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THE MAGNITUDE DISTRIBUTION OF METEORS IN METEOR STREAMS

Abstract: The magnitude distribution of meteors in different meteor showers is investigated on the basis of about 48,000 magnitude estimates and 28,000 altitude estimates obtained at the Skalnaté Pleso Observatory. The probabilities of perceiving meteors as a function of their magnitudes and positions are derived and applied to the construction of the expected apparent magnitude and altitude distributions for different magnitude functions $dN \sim \varkappa^M dM$. These are compared with the observation and the values of the constant $\varkappa$ are deduced. A seasonal invariability of the magnitude function of sporadic meteors, suggesting its independence of the geocentric velocity, is found. All seven major showers under investigation yield a pronouncedly lower value of $\varkappa$ than their sporadic background, which is confirmed by a significant lack of shower meteors in the telescopic magnitude range. Attention is paid to the variation of the magnitude function with the position within individual streams and to its changes with the magnitude. Some anomalies associated with the evolution of meteor streams are established.

1. Introduction

The recent development of observing techniques in meteor astronomy—in particular the application of radio techniques and measurements on artificial satellites—has considerably extended the range of particle sizes accessible to direct studies. Observations covering different magnitude ranges have proved beyond doubt that many of the statistical characteristics of meteor activity and meteor orbits substantially vary with the magnitude.

One of the most striking features is a different proportional representation of shower meteors in photographic, naked-eye, telescopic, and radio surveys; this difference is quite distinct even if the data of one survey are ample enough to be treated separately for different magnitudes or echo durations (Millman and McIntosh 1963). Telescopic observations reveal a general lack of faint meteors associated with the major showers known from naked-eye observations (Kresáková and Kresák 1955); on the other hand, showers composed of telescopic meteors only were found (Štepan 1959). The rates of very faint radio meteors show considerable variations attributed to their shower properties (Gallagher and Eshleman 1960) and the striking variations of the impact frequency on artificial satellites suggest the existence of dense micrometeorite showers (Dubin, Alexander and Berg 1963). The extension of a direct determination of the orbits to smaller particles established the presence of unusual types of short-periodic orbits, hitherto unknown (Davies 1957, Hawkins 1963), and the proportion of asteroidal orbits was shown to increase with decreasing brightness (Kresák 1964). Also the structure of meteoroids appears to vary with their sizes (Whipple 1952, Cook and Whipple 1955), being at the same time different for different meteor showers (Jacchia, Kopal and Millman 1950, Jacchia 1952, Verniani 1964); the colour indices suggest a different radiation mechanism of bright and faint meteors (Jacchia 1957, Ceplecha 1959, Davis 1963).

Although the abundance of meteors sharply increases with decreasing brightness, the ratio $\varkappa$ of meteor numbers in two neighbouring magnitude classes,

$$\varkappa = \frac{N_{M+1}}{N_M}, \tag{1}$$

remains approximately constant within broader magnitude intervals. By adopting a constant $\varkappa$ in

(1) the magnitude distribution is expressed by the magnitude function

$$dN = \varkappa^M \, dM \qquad (2)$$

which may be conveniently plotted as a linear relation between log N and M. The determination of the ratio for various meteor samples and magnitude ranges—e.g. for individual meteor showers, for sporadic meteors of a given period, for faint telescopic meteors or bright fireballs—may reveal differences among various meteor populations.

The determination of the constant $\varkappa$ is made difficult by selection effects depending on meteor magnitudes, which are inherent in every method of observation. As a rule, they are most interfering just near the detectable limiting magnitude, where the data are most abundant and thus of greatest weight from the purely statistical point of view. In visual observation they affect the whole magnitude range, since the effective field of view, controlling the number of meteors recorded, continuously varies with the apparent magnitude. The relation between the effective field of view and meteor magnitude may be found only empirically, with a special arrangement of observations different from the current practice.

For the investigation of the magnitude distribution, as an important contribution to the studies of the origin and evolution of meteors, meteor showers deserve special attention for the following reasons:

(a) Well-defined meteor streams represent the earliest evolutionary stage of a more complicated system, as a formation originating immediately after the separation of meteoroids from the parent body.

(b) The heliocentric orbits of the members of a shower are almost identical.

(c) Individual members of a stream are very probably more uniform as regards composition and structure than the members of different streams and sporadic meteors. A uniform age may also be met more frequently.

The similarity of the orbits ensures that the objective conditions for the influence of external agents—solar radiation, planetary perturbations, collisions—are uniform, differing for individual particles only by a random selection. The fact that the common velocity vector of individual meteors yields uniform conditions for the atmospheric collisions is of particular importance. Assuming a uniform composition and structure of all meteoroids of a given stream, the scale of absolute magnitudes may be directly associated with the scale of masses, or dimensions. This assumption is obviously only a rough approximation; however, for sporadic meteors even this is impossible due to the dispersion of geocentric velocities.

The data on the magnitude distribution of meteors available at present are rather sparse, and in some respects even discordant. Nevertheless, remarkable anomalies have been reported, suggesting

(a) different values of $\varkappa$ in different showers,

(b) a variation of $\varkappa$ with the location of the meteor sample within the stream,

(c) a variation of $\varkappa$ with the magnitude.

Attempts were made to explain these anomalies by different evolutionary processes; the explanations, which may be of basic significance for the theories of origin and evolution of meteor streams, are not yet generally accepted. The ratio $\varkappa$ for a number of meteor showers was derived by Levin (1953) using the visual observations of Hoffmeister (1948). He finds a broad range of $\varkappa$—from 1.7 (Lyrids) up to 4.4 (Virginids)—and attributes the differences, at least partially, to a different structure of the inner and outer regions of the streams, respectively. He suggests that the distribution of momenta at ejection from the parent comet, by which smaller particles attain higher relative velocities and disperse into a broader belt, causes a preponderance of larger particles in the inner part of the stream. An effect of this kind is also predicted by Whipple (1951) on the basis of his icy model of cometary nuclei. A relative concentration of larger particles in the central part of the stream is confirmed by Pickering (1902) in visual observation of the Leonids, by Plassman (1925) in visual observations of the Perseids, by Hawkins and Almond (1952) and by Kaščejev and Lebedinec (1959) in the radio observations of the Geminids, and by Weiss (1963) in radio observations of the δ Aquarids. A number of indications that $\varkappa$ decreases at the time of an extraordinarily strong meteor display was collected by Levin (1956).

Another evolutionary process—the operation of the Poynting-Robertson drag—requires a concentration of larger particles at the outer boundary of the stream, remote from the Sun (Wyatt and Whipple 1950). A corresponding trend of the magnitude distribution, more precisely speaking of the distribution of echo durations, was found by Lindblad (1952) in radio observations of δ

Aquarids and by Plavcová (1962) in radio observations of the Geminids. However, Lindblad's result finds no confirmation in the observations of McKinley (1954).

The changes of $\varkappa$ with the magnitude appear to be the best confirmed of all these anomalies, despite the selection effects which are most interfering just in this case. As a rule, $\varkappa$ decreases towards fainter meteors, as is seen from the radio observations of Browne, Bullough, Evans and Kaiser (1956), Kaščejev and Lebedinec (1959) and Weiss (1963). In visual observations of the Perseids a deficiency of faint meteors was found by Öpik (1923), Watson (1934), Kresák and Kresáková (1953) and Van den Bergh (1956), in telescopic observations of the Perseids by Kresáková (1958), in visual observations of the Leonids by Watson (1934). In both cases we have to do with old cometary showers of considerable dispersion. On the other hand, in the observations of the young compact shower of Draconids by de Roy (1933) and Richter and Sandig (1933) no decrease of $\varkappa$ can be established, as was shown by the analysis of Watson (1934) and Plavec (1957). This difference would suggest that the effect appears only after a longer evolution. Plavec (1950) attributes this to the operation of the Poynting-Robertson effect, Kresák (1960) to that of corpuscular sputtering by solar radiation.

2. *Observations and their errors*

Insufficient reliability of the observing data is a weak point of most of the results quoted in the preceding section. Good photometry is possible only for photographic observations which are not numerous enough for statistical purposes and are restricted to brighter meteors. Radio observations permit the study of the magnitude distribution using the distribution of echo amplitudes, or durations, but the relation between photometric and radio-echo characteristics is rather complicated by the position and aspect sensitivity involved. Despite their obvious shortcomings, due to the substitution of objective measurements by subjective estimates, naked-eye observations still remain one of the most promising means for obtaining informations on the magnitude distribution of meteors.

Visual observations of meteors have for a long time been one of the permanent programs of the Skalnaté Pleso observatory; in extent and homogeneity the series of data collected are comparable with the best series available elsewhere. The data are particularly extensive for the permanent meteor showers: in comparison with Hoffmeister's observations analysed by Levin (1953), the total number of magnitude estimates is about seven times greater. In most cases, the altitudes of individual meteors are also available. Inasmuch as the altitude distribution of meteors is connected with the distribution of their apparent magnitudes, it may be used as another base for the investigation of the magnitude distribution, yielding an independent check of the results.

