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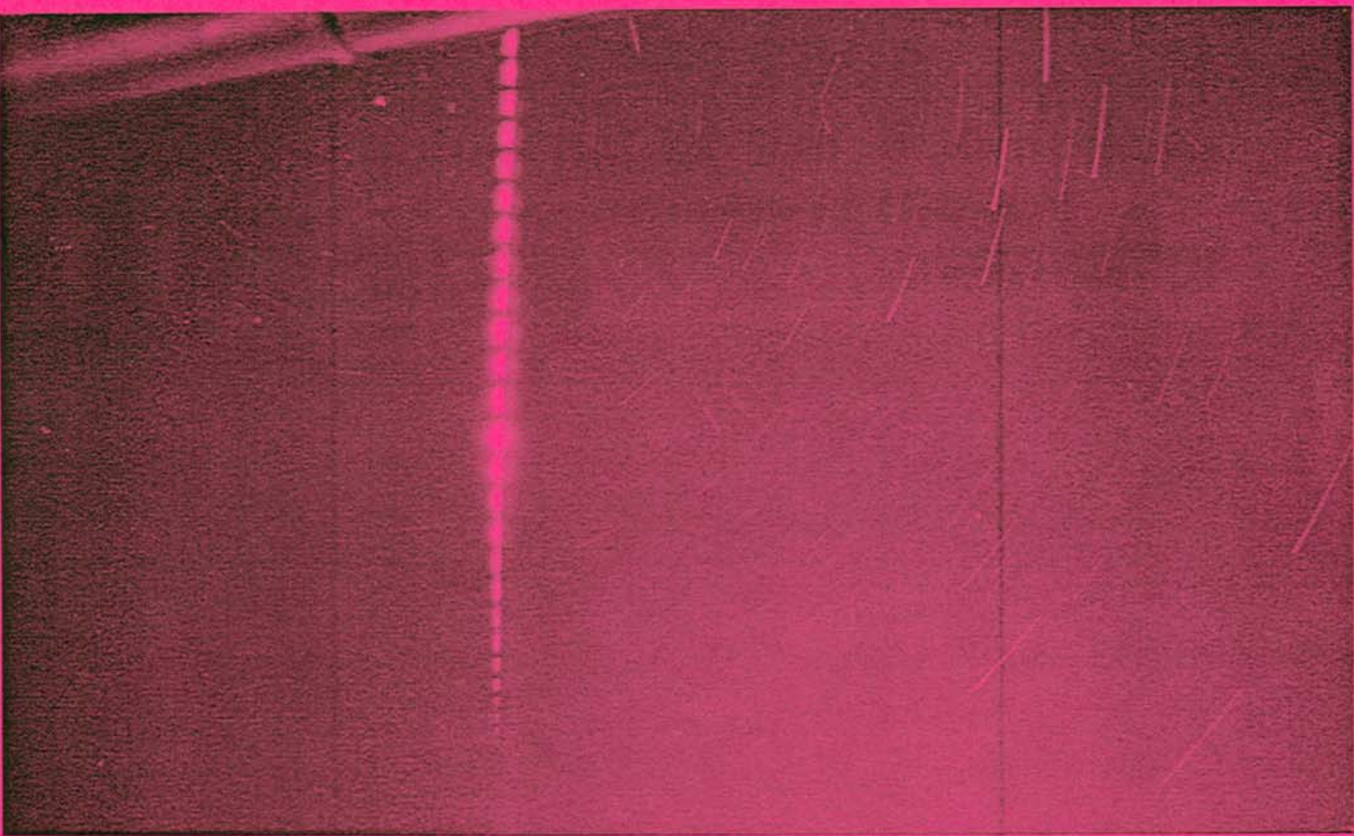

This brilliant fireball appeared on August 5, 2000, at $22^h10^m50^s$ UT, and was photographed by Bernd Heinrich of Potsdam, Germany. The photo was exposed from 22^h00^m to 22^h30^m UT. Bernd operates a semi-automatic fireball patrol half-hour exposures. The camera is equipped with a rotaing The fireball of magnitude −10 to −12 was also visually observed by Frank Enzlein, north of Berlin. The video camera CARMEN of Jürgen Rendtel registered a flash outside the field of view.

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Contents

Useful Information

The December issue *(WGN 28:6)*

The *December issue* will be mailed near the end of December in order to provide our readers with first information on the Leonid meteor shower. Contributions are, therefore, due on *December 10* at the latest. They should be sent to *Marc Gyssens*.

Subscriptions and ordering of publications

Volumes 28 and 29 (2000) of *WGN* are expected to contain at least 240 pages each and cost 35 DEM or 17.90 EUR per volume, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Subscription/membership information can be found in this issue, on pp. 133–134. 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.

From the Editor-in-Chief

Marc Gyssens

With the northern-hemisphere summer being over, we can both look back to our observational achievements the last few months as well as look forward to the Leonids. In this issue, we do both. Rainer Arlt reports on the 2000 Perseids, while David Asher and Robert McNaught give us their perspective on the 2000 Leonids. Even though the activity predictions for this shower are more modest than last year and certainly more modest than those for the two years to come, it is most important to cover the Leonids this year despite the Last-Quarter Moon, as the observations will be crucial for validating Asher and McNaught's model that proved so successful last year. Another confirmation of the predictions this year will virtually exclude the possibility that last year's success was mere luck and will help us in assessing expectations for the very promising years 2001 and 2002.

Definitely a highlight during the past month was the International Meteor Conference (IMC) *in Pucioasa, Romania, a small town beautifully located at the feet of the Carpathian Mountains. Because of the geographical location of Romania, the* IMO *Council feared that fewer meteor workers than usual would take the effort to travel, but these fears have turned out to be unfounded. Even though the weather could have been more cooperative, the conference was a big success, in local and international attendance (half of the about 90 participants were Romanian, and the other half of the participants came from thirteen different countries, including the Ukraine, Jordan, Argentina, and Japan) as well as with respect to the well-filled and interesting program. The event was very well organized, everybody was in a good mood despite the somber weather, and, like last year, several results and experiences were exchanged and joint projects set up. An aspect of each* IMC *that should also be mentioned here are of course the informal contacts which took place during the breaks, the meals, the excursion, and in the evenings, during which our hosts treated us to two astropoetry shows.*

What I personally found gratifying at the IMC, *is that a few people came forward to offer their help with certain aspects of the organizational work within the* IMO. *In my editorials, I have often pointed to our main weakness, which is that too few people do too much work. It seems that the awareness among our membership is growing that it is vital that a larger number of people make some commitment (however small) with regard to the tasks that involve running the* IMO. *I can only hope that this awareness will further increase. Only in this way, the future of the* IMO *can be guaranteed in the long run, and temporary inavailabilities of people involved in all the work that needs to be done do not necessarily have to result in delays, for example, in getting out this journal...*

The last IMC *is only just over, but many meteor workers are already looking forward to the next one! The* IMO *Council decided to have the next* IMC *in Cerkno, Slovenia, from September 20 to 23, 2001. I also hope to see most of this year's participants again, but, in addition, I also hope to see those whom I have missed this year! More information, both on this year's Conference and on the next one, can be found in this issue; more detailed information and a registration form for the* 2001 IMC *will be printed in the December issue.*

As the end of the year is approaching, we must ask you to renew your membership/subscription. We are pleased to announce that dues have remained unchanged compared to last year. However, we decreased *the equivalent prices in US Dollars to reflect changed currency rates! Several members and subscribers have already taken the opportunity of their presence at the* IMC *to renew. To the others, we ask not to delay your renewal unnecessarily; in this way, you are helping us in keeping our records straight! Renewal information can be found below.*

Meanwhile, enjoy reading this issue, and all the best for the 2000 Leonids, for which we also present some additional information!

Renew Your IMO Membership/WGN Subscription Now!

Ina Rendtel

General information

Please help us in keeping our records straight by renewing right now. In this way, you ensure that your subscription is processed well in time before the February issue has to be sent out and you save the already overloaded *IMO* officers to have to run on and off to the post office to mail back issues. To encourage you, **you may order one free copy from the Observational Report Series** (1988 to 1995 only) **if you pay before the end of this year!**

In addition, you may also consider ordering other *IMO* publications (price list on outside back cover) to save on banking costs, because one payment is always cheaper than two! *New* IMO *publications* are Report 12 containing the 1999 visual observations, and the Proceedings of the 1999 and 2000 *IMC*s, the latter of which will appear shortly and can already be ordered. You can also pay your subscription for *two* years, by which you can avoid a likely increase in dues for 2002! Finally, you can **become a supporting member** by adding at least 15 DEM (7.67 EUR) or 10 USD per year to your membership.

Do I have to pay?

For quite some time now, we offer the possibility to pay for two consecutive years, but people seem to forget whether or not they did so. **If the address label on the envelope mentions 2000, you should renew now!** People seeing a later year either have already renewed or paid for two years last year!

Payment instructions

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

- **in Europe:** pay in *German Marks* or *Euro* to *Ina Rendtel* by transferring to the postal giro account number 547234107 at Postbank Berlin, bank code 10010010. (Please send **no bank checks!**—If you must pay by check, pay to Robert Lunsford as indicated below.)
- **in the United Kingdom:** proceed as above, or pay to *Alastair McBeath*, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
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- **All others** pay in *US Dollars* to *Robert Lunsford*, 161 Vance Street, Chula Vista, California 91910, USA.

All people insisting on paying by check should pay to Robert Lunsford in US Dollars, as indicated above. Make checks payable to Robert Lunsford, not to the IMO!

Price list

Prices in German Marks (and Euros) remain unchanged. **To reflect currency rate changes, we decreased the equivalent amounts in US Dollars!**

Type of subscription	2001	2001 + 2002
Regular subscription (*WGN*)	35 DEM (17.90 EUR) or 20 USD	70 DEM (35.79 EUR) or 40 USD
Combined subscription (*WGN*, *FIDAC* News, Report)	70 DEM (35.79 EUR) or 40 USD	140 DEM (71.58 EUR) or 80 USD
Also possible outside Europe:		
Regular subscription with airmail delivery	70 DEM (35.79 EUR) or 40 USD	140 DEM (71.58 EUR) or 80 USD
Combined subscription with airmail delivery for *WGN* only	110 DEM (56.24 EUR) or 65 USD	220 DEM (112.48 EUR) or 130 USD

The 2000 International Meteor Conference

Pucioasa, Romania, September 21–24, 2000

Georg Dittie

I was asked to write the report about the *International Meteor Conference* (*IMC*) at Pucioasa, Romania. For me, this feels a bit strange, being both an experienced observer and a first-time participant at the *IMC*. Anyway, here are my impressions.

At first, the idea was to arrange an *IMC* in Eastern Europe, because, for wealthy Westerners, it is easy to come to Romania but it is not so easy for them to come to us. This idea worked well, and this *IMC* was filled with Romanian participants, interestingly a lot of them very young folks. Other participants from Eastern Europe came from Yugoslavia, Slovakia, Slovenia, Poland, Bulgaria, and the Ukraine. The rest of the world was also present. The longest journeys (at least in distance traveled) were for our participants from Jordan, Japan, and Argentina! I enjoyed to meet and discuss with all of them, and to have a lot of fun during the conference.

While this was my first *IMC*, it was definitely not my first international conference about astronomical topics!

Meteor work can be split into two categories, depending on the observing method.

First, there is the traditional way to observe meteors by the naked eye and to track them with the help of gnomonic maps or to count rates. This is done in smaller or less large groups. The existence of these groups explain the popularity of meteor astronomy among young people, especially in Eastern Europe. Observing this way costs very little, and one can have a lot of adventures and fun together—while producing a lot of valuable data, too. I remember the contribution by Marcin Kiraga, who presented Perseid meteor data gathered at a time when nobody else was looking!

Second, there are the more technological observing methods. In Western Europe, intensified video cameras connected to a sophisticated real-time evaluation system are used, and, of course, the development process is still in progress. Besides video work, there is also radio work, and two different ways to observe meteors by radio were presented. Mohammed Odeh from Jordan presented his empirical way of radio observations. He connects two antennas to a standard receiver and listens to distant radio stations which can be only received in the case that their waves are reflected by the ionized trail of a meteor. With trial and error, the method is improved. The other, very analytical approach to radio observation comes from Argentina. Juan Martín Semegone presented the radio receiver developed by a small working group of radio engineers with the goal to achieve very homogeneous results.

Of course, there were a lot of discussions on stage and at the lobby about the further progress of our observation techniques, i.e., interesting for me, since I am a kind of "astro-engineer" myself. Worth mentioning were a small brain storming about neural networks for pattern recognition of radio meteors and an unofficial debate about the possibility of video cameras without an expensive intensifier. The problems are still open, but it was an interesting exchange of thoughts.

The *IMC* at Pucioasa also showed a completely different way to be preoccupied with astronomy: astroculture! This is a mixture of self-written music (from folk music to techno), short poems, bizarre dances using flashlights to represent meteors, masquerades, and a small improvised opera, all dealing with how people are overwhelmed by watching a shooting star. Making poems seemed to be rather popular, and the stage was crowded with mostly young people reciting their verses. These shows were presented in connection with both the opening ceremony and the last night, when there was a special performance. This inspired nobody less than David Asher, our top theorist present and co-predictor of the Leonid storm in 1999, to concoct two (slightly satiric) limericks of his own and to climb on stage to present them. There was immense applause!

Like many other conferences, the *IMC* at Pucioasa offered a half-day excursion to the vicinity of the town to get an impression of the country. First, we visited an orthodox monastery and a small exhibition of modern religious art manufactured at that monastery. In the garden, there were displays of hand-woven clothes and wood cuttings, set between the apple trees. Most impressive (and for my taste most beautiful) was the large entrance gate of the monastery. This visit together with the astroculture performances shows the importance of art to the Romanian astronomers. The second part of our excursion brought us to the summer residence of the imported first Hohenzollern king of Romania, Carol I. I thought that the Bavarian king Ludwig II was crazy, but the achievements of his Romanian counterpart are not less impressive! We have had a lot of fun.

It was a marvelous idea to bring the *IMC* to Romania. The hospitality was great and the organization was absolutely perfect! We were picked up by bus from the airport exactly on time, the hotel was nice, we got an awful lot of food, but the best was the fine convention center, the "Centrul Cultural" of Pucioasa with a capacity for about 90 participants, half of which were from Romania. The local organization team found a good compromise between the number of presentations and the time available; most of the time, we could stay on schedule without too much pressure. Many big thanks to Valentin Grigore and the other organizers of the *IMC*. I, for one, am sure I will also be among the participants of the next *IMC* in Slovenia, another country I have not had the pleasure to visit before!

The 2001 International Meteor Conference

Cerkno, Slovenia, September 20–23, 2001

communicated by Mihaela Triglav

It was decided at the 2000 *IMC* to hold the 2001 *International Meteor Conference* in Slovenia. The conference will take place in a small town called Cerkno, in Hotel Cerkno, from September 20 (Thursday evening) to September 23 (Sunday, after lunch). It will be organized by the *Astronomical Association Javornik* with the help of the *Association for Technical Culture of Slovenia*.

Cerkno is a small town surrounded with hills at the feet of the Julian Alps. It is located about 60 km northwest of Ljubljana and 15 km north of Idrija (known from mercury mining). We plan to organize a shuttle service from Ljubljana (Brnik) airport and railway station to the conference site.

Accommodation will be provided in rooms with 2 to 4 beds, all meals will be served in the hotel restaurant, and lectures will be held in the hotel conference hall and small rooms for workshops. The full conference fee will be 200 DEM (We hope that we will manage to offer reductions for East-European participants).

More information as well as a registration form will be provided in the December issue of *WGN*. We are currently preparing a 2001 *IMC* Web page, the URL of which will also be announced in the next issue. You can contact the organizers via email: `mtriglav@yahoo.com` or `jure.zakrajsek@kiss.uni-lj.si`.

Figure 1 – Four Romanian participants, together with Khaled M. Tell and Mohammad Odeh from Jordan, during the excursion. (Photo R. Arlt.)

Erratum on "Leonid Radiants Determined by Double-station TV Meteor Observations"

Yoshihiko Shigeno, Hiroyuki Shioi, and Shoichi Tanaka

Table 1 – Averages and standard deviations of parameters determined for the Perseids and Geminids. The upper line gives the averages, the lower line gives the scatter in the data in standard deviation and does not indicate the errors in the averages. All data refer to eq. 2000.0.

Date (UT) (YMD)	$\lambda_\odot$	Radiant α	Radiant δ	SD	v_G (km/s)	SD (km/s)	a (AU)	e	q (AU)
19960812.689	140.°276	47.°97	+57.°87	0.°29	58.9	1.4	13.7	0.930	0.952
SD 0.059	0.°057	1.°13	0.°63	0.°15	1.1	0.7	–	0.063	0.008
19981211.678	259.°435	110.°23	+32.°98	0.°25	33.5	1.0	1.30	0.883	0.152
SD 0.032	0.°033	0.°36	0.°42	0.°15	0.9	0.5	–	0.010	0.006

Table 2 – Averages and standard deviations of the Leonid data.

Date (UT) (YMD)	$\lambda_\odot$	Radiant α	Radiant δ	SD	v_G (km/s)	SD (km/s)	a (AU)	≤ *mit* e	q (AU)
19951118.750	235.°979	154.°08	+21.°88	0.°38	71.0	1.9	14.9	0.934	0.985
SD 0.020	0.°021	0.°23	0.°36	0.°04	1.4	1.0	–	0.131	0.001
19981117.782	235.°236	153.°72	+21.°65	0.°26	70.8	1.3	11.9	0.917	0.984
SD 0.020	0.°021	0.°28	0.°16	0.°07	0.8	0.4	–	0.064	0.001
19991118.787	235.°994	153.°88	+21.°58	0.°26	71.1	1.3	15.8	0.938	0.986
SD 0.062	0.°062	0.°19	0.°07	0.°15	0.5	1.0	–	0.046	0.000

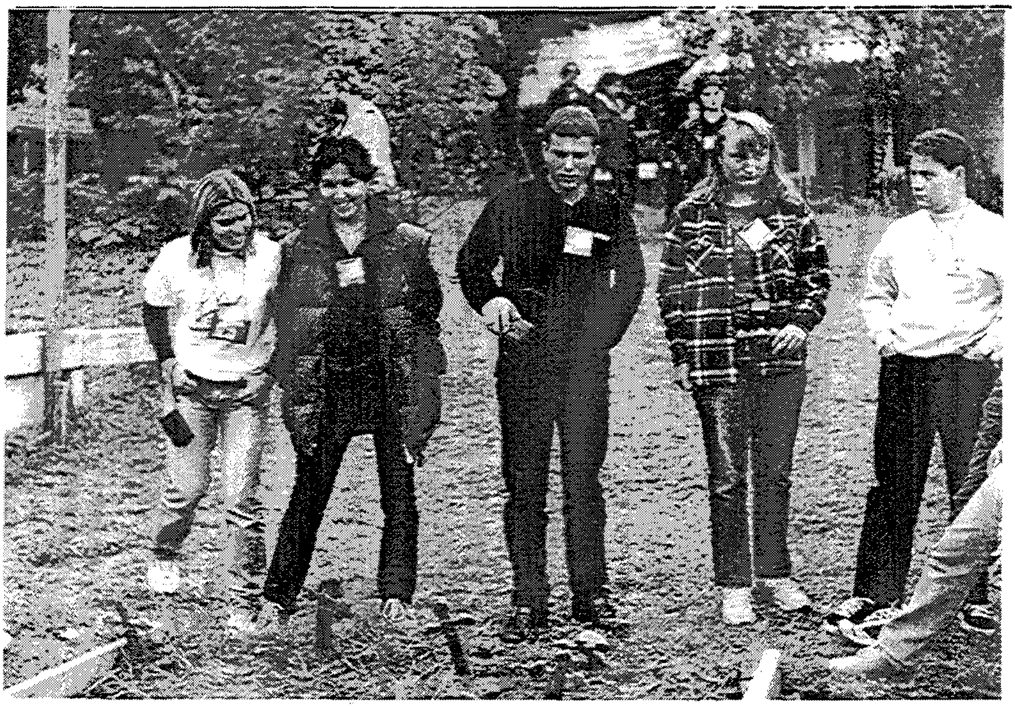

Figure 2 – From left to right, we see Mariya Krumova and Ivelina Momcheva from Bulgaria, a Romanian participant, and Gabrijela Triglav and Mirko Kokole from Slovenia. (Photo R. Arlt.)

All standard deviations in Tables 1 and 2 have inadvertently shifted one place to the right in the process of editing. When correcting this error, the roundings of these standard deviations must also be adapted. Please replace the relevant tables by the ones below and accept our apologies for the inconvenience. (Ed.)

Table 1 – Continued.

Date (UT) (YMD)	ω	Ω	i	Abs. mag.	H_b (km)	H_e (km)	Met.
19960812.689	151°0	140°3	113°3	2.8	114	98	19
SD	2°1	0°1	1°0	1.7	5	4	
19981211.678	323°3	259°4	22°6	3.7	101	85	7
SD	0°5	0°0	1°1	0.9	2	4	

Table 2 – Continued.

Date (UT) (YMD)	ω	Ω	i	Abs. mag.	H_b (km)	H_e (km)	Met.
19951118.750	173°3	236°0	162°3	2.2	111	92	3
SD	1°3	0°0	0°4	2.0	11	1	
19981117.782	171°9	235°2	162°5	4.0	118	100	6
SD	1°0	0°0	0°5	0.6	4	2	
19991118.787	174°1	236°0	162°7	1.7	128	93	9
SD	0°5	0°1	0°1	3.0	13	3	

The Leonids

Expectations for the 2000 Leonids

David J. Asher and Robert H. McNaught

In the early hours (UT) of November 18, 2000, the Earth will encounter the 8-revolution old trail of meteoroids and dust from Comet 55P/Tempel-Tuttle, and, a few hours later, the 4-revolution trail. Neither encounter will be as close as in the cases that have given the greatest Leonid storms of the past. We discuss what is expected from the 2000 Leonid shower, and what one can hope to learn from it.

1. Introduction

Storms or sharp outbursts occur in the Leonids, and similarly in other meteor showers, when the Earth passes through a *dust trail*—a narrow structure where the spatial density of meteoroids is very high. A new trail is generated each time an active comet returns to perihelion. Trails soon become rather long; in the case of the Leonids, particles further forward in a trail can pass through the ecliptic some years before particles that are further behind in the same trail.

Leonid meteors can only be produced by particles that collide with the Earth. Since all meteoroids in the Leonid stream have their descending node in the region of the ecliptic moderately near where the Earth is in mid-November, in order for a meteor to be produced it is necessary that

- the meteoroid reaches its node in mid-November; and
- the node is very near to the Earth's orbit.

Leonid meteor storms can therefore be predicted by calculating the nodal positions of the parts of trails that pass through the ecliptic in mid-November [1–4].

For further explanation, results, and reviews of relevant work, see [3,5,6]. In the present article, we discuss some of the reasons why the dust trail technique has substantial predictive power, and make a few specific comments about how the theory applies to the 2000 Leonids.

2. Storm prediction using dust trail method

This method of storm prediction successfully explains storms *and* non-storms over the past 200 years. This absence of "false positives" *and* "false negatives" is strong evidence that the technique is applicable to Leonid storms. Since trails are much narrower than the whole Leonid stream, most trails pass too far from the Earth's orbit for a significant outburst to occur; however, outbursts have been observed when the "miss distance" is close enough. In Figure 1, the elliptical contours denote the combinations of parameters for which a peak ZHR of 1000 is expected, based on a model fit calculated in [3], with ZHRs tending to be higher towards the center of the ellipse. The ZHR evidently depends on the miss distance. It also depends on how long after the passage of the comet the trail encounter occurs. For plausible ejection processes from the cometary nucleus, it is to be expected that the highest densities of meteoroids will be on orbits most similar to the comet's orbit, immediately after ejection. However, solar radiation pressure on small particles causes the meteoroids to fall behind the comet by a progressively further amount on each revolution. Therefore, the potential for higher ZHR storms tends to be behind the comet, as also noted in [7].

There is a dramatic reduction in the size of the storm area (2 dimensional region of parameter space in Figure 1 plots) as compared with the situation [7] when the comet orbit, rather than trails, is used as the predictor; cf. last plot in Figure 1. This feature, even on its own, gives the dust trail method greater predictive power, but more conclusive still is the precision with which trail calculations estimate the peak time of outbursts [8,3].

