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Atmospheric trajectories and light curves of the 2000 Leonid meteors

By

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Abstract: During the high activity of the Leonid meteor shower on the night 2000 November 17./18., the observations were carried out by an international team in Spain. The results of the double station video experiment are presented here. Almost 400 meteors were recorded, 180 of them on both stations. This count includes 110 Leonid meteors. Light curves and atmospheric trajectories of 90 Leonids were used for the purpose of the analysis.

1. OBSERVATION AND DATA PROCESSING

The observation were made at Curica and Lucainena de las Torres stations (see Table 1). Videocameras Panasonic S-VHS, second generation image intensifiers Dedal 41 and Arsat lenses 1.4/50 mm were used. The field of view of this configuration is about 25°. Moreover Lucainena station was equipped with another videocamera and second generation intensifier with lens 1.8/28 mm giving field of view 36°.

The obtained records stored on the S-VHS tapes were inspected by a human and digitalized with a PC framegrabber. Each meteor was then measured by an original software MetPhoto (Koten 2002). Subsequent trajectory computation was done by means of standard procedures.

For each meteor, the light curve was constructed as dependence of meteor brightness on its photometric mass. Integration of the meteor light curve results in the photometric mass of meteoroid. Meteors studied within this work cover range of masses from 0.1 to 10 mg.

2. DATA ANALYSIS

Only full or almost full light curves were used for the purpose of the analysis. The analysis was done in two ways:

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Table 1: Double station video experiment.

	Lucainena	Curica
longitude	357°46′1.6″	357°34′6.2″
latitude	37°02′13.7″	37°51′26.6″
height above sea level	707 m	1007 m
stations distance	92.7 km	
azimuth of southern station	349°	

1. the shape of the meteor light curve
2. the meteor height data

2.1 Light curves

The meteor light curve shape is described by the set of **F-parameters** (Fleming et al. 1993):

$$F_{\Delta M} = \frac{H_{B\Delta M} - H_{max}}{H_{B\Delta M} - H_{E\Delta M}}$$

where ΔM = 0.25, 0.5, 0.75, 1.00, ... 2.5, 2.75, 3.0. $H_{B\Delta M}$ and $H_{E\Delta M}$ are heights, where the meteor brightness is $M_{max} - \Delta M$ and M_{max} is the maximum brightness.

Table 2 shows results for several values of ΔM. Some meteors do not cover whole range of ΔM, because they are too faint. So not only the average F-values for each meteor are given, but also the values for $\Delta M = 0.25$, $\Delta M = 0.50$ and $\Delta M = 1.00$.

Table 2: The results of the light curves shapes analysis.

	meteors	range of F	average F
$F_{\Delta M=0.25}$	71	0.22 – 0.77	0.52±0.02
$F_{\Delta M=0.50}$	60	0.27 – 0.76	0.54±0.02
$F_{\Delta M=1.00}$	48	0.28 – 0.74	0.52±0.01
average F	71	0.23 – 0.75	0.53±0.02

Although there is a very broad range of F-values, the values for many meteors are concentrated in more narrow interval as shown in the bottom plot in Fig. 1. For example, for 58 of 71 meteors (e.i. 81.7%) the average F-value lies between 0.40 and 0.68, with $\overline{F} = 0.55 \pm 0.02$. Generally, we can conclude that the light curves of Leonids 2000 tend to be symmetrical, with the point of maximum light displaced slightly to the end of the luminous trajectory.

Recently, similar analysis was made for Leonids 1998 and 1999 (Koten & Borovička 2001). Comparison of the results is given in Table 3 and in Fig. 1. Both the table and the figure show that the value of F in 2000 is larger than those found for meteors observed in 1998 and 1999 and the range of F observed is lower than in previous years. Previously, we explained difference between 1998 and 1999 due different time of the meteoroid exposure to the harsh space environment. We supposed that meteoroids, which were exposed longer time, are more porous and fragile, so their light curves are skewed more to the beginning of the luminous trajectory, what results in smaller parameter F. But the last finding does not confirm such

