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The Leonid meteor shower 1996-2002: Results from forward-scatter radio observations

V. Porubčan([1])([2]), A. Hajduk([2]), G. Cevolani([3]) and G. Pupillo ([3])([4])

([1]) *Astronomical Institute FMPI Comenius University - 842 48 Bratislava, Slovakia*
([2]) *Astronomical Institute of the Slovak Academy of Sciences - 845 04 Bratislava, Slovakia*
([3]) *CNR-ISAC - via Gobetti 101, 40129 Bologna, Italy*
([4]) *DET, Università di Firenze - 50100 Firenze*
Osservatorio di Campi Salentina - 73012 Lecce, Italy

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Summary. — Results from the observations of the Leonid meteor shower in 1996-2002 by the BLM (Bologna-Lecce-Modra) forward-scatter radio system for meteor observation carried out along two baselines, Bologna-Lecce (Italy) and Bologna-Modra (Slovakia), are presented and discussed. The activity curves of long-duration echoes ($\geq$ 8 s) and their variations indicate multiple peak activity which are attributed to filamentary structure of the stream. The mass distribution exponent s in the period of the shower maximum shows significant changes in individual years, with a high contribution of larger particles chiefly in 1998.

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1. – The BLM forward-scatter system for meteor observation

Since September 1996, there has been operating a forward-scatter system for meteor observations, where a radio signal is transmitted along two mutually almost rectangular baselines. The transmitter is located at Budrio near Bologna (44.6°N; 11.5°E, Italy) and two receivers at Lecce (40.3°N; 18.2°E, Italy) and Modra (48.4°N; 17.3°E, Slovakia)— BLM. The system was built up for monitoring meteor activity, to study meteor flux from different baselines directions. The equipment utilizes a continuous wave transmitting frequency at 42.7 MHz, a fixed modulating tone at 1 kHz and 0.25 kW mean power transmitted in the direction of both receiving stations. The baseline distances between the transmitter and receivers are: Bologna-Lecce of 700 km (azimuth 307°) and Bologna-Modra of 590 km (azimuth 224°). Details about the equipment can be found elsewhere [1].

2. – Observations of the Leonid meteor shower in 1996-2002

The Leonids were observed by the equipment already in 1995 (Nov. 14-21), however, along the baseline Bologna-Lecce only as a test observation. Since 1996, the transmission has been carried out in both directions, so the data are recorded by both receivers and the shower was monitored each year almost regularly in the interval Nov. 10-24.

From the studies of echo counts provided by the BLM forward-scatter system it is apparent that a shower activity can be clearly recognized only for echoes of longer duration. In the counts of all echoes, shower echoes are almost completely covered by sporadic background echoes. This trend is observed also in the data from all years of the observation of the Leonids. Therefore, in the present study, the Leonid activity curves were derived only for long-duration echoes of duration ≥ 8 s. Shower activity was obtained by subtracting sporadic background counts from all echo counts (shower and sporadic) in corresponding hours. The Leonid activity curves (echoes ≥ 8 s) corrected for the radiant elevation were obtained by combining data from both stations: Lecce and Modra (fig. 1).

According to the 1996 data the shower echoes exhibit a rather flat maximum on Nov. 17 lasting for about 10-11 h (solar longitude 235.0°-235.4°, equinox 2000.0), with at least two peaks (235.23° and 235.29°). Though not so pronounced, the peaks are well consistent with the observations by the Ondřejov backscatter radar (235.20° and 235.32° [2]). Visual observations yield a peak at 235.17° (short-lived and richer in fainter meteors).

The 1997 Leonid activity curve indicates an apparent increase in the activity until 09:00-09:30 UT, Nov. 17 (solar longitude 235.1°), with some smaller enhancements in between. The 1997 Leonid maximum could not be observed by the BLM system due to the shower radiant being just on the horizon at the time of the peak itself. According to visual observations the maximum appeared on Nov. 17, 12:15 UT (solar longitude 235.22°) and an increased Leonid activity was observed in the interval 235.0°-236.0° [3].

