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THE DENSITY DISTRIBUTION OF TELESCOPIC METEORS AROUND THE EARTH'S ORBIT

Abstract: The density distribution of faint meteors around the earth's orbit is investigated on the basis of 1397 telescopic meteor observations (4573 meteors recorded during a net time of 1364 hours) obtained at the Skalnaté Pleso Observatory in 1946—1959. The variations of the spatial density of meteors with solar longitude are determined for three different models of apparent radiant distribution, and it is shown that no stable model can satisfactorily account for the genuine variations of meteor rates. The remaining variation is related to the distribution of approaching short-periodic cometary orbits, indicating a cometary origin for at least a part of the sporadic meteors. Some evidence suggests a marked concentration of telescopic meteor orbits to the plane of the ecliptic. In the magnitude range of $6-9^m$ the major meteor showers, known from photographic and naked-eye observations, appear at considerably reduced strength; on the other hand, several showers, composed predominantly of faint meteors, appear. On the whole the contribution of meteor showers to the sporadic background becomes lower with decreasing meteor brightness. This fact affects the variations of meteoric risk to space vehicles which are relatively moderate at the level of impact probability $10^{-6}m^{-2}day^{-1}$ (2 mm penetration of aluminium skin). Another increase of the amplitude of these variations, suggested by the observation of the faintest radio meteors and, in particular, by direct impact measurements on artificial satellites, evidently occurs lower in the scale of particle sizes.

1. Introduction

Recent studies have provided substantial evidence that the rate of meteoric particles encountered by the earth varies considerably not only owing to the occurrence of recognized meteor showers but also because of a non-uniform density distribution of the sporadic background. The irregularities, appearing periodically in the form of an annual variation of meteor rates, are of particular interest in connection with the constitution of meteor streams at advanced stages of dispersion, and with the meteoric risk to space vehicles, especially those moving in satellite orbits around the earth or launched to the moon. The evaluation of the annual variation is made difficult by the variability of geometrical conditions with geographic latitude and by the additional effect of diurnal variation produced by the rotation of the earth. In this respect radio observations, covering the whole period of the earth's rotation, are especially suitable; on the other hand, the instrumental effects of selection are more difficult to remove in this case than in the optical observations. Another difficulty arises from the possible irregular variations of the meteor velocity distribution with time. Different observing techniques imply different, and in general rather indeterminate, relations between geocentric velocity and sensitivity.

The main purpose of this paper is to analyze the distribution of meteor orbits around that of the earth on the basis of telescopic meteor observations carried out at the Skalnaté Pleso Observatory during the years 1964—1959. These observations include faint telescopic meteors down to the 10th apparent visual magnitude; more than half of the data are concerned with meteors of 8th and 9th magnitudes. These faint meteors are of particular significance for two reasons:

(1) In the constitution of meteor streams they may reveal evolutionary changes caused by the effects of solar radiation, which are substantially greater on smaller particles and need not appear

in the data obtained by naked-eye or photographic techniques.

(2) The likelihood of collision with a space vehicle is greater for smaller meteors, approximately by a factor of ten for each two magnitudes. For the telescopic meteors recorded during the Skalnaté Pleso program, the average probability of collision is about $10^{-6} m^{-2} day^{-1}$; this is not a negligible figure even for the size of space vehicles and duration of flight expected in the near future. The corresponding mass limit and perforation thickness—about $2 \times 10^{-3} g$ and 2 mm of aluminium skin, respectively, according to the recent estimates of Whipple (1963)—make this magnitude range particularly important for the penetration risk.

The first part of the observations elaborated here has already been published (Kresáková and Kresák 1955). Since then the observing data have been further extended by continuing the telescopic meteor program at the Skalnaté Pleso Observatory. By the end of 1959 they included 4573 meteors recorded during 1397 observations with a total net time of 1364 hours.

In the first treatment of the data the net annual variation of meteor rates was referred to a model of radiant distribution based on the relation derived by Hoffmeister (1931). This relation assumes a dependence of the apparent radiant density on the elongation from the apex only, the degree of apical concentration being determined by a single constant, which may be derived from the observed hourly rates at different altitudes of the apex. The analysis of the direction distribution in the same material enabled the establishment of a marked concentration of radiants towards the ecliptic (Kresák 1955); however the data were insufficient for evaluating this quantitatively.

In the meantime, substantial progress in our knowledge of the radiant distribution has been achieved by means of other observing techniques. The results derived by Hawkins (1956), Ellyett and Keay (1956) and Davies (1957) from radio-echo radiant surveys, by Öpik (1956) and Hawkins and Prentice (1957) from double-station naked-eye plots, and by Southworth and Hawkins (1963) from the Super-Schmidt photographic data are in a good agreement, at least from the qualitative point of view. They consistently suggest a more complicated radiant pattern with a marked ecliptical concentration, two regions of maximum occurrence symmetrically located in the ecliptic at distances of 60° to 90° from the apex, and

a secondary maximum at the apex. Keay (1963) extended the studies to the determination of the relative annual variation in the strength of the three main sources in question (helion, anti-helion and apex). A slight enhancement of the radiant density along a great circle joining the apex with the poles of the ecliptic is also indicated, but for most of the surveys this is near the threshold of detectability. Among the results of different authors only those of Bain (1960), using forward scatter radio echoes, are essentially discordant, confirming rather a uniform radiant distribution over the celestial sphere.

It must be emphasized that the complicated apparent radiant distribution described above poes not require any unnatural distribution of meteor orbits in space. As has been demonstrated by Levin (1960), even in this case the density distribution of true radiants of the particles down to a given mass limit, freed from the effects of the earth's orbital motion and penetration velocities, shows only one distinct maximum at the antapex and a smooth decline in all directions therefrom.

As the investigation of the annual variation of the meteor infall is the main purpose of the present study, the choice of a reference model of sporadic radiant distribution is necessary. It is the only way of removing the effect of the non-uniform radiant distribution over the visible and invisible hemisphere, respectively, from the statistics of hourly rates. The procedure is equivalent to the elimination of the diurnal variation, caused by the rotation of the earth, by adopting a basic level of activity for any orientation of the horizontal level with respect to the apex and ecliptic. Obviously, the result will depend upon the choice of the model. In order to check the sensitivity of the results to the uncertainty of this choice, three widely different models are adopted:

(A) The uniform radiant distribution over the celestial sphere, yielding constant hourly rates.

(B) An isotropic radiant distribution with respect to the apex, with a continuous decrease of the radiant density towards the antapex following Hoffmeister's relation (1931). The density gradient, or the-equivalent velocity constant $c = 3.9$, was computed directly from our observations (Kresáková and Kresák 1955).

(C) The standard distribution derived by Hawkins (1956) from the radio-echo data. This was adopted as a representative of the type of three-source models, including the three point-radiant models superimposed on a uniform background

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(Meeks and James 1959, Ellyett and Keay 1961).

In spite of possible variations of the radiant distribution with meteor magnitudes, the differences among these three models certainly surpass the whole range of uncertainty in the yearly mean radiant distribution. All three models assume an ideal sporadic background, with an invariable radiant distribution with respect to the apex and ecliptic during the whole year. The condition of an invariable heliocentric velocity distribution is of less significance in this respect, since the distribution of geocentric velocities, controlling the limiting masses of the meteors that become observable, depends primarily upon the distribution of the radiant elongations from the apex and only secondarily upon the distribution of heliocentric velocities or semi-major axes. The actual radiant distribution may considerably differ from the simplified models if the sporadic background is chiefly composed of a number of separate meteor showers. If the total number of meteor showers is high and the relative contribution of them low (like in the photographic meteor associations), the use of a model remains reasonable. On the other hand, the contribution of a limited number of strong and concentrated showers (like the major cometary showers) producing marked irregularities on the annual variation curve, may be readily identified and separated.

Some results in this respect, in particular a lack of permanent meteor showers in the telescopic magnitude range, have already been obtained from the first part of the Skalnaté Pleso observations (Kresáková and Kresák 1955). The extension of the observations over the period 1954—1959 makes it possible to search for additional enhancements of telescopic meteor activity and their recurrence. Other aims of the present study are to demonstrate whether there is any correlation between the distribution of telescopic meteor orbits and cometary orbits, to compare the annual variations of meteor rates obtained by telescopic and other techniques, and to consider the annual changes of meteoric risk to space vehicles moving in the earth-moon system.

2. Results of observations, 1953—1959

The observations of telescopic meteors referred to were made during routine comet searches with 25 × 100 Somet-Binar binoculars at the Skalnaté Pleso Observatory (20°15' E, 49°11' N). Different seasons of the year, different night hours and different positions of the field of view on the visible hemisphere are fairly uniformly covered by the observations, the limiting magnitude being 12.5 to 13^m for stars and about 11^m for meteors. Other particulars as to the method of observations may be found in the first article (Kresáková and Kresák 1955), in which data acquired with the same method were used. Table II of the article lists the hourly rates referred to the models (A) and (B) for the observations in 1946—1953. It is directly continued by Table II of the present article; for an easy discrimination between the two series of observations, each of which are arranged according to the solar longitude, the second series (1953—1959) begins with No. 2001. The list of observers who participated in the second series is given in Table I. For each of them the abbreviation used in Table II, the number of observations, the total net time of observation and the number of meteors recorded are listed.

Table I

Obs.	Abbr.	Period	o	τ	n
M. Antal	An	1956—1959	11	11.8	46
A. Antalová	Aá	1958—1959	41	32.0	77
M. Čapková	Čp	1959	5	3.8	5
Ľ. Kresák	K	1953—1956	69	50.0	150
M. Kresáková	V	1953—1955	54	38.5	109
J. Lexa	Lx	1959	1	0.9	1
Ľ. Pajdušáková-Mrkosová	P	1953—1959	87	108.0	257
R. Šáškyová-Podstanická	Ša	1953—1955	3	2.0	3
Sum . . .		1953—1959	271	247.0	648

The meaning of the individual columns of Table II is as follows: 1. the serial number of the observation, 2. the solar longitude, 3. the date of the observation, 4. the time limits in M.E.T., 5. the abbreviation of the observer, 6. the net time of observation τ in minutes, 7. the number of meteors recorded n_o, 8. the expected number of meteors n_c in model B, 9. the mean altitude of the apex H, 10. the observed hourly rate f_o, 11. the computed hourly rate f_c in model B, 12. the ratio of observed to computed hourly rate, $F = f_o/f_c$.

The following typographical errors should be corrected in the first part of Table II (Kresáková and Kresák 1955): No. 90 : $n_o = 2$, $n_c = 3$; No. 1008 : $H = 27$, $f_c = 4.0$.

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Table II

No.	⊙	Date	Time M.E.T	Obs.	τ	n_o	n_c	H	f_o	f_c	F
2001	0.4	1956 III. 21.	02 30—04 30	P	90	2	5	+11	1.3	3.5	0.4
2002	2.3	1955 III. 23.	19 45—20 20	K	30	0	1	—51	0.0	2.0	0.0
2003	2.3	1955 III. 23.	19 50—20 20	V	25	1	1	—51	2.4	2.0	1.2
2004	2.4	1955 III 23.	22 15—23 10	K	50	4	2	—27	4.8	2.5	1.9
2005	2.4	1955 III. 23.	21 25—21 50	V	20	0	1	—38	0.0	2.3	0.0
2006	4.4	1955 III. 25.	22 05—23 05	V	50	1	2	—28	1.2	2.5	0.5
2007	5.8	1957 III. 26.	20 00—21 15	P	65	1	2	—46	0.9	2.1	0.4
2008	11.2	1959 IV. 1.	20 20—21 30	Aá	45	2	2	—44	2.7	2.2	1.2
2009	22.8	1956 IV. 12.	20 35—21 35	P	60	0	2	—42	0.0	2.2	0.0
2010	22.8	1956 IV. 12.	21 45—23 00	P	65	1	3	—30	0.9	2.4	0.4
2011	23.0	1956 IV. 13.	02 00—03 15	P	70	0	4	+7	0.0	3.4	0.0
2012	23.3	1959 IV. 14.	02 50—03 20	Čp	30	1	2	+10	2.0	3.5	0.6
2013	23.3	1959 IV. 14.	02 50—03 20	P	30	0	2	+10	0.0	3.5	0.0
2014	24.0	1956 IV. 14.	01 30—03 30	P	100	4	6	+6	2.4	3.4	0.7
2015	24.0	1959 IV. 14.	19 30—20 30	Aá	50	0	2	—51	0.0	2.0	0.0
2016	24.1	1955 IV. 14.	23 00—23 40	K	35	1	2	—21	1.7	2.6	0.7
2017	24.2	1959 IV. 15.	02 15—03 05	P	50	3	3	+7	3.6	3.4	1.1
2018	25.1	1959 IV. 15.	22 30—23 30	An	60	11	3	—24	11.0	2.6	4.2
2019	31.8	1955 IV. 22.	20 35—21 05	V	25	1	1	—43	2.4	2.2	1.1
2020	37.3	1957 IV 27.	23 00—00 00	P	55	5	3	—17	5.5	2.7	2.0
2021	45.2	1956 V. 5.	21 45—22 30	P	60	1	2	—29	1.0	2.5	0.4
2022	45.3	1956 V. 5.	22 45—23 55	P	60	3	3	—17	3.0	2.7	1.1
2023	47.3	1956 V. 8.	01 00—03 00	P	100	4	6	+7	2.4	3.4	0.7
2024	48.4	1955 V. 9	21 15—21 45	K	30	1	1	—34	2.0	2.3	0.9
2025	48.4	1955 V. 9.	21 20—21 50	V	30	1	1	—33	2.0	2.4	0.8
2026	49.3	1959 V. 10.	21 20—21 50	Aá	30	1	1	—33	2.0	2,4	0.8
2027	51.3	1955 V. 12.	22 20—23 15	K	50	5	2	—20	6.0	2.7	2.2
2028	51.3	1955 V. 12.	23 15—23 50	K	30	1	1	—14	2.0	2.8	0.7
2029	56.2	1955 V. 18.	00 20—01 00	V	30	1	2	—2	2.0	3.1	0.6
2030	57.0	1956 V. 18.	01 00—02 40	P	90	2	5	+9	1.3	3.4	0.4
2031	60.0	1955 V. 21.	22 05—22 40	V	30	2	1	—22	4.0	2.6	1.5
2032	60.0	1955 V. 21.	22 10—22 40	K	30	3	1	—22	6.0	2.6	2.3
2033	60.0	1955 V. 21.	22 45—23 15	K	25	1	1	—16	2.4	2.8	0.9
2034	63.0	1954 V. 24.	21 25—22 05	K	40	3	2	—27	4.5	2.5	1.8
2035	78.5	1954 VI. 10.	00 30—01 35	K	40	1	2	+9	1.5	3.4	0.4
2036	81.1	1955 VI. 12.	23 10—23 40	K	30	1	2	—5	2.0	3.0	0.7
2037	82.0	1955 VI. 13.	22 45—23 10	K	25	2	1	—9	4.8	2.9	1.7
2038	82.0	1955 VI. 13.	22 50—23 20	V	30	1	2	—8	2.0	3.0	0.7
2039	89.9	1954 VI. 21.	22 10—23 10	K	45	2	2	—9	2.7	2.9	0.9
2040	89.9	1954 VI. 21.	22 30—23 10	V	30	2	1	—8	4.0	3.0	1.3
2041	94.7	1954 VI. 26.	23 00—23 30	K	30	1	2	—2	2.0	3.1	0.6
2042	94.7	1954 VI. 26.	23 05—23 30	V	25	1	1	—2	2.4	3.1	0.8
2043	96.8	1957 VI. 28.	22 30—01 00	P	90	6	5	+3	4.0	3.3	1.2
2044	98.6	1954 VII. 1.	00 30—01 10	K	35	1	2	+15	1.7	3.6	0.5
2045	101.6	1957 VII. 3.	23 15—00 30	An	75	2	4	+6	1.6	3.4	0.5
2046	104.0	1959 VII. 6.	23 30—00 35	Aá	50	2	3	+9	2.4	3.4	0.7
2047	104.1	1959 VII. 7.	01 10—02 15	Aá	55	1	4	+25	1.1	3.9	0.3
2048	104.1	1959 VII. 7.	01 10—02 15	Lx	55	1	4	+25	1.1	3.9	0.3
2049	105.8	1959 VII. 8.	22 30—23 15	Aá	40	2	2	—2	3.0	3.1	1.0
2050	106.8	1959 VII. 9.	23 00—00 00	Aá	60	3	3	+5	3.0	3.3	0.9
2051	107.7	1959 VII. 10.	22 30—00 00	Aá	80	7	4	+2	5.3	3.2	1.7
2052	108.6	1956 VII. 11.	00 15—02 30	P	120	2	8	+23	1.0	3.9	0.3
2053	108.7	1959 VII. 11.	22 30—00 10	Aá	85	1	5	+4	0.7	3.3	0.2
2054	110.5	1956 VII. 13.	00 00—02 30	P	70	3	4	+23	2.6	3.9	0.7
2055	112.4	1956 VII. 15.	00 00—01 45	P	85	5	5	+20	3.5	3.8	0.9
2056	112.5	1955 VII. 15.	21 35—23 45	V	115	4	6	—1	2.1	3.2	0.7
2057	112.6	1955 VII. 15.	23 20—00 00	K	40	2	2	+8	3.0	3.4	0.9
2058	113.3	1956 VII. 15.	23 40—00 50	P	45	6	3	+15	8.0	3.6	2.2
2059	118.3	1955 VII. 21.	23 40—00 05	V	25	1	2	+12	2.4	3.5	0.7
2060	119.4	1954 VII. 22.	21 20—22 10	K	45	2	2	—7	2.7	3.0	0.9
2061	121.4	1954 VII. 24.	22 60—23 05	K	40	2	2	0	3.0	3.2	0.9
2062	121.4	1954 VII. 24.	22 20—23 00	V	35	4	2	+2	6.9	3.2	2.2
2063	124.0	1955 VII. 27.	22 45—23 05	V	20	3	1	+5	9.0	3.3	2.7
2064	124.0	1959 VII. 28.	23 15—23 40	Aá	25	1	1	+10	2.4	3.5	0.7
2065	125.2	1954 VII. 28.	21 55—22 45	K	45	2	2	0	2.7	3.2	0.8
2066	125.2	1954 VII. 28.	22 00—22 45	V	40	1	2	0	1.5	3.2	0.5
2067	125.4	1957 VII. 28.	21 30—23 45	P	100	4	5	+3	4.8	3.3	1.5
2068	129.2	1954 VIII. 2.	02 00—02 30	K	30	0	2	+37	0.0	4.2	0.0
2069	129.5	1956 VIII. 1.	21 45—22 30	P	45	5	2	—1	6.7	3.2	2.1
2070	132.2	1957 VIII. 5.	01 00—02 40	P	100	8	7	+35	4.8	4.2	1.1
2071	132.3	1956 VIII. 4.	20 55—22 10	P	65	2	3	—5	1.8	3.0	0.6
2072	137.3	1956 VIII. 10.	02 00—03 05	P	55	2	4	+42	2.2	4.4	0.5

