ACTIVITY AND FLUX OF THE ORIONID METEOR SHOWER FROM VISUAL OBSERVATIONS

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ABSTRACT. Visual observations of the Orionid meteor shower carried out at the Skalnaté Pleso Observatory in 1945 - 1950, are analysed from the viewpoint of activity and flux determination. The maximum of activity appears at $\odot = 207.8^{\circ}$, with the particle flux of about 2×10^{-3} $km^{-2}h^{-1}$ down to the visual magnitude +4. The total mass influx of the Orionids is estimated at 360 kg per apparition for the whole Earth, down to the same magnitude limit.

АКТИВНОСТЬ И ПРИТОК МЕТЕОРНОГО ПОТОКА ОРИОНИД ИЗ ВИЗУАЛЬНЫХ НАБЛЮДЕНИЙ. В работе анализируются визуальные наблюдениая метеорного потока Орионид из Скалнатого Плеса из гг. 1945-1950, с точки зрения определения активности и потока частиц и массы. Полученно максимум активности находится на долготе солнца 207.8° и поток частиц около 2×10^{-3} $км^{-2}ч^{-1}$ до визуальной величины +4. Общий поток массы Орионид на Землью за год около 360 кг для метеоров до той самой граници визуальной звездной величины.

AKTIVITA A FLUX METEORICKÉHO ROJA ORIONÍD Z VIZUÁLNYCH POZOROVANÍ. V práci sa analyzujú vizuálne pozorovania meteorického roja Orioníd zo Skalnatého Plesa v rokoch 1945 - 1950, z hľadiska aktivity a fluxu. Odvodené maximum aktivity pripadá na slnečnú dĺžku 207.8° s fluxom častíc okolo $2 \times 10^{-3} km^{-2}h^{-1}$ pre meteory do +4 vizuálnej magnitúdy. Celkový ročný prítok hmoty Orioníd na celú Zem pre meteory do tej istej hranice vizuálnej magnitúdy sa odhaduje na 360 kg.

1. INTRODUCTION

Reappearance of Comet Halley and its expected approach to the Sun have stimulated more intensive studies of the Orionid and Eta Aquarid meteor showers genetically associated with the comet. From this point of view, it appears desirable to collect all available data on these showers. The longest series of regular observations of the Orionids, extending over 20 years is based on radar observations (Hajduk, 1982) providing a homogeneous set of data for nearly one third of the orbit of the stream.

Visual observations analysed here date from a period of several years preceding the introduction of radar into meteor astronomy. These observations coincide with the period of the comet's aphelion passage and, consequently, should be free from any irregularities which may appear in the vicinity of the parent comet. As for the activity and magnitude distribution, these data have already been studied by Štohl and Porubčan (1981). The present paper deals with the activity reassessed by applying an improved coefficient for the reduction of observed rates to the zenith, and with the flux estimates.

2. ACTIVITY

Visual observations of the Orionid meteor shower from the Skalnaté Pleso Observatory, as analysed here, consist of five returns of the shower observed in 1945 - 1950, i.e., during first years after foundation of the Observatory. The data comprise a total of 822 records of the shower meteors collected during 84.1 hours of net observational time, in 24 nights. The procedure of processing the data was in principle the same as applied in the paper mentioned above. The only exception was in reducing the observed hourly rates with the use of new correction factors, as derived by Zvolánková (1983) on the basis of visual observations of the Perseid meteor shower covering the same period and carried out by the same group of observers. In her analysis, Zvolánková searched for a reduction factor which would include not only a simple geometric projection as it is with the cos z_R factor (z_R = zenith distance of the radiant), but also the fact that the gradient of atmospheric density depends on the zenith distance of the radiant, i.e., that the apparent brightness of a meteor depends on the angle under which it enters the atmosphere. A factor of $\cos^{1.47} z_R$ was found as the best fit.

The observed rates multiplied by the personal coefficients and the coefficients for cloudiness, where applicable; and reduced to standard observing conditions with the radiant in the zenith by the $\cos^{-1.47} z_R$ factor, allowing for the daily motion of the radiant, are listed in Tab. 1 and plotted in Fig. 1. From the original set of data (Štohl and Porubčan, 1981), the observations of 1944 were omitted from the present analysis, as the meteor programme at the Observatory only started in that year and the observations were not homogeneous enough. Furthermore, some observations from 1945 and 1946 interfered by the moonshine, were not included in the analysis.

