ACTIVITY OF THE GEMINID METEORIC SHOWER IN THE YEARS 1944 - 1974

J. Zvolánková
Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica, Interplanetary Matter Division, Dúbravská cesta, 842 28 Bratislava, Czechoslovakia

Received 18 September 1985

ABSTRACT. More than 8000 visual records of the Geminids from the Skalnaté Pleso Observatory, made over a period of 8 years, have been employed in specifying the activity of the Geminid shower in the years 1944 - 1974, using the exponent $\gamma = 1.47$ in the reduction factor $\cos^{\gamma} z_R$.

АКТИВНОСЬ МЕТЕОРНОГО ПОТОКА ГЕМИНИД В 1944 - 1974 ГГ. На основании свыше 8000 наблюдений Геминид невооруженным глазом полученных в Обсерватории Скалнате Плесо в течение 8 лет используя показатель степени $\gamma = 1.47$ у поправочного фактора $\cos^{\gamma} z_R$ была определена активность потока Геминид в годах 1944 - 1974.

AKTIVITA METEORICKÉHO ROJA GEMINÍD V ROKOCH 1944 - 1974. Na základe viac než 8000 vizuálnych záznamov Geminíd získaných na Observatóriu Skalnaté Pleso počas 8 rokov použitím exponentu $\gamma = 1.47$ v redukčnom faktore $\cos^{\gamma} z_R$ bola spresnená aktivita roja Geminíd v období rokov 1944 - 1974.

1. INTRODUCTION

The Geminids are one of the best known meteoric showers in the Northern Hemisphere. They appear between December 4 and 16. According to Denning and King (Plavec, 1956) they last from December 1 to 17. Maximum of the shower occurs at the solar longitude 261.1°, i.e. on December 13/14 (Millman and McKinley, 1963). The maximum is relatively short and sharp. The hourly rate of 70 meteors is considered to be normal at the maximum for one visual observer under good observating conditions. At the boundaries of the shower the density of meteors is so small that it is difficult to determine the duration, especially if the observation conditions are not ideal. Ideal observation conditions, of course, occur only rarely. The limiting factors are: a) twilight phenomena, changes in the brightness of the celestial background related to the position of the Sun below the horizon (Slančíková, 1975), b) the moonlight during the whole period the Moon is above the horizon, its intensity depending on its phase and position. When the phase is small, its effect can be neglected, particularly as it occurs only during dusk or dawn. Close to full moon, the Moon has a disturbing effect nearly throughout the whole night and the decrease in the observed rate substantially diminishes its statistical weight even if the appropriate correction factors are applied. c) The third limiting factor is cloudiness which may either prevent observations altogether, or decrease the observed rate.

At the time of the Geminids' activity, i.e. in December, the weather in Europe is unstable. In the extensive files of observations of the Skalnaté Pleso Observatory there is not a single case of a continuous series of Geminid observations for more than 4 consecutive nights. The total number of nights in which more than 100 meteors were observed, is 7. The usable material contains 8296 records of meteors of which 5763 are Geminid records. Of the total number of observed Geminids 4397 were selected for further treatment. The total net time of observations of all observers is 158.88 hours.

If the limiting factors mentioned above and the dependence of the observed hourly rate on the zenith distance of the radiant are considered, only very few data are available to determine the activity curve (Zvolánková, 1983).

2. THE DATA AND THEIR ANALYSIS

Visual observations of the Geminid meteoric showers of 1944, 1946, 1947, 1948, 1949, 1953 and 1958, made as part of the program of systematic visual observations of sporadic and shower meteors at the Skalnaté Pleso Observatory, and of 1974 when the observations were made as part of a special program of Interkosmos related to the research into interplanetary matter, have been analysed.

This material has already been processed in detail in the past by a number of authors (Porubčan et al., 1980; Porubčan and Štohl, 1979) using $\gamma = 1$ in the reduction factor $\cos^{\gamma} z_R$. This analysis, in which the activity of the Geminid shower was determined for $\gamma = 1.47$, as found by Zvolánková (1983), is complementary to the earlier papers.