The 1998 Leonids with a large number of bright bolides observed on Nov. 16/17 were for meteor observers a very impressive observational event. The counts of echoes observed by the BLM system show a very broad maximum, however, due to overlapping long-duration echoes the peak itself could not be recorded. At least two secondary peaks at 234.48° and 234.84° are apparent. These peaks were recorded also by the backscatter radar at Ondřejov for echoes of duration > 10 s, showing a broad maximum (234.6°-234.7°) with at least three secondary peaks [4]. The event was recorded also by the photographic all-sky cameras at Modra Observatory (receiving station of the BLM system) [5]. Visual observations confirmed a very broad component of the 1998 Leonid fireballs with a peak between 234.4°-235.0° [6].

In 1999 the BLM forward-scatter observations show a pronounced maximum at 235.28° which is consistent with other radar and visual observations. The backscatter radar (Ondrejov) show the Leonid activity peak for 235.285° with prevailing fainter echoes [4]. The 1999 Leonids had only one distinct peak, which was at the same time the main outburst of the Leonids in this return of the parent comet to the Sun, displaying a meteor storm activity with the ZHR = 3700 on Nov. 18, 02:02 UT (solar longitude 235.285°) [7]. According to TV observations [8] the most prominent peaks appeared on Nov. 18 at 01:58 and 02:11 UT.

In 2000 the BLM observations show a multiple peak activity (236.10°, 236.19° and 236.25°). The peaks at 236.1° and 236.25° are consistent with visual results [9] and are close to the predicted time of the dust trail of the 1733 and 1866 perihelion passages of the Leonid parent comet, respectively [10].

