,
```

means that the observer entered at $18^{\rm h}39^{\rm m}59^{s}$ that 20% sky coverage was estimated. As a final example,

```
184502,lm,end,end
185611,lm,beg,beg
```

indicates that the observer took a break between $18^{\rm h}45^{\rm m}02^{\rm s}$ and $18^{\rm h}56^{\rm m}11^{\rm s}$.

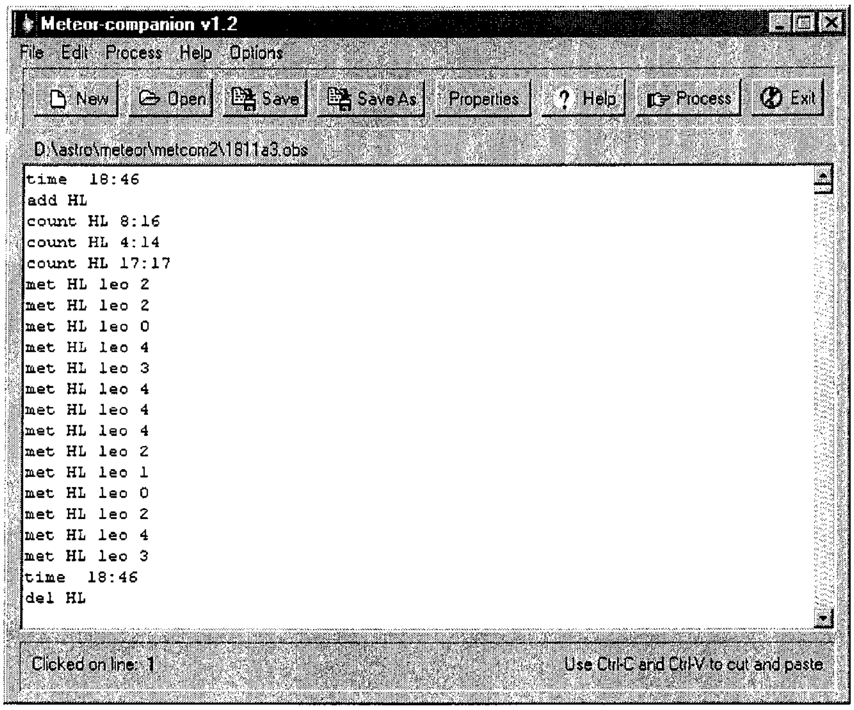


Figure 2 – Ivan Goethals's excellent freeware software METEOR COMPANION can be used to analyze the data collected by the Palm and transferred to a PC. The author has written a program to convert the Palm data into the "OBS language" used by that program.

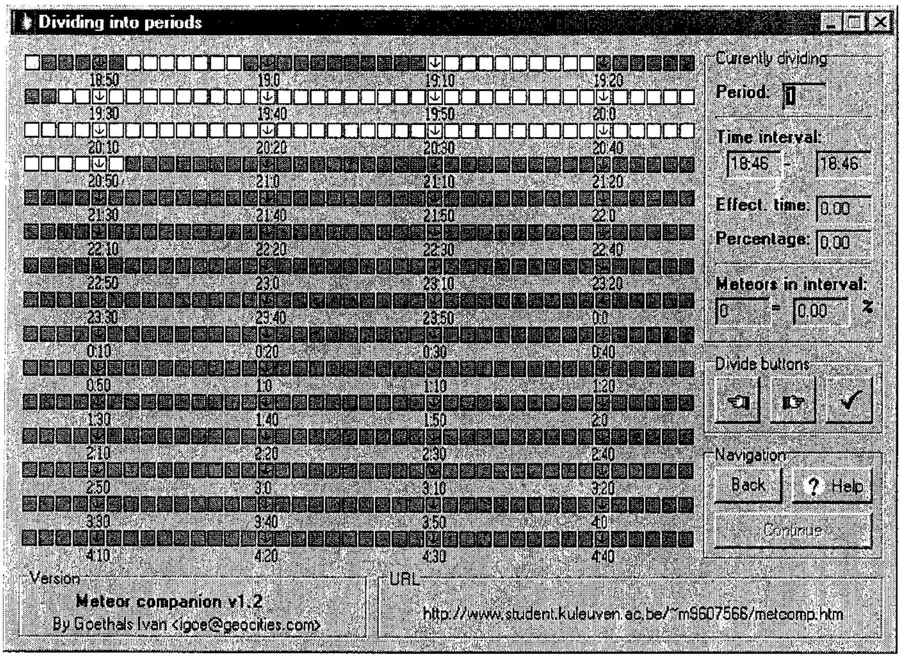


Figure 3 – METEOR COMPANION can quickly break up an observation to useful time intervals and produce magnitude distributions and statistics for each one. This software automatically creates *IMO*-style report forms. Note that the METEOR COMPANION homepage has moved to `/www.esat.kuleuven.ac.be/~igoethal/metcomp.htm`.