The observational data used in the present study were collected during the period 1944—1955, by the following observers: J. Ambruš, M. Antal, R. Bajcár, I. Bajcárová, G. Bakoš, A. Bečvář*, K. Bečvářová**, N. Blahová, Z. Bochníček, J. Bouška, Z. Ceplecha, I. Čajda, S. Dědek, L. Drozd, M. Dzubák*, M. Forgáč, H. Frajová, V. Guth, J. Guthová, M. Hájková, M. Hartmanová, V. Hoepfnerová, J. Ivan, T. Jančik, J. Kadaňka, V. Kiss, F. Kresák, Ľ. Kresák*, M. Kresáková, S. Krohová, J. Kučera, Z. Kvíz, V. Letfus, J. Lexa, B. Maleček, J. Malovec, D. Mayer, A. Mrkos*, O. Obůrka, Š. Olejník, B. Onderlička, Ľ. Pajdušáková*, A. Paroubek, Z. Píchal, J. Plavec, M. Plavec, Z. Plavcová, R. Podstanická, J. Sitar, J. Široký, J. Štohl, Š. Šuba, V. Thurzo, J. Uhlár, F. Vadovič, B. Valníček, M. Vránová.

In spite of the considerable number of collaborators the composition of the group was fairly steady, most frequently formed by four of the five observers denoted by asterisks and the recorder denoted by a double asterisk. The method of observation did not undergo changes during the 12-year period; the only change to be noted in connection with the present work was an introduction of the altitude records in 1964. The team was mostly composed of four non-plotting observers watching four principal directions (azimuths 0°, 90°, 180° and 270°, altitude 45°) and a recorder. Cloudiness, if present, was recorded in 10-minute intervals for each direction watched as a percentage of the meteors presumably escaping observation behind the clouds. The limiting stellar magnitude was generally not recorded because this is quite steady at the high-mountain location of Skalnaté Pleso (1783 m above sea-level). In order to suppress the effect of varying meteorological conditions, all observations, or partial intervals thereof, during which the cloudiness exceeded 20 % were discarded from further elaboration. The same was done with those observing records on which a sensible interference of moonlight, twilight or gale was noted.

After this preliminary selection the data given in Table I were found suitable for further treatment. It may be noted that there are more data on the magnitudes, both of shower (M_+) and sporadic meteors (M_-), than on their altitudes. The difference mainly concerns the observations from the first two years when no altitude estimates were recorded. The sporadic meteors are primarily considered as comparison samples useful for suppressing the effects coming from unavoidable moderate variations of observing conditions and personal factors of the variable team of observers. For the statistics of magnitudes they were taken only from those nights when shower meteors were recorded, too. The altitude distribution is less sensitive to minor variations of observing conditions, and it was decided to apply for this purpose all observations from the whole period of expected shower activity, irrespective of whether any shower meteors were recorded on the night in question. For this reason there are more altitude than magnitude estimates in the case of the Lyrids. Owing to a lack of data, the η Aquarids were not used at all for the derivation of the altitude distribution. The δ Aquarids appear simultaneously with the earlier Perseids; due to this coverage the results for sporadic meteors from the Aquarid period (denoted by asterisks) are not included in the sums given in the last line of the table.

Table I

Shower	Number of returns	Number of observations	Number of estimates			
			M_+	M_-	H_+	H_-
Lyrids	5	15	507	820	502	955
η Aquarids	3	9	66	315	—	—
δ Aquarids	9	48*	584	7012*	494	6282*
Perseids	10	138	19407	16691	8456	10659
Orionids	6	28	1015	1693	847	1149
Leonids	5	13	234	547	170	280
Geminids	7	33	4072	1930	3021	1425
all showers	45	236	25885	21996	13490	14468

An analysis of the errors committed in visual meteor observations will be published elsewhere. Nevertheless it appears reasonable to report here briefly on the main results as regards the accuracy of the magnitude and altitude estimates which will be used for investigating the magnitude distribution.

(I) The magnitude estimates: For naked-eye observations the probable error near the centre of the field of view is $\pm 0.4^m$. It slowly increases with the distance from the centre (transition to peripheral vision), so that the mean probable error in an unlimited field of view is $\pm 0.5^m$ to $\pm 0.6^m$. The errors also increase with increasing angular velocity; this is inferred from the telescopic observations where the probable random error amounts to $\pm 0.7^m$. Systematic differences among the estimates of individual observers are moderate, generally $\pm 0.2^m$ to $\pm 0.3^m$ for naked-eye observations and $\pm 0.4^m$ to $\pm 0.5^m$ for telescopic observations.

(II) The altitude estimates: For naked-eye observations, the probable error near the centre of the field of view is $\pm 4°$ to $\pm 5°$. It slowly increases with the distance from the centre, so that the mean probable error in an unlimited field of view is about $\pm 7°$. Systematic differences among the estimates of individual observers are less than the random errors, about $\pm 4°$. Both the greatest random and systematic differences occur at the altitudes of 50° to 70°, i.e. in the region where a considerable range of azimuths is under observation, but the zenith distance is still too great to allow a good direct estimate.

The size of the errors indicates that the visual magnitude and altitude estimates are suitable for a dependable derivation of the magnitude function, provided that the data are extensive enough within an interval of several magnitudes and that the selection effects are properly accounted for.

3. *Relation between apparent magnitude distribution and magnitude function*

For the conversion of the apparent magnitude distribution into the magnitude function (2) a knowledge of the coefficients of perception for individual magnitudes is necessary. These coefficients are proportional to the inverse values of the probability that an observer will witness a meteor of a given apparent magnitude appearing in a random position on the visible hemisphere. An equivalent, and perhaps more instructive, way is to determine the sizes of the effective fields of view. These are defined, separately for each magnitude, as limited circular regions in which the actual frequency of meteors is equal to the observed frequency in an unlimited field of view.

This procedure obviously requires that the positions of individual meteors be distributed over the visible hemisphere entirely at random or, in particular, that the rate of appearance of meteors be independent of the altitude. Levin (1956) has demonstrated that this is not the case. However, with a team of naked-eye observers watching different directions and covering a wide altitude range this assumption may be safely adopted as a feasible approximation; it holds good, first of all, for brighter meteors.

All methods for determining the coefficients of perception are based on the laws of probability, successfully applied to this problem for the first time by Öpik (1922) in his method of double counts. Later, similar procedures were applied by a number of authors to group observations of meteors, often without ensuring that the necessary conditions for the application of probability laws are fulfilled. For a dependable determination of the coefficients of perception it is necessary that either the directions watched by individual observers are distributed at random (which is practically impossible without changing the directions permanently in a complex way) or that they are identical at any time. This requirement is not met in the group observations commonly arranged, nor in our basic series of observations. To overcome this difficulty, a special observing program differing from the current practice was organized at the Skalnaté Pleso Observatory in the autumn of 1958.

A group of six observers (M. Antal, A. Antalová, Ľ. Kresák, M. Kresáková, Ľ. Pajdušáková and J. Štohl) viewed in the same, precisely specified direction; strict simultaneity and independence of observation was ensured. For each meteor the exact time of appearance, position and direction were recorded for the sake of an unambiguous identification; in addition the magnitudes (to 0.5^{m}), altitudes (to 5°) and angular distances from the centre of the field of view (to 5°) were independently estimated. The presence of two observers active in the main group since 1944 and 1946, respectively, and the determination of the relative personal factors of the others ensured that this team was comparable to that working in 1944—1955. A total number of 1351 observations recorded by the team were subsequently found to refer to 476 individual meteors. The coefficients of perception for different magnitudes were deduced as follows:

Let P denote the probability that an observer will record a meteor of certain characteristics which appears in the sky during the simultaneous watch. If we have a team of G observers, observing simultaneously under equal conditions and having uniform personal factors, the probability P_g that a meteor will be recorded just by g observers is given by the relation

$$P_g = \binom{G}{g} P^g (1 - P)^{G-g}. \qquad (3)$$

For the computation of the probabilities it is convenient to start from the average number of observers who have recorded a meteor (obviously, this need not be an integer). Denoting by n the number of individual meteors in question and by Σn the total number of records (i.e. a sum of meteors multiplied by the number of observers who saw them) we have:

$$\bar{g} = \frac{\Sigma n}{n} = \frac{PG}{1 - (1 - P)^G}. \qquad (4)$$

Σn, n and G being known from the observation, P may be found as an a posteriori probability, e.g using the auxiliary tables of Kvíz (1958).