The method of observation has not changed substantially over the whole period mentioned. The group of observers usually consisted of a recorder and four observers who watched the sky at an elevation of 45^{o} above the horizon in the four main directions (E, S, W, N). The cloudiness was recorded at intervals of 10 minutes in each direction. If it changed rapidly, it was recorded every 5 minutes. Each of the observers, on being asked by the recorder, reported the percentage of the observed area covered by clouds. The limiting stellar magnitude was usually not recorded because, as demonstrated by Kresáková (1966), it is practically constant at the high altitude of the Skalnaté Pleso Observatory.

In order to eliminate inhomogenity of the data, observations during which cloudiness exceeded 30%, as well as observations affected by the moonlight and all observations of observers with little experience were omitted.

Tab. 1

Year	M_c	G_c	G
1944	814	415	336
1946	1508	1036	240
1947	885	545	488
1948	232	133	40
1949	614	514	441
1953	927	591	587
1958	2233	1593	1476
1974	1083	936	789
Σ	8296	5763	4397

Table 1 summarizes the total number of meteors M_c, the total number of Geminid records G_c and the number of Geminid records G accepted for further processing in each individual year.

Tab. 2

Name	Abbr.	ΣN_p	Σt_p
Antal M.	Al	587	801
Antalová A.	Aa	235	470
Bečvář A.	T	440	1067
Bouška	Bu	19	107
Dzubák	M	72	500
Forgáč M.	F	72	270
Guth V.	G	78	166
Hajduková M.	Hj	90	170
Kiss V.	Ki	.6	86
Kresák Ľ.	K	502	1071
Kresáková M.	Ka	299	553
Mrkos A.	A	257	574
Olejník Š.	O	36	261
Pajdušáková Ľ.	L	563	1518
Paroubek A.	Pa	145	210
Podstanická R.	Š	103	210
Porubčan V.	Po	168	240
Svoreň J.	Sv	142	218

Name	Abbr.	ΣN_p	Σt_p
Štohl J.	St	224	440
Tremko J.	Tr	80	150
Uhlár J.	U	19	133
Zvolánková J.	Sl	260	318
Σ		4397	9533

Table 2 gives the name and abbreviation for each observer, the sum of all observed meteors used in the present paper, and the total net observing time in minutes.

The observed Geminids were divided into half-hour intervals. For each of these intervals and for each observer p the number of observed Geminids N_p, the net time t_p for which he observed and the average cloudiness were determined. These data and personal coefficients were used to calculate the corrected hourly rates per one observer according to the formula

$$f_o = 60 \sum_1^{\varepsilon} N_p \left[\sum_1^{\varepsilon} t_p / k_{op}\ k_{1p} \right]^{-1} \qquad (1)$$

where f_o is the corrected hourly rate, N_p the number of meteors observed by observer p in the given interval, t_p the net observing time, k_{op} the cloudiness coefficient, k_{1p} the personal coefficient, and ε the number of all observers who observed in the given interval.

The cloudiness coefficients k_{op}, calculated by Guth (1941), were used in this paper. Guth considered two types of cloudiness: a) a circular cloud and b) a continuous cloud cover limited by a great circle. The two coefficients are the same up to the clodiness of 30%. Since the records do not specify the type of cloudiness, all observations at which the cloudiness esceeded 30% were eliminated from further analysis.

For the years 1944-1949, the personal coefficients as determined by Štohl (1969) were used for the individual observers. In the other years, personal factors determined by Porubčan et al. (1980) were used.

