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The Geminid meteor shower of 1996-2003 from forward-scatter observations: Activity and mass distribution

G. Pupillo([1])([2])([3]), V. Porubčan([4])([5]), G. Bortolotti([1]), G. Cevolani([1]), C. Franceschi([1]), A. Hajduk([5]), L. Kornoš([4]), G. Trivellone([1]) and P. Zigo([4])

([1]) *ISAC-CNR - via Gobetti 101, 40129 Bologna, Italy*
([2]) *DET, Università di Firenze - 50139 Firenze, Italy*
([3]) *Osservatorio di Campi Salentina - 73012 Campi Salentina (Lecce), Italy*
([4]) *Department of Astronomy, Physics of the Earth and Meteorology FMPI Comenius University - 842 48 Bratislava, Slovakia*
([5]) *Astronomical Institute of the Slovak Academy of Sciences - 845 04 Bratislava, Slovakia*

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Summary. — Observations of the Geminid meteor shower in 1996-2003 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 width of the stream at a half maximum rate level is about two days. 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 with a population of smaller particles preceding the activity peak composed of larger particles.

PACS 96.50.Kr – Meteors meteoroids, and meteor streams.
PACS 95.85.Bh – Radio, microwave (> 1 mm).

1. – Introduction

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 near Bologna (44.6°N; 11.5°E, Italy) and the receivers are at Lecce (40.3°N; 18.2°E, Italy) and Modra (48.4°N; 17.3°E, Slovakia). The system was built up for a systematic monitoring of meteor activity in order to study meteor flux from different baselines directions and consequently to study the structure and potential sources of the population in a close surroundings 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.* [1].

The present paper is a third one in a series of the analyses of the activity and structure of major meteor showers observed by the BLM forward-scatter system and we present and discuss results of the observations of the Geminid meteor shower acquired by the equipment over eight years, 1996-2003.

2. – Observations of the Geminids in 1996-2003

The Geminid meteor shower is active for two weeks at the beginning of December, with the maximum at the solar longitude of about 262° (December 13-14) and visual peak frequency up 100. After recognition that the stream is probably associated with the asteroid 3200 Phaethon by Whipple in 1983 [2], the shower was studied more intensively.

The first observations of the Geminids by the BLM forward-scatter system were acquired in 1995, 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 December 8-19.

The studies of the echo counts obtained by the system reveal that a shower activity can be clearly recognized only for echoes of longer duration. In the counts of all echoes, the shower echoes can frequently be overlapped by sporadic background echoes. This trend is observed also in almost all years of the observation of the Geminids by the system. Therefore, to discriminate the activity of the shower, the activity curves were derived for echoes of duration ≥ 8 s.

The shower activity was obtained by subtracting the sporadic background counts from all echo counts (shower and sporadic), corrected for the radiant elevation in corresponding time intervals. The observations obtained for radiant elevation below 15°, due to large corrections to be applied to the observed echo counts, were not included in the stream activity curves. The activity curves around the shower maximum represented by the shower echo counts in 30 minute intervals (echoes ≥ 8 s) obtained by combining data from both the stations, Lecce and Modra, are plotted in fig. 1. The shower radiant for the central area between the receivers culminates at about 01:25 UT and is above horizon for 18 h. The gaps in plots on fig. 1 correspond to the periods when the radiant was for the stations below horizon.

The shower maxima observed by the BLM FS system (reduced for equinox 2000.0) are presented in table I. The activity curves in all return of the Geminids exhibit a slower increase of the activity from the beginning up to the maximum followed by a steep decrease. This feature of the stream activity is known also from visual and previous radar observations. The width of the shower to the half-maximum activity varies and is about two days.

The observations were carried out continuously in all years. Only for 2001 the data due to malfunction of the transmitter and the receiving station at Lecce are missing. At Modra, there are only partial obervations close to the maximum and sporadic background is missing. In individual years also pronounced secondary maxima on the shower activity are observed. In 1996 shower maximum was observed on December 14, 07:25 UT, solar longitude 262.63° (equinox 2000.0) and a secondary broader peak appeared on December 13 at about 22:15 UT (262.25°). The 1997 maximum appeared at 262.41° and a secondary peak at 262.01°. The 1999 maximum was not observed. In table I only the highest peak