The probability P depends upon various characteristics of the meteor, such as the brightness, angular distance from the centre of the field of view, direction, angular velocity, angular length, duration and train intensity. In the first approximation it is sufficient to consider the first two factors mentioned, i.e. the apparent visual magnitude M and the angular distance from the centre of the field of view D. These evidently surpass all other effects as regards their influence on the visibility conditions. Considering merely these two parameters, we obtain a two-dimensional display of the data, in which the a posteriori probability $P(M, D)$ may be determined for each point from the observed ratios $\Sigma n/n$ using formula (4).

The results of the observations referred to above, with $G = 6$, are presented in Table II. The estimates of the individual observers have been averaged and rounded off to obtain M and D; for this reason the probable error of these quantities, and hence also of the position in the plot M vs. D, is proportional to $g^{-\frac{1}{2}}$. The values of $\bar{g}$ were converted to $P(M, D)$ using formula (4) weighted according to the number of observations, and the relations between $P(D)$ and D for individual values of M were constructed. Further adjustments were made by smoothing the relations between $P(M)$ and M for individual values of D.

Table II

Observed values $\frac{\Sigma n}{n}$

D \ M	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
0							$\frac{6}{1}$		$\frac{2}{2}$	$\frac{1}{1}$
5			$\frac{6}{1}$		$\frac{12}{2}$	$\frac{15}{4}$	$\frac{5}{3}$	$\frac{1}{1}$	$\frac{3}{3}$	$\frac{3}{2}$
10			$\frac{5}{1}$	$\frac{6}{1}$	$\frac{44}{10}$	$\frac{33}{8}$	$\frac{39}{12}$	$\frac{29}{8}$	$\frac{9}{6}$	
15		$\frac{12}{2}$		$\frac{12}{2}$	$\frac{23}{5}$	$\frac{36}{9}$	$\frac{13}{8}$	$\frac{16}{6}$	$\frac{10}{8}$	$\frac{2}{1}$
20			$\frac{11}{2}$	$\frac{10}{2}$	$\frac{23}{6}$	$\frac{35}{10}$	$\frac{29}{16}$	$\frac{20}{13}$	$\frac{8}{8}$	
25		$\frac{6}{1}$	$\frac{6}{1}$	$\frac{21}{4}$	$\frac{45}{12}$	$\frac{23}{6}$	$\frac{47}{21}$	$\frac{29}{16}$	$\frac{7}{5}$	
30	$\frac{6}{1}$	$\frac{15}{3}$	$\frac{25}{5}$	$\frac{35}{7}$	$\frac{64}{19}$	$\frac{42}{13}$	$\frac{36}{16}$	$\frac{6}{3}$	$\frac{3}{3}$	$\frac{1}{1}$
35		$\frac{6}{1}$	$\frac{20}{4}$	$\frac{59}{13}$	$\frac{25}{6}$	$\frac{29}{12}$	$\frac{23}{15}$	$\frac{7}{5}$	$\frac{1}{1}$	
40		$\frac{20}{4}$	$\frac{40}{9}$	$\frac{25}{7}$	$\frac{32}{12}$	$\frac{30}{13}$	$\frac{10}{8}$			
45		$\frac{6}{2}$	$\frac{1}{1}$	$\frac{22}{10}$	$\frac{17}{9}$	$\frac{14}{5}$	$\frac{6}{6}$	$\frac{3}{2}$		
50		$\frac{3}{1}$	$\frac{2}{1}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{7}{5}$			
55		$\frac{4}{1}$	$\frac{3}{1}$	$\frac{7}{3}$			$\frac{2}{1}$			
60	$\frac{5}{1}$			$\frac{1}{1}$	$\frac{3}{3}$					
65			$\frac{6}{1}$	$\frac{1}{1}$						

By successive approximations the most suitable empirical relation between $P(M, D)$, M and D, shown in Figure 1, was found.

It is seen from the figure that almost all 1st magnitude meteors are witnessed up to a distance of 45° from the centre of the field of view, and many others even at greater distances. On the other hand, even in the field's centre one fifth of the 3rd magnitude meteors and one half of the 4th magnitude meteors escape unnoticed. The 5th magnitude meteors are witnessed only occasionally: one of five in the field's centre and none beyond $D = 30°$.

The relative probabilities $P(M)$ for individual magnitudes may be found by integration of $P(M, D)$ over the whole visible hemisphere. For an observer viewing the zenith and having his horizon perfectly uncovered we should have

$$P(M) = \int_0^{\pi/2} P(M,\ D) \sin D \, \mathrm{d}D. \qquad (5)$$

For the observations at Skalnaté Pleso, to which our results are to be applied, the geometrical conditions are not so simple. The centre of the field of view of each observer is at the altitude $H_o = 45°$, and the line of the true horizon passes, on the average, through the altitude $H_h = 10°$. A circle centered at H_o does not lie completely above the true horizon unless $D \leqq 35°$; for $D \geqq 35°$ that part of the circle which is unshielded will be denoted by $\psi(D)$. Denoting by 2ω the angle formed by the directions to the two points, where a circle of radius D centered at H_o intersects the circle of radius $(90° - H_h)$ centered at the zenith, we have, according to the cosine formula,

$$\sin H_h = \sin H_o \cos D + \cos H_o \sin D \cos \omega_o. \qquad (6)$$

Inserting $H_o = 45°$ and $H_h = 10°$ we obtain for the angle ω the following relation:

$$\cos \omega = 0.2456 \operatorname{cosec} D - \cot D. \qquad (7)$$

Thus in our specific case the simple formula (5) has to be replaced by

$$P(M) = \int_0^{\pi} P(M,\ D)\, \psi(D) \sin D \, \mathrm{d}D, \qquad (8)$$

where

$$\psi(D) = 1 \quad \text{for} \quad 0° \leqq D \leqq 35°,$$
$$\psi(D) = \frac{\omega}{\pi} \quad \text{for} \quad 35° \leqq D \leqq 125°,$$
$$\psi(D) = 0 \quad \text{for} \quad 125° \leqq D \leqq 180°.$$

The course of the integrands $P(M, D)\, \psi(D) \sin D$ for individual magnitudes M is graphically represented in Figure 2. The probabilities $P(M)$, which are proportional to the areas delimited by the curves and the horizontal axis, may be readily found by numerical integration. They are given in Table III together with the corresponding radii of the effective field of view $D_e(M)$ computed using the formula

$$D_e(M) = \cos^{-1} [1 - P(M)]. \qquad (9)$$

Obviously, these figures are reliable enough only within the magnitude range where both the total number of observed meteors and the number of multiple observations is high enough, i.e. between about $M = 1.5$ and $M = 3.5$. An extrapolation into the range of fireballs on one end and into the range of very faint naked-eye meteors on the other end requires a determination of $P(M)$ by different methods.

