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The Quadrantid meteor shower 1997-2004: Activity and mass distribution

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Summary. — Observations of the Quadrantid meteor shower in 1997-2004 by the BLM forward-scatter radio system for meteor observation carried out along two baselines, Bologna-Lecce (Italy) and Bologna-Modra (Slovakia), are analysed from the viewpoint of activity and mass distribution and results are discussed. The activity curves of long-duration echoes ($\geq$8 s) and their variations indicate a filamentary structure of the stream. The width of the stream at a half-maximum rate level is less than half a day (5–11.5 h). 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 in 1997 and small particles in 2001, 2003 and 2004.

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

1. – Introduction

The Quadrantid meteor shower has been known for about two centuries [1]. The shower is active in the beginning of January and ranks among regular meteor showers with a relatively high activity. The Earth crosses its densest part in half a day only, so the peak activity is rather frequently missed by visual observers. Contrary to visual observations, as the shower radiant is for the northern hemisphere sites with latitude above 42° circumpolar, its activity can be monitored by radio observations the whole day.

Since 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 system has been operating since September 1996. The transmitter is located at Budrio near Bologna (44.6°N; 11.5°E, Italy) and the receivers are

TABLE I. – *The maxima of activity and the mass distribution exponent s derived for the Quadrantids (sh) observed by the BLM forward-scatter radio system in 1997-2004 and sporadic (sp) meteors (M—Modra, L—Lecce).*

Year	Maximum (equinox 2000.0)	M-sh	L-sh	M-sp	L-sp
1997	283.04°	1.48	–	2.38	–
1998	282.99°	1.74	1.60	2.14	(2.67)
1999	283.21°	1.74	1.73	2.30	2.50
2000	283.39°	1.65	(1.50)	2.29	(1.94)
2001	283.31°	2.00	2.07	2.58	–
2002	–	–	–	–	–
2003	283.53°	1.99	–	2.37	–
2004	283.00°	2.03	1.94	2.55	2.67

at Lecce (40.3°N; 18.2°E, Italy) and Modra (48.4°N; 17.3°E, Slovakia). 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°) [2]. The present paper presents results of regular observations of the Quadrantid shower obtained by the BLM forward-scatter radio system.

2. – Observations of the Quadrantids in 1997-2004

The Quadrantids peak on January 3-4 and the shower is monitored by the BLM radio system since 1997 almost regularly in the period January 1–7.

From the studies of echo counts acquired 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, the shower echoes are frequently almost completely covered by the sporadic background echoes. This trend is observed also in the data from all years of the observation of the Quadrantids. Therefore, the Quadrantid 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), corrected for the radiant elevation, in corresponding time interval. The activity curves represented by the shower echo counts in 30 minute intervals (echoes ≥ 8 s) obtained by combining data from both stations, Lecce and Modra, are plotted in fig. 1.

Due to malfunction of the receiving station at Lecce in January 1997 the Quadrantids were observed only by Modra station. The observations were carried out continuously from January 1 until January 8 with a short interruption on January 3 between 12-15 UT. The shower peak activity appeared on January 3 at 08:15 UT, solar longitude 283.04° (equinox 2000.0). There is indication of additional two secondary peaks at solar longitude 282.96° and 283.15° and the shower activity with a half-maximum strength lasted for 8 hours. Another interesting feature of the 1997 Quadrantids is a very low value of the mass exponent $s = 1.48$ (table I), which indicates that a large number of long-duration echoes appeared in the shower in 1997.

