Contrib. Astron. Obs. Skalnaté Pleso **37**, 31 – 48, (2007)

Summer streams of the Taurid meteor complex

V. Porubčan[1,2], **P. Zigo**[2], **P. Pecina**[3], **D. Pecinová**[3], **G. Cevolani**[4],
G. Pupillo[4] **and J. Rozboril**[2]

[1] *Astronomical Institute of the Slovak Academy of Sciences, 845 04 Bratislava,
The Slovak Republic*

[2] *Faculty of Mathematics, Physics and Informatics, Comenius University,
828 48 Bratislava, The Slovak Republic*

[3] *Astronomical Institute of the Academy of Sciences, 251 65 Ondřejov,
The Czech Republic*

[4] *CNR-ISAC, via Gobetti 101, 401 29 Bologna, Italy*

Received: September 8, 2006; Accepted: January 19, 2007

Abstract. The activity and structure of daytime summer streams of the Taurid meteor complex, Zeta Perseids and Beta Taurids, based on radio observations carried out by Bologna-Lecce-Modra forward scatter system and Ondřejov backscatter meteor radar in 1997-2005 are analysed and discussed. The observations indicate a filamentary structure of the streams supported also by the mass exponent values derived for individual returns.

Key words: meteor streams – radio observations

1. Introduction

The Taurid meteor complex consisting of several meteoroid streams has a very long period of activity and due to favorite conditions at a low inclination the Earth encounters the meteoroids of the complex at both preperihelion and postperihelion passages. In the preperihelion passage the dominant stream of the complex are the autumn Taurids with the northern and southern branch. A complex structure of the stream recognized already Denning (1928) identifying thirteen active radiants in the constellations of Aries and Taurus. The postperihelion continuation of the autumn Taurids are summer daytime meteor streams the Zeta Perseids and Beta Taurids which were first recorded by radio observations at Jodrell Bank in 1947 (Clegg et al. 1947).

The first who noted that the Taurids might produce a stream observable during daylight hours in summer was Whipple (1940). But a suggestion that the Beta Taurids are related to the autumn Taurids made Almond in 1951 and later the suggestion was supported by Nilsson, Sekanina and others (Kronk 1988).

¿From observations in 1949 and 1950 the activity period of the Zeta Perseids was found to be June 1-16 with an average radiant at right ascension $\alpha=62^{\circ}$ and declination $\delta=+24^{\circ}$, the activity of the Beta Taurids was observed on June 26 - July 4, 1950 at an average radiant of $\alpha=86^{\circ}$, $\delta=+19^{\circ}$ (Aspinall and Hawkins 1951). The most complex data were obtained from the Harvard-Smithsonian Radio Meteor Project in 1961-1965 and 1969 (Sekanina 1973, 1976).

¿From the observations performed in the Southern Hemisphere in 1969 (radio equipment of the University of Adelaide) Gartrell and Elford (1975) pointed out that the Zeta Perseids are probably continuation of the Southern Taurids.

The annual activity of both the streams is low and Sekanina (1973) has found the period of activity of the Zeta Perseids, May 20-June 21, maximum at June 8 and for the Beta Taurids the activity period, June 12-July 6 and maximum at June 26. According to Cook (1973) the activity periods and maxima are June 1-17, June 7 for the Zeta Perseids and June 24-July 6, June 29 for the Beta Taurids.

The activity of the Zeta Perseids and Beta Taurids has not been monitored regularly for more decades and only very little information on both streams was acquired. Partial results concerning the stream's activity in the last years were published by Pecina et al. (2005) and Pupillo et al. (2006).

In the present paper the radio observations of the Zeta Perseids and Beta Taurids carried out by the Bologna-Lecce-Modra forward scatter system (Italy-Slovakia) and by the Ondřejov backscatter meteor radar (The Czech Republic) in the period 1997-2005 analysed from the viewpoint of showers activity and mass distribution exponent are presented and discussed.

2. Equipments and observations

The Budrio-Lecce-Modra (BLM) forward-scatter system for meteor observations has been operating since 1996. A radio signal is transmitted along two mutually almost rectangular baselines. The equipment utilizes a continuous wave transmitted at a frequency of 42.7 MHz, a fixed modulating tone at 1 kHz and 0.25 kW mean power which is transmitted in the direction of both receiving stations. Details about the equipment have been published by Cevolani et al. (1995).

The Ondřejov backscatter meteor radar (Plavcová and Šimek, 1960) operates at a frequency of 37.5 MHz, with a peak power of 10 kW and a pulse repetition frequency of 500 Hz. The equipment utilizes an antenna steerable in azimuth but fixed in elevation at 45°.

The BLM forward scatter equipment has been operating in selected periods of the year, which cover partially also the periods of activity of the summer Taurid complex streams, the Zeta Perseids and Beta Taurids and in the frame of observing campaign each year only one of both streams was observed. The Zeta Perseids were observed in 2000, 2001 and 2002. The Beta Taurids were observed in 1997, 1999 and 2004. Due to reconstruction of the equipment there are missing observations of the streams in 2003 and 2005.

At Ondřejov regular radio observations of the Zeta Perseids and Beta Taurids started in 2003 and continued in 2004, 2005. The first results concerning the activity and mass distribution of meteoroids in the streams in 2003 has been analysed and published by Pecina et al. (2005).

3. Relation between backscatter and forward scatter radio echo duration

To compare the observed echo rates obtained by two different radio systems - Ondřejov backscatter and BLM forward scatter - we have to have information on the type of echo duration. It is well known that meteor showers contain proportionally more bright meteors corresponding to overdense echoes of longer durations than in the category of underdense echoes. Thus it is necessary to find out which duration of echo registered by backscatter radar corresponds to a particular forward echo duration group.