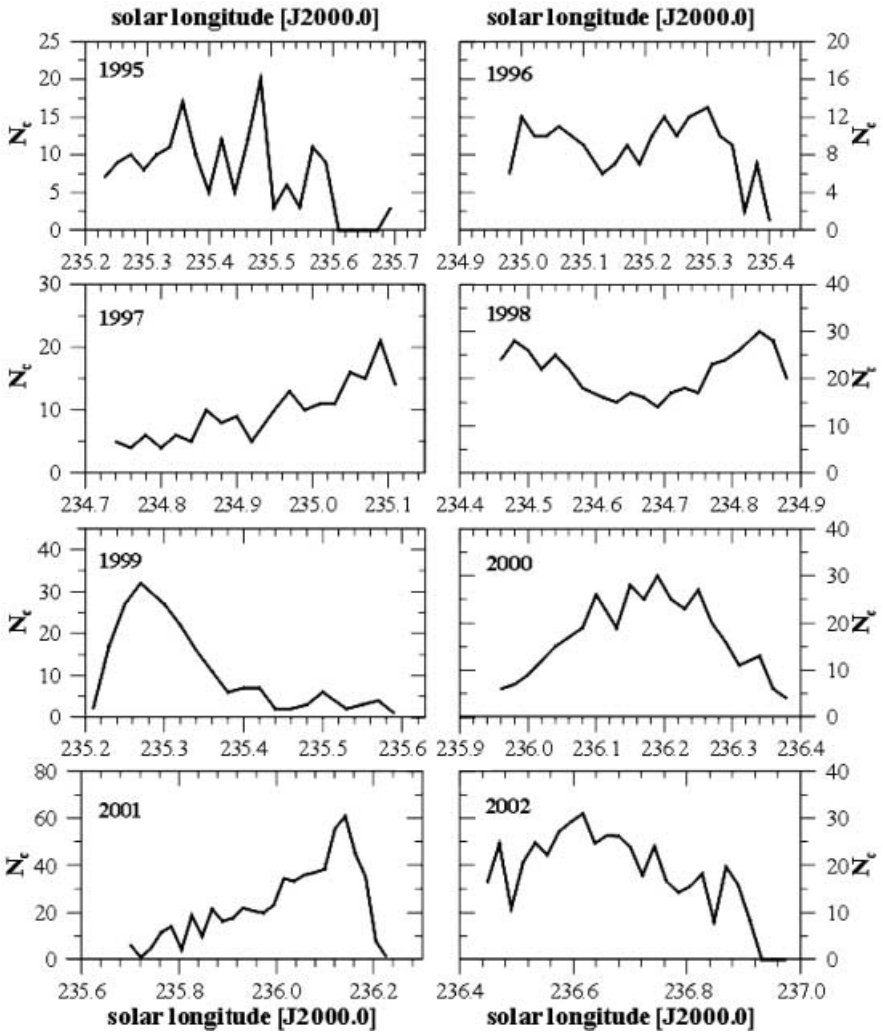

Fig. 1. – Counts of Leonid meteor shower echoes of duration ≥ 8 s in 30 minute intervals observed by the BLM forward-scatter radio system in 1996-2002. The curves represent the mean values of the data from Lecce and Modra. The 1995 curve is a test observation from Lecce.

The Leonids 2001 and 2002 were exceptional events for meteor observers again. In 2001 the BLM observations provide a distinct peak of the shower at solar longitude 236.13°. The peak was confirmed as well as by the Ondrejov backscatter radar so by visual observers. Visual data give two high activity peaks at 236.14° and 236.46° [11]. The second peak (Nov. 18, 18:16 UT) could not be recorded by the BLM system as the shower radiant was below horizon. The Leonids in 2002 showed two high maxima both from visual observation displaying ZHR over 2500 at solar longitudes 236.62° and 236.89° [12]. The BLM observations give the position of the peaks at 236.62° and 236.85°, respectively. The second peak is less pronounced due to relatively low elevation of the shower radiant at the peak.

TABLE I. – *The mass exponent s derived for the Leonids (sh) observed in 1995-2002 and sporadic (sp) meteors (M—Modra, L—Lecce, O—Ondřejov).*

Year	M-sp	L-sp	M-sh	L-sh	O-sh	visual-sh
1995	-	2.34	-	1.69	-	1.6 [13]
1996	2.22	2.32	1.63	1.50	-	1.65 [2]
1997	2.38	2.71	1.64	1.61	-	1.7 [3]
1998	2.32	2.67	1.20	1.15	1.23 [4]	1.3 [6]
1999	2.23	2.25	1.56	1.52	1.58 [4]	1.8 [7]
2000	2.44	2.28	1.84	1.56	-	1.8 [9]
2001	2.26	(2.10)	1.49	1.52	-	1.8 [11]
2002	2.40	(2.21)	1.55	(1.38)	-	1.9 [14]

3. – Mass exponent

The FS data from the BLM system enable derive the mass distribution exponent of the shower and sporadic meteor echoes from the observed echo durations. The mass distribution exponent s was derived from the cumulative numbers of echo duration considering diffusion for dominant process of an echo decay in the form [15]

$$\log N_c = \left(-\frac{3}{4}\right)(s-1)\log T_D + \text{const}, \tag{1}$$

where N_c is the cumulative number of echoes with the duration equal to and greater than T_D.

The values of s in individual years were obtained as the mean values from the period of the shower maximum (approx. 12 h) and the corresponding sporadic background. The mass exponent values derived for each station separately are listed in table I (M—Modra, L—Lecce) and are compared with those obtained from other radar (O—Ondřejov) and visual observations (referring mostly to the narrow peaks of the Leonid shower activity). The Lecce values for 2001 and 2002 listed in brackets could be derived only from not complete periods or are influenced by interferences and thus are of lower weight.

4. – Conclusions

The observations of the Leonids by the Bologna-Lecce-Modra forward-scatter system in 1996-2002 were analysed and the activity curves of long-duration echoes (≥ 8 s) were derived. The activity curves indicate multiple peak structure especially in 1996, 1998, 2000 and 2002, which is attributed to a filamentary structure of the stream. The analysis of the mass distribution s of meteoroids within the stream indicate a decrease of s with the approaching parent comet of the stream to perihelion and an increase after its passage in 1998. The lowest value of s was observed in 1998 and the derived results are consistent with the results obtained by other techniques.

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