Tab. 1 The observed hourly rates of the Orionids

Sun	Date	F_z	Sun	Date	F_z
200.96	15.10.47	4.12	206.79	20.10.47	23.44
201.09	15.10.50	7.04	207.02	20.10.46	33.17
201.94	16.10.47	7.04	207.06	20.10.46	22.34
202.14	16.10.50	11.59	207.09	21.10.46	17.72
203.02	16.10.46	8.88	207.34	21.10.49	20.45
203.06	16.10.46	8.51	207.37	21.10.49	22.61
203.11	17.10.50	13.02	207.78	21.10.47	30.04
203.33	16.10.45	8.28	207.82	22.10.47	27.09
203.37	17.10.45	11.70	207.86	22.10.47	24.99
203.43	17.10.45	12.95	207.91	22.10.47	26.59
203.46	17.10.45	13.97	208.33	22.10.49	12.68
205.22	19.10.46	10.13	208.89	23.10.47	13.01
205.34	19.10.49	11.54	209.77	23.10.47	21.17
206.00	19.10.46	18.22	210.81	25.10.47	7.12
206.04	19.10.46	16.02	211.11	25.10.46	18.56
206.11	20.10.46	16.45	211.85	26.10.47	3.78
206.15	20.10.46	14.40	212.12	26.10.46	12.19
206.19	20.10.46	15.28	212.16	26.10.46	10.78
206.34	20.10.49	16.50	213.09	27.10.46	7.15

The activity of the Orionids is known to persist over 14 days and the data presented here cover the shower activity extending from 200° to 214° in solar longitude. As can be seen from Fig. 1, observations in individual years are not complete enough to reconstruct the activity curve for each year separately. Therefore the observations from the whole period have been combined by solar longitude (equinox 1950.0) to produce a long-term average activity curve. The overall five - year mean hourly rates for successive 0.5° of solar longitude are represented by a histogram. In compiling these values the individual years and observations were given equal weights, and the overall activity of the shower was approximated by a regression polynomial of the third order resulting from a least squares fit.

Columns 1 through 3 of Tab. 1 summarize the observations and list, respectively, solar longitudes of the mid-points of about one-hour observing periods, dates, and resulting zenithal hourly rates. The data in the first two columns are identical with those presented in Tab. 4 of the previous analysis (Štohl and Porubčan, 1981). Applying the new reduction factor to the zenith, the changes of the rates are increased by $\cos^{0.47} z_R$ only. For the latitude of the Skalnaté Pleso the minimum value of z_R at the meridian transit of the shower radiant is 25°, and the mid-points of the analysed periods of the observations range from 32° to 63° in z_R. Thus the corresponding rates are changed by a factor of 1.08 to 1.45. Comparing the rates with those obtained applying the simple $\cos z_R$ factor, no change in the position of the maximum of activity of the Orionids is found. The maximum appears at the solar longitude of 207.8°

with the peak rate rising to 27 meteors per hour per one observer, down to the apparent magnitude +5.