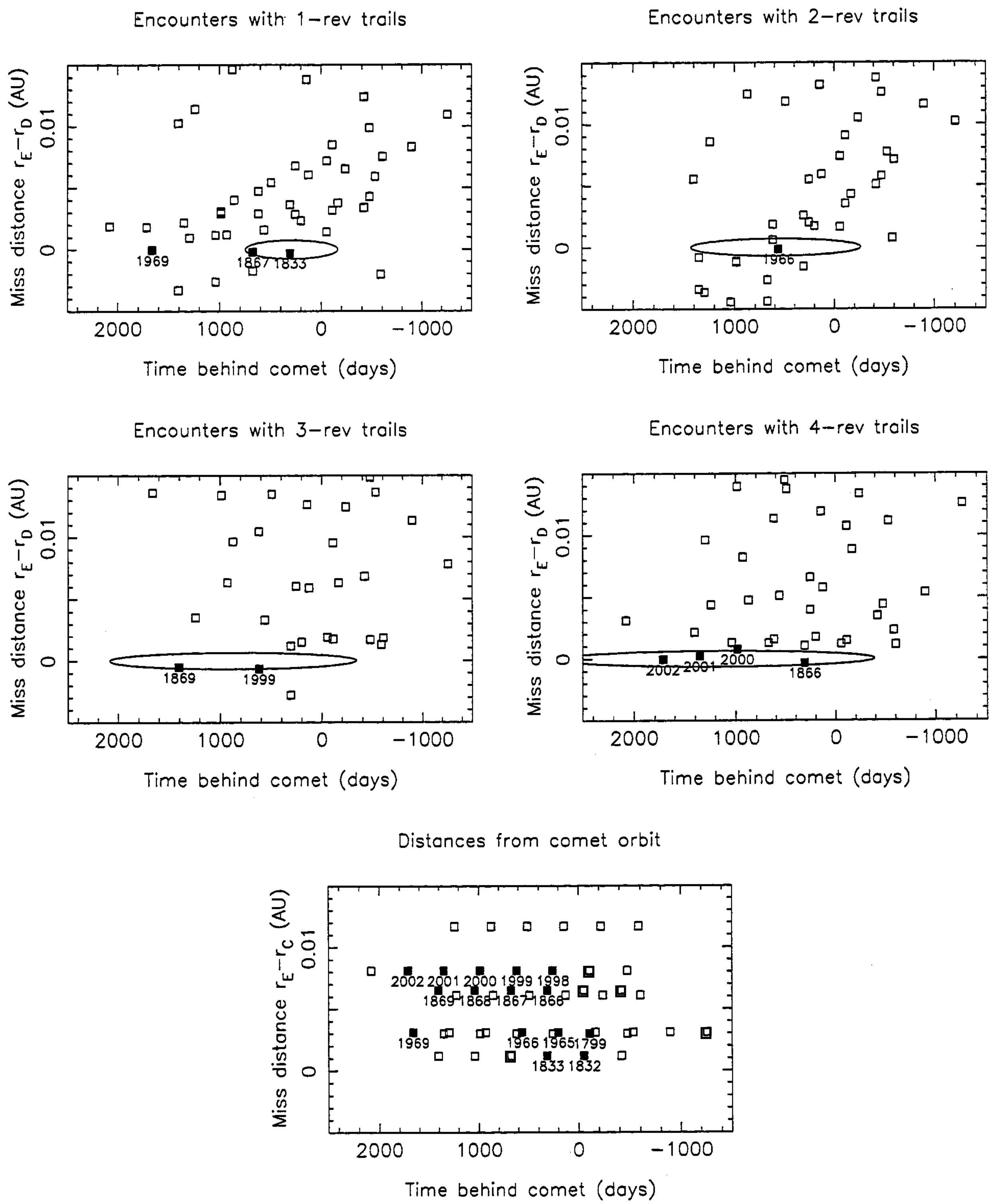

Figure 1 – Parameters of Earth encounters with Leonid dust trails, back to the 1800 return of 55P/Tempel-Tuttle. Data are given for 6 years at most returns, although there are one or two extra years around the two most recent returns (cf. [3], Table 1). Storms or sharp outbursts identified in Tables 2, 3, and 5 of [3] are shown as solid symbols, other years/encounters as open symbols. The miss distance from the nominal center of the trail is expressed as the difference between the heliocentric distances of the Earth and the descending node of particles in the trail, at the same longitude. The elliptical contour represents a model [3] fit of peak ZHR 1000, the peak ZHR for this particular model fit being assumed to reach a maximum when $r_E - r_D = 0$. The final plot relates to the node of the comet orbit rather than dust trail orbits, some other years of enhanced displays being additionally shown as solid symbols; trails older than 4 revolutions caused 1799, 1832, and 1868 [2], with still older, resonant material causing 1965 and 1998.

Figure 1 makes it clear that for 1- to 4-revolution trails, there are no other encounters in the past 200 years where storms 4 years after the comet are expected (1969 was an outburst, but not a storm). There is, therefore, no inconsistency in the fact that storm level activity will occur in 2002 a greater time after the passage of the comet than on any other occasion in the past two centuries.

Our conclusions for the coming years are consistent with [1,4], very precisely as regards times of outbursts, and reasonably as regards levels of activity. However, they are not in agreement with some other predictions. Without attempting to be comprehensive, we shall comment on the reasons for discrepancies in some cases.

Rather low ZHRs have been predicted in [9] for the encounters with the 4-revolution trail in 2000–2002. In this paper, the authors correctly reject the fitting of a double function consisting of background and storm components in cases when the background component indicates a peak close in time to the storm component. It is more reasonable that these are activity from the same dust trail. True background activity would be more likely to peak hours, sometimes even days away from a specific storm peak, owing to the dramatically different evolutionary and perturbation histories. Thus, interpreting parameters of the dust trails from the 'storm component' alone of such a double function fit would give questionable results. Their use of a single Lorentz profile to fit the whole activity curve shows a clear improvement.

Given their success in fitting such a profile to the overall storm activity curve, they then assume that such a profile represents the radial profile of the dust trail. Although little data exist to define the radial profile, and, ideally, a theoretical approach based on the ejection of dust from the comet nucleus is needed, an empirical model could be of value. However, such a radial profile is used in [9] to fit to data on stream widths derived from observations in both storm and non-storm years. The major assumption here is that the non-storm year data are still representative of dust trails. It is easy to demonstrate that, in 1998 and 1965, the activity is unrelated to dust trails a few revolutions old, owing to the large time difference between the observed maximum and the predicted times of dust trails [10]. Thus, the data points on stream widths at large values of $r_E - r_D$ are unrelated to recent dust trails and cannot be fitted to the data at small values of $r_E - r_D$. The data at small values of $r_E - r_D$ alone are not sufficient to support the conjecture of a shift in the center of the dust trail.

Nevertheless, the main reason for the much lower rates (two orders of magnitude) in 2001–2002 in [9] compared to [1,3,4] appears to be the calculated decrease in density as mean anomaly increases, equivalently to density change as a function of time behind the comet, as shown in Figure 6 of [9]. However, there are crucial differences between their Figure 6 and our Figure 1 here, involving the use of scaled data from 10P/Tempel 2 as data points in constructing the curve of activity from 55P/Tempel-Tuttle and the Leonids, the plotting of data from trails of different ages against a single mean anomaly axis (whereas trails become longer as they age, hence the elongation of the ellipses with age in Figure 1), and the mean anomaly at which the ZHR peak is attained.

Our analysis [3] indicates that the peak ZHR of a 1-revolution trail occurs at $\Delta a_0 = +0.16$ (difference in semi-major axis of particles compared to comet, at time of ejection), which is consistent with theoretical predictions based on the effects of solar radiation pressure on visual meteoroids (cf. [1,11,12]) which yield a value of Δa_0 around +0.2. For a 1-revolution trail, this represents a mean anomaly of 9°–11°. Figure 6 of [9] is thus discrepant in having the ZHR peak for a 1-revolution trail at a mean anomaly of 0°. The 10P/Tempel 2 data appear to represent multiple undifferentiated dust trails, including 0-revolutions. This would be expected for an object with perihelion distance 1.48 AU (implying lower ejection velocities and thus slower separation from the comet) and period 5.5 years (implying trails have less time to dissipate in one revolution, and different revolution trails more strongly overlap.) Even if the 1-revolution dust trail of 10P/Tempel 2 could be dissociated from the other dust trails, it is unlikely that any meaningful ZHR could be derived from it that would be comparable with the observed

Leonid ZHR data used for the other points plotted. However, the most serious problem with Figure 6 of [9] is that the points for the trails in the years 2000 to 2002 use a mean anomaly of the 4-revolution trail plotted onto the function for a 1-revolution trail. Being 4-revolution, the mean anomaly for these three points should be divided by approximately four, which would place these three prediction points much higher up the curve, significantly increasing the ZHR. These ZHRs should then be modified by the amount of attenuation in the subsequent three revolutions. In our analysis [3] this is a factor f_M assuming attenuation is by stretching alone. This is in addition to ZHR differences due to the width profile analysis, discussed in the previous paragraph.

Other research giving very different estimates from [1,3,4] includes [13,14]. The method of [13] appears to be largely empirical, and discrepancies with other results are not surprising. The procedure followed in [14] is physically valid, being based on calculating the perturbations on meteoroids rather than on the comet, but the discrepancy is due to the spatial resolution applied. Essentially, there can be substantial variations in density even over very small distances, such as an Earth diameter (cf. Table 4 of [3]). Some discussion of other prediction methods appears in the CCNet archive [15].

3. ZHR model

Although the numerical parameters describing the model ZHR fit (i.e., the locations of the elliptical contours in Figure 1) were determined empirically from ZHRs of outbursts over the previous two centuries, the dependences on miss distance and time behind comet relate to existing physical mechanisms, namely ejection processes and radiation pressure. It is therefore reasonable to expect estimated ZHRs to be of the right order of magnitude. In [5], we estimated a peak ZHR, due to the 3-revolution trail in 1999, of 500, with the range 200–2000 being in accord with the model used and with observed ZHRs of the previous 200 years. The observed ZHR was 3700 [16]. Possible contributory factors to the discrepancy include the following:

- Although there is a physical basis for relating ZHR to miss distance and time behind comet, there is no theoretical basis for using a double Gaussian specifically.
- The 1833 maximum was derived in [17] from the available historical reports. However, this was some 45 minutes before our calculated peak time. Given the fits of later outbursts to within a few minutes, and given that the 1833 storm was not expected in the way that later ones were, it is reasonable to believe that the actual peak would have been some 45 minutes later and the peak ZHR considerably higher than the derived ZHR.
- Problems of visual counting in 1999 argue for greater ZHRs than derived in [17], for 1833 and 1966 in particular. Moreover, [17] explicitly states that many of the estimates of historical ZHRs are lower bounds.

Adjusting some of the past ZHRs (e.g., doubling the 1833 value and increasing 1966 to 110 000) allows a very good fit of 1999 to observations, within the context of the assumed double Gaussian model, although it must be noted that making such adjustments is rather subjective and cannot be done uniquely.

For reference, we list our latest estimates (Table 1), which we calculated including a topocentric correction to the distance in the $r_{\mathrm{E}} - r_{\mathrm{D}}$ term. These have been published previously in a review article [6]. Some visibility maps can be found in [18].

4. Leonids 2000

The Earth will encounter the 8-revolution and 4-revolution trails at the times given in Table 1, with western Europe and western Africa being favored for the former, and North and part of South America for the latter. Outbursts will occur, our best estimate being that they will occur at well below storm level.

Table 1 – Trail encounters and outburst predictions.

Time (UT)	Trail	ZHR	Moon age	Visible from
2000, Nov 18, 03^h44^m	8-rev	100?	22	W. Africa, W. Europe, NE S. America
2000, Nov 18, 07^h51^m	4-rev	100?	22	N. America, C. America, NW S. America
2001, Nov 18, 10^h01^m	7-rev	2500?	3	N. and C. America
2001, Nov 18, 17^h31^m	9-rev	9000	3	Australia, E. Asia
2001, Nov 18, 18^h19^m	4-rev	15000	3	W. Australia, E., S.E., and C. Asia
2002, Nov 19, 04^h00^m	7-rev	15000	15	W. Africa, W. Europe, N. Canada, NE S. America
2002, Nov 19, 10^h36^m	4-rev	30000	15	N. America
2006, Nov 19, 04^h45^m	2-rev	100	28	W. Europe, W. Africa

Other authors who have made calculations relating to these trail encounters [1,4] estimate rather stronger activity (at the same times, which are very accurately known), which we regard as quite possible. The main reason for the uncertainty in the activity level is the lack of encounters, over the previous two centuries, having similar parameters: in particular, it simply happens to be the case that all the main data points have $r_E - r_D < 0$, opposite to the situation in both cases in 2000. The best constraint on 2000 may be 1801 (this is the unlabeled point just above 1966 in the 2-revolution plot of Figure 1). We are not aware of a meteor outburst or storm having been observed and recorded at that time, as discussed further in [3]. Clearly, activity up to some level could have been missed, or not recorded, but it is hard to say exactly what this level is.

The 4-revolution encounter in 2000 should prove that the 4-revolution trail, to be encountered again, further back along its length, in 2001 and 2002, does indeed exist, although, really, this is known in any case, since the comet was active enough (and so releasing meteoroids) to be discovered in 1865–66. Other authors [1,4] and ourselves agree as to the virtual certainty of higher (storm level) ZHRs in 2001 and 2002. The fact that the miss distances are significantly smaller in the 2001–2002 encounters may limit the influence 2000 will have on the predictions for the next two years. Perhaps of greatest interest this year, will be the relative strengths of the two trail encounters, although, with the 8-revolution trail, the interpretation may be made more uncertain because of the proximity of the encountered section of the trail to parts of the trail that have been disrupted.

The 8-revolution and 4-revolution encounters occur the night after the Earth's passage through the plane of the Comet's orbit. Of course, observers are strongly recommended to observe on more than one night, for other possible Leonid activity. For example, the night before the 4-revolution encounter, a shower of small meteors from the 2-revolution trail should be visible [4] from America, albeit the miss distance is less favorable than for the 4-revolution encounter. The extent to which distant encounters with trails have produced activity in the last two years is not completely clear, but is likely to be quite small, since the time of activity should be within a few minutes of prediction. The accuracy with which observed times match nominal calculated times of encounters with trails was shown [10] to be the first observational evidence that dust trails are substantially flattened sheets.

Present knowledge of background activity from the Leonids is less detailed than that relating to particular trail encounters. We have checked the evolution, under gravitational perturbations, of material ejected at every perihelion return of 55P/Tempel-Tuttle over the past 1400 years, by integrating particles separated by 0.01 AU from 0.2 AU below to 0.6 AU above the cometary value at the time of ejection. No obvious initial orbits that resulted in intersection with the Earth in 2000 were found, other than the solutions already known. It is conceivable that the resolution of 0.01 AU was insufficient, causing solutions to be missed (although a few particles were integrated at a finer resolution around what appeared to be the most promising cases). The chances are that the 8-revolution and 4-revolution encounters will produce the highest activity overall during the 2000 Leonids.

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Clear Skies for the Leonids?

Hartwig Lüthen and Petra Rendtel

Weather-based advise is given for observing the 2000 Leonids in Europe, North Africa, or North America.

1. Introduction

Will they storm—and when?

The year 2000 will be another year of alert for Leonid watchers. This time, the dust trail model [1] gives a reliable forecast for the times of maximal activity. We will pass the dust trails of 1733 and 1866 on November 18, at $3^{h}44^{m}$ and $7^{h}51^{m}$ UT, respectively. The miss distances (0.00077 AU in both cases) are slightly larger than in 1999 (0.00066 AU). Therefore, a lower rate is expected for the 2000 maxima than for the 1999 storm. Despite its spectacular success in forecasting the maximum times, the predictive power of the dust trail model for rates appears to be still rather limited. Thus, a good activity, perhaps even minor storm rates, are possible—reason enough to go out observing even though generally the 2000 display is estimated to be inferior to the 1999 and 2001/2002 storms. (*See also Asher and McNaught's follow-up article preceding this one.* Ed.)

Problem: The Last-Quarter Moon

Wherever one tries to observe, the Last-Quarter Moon will cause significant annoyance. The trouble is that the Moon will be located only about 10° from the radiant position. To avoid ruining the eyes' adaptation to the darkness, observers will be forced to look in the opposite direction, e.g., in the Taurus/Orion area. The impact of the Moon on one's observing will strongly depend on the transparency of the sky. Under clear mountain skies (e.g., on Tenerife) we often experienced limiting magnitudes around +6.0 to +6.5 and stunning sights of the Milky Way at First-Quarter Moon.

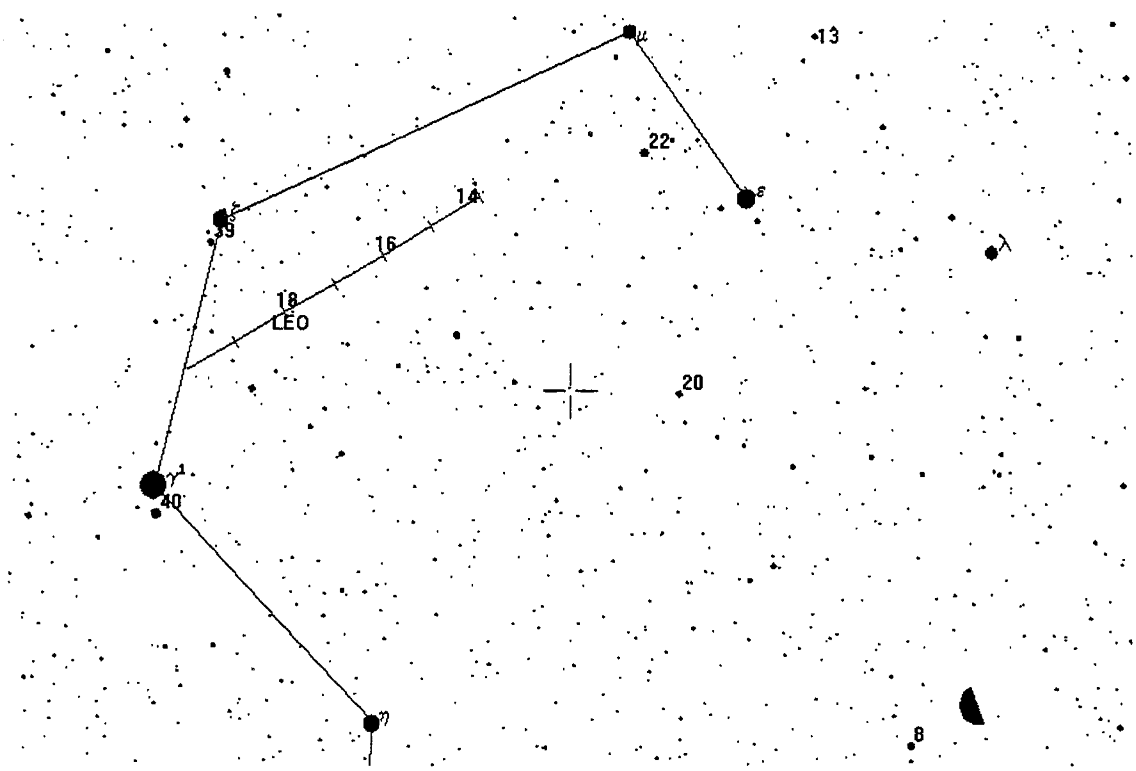

Figure 1 – Position of the Moon at the time of the computed European maximum. Leonid radiant (tracing in the upper right) according to the *IMO Visual Handbook* [2]; prepared with GUIDE 7.0. The stars of the sickle are also shown. Note that the distance between the Moon and the radiant is about 10°.

2. Where to watch?

Criterion 1: Altitude of the radiant and time of morning twilight

Thus, a good observing site for Leonid observations has to meet the following criterion: the radiant has to be high in a dark, dust-free sky in the relevant time interval. On the other hand, there should be at least 30–60 minutes until the morning twilight sets in, in order to witness the decline of the activity after the maximum. For the passage of the 1733 filament, the criterion favors Northwestern Africa and Western Europe, whereas North-American observers will witness the activity associated with the passage of the 1866 dust trail. The following tables give the conditions at various European cities and tourist resorts. Since the number of meteors seen by an observer depends on the sine of the altitude h of the radiant [2], this value is also given.

Generally in Western Europe, the radiant will be high in the sky at $3^{\rm h}44^{\rm m}$, thus observing will not be hampered by a low radiant altitude. The more one moves eastward, the higher the radiant will be in the sky, but the time between the maximum and the beginning of twilight will shrink. East of Romania and Poland, the maximum will occur in bright morning twilight, or even in daylight.

Table 1 – Observing conditions at November 18, 2000, 3^h44^m UT, the time of the predicted first maximum. Altitude of the Leonid radiant, $\sin h$, and times of the astronomical ($h_\odot = -18°$) and the nautical twilight ($h_\odot = -12°$) are given. The computations were done with Guide 7.0 (update of August 8, 2000, installed).

Observing site	Altitude of radiant at 3^h44^m UT	$\sin h$ at 3^h44^m UT	Astronomical morning twilight	Nautical morning twilight
Tenerife (Can. Isl.)	39°	0.62	6^h10^m	6^h38^m
Agadir (Morocco)	45°	0.71	5^h44^m	6^h12^m
Lisbon (Portugal)	45°	0.71	5^h50^m	6^h21^m
Malaga (Spain)	49°	0.75	5^h29^m	6^h00^m
Mallorca (Spain)	54°	0.81	5^h04^m	5^h36^m
Marseille (France)	54°	0.81	4^h56^m	5^h30^m
London (UK)	47°	0.73	5^h26^m	6^h06^m
Rome (Italy)	60°	0.87	4^h26^m	4^h59^m
Tozeur (Tunisia)	60°	0.87	4^h35^m	5^h05^m
Hamburg (Germany)	51°	0.78	4^h48^m	5^h29^m
Berlin (Germany)	53°	0.80	4^h33^m	5^h13^m
Warsaw (Poland)	56°	0.83	4^h02^m	4^h42^m
Split (Croatia)	61°	0.87	4^h12^m	4^h46^m
Pitesti (Romania)	64°	0.90	3^h40^m	4^h14^m

Criterion 2: Weather

Central Europe

Generally, Central-European weather in mid-November is rather terrible. Areas of low pressure cross the continent from west to east in rapid sequence. November is a stormy and foggy month. If high pressure eventually moves in, fog rapidly builds up, especially in the course of the night. In such a situation, one can try to be above the clouds on high mountains in the Alps. Otto Guthier and others experienced fine weather in the fireball night of November 16-17, 1998, on the Gornergrat in the Swiss Alps. However, the next night, they were clouded out. Sometimes, high winds dissipate the clouds at the southeastern side of the mountains. Between the frontal systems, one may find areas of scattered clouds suitable for observations. With satellite pictures available on the Internet, one can try to move into cloudless regions by car. However, as we learned from attempts for Draconid and Geminid observation, fog is invisible on IR satellite pictures. In 1998 and 1999, only one third of those who toured Germany (question of an observer: "Which highway is the right one?") in the maximum night in search for clear skies were successful.

Mediterranean

Generally, the statistics for the European continent improve if one moves southward. However, in mid-November, cloudy periods are frequent. Long-lasting low-pressure areas sometimes build up over the eastern and/or western Mediterranean Sea. Another source of clouds are the extended frontal systems of the low-pressure areas over central Europe, which may even sweep North Africa.

North Africa

The southern Mediterranean coast of Egypt and Tunisia are under the influence of the low pressure areas possibly building up over the Mediterranean or by the rapidly moving frontal systems of the central European lows. With every mile southward, the Sahara desert climate will influence more and more the cloud statistics. Areas of fine weather can be found in Southern Tunisia and Southern Morocco. Even here, frontal systems from Europe can move through, but they cross the area rapidly and do not reduce the chance for clear skies very much. However, in 1999, they spoiled views from Southern Tunisia.