The comparison can be made by using the formula for duration of overdense backscatter echo published by McKinley (1961) or Bronshten (1983):

$$T_{Db} = (\lambda/2\pi)^2 r_e \alpha_e / D - r_0^2/4D \simeq (\lambda/2\pi)^2 r_e \alpha_e / D, \tag{1}$$

where λ stands for the wavelength of the wave transmitted by the corresponding radar, r_e denotes the classical radius of electron, α_e is the electron line density within the meteor trail, D designates the ambipolar diffusion coefficient and r_0 is the initial radius of the meteor trail. Since usually the second term in the first part on the right hand side of formula (1) is small compared with the first one it is frequently ignored. The formula valid in the case of forwardscatter echo reads (e. g. McKinley, 1961):

$$T_{Df} = (\lambda/2\pi)^2 r_e \alpha_e / D \cos^2 \varphi, \tag{2}$$

where now 2φ is the forward-scatter angle, which is the angle between the direction of the wave transmition from the transmitter and the direction connecting the point of wave reflection at the meteor trail and the receiver. Assuming that we observe roughly the same echoes at similar heights we can compute the ratio T_{Df}/T_{Db} which reads:

$$T_{Df}/T_{Db} = 1/\cos^2 \varphi. \tag{3}$$

To be able to compute this ratio numerically we need to have information about possible value of φ from the known geographical positions of the transmitting and receiving stations when assuming a height level at which the meteor trail reflects the radio-wave. The angle φ depends generally on the orientation of the trail with respect to the transmitting station. The highest value it reaches in the middle of the line connecting both stations and the lowest value when it is close to one of these stations. For the baseline Budrio and Modra the former possibility results in $\varphi \simeq 70\overset{\circ}{.}6$ while latter one leads to $\varphi \simeq 47\overset{\circ}{.}3$. The corresponding $\cos\varphi$ then varies from 0.332 to 0.678. Therefore, $2.2 \leq T_{Df}/T_{Db} \leq 9.1$ can in principle hold true with the higher ratio corresponding to higher value of φ which seems to be more probable then the other one.

4. Analysis

¿From the studies of echo counts obtained by the BLM forward scatter system it is evident that shower echoes can be clearly recognized from sporadic background echo counts only for long duration echoes (Pupillo et al., 2004). Therefore, the activity curves from the BLM forward scatter were derived only for long duration echoes.

Shower activity was obtained by subtracting sporadic background echoes from all echo counts in corresponding hours. The activity curves represented by the hourly shower echo counts were derived, where possible, by combining the data from both receiving stations (Lecce and Modra) and the observed echo counts were corrected for the observability function of the BLM forward scatter system.

The observability functions (OF) for Bologna - Lecce and Bologna - Modra setups were computed using the ellipsoidal theory presented by Hines (1958). The observability function for the Bologna - Lecce part of the BLM forward scatter system is plotted in Fig. 1.

The baseline distance between the transmitter and receiver at Bologna and Lecce is 728 km, with the azimuth of 128°. The identical five element Yagi antennas with horizontal polarization are used for the transmission and reception of the radio signal. The length of the second baseline (Bologna - Modra) and corresponding azimuth are 612 km and 44°, respectively. The second baseline system utilizes two four element Yagi antennas with horizontal polarization.

Fig. 2 depicts the contour diagram of the normalized observability function for the baseline Bologna - Modra as a function of the azimuth and zenithal distance of the Zeta Perseids shower radiant for the midpoint of the baseline (43.4° N; 14.8° E). Similar contour diagram of the normalized observability function for the Bologna - Lecce baseline with the midpoint coordinates at 46.5° N and 14.4° E is plotted in Fig. 3.

The activity curves for the Ondřejov backscatter observations were obtained by subtracting the sporadic background echo counts from all echo counts on the days of shower activity in corresponding time intervals.

The observed data provided also a possibility to derive the mass distribution exponent presenting information on size distribution of particles in the streams and sporadic background. The mass exponent s was found from the cumulative numbers of echo duration considering diffusion as dominant process of an echo

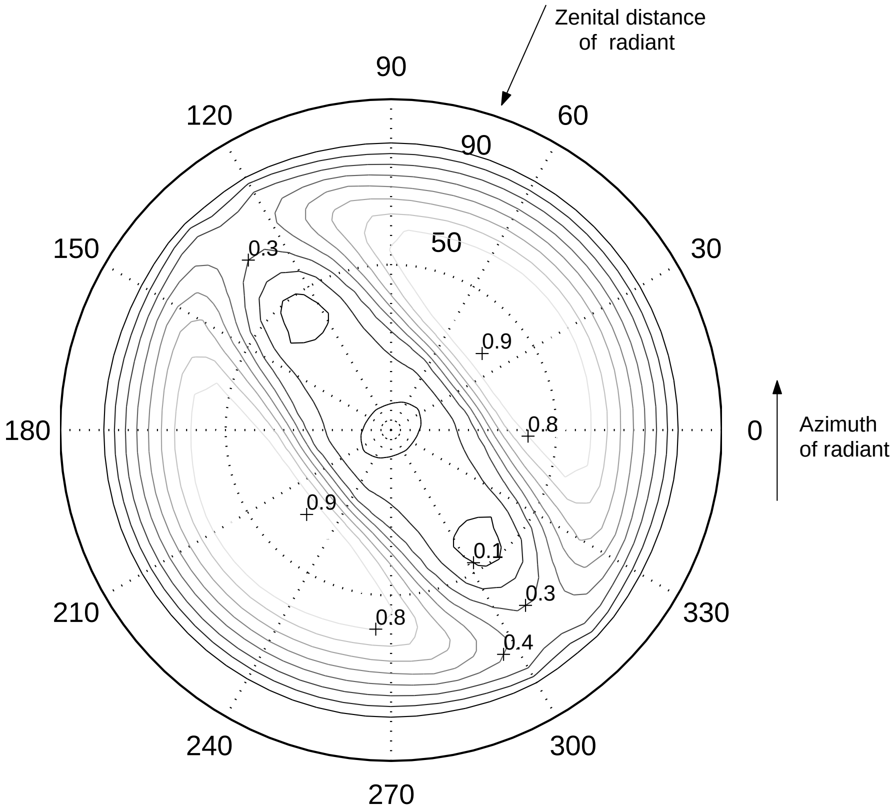


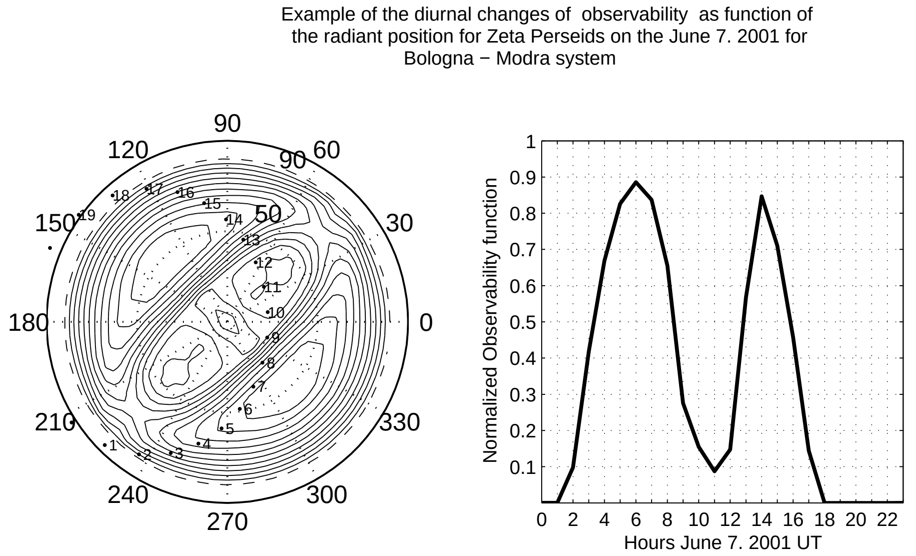
Figure 1. Observability function contours plot for the Bologna-Lecce forward scatter system, as a function of azimuth and zenithal distance of radiant for the midpoint of the transmitter and receiver path, normalized to maximum value.