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No.	$\odot$	Date	Time M.E.T	Obs.	τ	n_o	n_c	H	f_o	f_c	F
2073	140.0	1956 VIII. 12.	21 45—22 30	P	40	1	2	+2	1.5	3.2	0.5
2074	140.2	1956 VIII. 13.	02 00—03 15	P	70	2	5	+44	1.7	4.4	0.4
2075	144.1	1955 VIII. 17.	23 05—23 35	V	30	1	2	+14	2.0	3.6	0.6
2076	146.2	1958 VIII. 19.	21 00—23 00	An	120	7	6	+3	3.5	3.3	1.1
2077	147.5	1957 VIII. 20.	23 00—00 00	P	60	3	4	+16	3.0	3.7	0.8
2078	149.5	1957 VIII. 23.	00 10—01 00	An	50	2	3	+27	2.4	4.0	0.6
2079	149.8	1959 VIII. 23.	20 00—21 30	Aá	80	3	4	—7	2.3	3.0	0.8
2080	156.8	1959 VIII. 31.	02 30—03 30	P	60	7	5	+50	7.0	4.6	1.5
2081	158.3	1956 VIII. 31.	21 35—22 25	K	45	1	3	+5	1.3	3.3	0.4
2082	159.0	1954 IX. 2.	02 10—03 00	K	45	3	3	+46	4.0	4.5	0.9
2083	159.3	1956 IX. 1.	21 55—23 00	K	60	0	3	+8	0.0	3.4	0.0
2084	160.2	1956 IX. 2.	20 05—21 15	K	60	3	3	—6	3,0	3.0	1.0
2085	160.2	1956 IX. 2.	21 15—22 05	K	45	0	2	+2	0.0	3.2	0.0
2086	160.7	1958 IX. 3.	20 20—21 15	P	50	2	3	—5	2.4	3.0	0.8
2087	161.2	1956 IX. 3.	20 20—21 45	K	60	0	3	—3	0.0	3.1	0.0
2088	161.6	1956 IX. 4.	20 15—21 10	P	40	1	2	—5	1.5	3.0	0.5
2089	163.1	1956 IX. 5.	20 45—21 45	K	60	6	3	—1	6.0	3.2	1.9
2090	163.2	1956 IX. 5.	21 45—22 35	K	45	2	3	+7	2.7	3.4	0.8
2091	163.7	1958 IX. 6.	22 10—23 05	P	50	2	3	+10	2.4	3.5	0.7
2092	163.7	1958 IX. 6.	22 30—23 00	Aá	30	1	2	+11	2.0	3.5	0.6
2093	164.2	1956 IX. 6.	22 30—23 15	An	45	7	3	+12	9.3	3.5	2.7
2094	164.3	1955 IX. 7.	20 00—20 30	K	30	1	1	—8	2,0	3.0	0.7
2095	164.3	1955 IX. 7.	20 00—20 30	V	30	0	2	—8	0.0	3.0	0.0
2096	164.3	1959 IX. 7.	21 20—22 00	Aá	40	2	2	+2	3.0	3.2	0.9
2097	164.6	1958 IX. 7.	21 00—22 20	Aá	60	2	3	+2	2.0	3.2	0.6
2098	165.3	1955 IX. 8.	19 55—21 20	K	70	4	3	—6	3.4	3.0	1.1
2099	165.3	1955 IX. 8.	20 30—21 15	Ša	40	1	2	—3	1.5	3.1	0.5
2100	165.3	1955 IX. 8.	20 40—21 10	V	20	1	1	—3	3.0	3.1	1.0
2101	165.6	1958 IX. 8.	22 00—22 45	Aá	35	1	2	+8	1.7	3.4	0.5
2102	166.2	1955 IX. 9.	20 00—20 55	V	50	4	3	—6	4.8	3.0	1.6
2103	166.2	1956 IX. 9.	02 05—03 00	K	50	1	4	+47	1.2	4.5	0.3
2104	166.3	1955 IX. 9.	21 35—22 10	K	30	0	2	+4	0.0	3.3	0.0
2105	167.0	1956 IX. 9.	20 00—21 05	K	60	1	3	—6	1.0	3.0	0.3
2106	167.0	1956 IX. 9.	21 05—22 05	K	50	2	3	+2	2.4	3.2	0.8
2107	167.0	1956 IX. 9.	21 30—22 45	P	60	6	3	+6	6.0	3.4	1.8
2108	167.2	1956 IX. 10.	01 30—03 45	P	110	7	8	+47	3.8	4.5	0.8
2109	168.3	1959 IX. 12.	00 15—00 45	Aá	30	2	2	+28	4.0	4.0	1.0
2110	173.1	1955 IX. 16.	21 45—22 30	V	40	1	2	+6	1.5	3.4	0.4
2111	177.2	1954 IX. 20.	19 35—20 50	K	60	5	3	—8	5.5	3.0	1.8
2112	177.2	1954 IX. 20.	19 35—21 00	V	70	6	3	—7	5.1	3.0	1.7
2113	177.4	1958 IX. 21.	00 55—01 30	Aá	40	3	3	+35	5.1	4.2	1.2
2114	178.5	1957 IX. 21.	20 30—22 15	P	90	2	5	0	1.3	3.2	0.4
2115	179.3	1954 IX. 22.	23 20—00 10	K	40	1	3	+20	1.5	3.8	0.4
2116	179.3	1954 IX. 22.	23 35—00 45	V	60	4	4	+25	4.0	3.9	1.0
2117	179.5	1957 IX. 22.	22 15—00 30	P	90	2	6	+17	1.3	3.7	0.4
2118	181.1	1954 IX. 24.	19 20—19 55	K	30	3	1	—11	6.0	2.9	2.1
2119	181.3	1954 IX. 25.	00 45—02 30	K	90	13	6	+38	8.7	4.3	2.0
2120	181.6	1956 IX. 24.	19 45—20 15	K	30	0	1	—9	0.0	2.9	0.0
2121	182.6	1956 IX. 25.	19 45—20 40	K	50	0	2	—8	0.0	3.0	0.0
2122	185.1	1954 IX. 28.	19 50—20 30	K	30	1	1	—8	2.0	3.0	0.7
2123	185.5	1956 IX. 28.	19 25—20 10	K	45	2	2	—10	2.7	2.9	0.9
2124	185.5	1956 IX. 28.	20 10—20 45	K	30	0	2	—6	0.0	3.0	0.0
2125	186.5	1956 IX. 29.	19 10—19 45	K	35	3	2	—12	5.1	2.9	1.8
2126	186.5	1956 IX. 29.	19 45—20 20	K	35	1	2	—9	1.7	2.9	0.6
2127	186.8	1959 IX. 30.	21 00—22 00	Aá	60	7	3	+1	7.0	3.2	2.2
2128	189.3	1954 X. 3.	03 10—04 20	K	60	3	5	+56	3.0	4.7	0.6
2129	190.3	1957 X. 3.	22 15—23 45	P	60	1	4	+13	1.0	3.6	0.3
2130	192.0	1958 X. 5.	21 50—22 13	P	23	2	1	+5	5.2	3.3	1.6
2131	193.0	1958 X. 6.	21 50—23 10	P	70	1	4	+9	0.8	3.4	0.2
2132	196.2	1958 X. 10.	04 00—04 40	P	40	2	3	+59	3.0	4.7	0.6
2133	196.8	1958 X. 10.	19 30—20 15	Aá	40	1	2	—11	1.5	2.9	0.5
2134	197.7	1955 X. 11.	21 20—22 50	P	80	9	4	+4	6.8	3.3	2.1
2135	197.9	1955 X. 12.	01 05—02 45	P	90	7	6	+40	4.7	4.3	1.1
2136	197.9	1958 X. 11.	20 00—21 10	Aá	60	0	3	—7	0.0	3.0	0.0
2137	198.1	1958 X. 12.	03 15—04 05	P	50	3	4	+54	3.6	4.6	0.8
2138	198.7	1955 X. 12.	20 50—22 50	P	100	6	5	+2	3.6	3.2	1.1
2139	198.8	1958 X. 12.	18 30—19 15	Aá	35	1	2	—15	1.7	2.8	0.6
2140	201.6	1955 X. 15.	20 45—22 45	P	100	4	5	+1	2.4	3.2	0.8
2141	201.8	1955 X. 16.	00 20—02 30	P	110	6	8	+34	3.3	4.2	0.8
2142	202.8	1954 X. 16.	18 50—19 40	K	45	4	2	—15	5.3	2.8	1.9
2143	202.8	1954 X. 16.	19 00—19 40	V	35	2	2	—14	3.4	2.8	1.2
2144	206.9	1954 X. 20.	22 45—00 30	K	80	7	5	+16	5.2	3.7	1.4

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No.	☉	Date		Time M. E. T	Obs.	τ	n_o	n_c	H	f_o	f	F
2145	206.9	1954	X. 20.	22 45—00 30	V	80	7	5	+16	5.2	3.7	1.4
2146	207.1	1958	X. 21.	03 15—05 00	P	70	4	5	+56	3.4	4.7	0.7
2147	207.2	1957	X. 20.	23 30—01 30	P	90	2	6	+25	1.3	3.9	0.3
2148	207.7	1954	X. 21.	18 35—19 00	K	20	1	1	—17	3.0	2.7	1.1
2149	207.7	1954	X. 21.	18 35—19 00	V	20	1	1	—17	3.0	2.7	1.1
2150	207.8	1954	X. 21.	19 50—20 15	V	20	0	1	—12	0.0	2.9	0.0
2151	209.1	1958	X. 23.	04 25—05 00	Aá	20	0	2	+59	0.0	4.7	0.0
2152	209.1	1958	X. 23.	04 25—05 00	P	25	1	2	+59	2.4	4.7	0.5
2153	209.1	1958	X. 23.	04 30—05 05	An	30	0	2	+59	0.0	4.7	0.0
2154	209.8	1954	X. 23.	20 40—21 45	V	40	1	2	—5	1.5	3.0	0.5
2155	211.1	1958	X. 25.	04 00—05 00	P	40	2	3	+57	3.0	4.7	0.6
2156	211.2	1956	X. 24.	18 30—19 00	K	30	2	1	—18	4.0	2.7	1.5
2157	211.2	1956	X. 24.	19 00—19 25	K	25	1	1	—17	2.4	2.7	0.9
2158	212.2	1956	X. 25.	19 15—19 45	K	30	1	1	—16	2.0	2.8	0.7
2159	212.3	1957	X. 26.	01 00—03 30	P	150	4	11	+40	1.6	4.3	0.4
2160	213.7	1954	X. 27.	19 20—20 05	K	40	3	2	—15	4.5	2.8	1.6
2161	213.7	1954	X. 27.	19 20—20 05	V	40	0	2	—15	0.0	2.8	0.0
2162	215.7	1958	X. 29.	17 50—18 30	Aá	20	0	1	—20	0.0	2.7	0.0
2163	222.7	1958	XI. 5.	18 50—19 10	Aá	20	2	1	—20	6.0	2.7	2.2
2164	223.8	1958	XI. 6.	19 50—20 30	Aá	35	2	2	—15	3.4	2.8	1.2
2165	225.0	1953	XI. 7.	18 45—19 15	K	30	2	1	—21	4.0	2.6	1.5
2166	225.5	1955	XI. 8.	20 00—21 15	P	65	2	3	—13	1.8	2.8	0.6
2167	225.7	1955	XI. 8.	23 00—00 15	P	70	3	4	+12	2.6	3.5	0.7
2168	227.1	1953	XI. 9.	20 05—21 05	Ša	50	2	2	—14	2.4	2.8	0.9
2169	227.3	1953	XI. 10.	02 20—03 45	K	75	4	5	+43	3.2	4.4	0.7
2170	234.2	1957	XI. 16.	23 00—00 30	P	80	3	5	+12	2.3	3.5	0.7
2171	235.2	1958	XI. 18.	04 05—05 40	An	95	5	7	+52	3.2	4.7	0.7
2172	235.7	1958	XI. 18.	17 45—18 30	Aá	25	0	1	—27	0.0	2.5	0.0
2173	236.1	1957	XI. 18.	19 30—20 30	P	45	3	2	—20	4.0	2.7	1.5
2174	236.2	1958	XI. 19.	04 35—05 30	Aá	45	4	3	+52	5.3	4.6	1.2
2175	236.5	1959	XI. 19.	18 00—19 30	Aá	75	4	3	—25	3.2	2.5	1.3
2176	238.8	1954	XI. 21.	18 30—19 00	K	30	2	1	—26	4.0	2.5	1.6
2177	238.8	1954	XI. 21.	18 35—19 35	V	50	3	2	—25	3.6	2.5	1.4
2178	240.2	1958	XI. 23.	04 10—05 45	Aá	80	3	6	+50	2.3	4.6	0.5
2179	240.2	1958	XI. 23.	04 10—05 45	An	85	6	6	+50	4.2	4.6	0.9
2180	240.2	1958	XI. 23.	04 30—05 45	P	70	5	5	+51	4.3	4.6	0.9
2181	241.6	1959	XI. 24.	17 45—18 45	Aá	60	3	2	—28	3.0	2.5	1.2
2182	248.3	1953	XI. 30.	21 20—22 15	V	50	5	2	—10	6.0	2.9	2.1
2183	250.2	1953	XII. 2.	19 00—19 30	V	25	1	1	—28	2.4	2.5	1.0
2184	250.9	1958	XII. 3.	17 00—17 30	Aá	25	0	1	—32	0.0	2.4	0.0
2185	251.3	1953	XII. 3.	19 00—19 50	P	45	3	2	—28	4.0	2.5	1.6
2186	251.6	1953	XII. 4.	04 00—05 40	P	90	8	7	+46	5.3	4.5	1.2
2187	251.6	1953	XII. 4.	04 45—05 40	V	50	4	4	+47	4.8	4.5	1.1
2188	251.9	1958	XII. 4.	17 30—18 15	P	40	0	2	—33	0.0	2.4	0.0
2189	252.1	1958	XII. 4.	21 00—21 30	P	30	2	1	—16	4.0	2.8	1.4
2190	252.4	1953	XII. 4.	21 45—22 20	V	30	2	1	—9	4.0	2.9	1.4
2191	252.6	1953	XII. 5.	02 04—03 10	P	45	3	3	+32	4.0	4.1	1.0
2192	255.3	1958	XII. 8.	02 25—03 00	Aá	30	0	2	+32	0.0	4.1	0.0
2193	255.7	1953	XII. 8.	03 05—05 30	P	130	4	9	+42	1.8	4.4	0.4
2194	256.5	1953	XII. 8.	22 30—23 15	V	40	6	2	—3	9.0	3.1	2.9
2195	256.5	1953	XII. 8.	23 50—00 15	V	25	3	1	+8	7.2	3.4	2.1
2196	258.5	1953	XII. 10.	23 25—23 55	V	25	1	1	+4	2.4	3.3	0.7
2197	262.8	1953	XII. 15.	03 50—04 20	K	30	2	2	+39	4.0	4.3	0.9
2198	263.2	1954	XII. 15.	19 45—21 15	K	75	5	3	—25	4.0	2.5	1.6
2199	263.2	1954	XII. 15.	19 45—21 15	V	80	6	3	—25	4.5	2.5	1.8
2200	264.2	1954	XII. 16.	18 15—18 50	K	35	4	1	—36	6.9	2.3	3.0
2201	265.4	1957	XII. 17.	17 30—19 30	P	100	6	4	—37	3.6	2.3	1.6
2202	272.6	1953	XII. 24.	17 45—19 30	P	95	3	3	—39	1.9	2.2	0.9
2203	273.6	1953	XII. 25.	18 30—19 50	P	70	2	3	—37	1.7	2.3	0.7
2204	280.3	1956	I. 1.	19 00—21 00	P	100	3	4	—34	1.8	2.3	0.8
2205	282.0	1956	I. 3.	22 45—23 45	V	40	2	2	—6	3.0	3.0	1.0
2206	282.0	1954	I. 3.	22 45—23 45	K	50	3	3	—6	3.6	3.0	1.2
2207	284.0	1955	I. 5.	04 55—05 45	K	50	3	4	+35	3.6	4.2	0.9
2208	284.0	1955	I. 5.	04 55—05 55	V	45	2	3	+35	2.7	4.2	0.6
2209	285.3	1956	I. 6.	18 00—18 30	An	30	1	1	—45	2.0	2.1	1.0
2210	287.5	1956	I. 8.	22 30—23 45	P	65	3	3	—9	2.8	2.9	1.0
2211	288.8	1956	I. 10.	03 10—05 30	P	120	5	7	+30	2.5	4.1	0.6
2212	289.6	1957	I. 10.	04 15—06 15	P	100	3	7	+32	1.8	4.1	0.4
2213	289.6	1955	I. 10.	18 10—18 45	V	30	0	1	—46	0.0	2.1	0.0
2214	290.7	1959	I. 11.	20 00—20 30	P	30	0	1	—36	0.0	2.3	0.0
2215	290.8	1956	I. 12.	03 00—05 30	P	110	3	7	+29	1.6	4.0	0.4
2216	292.1	1959	I. 13.	04 45—05 50	P	60	0	4	+31	0.0	4.1	0.0

No.	$\odot$	Date		Time M.E.T	Obs.	τ	n_o	n_c	H	f_o	f_c	F
2217	296.7	1959	I. 17.	18 00—18 35	Aá	25	0	1	—49	0.0	2.1	0.0
2218	296.9	1956	I. 18.	03 30—05 30	P	100	2	7	+27	1.2	4.0	0.3
2219	297.9	1956	I. 19.	03 00—05 15	P	120	2	8	+26	1.0	3.9	0.3
2220	298.9	1955	I. 19.	20 25—21 55	V	80	2	3	—30	1.5	2.4	0.6
2221	300.9	1955	I. 21.	18 25—19 00	V	25	1	1	—49	2.4	2.1	1.1
2222	301.4	1957	I. 21.	19 05—20 05	P	60	1	2	—44	1.0	2.2	0.5
2223	302.9	1955	I. 23.	18 55—20 10	V	45	3	2	—45	4.0	2.1	1.9
2224	303.0	1955	I. 23.	21 45—23 15	V	80	2	4	—19	1.5	2.7	0.6
2225	306.1	1955	I. 26.	21 50—22 25	Ša	30	0	1	—24	0.0	2.6	0.0
2226	307.1	1955	I. 27.	20 15—21 45	V	50	0	2	—34	0.0	2.3	0.0
2227	308.0	1959	I. 28.	20 10—21 10	Aá	45	0	2	—37	0.0	2.3	0.0
2228	310.0	1959	I. 30.	18 10—19 25	Aá	60	1	2	—51	1.0	2.0	0.5
2229	310.0	1959	I. 30.	18 30—19 30	An	55	1	2	—50	1.1	2.1	0.5
2230	313.4	1959	II. 3.	04 30—05 30	Aá	50	2	3	+24	2.4	3.9	0.6
2231	313.4	1959	II. 3.	04 30—05 30	P	40	1	3	+24	1.5	3.9	0.4
2232	314.0	1959	II. 3.	17 50—19 30	Aá	60	0	2	—53	0.0	2.0	0.0
2233	314.2	1959	II. 3.	23 00—00 00	Aá	45	2	2	—12	2.7	2.9	0.9
2234	315.2	1959	II. 4.	22 00—22 50	Čp	50	0	2	—23	0.0	2.6	0.0
2235	315.5	1959	II. 5.	04 40—05 50	Aá	50	0	3	+23	0.0	3.9	0.0
2236	316.0	1957	II. 5.	03 30—05 30	P	100	4	6	+22	2.4	3.8	0.6
2237	316.2	1959	II. 5.	20 45—21 40	P	50	6	2	—35	7.2	2.3	3.1
2238	316.2	1959	II. 5.	21 00—22 30	Aá	75	11	3	—29	8.8	2.5	3.5
2239	316.2	1959	II. 5.	21 30—23 30	Čp	80	3	3	—22	2.3	2.6	0.9
2240	316.5	1959	II. 6.	04 40—05 40	P	50	2	3	+23	4.0	3.9	1.0
2241	316.5	1959	II. 6.	04 50—05 40	Aá	45	0	3	+23	0.0	3.9	0.0
2242	317.0	1957	II. 6.	03 00—05 30	P	120	2	7	+21	1.0	3.8	0.3
2243	317.5	1954	II. 6.	21 15—21 45	K	30	3	1	—32	6.0	2.4	2.5
2244	317.5	1959	II. 7.	04 30—05 40	Čp	50	1	3	+22	1.2	3.8	0.3
2245	317.5	1959	II. 7.	04 30—05 40	P	50	1	3	+22	1.2	3.8	0.3
2246	324.1	1956	II. 13.	21 35—22 45	P	60	2	2	—27	2.0	2.5	0.8
2247	324.3	1956	II. 14.	02 15—04 15	P	120	5	7	+15	2.5	3.6	0.7
2248	324.6	1959	II. 14.	04 25—05 40	P	70	0	4	+20	0.0	3.8	0.0
2249	324.6	1959	II. 14.	05 20—05 40	Čp	20	0	1	+21	0.0	3.8	0.0
2250	325.3	1955	II. 14.	21 50—22 30	V	35	0	1	—27	0.0	2.5	0.0
2251	327.3	1955	II. 16.	20 30—21 40	K	65	4	2	—38	3.7	2.3	1.6
2252	327.3	1955	II. 16.	20 35—21 40	V	60	1	2	—38	1.0	2.3	0.4
2253	328.3	1956	II. 18.	02 30—04 10	P	95	2	6	+14	1.3	3.6	0.4
2254	331.5	1954	II. 20.	19 00—19 50	K	45	3	2	—52	4.0	2.0	2.0
2255	331.5	1954	II. 20.	19 00—20 00	V	50	2	2	—52	2.4	2.0	1.2
2256	332.3	1955	II. 21.	18 10—20 00	V	40	2	1	—55	3.0	2.0	1.5
2257	332.5	1955	II. 21.	22 55—23 50	V	50	1	2	—18	1.2	2.7	0.4
2258	332.6	1954	II. 21.	19 45—20 50	K	60	3	2	—46	3.0	2.1	1.4
2259	332.6	1954	II. 21.	19 45—21 00	V	70	2	2	—45	1.7	2.1	0.8
2260	332.6	1955	II. 22.	03 50—04 35	K	40	0	2	+17	0.0	3.7	0.0
2261	333.3	1955	II. 22.	19 45—21 00	V	55	4	2	—45	4.4	2.1	2.1
2262	333.5	1955	II. 22.	23 25—00 15	K	40	0	2	—14	0.0	2.8	0.0
2263	335.7	1954	II. 24.	22 15—23 20	K	60	0	3	—24	0.0	2.6	0.0
2264	338.2	1957	II. 27.	04 00—05 15	P	65	1	4	+16	0.9	3.7	0.2
2265	338.9	1957	II. 27.	20 00—22 00	P	100	1	4	—40	0.6	2.2	0.3
2266	339.2	1957	II. 28.	03 00—05 15	P	110	0	6	+15	0.0	3.6	0.0
2267	350.6	1958	III. 24.	22 00—23 00	An	60	4	2	—28	4.0	2.5	1.6
2268	351.4	1955	III. 12.	21 25—22 30	V	60	0	2	—34	0.0	2.3	0.0
2269	352.4	1955	III. 13.	19 45—20 45	V	55	2	2	—49	2.2	2.1	1.0
2270	352.4	1955	III. 13.	19 55—20 45	K	45	2	2	—48	2.7	2.1	1.3
2271	352.4	1956	III. 13.	02 15—04 30	P	120	3	7	+11	1.5	3.5	0.4

3. Reduction to Hawkins model of radiant distribution

The relative meteor frequencies referred to model A are identical with the observed hourly rates f_o. Assuming model B we obtain the relative frequencies F which have been determined by the procedure described previously (Kresáková and Kresák 1955). It remains to compute the relative frequencies F' referred to model C which is defined in the article of Hawkins (1956). The expected values f_c', yielding $F' = 1$, are based on Hawkins' standard radiant distribution combined with the assumption that the observed frequency is proportional to the cosine of the zenith distance of the radiant.

Fortunately, one of the tables of expected hourly rates, computed by Hawkins by numerical integration in his model, is directly applicable to the observations at Skalnaté Pleso, the latitude

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difference being negligible (+49°2 against the tabular value of +50°). For each of our observations the expected hourly rate may be found by interpolation in this table. Provided that model C is valid, the reduced rates $F' = f_o/f_c'$ should be free from the effect of radiant distribution, and should reveal the irregularities in the density distribution of meteoroids around the earth's orbit. Hawkins' radio-echo rate, defined as the number of meteors brighter than 5^m penetrating an area of 1000 km² during one hour, is so close to the telescopic rate observed at Skalnaté Pleso that it is possible to intercompare the two sets of

is added by the dashed curves indicating a uniform ratio f_c'/f_c. From the figure it is evident that the existence of the two side-maxima (the helion and anti-helion source) implies a relative increase of meteor frequency in January—March and a decrease in July—September. The changes are more pronounced at lower apex altitude, i.e. in the evening hours; however, the resulting differences between f_c and f_c' are generally moderate, amounting to about 30 % in extreme cases.