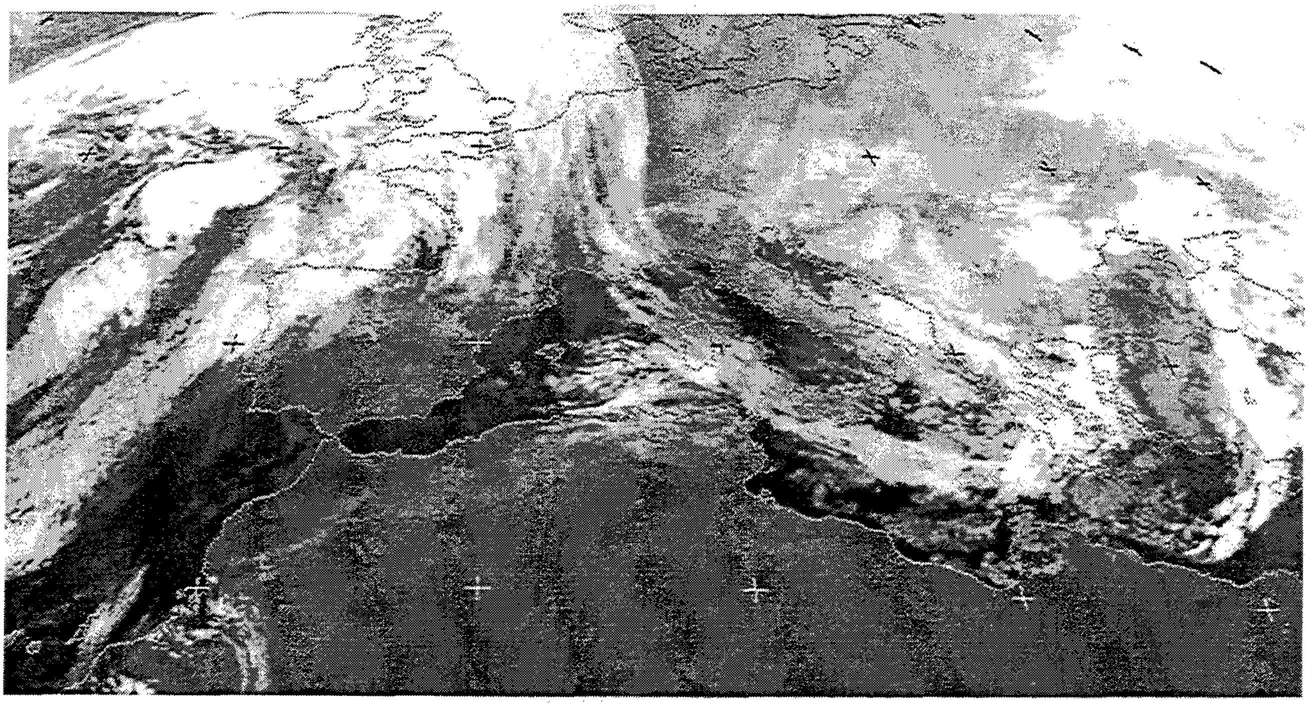

Figure 2 – Typical infrared METEOSAT image (November 17, 1997, 6^h00^m UT) covering this year's Leonid observation area. Western Europe and much of the Mediterranean is clouded out. Parts of Germany and Poland are apparently cloud-free, but fog-banks are revealed by close inspection of the photograph (fog is nearly invisible on IR satellite images). Tenerife (at the edge of the frame) and Southern Tunisia are free of clouds, while there are some scattered clouds in the region of Agadir. In 1999, clouds covered Tunisia, quite good weather prevailed in Spain, Southern France, and Northern Italy. Clouds moving from the north-east posed problems on the Canary Islands, but local weather was good in selected regions of the mountain on Tenerife.

Canary Islands (Tenerife, La Palma)

In November, the Canary Islands are often influenced by southwestern winds, whereas, in summer, northeastern Passat winds dominate. The local terrain strongly influences the weather. At the coastline facing the wind, clouds build up. Thus, November is a very rainy month in that region. However, in the central mountains, only a few kilometers away, one can be above the clouds and find clear weather. High mountains can be found on Tenerife in the caldera around the Teide volcano called Las Canadas (altitude 2000–2600 m). The 3700 m high Teide may also effectively shield off the clouds. A car ride of a few kilometers on Tenerife's Las Canadas can make a difference between rain and clear skies. This was the situation a large group of amateurs experienced in 1999. Another good site is the Roque de Los Muchachos (2400 m) on the island of La Palma, which is, however, more isolated and offers less chance for local clear weather when frontal systems pass. Even in the high mountain ranges, weather can change very rapidly, depending on the wind direction. If it is clear, the sky is often extremely transparent, which may be a relevant factor to avoid the influence of moonlight in 2000. Sand storms from North Africa, which often spoil conditions in the summer months, are rare in November.

Weather probabilities—detailed analysis of some possible sites

To get a better idea of the meteorological conditions in some of the potential travel targets, we downloaded a vast number of Meteosat (1996–1998) and NOAA (1995) satellite images from `http://www-grtr.u-strasbg.fr/quickMeteosatWorld` and `quickNoaa`. The pictures were typically of 0^h UT, 6^h UT (IR band), and 12^h UT (visual and/or IR). Based on the considerations above, we inspected weather at the following tourist locations: Tozeur (Tunisia), Agadir (Morocco) and Tenerife, and at Berlin (Germany) for a comparison to a typical Central-European site. We estimated the chance of seeing clear sky for each site in each available picture. Daily averages from the period of November 7 to 27 were computed and averaged to the annual value given in Table 2.

Table 2 – Probability percentages for clear skies estimated from satellite images (Meteosat, 1996–1998, NOAA, 1995) for the locations Tozeur, Agadir, Tenerife, and Berlin. The actual weather experienced by observers in the 1999 storm night is also given. Experiencing clear skies on the Canadas on Tenerife required a 5-km car ride, since the eastern parts of the mountain area were clouded out.

Year	Tozeur (Tunisia)	Agadir (Morocco)	Las Canadas (Tenerife)	Berlin (Germany)
1995	62%	–	–	26%
1996	56%	80%	82%	30%
1997	71%	82%	78%	28%
1998	69%	90%	91%	31%
1999	bad	fine	fine	bad

Possible strategies

Depending on where you live you may consider one of the following options:

1. stay and pray;
2. travel and pay;
3. drive to the hole in the clouds; or
4. fly "last minute" to the hole in the clouds.

Especially for residents of Central Europe, option (1) offers very low chances for actually seeing the display.

In 1999, the journey option (2) was quite attractive. A number of observers took a one-week vacation, traveled to sites like the Canary Islands, Morocco, Spain, and Jordan, spent a nice time there, and saw the Leonid meteor storm. With the Moon near the radiant and generally less promising ZHR forecasts, we guess that fewer observers will stick to that strategy this year.

Strategies (3) and (4) are especially attractive in 2000 with the Leonid maximum occurring on a weekend. Driving into an area of clear skies in Central Europe may be a gamble, although a number of observers took some long-distance car rides in 1999 (e.g., from Southwestern Germany to Northern Italy or Southern France). It may be a good idea to have a mobile Internet access to change routes rapidly, but observers are warned again that banks of fog—a very common sight in European November nights—are barely visible on IR satellite images.

In 1999, a number of observers of the *Arbeitskreis Meteore*, together with visiting US- and Canadian-based observers, tried option (4), and took a last minute flight from Germany to Southern Spain. After arriving in Malaga, they rented a car to escape the light-polluted city. After successfully observing the storm, they returned home two days later.

For such an approach, one needs weather forecasts three or four days in advance. A good site to look at is the German-language `http://www.wetterzentrale.de/topkarten`. Select the AVN and the MRF models and look for "Mittl. Wolken". A map of Europe and a forecast of the cloud cover, 72 hours or even 240 hours in advance, will appear. The English-language site `http://www.weather.nl` mirrors the "Topkarten" maps for the AVN model and includes predictions by various other climate models, some of which also give maps of the predicted cloud cover. As an example, Figure 3 shows a 55-hour forecast map generated by the SKIRON model of the University of Athens containing additional information on the altitude of the clouds in a gray-scale code. These predictions may at least help to decide on the destination a few days days before the event.

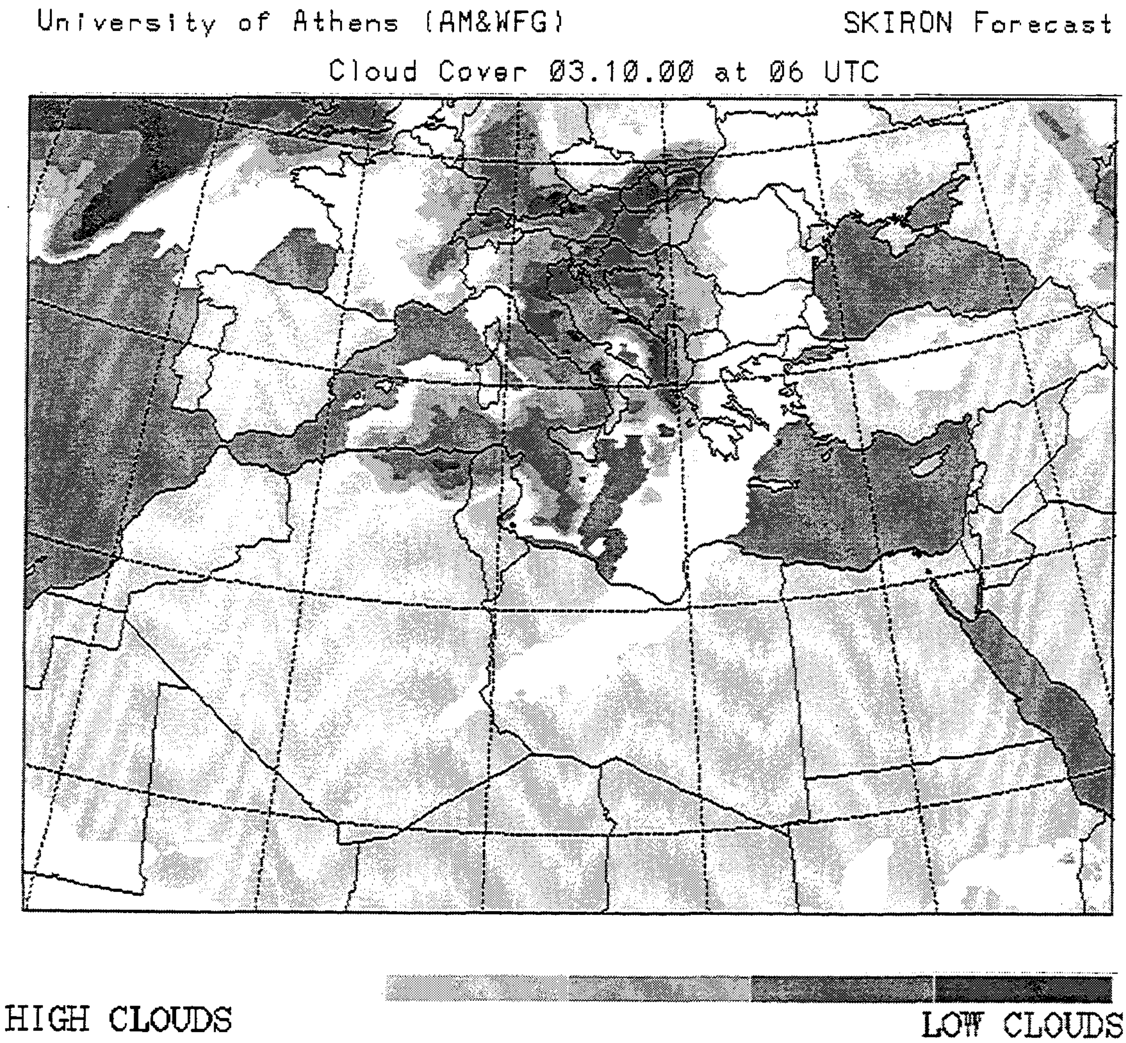

Figure 3 – Typical example of a forecast map downloaded from `http://www.weather.nl`. It is based on the SKIRON model from the University of Athens and contains information on cloud cover for up to 72 hours in advance. Such medium-range maps can help in finding a good site and deciding to which destination a last-minute plane ticket should be bought.

Table 3 – Observing conditions on November 18, 2000, 7^h51^m UT, the time of the predicted second maximum. The altitude of the Leonid radiant h at 7^h51^m UT, and the corresponding value of $\sin h$, are given. The computations were done with GUIDE 7.0 (update of August 8, 2000, installed).

City	h	$\sin h$	City	h	$\sin h$
Boston (Mass.)	45°	0.71	Houston (Texas)	25°	0.42
New York (NY)	43°	0.68	Corpus Christi (TX)	23°	0.39
Montréal (Québec)	42°	0.67	Albuquerque (NM)	17°	0.29
Cleveland (Ohio)	37°	0.60	Tucson (Arizona)	13°	0.22
Chicago (Illinois)	32°	0.52	Los Angeles (Cal.)	7°	0.12
Tampa (Florida)	35°	0.57	Salt Lake City (Utah)	8°	0.14
Kansas City (KS/MO)	27°	0.45			

American dreams

At 7^h51^m UT, the Earth will pass the 1866 dust trail [1]. The associated meteor activity is of great interest, since the potentially storm-producing events in 2001 and 2002 are related to the same trail. Thus, this year's observations will contribute to the knowledge of the particle distribution across the trail and therefore may refine the predictions for the next two years. The radiant will be sufficiently high in the sky for observers along the east coast of the USA (45°–35°, see Table 3). Moving to the west will decrease the altitude of the radiant.

A quick survey of weather images from the years 1996–1999 (downloaded from the archive `http://weather.unisys.com/archive/sat_ir`) reveals that, normally, there is a high-pressure area over Northern Mexico, sometimes extending northward to the southern states of the USA. Unfortunately, in these areas of best weather statistics, the radiant will be very low in the sky (23° in southern Texas, lower in New Mexico and hopelessly low in Arizona). Further to the north, frontal systems pass in rapid sequence, interrupted by areas of shower weather or even by areas free of clouds. In the northern continental USA and in the Great Lakes area, a "stay and pray" strategy may be more promising than in Central Europe. Clouds moving from southwest to northeast often prevail along the Atlantic coastline. A last-minute trip as suggested above may be a worthwhile consideration for inhabitants of the major cities along the Atlantic coast.

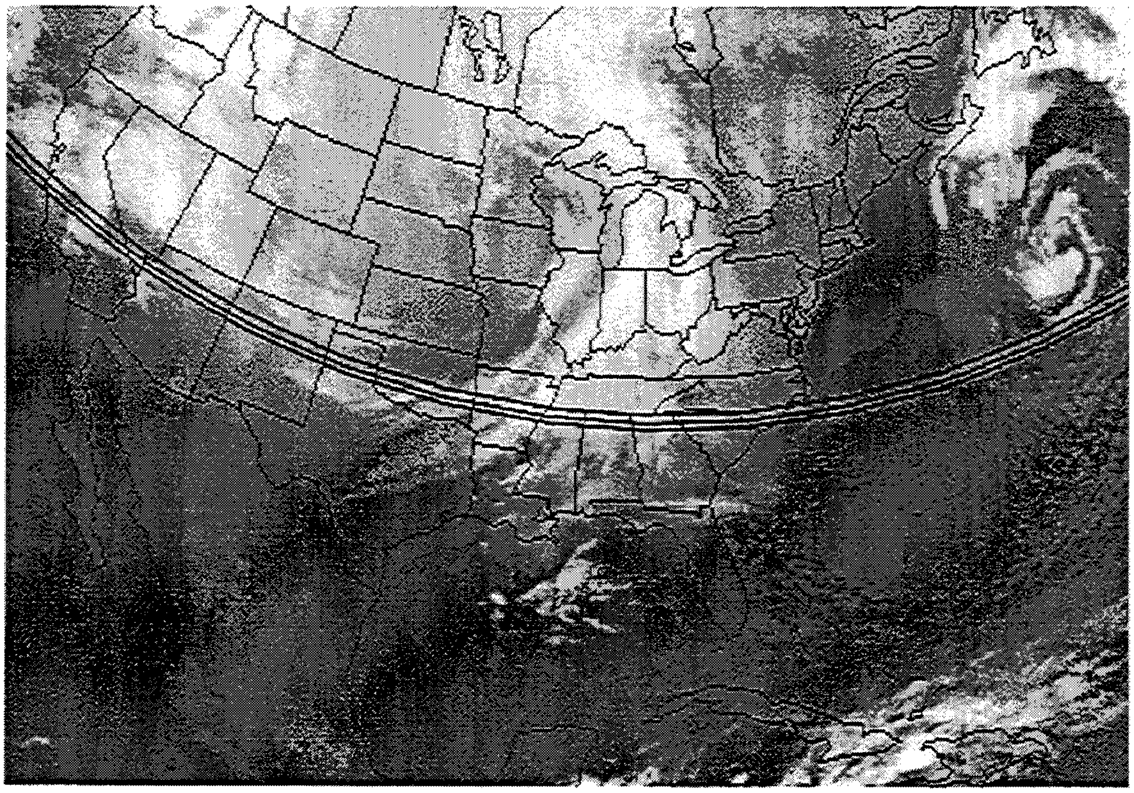

Figure 4 – Typical GOES image from the time of the Leonid maximum (November 17, 1996, 0^h00^m UT).

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Video Observations of the 1999 Leonid Meteor Storm Recorded at Different Locations

Jürgen Rendtel, Sirko Molau, Detlef Koschny, Stephen Evans, Osamu Okamura, and Mirko Nitschke

Recordings of the 1999 Leonid meteor storm obtained with intensified video meteor cameras at different locations distributed over about 6000 km were analyzed. We find a major activity peak at $2^h02^m \pm 2^m$ UT ($\lambda_\odot = 235.^\circ285 \pm 0.^\circ001$, J2000) and a significant sub-peak (at eastern locations) or an activity plateau (Iberian data) between 1^h39^m and 1^h53^m UT, possibly associated with the 1932 Leonid dust trail (all times topocentrically corrected). The descending branch of the asymmetric activity profile (full width at half maximum 49 ± 3 minutes) is 1.6 times steeper than the ascending branch. Quasi-periodic activity variations have been detected in all regional data sets, mainly at 15 minutes and 7–10 minutes. Magnitude data of several cameras indicate a lower mass cut-off of the Leonids near magnitude +3, or about 10^{-3} g meteoroid mass. The Leonid radiant is very sharp at $\alpha = 153.^\circ6 \pm 0.^\circ1$, $\delta = +21.^\circ9 \pm 0.^\circ1$ ($\lambda_\odot = 235.^\circ290$, J2000) with no detectable shift or size variation at the peak and the pre-maximum periods (about 25 and 15 minutes before the activity peak).

1. Introduction and description of the data

Different model calculations of the Leonid meteoroid stream indicated a sharp and dense peak on November 18, 1999, at 2^h08^m UT (cf. [1] and references therein). Observations applying different techniques were prepared on a world-wide scale. In this paper, we analyze recordings obtained by intensified video meteor cameras at different locations. Of these cameras, eight were ground-based and one was operated from a commercial aircraft. Camera positions are shown in Figure 1 and listed in Table 1. The cameras differed in their construction. Hence, the sensitivities and field sizes of the individual cameras were different as well. All relevant data of the video cameras are summarized in Table 2.

All cameras were unguided. In the case of the ground-based cameras, the atmospheric volume remained constant during the entire observation. The peak activity analysis concerns the 2-hour interval between 01^h00^m and 03^h00^m UT. Within this interval, the corrections for altitude and extinction etc. did not change significantly at the observing sites. This is also valid for the airborne observation, although the field center drifted depending on the aircraft's direction. The elevation of the center of the field of view was almost constant (about 30° above the horizon). For some short intervals the field center was moved towards the horizon. In these intervals, the rates increased significantly. These intervals were excluded from the analysis.

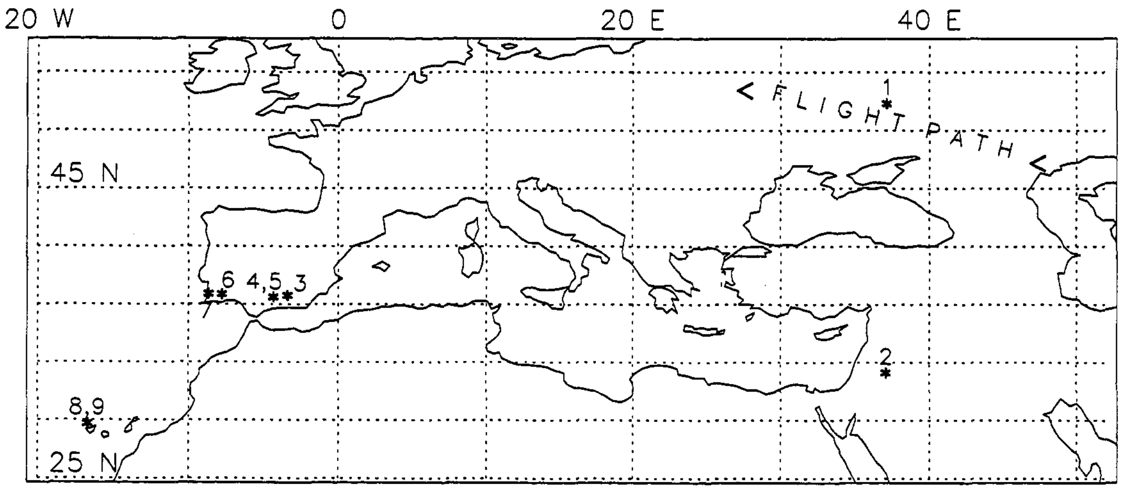

Figure 1 – Locations of the meteor video cameras included in this analysis, represented by stars. The numbers refer to the camera list in Table 1. Camera 1 was on an aircraft over Eastern Europe. The star refers to the position at 2^h08^m UT; the "<" signs mark the begin and end of the flight path from 01^h00^m to 03^h00^m UT.

Table 1 – Locations and characteristics of the intensified video meteor cameras operated during the 1999 Leonid meteor storm and included in this analysis (from east to west). The position of Okamura's camera (1) refers to 2^h08^m UT; in the 2-hour interval 1^h00^m–3^h00^m UT, the position changed from 47°5 E and 46°2 N to 27°7 E and 51°2 N. Of this data set, we only included the series obtained in the period 1^h00^m–3^h00^m UT in our analysis.

Nr	Camera	Observer	Region	Longitude	Latitude	Period (UT)
1	MIKI	Okamura	E. Europe	37°11′ E	50°18′ N	01^h00^m–03^h00^m
2	CAPCAM	Dittie	Jordan	37°07′ E	31°45′ N	23^h05^m–03^h11^m
3	ICC2	Koschny	Spain	03°23′ W	37°04′ N	23^h37^m–02^h56^m
4	AVIS	Molau	Spain	04°20′ W	36°57′ N	00^h02^m–04^h05^m
5	CARMEN	Rendtel	Spain	04°20′ W	36°57′ N	00^h04^m–04^h05^m
6	EMILY	Evans	Portugal	07°43′ W	37°09′ N	23^h09^m–06^h14^m
7	ELLI	Elliott	Portugal	08°36′ W	37°11′ N	23^h15^m–06^h15^m
8	VK1	Nitschke	Tenerife	16°40′ W	28°12′ N	01^h24^m–02^h29^m
9	IAC1	Bellot	Tenerife	16°40′ W	28°12′ N	02^h05^m–06^h36^m

Table 2 – Analysis details for the video meteor data: "$T_{\rm eff}$" is the effective observing time of which meteors were included in the magnitude and radiant analysis, respectively; "fov" is the diameter of the field of view; "lm(∗)" and "lm(↓)" are the limiting magnitudes for stars and meteors, respectively. The next three columns give the numbers of recorded meteors, Leonids, and non-Leonids. The "Data" column indicates which parameters are available: n—numbers, p—positions, m—magnitudes. "Analysis" shows the used method of tape inspection (see text).

Nr	$T_{\rm eff}$	fov	lm(∗)	lm(↓)	Met	LEO	Other	Data	Analysis
1	1h92	53°	6.0	5.0	–	4984	–	n	v
2	4h00	30°	6.0	5.0	927	786	141	n p m	a+v
3	3h31	10°	8.5	6.5	135	110	25	n	a
4	4h05	15°	9.0	7.0	395	212	183	n p m	a+v
5	4h01	28°	5.5	4.5	485	459	26	n p m	a+v
6	7h03	40°	5.5	4.5	570	543	27	n p m	a+v
7	6h99	50°	5.5	4.5	785	678	107	n p m	a+v
8	1h08	20°	8.0	6.0	92	72	20	n p m	a
9	4h21	20°	7.5	6.0	191	104	87	n	v

The analysis of positional data for radiant investigation is based on the cameras 2 and 4–8. Using a constant field center means that the Leonid meteors crossed the field of view in changing directions during the observation. The combination of positional data from all cameras yielded a suitable distribution of the trails for a radiant determination. The cameras 4 and 5 operated from the same location, had identical field centers, but a different limiting magnitude. For the rate calculations, identical meteors were counted only once.

During the observation all data were recorded on VHS video tapes. For the analysis the tapes were treated in two ways (see last column of Table 2):

(a) Automatic recognition and measurement of meteor data using the software MetRec [2].

(v) Visual inspection of the period 1^h00^m–3^h00^m UT, revision of meteor magnitudes, selection of meteor trails completely inside the field of view (fov).

The airborne recordings were visually inspected by three different observers. Here we use the average number of meteors per minute of the three counts.

Our experience with analyses of video recordings makes us confident that, with the combination of automatic and visual inspection, more than 90% of the recorded meteors were detected and included in this analysis.

All times were corrected for the topocentric time of the Leonid stream encounter as described by McNaught and Asher [3]. The counts in 1-minute intervals, centered to the full minute, were multiplied with the sine of the radiant altitude $\sin^{\gamma} h_{\mathrm{R}}$ (with $\gamma = 1.0$) to account for varying radiant elevation. Then, the number of Leonids was binned in 1-minute, 2-minute and 3-minute intervals, shifted by half of the bin length. There was no further smoothing for the analysis.