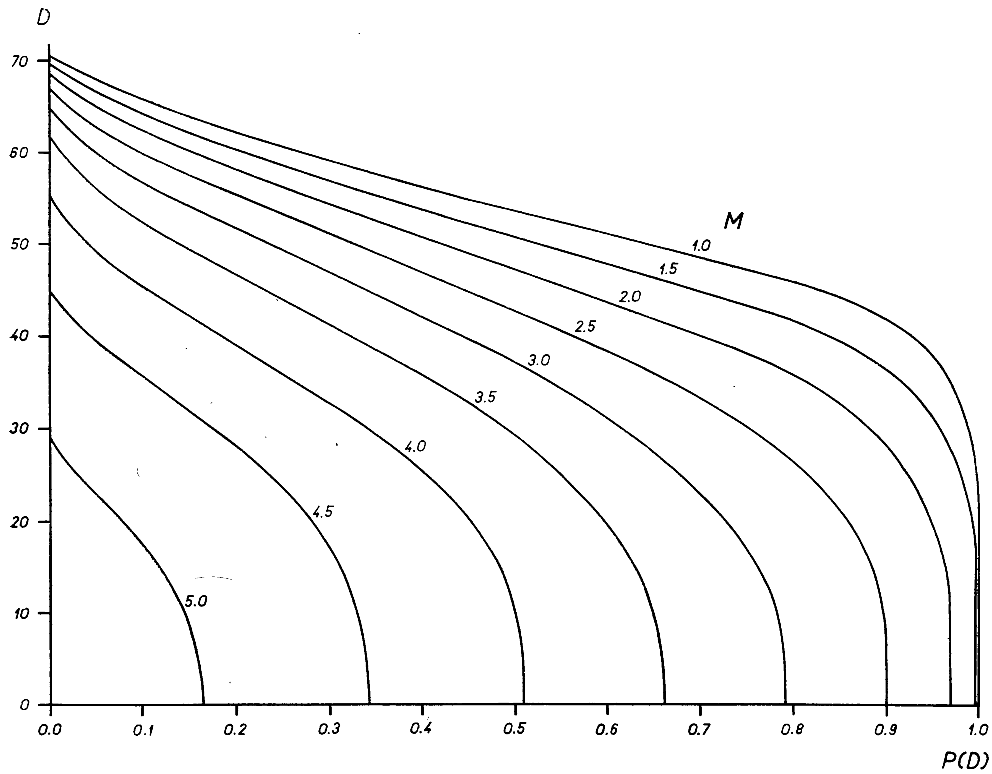


Figure 1

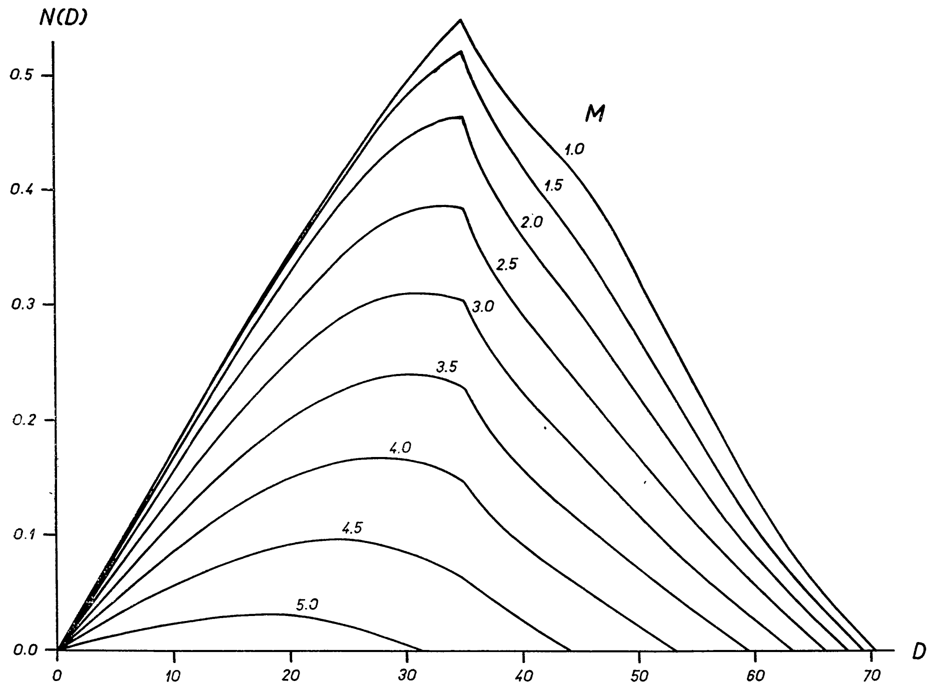


Figure 2

Table III

M	$P(M)$	$D_e(M)$
1.0	0.420	54.5
1.5	0.387	52.2
2.0	0.343	48.9
2.5	0.290	44.8
3.0	0.232	39.8
3.5	0.170	33.9
4.0	0.111	27.2
4.5	0.055	19.1
5.0	0.013	9.2

4. Extrapolation of $P(M)$ into range of brighter and fainter meteors

For an extrapolation of the relation between $P(M)$ and M additional assumptions are necessary. In agreement with the observing evidence as to the validity of formula (2) in a wide magnitude range of sporadic meteors (e.g. Millman and Burland 1956) we shall assume that the value of $\varkappa$ best suited to the observed magnitude distribution within the range $1.5 \leqq M \leqq 3.5$ holds good also for brighter and fainter meteors. In this case we may extend the basic data from the 1351 observations of the special programme to the total of 21996 sporadic meteor observations obtained in 1944—1955.

In order to find the best value of $\varkappa$ it must be remembered that:

(a) Extraordinarily bright fireballs, from about $M = -7$ upward, illuminate the sky so intensively that they cannot escape observations, irrespectively of their position in the sky. In this case $P(M) = 1$.

(b) For meteors of 2nd and 3rd magnitude the results of Table III hold with considerable accuracy.

(c) For the faintest naked-eye meteors, mostly witnessed by one observer only, the figures of Table III are very likely somewhat overestimated. The reason is that some of the multiple observations may be due to atypical meteors (anomalous trains and angular lengths) and to positive errors in magnitude estimates.

Assuming a constant $\varkappa$ we may express the a posteriori probability $P(M)$ as the ratio of the observed number of meteors $N(M)_o$ of magnitude M to the computed number $N(M)_c$, which is predicted by the distribution law (2), i.e.

$$P(M) = \frac{N(M)_0}{N(M)_c} = cN(M)_0 \, \varkappa^{-M}. \qquad (10)$$

The two unknowns on the right-hand side, c and $\varkappa$, must be adjusted so as to yield a series of $P(M)$ values which suits best the three conditions given above. We obtain, as the best solution,

$$c = 850,$$
$$\varkappa = 3.4.$$

Substituting other pairs of c and $\varkappa$, it may be checked that a good agreement becomes impossible if $\varkappa$ differs from 3.4 by more than ± 0.2.

Table IV

M	$\log N(M)_o$	$\log N(M)_c$	$P(M)$	$D_e(M)$
—8	0.477	—1.322		
—7	0.602	—0.790		
—6	—∞	—0.259		
—5	0.845	0.273		
—4	0.778	0.804	0.94	86.6
—3	1.301	1.336	0.92	85.4
—2	1.763	1.867	0.79	77.9
—1	2.182	2.399	0.61	67.0
0	2.568	2.930	0.435	55.6
1	3.008	3.461	0.352	49.6
2	3.523	3.993	0.339	48.6
3	3.857	4.524	0.215	38.3
4	3.835	5.056	0.060	20.0
5	3.464	5.587	0.0075	7.0
6	1.929	6.119	0.00006	0.6

The resulting values of $P(M)$ and $D_e(M)$ for $\varkappa = 3.4$ are shown in the last two columns of Table IV. In Figure 3 these values of $P(M)$ are graphically represented by open circles, full circles indicating the values taken from Table III. Obviously, the two sets of probabilities are not entirely independent. They are, indeed, based on different series of observations and obtained by different procedures, but the former set is bound to the assumption $\varkappa = 3.4$ which partially rests on the best $P(M)$ values of the latter set. Considering the relative reliability of the two determinations in different magnitude ranges, a smooth relation between $P(M)$ and M was drawn in Figure 3.

The curve shows some discontinuity near $M = 0$ which at first glance appears unfounded. However, there is a reasonable argument for believing that this change of the slope is genuine. A steeper increase of $P(M)$ begins at the point where the radius of the effective field of view, $D_e(M)$, is about 60° and most of the meteors are perceived by the peripheral vision. If the attention of the observer is attracted by a flash of light at a considerable distance from the centre of his field, a moment is needed to change the direction of view and see the meteor, or at least the luminous train left by it. It is quite reasonable to assume that just near the apparent magnitudes of 0 to -1^{m} the mean duration of the radiation and the mean initial brightness of the trains becomes sufficient to permit this type of observation frequently, which is generally impossible in the case of fainter meteors.

Table V

M	$P(M)$	$D_e(M)$	$N(M)_o$	$N(M)_c$	$O—C$	$\frac{N(M)_o}{N(M)_c}$
—8	1.00	90°0	3	0	+3	4.7 (—8 to —5)
—7	1.00	90°0	4	0	+4	
—6	1.00	90°0	0	1	—1	
—5	0.98	88°9	7	2	+5	
—4	0.95	87°1	6	6	0	1.00
—3	0.87	82°5	20	18	+2	1.11
—2	0.73	74°3	58	50	+8	1.16
—1	0.57	64°5	152	134	+18	1.13
0	0.48	58°7	370	383	—13	0.97
1	0.420	54°5	1019	1140	—121	0.89
2	0.343	48°9	3337	3165	+172	1.05
3	0.232	39°8	7187	7281	—94	1.01
4	0.064	20°6	6837	6828	+9	1.00
5	0.008	7°2	2911	2902	+9	1.00
6	0.00007	0°7	85	86	—1	0.99

The numerical results are shown in Table V where, in addition to the definitive values adopted for $P(M)$ and $D_e(M)$, a comparison of the observed meteor numbers $N(M)_0$ with the expected numbers $P(M)N(M)_c$ is presented. The residuals O — C are moderate; the ratio of the observed to the computed number of meteors differs but little from one, except an excess for the brightest fireballs ($M \leqq —5$). Nevertheless, this excess cannot be visualized as an indication that a genuine decrease of $\varkappa$ occurs in this magnitude range. As a matter of fact, two thirds of the excess fall to two extremely bright fireballs, one of —8$^{\text{th}}$ magnitude recorded on April 17, 1947, by a team of 3 observers and the other of —7$^{\text{th}}$ magnitude recorded on August 12, 1946, by a team of 4 observers.