decay in the form (Kaiser, 1955):

$$\log N_c = -\,(3/4)\,(s-1)\log T_D + const, \tag{4}$$

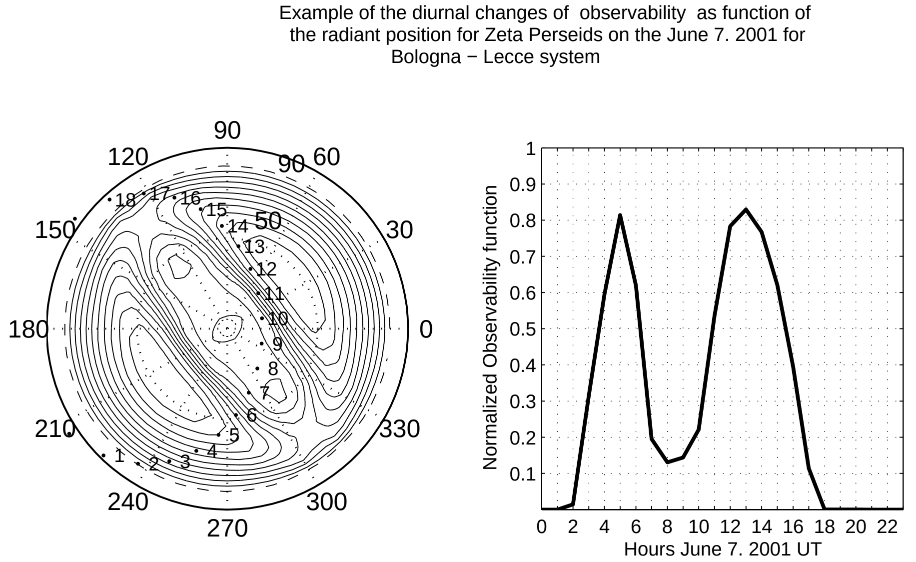
where N_c is the cumulative number of echoes with the duration equal to and greater than T_D.

The values of s in individual years were obtained as the mean values from the period of the shower maximum and sporadic background. The derived mass exponent values are listed in Tables 1 - 6.



Example of the diurnal changes of observability as function of the radiant position for Zeta Perseids on the June 7. 2001 for Bologna − Modra system

Figure 2. Observability function contours of the Bologna-Modra forward scatter system



Example of the diurnal changes of observability as function of the radiant position for Zeta Perseids on the June 7. 2001 for Bologna − Lecce system

Figure 3. Observability function contours of the Bologna-Lecce forward scatter system

5. Zeta Perseids

The Zeta Perseids are active in the first half of June with the radiant above horizon in the Northern mid-latitude sites for about 17 hours. The radiant culminates at about 11 LT. The peak activity according to Cook (1973) corresponds to solar longitude of 76.7° (eq. 2000) with the mean radiant at $\alpha = 62°$, $\delta = +23°$, while Sekanina from two Harvard radio surveys sets the peak for solar longitude 79° and radiant position $\alpha = 60.2°$, $\delta = +24.8°$ (Sekanina 1973) and for 83°, $\alpha = 63.3°$, $\delta = +27.1°$ (Sekanina 1976), respectively.

The BLM forward scatter monitored the stream activity in 2000, 2001 and 2002, the Ondřejov radar in 2003, 2004 and 2005 and activity curves in individual years are plotted in Fig. 4 (BLM) and Fig. 5 (Ondřejov). The curves presented for the BLM system are corrected for the observability function and are representing one hour counts of shower overdense echoes for two groups of echo duration $T_D \geq 1$ s and $T_D \geq 8$ s. The Ondřejov data represent the mean daily counts of shower underdense and overdense echoes (right plots) and shower echoes in three different echo duration groups (left plots with $T_D \geq 0.4$ s, $T_D \geq 1$ s and $T_D \geq 5$ s). No echoes with $T_D \geq 10$ s were observed in Ondřejov records. The maxima of activity and mass distribution exponent values at the maxima for individual years are listed in Table 1.

In 2000, the observations were carried out in June 9-16 and probably covered only the descending branch of activity. Thus the peak for echo duration ≥ 1 s observed at solar longitude of $79\overset{\circ}{.}8$ is probably not the main peak. Due to a high level of noise in Lecce, the mass exponent could be derived from the Modra data only and for the shower (June 9) and sporadic background (June 15) s is 1.98±0.04 and 2.48±0.04, respectively. The value of 1.98 indicates that the stream contained more relatively large particles.

In 2001 observations (June 5-15) the peak for echoes ≥ 1 s was observed at solar longitude of $76\overset{\circ}{.}5$ and was well defined at both stations (Lecce and Modra). The mass exponent derived for the shower meteors (June 7) s=2.24±0.03 and for the background meteors (June 12) s=2.38±0.04. This indicates that in 2001 return of the Zeta Perseids both populations were very similar, that is in the stream prevailed smaller particles.

The 2002 Zeta Perseids were observed over the period June 4-10. The peak activity appeared at $77\overset{\circ}{.}2$ and the mass exponent for the shower (June 8) and sporadic (June 4) were 2.25±0.01 and 2.80±0.05, respectively.

The 2003, 2004 and 2005 Zeta Perseids were observed at Ondřejov only. The method of observations was the same for all three shower returns and the 2003 results were analysed elsewhere (Pecina et al., 2005). The peak of overdense echoes was recorded for solar longitude of $78\overset{\circ}{.}8$ with the mass exponent of shower meteors s=2.12±0.08. Some mass segregation between faint radar meteors (i. e. the underdense echoes) and overdense echoes has been detected in 2003 since the maximum activity of underdense echoes appeared two days prior to maximum of overdense echoes.