2. Activity of the Leonids

In order to allow the reader to follow our analyzing procedure, we first show the raw data for the two cameras operated from Portugal (cameras 6 and 7; Figures 2–4). The atmospheric volumes observed by the two cameras did not overlap. Instead, they were of almost opposite direction and thus independent data series. It is obvious that longer bins reduce the scatter and reveal structures. The cross-correlation coefficients c_c of these two data series are $c_c(1\mathrm{min}) = 0.70$, $c_c(2\mathrm{min}) = 0.85$, and $c_c(3\mathrm{min}) = 0.90$, respectively. For the further analysis we used the 2-minute bins.

The situation further improves if we combine data of all cameras operated from a region which is small as compared to the expected structures in the Leonid meteoroid stream. In Figures 5–7, we show the combination of data from five cameras (cameras 3–7 in Table 1) operated from the Iberian peninsula within about 500 km maximum distance, observing different (non-overlapping) atmospheric volumes and thus giving independent data series (the exception of the data obtained with cameras 4 and 5 has been mentioned before; the data are effectively handled like those of one camera). The error bars shown in these figures hint on obvious structures as the modulation depth is larger than the error bars and the temporal resolution remains good. This comparison supports the use of 2-minute bins for our further analysis. This leads to four data series representing different regions: Eastern Europe (camera 1), Jordan (camera 2), Iberian peninsula (cameras 3–7) and Tenerife (cameras 8 and 9).

The general activity profiles of the Eastern European (airborne) camera, the Jordanian data, and the more western Iberian and Tenerife data show some significant differences (Figure 8). All rate profiles are asymmetric with a steep descending branch. This cannot be due to our correction $\sin^{\gamma} h_{\mathrm{R}}$ with $\gamma = 1.0$. It is often argued that a $\gamma > 1.0$ has to be applied, but in our case this would further increase the rates of the ascending branch and thus increase the asymmetry.

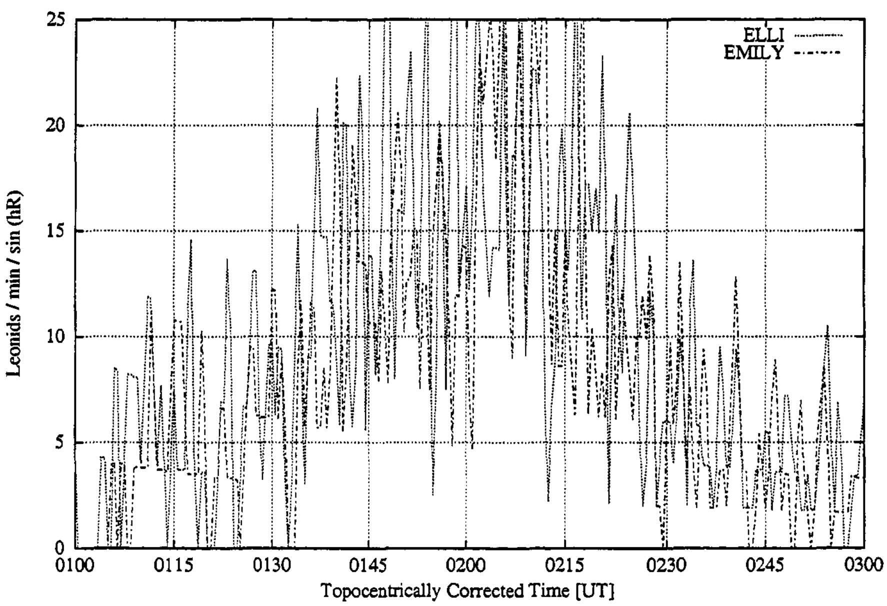

Figure 2 – Individual Leonid counts of the cameras 6 and 7 from Southern Portugal binned in 1-minute intervals. Here, the scatter is very large and not suitable for further analysis.

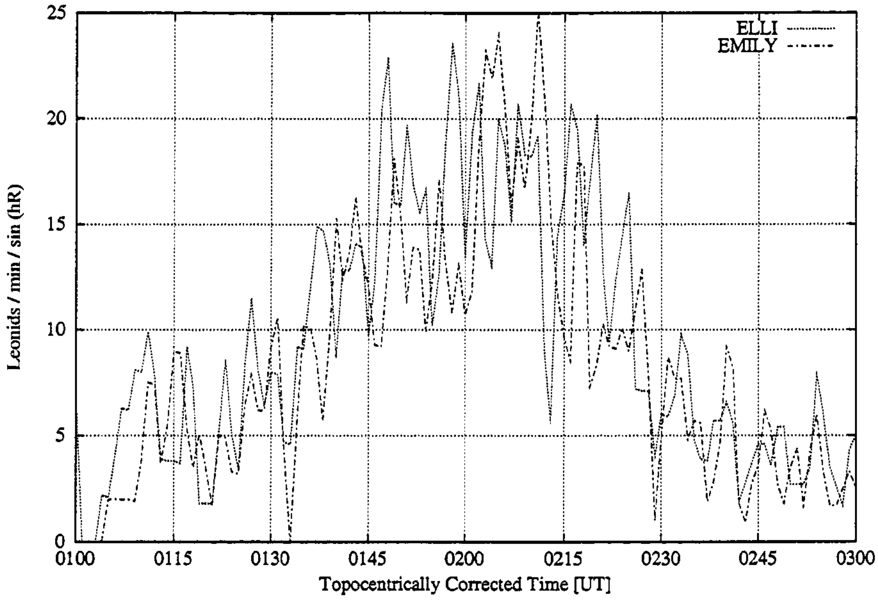

Figure 3 – Cameras 6 and 7 Leonid counts binned in 2-minute intervals. The scatter is still obvious, but the rates follow the same pattern and a combination of both profiles is useful. With 2-minute bins shifted by 1 minute, we can achieve a good temporal resolution and obtain a reliable rate.

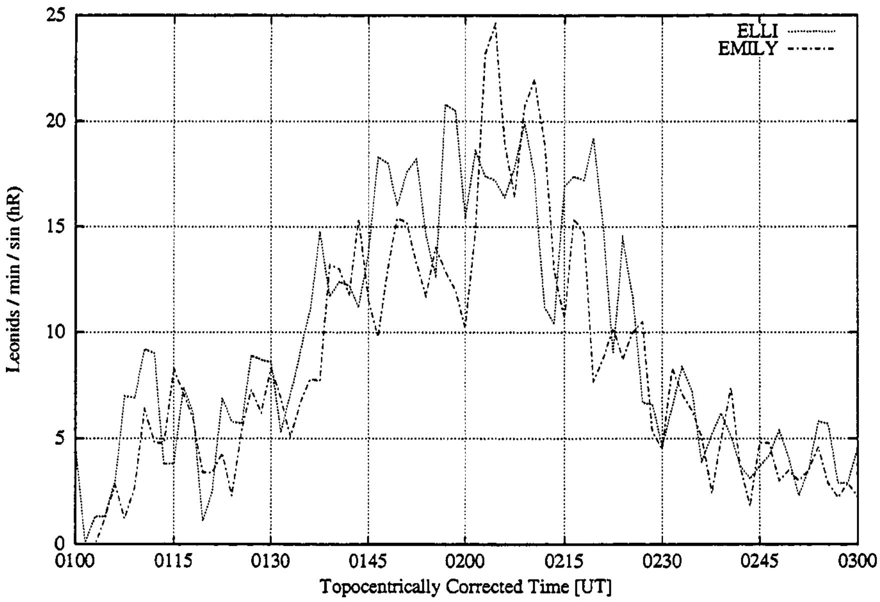

Figure 4 – Camera 6 and 7 Leonid counts binned in 3-minute intervals shifted by 1.5 minutes. The temporal resolution is also good and the curve looks much smoother than those shown in the previous figures.

Interestingly, we find a prominent secondary maximum in the East-European data at $1^h47^m \pm 2^m$, coinciding with a plateau of enhanced activity found in the Jordanian data in the period 1^h39^m–1^h53^m UT. This can tentatively be associated with the passage of the 1932 dust trail (cf. [1]) and also occurs in the visual Leonid data [4]. Furthermore, it seems that the intensity of this secondary peak is largest in the most northeastern data set, while this feature becomes very weak in the Iberian and Tenerife data. This also indicates the existence of small-scale structures within the meteoroid stream as derived from combined data obtained at locations also separated by several thousand kilometers [5].

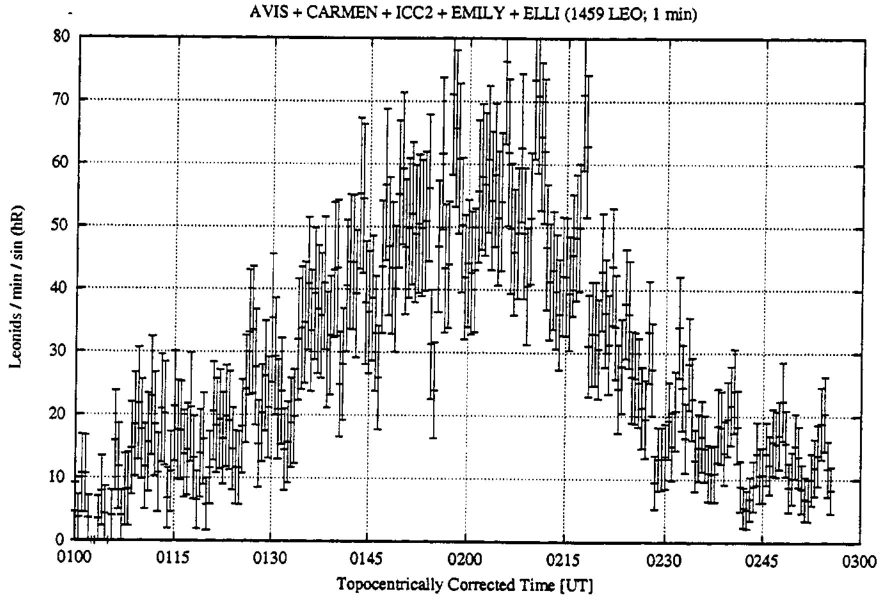

Figure 5 – Combination of the Leonid counts from all five cameras (lines 3–7 in Tables 1 and 2) based on the Iberian peninsula, binned in 1-minute intervals. Here we also show the error bars.

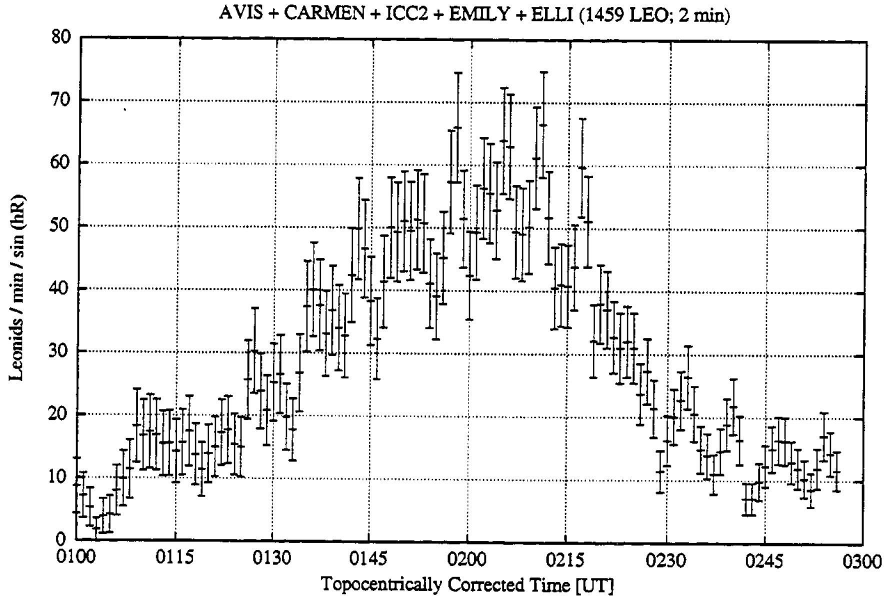

Figure 6 – Combination of Leonid counts from the "Iberian" cameras, binned in 2-minute intervals. The variations found in the rate curve are larger than the statistical scatter and should thus represent significant structures.

The general profiles allow to check the peak times found from the individual (regional) data sets. When speaking of "the peak," we consider the maximum of a smoothed activity profile, but not the interval of the highest count rate which may be caused by a short fluctuation off the center of the particle trail. For this purpose, we use a by-product of a method applied later to find short-term variations. The wavelet analysis [6] subtracts the highest frequency first (period equal to 2 time steps), and then frequencies obtained by a division by 2. At the third step of the procedure, we have removed all frequencies corresponding to 2, 4 and 8 time steps (i.e., all periods up to 16 minutes). The remaining profiles are then quite smooth (see, e.g., Figure 9) and allow to derive the Leonid peak times (Table 3).

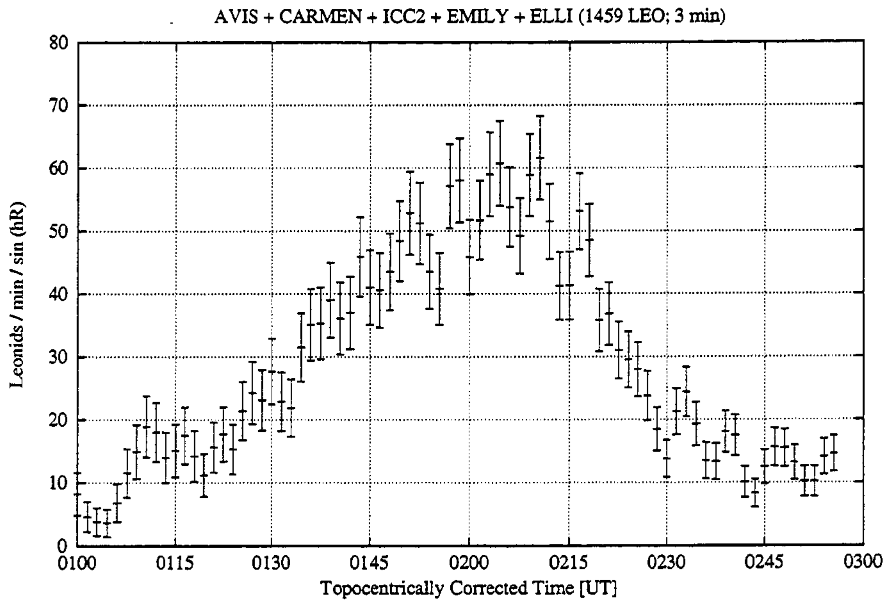

Figure 7 – "Iberian" Leonid counts, binned in 3-minute intervals. Due to smaller error bars, the structures become more obvious, but short term variations may be smeared out.

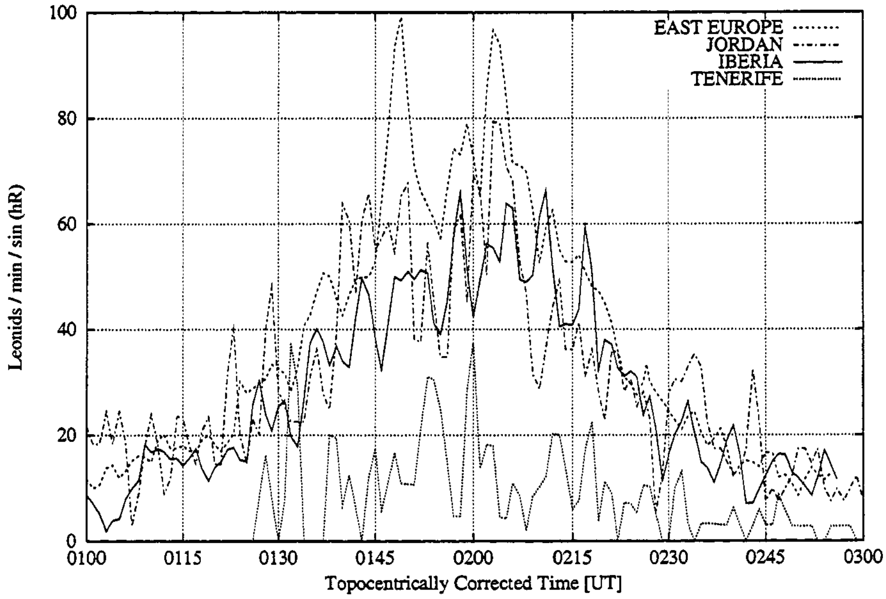

Figure 8 – Comparison of Leonid counts from all four regions (Eastern Europe, Jordan, Iberia, Tenerife) binned in 2-minute intervals. Note that the "Iberia" and "Tenerife" curves represent the combination of camera data, while the data of the "Jordan" and "Eastern Europe" series are from one camera each. The counts of the first three series are normalized for comparison.

Additionally, we applied a Gaussian fit to the four profiles shown in Figure 8 to derive the peak times. The results are also given in Table 3. Earlier peak times found this way may be a result of the asymmetric activity curves with the steep descending branch. Obviously, the profiles are not well approximated by Gaussian profiles, and, thus, the times derived from the procedure described above are more reliable. The smoothed profiles obtained from the first method yields a full width at half maximum (FWHM) of 49 ± 3 minutes (average of the three values listed in Table 3).

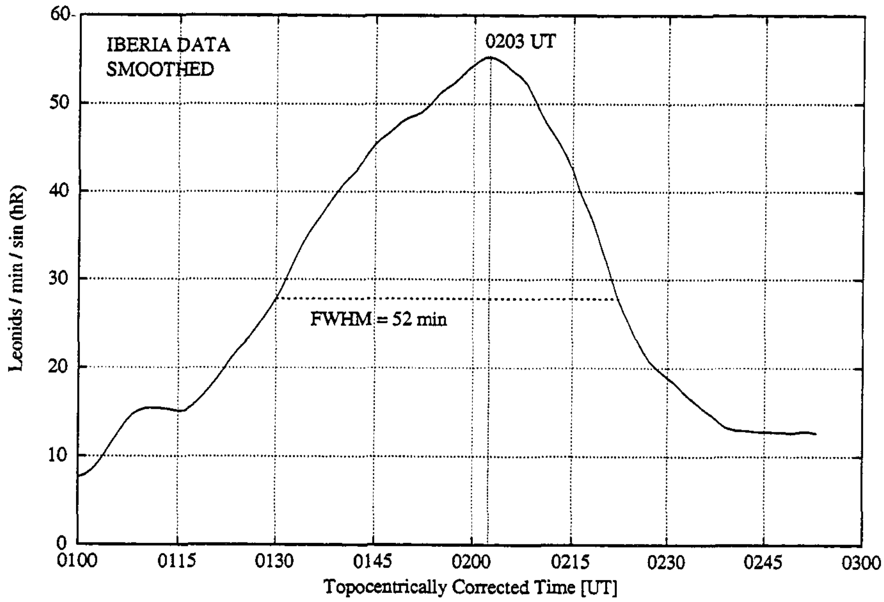

Figure 9 – Graph obtained from the Iberia profile shown in Figure 6 found after the extraction of the high-frequency portions from the raw data.

Table 3 – Topocentrically corrected times of the Leonid peak as derived from the data sets, first, with the wavelet analysis and, second, with a Gaussian fit. The larger error of the Tenerife data is due to the small sample. The tendency to earlier peak times (Jordan, Iberian peninsula) derived from the Gaussian fit is caused by the asymmetric shape of the activity profiles. The last three columns give the full width at half maximum (FWHM) and the duration of the ascending and descending branches from/to 0.5 of the peak rate to the maximum as derived from the smoothed profiles.

Region	Peak time (UT) (wavelets)	Peak time (UT) (Gauss)	FWHM	Ascending	Descending
E. Europe	$2^h03^m \pm 2^m$	$2^h01^m \pm 8^m$	49 min	29 min	20 min
Jordan	$2^h00^m \pm 2^m$	$1^h56^m \pm 6^m$	47 min	28 min	19 min
Iberian pen.	$2^h03^m \pm 2^m$	$1^h58^m \pm 6^m$	52 min	33 min	19 min
Tenerife	$2^h00^m \pm 5^m$	$1^h57^m \pm 8^m$	–	–	–

This is identical with the FWHM of the visual ZHR profile (Figure 3 of paper [4]). The duration of the ascending and descending branches as determined from the smoothed video count profiles are also almost identical for the different data series. The ascent from 0.5 of the peak rate to the maximum is 30 minutes, the descent lasts 19 minutes, i.e., the descending branch is 1.6 times steeper.

If we look carefully at the graphs (Figure 8 and, more detailed for the Iberian data, Figure 6), we will find rate fluctuations which seem to occur periodically, especially around the rate maximum. Such fluctuations clearly occur in the Iberian data (cameras 3–7; Figure 6). Similar fluctuations with virtually identical peak periods were also found from radar data obtained at sites further north in Germany and Sweden [5].

Of course, the analysis of such periodic variations occurring in a part of a time series is somewhat difficult. We applied a wavelet analysis which makes use of parts of the time series only (thus limiting the temporal resolution) and checks for frequencies which may occur (similar to a Fourier analysis).

The longer the temporal window (poor temporal resolution), the better the existing frequencies can be distinguished. The temporal and frequency resolution have to be optimized to find out which frequencies exist within a part of the time series. Then we obtain the graphs shown in Figures 12–14.

The right panel in each of these figures gives the integral of the power over the frequency range (ordinate). The most prominent frequency is marked with a dash-dot line. The lower panel shows the variation of the power of the selected frequency with time. A higher value of power means that the given frequency is more prominent. The general shape of the activity profile can be subtracted before searching for shorter periods. In this case, we only extract a long-period variation.

For comparison and tests we generated a number of test profiles.

We show two such profiles in Figure 10. In all cases, the artificial profile consists of a maximum within the window of 2 hours to which we add a random noise of 1/24 of the maximum's amplitude. One portion of the test series has additionally an 8-minute-period sine of the same amplitude added.

The results obtained by our procedure are shown in Figure 11. We clearly recover the 8-minute period (2.1 mHz) in the test data (upper graph in Figure 10). The other series with noise only (lower graph in Figure 10) does not show a prominent period. Of course the pattern resulting from the random noise differs among several tests, but clear prominent periods over significant portions of the series do not occur. For short periods of the "noise data," we may find power indicating a periodicity, but such features only last shortly.

The 8-minute period (2.1 mHz) can be found during the entire time of the test series, with a decrease when the analyzing window approaches the begin and end of the time series. The applied method recovers the periodic variations although they are not easily visible in the test time series (Figure 10). The result is also virtually identical for the "raw data" and the general shape of the profile subtracted as described above.

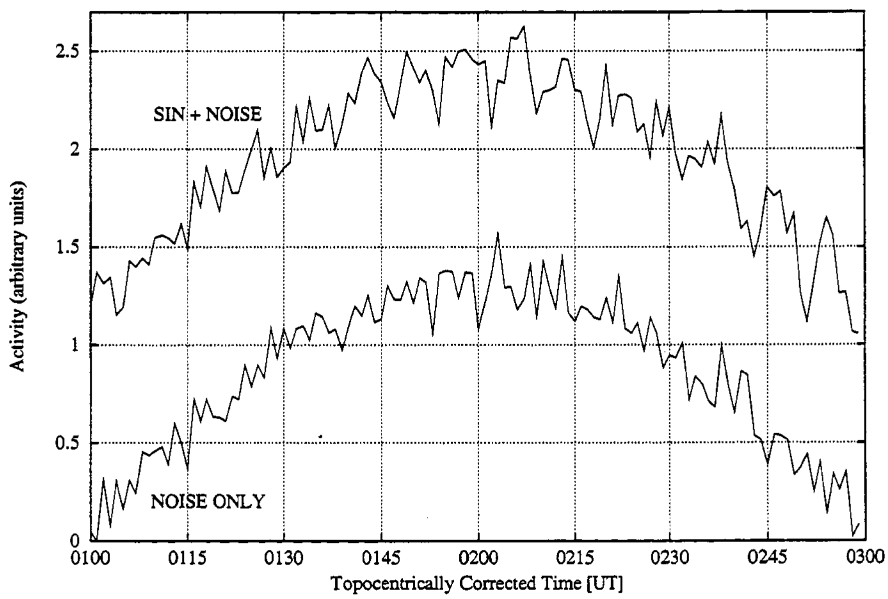

Figure 10 –Artificial activity profiles used for test of the frequency search. The profile consists of a peak in the middle of the 2-hour interval and a random noise of 1/24 of the peak value. The upper profile has an 8-min-sine with the same amplitude as the noise added.