It is of interest to compare our probabilities $P(M)$ (which are the inverse values of the coefficients of perception) with those published previously by other authors. Such a comparison is shown in Table VI. In those cases where only proportional values of $P(M)$ were given [Öpik 1923: $P(M)/P(2)$; Hoffmeister 1954: $P(M)/P(0)$] rough scaling factors of 0.3 and 0.4 were applied, the respective figures being given in parentheses. It is seen that individual sets of $P(M)$ are fairly consistent for the brightest naked-eye meteors; however the agreement becomes worse towards fainter meteors, the discrepancies attaining as much as an order of magnitude at $M = 5$. Our values are the lowest ones of all for $M \geqq 4$. We assume that the probabilities have been overestimated by most authors in this magnitude range, as it also follows from the work of Millman (1957). An alternative explanation would require a substantial decrease of $\varkappa$ for sporadic meteors near $M = 5$, but this possibility can be neither confirmed nor disproved on the basis of naked-eye observations alone. In general, little weight may be attributed to the statistical results in this magnitude range where

Table VI

Probabilities P(M)

M	Öpik (1923)	Kresák (1950)	Ceplecha (1951)	Hoffmeister (1954)	Astapovič (1958)	Kvíz (1958)	this study
—6	.	.	.	.	.	.	1.00
—5	.	.	.	.	.	.	0.98
—4	.	.	.	.	.	.	0.95
—3	.	.	.	.	.	.	0.87
—2	.	.	.	.	.	.	0.73
—1	.	.	.	.	0.65	0.59	0.57
0	.	0.466	0.538	(0.40)	0.54	0.51	0.48
1	.	0.381	0.294	(0.38)	0.44	0.46	0.420
2	(0.30)	0.268	0.225	(0.312)	0.33	0.36	0.343
3	(0.27)	0.166	0.175	(0.204)	0.23	0.20	0.232
4	(0.15)	0.101	0.112	(0.100)	0.093	0.07	0.064
5	(0.025)	0.055	0.085	(0.020)	0.034	0.03	0.008
6	.	.	.	(0.004)	0.015	0.01	0.00007

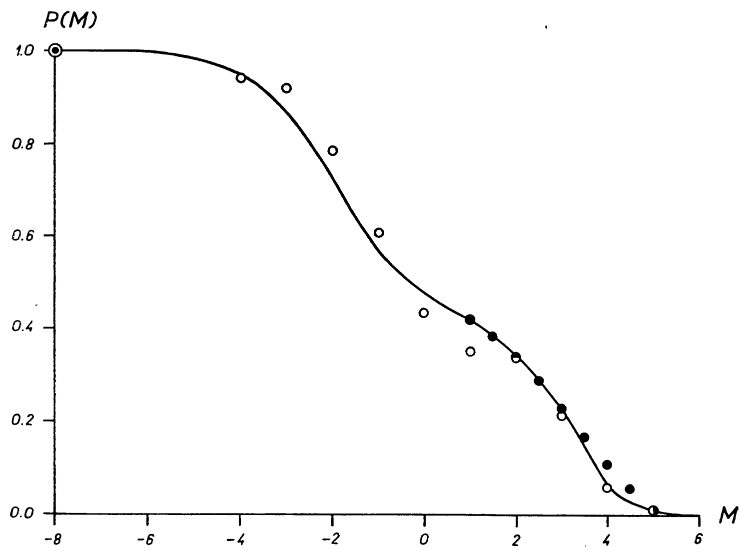


Figure 3

the counts are, at any rate, highly incomplete and sensitive to moderate variations of observing conditions.

Adopting the probabilities $P(M)$ given in the last column of Table VI the expected magnitude distributions of meteors recorded by one observer may be computed from

$$N(M) = k\ P(M)\varkappa^M. \tag{11}$$

The multiplication factor k may be chosen so as to yield $\Sigma N(M) = 100$; in this case we obtain the expected percentages of meteors of individual magnitudes. These are given in Table VII and Figure 4 for $\varkappa = 2{,}5$, 3.0, 3.5, and 4.0.

Table VIII gives the averages, medians and values of maximum occurrence of the magnitudes interpolated to tenths of $\varkappa$. It may be conveniently used for finding $\varkappa$ of a sample of meteors (e.g. a meteor shower) provided that the observing conditions are uniform with the series of observations from which the probabilities have been determined, and that the data are extensive enough to suppress random sampling errors.

Table VII

Expected percentages

M	2.5	3.0	3.5	4.0
—8	0.01	0.00	0.00	0.00
—7	0.01	0.00	0.00	0.00
—6	0.04	0.01	0.00	0.00
—5	0.09	0.02	0.01	0.00
—4	0.22	0.06	0.02	0.01
—3	0.50	0.17	0.07	0.03
—2	1.06	0.44	0.20	0.10
—1	2.07	1.02	0.54	0.30
0	4.35	2.58	1.58	1.01
1	9.51	6.78	4.85	3.53
2	19.42	16.60	13.87	11.54
3	32.84	33.69	32.85	31.22
4	22.65	27.88	31.71	34.45
5	7.08	10.46	13.87	17.22
6	0.15	0.27	0.43	0.60

Table VIII

$\varkappa$	$\overline{M}$	M_{med}	M_{max}
2.50	2.66	2.9	3.2
2.60	2.75	3.0	3.2
2.70	2.84	3.0	3.2
2.80	2.91	3.1	3.3
2.90	2.98	3.1	3.3
3.00	3.04	3.2	3.3
3.10	3.09	3.2	3.4
3.20	3.15	3.3	3.4
3.30	3.20	3.3	3.4
3.40	3.24	3.3	3.4
3.50	3.29	3.4	3.5
3.60	3.33	3.4	3.5
3.70	3.37	3.5	3.5
3.80	3.40	3.5	3.5
3.90	3.44	3.5	3.6
4.00	3.47	3.6	3.6

5. *Magnitude function derived from statistics of magnitudes*

The aim of the present work is not only to determine the magnitude function in different meteor showers but also to search for any variations of this function along the path traversed by the earth through the stream. For individual observations including, on the average, about 100

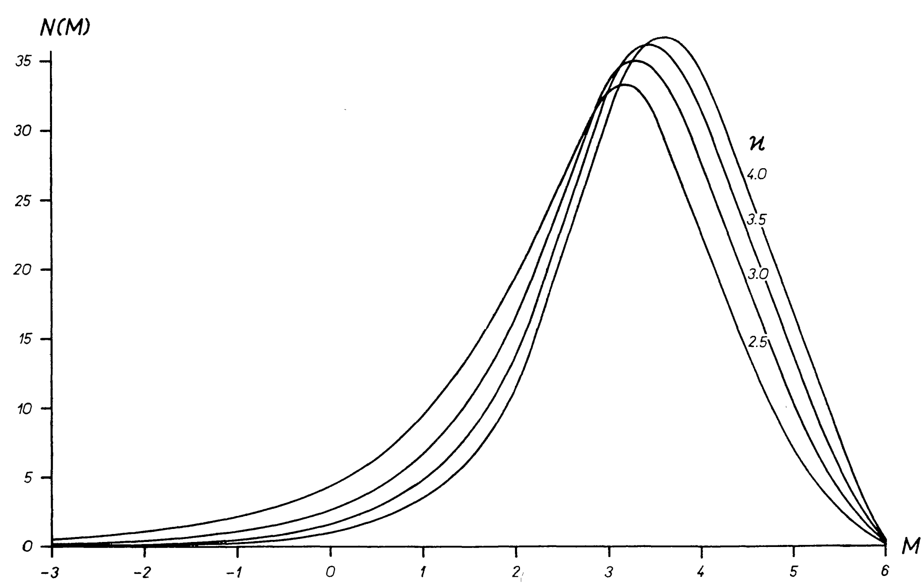


Figure 4

magnitude estimates of shower meteors and about 100 magnitude estimates of sporadic meteors, the ratio $\varkappa$ may be found from the average magnitudes using Table VIII. Obviously, the averages will essentially depend upon the atmospheric conditions, in particular upon the limiting stellar magnitude. As it has already been mentioned, the atmospheric conditions of Skalnaté Pleso are usually perfect, and those cases where interference by moonlight, twilight or cloudiness could be inferred were intentionally discarded. Nevertheless, minor variations are unavoidable even in the remainder; apart from the observing conditions they may also be due to the personal changes in the team of observers. They may unfavourably affect the determination of $\overline{M}_+$ and $\overline{M}_-$ but the difference $\overline{M}_+ - \overline{M}_-$, characteristic for the difference between the magnitude distributions within the shower and its sporadic background, will be practically free from this effect.

Table IX lists all observations arranged according to the showers and solar longitudes. For each of them the solar longitude $\odot$, the date, the time of beginning T_1 and end T_2 of the observation in M.E.T., the total number of shower N_+ and sporadic N_- meteors (each meteor multiplied by the number of observers who saw it), and the average magnitudes $\overline{M}_+$ and $\overline{M}_-$ are given.

The relation between $\varkappa$ and $\overline{M}$, as presented in Table VIII, assumes that $\varkappa$ is independent of magnitude. Although this may be adopted without great precautions for sporadic meteors, in meteor showers the situation may be different. The value of $\varkappa_+$ found from Table VIII with $\overline{M}_+$ as the argument is rather a mean value within the magnitude interval covered by naked-eye observations. It was mentioned in the introduction that many observations suggest a decrease of $\varkappa$ with increasing M in some of the meteor showers. To reveal this effect a knowledge of the whole magnitude distribution—not only of $\overline{M}_+$—is necessary. This is given in Table X for the shower meteors and in Table XI for the sporadic meteors from the same periods. In the latter table the data for δ Aquarids are omitted, because the period of their activity coincides with that of the early Perseids.