The expected hourly rates f_c' and the reduced hourly rates F' for both series of observations (1946—53 and 1953—59) are listed in Table III.
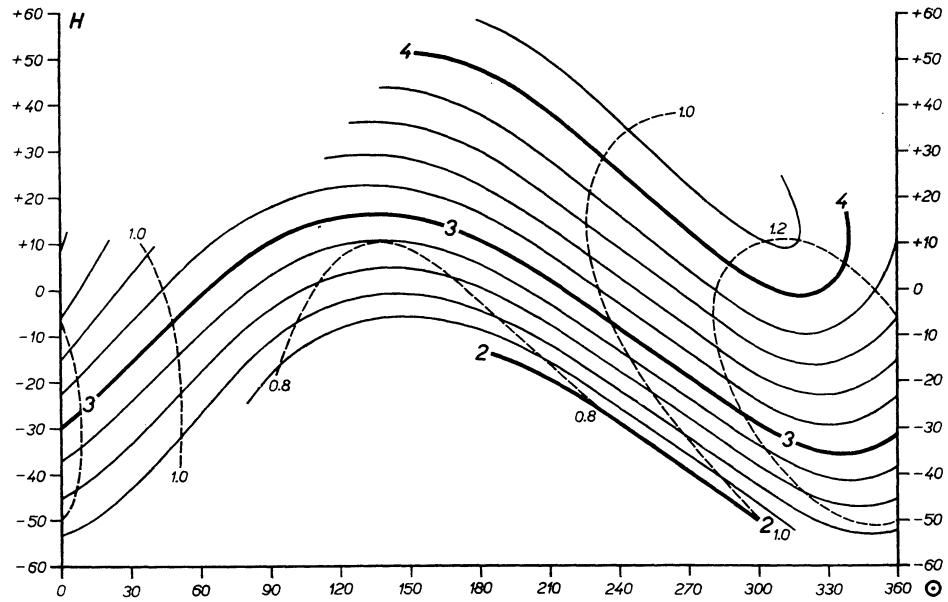
Figure 1

reduced hourly rates, F and F', without applying a scaling factor (this would be about 1.05).

In order to avoid a double interpolation in Hawkins' table as an additional source of inaccuracy, an auxiliary diagram for f_c' was constructed, with the solar longitude and apex altitude as independent variables. This diagram, shown in Figure 1, was used for determining f_c' for each observation from the quantities $\odot$ and H listed in Table II. It is instructive in demonstrating the differences among the models A, B and C, and the effect of the model choice on the resulting annual and diurnal variation. For model A the expected hourly rate is constant; for model B the loci of equal f_c are represented by horizontal straight lines; for model C the loci of equal f_c' are represented by the solid curves. Extra information

4. Separation of diurnal variation

The customary manner of separating the diurnal and annual variation from one another is the construction of the mean diurnal variation curves for individual months. A disadvantage of this procedure is that the weights of the frequency data are considerably decreased by the two-parameter distribution. Supposing, however, that the changes are not due to the occurrence of well-defined meteor showers, the random variations may be diminished by smoothing the curves.

In our case the 1397 observations were distributed into 125 cells according to the solar longitude $\odot$ and time T (in M.E.T) of the middle of the observation. The mean hourly rate for each cell was computed by adopting weights propor-

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Table III

No.	⊙	f_o	f'_c	F'	No.	⊙	f_o	f'_c	F'
1	0.4	1.1	2.6	0.4	65	20.3	1.5	3.1	0.5
2	0.4	3.3	2.6	1.3	66	21.1	1.7	2.5	0.7
3	0.4	3.3	2.6	1.3	67	21.3	2.7	3.2	0.8
2001	0.4	1.3	3.8	0.3	68	21.3	0.0	3.4	0.0
4	0.6	3.0	3.4	0.9	69	21.8	0.0	2.3	0.0
5	1.1	0.0	2.7	0.0	70	22.1	4.0	2.5	1.6
6	1.4	1.5	3·8	0.4	71	22.1	1.7	2.5	0.7
2002	2.3	0.0	2.5	0.0	72	22.1	1.7	2.6	0.7
2003	2.3	2.4	2.5	1.0	73	22.2	4.5	3.0	1.5
2004	2.4	0.0	2.8	0.0	74	22.2	1.7	2.8	0.6
2005	2.4	4.8	3.1	1.5	75	22.3	5.0	3.4	1.5
7	3.8	6.0	3.7	1.6	76	22.3	2.0	3.4	0.6
2006	4.4	1.2	3.0	0.4	77	22.3	2.7	3.5	0.8
8	4.9	6.9	3.8	1.8	78	22.8	1.3	2.5	0.5
2007	5.8	0.9	2.6	0.3	79	22.8	0.0	2.5	0.0
9	6.1	5.5	3.7	1.5	80	22.8	3.0	3.6	0.8
10	6.8	3.0	2.6	1.2	2009	22.8	0.0	2.5	0.0
11	6.9	2.2	3.8	0.6	2010	22.8	0.9	2.7	0.3
12	7.1	4.8	2.5	1.9	81	23.0	0.0	3.3	0.0
13	7.1	2.0	2.7	0.7	2011	23.0	0.0	3.5	0.0
14	7.1	3.0	2.6	1.2	82	23.2	0.9	2.9	0.3
15	7.3	2.8	3.7	0.8	83	23.3	0.0	3.5	0.0
16	7.3	3.4	3.7	0.9	2012	23.3	2.0	3.6	0.6
17	7.8	3.0	2.9	1.0	2013	23.3	0.0	3.6	0.0
18	8.0	3.3	2.4	1.4	2014	24.0	2.4	3.5	0.7
19	8.1	1.7	2.5	0.7	2015	24.0	0.0	2.3	0.0
20	9.1	6.0	2.8	2.1	84	24.1	3.2	2.7	1.2
21	9.6	2.4	3.7	0.7	2016	24.1	1.7	2.9	0.6
22	9.8	1.7	2.7	0.6	2017	24.2	3.6	3.5	1.0
23	10.0	1.2	2.4	0.5	85	24.8	1.8	2.5	0.7
24	10.0	4.8	3.4	1.4	86	25.0	0.0	2.5	0.0
25	10.1	0.8	2.8	0.3	87	25.1	3.3	2.8	1.2
26	10.2	2.4	3.1	0.8	88	25.1	2.0	2.8	0.7
2008	11.2	2.7	2.6	1.0	2018	25.1	11.0	2.9	3.8
27	11.7	4.3	2.4	1.8	89	25.2	3.8	3.3	1.2
28	11.7	1.8	2.4	0.8	90	25.9	2.2	3.3	0.7
29	12.3	2.8	2.7	1.0	91	26.0	0.0	2.4	0.0
30	12.4	1.0	3.5	0.3	92	26.0	2.7	2.5	1.1
31	12.5	3.2	3.7	0.9	93	26.1	2.2	2.9	0.8
32	13.0	3.7	3.6	1.0	94	26.1	6.0	3.0	2.0
33	13.2	2.0	2.8	0.7	95	26.2	1.8	3.2	0.6
34	13.5	1.8	3.6	0.5	96	26.5	3.2	2.5	1.3
35	14.0	3.0	2.5	1.2	97	26.5	1.2	2.6	0.5
36	14.0	1.1	2.6	0.4	98	27.5	2.2	2.5	0.9
37	14.2	2.7	3.6	0.8	99	27.5	2.6	2.6	1.0
38	14.2	1.7	2.6	0.7	100	28.0	1.2	2.5	0.5
39	14.3	2.2	2.7	0.8	101	28.4	0.0	2.4	0.0
40	14.3	2.6	3.0	0.9	102	28.9	0.0	3.5	0.0
41	15.0	3.7	2.7	1.4	103	29.6	5.0	3.4	1.5
42	15.0	0.9	2.6	0.3	104	30.2	1.5	3.4	0.4
43	15.1	0.0	3.3	0.0	105	30.6	2.4	3.5	0.7
44	15.2	3.2	2.5	1.3	2019	31.8	2.4	2.4	1.0
45	15.2	0.9	3.7	0.2	106	33.3	1.2	2.5	0.5
46	15.2	0.0	3.7	0.0	107	33.8	2.0	2.4	0.8
47	15.3	2.7	3.6	0.8	108	34.6	5.1	2.9	1.8
48	15.3	2.0	3.0	0.7	109	34.7	0.9	3.4	0.3
49	15.7	1.5	2.8	0.5	110	34.8	0.9	2.5	0.4
50	16.0	4.0	3.7	1.1	111	34.9	6.0	2.9	2.1
51	16.1	0.0	2.3	0.0	112	35.0	1.5	3.4	0.4
52	16.3	0.0	3.1	0.0	113	35.8	2.4	2.5	1.0
53	16.4	2.6	3.6	0.7	114	35.9	1.2	2.9	0.4
54	17.2	4.2	2.9	1.4	2020	37.3	5.5	2.9	1.9
55	18.1	0.0	2.3	0.0	115	37.5	3.0	2.7	1.1
56	18.2	9.0	3.6	2.5	116	37.5	2.4	2.7	0.9
57	18.3	1.2	3.5	0.3	117	37.6	0.0	3.2	0.0
58	18.6	2.7	3.4	0.8	118	38.5	4.4	2.5	1.8
59	19.0	2.0	3.0	0.7	119	38.5	4.4	2.5	1.8
60	19.0	2.0	2.9	0.7	120	39.2	4.8	2.5	1.9
61	19.1	1.3	2.3	0.6	121	39.6	3.6	3.2	1.1
62	20.2	2.2	2.7	0.8	122	39.6	1.2	3.2	0.4
63	20.2	0.0	2.8	0.0	123	39.6	2.0	3.3	0.6
64	20.2	7.6	3.0	2.5	124	39.6	4.0	3.3	1.2

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No.	⊙	f_o	f_c'	F'	No.	⊙	f_o	f_c'	F'
125	39.8	3.6	2.9	1.2	183	64.9	1.2	2.9	0.4
126	39.8	1.2	3.3	0.4	184	65.4	2.0	3.2	0.6
127	40.4	4.0	3.4	1.2	185	65.9	1.0	3.1	0.3
128	40.8	1.5	3.1	0.5	186	65.9	4.0	3.2	1.3
129	40.8	1.2	3.3	0.4	187	66.1	6.5	3.2	2.0
130	41.1	3.6	2.3	1.6	188	66.3	3.0	2.9	1.0
131	41.1	1.0	2.5	0.4	189	67.1	5.5	3.0	1.8
132	41.1	0.9	2.5	0.4	190	68.1	2.6	2.4	1.1
133	42.0	2.8	2.4	1.2	191	69.1	2.6	2.4	1.1
134	42.1	3.3	2.5	1.3	192	69.6	1.7	2.8	0.6
135	42.8	2.4	2.3	1.0	193	70.7	1.8	3.2	0.6
136	43.3	0.9	2.5	0.4	194	71.7	0.0	2.4	0.0
137	44.2	9.0	3.2	2.8	195	72.7	4.0	2.6	1.5
138	44.3	6.0	2.6	2.3	196	73.0	2.5	3.0	0.8
139	44.4	6.5	3.3	2.0	197	73.4	3.0	2.5	1.2
2021	45.2	1.0	2.5	0.4	198	74.5	1.8	3.0	0.6
2022	45.3	3.0	2.8	1.1	199	74.6	4.0	2.4	1.7
140	46.2	1.5	2.5	0.6	200	74.7	1.5	3.0	0.5
141	46.2	2.7	2.5	1.1	201	74.9	2.4	2.6	0.9
142	46.9	2.5	3.2	0.8	202	75.8	0.0	2.3	0.0
143	47.2	1.5	2.5	0.6	203	75.9	2.7	2.6	1.0
144	47.3	6.0	3.0	2.0	204	75.9	1.5	2.8	0.5
2023	47.3	2.4	3.3	0.7	205	75.9	0.0	2.7	0.0
145	48.0	3.0	3.2	0.9	206	76.8	0.0	2.3	0.0
2024	48.4	2.0	2.4	0.8	207	76.8	2.0	2.3	0.9
2025	48.4	2.0	2.4	0.8	208	77.3	1.0	2.8	0.4
146	48.6	1.8	3.2	0.6	209	77.3	0.0	2.6	0.0
147	48.6	2.0	2.4	0.8	210	77.5	0.0	2.3	0.0
148	49.1	1.5	2.4	0.6	211	77.9	2.0	3.1	0.6
2026	49.3	2.0	2.4	0.8	212	77.9	8.0	3.1	2.6
149	49.4	2.0	2.4	0.8	213	78.0	0.8	2.4	0.3
150	50.1	1.3	2.5	0.5	2035	78.5	1.5	3.1	0.5
151	50.3	1.2	2.5	0.5	214	79.7	4.5	2.7	1.7
152	50.3	2.2	2.5	0.9	215	80.1	2.0	2.7	0.7
153	50.3	2.4	3.3	0.7	216	80.2	0.0	2.8	0.0
154	50.5	2.0	2.3	0.9	217	80.9	1.0	3.0	0.3
155	50.8	1.2	2.7	0.4	218	81.1	1.0	2.5	0.4
156	50.8	4.8	2.8	1.7	219	81.1	1.6	2.7	0.6
157	51.0	0.0	3.3	0.0	2036	81.1	2.0	2.7	0.7
2027	51.3	6.0	2.7	2.2	220	81.2	0.0	3.1	0.0
2028	51.3	2.0	2.8	0.7	221	81.2	4.0	3.1	1.3
158	52.0	3.0	2.6	1.2	222	81.9	2.4	3.1	0.8
159	52.0	0.0	2.6	0.0	223	82.0	0.0	2.3	0.0
160	52.3	3.0	2.3	1.3	2037	82.0	4.8	2.6	1.8
161	52.4	2.0	3.2	0.6	2038	82.0	2.0	2.6	0.8
162	53.1	0.0	3.0	0.0	224	82.6	0.0	2.9	0.0
163	53.3	2.1	2.6	0.8	225	82.6	0.0	3.1	0.0
164	54.2	0.0	2.5	0.0	226	82.8	2.6	2.4	1.1
165	54.2	1.7	2.5	0.7	227	83.1	6.0	3.0	2.0
166	54.7	5.5	2.5	2.2	228	83.5	1.2	2.4	0.5
167	54.7	2.2	2.4	0.9	229	84.1	2.0	3.0	0.7
168	54.8	0.0	3.2	0.0	230	84.4	1.3	2.6	0.5
169	54.8	0.0	3.2	0.0	231	85.4	2.0	2.5	0.8
170	54.8	0.0	3.2	0.0	232	86.1	3.6	2.8	1.3
171	55.1	2.0	3.3	0.6	233	86.1	3.0	2.8	1.1
172	55.2	1.6	2.7	0.6	234	86.5	3.7	3.1	1.2
173	55.4	4.0	2.7	1.5	235	86.6	4.0	2.9	1.4
174	55.7	1.4	2.8	0.5	236	86.8	4.0	2.6	1.5
175	55.8	3.4	3.2	1.1	237	86.8	2.2	2.6	0.8
176	55.8	4.8	3.2	1.5	238	88.8	0.0	3.1	0.0
2029	56.2	2.0	3.0	0.7	239	89.8	0.0	3.0	0.0
2030	57.0	1.3	3.2	0.4	240	89.8	0.0	3.0	0.0
177	57.6	1.7	2.9	0.6	2039	89.8	2.7	2.5	1.1
178	57.7	2.4	3.0	0.8	2040	89.9	4.0	2.5	1.6
179	59.2	3.0	3.2	0.9	241	90.6	3.8	2.3	1.7
180	59.3	1.3	2.5	0.5	242	90.6	3.6	2.4	1.5
181	59.8	1.5	2.9	0.5	243	90.7	1.9	3.0	0.6
2031	60.0	4.0	2.5	1.6	244	91.5	5.1	3.1	1.6
2032	60.0	6.0	2.5	2.4	245	91.6	3.0	2.3	1.3
2033	60.0	2.4	2.6	0.9	246	92.2	3.3	3.1	1.1
2034	63.0	4.5	2.4	1.9	247	92.6	2.8	3.1	0.9
182	63.9	3.0	2.9	1.0	248	92.7	1.4	3.1	0.5

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No.	⊙	f_o	f_c'	F'	No.	⊙	f_o	f_c'	F'
249	93.5	2.2	2.6	0.8	307	111.7	3.4	3.3	1.0
250	93.5	7.2	2.8	2.6	308	111.7	4.8	3.1	1.5
251	94.5	8.4	2.9	2.9	309	111.7	1.5	3.0	0.5
2041	94.7	2.0	2.6	0.8	310	111.9	3.3	2.7	1.2
2042	94.7	2.4	2.6	0.9	311	111.9	2.7	2.5	1.1
252	94.8	4.0	3.0	1.3	312	111.9	8.0	2.8	2.9
253	95.4	0.0	2.4	0.0	313	111.9	4.2	3.2	1.3
254	96.1	1.1	2.4	0.5	314	112.2	6.0	2.8	2.1
255	96.1	1.1	2.4	0.5	315	112.2	2.7	3.2	0.8
256	96.4	1.5	2.8	0.5	2055	112.4	3.5	3.1	1.1
2043	96.8	4.0	2.8	1.4	2056	112.5	2.1	2.5	0.8
257	97.1	2.0	3.1	0.6	2057	112.6	3.0	2.8	1.1
258	97.6	1.5	2.5	0.6	316	112.8	3.0	2.6	1.2
259	98.0	0.0	2.6	0.0	317	113.1	2.4	2.7	0.9
260	98.1	3.1	2.6	1.2	318	113.1	5.1	2.7	1.9
261	98.1	6.0	2.6	2.3	319	113.3	2.8	2.6	1.1
262	98.2	0.0	2.2	0.0	2058	113.3	8.0	3.0	2.7
263	98.3	3.2	3.0	1.1	320	114.1	4.0	3.2	1.3
264	98.3	2.7	3.1	0.9	321	114.7	10.3	2.7	3.8
265	98.5	3.0	2.5	1.2	322	114.8	4.0	3.4	1.2
2044	98.6	1.7	3.1	0.5	323	115.0	5.2	2.7	1.9
266	99.3	4.7	3.0	1.6	324	115.0	6.0	2.7	2.2
267	99.3	2.7	3.0	0.9	325	115.5	1.3	2.8	0.5
268	100.7	0.0	2.3	0.0	326	115.8	9.0	3.3	2.7
269	100.7	3.4	2.3	1.5	327	115.8	3.3	3.3	1.0
270	100.9	7.0	2.8	2.5	328	115.8	4.0	3.4	1.2
2045	101.6	1.6	2.8	0.6	329	116.4	1.2	2.3	0.5
271	102.1	4.8	2.8	1.7	330	116.5	0.0	3.4	0.0
272	103.0	2.8	2.5	1.1	331	117.6	4.9	2.7	1.8
273	103.1	2.7	2.9	0.9	332	117.6	3.0	2.7	1.1
274	103.5	1.0	2.8	0.4	333	117.7	2.0	3.4	0.6
275	103.5	1.4	2.8	0.5	334	118.1	1.2	2.8	0.4
276	103.5	1.9	2.8	0.7	335	118.1	4.0	3.4	1.2
277	103.7	0.0	2.3	0.0	336	118.3	2.2	2.3	1.0
2046	104.0	2.4	2.9	0.8	2059	118.3	2.4	2.9	0.8
2047	104.1	1.1	3.3	0.3	337	118.5	2.2	2.7	0.8
2048	104.1	1.1	3.3	0.3	338	118.5	4.5	2.7	1.7
278	104.5	3.7	2.9	1.3	339	118.6	4.8	3.1	1.5
279	104.5	2.0	2.9	0.7	340	118.9	3.6	3.5	1.0
280	105.0	3.2	3.0	1.1	341	119.0	10.5	3.0	3.5
281	105.2	3.0	2.7	1.1	342	119.1	6.0	3.4	1.8
282	105.4	4.4	2.5	1.8	343	119.1	4.8	3.3	1.5
2049	105.8	3.0	2.5	1.2	344	119.2	1.2	2.5	0.5
283	106.5	5.3	3.0	1.8	345	119.4	2.0	3.6	0.6
2050	106.8	3.0	2.7	1.1	2060	119.4	2.7	2.3	1.2
284	107.1	3.5	2.6	1.3	346	119.9	4.8	3.3	1.5
285	107.1	3.5	2.7	1.3	347	119.9	5.5	3.3	1.7
286	107.1	3.0	2.7	1.1	348	119.9	4.0	3.5	1.1
287	107.1	3.0	2.7	1.1	349	120.0	5.5	3.3	1.7
288	107.6	2.2	3.0	0.7	350	120.1	9.0	3.4	2.6
289	107.6	4.0	2.5	1.6	351	120.2	2.2	2.5	0.9
290	107.7	0.0	3.2	0.0	352	120.8	6.0	3.5	1.7
2051	107.7	5.3	2.6	2.0	353	121.2	2.0	3.3	0.6
291	108.0	8.6	2.5	3.4	354	121.3	3.0	3.2	0.9
292	108.1	4.2	2.9	1.4	2061	121.4	3.0	2.5	1.2
2052	108.6	1.0	3.3	0.3	2062	121.4	6.9	2.6	2.7
2053	108.7	0.7	2.7	0.3	355	121.6	7.3	2.6	2.8
293	108.8	0.9	2.6	0.3	356	122.2	3.0	3.1	1.0
294	108.8	4.8	3.2	1.5	357	122.2	1.6	3.2	0.5
295	109.0	3.0	2.7	1.1	358	122.3	1.1	3.5	0.3
296	109.6	4.0	3.2	1.3	359	122.5	4.5	3.5	1.3
297	109.6	3.8	3.2	1.2	360	122.6	3.4	2.4	1.4
298	110.0	4.5	2.7	1.7	361	122.8	7.2	2.5	2.9
299	110.4	0.9	2.6	0.3	362	123.2	1.5	3.5	0.4
300	110.4	3.8	2.6	1.5	363	123.5	4.0	2.5	1.6
301	110.4	10.3	2.7	3.8	364	123.5	3.4	2.5	1.4
302	110.5	7.2	3.1	2.3	365	123.9	2.0	3.4	0.6
2054	110.5	2.6	3.2	0.8	366	123.9	2.0	3.5	0.6
303	110.7	6.0	2.5	2.4	2063	124.0	9.0	2.6	3.5
304	110.7	4.6	3.2	1.4	2064	124.0	2.4	2.8	0.9
305	111.0	3.0	3.3	0.9	367	124.2	1.6	2.4	0.7
306	111.6	1.3	2.5	0.5	368	124.5	4.0	2.7	1.5