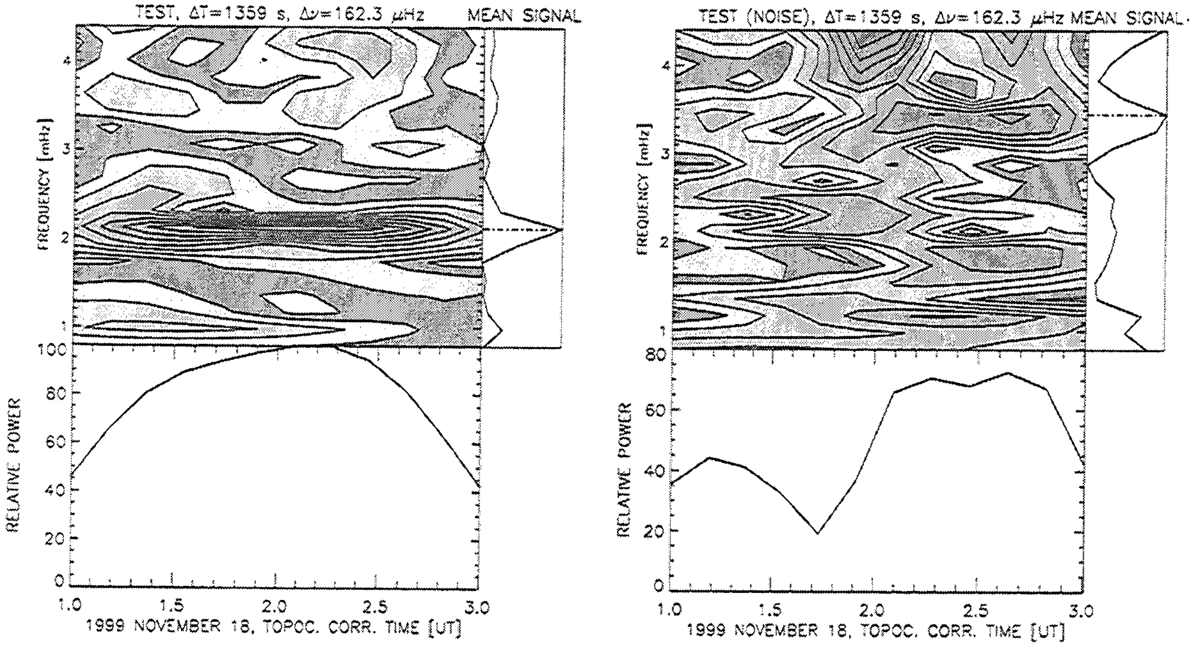

Figure 11 –Wavelet analysis of two test series. The contents of the figures is described in detail in the text. Figure 11, *left*, refers to the upper data in Figure 10. We clearly find the included 8-minute period (2.1 mHz). Figure 11, *right*, analyzing the lower data series of Figure 10, does not reveal any prominent period which exists over a significant portion of the series.

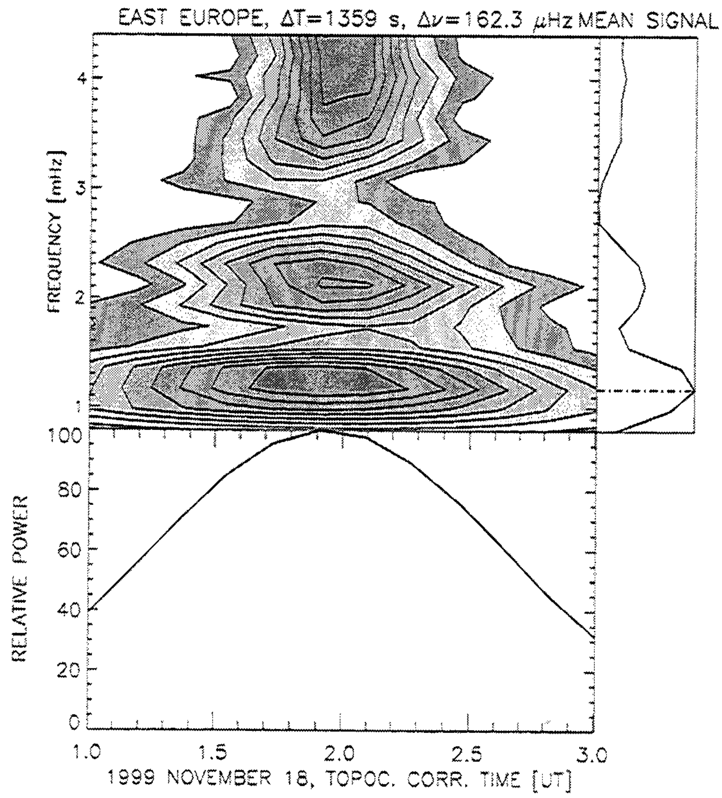

Figure 12 –Result of a wavelet analysis of the East-European data series (airborne camera 1). Most prominent frequencies are 1.2 mHz (14-minute period) and 2.1 mHz (8-minute period).

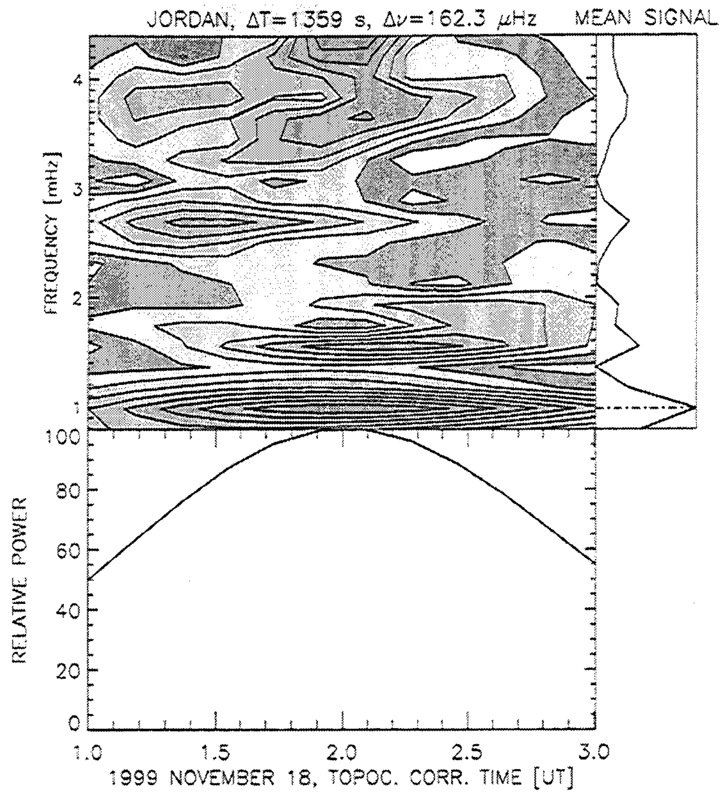

Figure 13 –Result of a wavelet analysis of the Jordanian data series (ground-based camera 2). Significant power occurs at 1.0 mHz (17-minute period), 1.6 mHz (10-minute period), and 2.7 mHz (6-minute period).

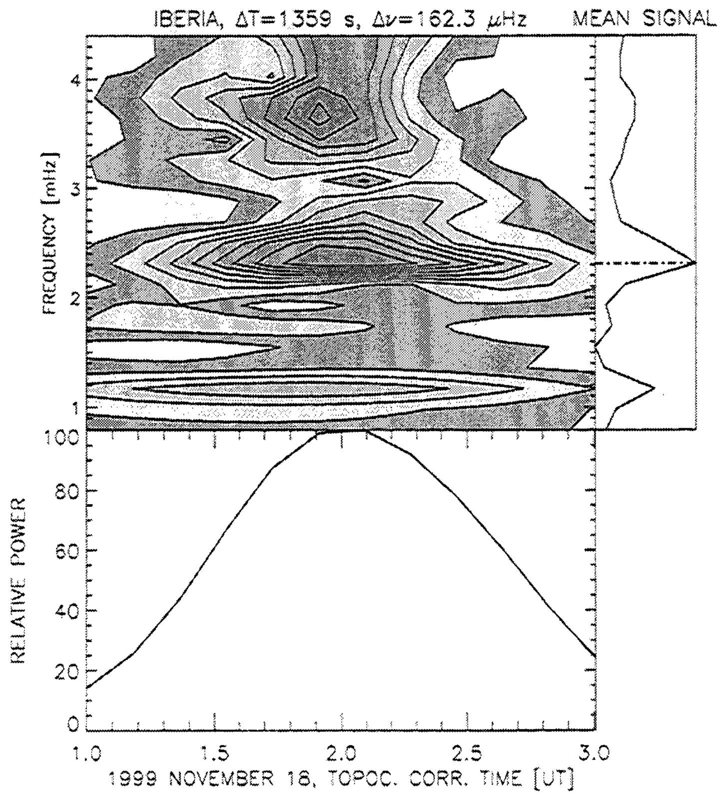

Figure 14 –Result of a wavelet analysis of the Iberian data series (ground-based cameras 3–7). Most prominent frequencies are at 2.3 mHz (7-minute period) and at 1.2 mHz (14-minute period).

Here, we have a close look at the results obtained from the Leonid data series from three geographical regions. Unfortunately, the Tenerife data do not allow to check whether these periodic rate variations also occur at this further western location. The statistics is comparatively poor because the radiant was much lower in the sky at the peak time and both cameras had a rather small field of view. Furthermore, the observations did not cover the entire interval of interest (cf. Table 1).

To start with the highest frequencies occurring at the upper edge of Figures 12–14, we find some indication of periodic variations around 4 mHz, or near a 4-minute period in all three series. This may be an artifact as it equals twice the bin length, although it does not occur in the test data which have the same binning. If we look at the error bars, e.g., in Figure 6 for the "Iberian" data, we find that the modulation depth of these short-term variations is quite small contrary to the long-term variations. Therefore, we will not pursue the 4 mHz pattern any further.

At the eastern longitudes (cameras 1 and 2), the largest variation occurs near 1 to 1.2 mHz (close to a 15-minute period). This period is most prominent centered at the activity peak, although the general shape of the profile was subtracted. Further periodic variations appear at 2.2 mHz (8-minute period) in the series of camera 1 (Figure 12) and at 1.6 mHz and 2.7 mHz (10- and 6-minute periods, respectively) in the camera 2 data (Figure 13). The long period can also be found in the Iberian data (Figure 14), but there is a quite intense fluctuation at 2.3 mHz (7-minute period), similar to quasi-periodic fluctuations detected in the two radar series (periods of 6.9 and 8.3 minutes [5]). A summary of periods detected in our data is given in Table 4.

Table 4 – Periods found in the three data series by applying a wavelet analysis, sorted by the period length. The most prominent period is printed in italics.

Region	Detected periods
Eastern Europe	*14 min*, 8 min
Jordan	*17 min*, 10 min, 6 min
Iberia	14 min, *7 min*

The quasi-periodic variations are most pronounced close to the peak period. This may indicate that we see a characteristic of the stream's center itself or the sign of a structure in the immediate vicinity of the 1899 dust trail. Investigations have shown that structures of a scale of a few hundred kilometers may survive in the Leonid meteoroid stream from 1899 to 1999 [5] and may be the reason for the observed quasi-periodic variations. If structures of smaller extension than the distance between the observing locations exist in the stream, the individual periodic patterns may be different. Even if the structures are crossed by several observing sites, they do not necessarily have to be in phase. The applied geocentric correction assumes a certain geometric situation, and the detected smaller features can be aligned in a different direction as compared to the main (1899) dust trail. Given the geocentric velocity of Leonid meteoroids of 71 km/s, periodic fluctuations of about 7–10 minutes would hint at structures within the stream at a scale of about 35 000 km along the Earth's passage, or 10 000 km vertical to the stream's plane.

3. Magnitude data

Our analysis is based on the maximum meteor brightness of trails completely inside the field of view. The maximum brightness is closely related to the meteoroid mass. Other than in the case of visual observation, it is not clear whether the recorded portion of the meteor trail includes the location of the maximum brightness. Hence, we have to decide which trails will be included in the analysis. Of course, each selection criterion will have specific consequences.

The most accurate selection is to choose only meteor trails with their *maximum brightness inside the field of view*. However, this is impractical, as we do not have in every case the complete magnitude curve available.

Alternatively, we can estimate the maximum brightness for all trails which *start and end inside the field of view.* This selection causes a loss of bright meteors for cameras with a small field of view and/or a field center which is far from the radiant, because bright meteors tend to have longer trails.

However, if we include *trails only partly inside the field of view*, we might miss the point of the maximum brightness, and the entire magnitude information becomes uncertain. Considering all meteors would include the longer trails, but with uncertain magnitude information.

In view of the above considerations, we decided to analyze the brightness of meteor trails completely inside the field of view only. Magnitudes were determined from six of the data series by visual inspection, because of limitations of the software for this purpose. Corrections (Table 5) were applied for the average angular velocity of Leonid meteors (depending on their angular distance from the radiant and the pixel resolution with camera 2 used as reference), as well as the spatial distance from the observer and the atmospheric extinction.

Table 5 – Corrections applied to the magnitude data of video meteors recorded by the different cameras, identified by their numbers in Table 1. The columns refer to the diameter and elevation of the field of view, its angular distance from the radiant at 2^h08^m UT, and the apparent velocity of Leonids in pixels per video frame. The last columns list the derived magnitude corrections for extinction, spatial distance, and apparent velocity.

Nr	Diam. fov	Elev. fov	Rad. dist.	Velocity px/frame	Δm ext. + dist.	Δm ang. vel.	Total Δm
2	30°	51°	35°	5.3	+0.5	0.0	+0.5
4	15°	43°	26°	8.7	+0.9	+0.5	+1.4
5	28°	45°	25°	3.7	+0.8	−0.4	+0.4
6	40°	40°	94°	4.9	+0.9	−0.1	+0.8
7	50°	48°	52°	4.4	+0.6	−0.2	+0.4
8	20°	70°	63°	17.5	+0.1	+1.3	+1.4

We find that, in the magnitude range +1 to +3, the population index is $r = 2.0 \pm 0.3$, i.e., the mass index is $s = 1.8 \pm 0.2$, with differences between the data sets of individual cameras. All magnitude distributions show a lack of faint Leonids with a turning point close to magnitude +3 (Figure 15). This indicates a lower mass limit higher than in the "average" Leonid meteoroid stream. The turning point at magnitude +3 corresponds to approximately 10^{-3} g meteoroids [7]. An alternative explanation for the cut-off may be linked to the observed differences between Leonid meteors and other meteors due to their structure or their atmospheric entry velocity and, therefore, higher luminous paths in the atmosphere. From the analysis of Leonid spectra [8],it has been concluded that Leonid meteoroids appear to be much more heterogeneous than meteoroids of other streams.

The unexpected turning point in the brightness distributions is most prominent in the data set of camera 4, which has the best limiting meteor magnitude. It does not occur in the profiles for non-Leonid meteors (Figure 16), so side effects from the instrumentation or analysis method do not explain the observation. Moreover, our selection of meteors completely inside the field of view tends to favor fainter Leonids to remain in the sample. Indeed, brighter meteors tend to have longer trails, while we are always able to determine the true maximum meteor brightness of faint and short Leonid trails. This gives the brighter Leonids a higher probability to be rejected.

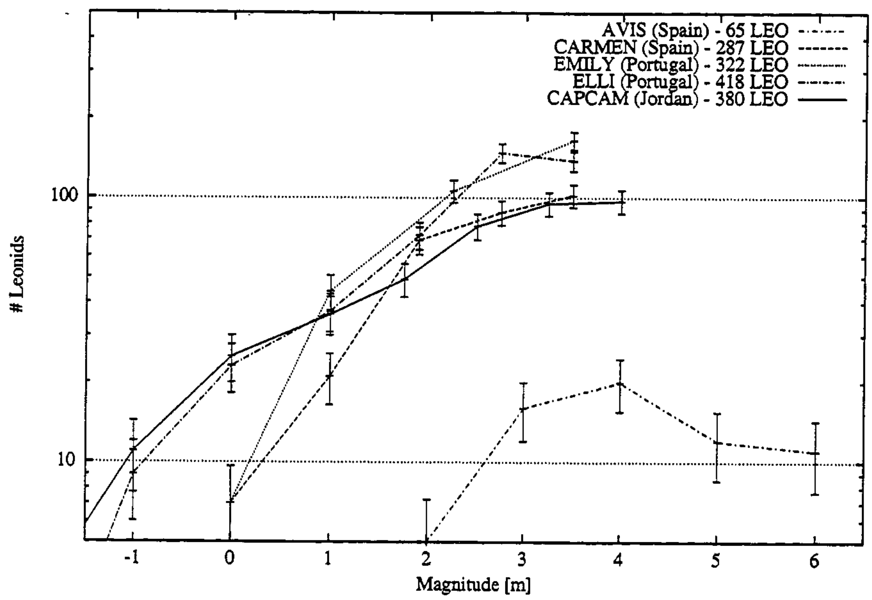

Figure 15 –Distribution of Leonid brightnesses derived from individual video cameras. Only Leonids with the start and end point inside the fov that are at least 1^m brighter than the camera's limiting magnitude for meteors are shown. There is a clear turning point at about $+3^m$.

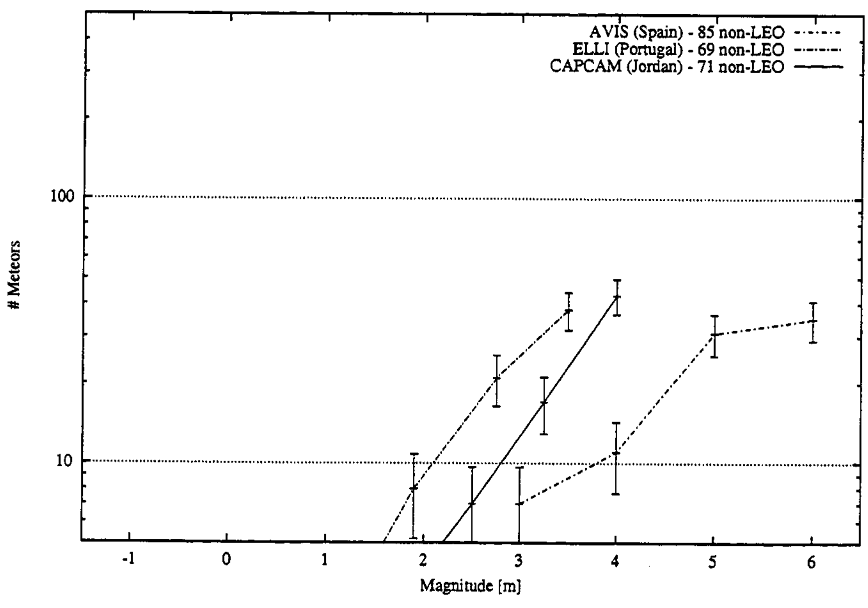

Figure 16 –Brightness distribution of non-Leonids for three individual video cameras, based on data of meteors with their start and end point inside the field of view. Only those meteors are included which are at least 1 magnitude brighter than the camera's limiting magnitude for meteors. Contrary to the Leonid magnitudes, there is no turning point at magnitude +3. The number of non-Leonids was much smaller than the number of Leonids.

Most airborne observers have neither confirmed the short-term fluctuations in their rate data nor the change in the slope of the magnitude distribution as described above. However, the tendency in magnitudes found by our ground-based cameras is supported by visual Leonid data which also hint at a lack of faint Leonids [4].

Almost all cameras from aircraft looked at low elevations above the horizon (around 15°), where they observe meteors in an atmospheric volume which is far away and the distances between the meteors vary a lot. Ground-based cameras observed at higher elevations, typically 40° to 45°. Thus, the meteors shall have a smaller scatter in distance, and their magnitude is not reduced that much by the square-distance effect and light scattering in the atmosphere.

Let us assume that the meteors appear between 80 and 120 km altitude above sea level. We compare two observers, one located at 2.9 km above sea level and looking at 40° elevation, the other at 12.0 km above sea level and observing at 15° elevation. Table 6 plots the distance to the closest/furthest meteors and the corresponding magnitude loss calculated by modeling the atmosphere as a Rayleigh scatterer (see [9]). Note that the table does not include any magnitude reduction due to different apparent angular velocities. This has an influence on both the number fluctuations and the magnitude data.

Table 6 – Distances and magnitude loss of a point light source as seen from an altitude $h_{\rm obs}$ above sea level, observing at an angle "Elevation" above the horizon. In the table, "$h_{\rm met}$" is the altitude of the light source (meteor), "s_i" the resulting distance to the observer, and "d_m" the magnitude loss due to the square distance law and Rayleigh scattering in the atmosphere.

Elevation	$h_{\rm obs}$	$h_{\rm met}$	s_i	d_m
40°	2.9 km	80 km	123 km	0.94
		100 km	154 km	1.42
		120 km	184 km	1.81
15°	12.0 km	80 km	286 km	2.60
		100 km	352 km	3.05
		120 km	416 km	3.42

We can see that the distance of a meteor varies between around 120 and 180 km for an elevation of 40°, versus 290 to 420 km at 15°. At the lower elevation, the sampled distance in the atmosphere is higher by more than a factor of 2. The volume is increased by about a factor of 10 (see [9] for details). Any local spatial "clumping" of material in the meteoroid cloud entering the atmosphere on a scale smaller than 100 km would thus be more pronounced in the observations at higher elevations; for low elevations the changes in number rates would be smeared out by the meteors visible closer or further than the cloud. However, larger structures of the order of several thousand kilometers, as proposed before, should remain visible.

The last column in Table 6 shows the reduction in magnitude of the meteors. On average, the meteors at the lower elevation seem to be 1.5 magnitude fainter than those at the higher elevation. In addition, the magnitude loss increases from about 0.9 to 1.8. Thus, a possible change in the slope of the magnitude distribution would be shifted by 1.5 to fainter magnitudes and be smeared out over a larger magnitude range. An additional effect (not modeled here in detail) is the apparent velocity of the meteor. For lower elevations, meteors appear on average slower, thus the light is not spread over as many pixels of the detector. Therefore, meteors appear brighter, again smearing out the bend in the magnitude curve, depending on the field of view of the camera used. While exact numbers could only be derived via some detailed modeling, e.g., as in [10],it is clear from this qualitative analysis that these effects may make any change in the magnitude distribution close to unrecognizable.

4. Radiant position

We determined the radiant position of the Leonids from more than 1100 selected trails with good accuracy using the software RADIANT [11]. Each Leonid appeared on at least five video frames, was of medium brightness (i.e., no blooming), and not close to the edge of the field of view.

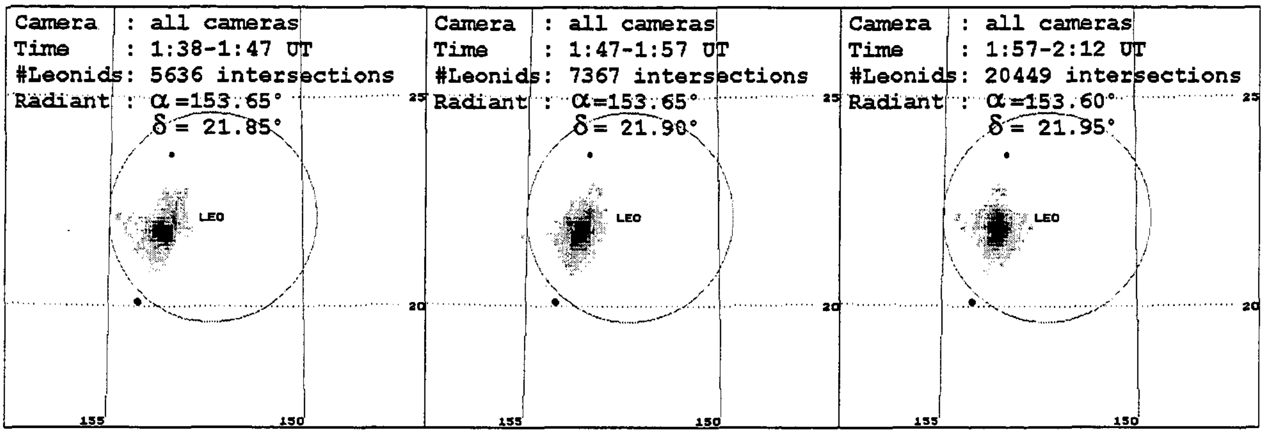

Figure 17 –Position of the Leonid radiant as obtained from individual video cameras. The distribution of meteors around the radiant is limited for a single camera; however, the individual radiant positions agree well. The two stars above and below the radiant are ζ and γ Leonis, respectively.

We find that the radiant positions derived from each camera's subset are almost identical, but reduced in accuracy, because of the limited distribution of trails around the radiant [12]. An average radiant is calculated from all Leonids with reasonably precise positional data recorded between $01^h38^m - 02^h12^m$ UT (i.e., the average of the three panels in Figure 17). The radiant is pin-point and lies at $\alpha = 153.^\circ6 \pm 0.^\circ1$ and $\delta = +21.^\circ9 \pm 0.^\circ1$ ($\lambda_\odot = 235.^\circ290$, J2000). This result from single-station Leonid recordings agrees with the radiant position derived from 28 photographic double-station Leonids by Betlem [13]: $\alpha = 153.^\circ27 \pm 0.^\circ17$ and $\delta = +21.^\circ88 \pm 0.^\circ15$ ($\lambda_\odot = 235.^\circ29$, J2000).