## 4. Data analysis

Normally, I do the data analysis and prepare *IMO*-style report forms on my desktop PC. A "hot sync" transfers all data on the PC. The files can be copied through the windows clipboard into an ASCII file. I have written a program which converts the data into the "OBS language" used by Ivan Goethals's excellent freeware meteor data analysis program METEOR COMPANION [4] (Figure 2)

The result can be, again through the clipboard, copied into that program. Breaking the data up into intervals and determining magnitude distributions is then a matter of a few mouse clicks (Figure 3), as is creating an *IMO*-compatible report form.

Alternatively, data analysis can be performed on the Palm itself. I have written an experimental program for doing so, also in Hot Paw Basic. Writing down the results from the display, however, can be a tedious process and will only be of use when a PC is not available (as a kind of back-up).

## 5. Counting meteors in a digital age: first impressions

The first test of the Palm as a meteor recording device came with the Lyrids 2001, using a partially completed version of METEORCOUNT. It became apparent that hitting some fields and the leftmost button of the Palm terminated the program. Since I did not manage to stop this by changing the software, I now tape a cardboard mask on the Palm to prevent these deadly keystrokes. I also found that the integrated display illumination was not useful (consumes battery and ruins adaptation; use a red light torch instead). The temperature in that night dropped down to sub-zero values. That made the display of the Palm dimmer, but did not stop the machine from functioning. Later the same year, during the Geminids, the Palm coped with temperatures of $-8°$ C (I held the Palm in my hand to keep it warm). With the Perseids 2001, the software was essentially bug-free. With some training, entering meteors was a pleasure, and I managed to submit a report to the *IMO* just 10 minutes after returning at home after the observing run.

## 6. A stormy experience

The night of November 18-19 2001 found my Palm at Bohyunsan observatory in Korea. I was not quite sure weather I wanted to use a tape recorder or dared to rely on the Palm for that decisive observation, so I initially used both, wearing a headset for easier use of the tape recorder and the Palm. When the rates increased, I decided to skip the method that was less comfortable. Amazingly, I discovered that entering meteors on the Palm actually became *easier* with rising meteor rates!

Entering a meteor every second made it less difficult to remember where the relevant fields were on the touch screen. Despite the temperatures dropping well below the freezing point, the Palm worked flawlessly. At around $16^h50^m$ UT, I stopped using the tape (basically because I found entering time marks on the tape every minute was deteriorating my concentration). People who heard the beeps of the palm commented, *"are you actually using a gameboy during the storm ?"* or even, *"Wow ! New high score!"*

Entering meteors required my full concentration (one had to memorize 5–6 nearly simultaneous meteors before entering them), but that experience was shared by most if not all other observers using tapes or paper rolls. At the end, I had recorded more than 4000 meteors. The Palm technique had demonstrated its capability of handling high rates. After returning to Europe, it was a matter of less than one hour to get the data to a desktop PC and generating all the *IMO* forms for this trip. Most of the time was spent to manually edit the report form (METEOR COMPANION gives $T_{\text{eff}}$ in hours to 2 decimals, which is clearly not enough for 1–2 minute time intervals. Also it does not accept more than about 1800 meteors at one time). Still, the effect was apparent. One user of tape recorders needed 12 hours for processing a similar number of meteors.