No.	○	f_o	f'_c	F'	No.	☉	f_o	f'_c	F'
369	124.7	2.2	2.5	0.9	431	143.2	4.0	2.6	1.5
370	124.7	4.0	2.6	1.5	432	143.3	4.5	3.7	1.2
371	125.0	6.0	2.3	2.6	433	143.5	3.0	3.5	0.9
372	125.0	2.0	2.6	0.8	434	144.1	5.1	3.8	1.3
373	125.0	1.3	2.6	0.5	2075	144.1	2.0	2.9	0.7
374	125.1	0.0	3.5	0.0	435	145.4	5.4	3.4	1.6
2065	125.2	2.7	2.5	1.1	436	145.9	3.2	3.3	1.0
2066	125.2	1.5	2.5	0.6	437	145.9	1.0	3.3	0.3
375	125.4	2.4	2.3	1.0	438	145.9	5.0	3.3	1.5
2067	125.4	4.8	2.6	1.8	439	145.9	4.0	3.6	1.1
376	125.7	2.4	2.3	1.0	2076	146.2	3.5	2.6	1.3
377	125.7	2.0	2.3	0.9	440	146.7	7.7	3.5	2.2
378	125.7	3.6	2.6	1.4	441	146.7	4.8	3.7	1.3
379	125.7	1.7	2.5	0.7	442	147.3	1.2	2.7	0.4
380	125.9	0.8	2.5	0.3	2077	147.5	3.0	3.0	1.0
381	126.6	6.5	2.3	2.8	443	148.2	2.6	2.7	1.0
382	126.9	5.1	2.5	2.0	444	148.3	4.5	3.2	1.4
383	127.4	4.4	3.2	1.4	445	149.4	0.0	2.5	0.0
384	127.6	5.5	2.7	2.0	446	149.4	2.0	2.9	0.7
385	127.6	6.9	2.4	2.9	2078	149.5	2.4	3.4	0.7
386	127.8	3.0	2.6	1.2	2079	149.8	2.3	2.2	1.0
387	127.8	3.0	2.7	1.1	447	150.4	0.0	2.7	0.0
388	128.9	2.2	3.5	0.6	448	150.4	6.0	2.6	2.3
2068	129.2	0.0	3.6	0.0	449	150.6	2.4	2.3	1.0
389	129.3	5.1	2.7	1.9	450	150.6	8.3	2.4	3.5
390	129.5	6.0	2.5	2.4	451	150.6	4.4	2.9	1.5
2069	129.5	6.7	2.4	2.8	452	150.7	0.0	3.7	0.0
391	129.7	2.8	2.2	1.3	453	150.8	0.0	2.4	0.0
392	129.8	0.0	2.5	0.0	454	150.9	4.5	3.0	1.5
393	130.2	2.4	2.2	1.1	455	151.0	2.0	3.2	0.6
394	130.2	2.4	2.5	1.0	456	151.0	0.0	3.2	0.0
395	130.4	6.0	3.5	1.7	457	151.0	3.0	3.2	0.9
396	130.5	9.8	3.1	3.2	458	151.3	4.0	2.2	1.8
397	130.6	8.0	3.6	2.2	459	151.5	2.0	2.2	0.9
398	130.6	2.0	3.5	0.6	460	151.8	3.0	2.4	1.3
399	130.6	4.0	3.5	1.1	461	152.3	0.0	2.2	0.0
400	130.6	2.2	3.6	0.6	462	152.4	2.6	3.7	0.7
401	131.2	4.0	3.0	1.3	463	152.4	3.0	3.6	0.8
402	131.3	9.3	3.5	2.7	464	152.5	1.2	2.2	0.5
403	131.4	6.0	2.3	2.6	465	152.5	1.7	2.3	0.7
404	131.4	10.7	2.6	4.1	466	152.5	6.0	3.9	1.5
405	131.9	3.4	2.6	1.3	467	152.8	0.7	2.5	0.3
2070	132.2	4.8	3.6	1.3	468	153.2	1.3	2.5	0.5
2071	132.3	1.8	2.3	0.8	469	153.4	3.9	3.6	1.1
406	132.6	5.3	2.2	2.4	470	153.9	6.0	3.8	1.6
407	133.6	2.2	2.8	0.8	471	154.0	2.0	2.4	0.8
408	133.7	0.0	3.3	0.0	472	154.2	1.2	3.8	0.3
409	133.7	2.0	3.7	0.5	473	154.8	3.4	3.3	1.0
410	134.2	5.1	3.7	1.4	474	154.8	5.3	3.5	1.5
411	134.2	3.4	3.7	0.9	475	154.9	6.9	2.3	3.0
412	134.2	0.9	3.7	0.2	476	155.0	2.0	2.6	0.8
413	134.3	3.4	2.5	1.4	477	155.1	2.8	3.2	0.9
414	134.4	1.7	3.1	0.5	478	155.1	3.2	3.7	0.9
415	134.8	2.1	2.3	0.9	479	155.1	2.2	3.8	0.6
416	135.3	6.0	2.8	2.1	480	155.3	4.0	3.1	1.3
417	135.9	1.1	3.8	0.3	481	155.4	4.0	2.2	1.8
418	136.2	3.0	2.6	1.2	482	156.1	6.0	2.3	2.6
419	136.2	7.1	2.5	2.8	483	156.2	0.8	2.7	0.3
420	136.9	4.2	3.6	1.2	484	156.3	7.5	3.3	2.3
2072	137.3	2.2	3.8	0.6	485	156.8	8.8	3.5	2.5
421	138.2	9.0	3.4	2.6	2080	156.8	7.0	4.0	1.8
422	138.4	2.0	2.9	0.7	486	156.9	5.2	3.9	1.3
423	139.4	8.0	2.9	2.8	487	157.0	2.2	3.0	0.7
2073	140.0	1.5	2.5	0.6	488	157.2	7.5	3.2	2.3
2074	140.2	1.7	3.8	0.4	489	157.3	7.5	2.3	3.3
424	142.2	4.0	2.2	1.8	490	157.4	6.9	2.5	2.8
425	142.2	6.0	2.3	2.6	491	157.8	1.5	2.1	0.7
426	142.2	6.0	2.4	2.5	492	158.1	3.0	3.9	0.8
427	142.2	4.0	2.6	1.5	493	158.1	4.0	2.1	1.9
428	142.3	0.0	3.8	0.0	494	158.1	0.0	2.4	0.0
429	142.4	4.0	3.6	1.1	495	158.1	0.0	2.4	0.0
430	142.4	4.0	3.8	1.1	496	158.2	4.2	3.2	1.3

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No.	☉	f_o	f_c'	F'	No.	☉	f_o	f_c'	F'
497	158.3	12.9	3.8	3.5	542	167.1	4.0	4.0	1.0
2081	158.3	1.3	2.6	0.5	2108	167.2	3.8	3.9	1.0
498	158.6	9.1	2.9	3.1	543	167.3	6.7	3.9	1.7
499	158.6	5.1	2.8	1.8	544	167.4	4.4	3.5	1.3
500	158.6	3.4	3.1	1.1	545	167.7	0.0	2.0	0.0
501	158.9	4.0	3.4	1.2	546	168.0	4.8	2.4	2.0
2082	159.0	4.0	3.9	1.0	547	168.0	4.6	2.5	1.8
502	159.1	6.0	2.3	2.6	548	168.1	6.5	3.1	2.1
503	159.1	4.5	2.3	2.0	549	168.1	2.0	3.0	0.7
2083	159.3	0.0	2.8	0.0	550	168.2	6.0	2.1	2.9
504	159.9	2.7	3.4	0.8	551	168.2	8.0	2.2	3.6
505	160.1	3.0	2.5	1.2	552	168.3	5.2	3.2	1.6
506	160.1	2.7	2.9	0.9	2109	168.3	4.0	3.5	1.1
507	160.1	3.0	3.1	1.0	553	168.4	12.0	3.3	3.6
2084	160.2	3.0	2.2	1.4	554	168.4	4.8	3.6	1.3
2085	160.2	0.0	2.5	0.0	555	168.4	6.0	3.7	1.6
508	160.5	2.4	2.5	1.0	556	168.5	2.4	3.8	0.6
2086	160.7	2.4	2.3	1.0	557	168.5	4.0	2.9	1.4
509	160.9	6.3	3.6	1.8	558	168.5	1.6	4.0	0.4
510	161.2	3.6	2.4	1.5	559	168.7	6.7	2.0	3.4
511	161.2	3.3	2.4	1.4	560	169.0	4.4	4.1	1.1
512	161.2	2.0	2.5	0.8	561	169.2	10.0	4.1	2.4
513	161.2	4.5	4.0	1.1	562	169.2	8.4	4.1	2.0
2087	161.2	0.0	2.4	0.0	563	169.3	2.0	3.1	0.6
2088	161.6	1.5	2.3	0.7	564	170.1	0.0	3.7	0.0
514	161.8	5.7	2.8	2.0	565	170.2	6.0	2.3	2.6
515	161.8	0.0	2.8	0.0	566	170.3	6.0	3.1	1.9
516	162.2	5.2	4.0	1.3	567	170.4	2.2	2.1	1.0
517	162.4	3.0	2.4	1.3	568	170.5	2.3	3.0	0.8
518	162.7	7.2	4.0	1.8	569	170.5	8.0	3.0	2.7
519	162.8	2.4	2.9	0.8	570	170.6	1.5	3.2	0.5
520	162.9	4.8	4.0	1.2	571	170.9	1.2	4.1	0.3
521	162.9	4.3	4.1	1.0	572	171.4	3.0	3.6	0.8
2089	163.1	6.0	2.4	2.5	573	171.4	1.5	4.1	0.4
2090	163.2	2.7	2.7	1.0	574	171.6	5.0	2.1	2.4
522	163.4	6.0	2.1	2.9	575	171.6	4.3	2.2	2.0
523	163.4	8.0	2.3	3.5	576	171.6	3.8	3.8	1.0
524	163.4	1.3	2.5	0.5	577	171.6	2.7	3.8	0.7
525	163.4	2.6	2.5	1.0	578	171.6	7.6	4.0	1.9
526	163.4	6.0	2.9	2.1	579	171.9	4.0	4.1	1.0
527	163.7	2.8	2.9	1.0	580	172.4	8.7	3.9	2.2
2091	163.7	2.4	2.8	0.9	581	172.4	2.2	4.1	0.5
2092	163.7	2.0	2.9	0.7	582	172.4	2.2	4.1	0.5
528	163.9	3.7	4.0	0.9	583	172.6	3.0	2.3	1.3
2093	164.2	9.3	2.9	3.2	584	172.6	4.0	2.4	1.7
529	164.3	4.0	2.2	1.8	585	172.8	4.8	3.6	1.3
2094	164.3	2.0	2.2	0.9	586	172.9	8.4	3.8	2.2
2095	164.3	0.0	2.2	0.0	587	172.9	4.8	4.1	1.2
2096	164.3	3.0	2.6	1.2	588	173.0	4.5	3.7	1.2
530	164.5	4.0	3.5	1.1	589	173.1	4.5	2.2	2.0
531	164.6	7.8	3.9	2.0	2110	173.1	1.5	2.8	0.5
2097	164.6	2.0	2.6	0.8	590	173.2	1.5	3.2	0.5
532	164.9	0.0	2.2	0.0	591	173.4	5.0	4.0	1.3
533	164.9	6.0	2.4	2.5	592	173.9	5.0	2.9	1.7
534	165.3	6.0	3.9	1.5	593	173.9	5.3	3.1	1.7
535	165.3	6.0	4.0	1.5	594	174.2	6.7	3.1	2.2
2098	165.3	3.4	2.2	1.5	595	174.3	2.9	4.0	0.7
2099	165.3	1.5	2.4	0.6	596	174.3	0.9	4.0	0.2
2100	165.3	3.0	2.4	1.3	597	174.3	2.2	4.0	0.6
536	165.4	0.0	3.1	0.0	598	174.4	5.3	2.8	1.9
2101	165.6	1.7	2.8	0.6	599	174.4	1.5	4.1	0.4
537	166.1	6.5	2.8	2.3	600	174.6	4.4	4.2	1.0
538	166.1	4.0	2.9	1.4	601	175.4	3.4	3.1	1.1
539	166.1	3.0	3.9	0.8	602	175.5	7.2	2.4	3.0
540	166.1	7.5	4.1	1.8	603	175.6	3.4	2.6	1.3
541	166.2	4.5	3.2	1.4	604	175.6	8.0	3.0	2.7
2102	166.2	4.8	2.2	2.2	605	175.7	8.0	3.2	2.5
2103	166.2	1.2	3.9	0.3	606	175.7	13.5	3.4	4.0
2104	166.3	0.0	2.6	0.0	607	175.8	2.8	2.8	1.0
2105	167.0	1.0	2.2	0.5	608	176.1	3.3	2.7	1.2
2106	167.0	2.4	2.6	0.9	609	176.1	0.0	2.9	0.0
2107	167.0	6.0	2.7	2.2	610	176.1	9.0	3.0	3.0

No.	$\odot$	f_o	f'_c	F'	No.	$\odot$	f_o	f'_c	F'
611	176.6	2.4	3.1	0.8	666	187.3	1.5	2.3	0.7
612	177.1	2.0	2.8	0.7	667	187.4	10.0	4.1	2.4
613	177.1	6.4	3.0	2.1	668	187.4	3.0	4.2	0.7
614	177.2	4.0	3.2	1.3	669	187.6	4.5	4.2	1.1
2111	177·2	5.5	2.2	2.5	670	187.8	3.4	4.2	0.8
2112	177.2	5.1	2.3	2.2	671	188.2	3.0	3.0	1.0
2113	177.4	5.1	3.7	1.4	672	188.3	6.2	4.1	1.5
615	177.8	4.0	4.1	1.0	673	188.3	2.4	2.2	1.1
2114	178.5	1.3	2.6	0.5	674	188.3	3.4	2.2	1.5
616	178.7	6.5	2.3	2.8	675	188.4	4.0	3.0	1.3
617	179.0	6.0	4.0	1.5	676	189.3	6.0	2.2	2.7
2115	179.3	1.5	3.3	0.5	2128	189.3	3.0	4.2	0.7
2116	179.3	4.0	3.5	1.1	677	189.7	1.5	2.0	0.8
618	179.5	3.0	2.4	1.3	678	190.3	2.8	2.7	1.0
2117	179.5	1.3	3.2	0.4	2129	190.3	1.0	3.2	0.3
619	179.9	1.0	2.1	0.5	679	190.5	9.0	3.9	2.3
620	180.4	0.0	2.4	0.0	680	190.5	3.0	4.0	0.8
621	180.5	6.8	2.6	2.6	681	191.0	3.0	2.7	1.1
2118	181.1	6.0	2.1	2.9	682	192.0	3.4	2.4	1.4
2119	181.3	8.7	3.8	2.3	2130	192.0	5.2	2.9	1.8
622	181.4	2.7	2.6	1.0	683	192.5	6.7	2.6	2.6
623	181.6	1.5	2.1	0.7	684	192.8	9.4	4.2	2.2
2120	181.6	0.0	2.2	0.0	685	192.9	6.9	2.4	2.9
624	181.7	7.4	4.1	1.8	2131	193.0	0.8	3.1	0.3
625	182.2	7.2	4.2	1.7	686	193.5	10.7	2.6	4.1
626	182.2	2.4	4.2	0.6	687	193.7	1.7	2.2	0.8
627	182.4	4.0	3.7	1.1	688	193.7	3.0	2.6	1.2
628	182.4	2.4	2.7	0.9	689	194.0	4.9	2.6	1.9
629	182.4	3.0	2.7	1.1	690	194.2	0.0	4.2	0.0
630	182.5	8.3	4.2	2.0	691	194.3	1.3	2.0	0.7
631	182.6	1.7	2.2	0.8	692	194.9	4.8	2.1	2.3
632	182.6	2.0	2.3	0.9	693	194.9	6.6	2.2	3.0
2121	182.6	0.0	2.3	0.0	694	195.0	3.7	2.7	1.4
633	182.7	10.7	4.1	2.6	695	195.0	2.4	3.0	0.8
634	183.2	6.5	3.0	2.2	696	195.4	4.3	2.3	1.9
635	183.4	12.0	3.3	3.6	697	196.0	1.6	4.2	0.4
636	183.4	4.8	3.9	1.2	698	196.1	4.8	3.7	1.3
637	183.4	2.0	2.7	0.7	2132	196.2	3.0	4.3	0.7
638	183.5	9.8	4.2	2.3	699	196.4	2.0	2.5	0.8
639	183.6	9.0	2.4	3.8	700	196.5	7.2	2.9	2.5
640	183.6	4.5	2.5	1.8	2133	196.8	1.5	2.3	0.7
641	183.6	3.0	4.1	0.7	701	196.9	5.3	2.0	2.7
642	183.7	7.0	4.2	1.7	702	197.0	1.3	2.8	0.5
643	183.9	0.0	4.2	0.0	703	197.0	6.0	3.1	1.9
644	184.6	0.0	2.4	0.0	2134	197.7	6.8	2.9	2.3
2122	185.1	2.0	2.3	0.9	704	197.8	3.8	3.7	1.0
645	185.3	4.3	3.5	1.2	2135	197.9	4.7	3.9	1.2
646	185.3	4.8	2.1	2.3	2136	197.9	0.0	2.5	0.0
647	185.3	4.4	2.2	2.0	2137	198.1	3.6	4.2	0.9
648	185.4	6.0	3.8	1.6	2138	198.7	3.6	2.9	1.2
649	185.4	5.0	3.9	1.3	2139	198.8	1.7	2.1	0.8
650	185.4	6.0	4.1	1.5	705	199.1	1.5	2.2	0.7
651	185.4	4.8	4.2	1.1	706	199.6	6.7	2.2	3.0
652	185.4	2.2	4.2	0.5	707	199.8	0.0	3.5	0.0
2123	185.5	2.7	2.2	1.2	708	199.9	4.8	2.4	2.0
2124	185.5	0.0	2.4	0.0	709	200.1	2.5	2.2	1.1
653	186.0	2.0	2.1	1.0	710	200.6	1.4	2.1	0.7
654	186.1	7.5	2.1	3.6	711	200.8	12.0	2.0	6.0
655	186.3	8.0	3.8	2.1	712	200.8	4.3	2.1	2.0
656	186.3	15.0	3.9	3.8	713	200.8	2.7	2.1	1.3
657	186.3	13.3	4.0	3.3	714	200.9	4.0	2.4	1.7
658	186.4	17.8	4.0	4.5	715	201.4	1.3	3.0	0.4
659	186.4	5.1	4.2	1.2	716	201.4	6.0	3.1	1.9
2125	186.5	5.1	2.1	2.4	717	201.6	2.8	4.1	0.7
2126	186.5	1.7	2.2	0.8	2140	201.6	2.4	2.9	0.8
660	186.6	5.3	2.7	2.0	718	201.7	2.4	4.3	0.6
661	186.6	8.0	4.1	2.0	719	201.8	1.7	2.2	0.8
662	186.8	5.5	2.3	2.4	720	201.8	1.7	2.1	0.8
2127	186.8	7.0	2.7	2.6	721	201.8	4.0	2.3	1.7
663	187.1	3.8	4.1	0.9	2141	201·8	3.3	3.9	0.8
664	187.2	5.1	3.5	1.5	722	201.9	4.0	3.0	1.3
665	187.3	8.4	3.8	2.2	723	202.0	6.2	4.3	1.4