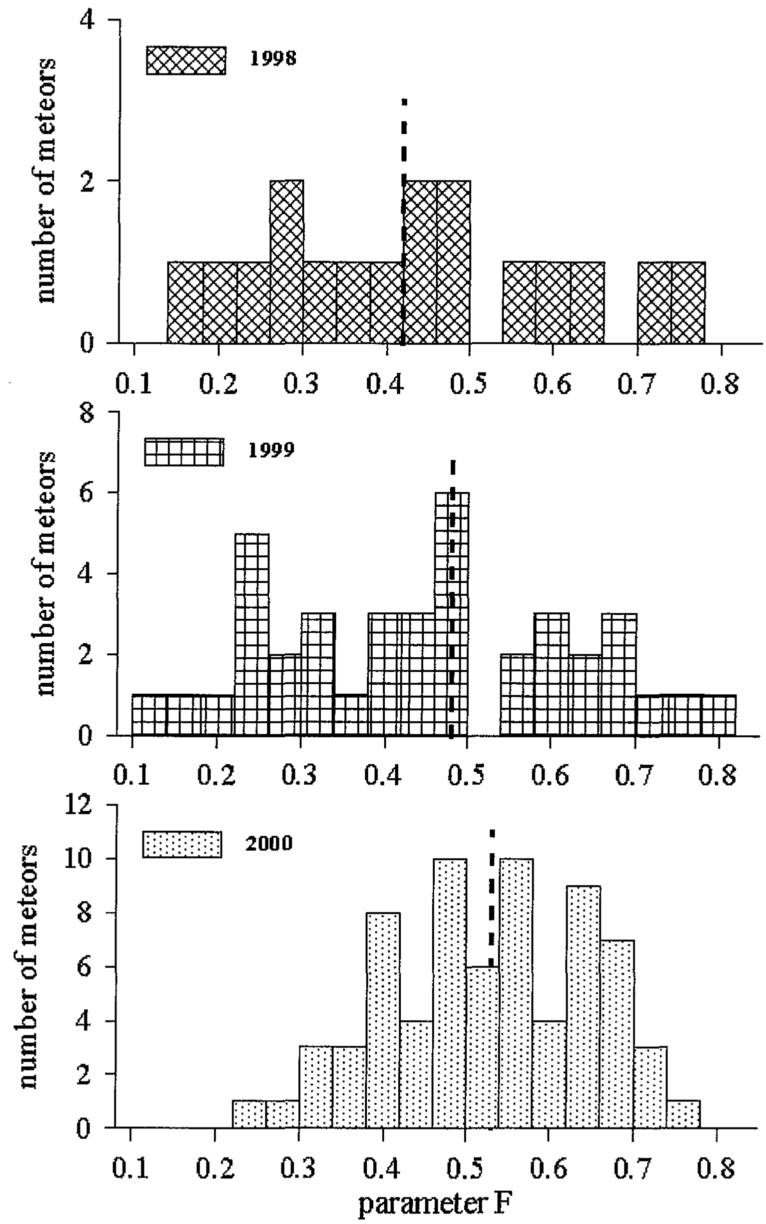

Fig. 1: The distribution of F-values for years 1998 (top), 1999 (middle) and 2000 (bottom). Dashed lines show the average values of F.

assumption. Meteoroids ejected eight comet revolutions ago produced meteors with higher value of the parameter F than younger meteoroids. Moreover, we do not exactly know how old were particles observed as meteors in 1998. Probably they originated from few last perihelion passages of the parent comet. It seems therefore that fresher meteoroids are more fragile.

Results comparable with previous years are obtained if we plot the average F-value against the photometric mass of meteor (Fig. 2). The lack of meteors in the lower right part is obvious. Larger meteoroids tend to create light curves skewed to the end of the luminous trajectory. This result was found for years 1998 and 1999, too.