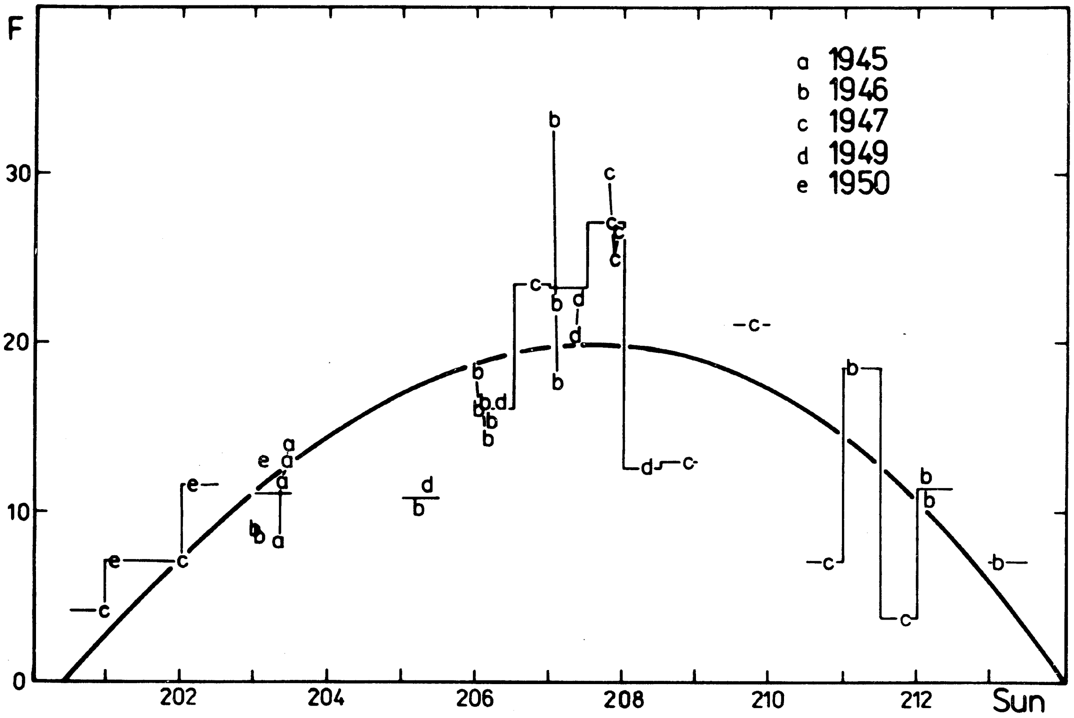

Fig. 1 The reduced hourly rates of the Orionids in individual years (different markings) plotted against the solar longitude at the time of observation (equinox 1950.0). Histogram: mean hourly rates in successive 0.5° of solar longitude. Heavy line: overall activity approximated by a least square solution regression polynomial.

3. FLUX

In order to find the particle flux, it is necessary to know the actual magnitude distribution of the observed meteors normalized to the absolute zenith magnitudes, and the area through which the meteors are passing. In finding the flux, the same procedure as applied for the flux estimate of the Geminid meteor shower (Porubčan and Štohl, 1979) was used. Here are outlined only the main steps of the procedure.

In the first step, the mean magnitude distributions f(m) normalized to standard conditions, and hourly rates in each interval of observation were derived. The rates were reduced to zenithal rates allowing for the motion of the radiant and zenith attraction. Since the probability of detection tends to decrease for fainter meteors, the observed mean rates must be corrected for missed meteors. The counts of meteors for each magnitude and for the whole hemisphere were computed using the probabilities of meteor detection as derived by Kresáková (1966).

In the next step, the observed magnitudes were corrected for different zenith distances and thereby normalized to the absolute zenith magnitudes. The corrections were made statistically, assuming a uniform distribution of meteors over the observed area. The limiting zenith distances z_i of the concentric zones around the zenith for which $m_i = m - m_z = -0.5^m, -1.5^m$, etc. ($m$ and m_z are apparent and zenith magnitudes, respectively) can be found from the formula

$$z_i = \arccos \left[0.5 \, HR^{-1} \, (2RH^{-1} + 1 - 10^{0.4 \Delta m_i}) \times 10^{-0.2 \Delta m_i} \right], \qquad (1)$$

where the Earth's radius for the observing site is R = 6366 km. For the mean atmospheric height of the Orionids we accepted H = 102 km, the value found for Super-Schmidt meteors moving with the Orionids velocity (Jacchia et al., 1967). Allowing also for the atmospheric absorption we obtain $z_i = 36.2^\circ$ and 57.7° for $m_i = -0.5^m$ and -1.5^m, respectively. For the first zone no correction for the apparent magnitude was applied, for the second zone the correction was -1^m. The total hourly rates of meteors of the absolute zenith magnitude m_z, $F(m_z)$, passing through a concentric area S, around the zenith down to $z = 57.7^\circ$ are

$$F(m_z) = 0.193 f_z(m) p^{-1}(m) + 0.273 f_z(m+1) p^{-1}(m+1) \quad , \qquad (2)$$

with $f_z(m)$ - the zenithal rate of meteors of magnitude m and p(m) - the probability of detection of a meteor of magnitude m.

Tab. 2

m_z	f_z	$f_z x p^{-1}$	F (particles per hour)	Mass (grams per hour)
-4	-	-	-	-
-3	0.33	0.38	0.07	0.11
-2	-	-	0.11	0.07
-1	0.24	0.42	0.58	0.15
0	0.87	1.81	1.24	0.12
1	1.37	2.26	5.05	0.20
2	5.56	16.2	12.2	0.19
3	7.71	33.2	34.3	0.22
4	6.53	102	104	0.26
5	2.47	309		
Σ			$157.6 \ nh^{-1}$	$1.32 \ gh^{-1}$
flux (ν)			$2 \times 10^{-3} \ nkm^{-2}h^{-1}$	$1.7 \times 10^{-8} \ kgkm^{-2}h^{-1}$
density ($D_\infty = \nu_\infty V_g^{-1}$)			$8.2 \times 10^{-9} \ nkm^{-3}$	$6.9 \times 10^{-14} \ kgkm^{-3}$

Tab. 2 lists the values of $f_z(m)$ and $F(m_z)$ derived from the period between solar longitudes 207° - 208°, including the maximum of the shower activity. The counts of meteors were restricted to the area S at a height of $H = 102$ km and limited by $z = 57.7^{\circ}$. Hence, $S = 7.87 \times 10^{4}$ km^{2} and the corresponding particle flux for meteors down to the visual magnitude +4, is 2.0×10^{-3} km^{-2}h^{-1}.