No.	☉	f_o	f'_c	F'	No.	☉	f_o	f'_c	F'
724	202.2	7.0	4.3	1.6	778	213.0	2.4	3.4	0.7
725	202.2	3.4	4.3	0.8	779	213.3	5.3	4.2	1.3
726	202.6	4.8	4.2	1.1	780	213.4	6.0	4.3	1.4
2142	202.8	5.3	2.1	2.5	2160	213.7	4.5	2.3	2.0
2143	202.8	3.4	2.2	1.5	2161	213.7	0.0	2.3	0.0
727	202.9	2.7	2.6	1.0	781	214.0	1.7	2.1	0.8
728	203.0	1.2	3.1	0.4	782	214.1	1.7	2.4	0.7
729	203.0	4.0	2.1	1.9	783	214.5	3.7	4.0	0.9
730	203.2	6.0	4.2	1.4	784	214.6	12.0	4.3	2.8
731	203.5	4.0	3.5	1.1	785	214.9	3.0	4.3	0.7
732	204.4	1.3	3.0	0.4	786	215.0	9.6	2.1	4.6
733	204.4	4.0	3.2	1.3	787	215.0	6.0	2.3	2.6
734	204.4	0.0	4.2	0.0	788	215.2	1.7	2.1	0.8
735	204.5	2.5	3.5	0.7	789	215.6	1.7	4.3	0.4
736	204.7	0.0	3.7	0.0	2162	215.7	0.0	2.1	0.0
737	205.4	5.2	4.3	1.2	790	216.9	4.0	3.4	1.2
738	205.5	3.0	4.0	0.8	791	216.9	1.6	4.3	0.4
739	205.8	4.5	2.1	2.1	792	217.1	10.0	4.1	2.4
740	205.9	3.0	2.9	1.0	793	218.6	7.2	4.3	1.7
741	206.4	6.7	4.3	1.6	794	221.6	6.0	4.3	1.4
2144	206.9	5.2	3.4	1.5	795	222.3	4.3	2.2	2.0
2145	206.9	5.2	3.4	1.5	2163	222.7	6.0	2.2	2.7
2146	207.1	3.4	4.3	0.8	796	222.9	4.8	4.3	1.1
742	207.2	2.0	4.3	0.5	2164	223.8	3.4	2.5	1.4
2147	207.2	1.3	3.7	0.4	797	224.1	5.1	4.3	1.2
743	207.4	9.4	4.3	2.2	2165	225.0	4.0	2.2	1.8
2148	207.7	3.0	2.1	1.4	798	225.1	2.0	4.3	0.5
2149	207.7	3.0	2.1	1.4	799	225.3	2.0	2.6	0.8
2150	207.8	0.0	2.4	0.0	2166	225.5	1.8	2.6	0.7
744	208.0	5.4	2.4	2.3	2167	225.7	2.6	3.5	0.7
745	208.2	3.4	2.1	1.6	800	225.9	0.9	4.3	0.2
746	208.2	6.9	2.1	3.3	801	226.1	1.3	4.3	0.3
747	208.9	3.6	4.3	0.8	802	226.9	1.2	2.9	0.4
748	208.9	6.2	4.3	1.4	803	226.9	3.6	2.9	1.2
749	208.9	5.6	4.3	1.3	2168	227.1	2.4	2.6	0.9
750	209.1	2.0	2.6	0.8	2169	227.3	3.2	4.2	0.8
2151	209.1	0.0	4.3	0.0	804	227.9	4.0	3.0	1.3
2152	209.1	2.4	4.3	0.6	805	227.9	2.4	3.2	0.8
2153	209.1	0.0	4.3	0.0	806	228.0	1.8	2.3	0.8
751	209.2	4.0	2.1	1.9	807	228.0	4.8	3.8	1.3
752	209.2	4.0	4.3	0.9	808	229.4	4.0	3.2	1.3
753	209.3	3.0	2.2	1.4	809	229.4	4.0	3.6	1.1
754	209.5	2.6	4.0	0.7	810	229.5	3.4	4.0	0.9
755	209.8	9.4	4.1	2.3	811	229.7	0.0	4.3	0.0
2154	209.8	1.5	2.7	0.6	812	230.7	3.0	2.1	1.4
756	210.5	4.0	2.3	1.7	813	230.7	5.5	4.3	1.3
757	210.5	5.1	3.9	1.3	814	231.0	3.0	2.2	1.4
758	210.6	4.4	3.1	1.4	815	231.6	0.0	2.4	0.0
759	210.9	9.0	4.2	2.1	816	232.3	4.3	2.2	2.0
760	210.9	10.1	4.3	2.3	817	232.8	2.7	2.1	1.3
2155	211.1	3.0	4.3	0.7	818	232.9	2.2	2.4	0.9
2156	211.2	4.0	2.1	1.9	2170	234.2	2.3	3.6	0.6
2157	211.2	2.4	2.2	1.1	819	234.3	3.6	4.3	0.8
761	211.3	2.0	2.4	0.8	820	234.6	2.4	4.2	0.6
762	211.3	4.5	2.9	1.6	821	234.8	6.9	3.9	1.8
763	211.8	3.0	2.1	1.4	822	235.0	5.5	4.3	1.3
764	211.8	4.0	2.5	1.6	2171	235.2	3.2	4.3	0.7
765	211.8	3.0	2.6	1.2	2172	235.7	0.0	2.0	0.0
766	211.9	2.0	2.7	0.7	823	235.8	4.7	3.8	1.2
767	211.9	4.8	2.9	1.7	2173	236.1	4.0	2.4	1.7
768	211.9	6.0	3.1	1.9	2174	236.2	5.3	4.3	1.2
769	211.9	4.0	3.2	1.3	2175	236.5	3.2	2.2	1.5
770	212.1	3.7	3.0	1.2	824	236.7	6.9	4.2	1.6
2158	212.2	2.0	2.2	0.9	825	236.7	6.0	4.3	1.4
771	212.3	4.0	2.2	1.8	826	236.7	7.0	4.3	1.6
2159	212.3	1.6	4.0	0.4	827	237.1	2.2	2.4	0.9
772	212.4	9.2	4.3	2.1	828	237.2	3.8	4.3	0.9
773	212.5	2.0	2.2	0.9	829	237.9	3.3	4.0	0.8
774	212.9	2.8	3.1	0.9	830	238.1	2.0	3.6	0.6
775	212.9	2.0	3.0	0.7	2176	238.8	4.0	2.2	1.8
776	212.9	4.4	4.3	1.0	2177	238.8	3.6	2.2	1.6
777	212.9	3.8	4.3	0.9	831	239.2	5.4	2.6	2.1

No.	⊙	f_c	f'_c	F'		No.	⊙	f_o	f'_c	F'
832	239.2	1.5	2.8	0.5		885	260.1	6.0	4.3	1.4
2178	240.2	4.2	4.3	1.0		886	260.3	8.0	4.3	1.9
2179	240.2	2.3	4.3	0.5		887	261.1	4.0	2.0	2.0
2180	240.2	4.3	4.3	1.0		888	261.2	2.7	2.1	1.3
833	241.3	2.0	4.3	0.5		889	261.2	4.8	2.6	1.8
834	241.3	0.8	4.3	0.2		890	261.4	8.0	2.3	3.5
835	241.6	2.8	2.0	1.4		891	261.7	8.0	4.0	2.0
2181	241.6	3.0	2.1	1.4		892	261.9	2·0	2.0	1.0
836	242.0	6.0	2.5	2.4		893	262.5	2.0	2.4	0.8
837	242.7	1.8	4.0	0.5		2197	262.8	4.0	4.3	0.9
838	242.7	3.2	4.3	0.7		2198	263.2	4.0	2.6	1.5
839	243.0	6.0	2.5	2.4		2199	263.2	4.5	2.6	1.7
840	243.7	6.0	4.3	1.4		894	263.8	4.0	4.3	0.9
841	243.8	2.4	4.3	0.6		895	264.2	4.0	2.0	2.0
842	244.0	1.7	2.3	0.7		896	264.2	0.0	2.1	0.0
843	245.5	1.0	2.3	0.4		2200	264.2	6.9	2.1	3.3
844	245.8	6.9	4.3	1.6		897	264.3	2.4	2.3	1.0
845	246.9	3.6	2.2	1.6		898	264.3	4.0	2.5	1.6
846	246.9	2.4	2.2	1.1		899	264.5	1.2	4.1	0.3
847	247.4	9.6	4.3	2.2		900	265.0	2.0	2.3	0.9
2182	248.3	6.0	3.0	2.0		901	265.0	2.6	2.2	1.2
848	248.4	18.0	4.3	4.2		902	265.1	3.0	2.5	1.2
849	248.7	5.0	2.2	2.3		903	265.4	8.4	3.7	2.3
850	249.6	7.2	4.3	1.7		2201	265.4	3.6	2.0	1.8
851	249.6	6.6	4.3	1.5		904	265.9	2.4	2.0	1.2
2183	250.2	2.4	2.3	1.0		905	266.0	3.0	2.0	1.5
852	250.7	1.1	2.0	0.6		906	266.2	3.4	3.9	0.9
2184	250.9	0.0	2.0	0.0		907	266.3	5.1	4.0	1.3
2185	251.3	4.0	2.3	1.7		908	266.5	5.5	4.1	1.3
2186	251.6	5.3	4.3	1.2		909	266.7	2.0	2.0	1.0
2187	251.6	4.8	4.3	1.1		910	267.0	0.0	2.0	0.0
853	251.8	1.1	2.3	0.5		911	267.4	2.7	2.8	1.0
854	251.8	7.2	4.1	1.8		912	267.5	4.2	4.3	1.0
855	251.9	2.6	2.8	0.9		913	267.6	2.7	4.3	0.6
2188	251.9	0.0	2.0	0.0		914	267.6	6.0	4.3	1.4
2189	252.1	4.0	2.9	1.4		915	267.7	9.0	4.3	2.1
2190	252.4	4.0	3.1	1.3		916	267.7	4.0	4.3	0.9
2191	252.6	4.0	4.2	1.0		917	267.8	3.4	4.3	0.8
856	253.4	1.7	4.3	0.4		918	267.8	4.4	2.0	2.2
857	253.5	5.1	2.0	2.6		919	268.3	2.0	2.0	1.0
858	253.5	3.4	2.2	1.5		920	268.3	4.0	2.1	1.9
859	253.8	2.0	2.3	0.9		921	268.4	4.0	2.5	1.6
860	253.8	8.4	4.0	2.1		922	268.4	6.0	2.7	2.2
861	253.9	1.1	2.5	0.4		923	268.4	1.5	2.9	0.5
862	253.9	4.5	2.5	1.8		924	268.5	3.8	2.1	1.8
863	253.9	4.6	2.6	1.8		925	268.7	2.0	4.3	0.5
864	254.0	2.0	2.4	0.8		926	269.1	2.0	4.3	0.5
865	254.7	4.6	3.1	1.5		927	269.5	3.4	3.8	0.9
866	255.2	5.4	4.3	1.3		928	269.6	6.0	4.0	1.5
867	255.2	6.0	4.3	1.4		929	269.6	4.8	4.1	1.2
2192	255.3	0.0	4.2	0.0		930	269.6	3.0	2.4	1.3
2193	255.7	1.8	4.3	0.4		931	269.9	3.8	2.9	1.3
868	255.9	10.0	4.3	2.3		932	270.2	3.8	3.4	1.1
869	256.2	7.3	4.3	1.7		933	270.5	4.4	3.3	1.3
2194	256.5	9.0	3.4	2.6		934	270.5	10.0	3.7	2.7
2195	256.5	7.2	3.8	1.9		935	270.6	9.1	4.0	2.3
870	256.6	1.9	2.2	0.9		2202	272.6	1.9	2.1	0.9
871	257.0	13.3	4.3	3.1		936	273.2	2.8	4.3	0.7
872	257.0	2.7	4.3	0.6		2203	273.6	1.7	2.2	0.8
873	257.8	1.5	2.0	0.8		937	273.8	3.6	4.3	0.8
874	257.8	1.5	2.0	0.8		938	274.2	4.0	2.3	1.7
875	257.9	4.5	2.5	1.8		939	275.1	3.4	4.3	0.8
876	258.0	12.0	4.3	2.8		940	275.9	14.0	4.3	3.3
2196	258.5	2.4	3.7	0.6		941	275.9	0.0	4.3	0.0
877	258.8	4.0	2.0	2.0		942	276.0	4.8	2.8	1.7
878	258.9	2.0	2.0	1.0		943	276.3	3.5	4.3	0.8
879	258.9	4.0	2.4	1.7		944	278.2	0.0	4.3	0.0
880	259.0	10.0	2.6	3.8		945	278.6	2.2	4.3	0.5
881	259.0	0.0	2.9	0.0		946	280.3	3.8	2.0	1.9
882	259.1	3.3	2.0	1.6		2204	280.3	1.8	2.5	0.7
883	259.1	3.7	2.2	1.7		947	280.5	4.9	2.1	2.3
884	260.0	2.7	2.6	1.0		2205	282.0	3.6	3.6	1.0

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No.	○	f_o	f_c'	F'	No.	☉	f_o	f_c'	F'
2206	282.0	3.0	3.6	0.8	1003	301.6	6.0	4.3	1.4
948	283.0	4.4	4.3	1.0	1004	301.6	0.7	2.1	0.3
949	283.6	3.8	4.2	0.9	1005	302.0	4.9	4.3	1.1
950	283.7	0.0	4.3	0.0	2223	302.9	4.0	2.4	1.7
2207	284.0	3.6	4.3	0.8	2224	303.0	1.5	3.4	0.4
2208	284.0	2.7	4.3	0.6	1006	303.5	3.4	4.3	0.8
951	285.3	2.0	1.9	1.1	1007	303.8	4.0	4.3	0.9
952	285.3	4.0	2.0	2.0	1008	303.9	3.0	4.2	0.7
2209	285.3	2.0	2.0	1.0	1009	304.5	6.0	4.3	1.4
953	285.4	6.9	2.1	3.3	2225	306.1	0.0	3.3	0.0
954	285.5	2.0	3.3	0.6	1010	306.5	3.0	4.2	0.7
955	285.7	3.0	4.3	0.7	2226	307.1	0.0	2.9	0.0
956	286.3	2.0	4.0	0.5	1011	307.2	1.1	3.6	0.3
957	286.6	0.0	2.1	0.0	1012	307.3	4.0	4.3	0.9
2210	287.5	2.8	3.6	0.8	1013	307.7	3.0	4.2	0.7
958	288.1	6.0	4.3	1.4	1014	307.7	6.0	4.2	1.4
959	288.7	2.0	2.1	1.0	1015	307.9	6.0	4.2	1.4
960	288.7	2.7	2.7	1.0	1016	307.9	3.2	3.3	1.0
961	288.7	3.4	2.7	1.3	2227	308.0	0.0	2.8	0.0
962	288.7	3.6	2.8	1.3	1017	308.1	1.8	4.2	0.4
963	288.8	3.0	4.3	0.7	1018	308.3	5.1	4.1	1.2
964	288.8	1.2	3.6	0.3	1019	308.7	3.5	4.2	0.8
2211	288.8	2.5	4.3	0.6	1020	308.9	0.0	2.8	0.0
965	288.9	2.0	2.1	1.0	1021	309.0	3.0	4.2	0.7
966	289.0	6.0	4.3	1.4	1022	309.2	3.4	3.6	0.9
967	289.1	4.3	4.3	1.0	1023	309.3	1.7	4.0	0.4
2212	289.6	0.0	2.0	0.0	1024	309.7	0.0	4.2	0.0
2213	289.6	1.8	4.3	0.4	1025	309.8	0.0	2.1	0.0
968	289.7	6.0	2.1	2.9	1026	310.0	4.0	4.2	1.0
969	289.7	2.3	2.5	0.9	2228	310.0	1.0	2.2	0.5
970	289.8	4.0	3.0	1.3	2229	310.0	1.1	2.2	0.5
971	289.9	3.6	2.1	1.7	1027	311.5	3.8	4.2	0.9
972	290.0	1.0	2.4	0.4	1028	312.1	0.0	2.4	0.0
973	290.6	3.0	3.2	0.9	1029	312.3	2.4	4.1	0.6
974	290.7	1.2	2.1	0.6	1030	312.9	1.2	2.5	0.5
2214	290.7	0.0	2.6	0.0	1031	312.9	2.4	2.5	1.0
2215	290.8	1.6	4.3	0.4	1032	313.0	1.5	3.5	0.4
975	291.0	1.5	2.5	0.6	1033	313.1	0.0	2.1	0.0
2216	292.1	0.0	4.3	0.0	2230	313.4	2.4	4.2	0.6
976	293.3	3.0	2.3	1.3	2231	313.4	1.5	4.2	0.4
977	293.3	1.5	2.3	0.7	1034	314.0	1.2	4.2	0.3
978	294.0	1.5	4.0	0.4	2232	314.0	0.0	2.1	0.0
979	294.0	3.2	4.0	0.8	1035	314.1	1.5	2.7	0.6
980	294.2	4.0	2.1	1.9	1036	314.2	1.2	3.4	0.4
981	294.2	0.9	2.1	0.4	2233	314.2	2.7	3.7	0.7
982	294.3	2.6	2.6	1.0	2234	315.2	0.0	3.4	0.0
983	294.4	1.5	3.7	0.4	1037	315.4	2.0	4.1	0.5
984	294.4	1.5	3.7	0.4	2235	315.5	0.0	4.2	0.0
985	294.6	7.6	4.3	1.8	1038	315.9	3.0	4.2	0.7
986	294.6	2.0	4.3	0.5	2236	316.0	2.4	4.2	0.6
987	294.7	2.5	4.3	0.6	2237	316.2	7.2	2.9	2.5
988	295.3	2.0	2.7	0.7	2238	316.2	8.8	3.2	2.8
989	295.4	2.4	3.5	0.7	2239	316.2	2.3	3.4	0.7
990	295.6	2.7	2.6	1.0	2240	316.5	4.0	4.2	1.0
991	295.6	2.4	4.3	0.6	2241	316.5	0.0	4.2	0.0
992	296.2	0.0	4.3	0.0	2242	317.0	1.0	4.2	0.2
993	296.6	1.7	2.2	0.8	2243	317.5	6.0	3.1	1.9
2217	296.7	0.0	2.0	0.0	2244	317.5	1.2	4.2	0.3
2218	296.9	1.2	4.3	0.3	2245	317.5	1.2	4.2	0.3
994	297.0	6.0	4.3	1.4	1039	318.7	2.0	2.6	0.8
995	297.2	1.0	2.0	0.5	1040	318.8	4.0	3.5	1.1
996	297.4	1.2	2.8	0.4	1041	319.1	1.8	4.2	0.4
997	297.4	2.4	3.2	0.8	1042	319.2	3.0	3.0	1.0
2219	297.9	1.0	4.3	0.2	1043	319.3	2.6	3.4	0.8
998	298.5	4.2	4.3	1.0	1044	319.6	3.3	2.2	1.5
2220	298.9	1.5	3.0	0.5	1045	320.3	4.2	3.2	1.3
999	300.4	1.5	2.0	0.8	1046	320.3	0.0	3.5	0.0
1000	300.7	3.4	4.3	0.8	1047	320.5	1.6	4.2	0.4
1001	300.7	6.9	4.3	1.6	1048	320.8	2.7	3.0	0.9
1002	300.8	1.5	4.3	.0.3	1049	320.8	0.0	3.2	0.0
2221	300.9	2.4	2.1	1.1	1050	321.2	2.2	4.1	0.5
2222	301.4	1.0	2.4	0.4	1051	321.5	2.0	3.1	0.6

No.	⊙	f_o	f_c'	F'
1052	321.5	0.0	3.1	0.0
1053	321.5	4.0	4.2	1.0
1054	322.3	0.9	4.2	0.2
1055	323.0	1.5	2.7	0.6
1056	323.9	3.6	4.1	0.9
2246	324.1	2.0	3.3	0.6
2247	324.3	2.5	4.1	0.6
2248	324.6	0.0	4.1	0.0
2249	324.6	0.0	4.1	0.0
1057	325.1	1.2	2.8	0.4
1058	325.1	0.0	4.1	0.0
2250	325.3	0.0	3.3	0.0
1059	325.7	2.4	2.2	1.1
1060	326.1	1.0	4.1	0.2
1061	327.3	2.0	2.2	0.9
2251	327.3	3.7	2.9	1.3
2252	327.3	1.0	2.9	0.3
1062	328.3	6.0	2.2	2.7
2253	328.3	1.3	4.1	0.3
1063	328.4	1.3	2.4	0.5
1064	328.6	4.3	2.6	1.7
1065	328.6	3.0	2.9	1.0
1066	328.9	3.0	4.1	0.7
1067	329.6	1.5	2.8	0.5
1068	329.6	5.0	2.9	1.7
1069	329.8	6.0	4.1	1.5
1070	330.6	2.2	2.6	0.8
1071	330.9	2.4	4.1	0.6
1072	331.2	1.5	3.5	0.4
2254	331.5	4.0	2.4	1.7
2255	331.5	2.4	2.4	1.0
2256	332.3	3.0	2.3	1.3
1073	332.5	3.0	3.3	0.9
2257	332.5	1.2	3.5	0.3
2258	332.6	3.0	2.6	1.2
2259	332.6	1.7	2.7	0.6
2260	332.6	0.0	4.0	0.0
2261	333.3	4.4	2.7	1.6
2262	333.5	0.0	3.6	0.0
1074	334.8	3.0	3.9	0.8
2263	335.7	0.0	3.4	0.0
1075	335.9	5.4	4.0	1.4
1076	337.1	1.5	2.4	0.6
1077	337.6	1.7	3.7	0.5
1078	337.7	3.0	4.0	0.8
2264	338.2	0.9	4.0	0.2
2265	338.9	0.6	2.9	0.2
1079	339.0	3.6	4.0	0.9
1080	339.2	4.8	2.6	1.8
1081	339.2	0.0	3.0	0.0
2266	339.2	0.0	4.0	0.0

No	⊙	f_o	f_c	F'
1082	340.2	4.8	2.9	1.7
1083	340.2	0.0	3.2	0.0
1084	340.2	3.6	4.0	0.9
1085	341.1	0.9	2.5	0.4
1086	341.3	2.4	3.6	0.7
1087	341.3	3.0	3.7	0.8
1088	341.3	4.5	4.0	1.1
1089	341.7	2.0	4.0	0.5
1090	341.8	0.0	2.3	0.0
1091	341.8	2.0	2.4	0.8
1092	342.2	2.2	3.2	0.7
1093	342.3	1.2	3.5	0.3
1094	343.2	1.1	3.2	0.3
1095	343.4	1.5	3.9	0.4
1096	343.4	0.0	4.0	0.0
1097	344.3	1.7	3.3	0.5
1098	344.4	0.9	3.9	0.2
1099	345.4	4.5	3.9	1.2
1100	345.5	1.7	3.9	0.4
1101	346.0	2.2	3.3	0.7
1102	346.3	2.8	3.4	0.8
1103	346.6	1.0	2.5	0.4
1104	347.1	2.0	3.7	0.5
1105	347.3	0.0	3.5	0.0
1106	348.4	3.0	2.5	1.2
1107	348.6	3.0	2.5	1.2
1108	348.8	3.0	3.1	1.0
1109	349.4	1.3	2.3	0.6
1110	349.4	3.0	2.5	1.2
1111	349.5	0.0	3.1	0.0
1112	350.2	1.3	3.9	0.3
2267	350.6	4.0	3.2	1.3
2268	351.4	0.0	3.0	0.0
1113	351.6	1.1	3.5	0.3
1114	352.3	3.0	3.2	0.9
2269	352.4	2.2	2.5	0.9
2270	352.4	2.7	2.6	1.0
2271	352.4	1.5	3.9	0.4
1115	352.9	2.4	2.7	0.9
1116	354.1	4.0	3.8	1.1
1117	354.2	2.4	3.9	0.6
1118	354.7	1.7	3.9	0.4
1119	355.6	2.0	3.8	0.5
1120	355.7	1.5	3.8	0.4
1121	356.9	3.0	3.8	0.8
1122	357.9	3.0	3.8	0.8
1123	359.4	2.7	2.5	1.1
1124	359.6	0.0	2.7	0.0
1125	359.9	3.3	2.6	1.3
1126	359.9	3.3	2.6	1.3

tional to the net duration of each observation, and compared with the expected rate for the three models A, B and C. The reduced frequencies F_o, F and F', i.e. the ratios of mean observed to computed frequencies in each model, are indicated in Fig. 2 by the circles with areas proportional to the sum of the net times of all observations included in the cell. For smoothing the variation curves the frequencies from adjacent cells (in both parameters, ⊙ and T) were used. For instance, the smoothed frequency at $T = 22^h$, ⊙ $= 120°$ to 150° is based on all observations centered between 21 : 30 and 22 : 30 at ⊙ $= 90°$ to 120°,

between 20 : 30 and 23 : 30 at ⊙ $= 120°$ to 150°, and between 21 : 30 and 22 : 30 at ⊙ $= 150°$ to 180°. In Figure 2 these smoothed values are joined by curves.