The corrections mentioned above were used to calculate the hourly rates f_o for all half-hour intervals. To be able to these hourly rates with each other, the rates had to be reduced to the radiant in the zenith. We denote the zenith hourly rate per one observer as f_z and the reduction factor as $\cos^{\gamma} z_R$. Hence,

$$f_z = f_o / \cos^{\gamma} z_R . \qquad (2)$$

Tab. 3

No.	Date	T	l_{1950}	ΣN_p	Σt_p	f_z	Observers
1	44.12. 4.	19:15	252.61	1	84	2.43	MOKi
2	44.12. 5.	18:45	253.61	1	39	5.21	TLM
3		19:15	253.63	1	90	1.80	TLM
4		19:45	253.65	4	90	5.48	TLM
5	44.12. 9.	23:45	257.88	4	21	17.27	L
6	44.12.11.	18:45	259.71	4	38	23.48	LU

No.	Date	T	l_{1950}	ΣN_p	Σt_p	f_z	Observers
7		19:15	259.73	4	60	11.77	LU
8		19:45	259.75	6	60	15.77	LU
9		20:15	259.77	2	14	24.99	LU
10		21:15	259.81	11	31	34.19	LUT
11		21:45	259.83	31	90	32.19	LUT
12	44.12.13.	00:45	260.98	28	22	92.21	TM
13		18:15	261.72	34	66	130.87	TLMO
14		18:45	261.74	62	120	101.85	TLMO
15		19:15	261.76	71	120	103.72	TLMOKi
16		19:45	261.78	23	60	65.76	TM
17	44.12.16.	18:15	264.77	3	120	7.30	TLOKi
18		21:45	264.92	2	24	6.71	TLMO
19		22:15	264.94	7	120	4.34	TLMO
20		22:45	264.96	5	120	2.91	TLMO
21		23:15	264.98	7	96	4.86	TLMO
22	44.12.17.	20:45	265.90	4	30	14.83	TMO
23		21:15	265.92	1	90	1.02	TMO
24		21:45	265.94	2	60	2.65	TM
25		22:15	265.96	3	60	3.59	TM
26	46.12. 1.	04:15	248.43	3	60	4.22	LA
27	46.12. 4.	02:45	251.41	7	53	8.77	LA
28	46.12.13.	18:15	261.21	21	63	101.74	LKBu
29		18:15	261.23	39	90	105.71	LKBu
30		19:15	261.25	2	6	65.97	LKBu
31		19:45	261.27	49	72	92.84	TLKA
32		20:15	261.29	84	106	94.42	TLKA
33	46.12.14.	20:45	262.33	10	38	26.34	KA
34		21:15	262.35	11	61	16.71	MKA
35	46.12.15.	20:45	263.35	2	180	1.28	TLMKABu
36	46.12.16.	20:45	264.36	6	108	6.53	MKABu
37	47.12.12.	20:45	260.03	10	34	30.98	TLKF
38		21:15	260.05	47	120	37.07	TLKF
39		21:45	260.07	38	120	27.25	TLKF
40		22:15	260.09	36	120	23.88	TLKF
41		22:45	260.11	45	120	28.00	TLKF
42		23:15	260.13	42	110	27.09	TLKF
43		23:45	260.15	40	120	22.96	TLKF
44	47.12.13.	00:15	260.18	57	120	32.09	TLKF
45		00:45	260.20	26	60	29.66	TKF
46		01:45	260.24	32	43	52.43	LK
47		02:15	260.26	40	60	48.25	LK
48		02:45	260.28	37	60	46.95	LK
49		03:15	260.30	36	60	48.83	LK
50	47.12.17.	20:15	265.09	2	60	3.69	AF
51	48.12. 9.	00:45	256.89	4	25	12.62	A