The positions are identical within the error margins for the immediate peak period and the intervals before and after the maximum, perhaps a little "sharper" between 1^h30^m and 2^h30^m UT. There is no difference at 1^h38^m–1^h47^m (enhanced activity found in the data series from Jordan and the airborne camera over Eastern Europe; left panel in Figure 17) which could tentatively be associated with the 1932 dust trail. But even then, the majority of meteors was caused by the 1899 dust trail, so a slightly different radiant position of the 1932 trail Leonids cannot be ruled out (cf. the three panels in Figure 17).

5. Conclusion

We analyzed video meteor data obtained over a large range between Eastern Europe ($\lambda = 37°$ E) and Tenerife ($\lambda = 17°$ W). According to these data, the general or main peak of the 1999 Leonid meteor storm occurred on November 18, 1999, $2^h02^m \pm 2^m$ UT, that is, at solar longitude $\lambda_\odot = 235.^\circ285 \pm 0.^\circ001$. This is in a very good agreement with the predictions of Asher and McNaught [1]. The general activity profile is skewed with a decreasing branch which is 1.6 times steeper than the ascending branch. The FWHM of the peak was determined to be 49 ± 3 minutes. The data of the two easterly sites show a significant sub-peak or activity plateau between 1^h39^m and 1^h53^m UT which may be associated with the passage of the 1932 dust trail. This feature is much less pronounced in the data sets obtained at more westerly locations. Obviously, we also find periodic rate variations of about 7 to 10 minutes' period, corresponding to structures within the stream of the order of 10 000 to 35 000 kilometers.

The magnitude data hint at a lower mass limit of the meteoroids. We find a lack of faint meteors which does not occur in the magnitudes of sporadic meteors.

The radiant of the Leonids is very sharp at $\alpha = 153.^\circ6 \pm 0.^\circ1$ and $\delta = +21.^\circ9 \pm 0.^\circ1$ ($\lambda_\odot = 235.^\circ290$, J2000) with no detectable drift or size variation in the peak and off-peak periods.

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The Perseids

The "New" Peak Failed: First Analysis of the 2000 Perseids

Rainer Arlt and Isabel Händel

We present a first global analysis of the 2000 Perseid meteor shower based on observations from 131 observers reporting 9622 Perseids. A tentative population index profile reveals little temporal variation and a value of $r = 2.1$ to $r = 2.2$ for the period near the maximum of the shower. The annual Perseid peak was found at $\lambda_\odot = 139\overset{\circ}{.}97 \pm 0\overset{\circ}{.}05$ with a heightened ZHR = 124 ± 13 compared with previous years. The early peak of fresh cometary material expected a few hours before the annual maximum could not be detected in 2000, according to a small number of seven reports.

1. Introduction

Year by year, we are getting farther from the parent comet of the Perseids, 109P/Swift-Tuttle, which passed its perihelion in 1992. At about the same time a dense part of the stream of much higher particle number densities passed perihelion which accompanies the Comet, but originates mainly in much older returns of the parent. This dense part of the stream caused enhanced Perseid activity a few hours prior to the traditional maximum. The number of years in which this additional peak is observed indicates the extent of the sheet.

The expected peak times were 5^h UT and 10^h UT on August 12 [1]. The first time favored observers located on the Canary Islands and the east coast of northern America, while the second time was suitable for West-American observers.

The maximum was not ideally observed in 2000, with a waxing gibbous Moon in the nights of August 11-12 and 12-13. Particularly the periods of end July and early August, coinciding with a New Moon, are well covered by observations, but the enthusiasm of observers was high enough to provide meteor astronomy with substantial material for the maximum, too.

We are most grateful for the enormous number of people submitting their data to the *IMO* very quickly. The following observers contributed to the below analysis which was carried out on September 1. Note that only observers reporting on the period August 10 to 13 are listed; otherwise, this first analysis would have become far too extensive given the short period between the Perseids' activity period and the editing of this issue.

Sana'a Abdo (ABDSA, Jordan), Luka Andrisić (ANDLU, Croatia), Poonam A. Aphale (APHPO, India), Rainer Arlt (ARLRA, Germany), Jure Atanačkov (ATAJU, Slovenia), J.N. Bachmayer (BACNJ, Germany), Asaf Barveld (BARAS, Israel), Chetana V. Bawle (BAWCH, India), Orlando Benitez Sanchez (BENOR, Spain), Bojan Besednik (BESBO, Yugoslavia), Adi Bjelak (BJEAD, Yugoslavia), Sara Bordovich (BORSA, Israel), Alexis Brandeker (BRAAL, Sweden), Emil Brezina (BREEM, Czech Republic), Andreas Buchmann (BUCAN, Switzerland), Vladimir Burgić (BURVL, Yugoslavia), Marija Cajetinac (CAJMA, Yugoslavia), Milan Cekić (CEKMI, Yugoslavia), Mathew Collier (COLMA, USA), Mary Cook (COOMA, UK), Stefano Crivello (CRIST, Italy), Hani Dalee (DALHA, Jordan), Denis Dermadi (DERDE, Croatia), Miha Devetak (DEVMI, Slovenia), Valentina Drljaca (DRLVA, Croatia), Marija Drobnjak (DROMA, Yugoslavia), Audrius Dubietis (DUBAU, Lithuania), Tomas Dvorak (DVOTO, Czech Republic), Khaled S. Eid (EIDKH, Jordan), Shlomi Eini (EINSH, Israel), Sven-Erik Enno (ENNSV, Estonia), Frank Enzlein (ENZFR, Germany), Marija Gajić (GAJMA, Yugoslavia), Petros Georgopoulos (GEOPE, Greece), George W. Gliba (GLIGE, USA), Shelagh Godwin (GODSH, UK), Cathy Hall (HALCA, Canada), Yehia B. Hamad (HAMYE, Jordan), Takema Hashimoto (HASTA, Japan), Roberto Haver (HAVRO, Italy), Zoltan Hevesi (HEVZO, Hungary), Anti Hirv (HIRAN, Estonia), Ken Hodonsky (HODKE, USA), Lumir Honzik (HONLU, Czech Republic), Kamil Hornoch (HORKM, Czech Republic), Marko Ivanović (IVAMA, Croatia), Helle Jaaniste (JAAHE, Estonia), Maja Jeromel (JERMA, Slovenia), Snežana Jovanović (JOVSN, Yugoslavia), Sayli S. Joshi (JOSSA, India), Swapma O. Joshi (JOSSW, India), Javor Kac (KACJA, Slovenia), Suvarna A. Khunte (KHUSU, India), Gregor Kladnik (KLAGR, Slovenia), Kocar Radim (KOCRA, Czech Republic), Jakub Koukal (KOUJA, Czech Republic), Ales Kratochvil (KRAAL, Czech Republic), Maris Kuperjanov (KUPMA, Estonia), Goran Kurtović (KURGO, Croatia), Martin Lehky (LEHMA, Czech

Republic), Raghunandan Lendghar (LENRA, India), Marko Leustek (LEUMA, Croatia), Anna Levina (LEVAN, Israel), Mike Linnolt (LINMI, USA), Irena Lisovski (LISIR, Israel), Vladimir Lukić (LUKVL, Yugoslavia), Hartwig Lüthen (LUTHA, Germany), Veikko Mäkelä (MAKVE, Finland), Antonio Martinez (MARAN, Venezuela), José A. dos Reis Martins (MARJO, Portugal), Pierre Martin (MARPI, Canada), Tony Markham (MARTO, UK), Edgardo Masa Martin (MASED, Spain), Alastair McBeath (MCBAL, UK), Markko Meriniit (MERMA, Estonia), Ondrej Mikulastik (MIKON, Czech Republic), Ana Milovanović (MILAA, Yugoslavia), Milan Milošević (MILMI, Yugoslavia), Koen Miskotte (MISKO, Netherlands), Blanka Mlakar (MLABL, Slovenia), Sirko Molau (MOLSI, Germany), Martin Nedved (NEDMA, Czech Republic), Snežana Nektarijević (NEKSN, Yugoslavia), Ahamad S. Nuaimat (NUAAH, Jordan), Kazuhiro Osada (OSAKA, Japan), Eric Palmer (PALER, USA), Gregg Pasterick (PASGR, USA), Suyin Perret-Gentil (PERSU, Venezuela), Vicent Peres (PERVI, Spain), Velimir Perisić (PERVE, Yugoslavia), Miloš Pesić (PESMI, Yugoslavia), Martin Plsek (PLSMA, Czech Republic), Jiři Polak (POLJI, Czech Republic), Mayuresh G. Prabhune (PRAMA, India), Irena Radić (RADIR, Yugoslavia), Marina Radujkov (RADMA, Yugoslavia), Gaurav B. Rathod (RATGA, India), Jürgen Rendtel (RENJU, Germany), Michal Rottenborn (ROTMI, Czech Republic), Branislav Savić (SAVBR, Yugoslavia), René Scurbecq (SCURE, Belgium), Miguel A. Serra (SERMI, Spain), Ana Setrajcić (SETAN, Yugoslavia), Ivica Skokić (SKOIV, Croatia), Vesna Slavković (SLAVE, Yugoslavia), Marko Sop (SOPMA, Croatia), Jiři Srba (SRBJI, Czech Republic), Jelena Stanicević (STAJE, Yugoslavia), Chris Stephan (STECH, USA), Enrico Stomeo (STOEN, Italy), Wes Stone (STOWE, USA), Pavel Svozil (SVOPA, Czech Republic), David Swann (SWADA, USA), Danilo Tomić (TOMDA, Yugoslavia), Sanjay D. Thorat (THOSA, India), Gabrijela Triglav (TRIGA, Slovenia), Mihaela Triglav (TRIMI, Slovenia), Josep M. Trigo Rodriguez (TRIJO, Spain), Marian Trlica (TRLMA, Czech Republic), Jan Turecek (TURJA, Czech Republic), Ovidiu Vaduvescu (VADOV, Canada), Kristina Veljković (VELKR, Yugoslavia), Johanna Vihalem (VIHJO, Estonia), Luc Rouppe van der Voort (VOOLU, Sweden), Song Wanfang (WANSO, China), Nikolai Wünsche (WUNNI, Germany), Oliver Wusk (WUSOL, Germany), Kim Youmans (YOUKI, USA), David Zagorc (ZAGDA, Slovenia), Zorana Zeravcić (ZERZO, Yugoslavia), Vladimír Znojil (ZNOVL, Czech Republic).

2. A tentative population index graph

The computation of a meaningful profile of the population index typically requires larger data sets than would be necessary for a significant ZHR profile. Therefore, our graph given here can only be tentative, but we endeavored to get a number of population indices in order to apply them for the ZHR computation instead of a constant, assumed value.

Table 1 gives an overview of the population indices based on a subset of observations available, namely of those which provided meteor numbers of about 20 or more on their own. The corresponding values from August 10 to 13 were used for the computation of the ZHR profile, below. Despite the large error margins, we may find an increased population index after the Perseid maximum compared with the entire period before the peak. Because of the low significance of the variations, we postpone the detailed study of the population index variations to a thorough analysis based on the full data set. Yet, we will use the r-values of Table 1 for the ZHR computations.

Table 1 – Population indices of the 2000 Perseids based on magnitude distributions with about 20 or more meteors; solar longitudes refer to equinox J2000.0.

Begin	End	$\lambda_\odot$ (J2000)	Distributions	r
Jul 25, 20^h30^m	Aug 06, 01^h30^m	$\sim 129°$	13	2.5 ± 0.4
Aug 06, 20^h50^m	Aug 10, 01^h40^m	$\sim 136°$	13	1.9 ± 0.3
Aug 10, 19^h30^m	Aug 11, 10^h00^m	$138.°7$	20	2.2 ± 0.5
Aug 11, 17^h00^m	Aug 12, 00^h00^m	$139.°5$	7	2.2 ± 0.3
Aug 12, 00^h00^m	Aug 12, 02^h30^m	$139.°64$	16	2.1 ± 0.3
Aug 12, 02^h30^m	Aug 12, 03^h40^m	$139.°72$	2	2.2 ± 0.3
Aug 12, 07^h00^m	Aug 12, 15^h00^m	$140.°03$	12	2.2 ± 0.3
Aug 12, 19^h40^m	Aug 13, 02^h10^m	$140.°51$	7	2.4 ± 0.6
Aug 13, 02^h30^m	Aug 13, 09^h00^m	$140.°76$	5	2.3 ± 0.4

3. The activity profile near the maximum

The amount of data available for selected periods near the maximum of the Perseids varies strongly. European geographical longitudes are particularly well-covered by reports, while Asian locations are hardly present in the data set. A first profile, shown numerically in Table 2 and graphically in Figure 1, was computed as follows.

We used the weighted average of individual counts as given by

$$\overline{\mathrm{ZHR}} = \frac{1+\sum_i n_i}{\sum_i T_{\mathrm{eff},i}/C_i},$$

where n_i are the Perseid numbers of each observing period, $T_{\mathrm{eff},i}$ their effective durations, and C_i the combined correction factors for each period, consisting of the limiting magnitude (lm) correction, field obstruction correction F, and radiant elevation (h_R) correction: $C_i = r^{(6.5-\mathrm{lm})} F/\sin h_\mathrm{R}$. The additional increase of the total shower meteor number by one results from small-number statistics [2] and has, of course, no significant effect in the case of the Perseids where numbers are large.

Table 2 – ZHR profile of the 2000 Perseids; solar longitudes refer to equinox J2000.0. Note the number of periods does not necessarily mean the number of individual observers contributing. The number of Perseids is n; errors are $\mathrm{ZHR}/\sqrt{n}$.

Date (UT)	$\lambda_\odot$	Periods	n	ZHR
Aug 10, $21^\mathrm{h}00^\mathrm{m}$	138°512	12	80	41 ± 5
Aug 10, $22^\mathrm{h}30^\mathrm{m}$	138°572	9	86	32 ± 4
Aug 10, $23^\mathrm{h}30^\mathrm{m}$	138°612	14	219	48 ± 3
Aug 11, $00^\mathrm{h}30^\mathrm{m}$	138°652	29	594	40 ± 2
Aug 11, $01^\mathrm{h}30^\mathrm{m}$	138°692	27	426	28 ± 2
Aug 11, $02^\mathrm{h}10^\mathrm{m}$	138°719	6	42	33 ± 5
Aug 11, $19^\mathrm{h}00^\mathrm{m}$	139°392	9	298	42 ± 3
Aug 11, $21^\mathrm{h}30^\mathrm{m}$	139°492	22	181	49 ± 4
Aug 11, $22^\mathrm{h}30^\mathrm{m}$	139°532	29	388	51 ± 3
Aug 11, $23^\mathrm{h}15^\mathrm{m}$	139°562	15	208	61 ± 4
Aug 11, $23^\mathrm{h}45^\mathrm{m}$	139°582	27	436	56 ± 3
Aug 12, $00^\mathrm{h}15^\mathrm{m}$	139°602	14	280	76 ± 5
Aug 12, $00^\mathrm{h}45^\mathrm{m}$	139°622	30	679	70 ± 3
Aug 12, $01^\mathrm{h}15^\mathrm{m}$	139°642	34	866	74 ± 3
Aug 12, $01^\mathrm{h}45^\mathrm{m}$	139°662	50	1570	74 ± 2
Aug 12, $02^\mathrm{h}15^\mathrm{m}$	139°682	19	454	74 ± 4
Aug 12, $03^\mathrm{h}00^\mathrm{m}$	139°712	9	158	72 ± 6
Aug 12, $04^\mathrm{h}40^\mathrm{m}$	139°778	7	354	84 ± 10
Aug 12, $07^\mathrm{h}00^\mathrm{m}$	139°871	4	195	98 ± 7
Aug 12, $08^\mathrm{h}30^\mathrm{m}$	139°931	9	212	88 ± 6
Aug 12, $09^\mathrm{h}30^\mathrm{m}$	139°971	8	173	124 ± 13
Aug 12, $12^\mathrm{h}00^\mathrm{m}$	140°071	13	233	98 ± 6
Aug 12, $20^\mathrm{h}30^\mathrm{m}$	140°411	7	45	55 ± 8
Aug 12, $21^\mathrm{h}30^\mathrm{m}$	140°451	7	50	41 ± 6
Aug 12, $22^\mathrm{h}30^\mathrm{m}$	140°491	11	128	62 ± 6
Aug 12, $23^\mathrm{h}30^\mathrm{m}$	140°531	27	323	64 ± 4
Aug 13, $00^\mathrm{h}30^\mathrm{m}$	140°571	17	267	47 ± 3
Aug 13, $01^\mathrm{h}30^\mathrm{m}$	140°611	13	325	50 ± 3
Aug 13, $03^\mathrm{h}10^\mathrm{m}$	140°678	6	74	43 ± 5
Aug 13, $06^\mathrm{h}40^\mathrm{m}$	140°818	15	278	51 ± 3

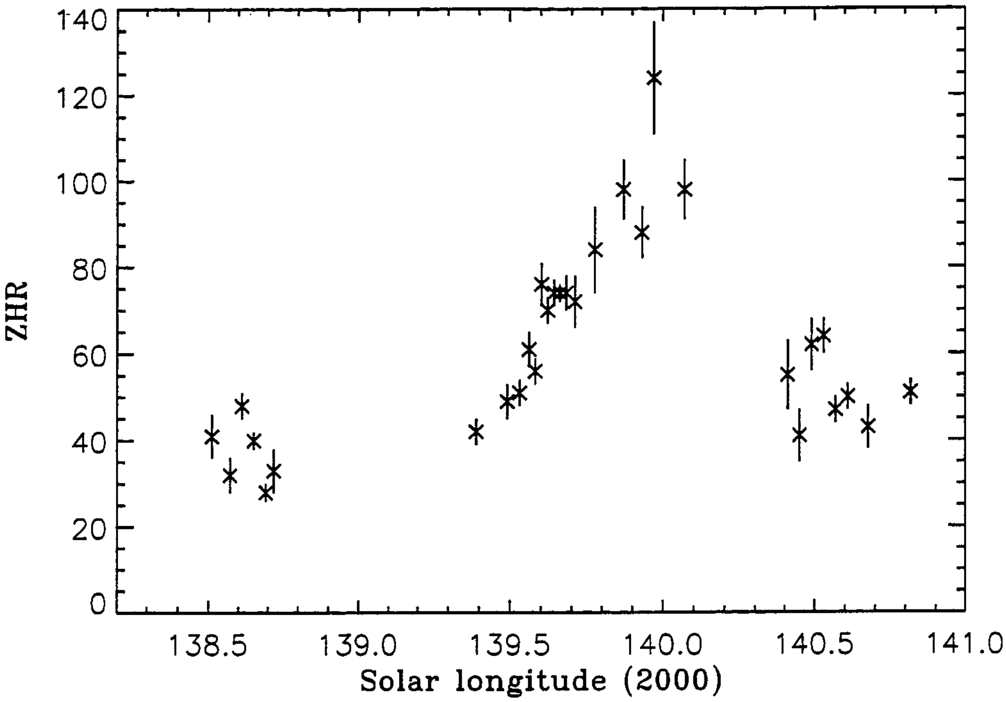

Figure 1 – Activity profile of the 2000 Perseids near their maximum.

The bin size for ZHR averages varies as the number of available observations is changing with geographical longitude. If the mid-time of a given observing period falls into a certain bin, it is used for this specific average. This means that a moderate smoothing occurs as the observing periods may have extended beyond the bin limits, despite its middle falling within these limits. No additional smoothing was made by bin-shifts of half the bin-width. This means that each observing period is used for exactly one ZHR average. From August 11, 23^h00^m UT, to August 12, 2^h30^m UT, a minimum bin size of 30 minutes was possible because of the great abundance of European data.

In the first profile thus obtained, we particularly note the two distinct gaps in the series due to a lack of East-Asian data and the natural scarceness of reports from the Pacific Ocean. Hawaiian data can fill the Pacific data gap until almost 15^h UT, though.

4. The "new" Perseid peak—still there?

The early Perseid peak of comparatively fresh material, which was expected for 5^h UT on August 12, was first reported missing in a Shower Circular sent through the *IMO-News* mailing list on August 16. It turned out, though, that a short window near 5^h UT was not covered by observations at all. As a consequence, the negative result needed revision. Meanwhile, a very limited number of observing periods logged from the Canary Islands and the United States have been received, and an estimate of the peak ZHR has been computed. (The rest of the profile with its data deadline of September 1 was not re-calculated.) The results are discussed below.

Straightforwardly averaging the new data according to the above equation yields a ZHR of 85 ± 5, fitting well the ascending branch of activity towards the annual maximum of the Perseids near $\lambda_\odot = 140\overset{\circ}{.}0$. It must be noted, though, that the error margin quoted here merely accounts for the "fluctuations" of random events given by $\mathrm{ZHR}/\sqrt{n}$, and, therefore, is a clear underestimation of the errors introduced by various observational problems. The scatter in the six observing periods contributing to the ZHR for the period around the expected early Perseid peak is indeed extremely large. Therefore, we shall now scrutinize the individual reports for the sake of trying to obtain a more accurate ZHR value, possibly revealing that the early Perseid peak was present after all.

Experienced observer Wes Stone observed from Oregon between 5^h00^m and 11^h10^m UT. The radiant was still low in the beginning (24° at the middle of the first hour), and his individual Perseid ZHRs increased from about 60 to about 130. The non-Perseid corrected hourly rates—which we will henceforth simply call HR_{np}—are 11, 14, and 29 for the first three hours, so not exceptional. We consider this report significant without additional adaptations; it does not show an early Perseid maximum, but that may have been missed due to low radiant elevation.

Chris Stephan faced higher radiant elevations in Florida and observed from 5^h00^m to 8^h05^m UT. No break-down of the period is given, and the ZHR is 50. The number of non-Perseid meteors suggests $HR_{np} = 12$. As the sporadic rate is significantly increased by various Aquarids, α-Capricornids, and κ-Cygnids, we may assume that the value HR_{np} after say 11^h pm local time should be in the vicinity of 20. A tentative perception correction of $c_p \approx 0.6$ may be chosen here, eventually yielding ZHR $\approx$ 80 which is close to the above average and close the average of Wes's first and second periods.

The experienced observer Orlando Benitez Sanchez from the Canary Islands reported from 1^h02^m to 5^h23^m UT. The corresponding ZHR values for the 2.66-hour and 1.61-hour periods are 46 and 38, respectively—very low. The average non-Perseid rate for the entire observation is about $HR_{np} \approx 16$ giving $c_p = 0.8$. The corrected ZHRs are 58 and 48 and lie at the lower end of the probable ZHR-range. Even if the first ZHR scaled to the reliable average of 70 derived from numerous European observing periods (see Table 2), we do not get higher than 60 for Orlando's second period; no mention of an early peak.

Another experienced observer, José Alfonso dos Reis Martins from Portugal, reported from 2^h31^m to 4^h30^m UT. The ZHRs of these two hours are 98 and 96, respectively, the average non-Perseid rate is $HR_{np} = 25$, though. We may suppose a $c_p = 1.25$ and get ZHR = 78 and ZHR = 77, again, close to the straightforward average of 85, and, again, no sign of an early Perseid peak.

Two observers on La Palma, Luc Rouppe van der Voort and Alexis Brandeker, were in an ideal position to cover the predicted time of the early maximum and reported 1.5 hours of clear skies between 4^h05^m and 5^h35^m UT. They report Perseid numbers corresponding to ZHRs of 160 and 190, respectively. The numbers appear very high, but the non-Perseid meteors reported only by the first observer indicate $HR_{np} = 5$. It seems that we are not able to calibrate the observations additionally and have to assume that the ZHR could have well been much higher than 85 according to these reports from a very favorable location. Both observers submitted meteor reports for the first time, though.

Finally, casual observer Ovidiu Vaduvescu from Ontario reported a long session from 2^h00^m to 9^h30^m UT, of which the first three hours ware monitored under favorable conditions; the rest suffered from strong aurorae. The uncorrected Perseid hourly rates were 7, 12, and 6 under excellent lm = +6.5 conditions during the first part. These numbers are far too small; we only have the chance to scale the rates according to the first hour for which we have the reliable average European ZHR of about 70. The perception coefficient would thus be $c_p = 0.26$ giving a ZHR = 98 for the period centered at 3^h30^m UT and ZHR = 41 for that at 4^h30^m UT.

5. Conclusion

In a concluding sentence, we may present the average of the first four observers with their adapted ZHR values: $\overline{\text{ZHR}} = 66$. Giving only 50% weight to the "newcomers," the average of all seven observers is $\overline{\text{ZHR}} = 84 \pm 5$. The error is again the simple $\text{ZHR}/\sqrt{n}$, and we are certainly not exaggerating when we assume the total error to be no less than ± 10.

In addition, the thorough investigation and re-scaling of individual reports for the sake of an improved ZHR for the period near 5^h UT gives an example of how well an arbitrary set of observers gives a meaningful average, despite their enormous perceptional differences: the "improved" ZHR is almost exactly the same as the brute-force average from the original data.