Table 3: The comparison of the light curves of Leonids 1998, 1999 and 2000.

year	1998	1999	2000
number of meteors	20	46	71
revolution	1-2 ?	3	8
average F	0.42±0.05	0.48±0.03	0.53±0.02

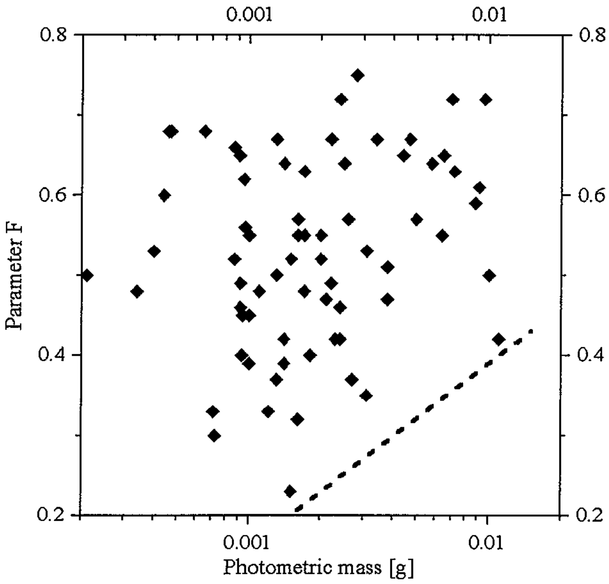

Fig. 2: This plot of the parameter F against the photometric mass of meteor shows the lack of meteors in the lower right part.

2.2 Heights of meteor

The previous findings are in good agreement with the height data analysis. The atmospheric trajectory was computed for each meteor, so we can study beginning height, height of the maximum light and terminal height in dependence on the meteor photometric mass. Thus the comparison with the dust-ball model (Hawkes & Jones 1975) could be done. Simple plot of these heights is shown in Fig. 3.

In comparison with previous years, this simple plot is more illustrative and we can easily recognize dependence of the beginning height on the photometric mass. With increasing photometric mass the beginning height increases, too. One may suspect that it could be an instrumental effect. For more detailed investigation we constructed plots of beginning distance from station vs. photometric mass, beginning height vs. beginning distance, beginning height vs. zenith distance of the beginning and beginning height vs. zenith distance of the radiant. None of these plots shows any indication of dependence, so we conclude that the dependance of beginning height on photometric mass is real. This dependance is not in agreement with the dust-ball model of meteoroids, which predicts constant beginning height of meteors (Hawkes & Jones 1975). Nevertheless, we found similar behaviour in our recent work