No.	Date	T	l_{1950}	ΣN_p	Σt_p	f_z	Observers
52		01:15	256.91	1	30	2.65	A
53	48.12.10.	01:45	257.95	1	15	4.38	L
54		02:15	257.97	5	30	11.34	L
55		02:45	257.99	1	15	4.78	L
56	48.12.12.	02:15	260.01	11	20	46.47	A
57		02:45	260.03	15	30	44.50	A
58		03:15	260.05	2	10	19.02	A
59	49.12.12.	20:45	260.52	26	36	69.09	TA
60		21:15	260.54	32	56	48.51	TA
61		21:45	260.56	31	60	40.00	TLA
62		22:15	260.58	27	46	41.73	TL
63	49.12.13.	20.45	261.53	30	54	53.15	TA
64		21:15	261.55	52	60	74.10	TA
65		21:45	261.58	55	60	71.06	TLA
66		22:15	261.60	50	60	59.23	TL
67		22:45	261.62	56	60	62.72	TLA
68		23:15	261.64	49	60	52.50	TA
69		23:45	261.66	1	6	10.36	TA
70	49.12.14.	19.45	262.51	9	40	28.84	TA
71		20:15	262.53	11	60	20.09	TA
72		20:45	262.55	1	4	23.96	TA
73	53.12.13.	23:15	261.63	60	72	45.77	AlPaŠKa
74		23:45	261.65	115	120	51.63	AlPaŠKaG
75	53.12.14.	00:15	261.67	78	110	39.06	AlPaŠGK
76		01:45	261.73	19	50	20.78	AlPaŠGK
77		02:15	261.75	94	150	35.58	AlPaGKŠ
78		02:45	261.77	132	150	54.17	AlPAŠGKKa
79		03:15	261.80	34	25	90.11	AlPaŠGKa
80	53.12.15.	00:15	262.69	23	72	17.74	PaŠGKa
81		00:45	262.71	26	120	11.97	PaŠGKa
82		01:15	262.73	6	48	6.96	PaŠGKa
83	58.12.12.	17:45	260.09	8	100	24.87	StAlAaLHj
84		18:15	260.11	18	150	28.54	StKaAaLK
85		18:45	260.13	13	150	17.24	AlKaAaTrK
86		19:15	260.15	39	150	37.82	StAlKaLK
87		19:45	260.17	33	150	26.46	StAlAaLHj
88		20:15	260.19	40	150	28.08	StAaKaLK
89		20:45	260.22	69	150	44.17	AlKaAaTrK
90		21:15	260.24	71	150	38.43	StAlKaLK
91		21:45	260.26	56	150	27.34	StAlAaLHj
92		22:15	260.28	93	150	42.98	StKaAaLK
93		22:45	260.30	100	150	45.17	AlKaAaTrK
94		23:15	260.32	107	150	43.64	AlStKaLK
95		23:45	260.34	123	150	48.14	AlStAaLHj
96	58.12.13.	00:15	260.36	93	150	36.53	StKaAaLK

No.	Date	T	l_{1950}	ΣN_p	Σt_p	f_z	Observers
97		00:45	260.39	131	150	53.29	AlKaAaTrK
98		01:15	260.41	98	150	38.10	AlStKaLK
99	58.12.13.	01:45	260.43	98	150	38.64	AlStAaLHj
100		02:15	260.45	100	150	42.23	StKaAaLK
101		02:45	260.47	103	150	47.20	AlKaAaTrK
102		03:15	260.49	42	90	40.00	StLk
103		03:45	260.51	41	60	69.13	AaHj
104	74.12.13.	21:41	261.16	85	120	51.21	PoSlSvAl
105		22:11	261.18	83	120	47.33	PoSlSvAl
106		23:53	261.25	111	90	68.19	PoSlAl
107	74.12.14.	00:23	261.27	99	90	59.94	PoSlAl
108		02:26	261.36	60	53	67.78	SlSvAl
109		03:57	261.42	112	120	70.45	PoSlSvAl
110		04:27	261.45	99	120	69.41	PoSlSvAl
111		20:23	262.12	25	60	43.78	SlSv
112		22:49	262.22	38	81	28.67	PoSlSv
113		23:19	262.25	54	118	26.68	PoSlSvAl
114	74.12.15.	01:23	262.33	23	58	21.42	SlAl

