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The Lyrid meteor stream: Activity and mass distribution

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Summary. — Observations of the Lyrid meteor shower in 1997-2005 by a forward-scatter radio system for meteor observation operating simultaneously along two baselines, Bologna-Lecce (Italy) and Bologna-Modra (Slovakia), are analysed and discussed. The activity curves of long-duration echoes (≥ 8 s) and their variations indicate a complex structure of the stream. The Earth crosses the stream at a half maximum rate level in about two days. The overall activity peak derived from all observed returns is at solar longitude 32.30° (eq. 2000.0). The mass distribution exponent s and its variations in the period of the shower maximum indicate a relatively stable population of meteoroids in the stream exhibiting filamentary structure.

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PACS 95.85.Bh – Radio, microwave (> 1 mm).

1. – Introduction

The Lyrid meteor shower ranks among regular annual meteor showers active for about one week of the second half of April in most years with a fairly low visual rate about 10-15 meteors per hour at maximum on April 21-22. The shower radiant derived from photographic observations has the right ascension $\alpha = 272.0°$ and the declination $\delta = 33.3°$ at solar longitude 31.8° (equinox: 1950.0) [1]. The parent of the stream is C/1861 G1 (Thatcher), which is the comet with the longest period of revolution ($P = 415$ years) having a known meteoroid stream. The Lyrids occasionally exhibit enhanced activity maxima, the last one in 1982 with the visual Zenithal Hourly Rate (ZHR) of about 250 meteors [2].

References to the shower activity are infrequent, most are concerned with individual years. The longest series of Lyrid observations analyzed so far are eighteen returns (over a period of thirty years) of the stream observed by meteor radars in Springhill, Canada

(1958-1967) and Ondřejov, Czechoslovakia (1980-1987) giving the width of the rate profile at half-amplitude 1.5 days and maximum for solar longitude $31.5^\circ \pm 0.05$ (eq. 1950.0) [3].

The first test observations of the Lyrids by the BLM (Bologna-Lecce-Modra) forward-scatter system were acquired in 1992, however, along the Budrio-Lecce baseline only. Regular simultaneous observations of the shower along both the baselines started in 1996. The shower was almost regularly monitored in the period April 18-25.

The present paper presents observations of the Lyrid shower observed in nine returns of the stream (1997-2005) obtained by a forward-scatter system operating along two baselines Budrio (44.6ºN; 11.5°E, Italy)-Lecce (40.3°N; 18.2°E, Italy) and Budrio-Modra (48.4°N; 17.3°E, Slovakia). In the paper an analysis of activity and mass distribution of meteoroids in the stream are presented and discussed.

2. – Lyrids in 1997-2005

2˙1. *Equipment.* – Since September 1996, there has been operating over Italy and Slovakia a forward-scatter system for meteor observations, with a radio signal transmitted along two mutually almost rectangular baselines. The transmitter is located at Budrio (44.6°N; 11.5°E, Italy) near Bologna and receivers are at Lecce (40.3°N; 18.2°E, Italy) and Modra (48.4°N; 17.3°E, Slovakia). The BLM system was built up for a systematic monitoring of meteor activity in order to study meteor flux from different baselines directions and study the structure and potential sources of the population in a close surrounding of the Earth's orbit.

The equipment utilizes a continuous wave transmitting frequency at 42.77 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 system and its operation have been published by Cevolani *et al.* [4].

2˙2. *Activity.* – Earlier analyses of activity of meteor showers observed by the BLM exhibit that shower echoes can be clearly recognized from sporadic background echoes by the system only for overdense echoes [5]. In all echo counts shower echoes are very frequently almost entirely overlapped by sporadic echoes. Therefore, for the present analysis the shower activity was derived for echoes of duration ≥ 8 s and was calculated by subtracting sporadic echoes counts from all echoes counts in corresponding hours. For sporadic the days were taken well off the shower maximum and whenever it was possible the sporadic background is the mean value relative to two days (one before and one after the peak of the shower activity).

2˙3. *Mass distribution exponent.* – The mass distribution exponent s was derived from cumulative echo counts of partitioned in different echo duration groups, considering the ambipolar diffusion for dominant process of an echo decay, using the known formula derived by Kaiser [6] in the form

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

where N_{c} is the cumulative number of echoes with the duration equal to or greater than T_D.