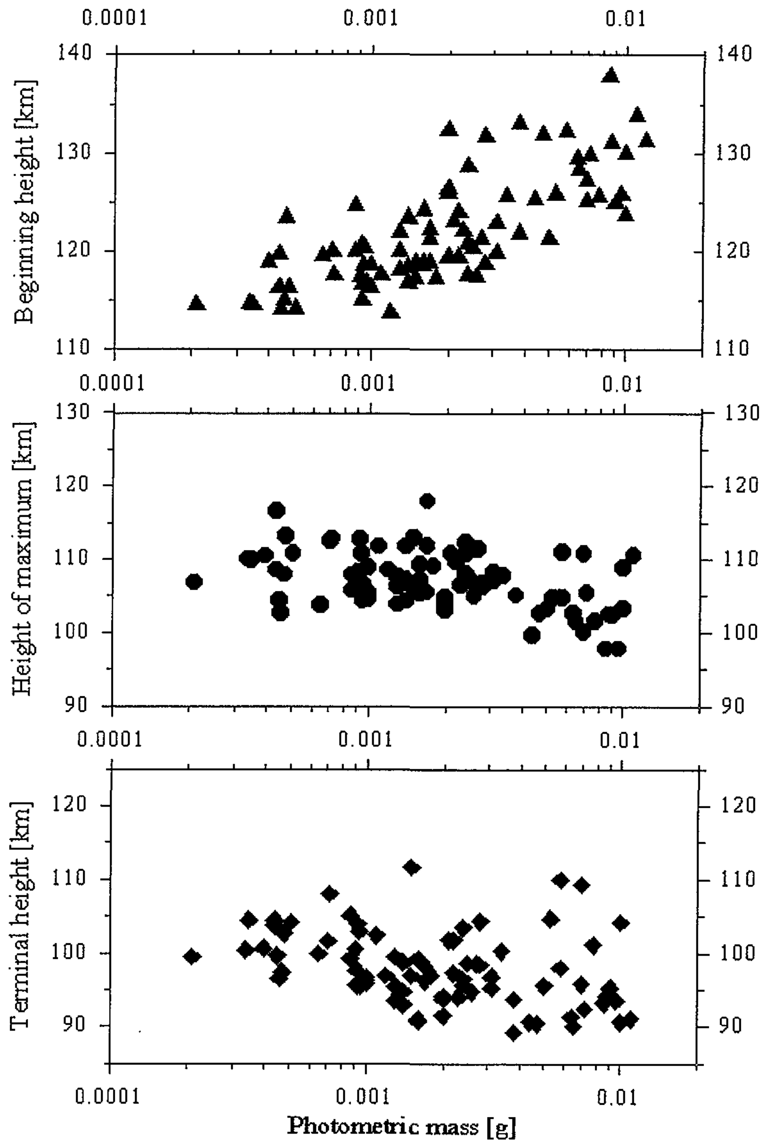

Fig. 3: Beginning height (top), height of maximum light (middle) and terminal height (bottom) as function of meteor photometric mass.

(Koten & Borovička 2001) also for other high velocity meteor showers.

Despite the beginning height disagreement, the height of maximum light and the terminal height show the behaviour predicted by the model. These heights are almost constant approximately up to the value of the photometric mass $m_p = 2\ \mu g$. For higher masses they decrease with increasing mass.

Recently, meteors with beginning heights up to 200 km were found (Spurny et al. 2001). Within this work we found other five meteors that start they luminous trajectories higher than 140 km above the ground. The largest beginning height is almost 180 km. The list of them is given in Table 4. The peculiarity of these meteors is evident from Fig. 4, where they are compared with ordinary Leonids. It should be note, however, that all meteors with high

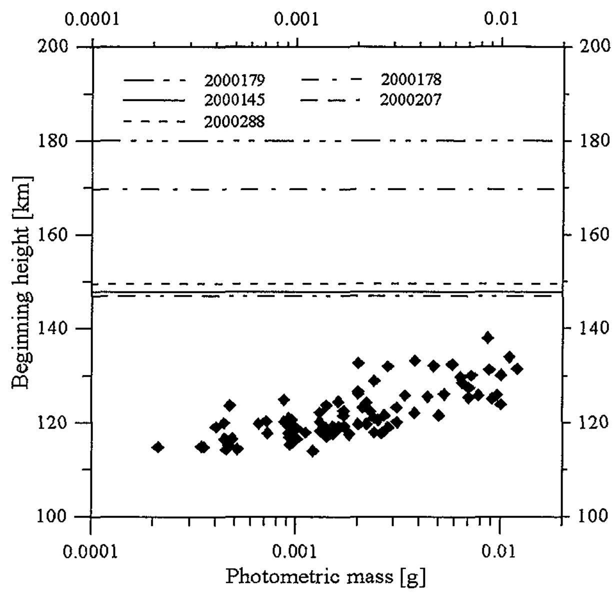

Fig. 4: Beginning height of five exceptional meteors as compared with beginning heights of the ordinary meteors. Only the height levels are marked because we do not know masses of these meteors. All of them leave field of view of our cameras.

beginning were probably quite bright with photometric masses of 0.1 g or more.

Table 4: List of meteors with beginning height above 140 km. All of them were observed on November 18, 2000.

meteor	time [UT]	beginning height [km]
2000145	3:08:03	147.9
2000178	3:29:34	169.7
2000179	3:30:07	179.9
2000207	3:46:31	147.8
2000288	4:55:29	149.4

3. CONCLUSIONS

The light curves and the atmospherical trajectories of 2000 Leonid meteors were studied and compared with meteors belonging to other Leonid filaments recorded during previous years. For all studied years we found that the light curve shapes vary very much from meteor to meteor. Nevertheless, differences in average shapes for each year are significant. Light curves of 2000 Leonids produced by meteoroids ejected from the parent comet eight revolution ago are skewed slightly to the end of the luminous trajectory, whereas the younger meteoroids produced light curves with maximum brightness point located before the middle of the trajectory. This implicates probably the most important finding this work, that the light curve shape described by means of the parameter F is not proportional to the time of the meteoroid exposure to the space environment.

Another interesting result come out from the height analysis. For all Leonid filaments we found that beginning height is increasing with increasing photometric mass. It seems that this properties is common for all shower with cometary origin. Heights of maximum brightness and end of luminous trajectory show behaviour which agrees with the dust-ball model predictions.

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