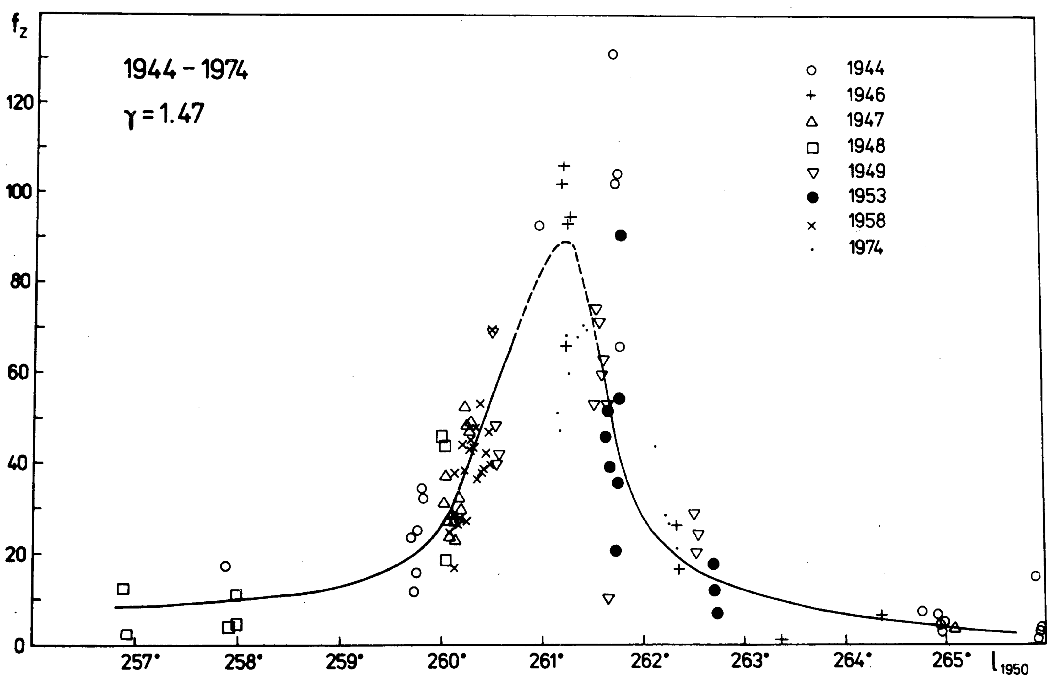

Fig. 1 Zenith hourly rates of the Geminid shower for γ = 1.47 and all years considered in dependence on the solar longitude. The individual years are distinguished by symbols.

Table 3 gives for all half-hour intervals the zenith hourly rates f_z, calculated using exponent $\gamma = 1.47$. Apart from these hourly rates, the table also gives the following data: the ordinal number, the date, the time T of the middle of the half-hour interval in UT, the solar longitude l_{1950}, the total number of meteors ΣN_p observed in the given interval by all observers, the total net time of observation Σt_p of all observers in that interval, and the abbreviations of the individual observers participating in the observations. The data is written for the first half-hour interval of a particular day and applies until the next date is given.

Figure 1 gives the zenith hourly rates of the Geminids for $\gamma = 1.47$, all years and solar longitude $l_{1950} = (256^\circ - 266^\circ)$. The individual years are distinguished by symbols.

Tab. 4

l_{1950}	$\bar{f}_z$	n	l_{1950}	$\bar{f}_z$	n
$248^\circ - 9^\circ$	4.22	1	$260^\circ - 1^\circ$	39.88	42
$251^\circ - 2^\circ$	8.77	1	$261^\circ - 2^\circ$	67.25	30
$252^\circ - 3^\circ$	2.43	1	$262^\circ - 3^\circ$	22.76	12
$253^\circ - 4^\circ$	4.33	3	$263^\circ - 4^\circ$	1.28	1
$256^\circ - 7^\circ$	7.64	2	$264^\circ - 5^\circ$	5.44	6
$257^\circ - 8^\circ$	9.44	4	$265^\circ - 6^\circ$	5.10	5
$259^\circ - 260^\circ$	23.73	6			