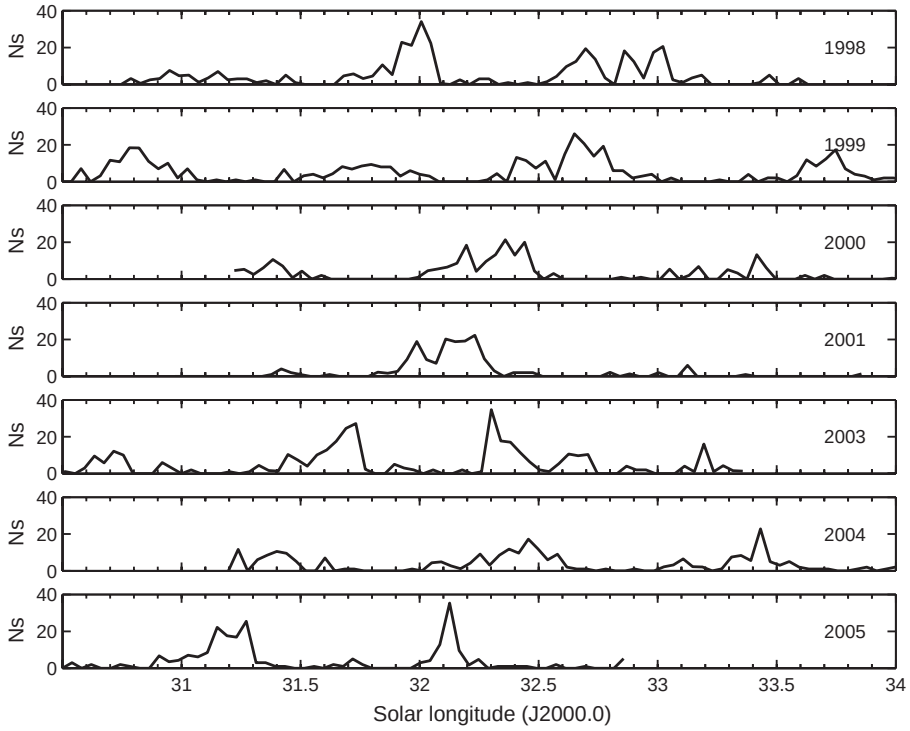

Fig. 1. – Counts of the Lyrid meteor shower echoes of duration $\geq$ 8 s in one-hour intervals observed by the BLM forward-scatter radio system in Lecce in 1998-2005.

The mass exponent was found by a solution of a least-squares fit of 13 echo duration subsets equidistantly distributed in a logarithmic scale in the 1–20 s duration interval. The exponents for shower echoes (s_{sh}) and for sporadic echoes (s_{sp}) have been calculated on 6 h time intervals centered on the peak of the shower activity and on the sporadic background activity, respectively.

2˙4. *Results*. – The activity curves of the Lyrids corrected for the zenith distance of the shower radiant, derived for three days around the maximum of activity separately for both receiving stations (Lecce and Modra) and depicted in hourly shower echo counts are shown in figs. 1 and 2. The Lyrid radiant ($\alpha = 272°$, $\delta = 33°$) culminates at 04:05 LT and is above horizon for the Northern mid-latitude sites for about 18 hours. The observed solar longitudes of the shower maxima (eq. 2000.0) are listed in table I. Only the echo counts for which the shower radiant elevation was $h \geq 20°$ are in the depicted plots. Large correction for the radiant elevation below 20° can result in unreal distorted hourly echo counts. As shown in figs. 1 and 2 the echo counts observed in Modra until 2000 are systematically lower than those observed in Lecce. This was due to a lower sensitivity of the Modra receiver with respect to the Lecce one.

Table I lists also the values of s derived separately for the shower and sporadic meteors at both receiving stations.

In 1997 Lyrids were observed in direction to Modra and the observed maximum is rather flat with two peaks at 32.17° and 32.30° (higher one). The mass exponent derived

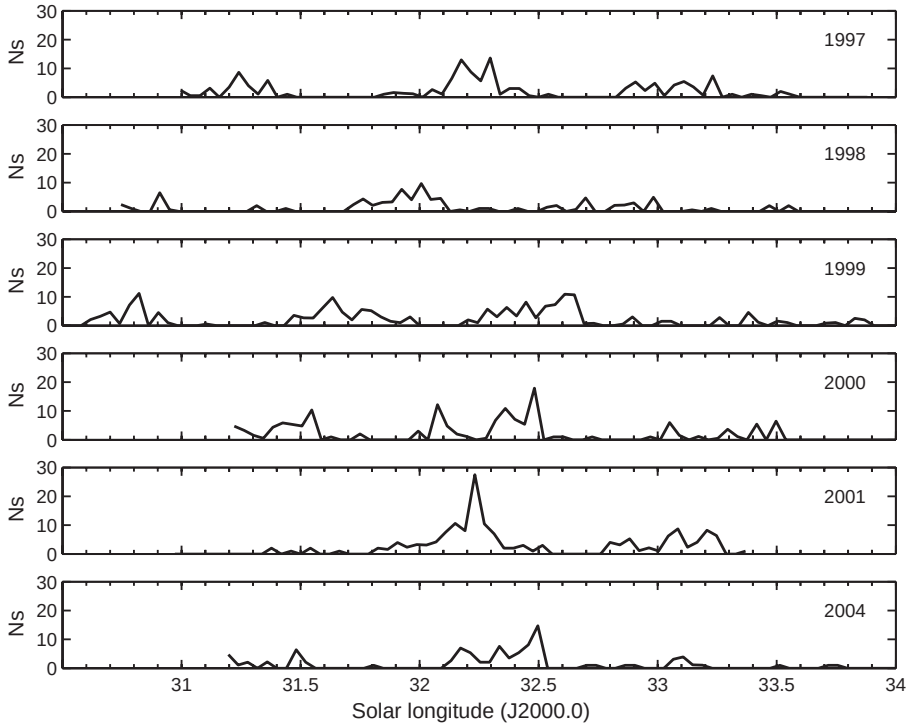

Fig. 2. – Counts of the Lyrid meteor shower echoes of duration $\geq$ 8 s in one-hour intervals observed by the BLM forward-scatter radio system in Modra in 1997-2004.

for the period of 6 hours around the peak $s = 1.96$ and the value for sporadic background due to low number of echoes is uncertain (in brackets).