## 7. What do you need to go digital?

If you like to run METEORCOUNT, you need the following:

- *a Palm compatible handheld.* The smallest and cheapest units are ok; color Palms possibly may be too battery-consuming and cold-sensitive. Avoid running to many "hacks" and other utilities which tend to make the system unstable;
- *YBASIC and MATHLIB* installed on the Palm, being shareware or freeware, respectively;
- *the* METEORCOUNT *BASIC program*;
- *a PC* running Windows 95/98 and DOS programs;
- *the Palm desktop program* (supplied with the Palm);
- *the DOS program* `palmcvt.exe` to convert your data to the OBS language;
- METEOR COMPANION *software* to analyze the date and prepare *IMO*-style report forms.

You can download the complete package at Jost Jahn's homepage `www.meteore.de/intro.htm`. The package contains also a complete manual, and a freeware utility to disable the Palm's power saving auto-shut-off function. I will post software updates of the METEORCOUNT program to that site, too.

## 8. Further ideas

It can be imagined that, provided computer-assisted recording is becoming more popular, the *IMO* may collect raw meteor data in the Palm format, instead of pre-analyzed data sets. This would allow to adapt binning intervals to the intended type of analysis. It goes without saying that his idea will require some planing, and discussions with those who archive and analyze meteor counting data.

## Acknowledgments

I thank Ivan Goethals and Rainer Arlt, and especially Jost Jahn, for their encouraging comments. Jost Jahn made the program available through the Internet.

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# SPA Meteor Section Results: January–February 2001

*Alastair McBeath*

Details from information submitted to the *SPA Meteor Section* from 2001 January and February are presented. The Quadrantid peak was not especially well-covered visually, although radio results suggested a main maximum roughly as expected at $12^h \pm 1^h$ UT on January 3, with a lesser, secondary, maximum around January 3 from $21^h$ to $23^h$ UT ($\lambda_\odot$(*eq. J2000.0*) $= 283\overset{\circ}{.}56 - 283\overset{\circ}{.}64$). Several fireballs between January 25-27, coincident in date with enhancements in the radio data from January 24-26, $\lambda_\odot = 304° - 306°$, may have been associated with the possible January Coma Berenicid minor shower [1]. February 8 and 9 produced several fireball events over the UK, two of which were seen from more than two sites. The best of these was a magnitude −6 or brighter fireball at $19^h42^m$ UT on February 8-9 reported from 25 locations.

## 1. Introduction

The year began with some unhelpful winter weather, for once shared roughly equally among all our visual observers, both in the UK and beyond. Consequently the Quadrantid peak was best-viewed by radio. As in 2000, 2001 February's chief interest lay in some sporadic fireballs. Table 1 has the observing tallies for both months.

All the radio results except those from Dirk Artoos came from *Radio Meteor Observation Bulletins* 90-92 (2001 January to March inclusive), submitted by Chris Steyaert.

The radio observers comprised:

> Enric Fraile Algeciras (Spain), Dirk Artoos (Belgium), Mike Boschat (Nova Scotia, Canada), Gabor Bucsi (Hungary), Patrick Decomble (France), Maurice de Meyere (Belgium), Ghent University (Belgium), Will Kelsey (Arkansas, USA), Stan Nelson (New Mexico, USA), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Ton Schoenmaker (Netherlands), Dave Swan (England), Ervin Szlanicska (Slovakia), Pierre Terrier (France), Garfield Tsao (Taiwan), Bruce Young (Queensland, Australia), Ilkka Yrjölä (Finland)

The raw data was analysed as outlined in [2], and Figure 1 gives a representative overview of what most observers reported in January and February.