The 2004 Ondřejov observations were carried out on May 30-31 together with June 18 in order to detect the sporadic background of the Zeta Perseids and June 6-12 to establish the core of the shower. The 2004 peak was recorded **at** 81°.5. This value exhibits that the peak activity of the stream can change from one shower return to another also for a few degrees. The result thus indicates a filamentary structure of the stream. As evident from the mass exponent value s=2.28±0.21, the stream was dominated by smaller particles.

Table 1. The maxima of activity and mass distribution exponent *s* derived for the Zeta Perseids observed by the BLM radio system in 2000-2002 and from the Ondřejov meteor radar observations in 2003-2005.

Year	Maximum (eq. 2000.0)	s-sh (shower)	s-sp (sporadic)	observation (receiver)
2000	79°.8	1.98±0.04	2.48±0.04	Modra
2001	76°.5	2.24±0.03	2.38±0.04	Lecce and Modra
2002	77°.2	2.25±0.01	2.80±0.05	Lecce and Modra
2003	78°.8	2.12±0.08	2.24±0.09	Ondřejov
2004	81°.5	2.28±0.21	2.50±0.15	Ondřejov
2005	(81°.2)	2.28±0.14	2.49±0.10	Ondřejov

Table 2. Mass distribution index *s* computed for the Zeta Perseids from the BLM forward scatter system observations at Modra in 2000-2002. The index *s* was computed within 8-hours time intervals. d means the day in June, h is the hour of the beginning time interval in UT. $L_\odot$ is the solar longitude of the middle of the corresponding interval and *s.d.* is standard deviation.

2000				
d	h	$L_\odot$	s	s.d.
9	7	78.°91	1.90	0.05
10	2	79.°67	2.01	0.04
11	2	80.°63	1.99	0.04
12	2	81.°58	2.04	0.10
13	2	82.°54	2.18	0.07
14	2	83.°49	2.33	0.09
15	2	84.°44	2.08	0.03
16	2	85.°32	2.18	0.09

2001				
d	h	$L_\odot$	s	s.d.
4	10	74.°00	2.35	0.09
5	2	74.°64	2.27	0.08
6	2	75.°59	2.41	0.10
7	2	76.°55	2.18	0.07
8	2	77.°50	2.29	0.05
9	2	78.°46	2.31	0.07
10	2	79.°42	2.30	0.08
11	2	80.°37	2.23	0.07
12	2	81.°33	2.35	0.07
13	2	82.°29	2.29	0.06
14	2	83.°24	2.24	0.07
15	2	84.°20	2.55	0.12

2002				
d	h	$L_\odot$	s	s.d.
5	2	74.°39	2.38	0.11
6	2	75.°35	2.27	0.05
7	2	76.°30	2.21	0.06
8	2	77.°26	2.11	0.06
9	2	78.°22	2.36	0.07
10	2	79.°17	2.28	0.09

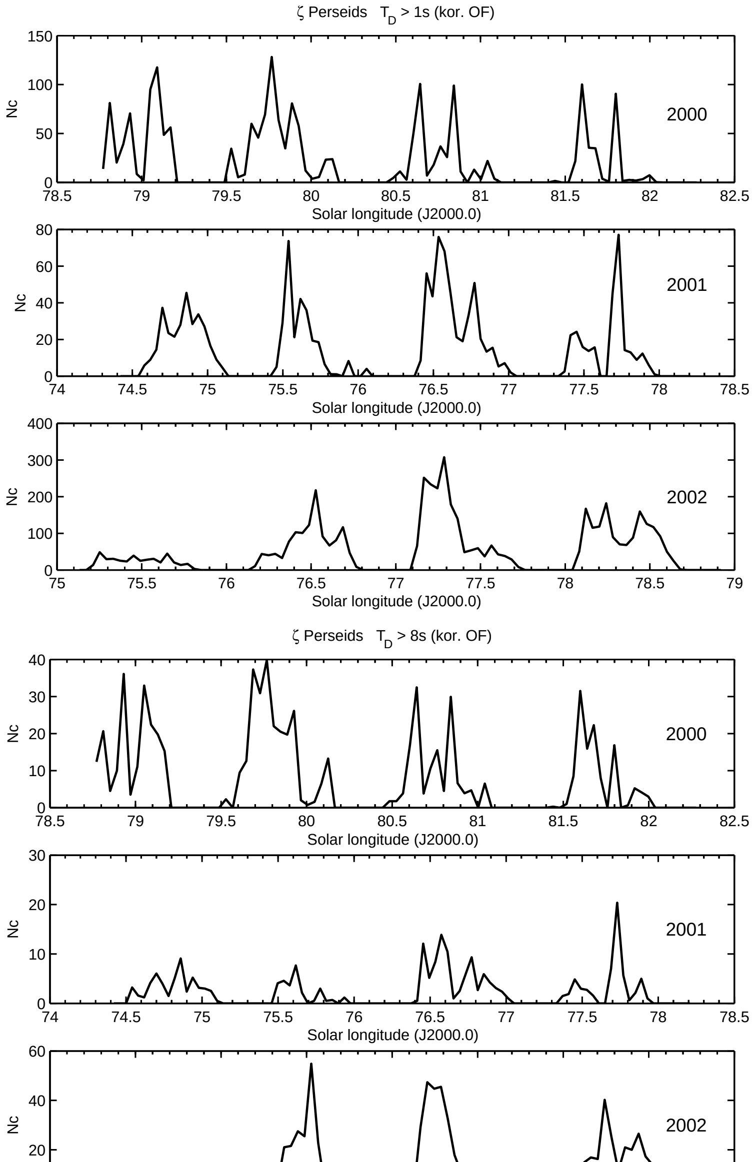


Figure 4. Zeta Perseids 2000-2002 observed by the BLM forward scatter system for echo durations T>1 s (three upper plots) and T>8 s (three lower plots).