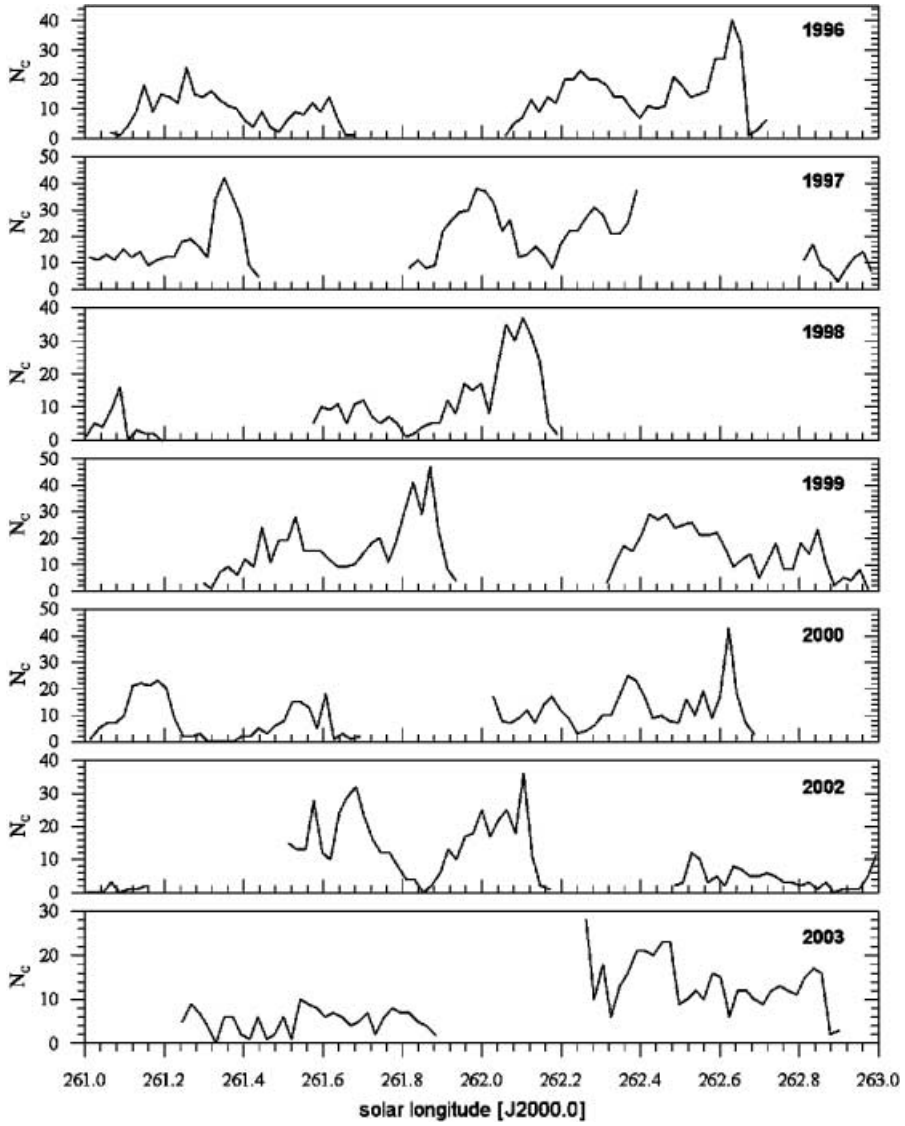

Fig. 1. – Counts of the Geminid meteor shower echoes of duration ≥ 8 s in 30 minute intervals observed by the BLM forward-scatter radio system in 1996-2003. The curves represent the mean values of the data from Lecce and Modra.

from the observed echo counts is presented (in brackets). In 2002 a very pronounced splitting of the maximum is evident, with the maximum at 262.10° and another peak just before maximum at 261.68°.

TABLE I. – *The maxima of activity and mass distribution exponent s derived for the Geminid meteor shower (sh) observed by the BLM forward-scatter radio system in 1996-2003 and sporadic (sp) meteors (L—Lecce, M—Modra).*

Year	Maximum (equinox 2000.0)	Interval	L-sh	M-sh	L-sp	M-sp
1996	262.63°	262.15°– 262.66°	1.81	1.72	2.48	2.26
		261.14°– 261.64°	1.91	1.92		
1997	262.41°	261.90°– 262.41°	1.58	1.80	2.63	2.68
		260.87°– 261.38°	1.82	1.99		
1998	262.10°	261.62°– 262.14°	2.00	1.88	2.46	2.36
1999	(261.83°)	261.37°– 261.88°	1.86	1.66	2.22	2.18
		262.39°– 262.90°	1.76	1.58		
2000	262.62°	262.12°– 262.63°	1.78	2.01	2.59	2.40
2002	262.10°	261.60°– 262.11°	1.90	2.02	2.40	2.49
2003	262.46°	262.36°– 262.86°	1.55	2.08	2.36	2.45
		261.34°– 261.84°	1.76	2.17		

3. – Mass distribution

The mass distribution exponent s was derived from the cumulative numbers of echo duration considering diffusion as dominant process of an echo decay in the form [3]

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

where N_{c} is the cumulative number of echoes with the duration equal to and greater than T_{D}.

Though at lower heights the duration of the echo is affected also by a second mechanism of reducing the electron line density of a meteor trail, which was previously attributed to attachment of free electrons to neutral air particles [4], later Baggaley [5] and others have demonstrated that the attachment is not a dominant factor for ionization loss of meteor trails. More recently Jones *et al.* [6] have shown that a series of chemical reactions involving ozone is likely to be more important than the electron attachment.

However, in this preliminary study of the mass distribution exponent in the Geminid stream from forward-scatter data no correction for attachment effect was taken into account, though the geocentric velocity of the stream is relatively low (35 km/s). To avoid the problem a narrower interval of echo duration for the derivation of s has been chosen. Thus the acquired values of s refer to the interval of echo duration from 1 s to 10 s.

The values of s in individual years were obtained as the mean values from the period of the shower maximum (approximately 12 h) and the corresponding sporadic background. The mass exponent values derived for each station separately (L—Lecce, M—Modra) are listed in table I.

An interesting result of previous backscatter radar observations of the Geminids is connected with mass separation of meteoroids in the stream, with the peak of smaller particles preceding the peak of larger particles [7]. To verify the finding, we have extended the mass distribution analysis, in the years with sufficient statistics of data, to days before the day of the maximum too. The mass exponent s values were derived from the periods

12 hours about the culmination of the shower radiant and are listed in table I with the corresponding solar longitude intervals. The results are summarized in the second rows relatively to the individual years. The s values are consistent with the fact that the population of smaller particles is generally preceding the larger ones which are more concentrated into the densest part of the stream.

4. – Conclusions

Observations of the Geminid meteor shower by the Bologna-Lecce-Modra forward-scatter system in 1996-2003 were analysed and the activity curves for long-duration echoes (≥ 8 s) and mass distribution exponents were derived. The activity curves confirm that the Geminds are a concentrated stream and the Earth crosses its central dense part in about two and half days. The shape 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 from year to year. The observations indicate a mass separation in the stream with smaller particles appearing predominantly prior to the maximum represented according to lower s values by larger meteoroids.

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