The values of $\overline{M}_+$, $\varkappa_+$, $\overline{M}_-$ and $\varkappa_-$ obtained from Tables VIII, X and XI are given in Table XII; the comparison of the observed magnitude distributions with those predicted for an invariable $\varkappa$ is shown in Figure 5. The left-hand side of the figure refers to the shower meteors, the right-hand side to their sporadic background, the numbers of meteors included in each sample being also indicated. No striking departure of the observed distribution from that computed is apparent. The question whether $\varkappa$ is independent of M in individual showers will be considered in section 9; at this point the following rough conclusions may be drawn:

(1) The magnitude function of sporadic meteors observed during the periods of activity of different showers is always practically the same. The observed variations of $\varkappa_-$ (within $\pm 5\%$ for all seven cases and within $\pm 1\%$ for the three periods where the data are most extensive) may be attributed to random errors of sampling.

(2) As the mean geocentric velocity of sporadic meteors undergoes essential seasonal variations, it may be concluded from (1) that the ratio $\varkappa_-$ is independent of the geocentric velocity, at least within the limits set by the accuracy of this method.

(3) The ratio $\varkappa$ is systematically lower for shower meteors than for sporadic meteors.

(4) The dispersion of the values of $\varkappa_+$ is about twice as great as that of $\varkappa_-$. This suggests genuine differences among individual showers which, however, are less than those between sporadic and shower meteors.

(5) As among sporadic meteors, in meteor showers no correlation between $\varkappa$ and the geocentric velocity, or type of orbit, is established. It is just the η Aquarids and Orionids, associated with the same comet and differing wery little in geocentric velocity, that differ most significantly from one another as regards the ratio $\varkappa$.

(6) The relatively stable value of $\varkappa_-$ throughout the year, compared with a much smaller $\varkappa_+$ in permanent meteor showers, indicates that the contribution of minor showers with $\varkappa$ similar to that of the permanent major showers is either relatively small, or relatively invariable. It must be remembered, however, that our analysis does not refer to the whole range of solar longitudes but only to shorter intervals, including on the whole about 100°.

6. *Relation between apparent altitude distribution and magnitude function*

The magnitude function may be derived even without direct magnitude estimates, using the observed distribution of meteors in altitude. In

Table IX

Lyrids

No.	⊙	Date	T_1	T_2	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$
1	25.56	45. 4. 15	20 : 43	22 : 13	2	22	1.50	3.18
2	26.63	45. 4. 16	22 : 36	00 : 36	6	36	3.50	3.72
3	27.10	47. 4. 17	21 : 15	01 : 18	15	91	3.67	3.12
4	29.02	47. 4. 19	22 : 01	22 : 37	1	18	3.00	2.89
5	29.79	52. 4. 19	23 : 17	01 : 17	20	73	2.15	3.00
6	30.09	47. 4. 20	22 : 33	02 : 52	26	104	2.77	3.28
7	30.78	52. 4. 20	22 : 02	03 : 00	18	58	2.83	3.53
8	30.80	52. 4. 20	23 : 12	03 : 01	83	127	2.34	3.28
9	31.24	46. 4. 21	21 : 10	00 : 27	282	160	3.18	3.39
10	31.95	47. 4. 22	21 : 29	23 : 29	21	30	1.95	3.67
11	32.24	46. 4. 22	23 : 24	23 : 44	17	5	4.00	4.00
12	32.71	52. 4. 22	23 : 12	00 : 42	10	25	3.70	2.76
13	33.83	51. 4. 24	20 : 35	21 : 51	1	12	4.00	3.67
14	35.08	46. 4. 25	21 : 08	21 : 45	3	21	3.00	2.81
15	36.06	46. 4. 26	21 : 04	22 : 06	2	38	2.50	3.79

η Aquarids

No.	⊙	Date	T_1	T_2	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$
1	40.10	46. 4. 30	01 : 00	02 : 00	4	31	3.50	3.55
2	40.58	52. 4. 30	01 : 35	02 : 50	6	35	2.33	3.37
3	41.04	46. 5. 1	00 : 16	01 : 17	4	13	1.25	2.92
4	42.03	46. 5. 2	00 : 13	02 : 31	1	53	4.00	3.13
5	43.02	46. 5. 3	01 : 03	02 : 45	32	64	2.03	3.38
6	43.26	49. 5. 3	01 : 40	02 : 44	8	20	2.50	3.00
7	43.98	46. 5. 4	00 : 32	02 : 34	8	67	3.75	3.03
8	45.19	49. 5. 5	01 : 32	02 : 30	2	9	4.00	3.44
9	45.91	46. 5. 6	00 : 50	02 : 10	1	23	3.00	2.91

δ Aquarids

No.	⊙	Date	T_1	T_2	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$
1	118.61	46. 7. 21	23 : 38	01 : 10	1	15	3.00	2.67
2	121.45	46. 7. 24	21 : 18	02 : 02	9	156	3.22	2.95
3	122.21	47. 7. 25	23 : 14	02 : 33	5	198	3.20	3.23
4	122.42	46. 7. 25	21 : 30	02 : 15	20	262	2.60	3.27
5	122.45	50. 7. 25	00 : 15	02 : 00	10	159	2.10	2.98
6	122.67	49. 7. 25	23 : 05	02 : 00	15	75	2.80	3.20
7	122.85	44. 7. 25	22 : 19	22 : 42	1	6	4.00	3.67
8	123.37	46. 7. 26	21 : 42	02 : 00	17	215	3.00	3.16
9	123.42	50. 7. 26	01 : 16	02 : 05	1	38	2.00	3.03
10	123.55	45. 7. 26	21 : 25	23 : 02	8	15	2.50	2.33
11	123.62	49. 7. 26	22 : 49	02 : 02	16	143	3.81	3.31
12	123.86	44. 7. 26	22 : 45	00 : 45	20	101	3.00	3.10
13	124.13	47. 7. 27	00 : 05	02 : 06	12	111	2.67	3.28
14	124.33	46. 7. 27	21 : 25	02 : 23	7	293	3.86	3.21
15	124.49	45. 7. 27	21 : 22	22 : 10	2	39	3.00	2.15
16	124.61	49. 7. 27	00 : 37	02 : 00	3	30	3.67	3.17
17	124.78	48. 7. 27	21 : 30	01 : 30	11	131	2.82	3.01
18	124.81	52. 7. 27	23 : 15	02 : 15	22	219	2.77	3.48
19	125.08	47. 7. 28	23 : 16	02 : 21	52	273	2.60	2.92
20	125.30	46. 7. 28	21 : 58	02 : 28	89	290	2.83	3.34
21	125.76	48. 7. 28	22 : 25	01 : 46	17	233	3.00	2.77
22	125.99	51. 7. 29	22 : 20	02 : 00	12	126	2.67	2.87
23	126.42	45. 7. 29	21 : 08	23 : 08	13	110	2.00	3.20
24	126.67	48. 7. 29	21 : 54	23 : 54	22	59	2.64	3.41
25	127.28	46. 7. 30	21 : 30	02 : 17	31	398	2.71	3.12
26	127.66	48. 7. 30	21 : 53	01 : 30	17	184	2.35	3.14
27	127.88	51. 7. 31	22 : 55	00 : 30	4	36	3.50	3.39
28	127.91	51. 7. 31	22 : 26	02 : 20	5	166	2.40	3.09
29	128.14	46. 7. 31	21 : 59	01 : 25	21	252	3.38	3.10
30	128.87	51. 8. 1	22 : 25	02 : 20	2	242	3.00	3.01
31	129.78	51. 8. 2	22 : 30	00 : 02	3	63	3.00	2.90
32	129.78	51. 8. 2	22 : 35	23 : 50	1	28	3.00	3.11
33	130.06	46. 8. 2	21 : 38	01 : 40	23	206	2.87	3.15
34	130.27	49. 8. 2	22 : 23	00 : 23	3	131	4.33	2.98
35	130.55	48. 8. 2	21 : 45	02 : 30	16	188	2.88	3.07
36	131.22	49. 8. 3	22 : 13	00 : 13	4	66	3.00	3.30
37	131.44	48. 8. 3	22 : 00	23 : 00	3	15	3.00	3.20
38	131.71	51. 8. 4	23 : 20	00 : 02	5	41	3.00	3.22
39	132.02	46. 8. 4	23 : 17	02 : 30	23	214	3.52	3.09
40	132.98	46. 8. 5	23 : 02	02 : 39	1	264	5.00	3.50
41	133.67	51. 8. 6	22 : 54	02 : 41	3	238	3.00	2.99
42	133.68	51. 8. 6	23 : 50	02 : 30	5	36	1.80	3.36
43	134.27	44. 8. 6	20 : 38	21 : 38	1	11	3.00	2.55
44	134.37	48. 8. 6	21 : 20	02 : 30	10	156	4.00	3.24
45	134.62	51. 8. 7	22 : 06	02 : 30	2	75	1.00	3.40
46	134.90	46. 8. 7	22 : 46	02 : 47	9	228	2.78	3.42
47	135.10	45. 8. 7	21 : 27	01 : 59	1	189	0.00	3.15
48	135.83	46. 8. 8	21 : 36	02 : 51	6	288	3.00	3.53