It is apparent that the general trend of the diurnal variation sensitively depends on the model of radiant distribution adopted. The amplitude of the diurnal variation markedly decreases if we take into account the non-uniformity of radiant distribution (models B and C). On the other hand, the annual variation is less influenced by the choice of the reference model, some of its characteristics remaining preserved in

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Figure 2

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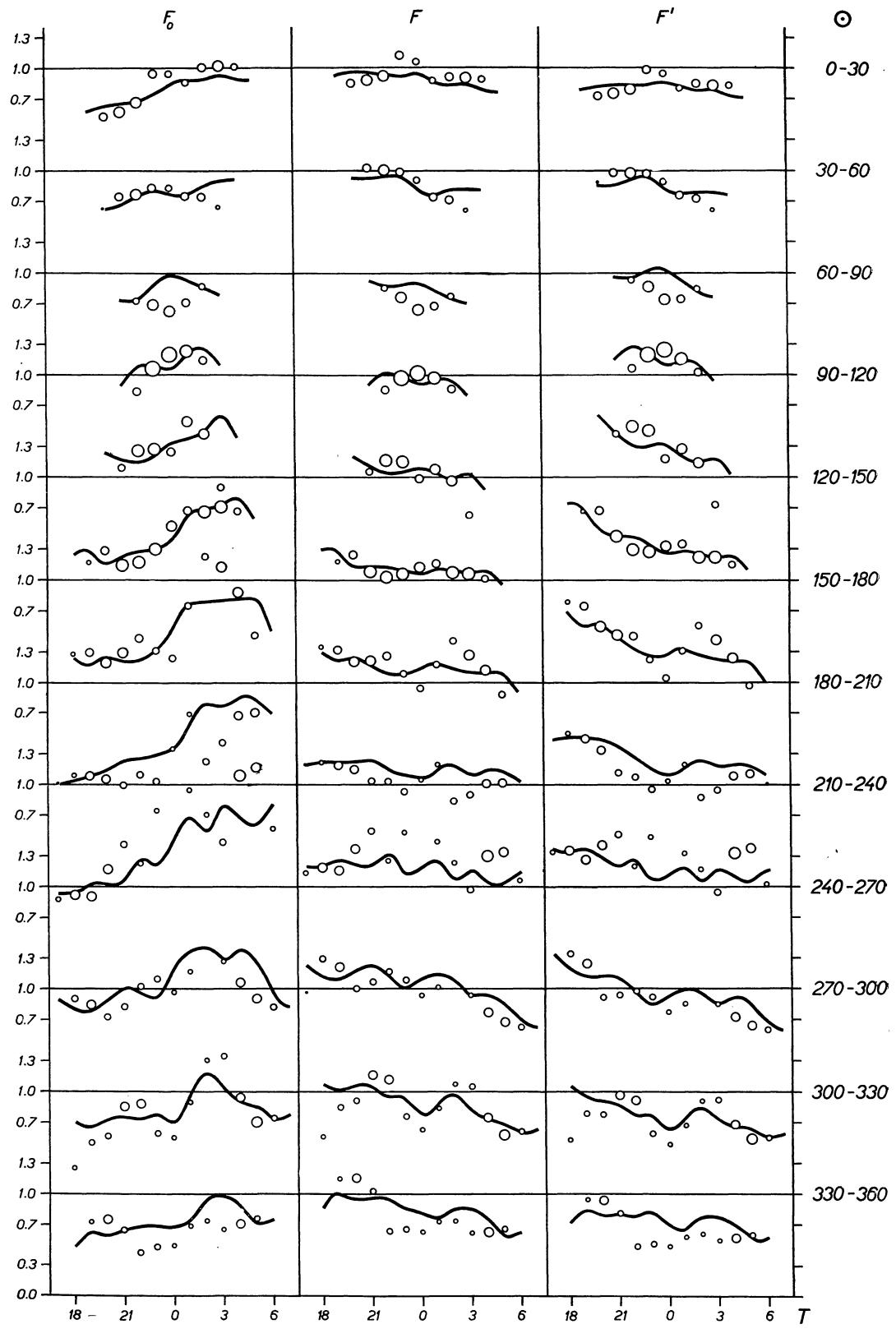
spite of the reversed trend of the diurnal variation in models A and C. It may be noted that all night long the reduced frequencies are above the average between $\odot = 150°$ and $270°$, and below the average between $\odot = 0°$ and $90°$ for each of the models. This is an important indication of a genuine non-uniformity of the spatial distribution of telescopic meteor orbits.
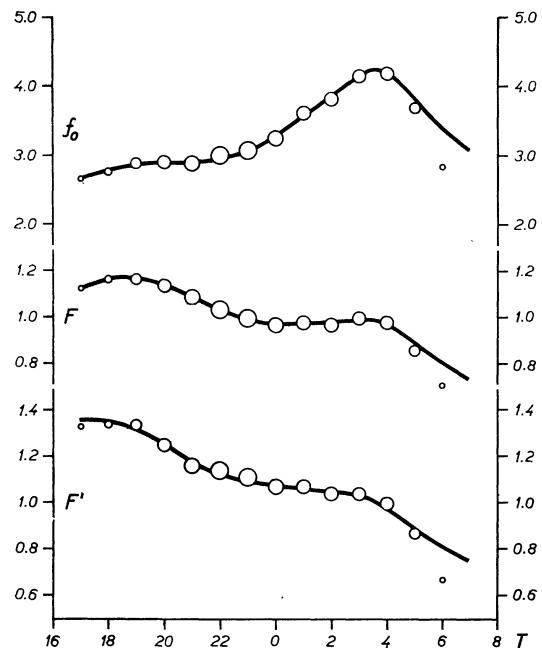
Figure 3

The mean diurnal variations of meteor rates in models A, B and C are shown in Figure 3. The areas of the circles are again proportional to the total net time of all observations included. The observed variation (f_o — model A), with a sharp maximum at about 4^h local time, is in good agreement with the results of other authors (cf. Millman and McKinley 1963, Fig. 5). The evening maximum of telescopic meteors, suggested by Astapovič (1935), is not confirmed. The diurnal variation curves for model B, and in particular C, show a slow continuous decrease of reduced frequencies from the evening to the morning, which may be interpreted as a result of overcorrection. Basic data on the diurnal variation are summarized in Table IV where o denotes the number of observations, $\Sigma\tau$ their total net time in minutes and Σn the total number of meteors recorded.

Perhaps the most instructive picture of the combined operation of the diurnal and annual

Table IV

Time M.E.T.	o	Στ	Σn	f_o	F	F'
16 : 30—17 : 30	11	450	20	2.67	1.13	1.33
17 : 30—18 : 30	82	3865	179	2.78	1.17	1.34
18 : 30—19 : 30	158	8247	399	2.90	1.17	1.34
19 : 30—20 : 30	229	12430	605	2.92	1.14	1.25
20 : 30—21 : 30	304	16336	790	2.90	1.09	1.16
21 : 30—22 : 30	367	20560	1031	3.01	1.04	1.14
22 : 30—23 : 30	356	20869	1075	3.09	1.00	1.11
23 : 30— 0 : 30	258	15779	858	3.26	0.97	1.07
0 : 30— 1 : 30	242	14751	889	3.62	0.98	1.07
1 : 30— 2 : 30	227	14096	897	3.82	0.97	1.04
2 : 30— 3 : 30	188	12190	846	4.16	1.00	1.04
3 : 30— 4 : 30	193	12736	890	4.19	0.98	1.00
4 : 30— 5 : 30	137	8951	550	3.69	0.86	0.87
5 : 30— 6 : 30	41	2383	113	2.85	0.70	0.67
6 : 30— 7 : 30	1	55	4	4.36	1.05	1.02
Σ	1397	81849	4573	3.21	1.00	1.05

variation is a two-dimensional graphical representation, in which the local time is plotted against solar longitude. This co-ordinate system is used in Fig. 4; curves of constant reduced hourly rates obtained by combining the observations in normal places, interpolating, and smoothing the results, are shown for each of the three models A, B and C. They are drawn and labelled for each tenth of the average frequency—in full lines for the values equal to, or greater than, the average frequency (10, 11 etc.), in dashed lines for those lower than this. The dotted-and-dashed lines indicate the limits of civil twilight, beyond which the frequencies cannot be extrapolated from optical observations.

The fit of the observations with individual models may be inferred from the run of the curves. For a perfect representation of the diurnal variation, the curves should change into vertical straight lines; for a perfect representation of the annual variation, they should change into horizontal straight lines; and for an entire agreement between theory and observation they should vanish. Obviously, systematic departures may be anticipated in the annual rather than in the diurnal variation, and the vanishing of the diurnal variation alone would offer convincing proof of a non-uniform distribution of meteors around the orbit of the earth.

Figure 4 indicates that model A is distinctly inferior to models B and C. A systematic increase of meteor rates from the evening to the morning hours and a sharp maximum in the autumn reveal the main features of diurnal and annual variations, established long ago in the naked-eye range. In

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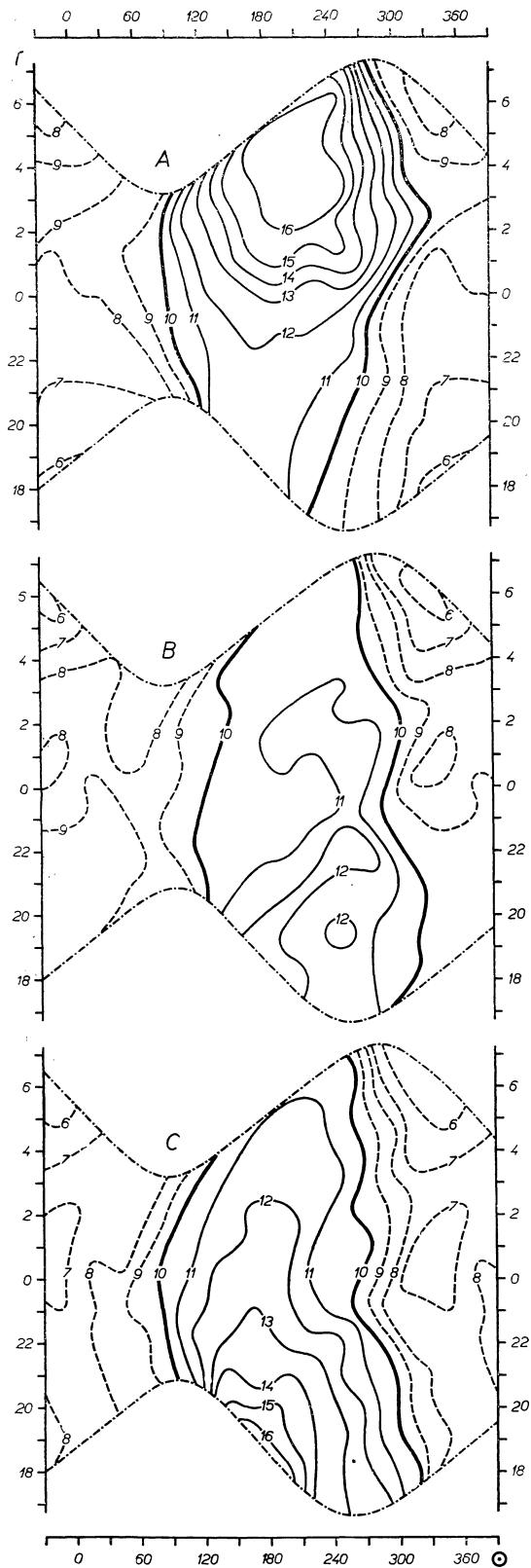
Figure 4

model B the total amplitude is essentially reduced, and the curves, as expected, run mainly in the vertical direction. Model C, which represents satisfactorily the radio observations (Hawkins 1956) and the naked-eye observations (Hawkins and Prentice 1957), is, surprisingly, less consistent with the telescopic observations than is model B. It appears as if there were an overcorrection of the observed variation (note the mirror-like images for models A and C and the reversed trend of the diurnal variation in Fig. 3). The triple-maximum radiant distribution suggested by Hawkins would evidently fit better with a diminished density gradient. This may be attributed either to the selective effect of angular velocities applying to telescopic observations, or to an increasing preponderance of direct orbits with decreasing size of particles (Kresáková and Kresák 1955, Kresák 1964). It may be noted that the equivalent velocity constant $c = 3.9$ involved in model B is higher than that obtained from naked-eye observations, indicating a lower degree of apical concentration for telescopic meteors as well.

It is clear that none of the models of radiant distribution can account for the annual variation in terms of the earth's rotation combined with the tilt of its axis. Evidently, such features as a rapid increase of meteor rates in June and July, or a decrease in December and January cannot be explained by any other acceptable model of radiant distribution. Although the trend of diurnal variation in model A is entirely reversed in model C, nevertheless the annual variation preserves its main features unchanged. Figure 4 demonstrates that the belt of enhanced meteor activity stretches between $\odot = 120°$ and $\odot = 270°$ irrespectively of the model adopted, and that the variation of the model principally produces displacements of the absolute maximum in the vertical direction without markedly changing its solar longitude. Hence actual variations of meteor density around the earth's orbit are established beyond doubt.

5. Annual variation

Since the course of the net annual variation, freed from the effects of the earth's orientation, depends on the model of radiant distribution adopted, we shall investigate this separately for all three models defined in section 1. The differences among the three independent solutions will measure the uncertainty of the meteor density

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distribution arising from the lack of information as to the distribution of radiants.

In order to construct the annual variation curves the weighted averages f_o, F, F' and the medians M_{fo}, M_F, $M_{F'}$ have been computed for each 10° of solar longitude. On the average, each of these values is based on 127 meteors recorded during 38 hours of observation (expected sampling error ± 9 %), the extreme cases being 40 meteors during 13 hours between $\odot = 60°$ and $70°$ (expected sampling error ± 16 %) and 323 meteors during 78 hours between $\odot = 160°$ and $170°$ (expected sampling error ± 6 %). The weighed averages, formed by assuming weights proportional to the duration of individual observations, are obviously more representative for the mean meteor density than are the medians. Nevertheless, the comparison of average and median values may serve as a convenient measure of the asymmetrical scatter of frequencies and, consequently, as an indicator of possible telescopic meteor

showers. The results are summarized in Table V, with a notation analogous to Table IV. A graphical representation, shown in Figure 5 and 6, requires a detailed inspection.

The upper part of these figures shows the annual variation of observed meteor rates f_o (model A). The general trend agrees well with the annual variation found by other observing techniques and in other magnitude ranges, with a maximum in autumn months (positive apex declinations) and a minimum in spring months (negative apex declinations). A strong secondary maximum near $\odot = 250°$ and a steep increase between $\odot = 80°$ and $\odot = 130°$ are the most pronounced deviations from a smooth curve; the total amplitude is about 2.2 : 1.

The next curve of reduced rates F, referred to model B, confirms the conclusion that the general trend of f_o cannot be predominantly attributed to the yearly motion of the apex. The prevalence of meteors in the autumn months

Table V

$\odot$	o	$\Sigma\tau$	Σn	f_0	M_{fo}	F	M_F	F'	$M_{F'}$
0—10	29	1835	92	3.01	2.77	1.10	0.91	0.96	0.88
10—20	40	2543	104	2.45	2.00	0.90	0.80	0.80	0.72
20—30	52	2972	113	2.28	1.76	0.85	0.72	0.76	0.63
30—40	25	1208	54	2.68	2.40	1.00	0.96	0.96	0.89
40—50	29	1755	75	2.56	2.00	0.94	0.85	0.92	0.83
50—60	36	2120	77	2.18	2.00	0.79	0.62	0.80	0.65
60—70	15	757	40	3.17	3.00	1.07	1.00	1.14	1.08
70—80	23	1360	45	1.99	1.80	0.65	0.51	0.72	0.58
80—90	31	1788	61	2.05	2.00	0.66	0.67	0.75	0.74
90—100	31	1835	90	2.94	2.67	0.90	0.77	1.07	0.90
100—110	39	3033	142	2.81	3.00	0.84	0.91	1.01	1.11
110—120	58	3393	226	4.00	3.69	1.12	0.98	1.38	1.17
120—130	53	2953	171	3.47	3.00	1.06	0.91	1.34	1.15
130—140	34	1938	143	4.43	3.43	1.19	0.98	1.47	1.16
140—150	30	1765	103	3.50	3.75	0.93	0.92	1.13	1.08
150—160	62	3895	263	4.05	3.33	1.08	0.88	1.33	1.04
160—170	85	4661	323	4.16	3.82	1.12	0.98	1.37	1.20
170—180	64	3671	240	3.92	4.00	1.05	1.01	1.27	1.22
180—190	69	3339	282	5.07	4.50	1.31	1.14	1.55	1.28
190—200	42	2416	166	4.12	3.60	1.24	1.03	1.47	1.18
200—210	62	3524	226	3.85	3.43	1.08	1.00	1.27	1.14
210—220	46	2480	176	4.26	3.91	1.14	1.13	1.29	1.20
220—230	25	1429	70	2.94	3.43	0.84	0.86	0.92	0.92
230—240	29	1837	116	3.79	3.60	1.10	1.15	1.17	1.28
240—250	24	1765	131	4.45	3.92	1.21	1.16	1.30	1.40
250—260	46	2487	192	4.63	4.00	1.34	1.30	1.37	1.27
260—270	53	2605	162	3.73	3.75	1.30	1.30	1.28	1.25
270—280	16	949	60	3.79	3.56	1.17	0.85	1.11	0.87
280—290	36	2227	117	3.15	3.00	1.13	0.98	1.07	0.95
290—300	34	2075	74	2.14	1.57	0.72	0.61	0.65	0.58
300—310	34	2125	106	2.99	3.00	0.86	0.80	0.76	0.73
310—320	37	2265	83	2.20	2.00	0.80	0.62	0.66	0.56
320—330	33	2186	86	2.36	2.00	0.91	0.69	0.75	0.56
330—340	25	1625	61	2.25	2.18	0.86	0.81	0.72	0.63
340—350	30	1858	61	1.97	2.00	0.74	0.66	0.60	0.55
350—360	20	1175	42	2.14	2.40	0.80	0.85	0.67	0.79
Σ	1397	81849	4573	3.21	3.00	1.00	0.91	1.05	0.93

Figure 5

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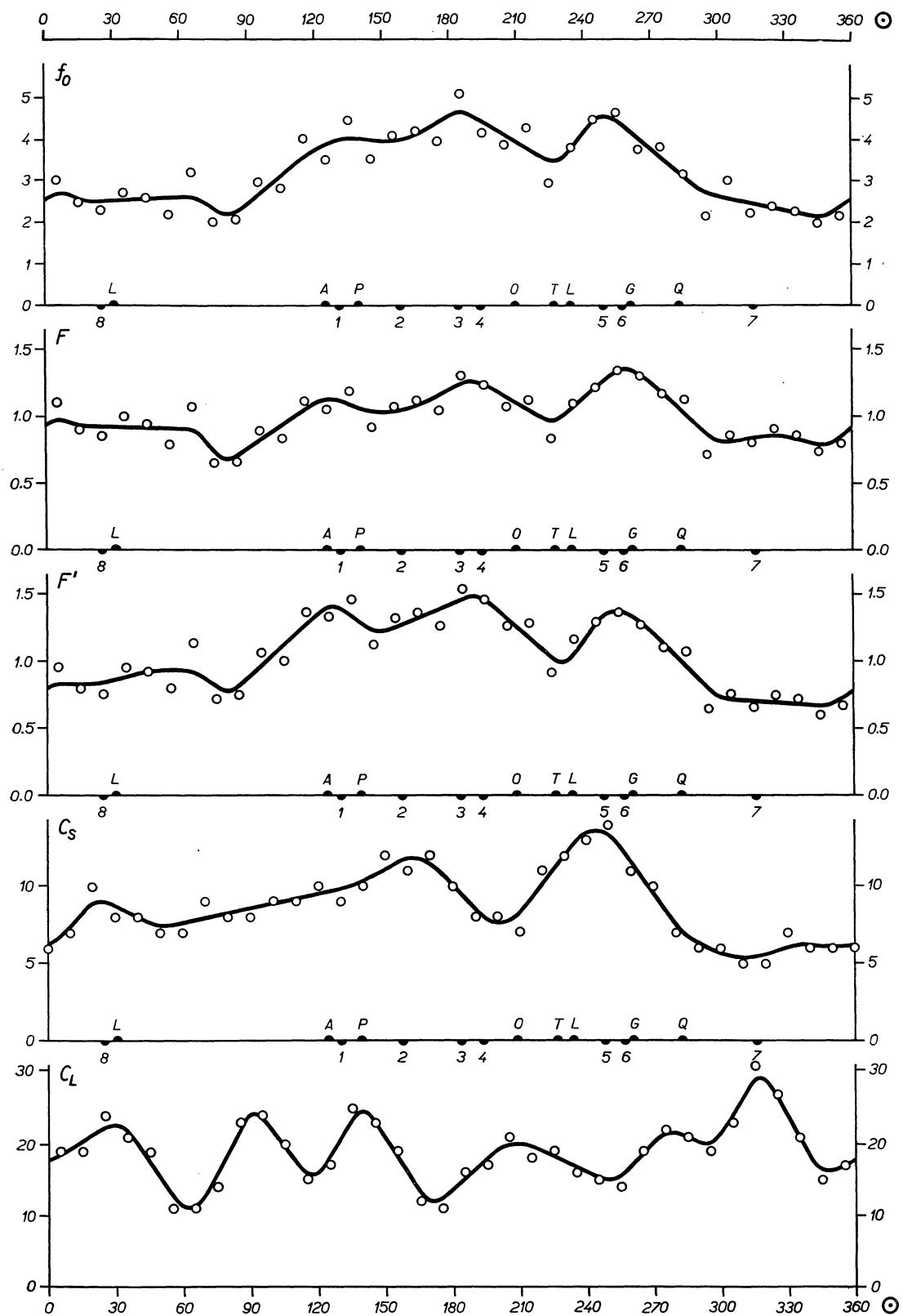
against spring months remains preserved despite the assumption of a marked apical concentration of radiants, inversing the trend of the diurnal variation (cf. Fig. 3). The curve suggests a low level of telescopic meteor activity, relatively free from disturbances, between $\odot = 290°$ and $\odot = 100°$ (January till June). Three broad maxima at $\odot = 130°$, $190°$ and $260°$ emerge from this permanent background with amplitudes of $1.3 : 1$ to $1.6 : 1$.

The same general features are apparent also on the variation curve of F', referred to model C,

between $\odot = 290°$ and $360°$, the amplitudes of the three maxima amount to $2 : 1$.