The annual maximum of the Perseids falls near $\lambda_\odot = 139°97 \pm 0°05$. The error margins are a little smaller on the early side and larger on the late side of this moment. The peak time thus agrees with the average annual time of maximum at $\lambda_\odot = 140°0$. The highest ZHR is 124 ± 13, which is somewhat higher than previous years' averages. As this average comprises only six individual observers, the actual peak value may alter by a few per cent once the complete set of observations is involved.

From particle simulations in [3], a possible die-out of the early, "new" peak was predicted for 2001–2002, as well as a later revival of its activity in 2004–2006. It seems now that the "new" peak has died out earlier. Obviously, the Perseids remain a very interesting target of study in meteor astronomy.

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Ongoing Meteor Work

On the Existence of the June Lyrid Meteor Shower

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The possible existence of the June Lyrid meteor shower is examined from data in the *IMO* archive from 1984 to 1997. It is concluded that the activity is weak but detectable in most years. The mean activity curve shows a symmetrical rise and fall about a maximum of ZHR = 3, although annual variations are undoubtedly present. The solar longitude of the maximum has remained practically constant since the discovery of the stream in the late 1960s.

1. Introduction

The discovery of the June Lyrid meteor shower is attributed to the American observer Stan Dvorak, who first detected the shower on the evening of June 15, 1966, from California [1]. Although it has been commented that the June Lyrids are the archetypal one-orbit meteor stream, June Lyrid reports have been made on numerous occasions since. The most detailed study of a single year was made of the 1969 maximum [2]. This study showed a sharp maximum of ZHR = 9 at $\lambda_\odot = 84°5$, with a broad maximum of ZHR ≈ 6 from June 13–17.

After 1969, observations are more erratic, with activity around 4–5 per hour in 1975, 1979, and 1980, but only very weak activity seen in other years. This suggests that the stream is of highly variable density. During the 1980s and 1990s, this stream has dropped off the working lists of such organizations as the *IMO* [3] and the *BAA* [4], nor is it included in the compilation of 50 meteor showers given by Jenniskens [5].

However, the shower appears at a time of the year when northern nights are at their shortest, but before the summer period when observers have the greatest quantity of free time. At this time of year, the number of observations made is very low, and weak shower activity can easily be missed, thus the absence of positive observations is not necessarily indicative of inactivity.

2. The parent comet

The 1969 study of the shower suggested a possible association with Comet C/1915 C1 (Mellish). This is surprising, given that the orbit of this comet was slightly open ($e = 1.000151$) and also reached perihelion outside the Earth's orbit ($q = 1.005$ AU), having a highly inclined orbit ($i = 55°$) [6]. The inclination ensures that the minimum distance between the comet's orbit and the Earth (about 0.3 AU) is greater than about 0.1 AU, the generally accepted minimum distance required to give rise to significant meteor activity.

Comet C/1915 C1 (Mellish) was discovered on February 10, 1915, by the American comet hunter Mellish, and was the brighter of his two comet discoveries of the year. It was of magnitude +9 at discovery, and approaching perihelion. Its minimum geocentric distance was 0.35 AU in early June, almost the smallest possible. At this point, the comet reached magnitude +4, and showed a tail 6° long. After perihelion, on July 17.6523, 1915, the comet faded only slowly and was still of magnitude +10 at the end of the year. The last observation of the comet was made at around magnitude +16 on October 21, 1916.

An interesting circumstance which would allow material to be more widely dispersed in the orbit than usual is the fragmentation of the nucleus that was observed during the approach to perihelion. During April 1915, the nucleus or, more exactly, the nuclear condensation, was seen to be elongated. During May, three secondary nuclei were detected, one of which was observed for five weeks, although the other two were much shorter-lived.

Despite the current hyperbolic orbit, the original and future orbits are closed ($1/a = +0.000075$ and $+0.000960$, respectively) [6]. The former value indicates that the comet originated in the Oort Cloud.

Support for the association of the June Lyrids with Comet Mellish comes from a radar orbit calculated by Sekanina from observations at the 1969 return of the shower [7]. This study, however, found that the shower meteors have a short-period orbit of just 2.94 years. Such a short period would indicate extremely rapid evolution in the orbits of the meteoroids released close to perihelion but, at the same time, permits an explanation of how a non-periodic comet can give rise to an annual stream 70+ years after passing perihelion.

3. The June Lyrid radiant and its characteristics

The 1999 *IMO Meteor Shower Calendar* [3] gives a duration of the shower from June 11 to 21, with a maximum on June 16, at $\lambda_\odot = 85°$. This is close to the limits and values given by Kronk: maximum on June 15 ($\lambda_\odot = 84.^\circ5$), with limits June 10 and 21, respectively. Both sources quote the radiant determined by Hindley in the 1969 *BAA* study [4] of $\alpha = 278°$ and $\delta = +35°$, with a radiant drift slightly under 1° per day in right ascension and negligible in declination.

The meteors are characteristically slow (31 km/s) and faint ($r = 3.0$). A value of $\gamma = 1$ is assumed.

4. June Lyrids in the IMO Visual Meteor Database

The 1999 *IMO Meteor Shower Calendar* [3] comments that evidence for the existence of this shower has been virtually zero since the 1970s, however noting that several observers independently reported some activity in 1996 [8]. However, a Spanish study [9], based on observations by members of *SOMYCE* covering 1988–1990, showed significant activity, reaching ZHR = 5. This study was provoked by observations by the *Agrupación Astronomica de Tenerife* (*AAT*) in 1990 that indicated weak, but detectable activity from the June Lyrids at ZHR ≈ 3 close to maximum ($\lambda_\odot = 85.^\circ8$) [10]. A similar conclusion was found from follow-up observations in 1991

[11]. Such group observations can be criticized, although the *AAT* observing technique involved several observers in the same observing site who would observe completely independently. The observers only communicated results after the observations had finished to ensure that mutual influence was minimized.

A search through the *IMO* archive yields a total of 386 observing reports that specifically mention the June Lyrids. Of these, no fewer than 265 reports are positive (68.6%), in the sense that at least one June Lyrid is recorded by the observer. A total of 616 June Lyrids are found in 522.38 hours of observing. While these are not especially large totals, the ratio of June Lyrids reported to total observing hours is actually higher than for some well-established showers in the Jenniskens global study of meteor shower activity (e.g., Virginids, κ-Cygnids, and—most surprisingly—the Leonids) [5]. The 386 observing reports include 2930 sporadics.

Of the observing reports which do not register June Lyrids, no less than 36% concern observations in poor conditions (a limiting magnitude of +5.5 or brighter), which is a strong limiting factor to detection when, as, in this case, the population index is large.

Some June Lyrids are registered every year from 1985 to 1997 (the last year analyzed here). A year-by-year breakdown of June Lyrid observations in the *IMO Visual Meteor Database* is given in Table 1. Note that, in 1996, the year when significant June Lyrid activity was independently reported [8], the number of June Lyrids in the database is the highest of any year, and the median ZHR is the highest found in a large sample of data.

Table 1 – June Lyrid data from the *IMO Visual Meteor Database*. The columns show the year, the total number of observing reports in the database, the number of reports that include at least one June Lyrid, the number of reports that show no June Lyrids, the total effective observing time, the total number of June Lyrids, and the median ZHR for all observations made that year.

Year	Total Reports	Positive Reports	Negative Reports	$T_{\rm eff}$	June Lyrids	Median ZHR
1985	9	9	0	$18^{\rm h}.77$	18	2.3
1986	13	13	0	$13^{\rm h}.96$	35	7.2
1987	3	3	0	$6^{\rm h}.05$	12	6.6
1988	54	33	21	$61^{\rm h}.48$	81	1.2
1989	17	15	2	$24^{\rm h}.98$	28	1.8
1990	20	14	6	$34^{\rm h}.42$	40	0.9
1991	37	31	6	$57^{\rm h}.35$	87	1.8
1992	15	11	4	$24^{\rm h}.47$	20	0.7
1993	66	45	21	$89^{\rm h}.35$	84	1.8
1994	29	15	14	$37^{\rm h}.64$	41	0.4
1995	16	10	6	$23^{\rm h}.79$	18	1.5
1996	71	51	20	$89^{\rm h}.18$	127	2.9
1997	36	15	21	$38^{\rm h}.94$	25	0.0
Totals	386	265	121	$522^{\rm h}.38$	616	1.6

Although the June Lyrids could be observed from some southern hemisphere locations, all observing reports are from the northern hemisphere (see Figure 1).

The short duration of the northern summer nights limits observations from northern Europe. Most reports come from Central Europe and Japan, but there are also significant numbers of observations from mainland Spain and from the Canary Islands, as well as from especially the East Coast of the United States.

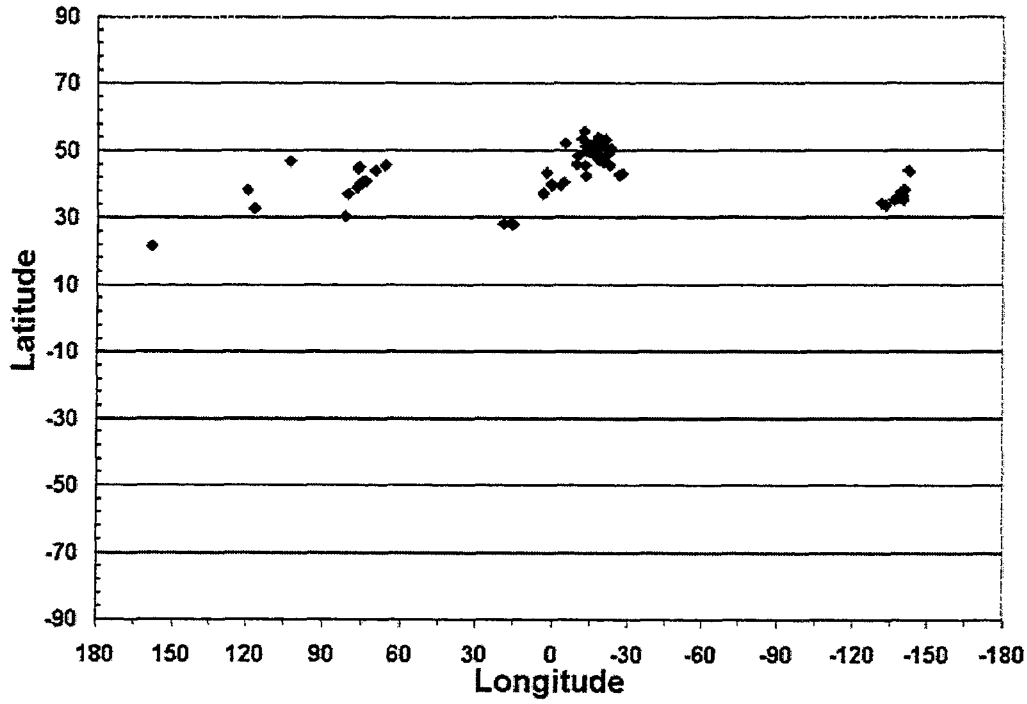

Figure 1 – The geographical distribution of June Lyrid observing reports in the *IMO* archive. A large number of reports come from Japan (almost a complete outline to the right of the plot) and Central Europe (the large cluster of points slightly right of center). Lesser clusters of data are seen from Spain and the Canaries (lower center) and the USA (to the left), particularly its East Coast. No observations have been reported from latitudes south of Hawaii.

When the data are plotted as ZHR against solar longitude (Figure 2), we see the characteristic peak around the supposed date of maximum ($\lambda_\odot \approx 85°$) that suggests that the activity is real. However, due to the large errors on the majority of the points, it is difficult to determine the trend or to estimate accurately the date of maximum.

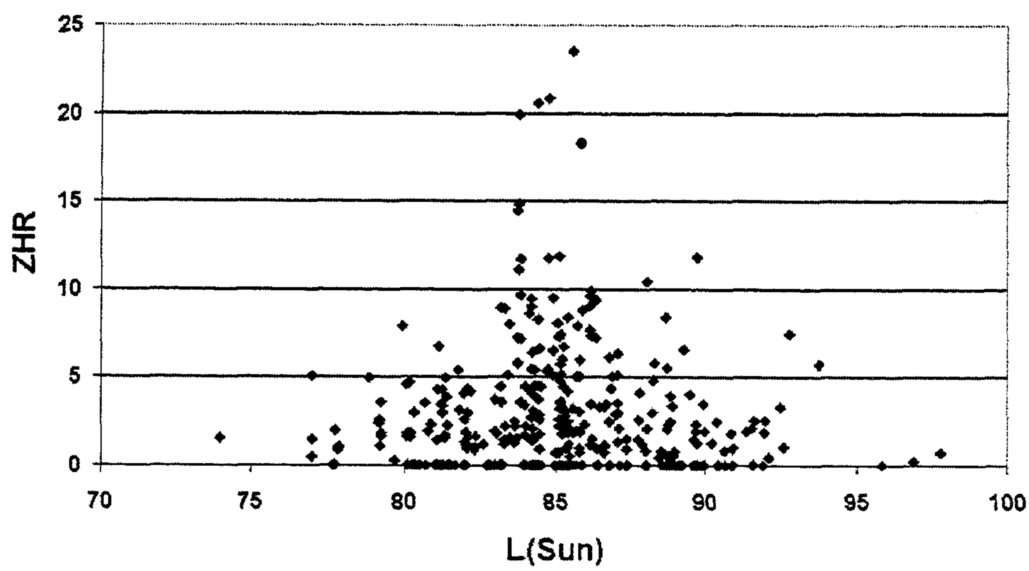

Figure 2 – The activity curve for the June Lyrid meteor shower from the data in the *IMO Visual Meteor Database*.

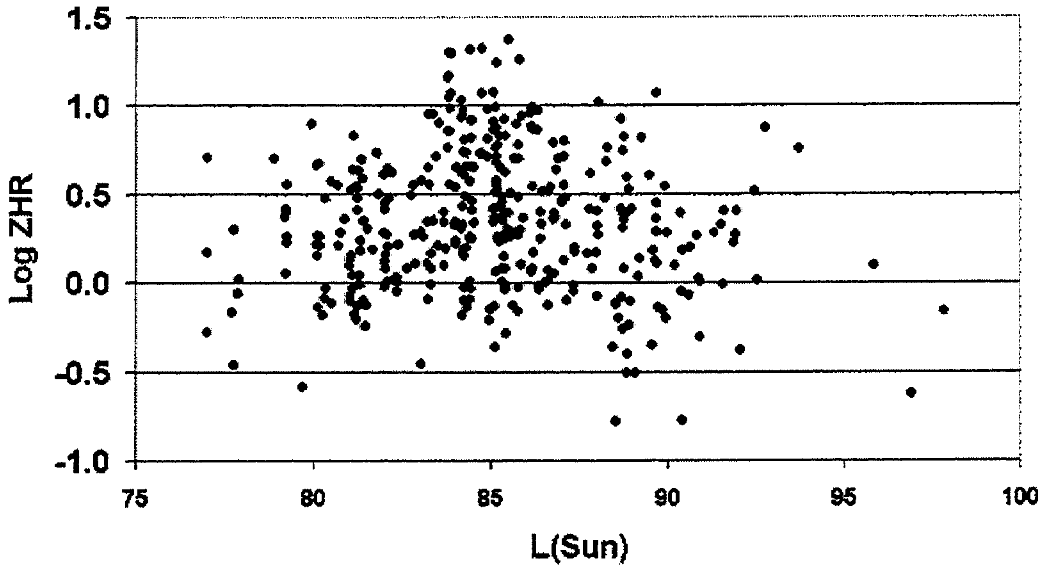

Figure 3 – The activity curve for the June Lyrid meteor shower, plotted as log ZHR against solar longitude, from the data in the *IMO Visual Meteor Database*.

To estimate the fundamental parameters of the shower, the logarithm of the ZHR is plotted against the solar longitude (Figure 3), and a least-squares fit made. This, however, is complicated by the large number of negative observations. To account for these, an equivalent ZHR is calculated for each upper limit, assuming that 0.5 shower members were observed.

In the log ZHR-against-$\lambda_\odot$ plot, we see a clear correlation with a relatively well-defined maximum. Fitting the rising and falling branches, we find the following fit:

$$b_+ = 0.066, \quad b_- = 0.053, \quad \lambda_\odot(\max) = 84\overset{\circ}{.}2, \quad \mathrm{ZHR}(\max) = 3.1.$$

The solar longitude of the maximum is practically identical to that determined in the 1969 study. Testing the fit for significance with Student's t-test yields $t = 4.7$, giving a level of significance of over 99.9% for the correlation of log ZHR against $\lambda_\odot$.

The difference between the calculated slope of the rising and the falling branches is too small to be considered significant, although there is some suggestion of structure in the rising branch. If we take the limits of the shower to be when its activity is above ZHR = 1, and assume that $b_- = b_+ = 0.060$, then we find that the limits of the shower activity are $\lambda_\odot = 76°$ and $\lambda_\odot = 92°$, respectively (June 7–23). This duration, though, will be too optimistic due to confusion with the sporadic background, which will occur away from the maximum.

5. Conclusions

The evidence of the *IMO Visual Meteor Database* suggests that the June Lyrid meteor shower does exist, although its maximum is now significantly advanced compared to when this shower was first detected. The mean ZHR over the period 1985–1997 is 3.1, although this figure experiences significant variations from year to year. In particular, the shower was strongly active in 1986, when the peak ZHR may have reached 10, although almost all the observations come from a single group of observers at one site. In contrast, the shower was not detected, or was only marginally detected, in 1997. There was, however, significant activity in 1996, although at a level close to the mean level over the years considered here. At present, there is not enough data to suggest the existence of a possible periodicity in the shower's activity.

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Note

The *IMO Working List of Meteor Showers* has no streams with maximum in June apart from the recently re-introduced June Bootids that are not an annual shower.

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Low-Precision Formulae for Calculating Julian Day from Solar Longitude

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Low-precision formulae for calculating the Julian day from a given solar longitude (equinox J2000.0) and approximate date (e.g., month and year) are presented. The maximum error of the algorithm is less than half an hour for dates between 1900 and 2100.

1. Introduction

The problem of finding the solar longitude at a given time, can be solved analytically. That can be done with high accuracy using the VSOP87 series of Bretagnon and Francou [1] or with low accuracy (e.g., Seidelmann [2]). However, the inverse problem of finding the date in a given year, for a given solar longitude, is usually solved iteratively, using the algorithms mentioned above. In Section 2, I present a low-accuracy algorithm for calculating the Julian day for a given year and solar longitude in equinox J2000. The accuracy of the algorithm for dates between 1900 and 2100 is discussed in Section 3.

2. The algorithm

The input arguments of the algorithm are the following:

1. solar longitude ($\lambda_\odot$), for the J2000.0 equinox, in radians; and

2. the approximate date (e.g., month and year) near which the algorithm will search for the exact Julian day corresponding to the solar longitude. The approximate date is needed in order to distinguish between the solar longitudes in successive years.

The parameters of the algorithm were fitted to the VSOP87 theory [1] using a least-squares method. The parameters and their values are as shown in Table 1.

Table 1 – Theory parameters

Name	Value	Units
M_0	2451182.24736	day
M_1	365.25963575	day year^{-1}
A_1	1.94330	day
ϕ_1	−1.798135	radian
A_2	0.013053	day
ϕ_2	2.634232	radian
B_1	78.19527	day
B_2	58.13165	day radian^{-1}
P_2	−0.0000089408	day day^{-1}

The algorithm to calculate the Julian day using the J2000.0 solar longitude $\lambda_\odot$, the year Y, and the month M, is as follows:

1. Calculate N, the number of years since 2000.0:

$$N = Y - 2000.$$

2. Calculate the Julian day for which the mean anomaly of the Sun equals zero:

$$\mathrm{JD}_{M=0} = M_0 + M_1 N.$$

3. Calculate the approximate Julian day $\mathrm{JD}_{\mathrm{app}}$ from the month and year, using an arbitrary day in the month (e.g., 15).
4. Calculate the difference in days ΔT between $\mathrm{JD}_{M=0}$ and JD:

$$\Delta T = A_1 \sin(\lambda_\odot + \phi_1) + A_2 \sin(2\lambda_\odot + \phi_2) + B_1 + B_2\lambda_\odot + P_2 \times (\mathrm{JD}_{\mathrm{app}} - 2451545).$$

5. If $|JD_{\mathrm{app}} - \mathrm{JD}_{M=0} - \Delta T| > 50$, then $\Delta T = \Delta T + 365.2596$, else ΔT remains changed.[1]
6. Finally, the Julian day JD corresponding to $\lambda_\odot$ is given by

$$\mathrm{JD} = \mathrm{JD}_{M=0} + \Delta T.$$

The algorithm is available as a JAVASCRIPT script and MATLAB script from `http://wise-obs.tau.ac.il/~eran/Wise/Util/SolLon.html`.

3. Discussion

The algorithm presented above was tested against the solar longitude calculated from the year 1900 to the year 2100 in 0.2 day steps. The minimum difference (real – calculated) is −0.0194 days, while the maximum is +0.0172 days, and the standard deviation of these values is 0.0058 days. Figure 1 shows the algorithm error as a function of years since 2000.

[1] The value 50 is arbitrary. It is designed to check if the preliminary result ($\mathrm{JD}_{M=0} + \Delta T$) is in proximity to $\mathrm{JD}_{\mathrm{app}}$.

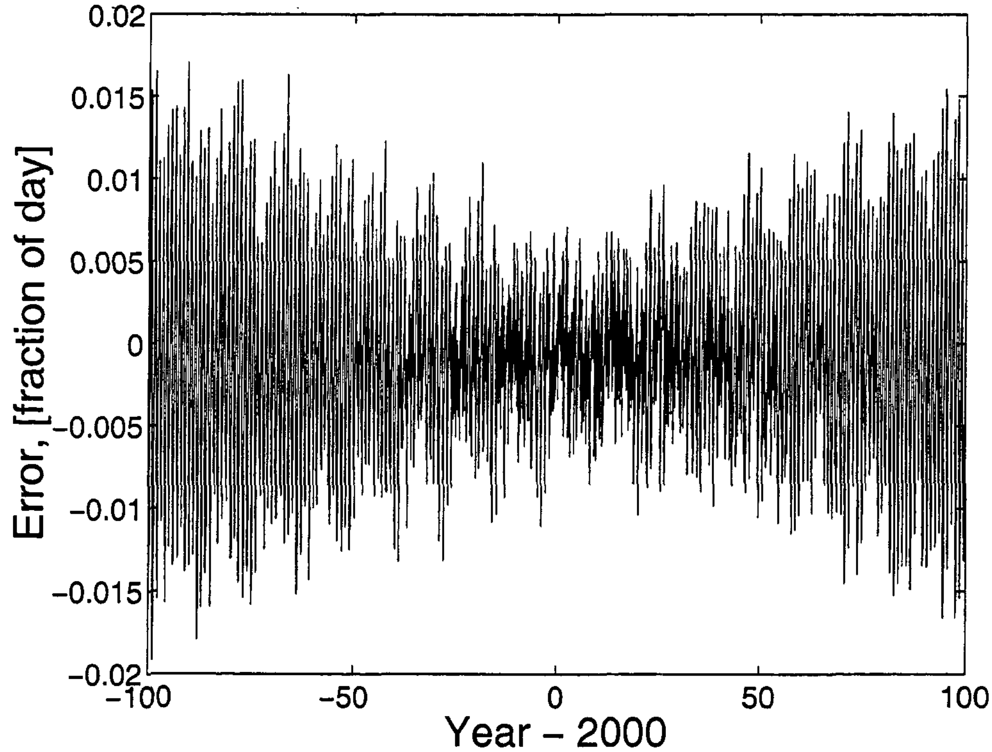

Figure 1 – The algorithm error in days as function of year from 2000

References

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Observational Results

SPA Meteor Section Results: November–December 1999

Alastair McBeath

Results and reports submitted to the *SPA Meteor Section* for November and December, 1999, are summarized, except for the Leonid details already discussed [1–3]. The Taurids received some useful coverage in early November, without anything unusual being detected. A brilliant fireball occurred around 22^h10^m UT on November 28 over southeast Ireland, after which about 271 g of L6 chondritic meteorites were recovered near Leighlinbridge, County Carlow, Ireland, the first recovered meteorite fall in the British Isles since 1991. Two other bright fireballs occurred on November 27-28 and 29-30 over Europe as well. December 13-14 saw the highest Geminid ZHRs, 100 ± 10, during a well-observed Geminid epoch. Radio data showed strong echo counts on both December 13 and 14, with the latter date ($\lambda_\odot \approx 263°$, eq. J2000.0) producing the highest counts generally, but with no specific clear maximum time. The Ursid peak was detected by radio only, giving a very weak showing in most datasets especially around $\lambda_\odot = 269°$–$270°$.