To estimate the meteoroid mass influx through the observed area S, the mass $M(m_z)$ of a meteor of zenith magnitude m_z must be known. $M(m_z)$ can be derived from the formula

$$M(m_z) = M(0) \times 10^{-0.4 m_z} \quad , \tag{3}$$

where M(0) is the mass of a zero visual magnitude meteoroid. Applying the mass scale derived by Jacchia et al. (1967), $M(0) = 0.1$ g can be accepted for the Orionids ($V_{\infty} = 67.4$ kms^{-1}). The total mass influx through the observed area is given by

$$M_t = \Sigma\, F(m_z) \,.\, M(m_z) \quad . \tag{4}$$

The estimated M_t for the Orionids within the interval of solar longitude 207° - 208° and for m_z down to +4 and the area S, is 1.32 g per hour, or 1.7×10^{-8} kgkm^{-2}h^{-1}.

The Earth by its gravitational force collects a beam of meteoroids moving in paralell orbits from a larger area than is its cross-section. The effective target area S_{∞}, is

$$S_{\infty} = \pi (R + H)^{2}\, V_{\infty}^{2}\, V_{g}^{-2} \quad . \tag{5}$$

For the Orionids ($V_g = 66.5$ kms^{-1}) the target area, is $S_{\infty} = 1.35 \times 10^{8}$ km^{2}. The corresponding flux of particles ν_{∞}, undisturbed by the Earth's gravitational force, is

$$\nu_{\infty} = \nu \,.\, k^{-1} \quad , \tag{6}$$

where ν is the observed flux and $k = 1 + g(R + H) \,.\, V_{g}^{-2}$, is the perturbational focussing factor (Levin, 1961). With $g = 9.5 \times 10^{-3}$kms^{-2}, $k = 1.014$. The total influx of the Orionids encountering the Earth is given by

$$\Phi = \nu_{\infty} \,.\, S_{\infty} \quad . \tag{7}$$

Inserting the observed values, the flux of the Orionids on the Earth at the maximum of activity amounts to about 54 kg per day for meteors down to the magnitude +4. Provided that the relative mass distribution during the whole period of activity is the same, the total mass influx can be found by integrating the activity curve as approximated by the regression polynomial in Fig. 1. Direct assessment of the influx, as at the peak of activity, was not possible for a poor coverage of the activity curve by the observations. The estimated total mass influx of the Orionids is of about 360 kg.

It appears worthwhile to compare the above fluxes with the results derived from radio observations. Visual estimates with the limiting visual magnitude +4 correspond approximately to the overdense-echoe boundary. Hajduk (1982) derived the flux of the Orionids on different dates from radar observations at Ondřejov and Springhill (limiting magnitude +7), with a value of about 1.4×10^{-16} kgm^{-2}s^{-1} for the distance of 0.16 AU from the comet's orbit at the heliocentric distance of 1 AU. In a new model of the structure of the Comet Halley meteor stream (the Eta Aquarids and Orionids), McIntosh and Hajduk (1983) adopted the flux of 2×10^{-16} kgm^{-2}s^{-1} (7.2×10^{-7} kgkm^{-2}h^{-1}) as the probable mean value. Jones (1983), analysing his 1980 and 1981 observations obtained by an imaging radar system (limiting magnitude +8.1) estimated the particle flux of the Orionids at 0.109 km^{-2}h^{-1}. Since a direct comparison of the visual and radar fluxes is not possible, a rough assessment can be made by extrapolating the visual data with a mean magnitude distribution index r, assuming its validity even for fainter meteors. The mean r derived from the same observations of the Orionids as analysed here, is r = 3.08 (Štohl and Porubčan, 1981). The extrapolated particle flux down to the visual magnitude +7 is 0.057 km^{-2}h^{-1}, which is in good agreement with the estimate by Jones (approx. 0.05 km^{-2}h^{-1} for magnitude +7.35). As for the mass flux, visual observations yield 3.2×10^{-8} kgkm^{-2}h^{-1}, which is one order of magnitude less than the estimate by McIntosh and Hajduk.

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