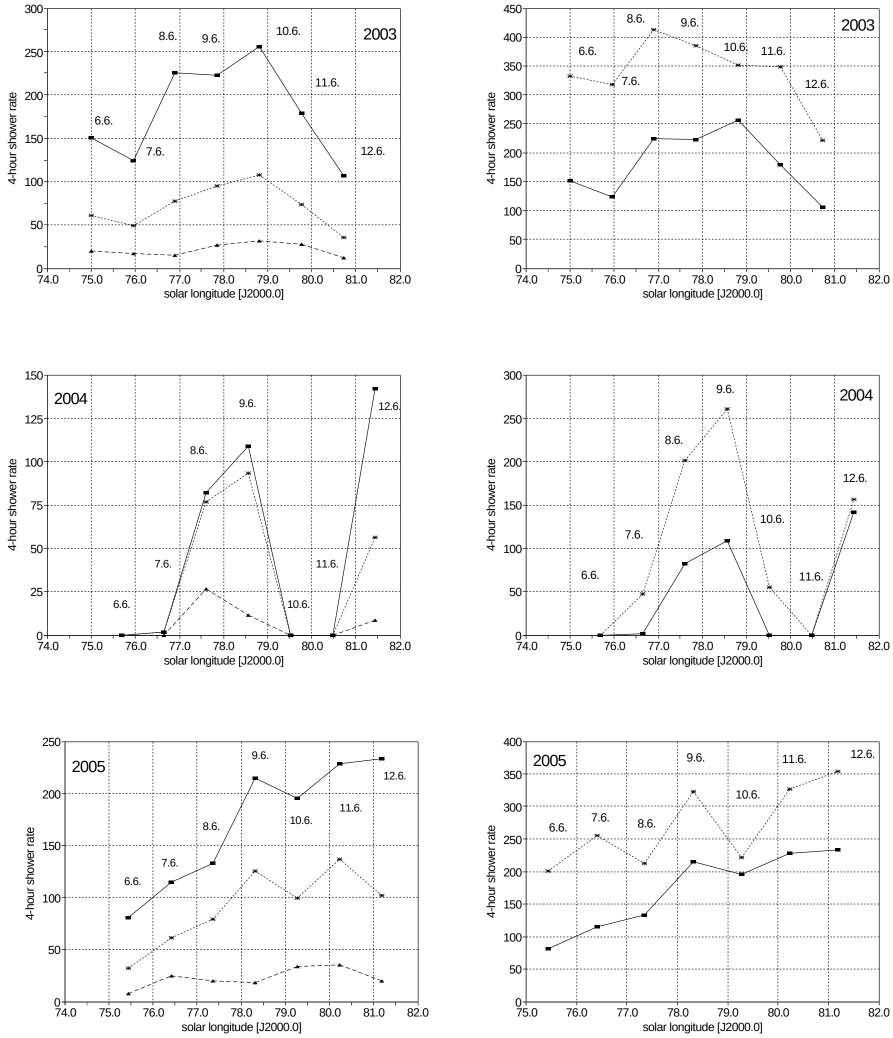


Figure 5. Zeta Perseids 2003, 2004 and 2005 as observed by the Ondřejov meteor radar. Right hand side pictures show the activity curves of all overdense echoes (full lines) and underdense echoes (dotted lines) while the left hand side pictures present the activity of overdense echoes in three duration categories. The full lines depict echoes having duration in excess of 0.4 s, the dotted lines correspond to echoes with duration over 1 s while the dashed lines delineate the activity of echoes with duration greater than 5 s.

Table 3. Mass distribution index s computed for the Zeta Perseids from the Ondřejov meteor radar observations in 2003-2005. The indices were computed from 4-hour time intervals and only indices whose standard deviations (*s.d.*) do not exceed 10% percentage of the index itself are presented. d means the day in June, h is the hour of the beginning time interval in UT. $L_{\odot}$ is the solar longitude of the middle of corresponding interval for J2000.0.

2003					2004					2005				
d	h	$L_{\odot}$	s	s.d.	d	h	$L_{\odot}$	s	s.d.	d	h	$L_{\odot}$	s	s.d.
6	3	$74\overset{\circ}{.}99$	2.29	0.07	8	3	$77\overset{\circ}{.}61$	1.53	0.08	6	3	$75\overset{\circ}{.}45$	2.39	0.07
7	3	$75\overset{\circ}{.}95$	2.18	0.17	9	3	$78\overset{\circ}{.}56$	2.01	0.13	7	3	$76\overset{\circ}{.}41$	1.79	0.04
8	3	$76\overset{\circ}{.}90$	2.45	0.10	12	3	$81\overset{\circ}{.}43$	2.28	0.21	8	3	$77\overset{\circ}{.}36$	2.02	0.03
9	3	$77\overset{\circ}{.}86$	2.20	0.05						9	3	$78\overset{\circ}{.}32$	2.22	0.13
10	3	$78\overset{\circ}{.}81$	2.12	0.08						10	3	$79\overset{\circ}{.}28$	1.89	0.09
11	3	$79\overset{\circ}{.}77$	1.87	0.03						11	3	$80\overset{\circ}{.}23$	1.88	0.09
12	3	$80\overset{\circ}{.}83$	2.24	0.21						12	3	$81\overset{\circ}{.}19$	2.28	0.14

In 2005 the Zeta Perseids were monitored in the period May 31 - June 13 and probably the peak itself was not observed. The data show a steady increase of activity till the end of observations. At the peak activity the mass exponent exhibits the same value as in 2004.

It follows from the comparison of 2004 activity with the activity in 2003 and 2005 that 2004 activity was less than one half of the activity in adjacent years as if in this year only the part of stream between two filaments was active. Also some mass segregation was detected since the maximum activity of echoes having $T_D \geq 5$ s occurred one day prior to maximum of remaining echoes. No such effect has been observed in 2005 when the positions of activity peaks of all echo categories coincided.

The mass distribution indices s computed for the Zeta Perseids from the BLM and Ondřejov meteor radar observations and each day of observations are listed in Table 2 and Table 3, respectively.

6. Beta Taurids

The Beta Taurids are active in the second half of June and beginning of July (Cook, 1973). The shower radiant culminates at 11:15 LT and is above horizon for the Northern mid-latitude observations for about 16 hours. The peak of activity presented by Cook (1973) is proposed for June 29 (solar longitude $96\overset{\circ}{.}7$, eq. J2000). On the other hand, from two Harvard radio surveys the peak of shower activity appears on June 26.6, with the radiant at $\alpha = 79\overset{\circ}{.}4$, $\delta = +21\overset{\circ}{.}2$ (Sekanina, 1973) or on June 26.1, with the radiant at $\alpha = 83\overset{\circ}{.}9$, $\delta = +23\overset{\circ}{.}6$ (Sekanina, 1976).

The shower activity was monitored by the BLM forward scatter system in 1997, 1999 and 2004 and by the Ondřejov meteor radar in 2003, 2004 and 2005. The activity curves in individual years are plotted in Fig. 6 (BLM) and Fig. 7 (Ondřejov). The activity curves from the forward scatter curves are corrected for the observability function and depict one hour counts of shower overdense echoes for echo duration groups of $T_D \geq 1$ s and $T_D \geq 8$ s. The Ondřejov data stand for the mean daily counts of shower underdense and overdense echoes (right plots) and for shower echoes counts in three different echo duration categories coinciding with those used for Zeta Perseid echoes. Also within the Beta Taurid shower no echoes with $T_D \geq 10$ s were observed in Ondřejov. The maxima of activity together with mass distribution exponent values in corresponding maxima of individual years are summarized in Table 4.