Perseids

No.	⊙	Date	T_1	T_2	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$
1	117.58	46. 7. 20	21 : 36	23 : 10	8	60	2.00	3.42
2	118.61	46. 7. 21	23 : 38	01 : 10	2	15	-1.00	2.67
3	121.30	47. 7. 24	01 : 24	02 : 24	2	55	2.00	3.36
4	121.45	46. 7. 24	21 : 18	02 : 02	30	156	1.80	2.95
5	122.21	47. 7. 25	23 : 14	02 : 33	18	198	2.17	3.23
6	122.42	46. 7. 25	21 : 30	02 : 15	48	262	2.08	3.27
7	122.67	49. 7. 25	23 : 05	02 : 00	5	75	3.00	3.20
8	123.37	46. 7. 26	21 : 42	02 : 00	42	215	2.36	3.16
9	123.42	50. 7. 26	01 : 16	02 : 05	8	38	1.00	3.03
10	123.56	45. 7. 26	21 : 25	23 : 02	2	15	0.00	2.33
11	123.86	44. 7. 26	22 : 45	00 : 45	14	101	2.07	3.10
12	124.13	47. 7. 27	00 : 05	02 : 06	17	111	1.35	3.28
13	124.33	46. 7. 27	21 : 25	02 : 23	73	293	1.90	3.21
14	124.49	45. 7. 27	21 : 22	22 : 10	3	39	0.00	2.15
15	124.78	48. 7. 27	21 : 30	01 : 30	26	131	2.27	3.01
16	124.81	52. 7. 27	23 : 15	02 : 15	9	219	2.67	3.48
17	125.08	47. 7. 28	23 : 16	02 : 21	17	273	1.88	2.92
18	125.30	46. 7. 28	21 : 58	02 : 28	85	290	2.20	3.34
19	125.76	48. 7. 28	22 : 25	01 : 46	27	233	2.74	2.77
20	125.77	52. 7. 28	00 : 10	01 : 10	6	27	2.00	4.26
21	125.99	51. 7. 29	22 : 20	02 : 00	6	126	2.00	2.87
22	126.01	51. 7. 29	00 : 00	01 : 30	5	35	3.20	3.77
23	126.42	45. 7. 29	21 : 08	23 : 38	7	110	2.29	3.20
24	126.67	48. 7. 29	21 : 54	23 : 54	25	59	2.72	3.41
25	127.28	46. 7. 30	21 : 30	02 : 17	124	398	2.52	3.12
26	127.66	48. 7. 30	21 : 53	01 : 30	47	184	2.98	3.14
27	127.88	51. 7. 31	22 : 55	00 : 30	6	36	2.83	3.39
28	127.91	51. 7. 31	22 : 26	02 : 20	23	166	1.96	3.09
29	128.14	46. 7. 31	21 : 59	01 : 25	80	252	2.98	3.10
30	128.63	52. 7. 31	23 : 32	01 : 33	26	120	2.62	3.37
31	128.87	51. 8. 1	22 : 25	02 : 20	39	242	2.03	3.01
32	128.89	51. 8. 1	23 : 55	02 : 00	22	57	3.55	3.39
33	129.56	48. 8. 1	22 : 14	00 : 50	39	99	2.87	3.44
34	129.78	51. 8. 2	22 : 35	23 : 50	6	28	1.83	3.11
35	130.06	46. 8. 2	21 : 38	01 : 40	136	206	1.95	3.15
36	130.27	49. 8. 2	22 : 23	00 : 23	53	131	2.66	2.98
37	130.55	48. 8. 2	21 : 45	02 : 30	69	188	2.49	3.07
38	131.10	46. 8. 3	00 : 10	01 : 15	48	72	3.10	3.57
39	131.22	49. 8. 3	22 : 13	00 : 13	29	66	2.55	3.30
40	131.44	48. 8. 3	22 : 00	23 : 00	9	15	2.11	3.20
41	131.63	51. 8. 4	22 : 35	23 : 25	2	8	-1.00	2.38
42	131.71	51. 8. 4	23 : 20	00 : 02	21	41	1.29	3.22
43	132.02	46. 8. 4	23 : 17	02 : 30	141	214	2.64	3.09
44	132.98	46. 8. 5	23 : 02	02 : 39	169	264	2.78	3.50
45	133.24	49. 8. 5	00 : 48	02 : 48	89	109	2.27	3.04
46	133.67	51. 8. 6	22 : 54	02 : 41	50	238	2.80	2.99
47	133.68	51. 8. 6	23 : 50	02 : 30	32	36	3.16	3.36
48	134.18	45. 8. 6	23 : 28	02 : 39	123	135	2.19	3.26
49	134.27	44. 8. 6	20 : 38	21 : 38	2	11	3.50	2.55
50	134.30	44. 8. 6	21 : 00	22 : 40	3	11	3.00	2.09
51	134.37	48. 8. 6	21 : 20	02 : 30	167	156	2.89	3.24
52	134.62	51. 8. 7	22 : 06	02 : 30	81	75	2.77	3.40
53	134.64	51. 8. 7	00 : 01	02 : 45	73	255	2.85	3.31
54	134.66	47. 8. 7	00 : 29	01 : 39	13	26	2.23	2.96
55	134.90	46. 8. 7	22 : 46	02 : 47	328	228	2.62	3.42
56	135.10	45. 8. 7	21 : 27	01 : 59	106	189	2.55	3.15