Increased use of the video technique meant for the first time in some years, no photographic results were received by the Section. Some of the video data was received directly from the individual observers, but as in recent times much arrived as monthly summaries produced by the German *Arbeitskreis Meteore (AKM) group.* These can be found among the notices issued on the *IMO-News* e-mailing list, but together with the other *AKM* results used here, they have been extracted from the *AKM's* monthly journal *Meteoros*, numbers 4:2, 4:3 and 4:4-5 (all 2001), provided by Ina Rendtel

Video observers included:

> Pete Gural (Virginia, USA) and the AKM reporters (in Germany where not noted): Detlef Koschny (Netherlands), André Knöfel, Rob McNaught (New South Wales, Australia), Sirko Molau, Mirko Nitschke, Jürgen Rendtel, Jörg Strunk, Ilkka Yrjölä (Finland)

Visual observations came from:

> *American Meteor Society (AMS)* reporters George Gliba, Robin Gray, Wayne Hally, Robert Hand, Paul Martsching, Felix Martinez, Jim McGraw, Norman McLeod, James Smith, David Swann, Roger Venable, Kim Youmans (all in the USA; data provided as summaries in the *AMS* journal *Meteor Trails* 11 (June 2001) by Bob Lunsford); AKM members Frank Enzlein, Sven Näther, Jürgen Rendtel, Roland Winkler (all in Germany); Jay Brausch (North Dakota, USA), Shelagh Godwin (England), Phil Heppenstall (England), Bob Lunsford (California, USA), Alastair McBeath (England), Jonathan Shanklin (South Atlantic and England), George Spalding (England), Richard Taibi (Maryland, USA)

## 2. January

The year commenced with a chance for a reasonably well-observed Quadrantid return, as waxing gibbous moonset left much of the second half of the night dark for visual watching on January 3 and 4. Unfortunately, as so often happens, the northern winter weather intervened, and far less observing than was needed could be managed. Consequently, very few visual observations were available across the expected peak time of about $12^{h}$ UT on January 3 [3], even in the preliminary *IMO* report [4]. European ZHRs on January 2-3 rose from about $15 \pm 7$ to $40 \pm 12$ between $1^{h} - 6^{h}$ UT in our results, with American data after this yielding average ZHRs for the night of about 50-70, but with a peak sometime between $11^{h} - 14^{h}$ UT (though there is very little data soon after $14^{h}$), when ZHRs rose to over 100. *IMO* results supported a peak around $13^{h}30^{m} \pm 1^{h}$ UT then with ZHRs around $130 \pm 25$. The majority of available radio results confirm a main peak between $10^{h} - 14^{h}$ UT on January 3, especially strongly at $12^{h} \pm 1^{h}$ UT, which is closer to the predicted time than the visual observations implied. A secondary peak appears in the radio data at around $21^{h} - 23^{h}$ UT ($\lambda_{\odot} = 283\overset{\circ}{.}56 - 283\overset{\circ}{.}64$), something which was found weakly even in several of the more complete European datasets, although the Quadrantid radiant was then near its lowest elevation for the day from such places. This indicates the secondary peak was most likely a real feature during the radio Quadrantids this year, although given the nature of radio observations, it is not absolutely definite the source was the Quadrantids. A Quadrantid origin is perfectly feasible however. I should note here that this secondary peak occurred between $0\overset{\circ}{.}2 - 0\overset{\circ}{.}25$ $\lambda_{\odot}$ later than the secondary, mainly radio, peak found in 2000 [5]. There are sadly no visual reports covering this time available in the *SPAMS* files to confirm this, but with something unusual found now after the main Quadrantid peak in two consecutive years, it is worth re-stressing to visual observers the importance of coverage right across all major shower peaks. Table 2 gives magnitude distributions for the better-sky Quadrantids and January sporadics. Train data were received for too few meteors to allow a thorough analysis of them, but some 7% of Quadrantids and 6% of sporadics left trains this year.

As often happens, visual observing became infrequent after the Quadrantids, and much of the coverage was by radio only through the rest of January. All the usual minor peaks in activity (see [2]) were recovered to a greater or lesser extent, but most were typically ill-defined in the available data. The $\lambda_{\odot} = 289°$ peak (January 9) appeared in most datasets at some stage between $\lambda_{\odot} = 287° - 289°$, a greater spread than has been seen before, while neither the $\lambda_{\odot} = 298°$ or $300° - 302°$ peaks (January 18 and 20-22 respectively) were at all clearly found, the $\lambda_{\odot} = 298°$ one occurring in just 1/3 of the datasets, while an equal number found a similarly weak peak at $\lambda_{\odot} = 299°$ instead.

A few single-observer sightings of bright fireballs appeared during the month, but four reports on a $-5/-6$ or brighter fireball at $22^{h}02^{m}$ UT on January 15-16 were secured from Scotland. Unfortunately, the observers were not able to provide sufficient details to enable even a rough track to be implied, though the object probably passed high over the North Sea well off the Scottish east coast.