Table 4. The maxima of activity and mass distribution exponent *s* derived for the Beta Taurids observed by the BLM radio system in 1997-2004 and Ondřejov meteor radar in 2003-2005. The Ondřejov 2004 shower value of *s* could not be computed because of very low shower rates.

Year	Maximum (eq. 2000.0)	s-sh (shower)	s-sp (sporadic)	observation (receiver)
1997	94°.7	2.37±0.09	2.23±0.08	Modra
1999	96°.4	2.14±0.02	2.38±0.03	Lecce and Modra
2003	94°.1	2.23±0.13	2.37±0.10	Ondřejov
2004	95°.9	2.10±0.02	2.38±0.04	Lecce
	(95°.8)	-	2.40±0.08	Ondřejov
2005	(98°.4)	2.12±0.22	2.37±0.15	Ondřejov

The 1997 Beta Taurids observation was carried out only in the direction to Modra (June 20-July 1) and due to a very low echo counts and shower activity, the curve in Fig. 6 for 1997 depicts all echo counts (shower and sporadic). The peak of activity was observed at 94°.7. The mass exponent derived from an interval of 8 hours about the peak (period the least contaminated by background) for all echo counts, is s=2.37±0.09 and sporadic background value from the end of observations is s=2.23±0.08.

In 1999 the transmission was made along both baselines in the period June 24 - July 1 and the peak was observed for 96°.4, with mass exponent for the shower s=2.14±0.02 and for sporadic background s=2.35±0.03.

The 2003 shower was observed at Ondřejov (Pecina et al., 2005). The peak of activity of overdense echoes appeared at 94°.1. The mass exponent from the period of the peak is s=2.23±0.13 and sporadic background from the end of observation is s=2.37±0.00. The sporadic background value was only two days beyond the peak and thus still much influenced by the shower echoes.

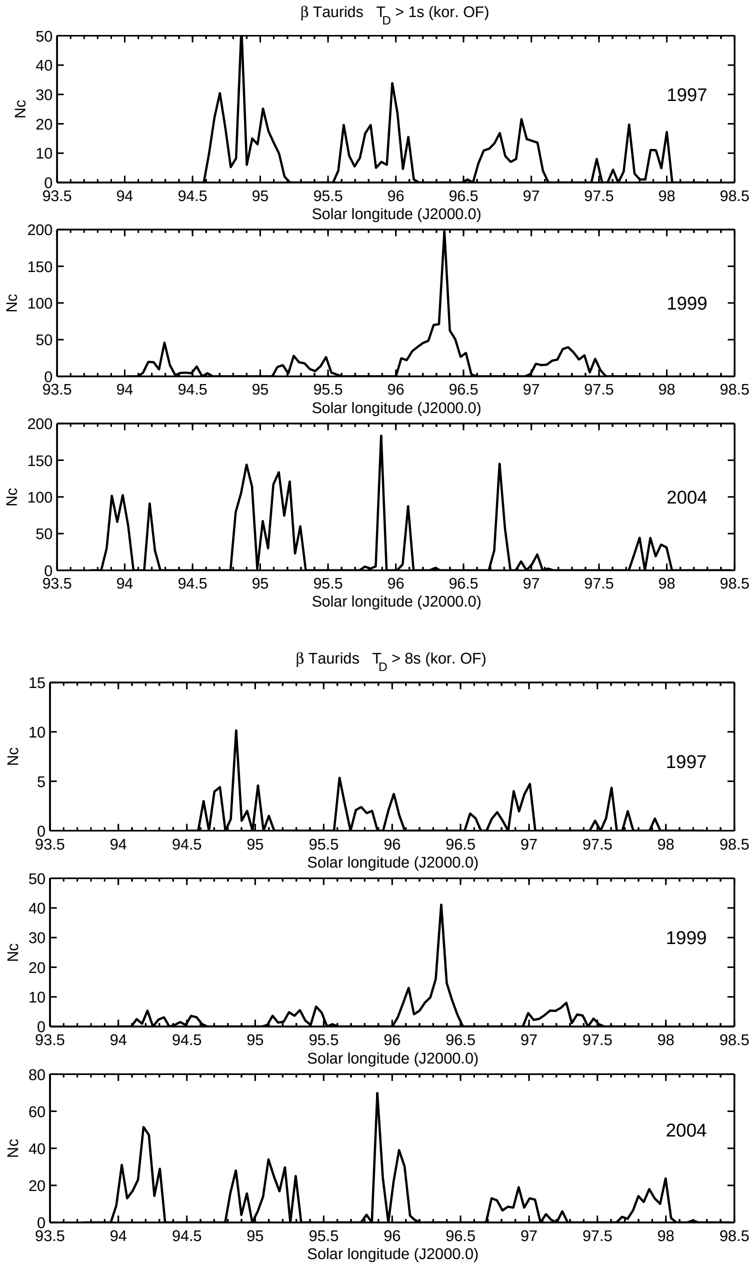


Figure 6. Beta Taurids 1997-2004 observed by the BLM forward scatter system for echo durations T>1 s (three upper plots) and T>8 s (three lower plots).