1. Introduction

With the Moon-free parts of both months favoring the expected major shower maxima, as well as the lower-activity Taurid peaks in November, this period was the busiest of the year for the Section, as expected.

Most observations occurred between November 16-17 and 18-19, inclusive, data which have been thoroughly discussed already [1–3]. To avoid needless duplication, the totals in Table 1 exclude the results from this part of November, while the following lists of observers feature only those people who observed away from this spell.

Photographic results came from the *Arbeitskreis Meteore* (*AKM*) members Jürgen Rendtel, Ina Rendtel, and Jörg Strunk, all using fireball cameras in Germany. Along with the other *AKM* data noted here, these reports were extracted from their journal *Meteoros* 2:12 (1999), 3:1 and 3:2 (both 2000), provided by Ina Rendtel. In addition, Morton Henderson in Scotland provided details of his unfortunately unsuccessful Geminid photography in December.

Most of the radio data was submitted by Chris Steyaert in the form of *Radio Meteor Observation Bulletins* (*RMOBs*) 76 and 77, from December 1999 and January 2000 respectively, though R.B. Minton (New Mexico, USA) also provided copies of his data directly in advance of *RMOB* publication. The *RMOB*-only observers were as follows:

> Enric Fraile Algeciras (Spain), Mike Boschat (Canada), Maurice de Meyere (Belgium), Ghent University (Belgium), Werfried Kuneth (Austria), Sadao Okamoto (Japan), Ton Schoenmaker (Netherlands), Pierre Terrier (France), and Ilkka Yrjölä (Finland).

Figure 1 shows an illustrative graph for November–December, which picks out the main features found by most observers. The lack of prominence adopted by the Leonids in the Japanese data allows us to more clearly note other features of interest in the radio results.

Video observations were received from Steve Evans in England (Geminids only; these data also summarized with the *AKM* results in *Meteoros* 3:1 (2000), p. 3), and *AKM* members Michael Gerding, Sirko Molau, Mirko Nitschke, Jürgen Rendtel, and Ulrich Sperberg in Germany. Of the trails identified so far, 484 were Taurids, and 114 Geminids.

The non-Leonid visual watchers included the following:

> *AKM* observers Franziska Böttcher, Frank Enzlein, Christoph Gerber, Matthias Growe, Sven Näther, Jürgen Rendtel (Germany and La Palma), Ulrich Sperberg, Roland Winkler, Nikolai Wünsche (all in Germany only, except where noted); Mary Cook (England), Martin Galea De Giovanni (Malta), Shelagh Godwin (England), Chris Hall (England), Morton Henderson (Scotland), Tony Markham (England), Michael Maunder (England), Alastair McBeath (England), Tom McEwan (Scotland), Alexei Pace (Malta), Trevor Pendleton (England), Ian Rigney (England), George Spalding (England), Umberto Mule' Stagno (Malta), and Joseph Zammit (Malta).

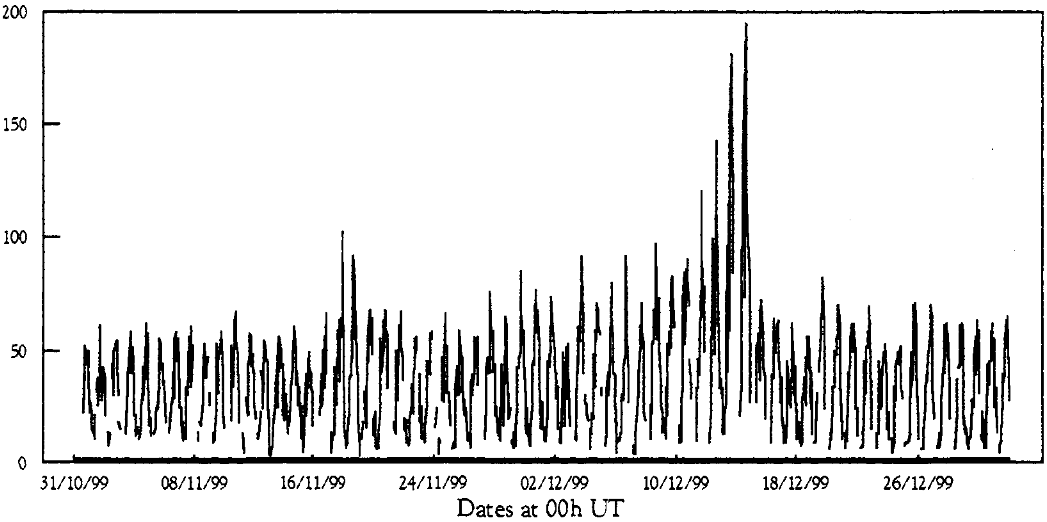

Figure 1 – Raw hourly radio meteor echo counts from November and December, 1999, in data collected by Sadao Okamoto (given in *RMOB* 77, January 2000). Sadao operated his set-up continuously, so the majority of breaks are due to almost daily radio noise interference during the local daytime and evening hours, with very occasional bursts of Sporadic-E. The dominant Geminid peak results from a more favorable observing geometry for this shower than for the Leonid storm.

The Maltese results came courtesy of Martin Galea De Giovanni of the *Astronomical Society of Malta*. In addition, preprint copies of results articles prepared from South-African visual data on the Leonids and Geminids were received from the *Astronomical Society of South Africa*'s Comet and Meteor Section Director, Tim Cooper [4,5].

Table 1 – Visual, photographic, video, and radio hours' totals, plus visual, photographed, and video meteor numbers, recorded in each month (excluding the period from 12^h UT on November 16 to 12^h UT on November 19), with a partial breakdown of visual meteor types.

Month	Visual	STA	NTA	LEO	Meteors	Photo	Trails	Video	Trails	Radio
November	82^h	68	80	38	713	139^h	8	132^h	259	3243^h
Month	Visual	GEM	URS	COM	Meteors	Photo	Trails	Video	Trails	Radio
December	116^h	1591	7	1	2559	2^h	0	58^h	476	4175^h

2. November

The expected minor radio peaks in pre-Leonid November from [6] were all recovered again in 1999, around $\lambda_\odot = 219°$, $\lambda_\odot = 224°$, and $\lambda_\odot = 227°$ (November 2, 7, and 10, respectively), and, in 40% of the available data sets, the $\lambda_\odot \approx 229°$ peak (November 12) was also found, which was not the case in 1997 or 1998 at this time (though minor peaks around $\lambda_\odot$ = 230°–231° were detected then).

Visually, most nights between November 2-3 and 16-17 received some coverage, and low Taurid rates were found throughout. The Northern Taurids seemed somewhat more dominant on November 2-3 and 8-9, the Southern branch more prevalent on November 6-7 and 9-10, but the meteor numbers were low enough to make the reliability of these results questionable. Combined Taurid rates were at their best (ZHRs of 9–12 ± 5–6) on November 2-3 and 8-9 to 9-10 in our data. A handful of late Orionids was also picked up.

Using data from October and November on 30 Southern and 49 Northern Taurids seen by reliable watchers in good conditions (limiting magnitude at least +5.5, cloud cover less than 20%), corrected mean magnitudes of +3.53 and +3.08, respectively, were computed. The November sporadics' value (270 meteors) was +3.25, for contrast. From reported train details, the two Taurid branches showed 6% (1.5/25 meteors) and 3% (1.5/44 meteors) trains, respectively, as opposed to 6% (11/170 meteors) of sporadics. Some further details on the November sporadic magnitude and train distributions were given in [2].

Messages posted to the *IMO-News* e-mailing list between October 20 and November 11 concerned the possibility that Comet C/1999 J3 LINEAR might produce activity of swift meteors from a radiant near γ Ursae Majoris around November 11. Notices were also e-mailed to regular *SPAMS* observers and via the *SPA* Website on October 30, highlighting this possibility, and several useful visual reports from the November 8–12 period were subsequently received. No definite visual rates of meteors from this source could be identified, as also found in the more detailed visual data presented in [7]. Interestingly, [7] also drew attention to enhanced radar activity found in the Ondřejov, Czech Republic, data from 21^h–3^h UT on November 11-12. The center of this period was at $\lambda_\odot = 229\overset{\circ}{.}16$, coincident with the date highlighted as weakly detected in the radio results above, which was not found in 1997 or 1998. The radio data provide only slight possible confirmation of the suggested radar maximum time, however, and it should be noted that, as a minor peak had been found in radio data from 1993–1996 at $\lambda_\odot = 229°$ anyway, the 1999 event may not be at all significant.

Very few visual reports were received after the Leonids, and even the expected minor radio peaks in the latter part of November were generally found less easily than in past years, around $\lambda_\odot = 238°$ and $\lambda_\odot = 240°$–$248°$ (November 21 and November 23–December 1), almost as if meteor activity were recovering after the Leonid storm. There was no indication in the radio signatures around $\lambda_\odot = 239°$ that any unusual α-Monocerotid activity had taken place then (expected peak around 1^h UT on November 22). The strongest, and best-detected, non-Leonid radio peak, found in all the available data sets, occurred at $\lambda_\odot \approx 247°$ (November 30), not a timing noted quite as well before. Roughly coincident with this was a loose "cluster" of three magnitude -10 to -15 fireballs seen from European sites, one each on November 27-28, 28-29, and 29-30. The first occurred around 21^h30^m UT on November 27, and was later identified from Spanish data as most probably being the re-entry of the Chinese Shenzhou Long March rocket [8].

The November 28-29 event was a definite natural meteor. This brilliant bolide occurred at about 22^h10^m UT moving roughly northeast to southwest over the southern Irish Sea, but mostly over southeastern Ireland, from where sonic booms were reported near the town of Carlow, around 60 km southwest of Dublin. James Martin on the Isle of Man, some 175 km northeast of the meteor's end point, estimated the object as being magnitude -12 at least, low in his southwestern sky. Reports from the Carlow vicinity indicated the final brightness lit up the countryside like daylight, however, and houses were shaken as if a bomb had exploded nearby. This information, plus the object's probable trajectory, quickly suggested meteorites might have fallen, and a reward of up to 20 000 GBP was offered by a private meteorite collector in Scotland for any objects recovered. Despite this, it was only in mid-December that the first meteorites were found near the town of Leighlinbridge, County Carlow, and mid-January 2000 before they were identified as such. Four meteorites have now been confirmed, totaling about 271 g in weight, and classified by the Natural History Museum in London as being of L6 chondritic composition.

The final brilliant fireball in this spell was caught by the all-sky fireball cameras of *AKM* observers in Germany at five sites, making it the most widely-recorded single meteor in 1999 for the German team. A photograph of its trail appears in *Meteoros* 3:2 (2000), p. 27, captioned as indicating the event had an unusual light curve.

3. December

Early December brought the usual low rates of minor shower meteors for visual observers, with the majority of watching carried out during the first half of the month. The radio observers recorded no untoward events, with the minor $\lambda_\odot = 249°$–$250°$, $\lambda_\odot \approx 254°$, and $\lambda_\odot \approx 256°$ (December 2-3, 7, and 9) peaks from [6] all detected again by most systems. Half the available datasets showed the $\lambda_\odot \approx 256°$ peak extending to $\lambda_\odot \approx 257°$ again, as has been seen before. The $\lambda_\odot \approx 252°$ (December 5) peak first found in 1997 and recovered in 1998 [9] was only seen weakly in 40% of the data sets from 1999, but a comparably weak maximum was found in two other datasets around $\lambda_\odot = 251°$.

With moonlight favoring the Geminid maximum in mid-December, an especial concentration of effort centered around this time came from the visual observers. Reports are available for every night from December 6-7 to 15-16 except 11-12, allowing ZHRs to be computed, with the one missing night fortunately covered by the South-African results [5]. Mean ZHRs for each night are given in Table 2. Individual ZHRs of around or over 100 were recorded throughout the moonless (i.e., after midnight UT) part of December 13-14 through to the first half of December 14-15, but the highest rates were not observed, as these occurred around 17^h UT on December 14 [10]. In the radio data, the strongest echo peaks were found on December 14-15 ($\lambda_\odot \approx 263°$), as Figure 1 shows, but there was no clear evidence supporting a single peak time in the available results. Indeed, counts were almost as high in many reports the previous day as well. Geminid and December sporadic magnitude details are given in Table 3. Around 6% of Geminids (24/372.5 meteors) and 5% of sporadics (4/81.5 meteors) left persistent trains, though the paucity of train reports has prevented a fuller examination of these here.

Table 2 – Mean Geminid ZHRs and standard errors for each indicated night in December 1999, based on data from European and South-African sites. The inflated value for December 7-8 resulted from poor sky conditions, while, on December 11-12, only a single observer's data from South Africa was available (Cliff Turk—data in [5]).

Date	ZHR	Date	ZHR	Date	ZHR	Date	ZHR	Date	ZHR
Dec 6-7	6 ± 4	Dec 8- 9	4 ± 3	Dec 10-11	7 ± 1	Dec 12-13	34 ± 7	Dec 14-15	68 ± 11
Dec 7-8	12 ± 6	Dec 9-10	8 ± 2	Dec 11-12	17 ± 8	Dec 13-14	103 ± 10	Dec 15-16	10 ± 4

Table 3 – Global magnitude distributions, including mean limiting magnitudes and corrected mean magnitudes for the Geminids and December sporadics seen in good sky conditions.

Shower	-3^-	-2	-1	0	$+1$	$+2$	$+3$	$+4$	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
Geminids	9	6.5	11.5	43	59.5	74.5	98.5	50	20	372.5	5.7	2.81
Sporadics	1	1.5	1.5	3	5.5	11.5	21.5	22	14	81.5	5.7	3.78

Few visual watches were possible after the Geminid maximum, and the moonlit Ursid peak due on December 22-23 passed virtually unobserved except by radio. The weakness of the $\lambda_\odot = 269°–271°$ (December 21–23) period, though recorded at $\lambda_\odot \approx 269°$ in 70% of the radio data sets on-hand, was remarkable compared to past years, and strongly suggests the Ursids produced at best only a low, normal return in 1999. Both minor late-month radio peaks, around $\lambda_\odot = 272°–275°$ and $\lambda_\odot = 278°–279°$ (December 24–27 and 30–31) were detected much as in previous years, the former especially around $\lambda_\odot = 273°$, as last seen in 1997.

Acknowledgments

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BAA Observations of the 1999 Geminids: A Preliminary Report

Neil Bone

An overview is given of 1999 Geminid observations by members of the *British Astronomical Association (BAA)*.

BAA observers, mainly in the southern UK, enjoyed considerable success in visual coverage of the Geminids in 1999. As in other recent years, activity was excellent for several nights centered on the December 13-14 maximum.

Following the disappointment of missing the Leonid storm peak due to clouds and rain, observers in the UK fared rather better for the Geminids just a few weeks later. The southern half of the country appears to have been particularly favored. Clear skies followed heavy showers in the afternoon and evening on both December 12-13 and 13-14. Conditions were very cold, however, and, at some locations, reflection of street lighting from lying snow was a problem. Coverage was obtained on eight nights between December 6-7 and 15-16, inclusive. The bulk of reports come from December 12-13 and 13-14.

The Geminid maximum was expected around December 14, 1999, 10^{h} UT [1], after dawn for UK-based observers. It was anticipated that we would see rates rising towards the peak late on the night of December 13-14 with, perhaps, high rates early on December 14-15 declining as that night wore on. The waxing crescent Moon increasingly restricted evening observations from maximum night onwards, and the dark, post-midnight hours were to prove most fruitful.

The 43 observers listed below contributed $136^{\mathrm{h}}54^{\mathrm{m}}$ of visual watch time, amounting to 2524 meteors (447 sporadics, 2030 Geminids, and 47 others). Len Entwisle and Steve Evans also obtained some useful low-light video coverage.

> M. Adamson, M. Beales, S. Beaumont, J. Bingham, N. Bone, E. Boots, G. Boots, R. Bowen, K. Boyle, C. Bradley, P. Brierley, R. Bullen, P. Carter, L. Chatfield, S. Dobak, A. Drummond, R. Dymock, P. Dyson, L Entwisle, M. Flowers, K. Gwilliam, C. Hall, C. Heapy, J. Lang, J. Latham, H. McGee, S. Moore, N. Morrison, P. Phillips, A. Pratt, J. Shanklin, J. Smith (Canada), G. Spalding, P. Spence, M. Stephens, D. Swain, M. Taylor, P. Thomsett, C. Thomson, C. Turk (South Africa), A. Vincent, A. Wells, P. Yates, and Worthing AS.

Observations were analyzed as for previous reports [2–4] to obtain sporadic CHRs and sky- and radiant-altitude corrected Geminid ZHRs. As before, population index $r = 2.44$ was adopted in calculating Geminid ZHRs. Results are shown in Table 1.

As in recent past years, Geminid activity was already quite high by December 12-13, with ZHR of the order of 25–30. Highest activity was observed after midnight on December 13-14. In agreement with the earlier report by Rendtel [5], activity on the evening following maximum was still high. These results suggest that the Geminid maximum remains broad, with a long span of high activity to either side of the peak. In contrast with the well-observed maximum of 1996 [6], few bright Geminids were seen by UK observers in 1999. Our interval of highest activity came ahead of the shower peak, and was marked mainly by meteors in the magnitude range from +1 to +3. On December 13-14, only 12% of Geminids were of magnitude 0 or brighter. On December 14-15, however, 20% of Geminids fell into this brighter range. The relative increase in frequency of bright Geminids (indicative of particle mass-sorting in the steam) is well known, and has been thoroughly documented by Spalding [7] and others.

No fireballs were reported from the 1999 Geminid return, but a couple of bright meteors were perhaps noteworthy. A magnitude −4 Geminid was seen at December 13, $7^{\mathrm{h}}03^{\mathrm{m}}$ UT, by Paul Brierley in northwest England, and Mike Beales in Hertfordshire, just north of London. Another very fine Geminid was seen on December 14-15 at $22^{\mathrm{h}}35^{\mathrm{m}}$ UT by Roger Dymock in Hampshire and the author in Sussex, both on the south coast of England. This meteor ended in a terminal burst of magnitude −4 low in Eridanus, and left a 1-second persistent train.

Table 1 – Geminid ZHRs 1999; solar longitudes $\lambda_\odot$ refer to equinox J2000.0, CHR is the corrected sporadic rate, $h_{\rm R}$ is the altitude of the Geminid radiant.

1999 Dec (UT)	$\lambda_\odot$	$T_{\rm eff}$	lm	F	spo	CHR	Gem	$h_{\rm R}$	ZHR
Dec 07, $00^{\rm h}49^{\rm m}$	254°46	$1^{\rm h}50$	5.1	1.00	3	11.2 ± 6.5	2	63°0	5.2 ± 3.7
Dec 08, $00^{\rm h}02^{\rm m}$	255°45	$1^{\rm h}00$	5.4	1.00	6	23.2 ± 9.5	3	57°8	9.5 ± 5.5
Dec 08, $01^{\rm h}25^{\rm m}$	255°51	$1^{\rm h}25$	5.2	1.00	7	27.7 ± 10.5	5	67°2	13.8 ± 6.2
Dec 08, $03^{\rm h}43^{\rm m}$	255°61	$1^{\rm h}25$	6.1	1.00	8	10.5 ± 3.7	1	66°5	1.2 ± 1.2
Dec 08, $04^{\rm h}50^{\rm m}$	255°65	$1^{\rm h}00$	6.1	1.00	5	8.2 ± 3.7	1	57°9	1.7 ± 1.7
Dec 08, $23^{\rm h}05^{\rm m}$	256°43	$1^{\rm h}00$	5.4	1.00	3	11.6 ± 6.7	1	49°9	3.5 ± 3.5
Dec 09, $03^{\rm h}25^{\rm m}$	256°61	$1^{\rm h}75$	6.4	1.00	12	7.8 ± 2.3	7	67°9	4.7 ± 1.8
Dec 09, $04^{\rm h}45^{\rm m}$	256°67	$1^{\rm h}00$	6.4	1.00	10	11.3 ± 3.6	1	58°0	1.3 ± 1.3
Dec 12, $20^{\rm h}38^{\rm m}$	260°39	$1^{\rm h}00$	5.0	1.00	4	25.3 ± 12.6	4	29°8	30.7 ± 15.3
Dec 12, $22^{\rm h}13^{\rm m}$	260°45	$2^{\rm h}00$	5.4	1.09	5	10.5 ± 4.7	16	44°3	33.3 ± 8.3
Dec 12, $23^{\rm h}25^{\rm m}$	260°50	$3^{\rm h}00$	5.7	1.00	10	8.9 ± 2.8	29	55°3	24.0 ± 4.5
Dec 13, $00^{\rm h}32^{\rm m}$	260°55	$3^{\rm h}00$	5.7	1.00	8	6.3 ± 2.2	30	64°4	22.6 ± 4.1
Dec 13, $01^{\rm h}22^{\rm m}$	260°59	$1^{\rm h}00$	5.2	1.00	3	14.8 ± 8.5	15	69°3	51.1 ± 13.2
Dec 13, $02^{\rm h}34^{\rm m}$	260°64	$1^{\rm h}50$	5.25	1.00	6	18.6 ± 7.6	16	70°4	34.5 ± 8.6
Dec 13, $03^{\rm h}27^{\rm m}$	260°68	$3^{\rm h}00$	5.83	1.00	17	12.9 ± 3.1	45	66°1	29.8 ± 4.4
Dec 13, $04^{\rm h}23^{\rm m}$	260°72	$2^{\rm h}67$	5.83	1.00	26	22.2 ± 4.4	42	58°9	33.4 ± 5.2
Dec 13, $05^{\rm h}30^{\rm m}$	260°76	$1^{\rm h}00$	6.0	1.00	9	16.6 ± 5.5	14	49°0	29.0 ± 7.8
Dec 14,$00^{\rm h}30^{\rm m}$	261°57	$1^{\rm h}00$	5.5	1.00	5	17.1 ± 7.6	37	64°6	99.9 ± 16.4
Dec 14, $01^{\rm h}32^{\rm m}$	261°61	$5^{\rm h}25$	5.47	1.10	19	14.1 ± 3.2	169	70°2	94.3 ± 7.3
Dec 14, $02^{\rm h}28^{\rm m}$	261°65	$4^{\rm h}10$	5.6	1.05	20	15.5 ± 3.5	131	71°4	79.0 ± 6.9
Dec 14, $03^{\rm h}36^{\rm m}$	261°70	$5^{\rm h}00$	5.46	1.05	10	7.5 ± 2.4	164	63°9	97.0 ± 7.6
Dec 14, $04^{\rm h}34^{\rm m}$	261°74	$5^{\rm h}47$	5.52	1.04	21	13.3 ± 2.9	147	56°4	80.4 ± 6.6
Dec 14, $05^{\rm h}53^{\rm m}$	261°80	$2^{\rm h}00$	5.0	1.00	5	15.8 ± 7.1	34	44°7	92.1 ± 15.8
Dec 14, $22^{\rm h}28^{\rm m}$	262°50	$2^{\rm h}00$	5.25	1.00	0	0	37	47°9	76.0 ± 12.5
Dec 14, $23^{\rm h}25^{\rm m}$	262°54	$1^{\rm h}00$	5.5	1.00	3	10.3 ± 5.9	25	56°7	73.0 ± 14.6
Dec 15, $00^{\rm h}56^{\rm m}$	262°60	$1^{\rm h}00$	6.0	1.00	3	5.5 ± 3.2	21	67°0	35.6 ± 7.7
Dec 15, $01^{\rm h}45^{\rm m}$	262°64	$1^{\rm h}00$	5.5	1.00	1	3.4 ± 3.4	16	68°6	41.9 ± 10.4
Dec 15, $02^{\rm h}10^{\rm m}$	262°66	$1^{\rm h}00$	6.4	1.20	4	5.4 ± 2.7	33	70°9	45.8 ± 8.0
Dec 15, $03^{\rm h}11^{\rm m}$	262°70	$2^{\rm h}00$	5.85	1.16	9	11.6 ± 3.9	39	66°2	44.1 ± 7.1
Dec 15, $06^{\rm h}20^{\rm m}$	262°83	$1^{\rm h}33$	6.0	1.00	1	1.4 ± 1.4	8	40°2	14.6 ± 5.2
Dec 15, $23^{\rm h}39^{\rm m}$	263°57	$2^{\rm h}16$	5.6	1.09	3	4.6 ± 2.7	7	59°0	9.2 ± 3.5
Dec 16, $05^{\rm h}37^{\rm m}$	263°82	$1^{\rm h}75$	5.8	1.00	15	20.3 ± 5.2	3	46°1	4.4 ± 2.2

Persistent trains were left by 3.5% of Geminids overall, compared with 7.7% of sporadics.

For many seasoned *BAA* observers, the excellent Geminid return of 1999 came as some sort of compensation at the end of a year in which they had missed the total solar eclipse, Perseid maximum, and the Leonid storm—all due to clouds. The 2001 return of the shower, with peak over western European longitudes under moonless skies, is eagerly anticipated!

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