Three further UK fireball reports, again all from single witnesses only, arrived from between around $6^{h}$ UT on January 24-25 to $0^{h}40^{m}$ UT on January 26-27, the meteors all in excess of magnitude $-5$. Also in this period, around $0^{h}20^{m}$ UT on January 26, a further bright fireball was spotted from western Canada (according to a report posted on the *Cambridge Conference Network* e-mail list: see *CCNet* 14/2001, 27 January 2001). As noted in [1], the possible minor shower of the January Coma Berenicids may have been associated with a loose "cluster" of fireballs on 1998 January 24-25. This period in 1998 coincided with a new radio peak found in that year around $\lambda_{\odot} = 304° - 305°$. In 2001, this minor radio event was recovered in most results, and showed two slightly stronger phases at $\lambda_{\odot} = 304°$ and $306°$ (January 24 and 26 respectively) in several datasets. Investigations into the visual and video reports from this period by Roberto Gorelli and myself are still in progress, though our preliminary analysis (posted on the *IMO-News* and *Meteorobs* e-mailing lists on 2001 March 3) suggested there may well be a minor radiant active in north-west Leo or eastern Coma Berenices. Whether the 2001 very loose fireball "cluster" and the somewhat extended $\lambda_{\odot} = 304°$ radio peak were linked, or merely coincidental, remains unclear, but there is again the suggestion that something worth regularly examining is happening around the January 20-27 period.

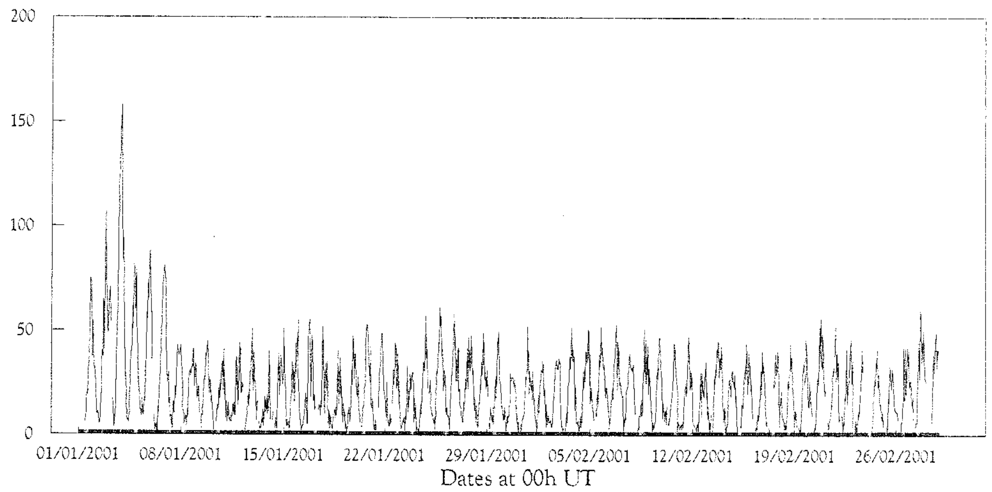


Figure 1 – All-echo raw hourly radio meteor counts from 2001 January and February, in data collected by Sadao Okamoto. Sadao's set-up was running continuously, so the gaps are when interference prevented accurate data recording. The early January Quadrantid "bulge" is naturally very clear, but the other minor peaks during the rest of January and February can mostly be picked out too.