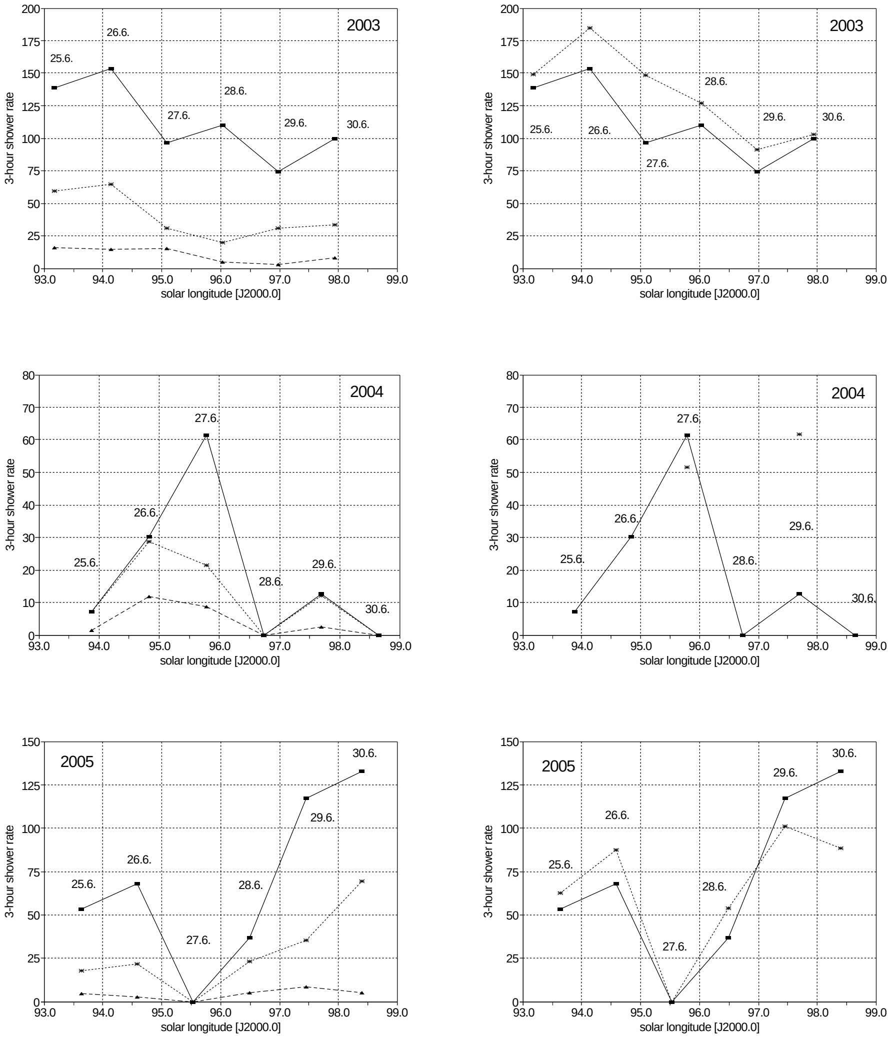


Figure 7. Beta Taurids 2003, 2004 and 2005 as observed by the Ondřejov meteor radar. Right hand side pictures show the activity curves of all overdense echoes (full lines) and underdense echoes (dotted lines) while the left hand side pictures present the activity of overdense echoes in three duration categories. The full lines depict echoes having duration in excess of 0.4 s, the dotted lines correspond to echoes with duration over 1 s while the dashed lines delineate the activity of echoes with duration greater than 5 s. The activity of underdense echoes in 2004 appeared only in two days. As a consequence, the corresponding curve was not constructed.

The observations in 2004 were performed simultaneously by both radio equipments. Very low activity of the shower was detected in 2004 at Ondřejov. Thus the peak presented in Table 4 (solar longitude of 95°.8) is very uncertain. The 2004 Ondřejov observations of the Beta Taurids were carried out on June 19 and July 7-8 (background) and June 25-July 1. The data from Modra were contaminated by strong interferences and spurious long duration echoes overlapping the standard shower echo activity and therefore only data from Lecce were used. The BLM data from Lecce give the peak for 95°.9. The peaks obtained by both equipments are consistent. ¿From Fig. 7 is clearly evident the mass segregation since the peak of activity of echoes with $T_D \geq 1$ s preceded the peak of all remaning echoes.

In 2005 the Ondřejov radar monitored the activity of the Beta Taurids in the period June 25-30 and the peak of activity of overdense echoes appeared at solar longitude of 98°.4. As in 2003 also in 2005 no mass segregation was detected.

The mass distribution indices *s* computed for the Beta Taurids from the BLM and Ondřejov meteor radar observations each day of observations are presented in Table 5 and 6.

Table 5. Mass distribution index *s* computed for the Beta Taurids from the BLM forward scatter system observations at Modra in 1997 and 1999. The index was computed within 8-hours time intervals. d means the day in June, h is the hour of the beginning time interval in UT. $L_\odot$ is the solar longitude of the middle of the corresponding interval and *s.d.* is standard deviation.

1997				
d	h	$L_\odot$	s	s.d.
20	7	89.°19	2.28	0.07
21	2	89.°95	2.17	0.06
22	2	90.°90	2.19	0.05
23	2	91.°86	2.37	0.10
24	2	92.°81	2.23	0.04
25	2	93.°76	2.04	0.06
26	2	94.°72	2.13	0.10
27	2	95.°67	2.16	0.07
28	2	96.°62	2.15	0.06
29	2	97.°58	2.04	0.07
30	2	98.°53	1.98	0.09

1999				
d	h	$L_\odot$	s	s.d.
24	13	92.°77	2.43	0.12
25	2	93.°28	2.27	0.10
26	2	94.°24	2.07	0.05
27	2	95.°19	2.08	0.06
28	2	96.°14	1.98	0.06
29	2	97.°10	1.95	0.04
30	2	98.°05	2.09	0.05
01	0	98.°92	2.07	0.03

Table 6. Mass distribution index *s* computed for the Beta Taurids from the Ondřejov meteor radar observations in 2003-2005. The index was computed within 4-hour time intervals and only indices whose standard deviations (*s.d.*) do not exceed 10% percentage of the index itself are presented. d means the day in June, h is the hour of the beginning time interval in UT. $L_\odot$ is the solar longitude of the middle of corresponding interval for J2000.0.

2003					2004					2005				
d	h	$L_\odot$	s	s.d.	d	h	$L_\odot$	s	s.d.	d	h	$L_\odot$	s	s.d.
26	4	94°.13	2.23	0.13	25	4	93°.88	1.59	0.10	25	4	93°.63	2.16	0.17
27	4	95°.08	1.75	0.14	26	4	94°.84	1.50	0.10	26	4	94°.59	2.15	0.19
28	4	96°.04	2.82	0.13	27	4	95°.79	2.48	0.13	28	4	96°.45	2.08	0.15
29	4	96°.99	2.42	0.24	29	4	97°.70	2.08	0.16					
30	4	97°.94	2.14	0.20	29	4	97°.82	1.91	0.14					
01	4	98°.90	2.12	0.18										

7. Discussion and conclusions

In parallel with the Zeta Perseids and Beta Taurids, there are active also the Daytime Arietids discovered by radio observations at Jodrell Bank in 1947. The Arietids are the strongest daylight meteor shower of the year active from May 22 to July 2, with the activity maximum on June 8 and radiant at $\alpha = 45°$, $\delta = +24°$ (Kronk, 1988). The radiants of all the three showers have almost the same declination and in the right ascension are separated approximately equally by 20°. Unless at least velocities of individual meteors are available, it is difficult to distinguish between echoes of the Arietids and Zeta Perseids derived from radio observations activity curves as their radiants and activity maxima are very close.

To avoid the problem, the shower peaks in the forward scatter observations by the BLM system were derived from the observed activity curves obtained by taking into account the observability functions of particular showers. The calculated observability functions for the Arietids, Zeta Perseids and Beta Taurids are plotted in Fig. 8. As evident, the corresponding peaks of the optimum detection of the streams are separated only by one to three hours in local time. This causes a problem especially in separation of the peaks of the Arietids and Zeta Perseids.