In the next four years 1998-2001 the observations were carried out along both baselines and positions of the Lyrid maxima found separately for Lecce and Modra are consistent (table I). The only deviation is observed for the year 2000 when the difference in the

TABLE I. – *The maxima of activity and mass distribution exponent s of the Lyrid meteor shower (sh) observed by the BLM forward-scatter radio system in 1997-2005 and sporadic (sp) meteors (L—Lecce, M—Modra). Values in brackets are due to low numbers of uncertain echoes.*

Year	Lecce (eq. 2000.0)	Modra (eq. 2000.0)	s_{sh} L	s_{sh} M	s_{sp} L	s_{sp} M
1997	-	32.30°	-	1.96	-	(2.71)
1998	32.01°	32.01°	1.87	1.71	2.59	2.51
1999	32.65°	32.62°	2.16	2.18	2.47	2.64
2000	32.36°	32.48°	2.05	1.65	2.65	2.74
2001	32.23°	32.23°	2.28	-	2.42	-
2003	32.30°	-	2.15	-	(2.18)	-
2004	(32.46°)	32.50°	-	2.01	-	2.77
2005	32.13°	-	1.80	-	2.14	-

maxima observed at the two stations is 0.12° (32.36° for Lecce and 32.48° for Modra) corresponding to about 2.9 h. This shift in maxima between relatively close stations may indicate existence of very narrow filaments in the stream consisting of populations of particles of different sizes [7]. This can be inferred also from the different values of the mass exponent s between both receivers for the peaks of activity (2.0 and 1.65 for Lecce and Modra, respectively). The peak observed at Modra was composed predominately of larger particles. The corresponding sporadic background values of s (2.65 and 2.74) are at the same time in comparison with the differences in the shower values consistent.

On the other hand, a large-scale filamentary structure of the Lyrids confirms also the different values of s in 1998 and 1999. For each of these two years solar longitudes of the peak and s are consistent for both stations. But the s value in 1998 and 1999 is significantly different, while s for the sporadic background in both years is also consistent. The 1998 return of the stream was relatively reacher in larger particles than in 1999.

The observations of the Lyrids in 2002 were interrupted just at the expected shower peak and therefore were not analyzed. In 2003 and 2005 due to malfunction of transmission towards Modra the observations were made only in direction to Lecce and in 2004 observations were performed only in direction to Modra. Even so the observed activity peaks and s are in agreement with the results of observations in the preceding years.

Though, the observed Lyrid maxima in individual returns show a variance, the overall activity peak derived from all eight returns at solar longitude 32.30° (eq. 2000.0) is completely consistent with the results of the previous radio studies of the Lyrid long-term activity profile setting the maximum at solar longitude 32.2° [3].

The close agreement of these results over a time span of some decades with the presence of a sharp peak in the Lyrid maximum activity documents that the Lyrids are a permanent meteor stream with relatively stable populations of particles not seriously affected by planetary perturbations (as for Orionids and Eta Aquarids, for example). This is well supported also by the evidence of no motion in the streams orbital nodes for at least 2600 years [8].

3. – Conclusions

Observations of the Lyrid meteor shower by the Bologna-Lecce-Modra forward-scatter system in 1997-2005 were analysed and the activity curves for long-duration echoes ($\geq$8 s) and mass distribution exponents were derived.

The activity curves confirm that the Lyrids are a regular and low activity stream, which crosses the Earth's orbit by its central denser part in less than two days. The shape of the activity curve and position of maximum may change from year to year. For the period of observations (1997-2005) the position of the shower peak varied within 32.0°–32.6°.

The shower exhibits a multiple peak structure in almost all returns and shows a filamentary structure consisting of different populations of meteoroids as confirmed by the mass distribution exponent. Besides a large-scale filamentary structure evident from the variable s in different returns, the observations indicate the existence of very narrow filaments in the stream consisting of population of particles of different sizes.

The mass exponent derived for the central part of the stream reveals that the meteoroids within the stream are not distributed homogeneously and their distribution may change from year to year.

The overall activity profile exhibits a peak at solar longitude 32.30° which is consistent with the previous global analysis of radio observations of the Lyrids over a time

span of thirty years giving the overall activity peak at 32.20° [3]. These very similar results suggest that Lyrids have the characteristics of a meteor stream with relatively stable populations of particles not seriously affected by planetary perturbations and non-gravitational forces.

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