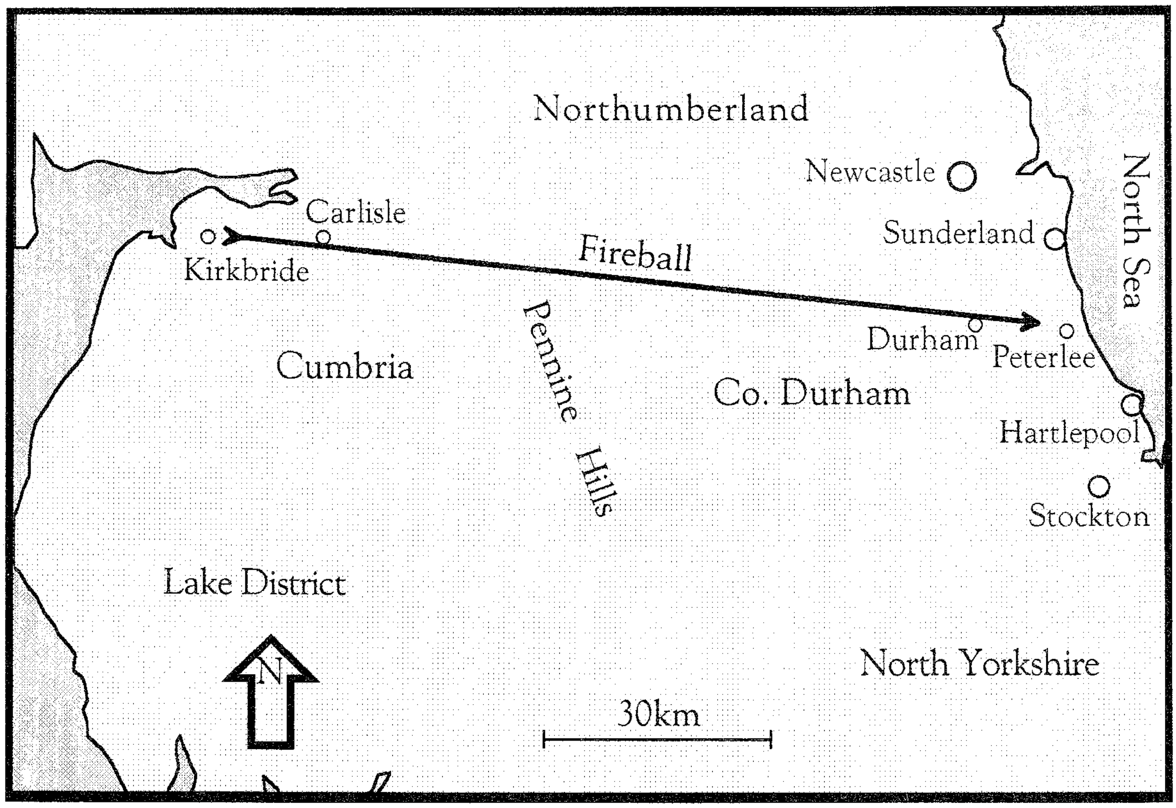


Figure 2 – A sketch map showing the most probable surface trajectory for the $19^h42^m$ UT bolide on February 8-9 across northern England.

## 3. February

The month was a disappointing one for our visual observers, and very little watching was practical thanks to the weather. Our radio reporters found the normal minor peaks from past years [2], with no striking new ones, though as in January, some were less well-defined than noted before. The $\lambda_{\odot} = 314° - 318°$ period (February 3-7; sometimes extending from $\lambda_{\odot} \approx 312° - 320°$) produced one of the stronger peaks of the month in several datsets between $\lambda_{\odot} = 316° - 319°$, but without any real consensus between the different observers. Despite its radiant's high southerly declination, this might be associated with the $\alpha$-Centaurids, whose peak was due around February 8 ($\lambda_{\odot} = 319°$), but the $\lambda_{\odot} = 316° - 319°$ peak was more noticeable in the European results than any others, making this less likely. Bruce Young's data from Australia showed his strongest peak for the month around $\lambda_{\odot} = 316°$ for instance, though the difference to other minor peaks through the month was negligible, and the source cannot be confirmed.

The main meteoric events of the month for visual watchers in Britain were sightings of four fireballs of magnitudes at least $-5$ to $-9$ on February 8-9 and 9-10. The first event, at $19^h42^m$ UT on February 8-9, was the most widely-seen, with 25 sightings from observers between Perth and Dundee in Scotland south to Greater Manchester, Cheshire and North Wales, nine south of the suggested surface track, the remainder almost under it or to the north. With full Moon in the sky, only a minority of the observers were able to give useful sky positions for the visible trail, and not all of them spotted the entire event, so the details here are only best estimates. Figure 2 gives a map of the most likely projected surface track, which was around 110 km long. Its visible start height was around 80 km above the Kirkbride area of Cumbria (54°53′ N, 3°13′ W), and the end height was around 60 km, over the hills between Durham and Peterlee in County Durham, near the village of Ludworth (54°46′ N, 1°27′ W). Assuming these details to be approximately correct, the meteoroid approached Earth at a very shallow angle of descent, around 10° from horizontal, yielding an atmospheric path length of around 115 km. Flight-time estimates from seven observers suggested a mean value of around 6 s, equivalent to a mean atmospheric velocity, not allowing for deceleration, of around 19 km/s. All this information would imply a splashdown for any surviving meteorites some 200 km north of the Dutch mainland, in the southern North Sea. No reports of sounds heard during or after the fireball's flight were received, though several people commented on seeing fragments being shed for part of the trail, especially towards its end (probably two or three main pieces). No long-lasting persistent train was noted, but some sightings suggested a wake may have occurred, lasting for less than a second. The fireball was clearly colorful, with blue, green, yellow-red or orange mentioned by different people as dominant. As for its brightness, it was probably at least magnitude $-5$ or $-6$, possibly somewhat brighter.