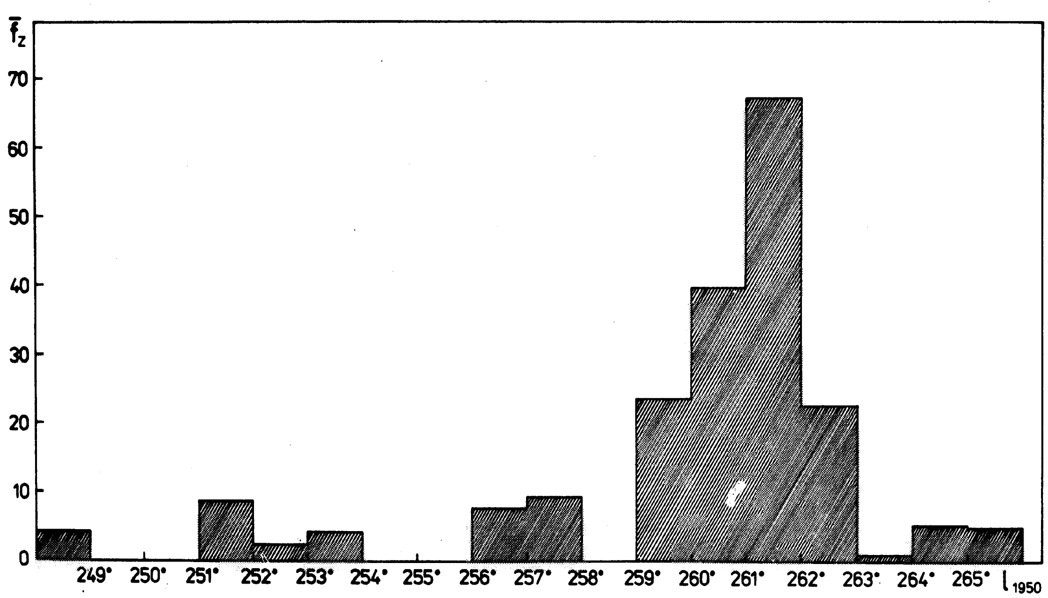

Fig. 2 Mean zenith hourly rates of the Geminid shower for $\gamma = 1.47$ in dependence on the solar longitude.

Table 4 gives the mean zenith hourly rates $\bar{f}_z$ in one-degree intervals in dependence on the solar longitude, and the number of half-hour intervals n from which the average was calculated. These values are illustrated in the histogram in Fig. 2.

3. CONCLUSION

As a result of the lack of continuous observations mentioned earlier, it is difficult to determine the hourly rate curve as a whole reliably. Observations are completely lacking for some longitudes of the Sun (or they had to be omitted due to the disturbing effects of the Moon or clouds) and for most longitudes observations made only in one year are available.

The maximum zenith hourly rate per one observer under undisturbed observation conditions for $\gamma = 1.47$ is 130 meteors at solar longitude 261.72° (Dec.13, 1944).

If the zenith hourly rates calculated for the exponent $\gamma = 1.47$ are compared with those for $\gamma = 1$ (Porubčan et al., 1980, Tab. 4), we can see that the former are substantially higher than the latter. The histogram in Fig. 2 shows that the maximum of the shower´s activity occurs at the solar longitude 261°-262°.

REFERENCES

Guth, V.: 1941, Mitt. u. Beob. d. Tchech. Astron. Ges. 6, 9.

Kresáková, M.: 1966, Contr. Astron. Obs. Skalnaté Pleso 3, 75.

Millman, P.M., Mc Kinley, D.W.R.: 1963, In The Moon, Meteorites and Comets. The Solar System, Vol. 4, Chicago, Chicago Press, 674.

Plavec, M.: 1956, Meteorické roje, 207 pp. Prague, Publishing House of the Czechoslovak Academy of Sciences.

Porubčan, V., Kresáková, M., Štohl, J.: 1980, Contr. Astron. Obs. Skalnaté Pleso 9, 125.

Porubčan, V., Štohl, J.: 1979, Bull. Astron. Inst. Czechosl. 30, 65.

Porubčan, V., Štohl, J.: 1979, Contr. Astron. Obs. Skalnaté Pleso 8, 71.

Slančíková, J.: 1975, Bull. Astron. Inst. Czechosl. 26, 321.

Štohl, J.: 1969, Contr. Astron. Obs. Skalnaté Pleso 4, 25.

Zvolánková, J.: 1984, Bull. Astron. Inst. Czechosl. 34, 122.