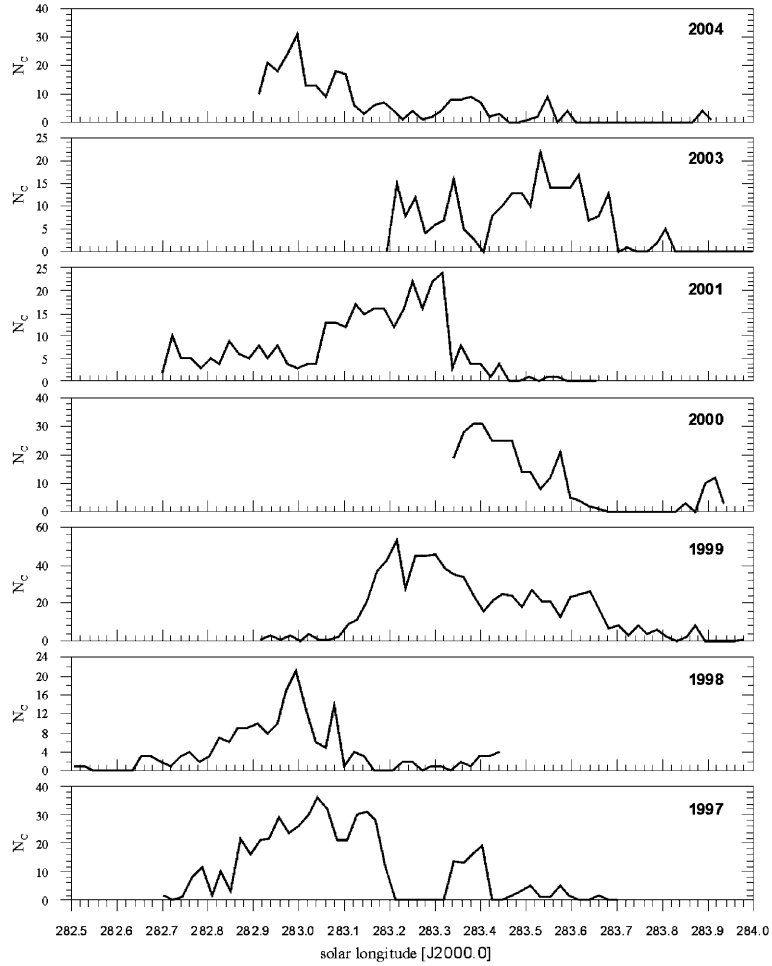

Fig. 1. – Counts of Quadrantid meteor shower echoes of duration ≥ 8 s in 30 minute intervals observed by the BLM forward-scatter radio system in 1997-2004. The curves represent the mean values of the data from Lecce and Modra. The 1997 and 2003 curves are from Modra only.

The 1998 Quadrantids show an asymmetric activity curve with a slower increase in the ascending branch and a steep decrease of the descending branch. The maximum appeared on Jan 3 at 13:15 UT (solar longitude 282.99°). In the descending branch of activity there is a secondary peak observed at about 283.08°. The width of the shower activity corresponding to the half-maximum rate was 5 hours. According to visual observations in 1998 [3] the shower peak appeared at about 283.15° and was followed by several spectacular fireballs at solar longitude of about 283.5°.

According to the 1999 data the shower echoes exhibit a rather broad activity profile lasted almost 11.5 h, with at least three secondary peaks. The peak was observed on January 4 at 00:15 UT, solar longitude 283.21°, followed by a secondary peak centred at solar longitude 283.28°. The data show a well defined asymmetric activity curve, specular respect to that observed the previous year, with a steeper ascending then descending branch.

Also the 2000 Quadrantid shower return was hampered by malfunction of the transmitter in the first days of observation. However, the peak of activity and the descending branch of the curve were detected. Provided that the activity curve was symmetric, the half-maximum activity of the 2000 Quadrantids lasted for 5 h. The maximum appeared on January 4 between 10:45–11:45 UT (283.38°–283.40°).

In 2001 the BLM forward-scatter observations show a pronounced double peak on January 3, 13:45 UT at 283.25° and 15:15 UT at 283.31°. The width of the shower at the half-maximum rate corresponds to 6.5 hours and, as in the previous years, the shower activity is accompanied by several secondary maxima. The mass exponent (table I) with the value around 2 for the shower echoes indicates that in the 2001 shower-dominated small particles.

The 2002 data are due to reconstruction of the equipment missing and the 2003 Quadrantids were observed only from Modra. As in the 2001 Quadrantids the data show multiple secondary peaks and an asymmetric activity curve with a steep decrease of the activity after maximum. The peak was observed on January 4, 08:45 UT at 283.53° and three highest secondary maxima appeared at solar longitude 283.21°, 283.34° and 283.62°. The activity above half-maximum strength lasted for about 7 hours and the mass exponent shows that in the shower-dominated smaller particles. Visual data obtained by the SPA Meteor Section observers [4] show two maxima at 283.22° and 283.56°. The second peak is consistent with the shower maximum observed by the BLM forward-scatter system and the first visual peak corresponds to the secondary FS peak. Moreover, the SPA results present also radio observations of the 2003 Quadrantids and four peak have been detected at solar longitudes 282.65°, 283.03°, 283.29° and 283.59°. The last two peaks are identical with the peaks detected also by the BLM FS system.

In 2004 the Quadrantids were monitored by both receivers (Lecce, Modra) and the peak activity was detected on January 4, 02:15 UT at 283.0°. A pronounced secondary peak appeared at 283.08°. Similar to the 1999 Quadrantids and contrary to all other observed years, the descending branch of the activity curve of the 2004 Quadrantids is not steep.

3. – Mass distribution

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 [5]

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

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. 6 h) and the corresponding sporadic background. Only the values of s in 2000 were calculated from an interval of 3 h. The mass exponent values derived for each station separately are listed in table I (M—Modra, L—Lecce). The Lecce values of s listed in brackets mean that these were derived from a statistically low number of echoes and thus are of lower weight. The Modra values of s refer to the interval of echo duration from 1 s to 15 s. However, there is used a dynamic threshold level for the receiver in Lecce, which automatically changes the threshold level for the duration of the recorded echoes during the observations. This means that not all echoes

up to a certain duration are registered and thus this lowers the number of short duration echoes. Therefore, the s values for Lecce were derived from the echo duration interval 2 s to 15 s.

4. – Conclusions

Observations of the Quadrantid meteor shower by the Bologna-Lecce-Modra forward-scatter system in 1997–2004 were analysed and the activity curves for long-duration echoes (≥ 8 s) and mass distribution exponents were derived. The activity curves confirm that the Quadrantids are a very narrow stream and the Earth crosses its central dense part, corresponding to the half-maximum rate, in less than half a day (in 5–11.5 h). The form of the activity curve may change from year to year and indicate a multiple peak structure of the stream in almost all years and exhibits its filamentary structure. The mass exponent derived for the dense central part of the stream evidences that the meteoroids within the stream are not distributed homogeneously and their distribution may change significantly from year to year. The lowest value of $s = 1.48$ indicating a predominance of large meteoroids in the stream was observed in 1997 and the highest s of about 2 exhibiting a high predominance of small particles was observed in 2001, 2003 and 2004.

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