The Ondřejov meteor radar utilizes an antenna steerable in azimuth and fixed in elevation. In this case the overlapping of the Zeta Perseids and Beta Taurids by the Arietids was much lowered by the chosen method of observation - steering the antenna with respect to the shower radiant along the corresponding almucantar. The possible directions of observation using this method are generally two. We have chosen the optimum one at which the difference between the azimuths of the Arietids radiant and maximum antenna gain was the largest.

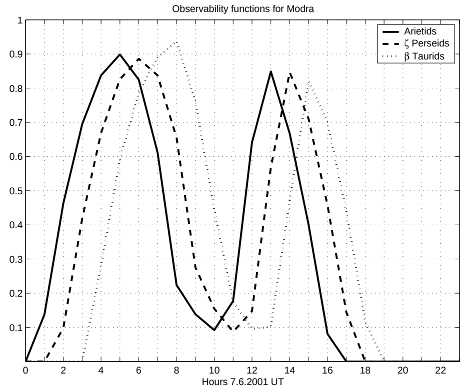


Figure 8. The course of the observability function of the Bologna-Modra forward scatter system for the Arietids (full line), Zeta Perseids (dashed line) and Beta Taurids (dotted line).

The relation of the summer daytime showers with the autumn Taurid complex streams suggested by Whipple (1940) was investigated also by other authors. According to Štohl (1986) the whole complex of interplanetary bodies associated with comet Encke includes a very large number of otherwise sporadic meteors dispersed in a very broad "sporadic stream" in which the Beta Taurids and other minor streams are only areas of higher spatial density. The possible stream is compatible with the idea of fragmentation of a large comet a few thousand years ago of which comet Encke and associated larger bodies together with meteoroids are remnants (Whipple and Hamid, 1952; Kresák, 1980; Clube, 1983). Recently, Porubčan et al. (2006) searched for co-parents of the summer Taurids complex streams among known NEOs and found two candidates for the association with the Zeta Perseids (1999 RK45 and 2003 QC10) and two for the Beta Taurids (2003 UV11 and 2004 TG10). Further, they have shown that the Beta Taurids are postperihelion continuation of the Northern Taurids and Zeta Perseids are continuation of two complex filaments related to the Southern Taurids.

In summary the activity of the summer Taurid complex streams, the Zeta Perseids and Beta Taurids over the period 1997-2004 was studied by two different radio equipments applied for meteor observations: BLM forward scatter system and Ondřejov backscatter meteor radar. The observed positions of maxima of the streams (Table 1 and 4) are in a general agreement with the previous analyses. The observations indicate a filamentary structure of the streams, the existence of which is supported also by the mass exponent values found for individual returns of the streams.

Acknowledgements. The authors thank the referee for stimulating comments and acknowledge the support of the research to the Institute ISAC CNR, Bologna and to VEGA, the Slovak Grant Agency for Science, grant No. 1/3067/06, and to the Grant Agency of The Czech Republic, grant No. 205/03/1405.

References

Aspinall, A., Hawkins, G.S.: 1951, *Mon. Not. R. Astron. Soc.* **111**, 18

Baggaley, J.W.: 1972, *Mon. Not. R. Astron. Soc.* **159**, 203

Bronshten, V.A: 1983, *Physics of Meteoric Phenomena*, Kluver Academic Publ.,Dordrecht, Holland

Cevolani, G., Bortolotti, G., Franceschi, C., Grassi, G., Trivellone, G., Hajduk, A., Kingsley, S.P.: 1995, *Planet. Space Sci.* **43**, 765

Clegg, J.A., Hughes, V.A., Lovell, A.C.B.: 1947, *Mon. Not. R. Astron. Soc.* **107**, 369

Clube, S.V.M.: 1983, in *Asteroids, Comets, Meteors I.*, eds.: C.L. Lagerkvist and H. Rickman, Uppsala Univ., Uppsala 1983, 369

Cook, A.F.: 1973, in *Evolutionary and Physical Properties of Meteoroids*, eds.: C.L. Hemenway, P.M. Millman and A.F. Cook, NASA SP-319, Washington D.C., 183

Denning, W.F.: 1928, *J. Brit. Astron. Assoc.* **38**, 302

Gartrell, G., Elford, W.G.: 1975, *Australian Journal of Physics* **28**, 591

Hines, C.O.: 1958, *Canad. J. Phys.* **36**, 117

Jones, J., McIntosh, B.A., Šimek, M.: 1990, *J. Atmos. Terr. Phys.* **52**, 253

Kaiser, T.R.: 1955, *Meteors*, Pergamon Press, London, U.K.

Kresák, L.: 1980, in *Solid Particles in the Solar System*, eds.: I. Halliday and B.A. McIntosh, D. Reidel, Dordrecht, 211

Kronk, G.W.: 1988, *Meteor Showers: A Descriptive Catalogue*, Enslow Publishers, USA

McKinley, D.W.R.: 1961, *Meteor Science and Engineering*, McGraw Hill, New York, USA

Pecina, P., Pecinová, D., Porubčan, V., Tóth, J.: 2005, *Earth, Moon, Planets* **95**, 681

Plavcová, Z. and Šimek, M.: 1960, *Bull. Astron. Inst. Czechosl.* **11**, 228

Porubčan, V., Kornoš, L., Pecina, P., Cevolani, G. and Pupillo, G.: 2006, *Il Nuovo Cimento* **28C**, 933

Pupillo, G., Porubčan, V., Cevolani, G., Bortolotti, G., Franceschi, C., Trivellone, G., Zigo, P., Hajduk, A.: 2004, *Il Nuovo Cimento* **27C**, 213

Pupillo, G., Porubčan, V., Pecina, P., Pecinová, D., Cevolani, G. and Zigo, P.: 2006, *Il Nuovo Cimento* **28C**, 941

Sekanina, Z.: 1973, *Icarus* **18**, 253

Sekanina, Z.: 1976, *Icarus* **27**, 265

Štohl,J.: 1986, in *Asteroids, Comets, Meteors II.*, eds.: C.L. Lagerkvist, B.A. Lindblad, H. Lundstedt and H. Rickman, Reprocentralen HSC, Uppsala 1986, 565

Whipple, F.L.: 1940, *Proc. Amer. Phil. Soc.* **83**, 711

Whipple, F.L. and Hamid, S.E.: 1952, *Helwan Obs. Bull.* **No.41**, 1