The general trend of the average meteor rates is confirmed by the variation curves of the medians (Fig. 6). The differences are moderate; most conspicuous is the smoothing of the double wave between $\odot = 120°$ and $200°$, which indicates that the maxima near $\odot = 130°$ and $190°$ are probably due to temporary meteor showers. The third maximum near $\odot = 250°$ is especially pronounced, owing either to a permanent shower of greater nodal dispersion, or to a permanent
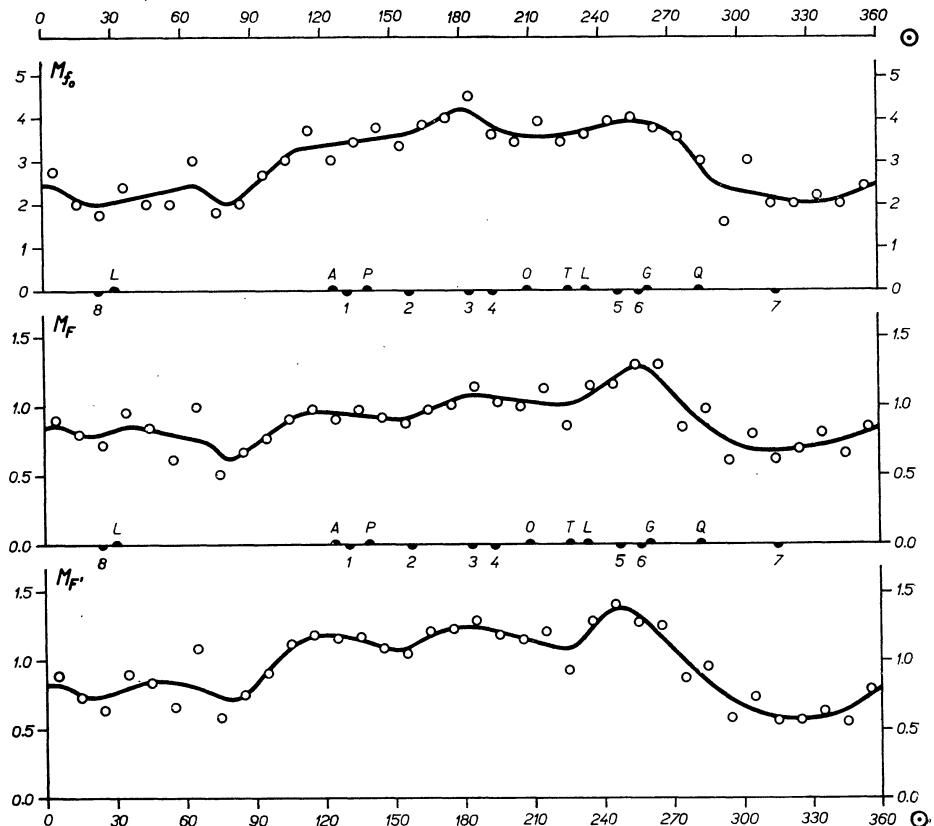
Figure 6

which is probably the best representation of the net annual variation freed from the effect of apparent radiant distribution. Contrary to expectation, the inclusion of the helion and anti-helion source makes the variations even more pronounced by increasing the maxima at $\odot = 130°$ and $190°$. The indication of another maximum appears at $\odot = 60°$, but this is just the region most poorly covered by the observation. Referring the frequencies to the permanent background activity

enhancement of meteor density in this region (several showers?)

6. Relation to cometary orbits

One of the potential sources of a non-uniform distribution of meteors around the earth's orbit is a non-uniform distribution of the orbits of their parent comets. The statistics of sporadic meteor orbits (e.g. Southworth and Hawkins 1963)

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shows that a substantial part of the pseudo-sporadic background consists of loose meteor associations, many of which are generically related to short-periodic comets. These associations cannot be recognized as separate meteor showers owing to the low spatial density and considerable dispersion of the respective streams; moreover, several of them may be active at the same time. It appears highly probable that every short-periodic comet that passes near enough to the earth's orbit may furnish meteors and increase — whether appreciably or not — the permanent level of sporadic meteor activity.

Correlations between the annual variation of sporadic meteor rates and the distribution of the points of approach to cometary orbits have already been considered by several authors. There are obvious difficulties as to the definition of the "comet index"— a quantity to be compared with the annual variation of meteor activity. First of all, the available statistics of cometary orbits is rather incomplete, biased by the discovery conditions. Many meteor associations may spring from comets which are too faint to be observed at present, or those which have been deflected by planetary perturbations into quite different orbits after the stream has formed. Moreover the relative contribution of individual comets is different, depending upon a number of factors: (a) The constitution of the stream, i.e. the total number of meteors within the respective range of sizes, their dispersion and period of revolution. (b) The conditions of encounter with the earth, including the distance from the comet orbit at the point of nearest approach and the geocentric velocity. (c) The local conditions of observation, depending on the radiant co-ordinates and geographic latitude of the observing place.

Hoffmeister (1948), who investigated the correlation for naked-eye meteors, compares the changes of meteor activity with the distribution of all comets observed in 1878—1938 which approached the earth within 0.2 A.U. He discards only those comets which cannot contribute to the northern hemisphere meteor activity owing to a high southern declination of the radiant, and attributes to the others different weights according to the minimum distance from the earth's orbit. His procedure was criticized by Levin (1961) for making no discrimination between short-periodic and nearly parabolic comets.

For the present study we made use of the comprehensive list of cometary orbits approaching the earth within 0.3 A.U., compiled by Kramer (1953). The comets of this list were divided into two categories according to whether their periods of revolution were less or greater than 500 years. With regard to the periods of recognized cometary showers, a correlation with meteor frequencies appears reasonable for the former group but highly improbable for the latter. Thus the latter group may be used for the sake of comparison, to reveal the possible selection effects of the annual variation of discovery conditions on the nodal distribution of known comets. A greater value of the minimum distance admitted, 0.3 A.U., is reasonable because we are particularly interested in dispersed showers of longer duration. The stream associated with each of the comets was considered as possibly active within 30° of solar longitude before and after the closest approach for the former category of comets (regularly of low inclination) and within 15° for the latter group (with orbital planes distributed at random). Table VI gives the results of cometary statistics for each 10° of solar longitude: c_S indicates the number of periodic comets ($P < 500^y$) approaching the earth within the respective longitude interval; C_S their sum over $\pm 30°$ of $\odot$; c_L the number of long-periodic and nearly parabolic comets ($P > 500^y$) approaching the earth within the respective longitude interval; and C_L their sum over $\pm 15°$ of $\odot$. The values of C_S and C_L represent our "cometary indices".

In Figure 7 the reduced meteor frequencies F (referred to model B, solid circles) and F' (referred to model C, blank circles) ate plotted against C_S. Considering that the meteor frequencies are compared here merely with the numbers of potential parent comets, which may widely differ as to the observable meteor contribution, a positive correlation appears highly probable. The regions of the earth's orbit which lack in approaches of periodic comets ($C_S < 10$) are mostly characterized by a low sporadic meteor activity, whereas an enhancement of the activity occurs, as a rule, in the regions where the number of approaching comets is high.

The annual variation of C_S and C_L is indicated in the lower part of Figure 5. It is seen that the density distribution of short-periodic cometary orbits around the earth's orbit agrees well with the distribution of telescopic meteors. In particular, the annual minimum is consistently situated between $\odot = 290°$ and $\odot = 360°$, an under-average frequency of meteors combined with an

Table VI

$\odot$	c_s $\Delta\odot = 10°$	C_s $\Delta\odot = 60°$	c_L $\Delta\odot = 10°$	C_L $\Delta\odot = 30°$
0—10	0	7	5	19
10—20	2	10	7	19
20—30	2	8	7	24
30—40	1	8	10	21
40—50	3	7	4	19
50—60	0	7	5	11
60—70	0	9	2	11
70—80	1	8	4	14
80—90	2	8	8	23
90—100	3	9	11	24
100—110	2	9	5	20
110—120	0	10	4	15
120—130	1	9	6	17
130—140	1	10	7	25
140—150	3	12	12	23
150—160	2	11	4	19
160—170	3	12	3	12
170—180	2	10	5	11
180—190	0	8	3	16
190—200	2	8	8	17
200—210	1	7	6	21
210—220	0	11	7	18
220—230	3	12	5	19
230—240	1	13	7	16
240—250	4	14	4	15
250—260	3	11	4	14
260—270	2	10	6	19
270—280	1	7	9	22
280—290	0	6	7	21
290—300	0	6	5	19
300—310	1	5	7	23
310—320	2	5	11	31
320—330	2	7	13	27
330—340	0	6	3	21
340—350	0	6	5	15
350—360	2	6	7	17
Σ	52	312	226	678

$\odot = 240°$; the frequency of approaches and the frequency of meteors are consistently above the average level but the positions of the maxima do not coincide.

On the other hand, comets moving in very prolonged orbits exhibit no correlation with meteor rates at all. This excludes any alternative explanation of the agreement, obtained for short-periodic comets, in terms of seasonal selective effect of the discoveries of comets on the distribution of their nodes. Moreover, short-periodic comets are even less sensitive to such effects, due to the alternation of discovery conditions from one return to another. Consequently, there is strong evidence that at least some of the irregularities of the annual variation are due to minor meteor streams of cometary origin, with the parent comets known, but too dispersed to be distinguished separately.

7. Contribution of major meteor streams

The relative lack of fainter shower meteors has already been established in our data elaborated previously (Kresáková and Kresák 1955, Kresáková 1958, 1965). In the present analysis we shall deal only with the results obtained during the Skalnaté Pleso telescopic survey. Although a number of special shower observations is now available (these will be published elsewhere) they are not directly comparable, as regards the frequency of meteors, with the main series of systematic observations. It should be borne in mind that the sporadic meteor survey was combined with comet searches. With this method of observation, the fields of view are fairly uniformly distributed over the visible hemisphere and also with respect to the radiant of each shower; at the same time the meteor rates are somewhat reduced by the sweeping motion of the telescope. Unlike this, special shower observations were made with a fixed position of the field of view which may systematically affect the meteor rates, inclusive of the sporadic background.

The restriction of shower observations to those made by the same method as the basic series of sporadic meteor observations does not leave sufficient data for examining the changes of shower activity in shorter time intervals. Compound sporadic and shower frequencies are available for almost every degree of solar longitude, the average

under-average frequency of cometary approaches continuing until $\odot = 100°$. The agreement of the two curves is worse between $\odot = 140°$ and

Figure 7

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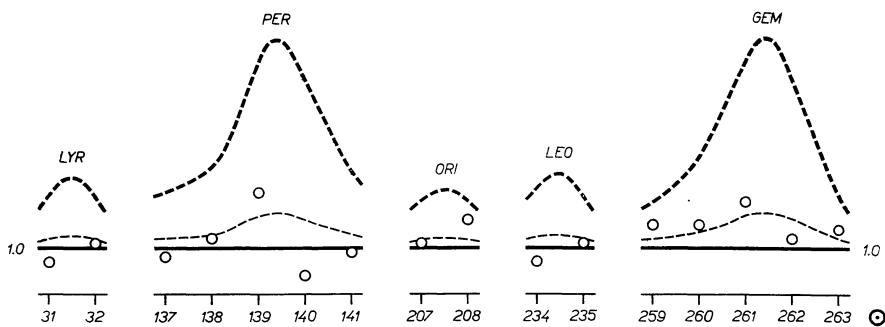
Figure 8

duration of observation being about 4 hours per one degree, and the average natural uncertainty about ± 30 % of the observed frequency.

In order to intercompare the activity of major meteor showers in the naked-eye and telescopic magnitude range, respectively, the intervals of solar longitude in which the naked-eye frequency of shower meteors exceeds that of sporadic meteors have been selected. This was done using the Skalnaté Pleso observations from the period 1944—1953 (Kresáková 1965) which, like the telescopic observations, are fairly uniformly distributed in the night hours and include the same latitude effect. The only exception was necessary in the case of Quadrantids where, due to a lack of our own observations, the frequency had to be esti-

mated from other sources. Obviously, no correction factors depending on the zenith distance of the radiant were applied. The mean naked-eye relative frequencies F_N (i.e. the numbers of all meteors divided by those of sporadic meteors) are given in Table VII for each degree of solar longitude where $F_N \geq 2$. They are also graphically represented by the heavy dashed curves in Figure 8.

The values of F_N may be directly compared with the telescopic rates F (referred to model B) and $F'' = 0.95F'$ (referred to model C)*. These are given, together with their natural uncertainties $\pm Fn_o^{-\frac{1}{2}}$, $\pm F''n_o^{-\frac{1}{2}}$, in the last two columns of Table VII. Evidently, the distinction between the two models is of minor importance in this respect, the difference between F and F'' being generally less than their natural uncertainties. In Figure 8 the values of F are plotted by open circles and the mean sporadic background level $F = 1$ by the full heavy line.

Telescopic observations of the Perseid shower of 1956, made with the same instrument but elaborated by an entirely different method based on the apparent direction distribution, led to the conclusion that the Perseids are relatively six times less abundant in the telescopic range than in the naked-eye range (Kresáková 1958). For the sake of comparison with this result, which was tentatively extended to all major showers, diagram 8 was supplemented by thin dashed curves connecting the values of $\frac{1}{6}(F_N + 5)$.

Figure 8 and Table VII yield no indication of a telescopic activity of the Lyrids, Leonids, or Quadrantids. This fact alone is not very significant because these showers are known to exhibit

Table VII

⊙	Shower	F_N	F	F'
31	Lyr	2.1	0.7 ± 0.7	0.7 ± 0.7
32	Lyr	2.1	1.1 ± 1.1	1.0 ± 1.0
137	Per	2.2	0.8 ± 0.3	0.9 ± 0.3
138	Per	2.7	1.2 ± 0.6	1.4 ± 0.7
139	Per	5.0	2.2 ± 1.1	2.6 ± 1.3
140	Per	4.7	0.4 ± 0.2	0.5 ± 0.3
141	Per	2.7	0.9 ± 0.2	1.1 ± 0.3
207	Ori	2.0	1.1 ± 0.2	1.1 ± 0.2
208	Ori	2.0	1.6 ± 0.4	1.9 ± 0.5
234	Leo	2.3	0.7 ± 0.3	0.7 ± 0.3
235	Leo	2.1	1.1 ± 0.2	1.0 ± 0.2
259	Gem	2.0	1.5 ± 0.4	1.5 ± 0.4
260	Gem	3.0	1.5 ± 0.4	1.5 ± 0.4
261	Gem	5.1	1.9 ± 0.6	2.0 ± 0.6
262	Gem	4.6	1.2 ± 0.5	1.2 ± 0.5
263	Gem	2.1	1.4 ± 0.4	1.3 ± 0.3
283	Qua	3.0	1.0 ± 0.5	0.9 ± 0.5
9			2.5 ± 1.1	2.0 ± 0.9
39			2.0 ± 0.7	1.8 ± 0.6
44			2.4 ± 0.6	2.2 ± 0.5
181	3		1.8 ± 0.4	2.1 ± 0.4
186	3		1.7 ± 0.3	2.0 ± 0.3
193	4		1.8 ± 0.3	2.0 ± 0.4
248	5		3.2 ± 0.6	3.1 ± 0.6
249	5		2.0 ± 0.9	2.2 ± 1.0
271			2.4 ± 0.7	2.0 ± 0.6
281			2.2 ± 1.2	2.2 ± 1.2

* The factor of 0.95 converts the unit of meteor activity used by Hawkins (1956) into the mean hourly rate of the Skalnaté Pleso survey; see the last line of Table IV and V.

substantial variations in strength from one return to another, and their maxima are rather sharp. Nevertheless, a striking lack of shower meteors, as compared with the naked-eye observations, is apparent also for the remaining three showers: none of the 17 values of F exceeds the corresponding value of F_N, and only 6 of them exceed that corresponding to the expected activity after the 6-fold reduction! Even for the rich shower of Perseids an enhancement of meteor activity is definitely established on the night of the maximum only. We conclude that in the magnitude range 7^m to 9^m the relative contribution of major meteor showers, as compared with the sporadic background, is merely 10 to 15 percent of that observed in the naked-eye range. Assuming that

$$dn \sim \varkappa^m \, dm \qquad (1)$$

this would correspond to a ratio $\varkappa_{\text{shower}}/\varkappa_{\text{sporadic}} = 0.60$ to 0.66 which agrees well with the results of Kresáková (1965).

8. Telescopic meteor showers

Another problem of substantial interest is the occurrence of telescopic meteor showers unknown from the naked-eye observations. This possibility is suggested by the work of Gallagher and Eshleman (1960) and others. Observations with an abnormally high meteor rate, as far as it cannot be attributed to random variations of the background activity, may be explained by

(a) the occurrence of a purely telescopic meteor shower, i.e. a shower with a very high value of the magnitude distribution constant $\varkappa$ at the transition from the naked-eye to the telescopic magnitude range,

(b) the occurrence of a temporary meteor shower, with a normal magnitude distribution, but not appearing annually and thus not included in the list of major meteor showers.

In the latter case we should expect a short duration of the shower, because broad meteor showers may appear and disappear again only after very strong planetary perturbations. The existence of broad meteor clouds isolated in the orbit is excluded by the evolutionary way of meteor streams which, owing to the integration of the differences in the mean daily motion, disperse much more rapidly along the orbit than in the direction perpendicular to it. As a matter of fact, most temporary showers do not last longer than a few hours, a duration of several days (e.g. the Corvids: Hoffmeister 1948) being rather an exception.

A method for identifying meteor showers in the Skalnaté Pleso telescopic survey has been derived in the preceding paper (Kresáková and Kresák 1955). It consists in the computation of the a priori probabilities P' that the meteor frequency will be equal to, or greater than, the observed frequency from

$$P' = \sum_{n=n_o}^{\infty} \frac{e^{-i} i^n}{n!}, \qquad (2)$$

where

$$i = \frac{\tau F_c}{60}. \qquad (3)$$

F_c denotes the expected hourly rate based on the model of radiant distribution selected. The observations from the period 1946—1953 which in model B yield probabilities $P' < 0.02$ are listed in Table XII of the quoted article; six additional observations of this type, from the years 1954—1959, are listed in Table VIII.

It is interesting to note that two of these six observations (Nos. 2119 and 2194) coincide well with the epochs of suspected telescopic shower activity found previously (centres Nos. 3 and 6). Moreover, observation No. 2093 shows a fair agreement with centre No. 2. Observations Nos. 2237 and 2238 confirm one another in suggesting some shower activity on February 5, 1959, without any confirmation from the preceding years at corresponding solar longitudes. Observation No. 2018 finds no confirmation at all in other data; nevertheless just in this case the pro-

Table VIII

No.	⊙	Date	Time M.E.T.	Obs.	τ	n	f_o	f_c	F	P'	Act.
2018	25.1	1959 IV. 15	22 30—23 30	An	60	11	11.0	2.6	4.2	0.0001	8
2093	164.2	1956 IX. 6	22 30—23 15	An	45	7	9.3	3.5	2.7	0.018	2?
2119	181.3	1954 IX. 25	00 45—02 30	K	90	13	8.7	4.3	2.0	0.015	3
2194	256.5	1953 XII. 8	22 30—23 15	V	40	6	9.0	3.1	2.9	0.019	6
2237	316.2	1959 II. 5	20 45—21 40	P	50	6	7.2	2.3	3.1	0.014	7
2238	316.2	1959 II. 5	21 00—22 30	Aá	75	11	8.8	2.5	3.5	0.0004	7

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bability P' is so low that a random increase of the sporadic background activity may be hardly admitted as an explanation.

If the probabilities P' would have been computed using another model of radiant distribution, some alternation of the list would result. In particular, the centres of activity Nos. 1—4 would become even more prominent than suggested previously (Kresáková and Kresák 1955) if we should replace model B by model C.

The eight principal centres of telescopic meteor activity are indicated by their numbers on the horizontal axes of Fig. 2 and 3, together with the maxima of the major permanent night-time showers (L = Lyrids, A = δ Aquarids, P = Perseids, O = Orionids, T = Taurids, L = Leonids, G = Geminids, Q = Quadrantids). As has been already pointed out, the epochs of increased telescopic meteor activity do not coincide at all with those of the major showers known from naked-eye and photographic observations. This is also the case with the two newly found centres at $\odot = 316°$ (No. 7) and $\odot = 25°$ (No. 8). There remains only centre No. 6 around $\odot = 256°$, for which a possible association with the Geminid stream was suggested. Now we believe that, even in this case, the association is very improbable for the following reasons:

The telescopic meteor shower in this position displayed an unusual activity in 1948, contrary to the Geminids which show little variation from one year to another and were not extraordinarily abundant in 1948. An independent confirmation of the event of 1948 may be found in a short note added by Schmitt (1949) to his observations of the periodic comet Honda—Mrkos—Pajdušáková on December 8—14, 1948: "Forte activité d'étoiles filantes dans la région; le 10. déc. 4 étoiles filantes traversent le champs ($15' \times 15'$) pendant la durée de l'observation (13 minutes)." With regard to the small field of view this frequency is conspicuous indeed.

In order to check the possible periodicity of this shower, hourly rates of telescopic meteors observed during the Skalnaté Pleso survey between $\odot = 250°$ and $262°$ have been plotted in Figure 9. Observations of 1948 are denoted by open circles, those of other years by solid circles; smaller circles refer to the observations before midnight, larger circles to those after midnight. The horizontal heavy line indicates the average level of the background activity in the neighbouring

10° intervals of solar longitude ($\odot = 240°$ to $250°$ and $260°$ to $270°$). The arrow labelled by S indicates the instant of the observation by Schmitt, the arrow labelled by G the instant of the maximum activity of the Geminid shower according to the naked-eye, photographic and radio observations. It is seen that the activity in all years except 1948 moderately increases to the right, compatibly with the approach to the centre of the Geminid stream. The trend is similar to that found from naked-eye observations, except that the relative contribution of the Geminids to the sporadic background is substantially lower (cf. Fig. 8). For the year 1948 the picture is entirely different, and even a rough curve of hourly rates may be constructed. Its maximum is situated between $\odot = 257°$ and $258°$, in the close vicinity of the observation of Schmitt.