Another, but single, bright fireball report from February 8-9, around $20^h - 20^h15^m$ UT, was received, which seemed to have passed on a similar track to the $19^h42^m$ one. No other sightings were retrieved however, and although a timing mistake is unlikely, it may be the explanation for this event. The following night, February 9-10, brought two vague reports from Northumberland and Lancashire suggesting a bright or very bright fireball had passed over the northern UK at around $19^h20^m$ to $19^h30^m$ UT, moving west to east. No further details could be established, and it is possible both observers mistook the time for the object an hour later.

This second event on February 9-10 was at $20^h21^m$ UT, and 8 observations of it were collected from observers between Harrogate in North Yorkshire north to the Dundee area in east-central Scotland. It was probably around magnitude from $-5$ to $-9$ at best. Most sightings mentioned some fragmentation occurred during the object's flight, with orange, red or green-blue popular colors in the statements to mention such. Unfortunately, the bright Moon again caused problems as on the previous evening, and even fewer accurate sky positions were obtained on this meteor, too few in fact to derive a useful atmospheric track. In all likelihood, the fireball was travelling roughly west to east some way offshore of the Dundee to Aberdeen stretch of coast, the whole flight perhaps between 40 and 200 km out over the northern North Sea. The fact that all the observers were west and south of the fireball's flight made it more difficult to try to compute a usable trajectory.

Returning now to the minor radio meteor echo count maxima, the peak around $\lambda_\odot = 320° - 322°$ (February 9-11) extended to $\lambda_\odot = 323°$ in 7 of 9 datasets, while the $\lambda_\odot = 326°$ one (February 15) was found chiefly at 325°, as last in 1998. The $\lambda_\odot = 331°$ peak was only present in 1 of 8 datasets, but a minor peak was present in half the available results the following day, February 21. The end-month peaks from $\lambda_\odot = 333° - 342°$ (February 22 to March 3) were found strongest in most observations slightly later than normal, around $\lambda_\odot = 338° - 339°$ (February 27-28).

Table 1 – Visual, radio and video hours' totals, plus visual meteor numbers and video trails recorded in each month. In January, the visual meteor tally included 937 Quadrantids.

| Month | Visual | Meteors | Radio | Video | Video meteors |
|---|---|---|---|---|---|
| January | $90^{h}_{.}6$ | 1,706 | $7187^{h}$ | $440^{h}_{.}5$ | 1,454 |
| February | $25^{h}_{.}4$ | 122 | $5784^{h}$ | $231^{h}_{.}5$ | 850 |

Table 2 – Global magnitude distributions for the Quadrantids and January sporadics seen in good sky conditions (LM +5.5 or better, average cloud cover smaller 20%), including mean LM and corrected mean magnitudes.

| Shower | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5+ | Tot | LM | m6.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUA | 0 | 4 | 13 | 43 | 56 | 93 | 91 | 65 | 33 | 398 | 6.25 | 2.57 |
| SPO | 1 | 1 | 4 | 10 | 31 | 36 | 50 | 47 | 27 | 207 | 6.16 | 3.09 |

## Acknowledgments

As always, my grateful thanks go to all our observers and correspondents, including those largely unnamed ones who contributed fireball reports. In regard to the February 8 and 9 fireballs particularly, I am happy to additionally thank Mike Dale and Rachel Mason of *Royal Observatory Edinburgh*, John Lambert of *Newcastle* and *Northumberland Astronomical Societies*, Jeff Lashley at the *Mills Observatory*, Dundee and Don Simpson of *Sunderland Astronomical Society*, for their ready assistance in collecting and forwarding many of the sightings.

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