The observations of the present program do not permit the derivation of the radiant co-ordinates, but a position in the morning sky is suggested by the diurnal variation of meteor rates. Fortunately, records of visual observations from the nights of 1948 Dec. 9th (1 : 35 — 2 : 35 M.E.T.), Dec. 10th (2 : 45 — 3 : 45 M.E.T.) and Dec. 12th (3 : 10 — 4 : 10 M.E.T.) are available at the Skalnaté Pleso Observatory. The net hourly rates per one observer are as follows:

	$\odot$	f_o sporadic	f_o Geminids
Dec. 9	256.9	16 ± 3	6 ± 2
Dec. 10	258.0	24 ± 4	6 ± 2
Dec. 12	260.0	22 ± 4	32 ± 5

The hourly rates of the Geminids are rather low on the former two nights; at the same time those of sporadic meteors are higher than usual (by about 50 %), although by far not so increased as
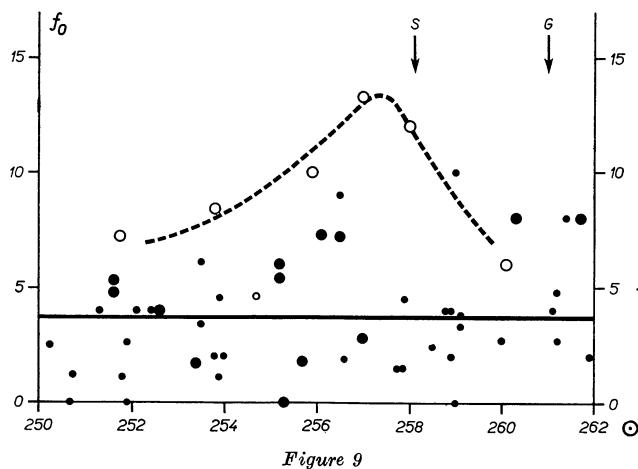
Figure 9

for the telescopic observations (as much as by 200 % at $= 257.0°$). The records include the indication of the apparent direction of motion of each meteor. These suggest an active radiant between $\alpha = 130°$ and $170°$, $\delta = +20°$ and $+50°$, in the constellation of Leo Minor or its close vicinity. The distance of this region from that observed by Schmitt ($60°$ to $100°$) supports our conclusion that even a considerable magnifying power does not prevent observation of meteors the radiants of which are situated at great angular distances from the field of view (Kresák 1955). The uncertainty in the radiant position is too great to permit a reliable identification with any cometary radiant or photographic meteor orbit. Only some possibilities may be suggested, i.e.

(a) the association with Comet 1798 II and the corresponding radiant No. 260 of Kramer's list (1953): $\odot = 251.6°$, $\alpha = 158.5°$, $\delta = +34°$,

(b) the association with the Harvard photographic meteor No. 1193 of 1942, Dec. 8 (Jacchia 1952): $\odot = 255.6°$, $\alpha = 144.3°$, $\delta = +38.4°$,

(c) the association with the Harvard Super-Schmidt meteors No. 5551 of 1952, Dec. 9 and No. 9467 of 1953, Dec. 10: $\odot = 257°$ and $258°$, $\alpha = 134°$ and $133°$, $\delta = +32°$ and $+33°$.

Another centre of activity, No. 7, is confirmed by the Jodrell Bank radio observations with the rotating areal equipment, 1954—1958. Evans (1960) quotes three suspected showers unknown before. One of them, observed in 1958, with a maximum mean daily rate 2—3 times the mean hourly sporadic rate, occurred at $\odot = 316.5°$, i.e. almost exactly in the same position as the observations Nos. 2237 and 2238. ($\odot = 316.2°$). The difference of one year between the two apparitions suggests a recurrent shower; this is borne out by a shower duration of at least four days indicated by the Jodrell Bank records. Unfortunately, visual observations from the beginning of February are rather sparse, owing to bad atmospheric conditions at most northern stations. Even in the comprehensive Catalogue of Hourly Rates compiled by Olivier (1960) too few observations refer to this period to allow a confirmation of the annual recurrence, the hourly rates being moderately above the average, in particular in the morning hours. The diurnal variation curve constructed from Evans' observations suggest a radiant position between $\alpha = 200°$ and $240°$, $\delta = +40°$ and $+70°$. The uncertainty is too great to permit an identification with the orbit of some comet or photographic meteor association.

The newly found centre No. 8 cannot be identified with any known shower, either. It is certainly not identical with the Lyrids, because the difference of solar longitudes is too large (about $8°$) and, moreover, the Lyrid radiant was relatively low at the time of the observation.

In their preliminary report on the Springhill radio meteor counts Millman and McIntosh (1963) give a list of eleven well marked peaks in the annual course of meteor rates. In addition to eight major showers, known previously from naked-eye and photographic observations, the summer daytime showers and two unidentified peaks of Sept. 8 and Sept. 30 are quoted. The latter two, although ranging amongst the most active showers of the year as regards the total number of echoes recorded, reveal a remarkable lack of long duration echoes. The corresponding lack of bright meteors reasonably explains why they are insignificant in the naked-eye and photographic observations. It is interesting to note that the higher of the two peaks (Sept. 30, $\odot = 186°$) perfectly coincides with our centre No. 3, representing the absolute annual maximum in our survey (Fig. 5). It has been shown by comparison with the annual variation curve of Hoffmeister (Kresáková and Kresák, 1955) that the enhanced activity in this part of the earth's orbit is the only substantial difference between the annual variation in the naked-eye and telescopic range, as far as the night hours and northern geographic latitudes are concerned. In view of the evidence presented by Millman and McIntosh it may be concluded that around $\odot = 180°$ to $190°$ the earth encounters a meteor stream with a peculiar magnitude distribution (unusually high value of the factor $\varkappa$) which appears only if the sensitivity of the observing method is raised above the naked-eye and photographic magnitude limit. Further telescopic and radio observations of this interesting shower are urgently needed.

Other particulars concerning other suspected telescopic meteor showers have been given in the previous paper (Kresáková and Kresák, 1955). The recurrence of one half of them is supported by the respective observations of Table VIII. Additional observations from the years 1954—1959 confirm the conclusion that the shower activity in the range of faint telescopic meteors (7^m—9^m) comes from other sources than the major naked-eye meteor streams, and that the shower rates do not exceed the rates of sporadic meteors on more than ten nights per year. The degrees of solar

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longitude at which the mean telescopic meteor rate exceeded the background rate, predicted from models B and C, by a factor of two or more are listed in the lower half of Table VII. The periods during which a recurrent telescopic shower activity may be most reasonably anticipated, and future observations of telescopic meteors recommended, are: February 5—6 ($\odot$ = 316°—317°), August 2—3 ($\odot$ = 131°), August 28—September 1 ($\odot$ = 156°—159°), September 26—October 1 ($\odot$ = 182°—188°) and October 6—8 ($\odot$ = 193°—195°).

9. Comparison with results of other surveys

A number of determinations of the annual variation of meteor rates, mostly based on radio observations, have appeared recently. However, their direct intercomparison is difficult for the following principal reasons:

(a) If we compare the observed variations we must consider that the optical observations may cover only one part of the day. The preliminary results of Millman and McIntosh (1963) demonstrate that the course of the annual variation may become entirely reversed if we use different day and night hours for obtaining the frequencies.

(b) The elimination of the diurnal variation, by which this difficulty might be overcome, is possible only with the aid of a correct model of the radiant distribution. From the results of section 4 (Fig. 4) we infer that in principle it is impossible to derive a stable model of the sporadic radiant distribution which would hold satisfactorily throughout the year. Conceivably, the transition from a mere apex concentration (e.g. model B) to a three-source concentration (e.g. model C) represents an objective refinement. For the problem of annual variation, however, this refinement is hardly a substantial approach to the truth, because even the relative strength of the three main sources undergoes considerable variations, as has been demonstrated by Keay (1963a). Unresolved meteor showers cause further complications.

(c) Even if the selection effects of individual observing techniques are properly eliminated, a difference must remain, partly due to the difference in geographic latitude (Keay and Ellyett 1961, Kresák 1964a), and partly due to the difference in the size of the meteors under observation.

In spite of these circumstances a remarkable similarity of the annual variation derived from the Skalnaté Pleso and other surveys has been established. There is a pronounced resemblance to the curve of Hoffmeister (1937) based on the naked-eye observations of Heybrock, Schmidt and himself (cf. Fig. 6 in : Kresáková and Kresák 1955). In this case the observing conditions were practically identical as regards the night hours included and the latitude difference is negligible. Hence we conclude that the single discrepancy around $\odot$ = 180°—190° is due to the difference in the magnitude range covered by naked-eye and telescopic observations, respectively, i.e. to a meteor shower composed almost exclusively of very faint meteors. As has already been mentioned, the existence of such a shower is decidedly confirmed by the Springhill radio observations (Millman and McIntosh 1963).

Another outstanding similarity is met if the variation referred to the three-source model is compared with the radio-echo results of Weiss and Keay (cf. Fig. 3 in: Kresák and Kresáková 1963 and Fig. 6 in: Keay 1963b). This agreement between the observations at places, spaced by 84° and 92° in geographic latitude, is of particular importance, suggesting that the main anomalies in the annual variation of sporadic meteor rates are due to meteors coming from the region of the celestial equator. This position of the radiants suggests a prevalence of short-periodic orbits of low inclination, which also, according to the telescopic meteor apparent direction distribution (Kresák 1955) and the photographic meteor magnitude distribution (Kresák 1964b), increases towards fainter meteors.

On the other hand, a striking discrepancy is found when our results are compared with those of Hawkins (1956), even if the same radiant distribution model C is applied (cf. Fig. 3 in: Kresák and Kresáková 1963). It is surprising that our telescopic observations agree much better with the observations at Adelaide and Christchurch, in the southern hemisphere, than with those at Jodrell Bank, located in approximately the same geographic latitude as Skalnaté Pleso. The difference between the annual variation of radio-echo and that of photographic rates in the northern hemisphere has already been pointed out by Hawkins and Prentice (1957), who attribute it to the fact that the sensitivities of the two methods of observation vary with the geocentric velocities of the meteors. This interpretation requires a concentration of high-velocity meteors

in the sector of the earth's orbit traversed in the summer months. However, direct measurements of meteor velocities, e.g., those by McKinley (1951), show, on the contrary, that there is only an average number of high-velocity meteors in June and July, and a maximum in September and October, consistent with the extreme declination of the apex.

In a previous paper we have pointed out the remarkable symmetry of the ratio of corrected meteor rates Jodrell Bank vs. Skalnaté Pleso with respect to the summer solstice (cf. Fig. 4 in: Kresák and Kresáková 1963). In order to explain this symmetry we have suggested a seasonal solar effect, appearing in a correlation between the duration of the daily illumination by the Sun and the ratio of ionizing to luminous efficiency of meteors. In favouring this type of explanation we insisted on the finding of Hawkins (1956) that the sporadic radiant distribution pattern remains practically invariable throughout the year and that good frequency estimates may be obtained if the rates, predicted from the diurnal variation computed for model C, are multiplied, for each month, by an annual variation factor (Table 3 in: Hawkins 1956).

The data published since then by Evans (1960) and, in particular, by Kaščejev, Dudnik, Lagutin, Lebedinec, Lukjaško and Lysenko (1962) and, by Millman and McIntosh (1963) make it clear that the Hawkins' model fails to explain the observed diurnal variation in June—July. During this period where, according to Hawkins, the meteor rates are increased by a factor of 1.6 to 1.8 against the year's mean the surrounding of the helion source is apparently much more active than that of the antihelion source. This anomaly is evidently due to the occurrence of the well-known summer daytime showers, which in Hawkins' annual variation curve are added to the sporadic background. The analyses based on optical observations do not include this, because the radiants rise above the horizon until shortly before sunrise. On the other hand, the radio observations from the southern hemisphere could not record these daytime showers due to the low maximum elevations of their northern radiants. This is presumably the correct explanation why the northern hemisphere visual observations agree much better with the southern than northern hemisphere radio observations, the symmetry of the residuals with respect to the solstice being only a matter of chance.

10. Implications for meteoric risk to space vehicles

The meteors observed during the Skalnaté Pleso survey yield a probability of collision with an artificial satellite of about $10^{-6}\,\mathrm{m}^{-2}\,\mathrm{day}^{-1}$. According to the recent estimates of Whipple (1963), a collision with a meteoric particle of this kind should perforate a 2 mm aluminium skin. The uncertainty of this estimate is still considerable and this article does not attempt to discuss the difficult problem of meteor masses and penetration; nevertheless, our results allow us to estimate at least the manner in which the risk varies throughout the year.

Obviously, encounters of a satellite with dense meteoric streams would be most dangerous, and from this point of view it appears very satisfactory that, in the magnitude range investigated, such concentrations of particles are sparse, not to say entirely absent. The highest meteor rate among about 1400 observations made during 14 years (that of Dec. 1, 1946), exceeds the mean rate by a factor of 5 only, although the expected random variations are large owing to the low meteor frequencies in telescopic observations. The mean rate in a 1° interval of solar longitude exceeds the year's mean rate by a factor of two in not more than 3—4 percent of all cases.

The major meteor showers represent a risk that is negligible in most cases (as compared with the sporadic background) and is generally much lower than might be anticipated on the basis of photographic and naked-eye observations of larger bodies, or on the basis of impact measurements of smaller bodies. The pronounced shower characteristics of the micrometeorite activity, detected by the measurements on artificial satellites (variations of the risk of the order of $10^2 : 1$ and more) evidently appear much lower in the scale of particle sizes. A comparison of the actual distribution of hourly rates with the Poisson distribution law also does not reveal fluctuations of the type suggested by Gallagher and Eshleman (1960) for the faintest radio meteors, about 5^{m} below the magnitude limit of our survey.

Moreover, the observed variations of hourly rates—which in our analysis are obviously restricted to night hours—permit a demarcation of sections on the earth's orbit which are not only relatively free from sudden increases of shower activity but also generally lacking in encounters with telescopic meteors. The safest period of permanently low activity lasts from January till

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May, whereas the periods of highest activity occur from August up to the first half of October and in December. The daytime activity in June—July, not included in our observations, apparently adds this period to the unfavourable ones.

These conclusions obviously refer only to the vicinity of the earth's orbit, not far beyond the distance of the Moon. For space vehicles orbiting to greater distances, comparable to those of the planets, another fact is of interest. The concentration of meteor orbits to the ecliptical plane and the preponderance of direct orbits over retrograde ones, vhich are considerable just in the photographic and naked-eye magnitude range, apparently become even more prominent in the telescopic magnitude range. At the earth's distance from the Sun the systematic variation of meteor density with heliocentric latitude is larger than that with heliocentric longitude, produced by the occurrence of meteor showers. Hence, for travel to the planets the meteoric risk will depend upon the inclination of the orbit to a greater extent than upon the position of the node.

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РАСПРЕДЕЛЕНИЕ ТЕЛЕСКОПИЧЕСКИХ МЕТЕОРОВ ВДОЛЬ ЗЕМНОЙ ОРБИТЫ

В работе исследуются изменения численности телескопических метеоров на основании наблюдений, полученных в обсерватории Скальнате Плесо в период 1946—1959 гг. В общем этот материал, который состоит из 4573 метеоров зарегистрированных при 1397 наблюдениях, является наиболее обширной и однородной из всех до сих пор напечатанных серий телескопических наблюдений.

Основной задачей работы является изучение распределения плотности орбит слабых метеоров вдоль орбиты Земли. Суточная и годичная вариации численностей исследуются на основании трех разных моделей распределения спорадических радиантов на небе: (A) равномерного распределения; (B) концентрации радиантов к апексу в соответствии с формулой Хоффмейстера; (C) модела Хокинса с двумя боковыми максимумами в плоскости эклиптики. Результаты, особенно двухразмерное изображение суточной и годичной вариаций для отдельных моделей (рис. 4) доказывают, что истинное распределение орбит неравномерное и невозможно его представить какой-нибудь постоянной моделью, что касается особенно годичной вариации. Однако выявляется некоторая корреляция с распределением узлов короткопериодических комет, показывающая кометное происхождение части телескопических метеоров. Ход годичной вариации (рис. 5), его сравнение с радиолокационными наблюдениями полученными в южном полушарии и связь с распределением короткопериодических комет показывают выразительную концентрацию орбит телескопических метеоров к плоскости эклиптики, что подтверждают даже

некоторые наши опечатанные раньше результаты (распределение направлений телескопических метеоров, связь между распределением метеоров по звездной величине и типом орбит).

В сравнении с фотографическими и визуальными наблюдениями более ярких метеоров главные известные метеорные потоки проявляются существенно слабее в диапазоне 6—9-ой звездной величины; их относительное число в сравнении со спорадическим фоном в 5—10 раз меньше (рис. 8). Наоборот, при пониженной яркости появляются новые потоки, которые, однако, только изредка достигают численности вдвое большей численности метеоров фона. В общем в течение 14-летнего периода было найдено только 8 телескопических потоков, которые не обнаруживаются при фотографических и визуальных наблюдениях.

Некоторые из этих потоков (напр. наиболее отчетливый поток при $\odot = 184°$, совпадающий с максимумом годичной вариации телескопических метеоров и поток при $\odot = 316°$) можно найти даже по радиолокационным наблюдениям более слабых метеоров; при других потоках можно, повидимому, говорить только об одной более выразительной встрече ($\odot = 248°$ в 1946 г., $\odot = 257°$ в 1948 г., $\odot = 25°$ в 1959 г.). В некоторых случаях становилось возможным вычислить даже приближенное положение радианта. Различие между принадлежностью ярких и слабых метеоров к отдельным потокам доказывает, что распределение по величине частиц для отдельных метеорных роев значительно отличается.

Исследованный диапазон телескопических метеоров, которому отвечает вероятность столкно-

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вения приблизительно 10^{-6}м$^{-2}$ сутки$^{-1}$ и проникновение 2-мм слоем алюминия, особенно важный с точки зрения столкновений искусственных спутников с метеорами. Опасность встречи с метеорными потоками оказывается относительно небольшая, существенно меньше опасности, вытекающий из экстраполяции результатов фотографических и визуальных наблюдений. Внезапные повышения численности метеоров на несколько порядков, регистрируемые искусственными спутниками, очевидно появляются в шкале размеров значительно ниже. В общем, наиболее безопасный период года с постоянно низкой численностью: январь — май, высокие численности с более частым появлением роев встречаются в августе, сентябре, в первой половине октября и в декабре. К этим периодам надо прибавить еще период летних дневных потоков, которые невозможно оптически наблюдать.

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ROZLOŽENIE TELESKOPICKÝCH METEOROV POZDĹŽ DRÁHY ZEME

V práci sa analyzujú zmeny frekvencie teleskopických meteorov podľa pozorovaní vykonaných na Skalnatom Plese v rokoch 1946—1959. Celkove je materiál počtom 4573 meteorov, zaznamenaných pri 1397 pozorovaniach, najobsiahlejším a najhomogénnejším zo všetkých dosiaľ publikovaných radov teleskopických pozorovaní.

Hlavným cieľom práce je výskum rozloženia dráh slabých meteorov pozdĺž dráhy Zeme. Denná a ročná variácia frekvencií skúma sa na základe troch odlišných modelov rozloženia sporadických radiantov po oblohe: (A) rovnomerného rozloženia, (B) koncentrácie radiantov k apexu podľa Hoffmeisterovho vzťahu, (C) Hawkinsovho modelu s dvoma bočnými maximami v rovine ekliptiky. Výsledky, najmä dvojrozmerné znázornenie dennej a ročnej variácie v jednotlivých modeloch (obr. 4) dokazujú, že skutočné rozdelenie dráh nie je rovnomerné a nemožno ho vystihnúť žiadnym stálym modelom, najmä pokiaľ sa týka ročnej variácie. Ukazuje sa však určitá korelácia s rozložením uzlov krátkoperiodických komét, dokazujúca kometárny pôvod aspoň časti teleskopických meteorov. Priebeh ročnej variácie (obr. 5), jeho porovnanie s radarovými pozorovaniami z južnej pologule a vzťah k rozloženiu krátkoperiodických komét potvrdzujú výraznú koncentráciu dráh teleskopických meteorov k rovine ekliptiky, tak ako o nej svedčia i niektoré naše inde publikované výsledky (rozdelenie smerov teleskopických meteorov, vzťah medzi rozdelením meteorov podľa veľkosti a typom dráhy).

Hlavné známe meteorické roje sa v rozsahu 6^m—9^m uplatňujú podstatne slabšie ako pri fotografických a vizuálnych pozorovaniach jasnejších meteorov; ich relatívne zastúpenie proti sporadickému pozadiu je 5—10-ráz menšie (obr. 8).

Naopak sa s poklesom jasnosti objavujú nové roje, ktoré však iba celkom výnimočne dosahujú dvojnásobok frekvencie sporadického pozadia. Celkove sa podarilo v 14-ročnom období zistiť iba 8 teleskopických rojov, z ktorých žiaden sa neprejavuje vo fotografických a vizuálnych pozorovaniach. Niektoré z nich (napr. najvýraznejší roj okolo $\odot = 184°$, totožný s maximom ročnej variácie teleskopických meteorov, roj okolo $\odot = 316°$) možno identifikovať i v radarových pozorovaniach slabších meteorov; pri iných išlo zrejme o jediné výraznejšie stretnutie ($\odot = 248°$ v r. 1946, $\odot = 257°$ v r. 1948, $\odot = 25°$ v r. 1959). V niektorých prípadoch bolo možné vypočítať i približnú polohu radiantu. Rozdiel medzi rojovými asociáciami jasnejších a slabších meteorov dokazuje, že rozdelenie čiastočiek podľa veľkosti sa v jednotlivých rojoch značne líši.

Skúmaný rozsah teleskopických meteorov, ktorému zodpovedá pravdepodobnosť zrážky asi $10^{-6} m^{-2} deň^{-1}$ a prienik 2 mm vrstvou alumínia, je osobitne význačný pre riziko zrážok umelých družíc s meteormi. Ukazuje sa, že nebezpečie zo strany meteorických rojov je relatívne malé, podstatne menšie, ako by vyplývalo z extrapolácie výsledkov fotografických a vizuálnych pozorovaní. Náhle zvýšenia frekvencie meteorov o niekoľko rádov, aké sa registrujú na umelých družiciach, sa zrejme objavujú až oveľa nižšie v škále veľkostí. Celkove najbezpečnejšie obdobie so stálou nízkou frekvenciou trvá od januára do mája, vysoké frekvencie s častejším výskytom rojov pripadajú na august, september, prvú polovicu októbra a december. K nim, pravda, treba ešte prirátať obdobie letných denných rojov, ktoré opticky nemožno pozorovať.

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