No.	⊙	Date	T_1	T_2	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$
57	135.30	44. 8. 7	21 : 10	00 : 10	12	16	2.58	3.00
58	135.83	46. 8. 8	21 : 36	02 : 51	302	288	2.94	3.53
59	136.02	53. 8. 8	21 : 14	02 : 44	275	266	2.61	3.53
60	136.06	45. 8. 8	22 : 15	01 : 35	101	135	3.12	3.37
61	136.23	44. 8. 8	21 : 36	22 : 30	8	7	1.38	3.14
62	136.26	44. 8. 8	21 : 10	00 : 40	25	38	1.40	3.13
63	136.28	48. 8. 8	21 : 27	02 : 27	159	185	2.81	3.25
64	136.50	51. 8. 9	22 : 36	00 : 52	16	70	3.00	3.16
65	136.58	51. 8. 9	00 : 30	02 : 45	77	61	3.22	4.16
66	136.70	46. 8. 9	21 : 42	22 : 40	9	22	2.67	2.73
67	136.75	50. 8. 9	21 : 42	02 : 00	116	130	2.68	3.04
68	137.02	53. 8. 9	23 : 20	02 : 45	124	52	2.52	3.35
69	137.04	45. 8. 9	22 : 13	02 : 48	299	358	3.02	3.34
70	137.17	44. 8. 9	20 : 35	22 : 46	52	43	2.10	3.26
71	137.22	44. 8. 9	21 : 10	00 : 20	24	32	2.25	2.94
72	137.27	48. 8. 9	22 : 40	02 : 35	191	185	2.52	3.34
73	137.72	50. 8. 10	21 : 25	02 : 40	228	193	3.00	3.35
74	137.74	46. 8. 10	21 : 11	03 : 03	318	171	2.53	3.43
75	137.94	53. 8. 10	21 : 34	02 : 32	180	117	2.29	3.47
76	137.95	53. 8. 10	21 : 30	02 : 41	612	309	2.87	3.61
77	138.04	45. 8. 10	00 : 18	02 : 43	247	147	2.78	3.14
78	138.14	44. 8. 10	21 : 15	22 : 30	18	10	1.78	3.20
79	138.16	48. 8. 10	21 : 20	00 : 10	196	133	2.82	3.15
80	138.16	44. 8. 10	21 : 05	23 : 44	209	85	2.11	2.66
81	138.26	52. 8. 10	00 : 56	02 : 56	40	16	1.40	2.81
82	138.35	47. 8. 11	20 : 47	22 : 00	38	15	2.74	4.13
83	138.66	50. 8. 11	21 : 18	02 : 00	339	125	2.73	3.11
84	138.70	46. 8. 11	21 : 14	03 : 08	418	103	2.00	3.20
85	138.71	54. 8. 11	00 : 55	01 : 55	98	35	2.04	3.00
86	138.91	53. 8. 11	21 : 33	02 : 45	1281	228	2.92	3.46
87	138.95	45. 8. 11	23 : 04	01 : 35	248	64	2.65	3.14
88	138.95	53. 8. 11	23 : 51	02 : 37	246	45	2.70	3.40
89	139.13	44. 8. 11	20 : 55	00 : 10	117	28	1.76	2.89
90	139.16	44. 8. 11	21 : 53	01 : 00	600	90	1.90	2.42
91	139.17	52. 8. 11	22 : 20	02 : 50	461	101	2.13	2.73
92	139.36	47. 8. 12	21 : 52	23 : 25	169	48	2.38	3.35
93	139.39	51. 8. 12	20 : 40	03 : 00	356	73	2.77	3.37
94	139.41	51. 8. 12	22 : 15	02 : 46	695	204	2.18	3.11
95	139.41	51. 8. 12	21 : 53	02 : 48	563	264	2.70	3.43
96	139.63	50. 8. 12	21 : 12	02 : 20	442	104	2.83	3.39
97	139.65	46. 8. 12	20 : 42	03 : 07	404	87	2.05	2.61
98	139.87	53. 8. 12	21 : 38	02 : 39	656	147	2.60	3.23
99	139.90	53. 8. 12	23 : 17	02 : 33	197	43	2.25	3.14
100	139.94	45. 8. 12	00 : 23	01 : 37	57	23	2.98	3.39
101	140.09	44. 8. 12	21 : 10	00 : 20	80	30	2.16	2.60
102	140.13	52. 8. 12	22 : 23	02 : 52	528	205	2.40	3.20
103	140.14	44. 8. 12	20 : 28	03 : 15	1316	246	2.53	3.20
104	140.40	51. 8. 13	23 : 43	02 : 52	423	126	2.39	3.48
105	140.40	51. 8. 13	23 : 45	02 : 37	366	186	3.29	3.78
106	140.40	51. 8. 13	23 : 18	03 : 00	160	59	3.14	3.44
107	140.59	50. 8. 13	21 : 35	01 : 58	303	154	2.66	2.87
108	140.80	45. 8. 13	21 : 03	23 : 47	140	150	2.84	3.50
109	140.83	53. 8. 13	21 : 35	02 : 46	583	252	3.04	3.60
110	141.09	52. 8. 13	22 : 21	02 : 45	258	150	2.44	3.39
111	141.35	47. 8. 14	21 : 49	02 : 50	131	136	2.47	3.32
112	141.50	46. 8. 14	20 : 31	23 : 31	55	34	1.93	2.88
113	141.76	53. 8. 14	21 : 35	01 : 00	185	167	2.89	3.35
114	142.00	44. 8. 14	20 : 42	23 : 48	93	82	2.86	3.02
115	142.05	52. 8. 14	22 : 20	02 : 41	222	289	2.69	3.51
116	142.30	47. 8. 15	21 : 30	02 : 35	161	250	2.45	3.29
117	142.44	46. 8. 15	20 : 29	22 : 24	9	39	2.11	3.23
118	142.50	50. 8. 15	22 : 55	23 : 50	20	15	3.30	2.47
119	142.76	53. 8. 15	00 : 00	01 : 00	59	55	3.41	3.64
120	142.99	44. 8. 15	21 : 30	00 : 30	75	134	2.32	3.21
121	143.01	52. 8. 15	22 : 17	02 : 50	103	199	3.04	3.61
122	143.25	47. 8. 16	22 : 21	01 : 32	25	80	2.36	3.60
123	143.79	45. 8. 16	23 : 26	02 : 53	48	147	2.92	3.60
124	143.93	44. 8. 16	20 : 43	00 : 16	87	149	2.82	3.14
125	144.31	47. 8. 17	01 : 55	02 : 55	4	33	2.25	3.52
126	144.42	50. 8. 17	22 : 48	23 : 52	5	35	3.40	3.31
127	144.85	44. 8. 17	20 : 38	22 : 15	5	52	3.80	2.44
128	145.01	48. 8. 17	01 : 00	03 : 00	7	44	1.86	3.45
129	145.18	47. 8. 18	23 : 19	00 : 49	7	49	2.14	3.31
130	145.34	46. 8. 18	21 : 27	22 : 27	5	24	3.20	3.42
131	145.73	45. 8. 18	00 : 22	02 : 50	11	125	2.73	2.98
132	145.83	44. 8. 18	20 : 38	23 : 38	7	138	2.14	2.89
133	145.99	48. 8. 18	01 : 50	03 : 04	4	25	3.50	3.24
134	146.29	46. 8. 19	20 : 48	22 : 25	13	56	2.92	2.88
135	146.79	44. 8. 19	20 : 25	23 : 25	6	140	3.00	3.36
136	147.28	46. 8. 20	21 : 05	23 : 17	29	113	2.76	3.40
137	147.75	44. 8. 20	20 : 50	22 : 50	7	82	1.71	3.23
138	148.73	44. 8. 21	20 : 51	23 : 31	3	126	1.33	3.24
Orionids								
1	200.96	47. 10. 14	03 : 40	04 : 40	6	32	3.33	3.31
2	201.09	50. 10. 14	01 : 10	02 : 10	7	21	3.00	3.14
3	201.64	44. 10. 14	01 : 36	04 : 08	10	142	3.00	2.82
4	201.94	47. 10. 15	03 : 25	04 : 05	8	19	3.25	3.26
5	202.13	50. 10. 15	02 : 30	03 : 30	14	13	2.86	2.31
6	202.52	44. 10. 15	21 : 25	02 : 27	19	109	2.74	3.29
7	202.93	46. 10. 16	18 : 33	00 : 58	18	53	2.72	2.85
8	203.11	50. 10. 16	02 : 00	03 : 00	15	21	2.60	3.00
9	203.37	45. 10. 16	00 : 28	04 : 35	72	182	2.99	3.45
10	205.21	46. 10. 18	04 : 40	05 : 10	8	5	1.88	3.00
11	205.34	49. 10. 18	02 : 00	03 : 00	16	18	2.31	2.78
12	206.09	46. 10. 19	23 : 22	04 : 52	109	189	2.71	3.25
13	206.33	49. 10. 19	02 : 00	03 : 00	23	21	3.09	3.52
14	206.42	45. 10. 19	03 : 40	04 : 57	36	35	2.00	3.06
15	206.80	47. 10. 20	00 : 40	01 : 40	30	21	3.27	2.90
16	207.08	46. 10. 20	23 : 50	04 : 30	140	167	2.95	3.25
17	207.34	49. 10. 20	02 : 07	03 : 37	46	39	3.30	3.44
18	207.91	47. 10. 21	00 : 30	04 : 46	201	168	3.05	3.26
19	208.32	49. 10. 21	02 : 05	03 : 05	18	35	3.28	3.14
20	208.55	44. 10. 21	00 : 45	02 : 45	36	45	2.89	3.33
21	208.89	47. 10. 22	03 : 15	04 : 15	21	35	2.90	2.91
22	209.43	44. 10. 22	22 : 20	23 : 25	10	15	1.80	3.40
23	209.78	47. 10. 23	00 : 26	01 : 26	24	29	3.13	3.21
24	210.81	47. 10. 24	01 : 27	02 : 27	10	33	2.60	3.73
25	211.10	46. 10. 24	02 : 32	03 : 32	43	39	3.14	3.51
26	211.85	47. 10. 25	02 : 43	03 : 23	4	28	3.75	3.36
27	212.12	46. 10. 25	02 : 42	04 : 42	58	154	3.47	3.37
28	213.08	46. 10. 26	02 : 22	03 : 02	13	25	3.54	3.20
Leonids								
1	224.16	46. 11. 6	04 : 08	05 : 11	4	39	2.75	3.36
2	227.52	48. 11. 9	00 : 53	01 : 53	5	31	2.00	3.13
3	228.63	48. 11. 10	03 : 45	04 : 15	1	7	3.00	3.14
4	230.53	44. 11. 12	23 : 49	01 : 49	6	57	2.50	3.39
5	230.63	48. 11. 12	03 : 15	04 : 15	8	22	3.00	3.27
6	231.17	46. 11. 13	03 : 17	04 : 17	11	11	2.09	3.09
7	232.59	44. 11. 14	00 : 38	03 : 12	24	185	2.92	3.10
8	233.18	46. 11. 15	02 : 50	04 : 50	59	37	2.54	2.57
9	233.65	48. 11. 15	03 : 08	04 : 25	6	3	2.33	2.67
10	234.44	53. 11. 16	04 : 16	05 : 16	34	27	2.29	3.41
11	235.19	46. 11. 17	02 : 35	04 : 35	59	54	2.92	3.48
12	237.95	47. 11. 20	02 : 32	03 : 32	6	49	3.33	3.37
13	238.26	46. 11. 20	04 : 01	05 : 01	11	25	2.27	3.20
Geminids								
1	247.27	46. 11. 29	01 : 50	02 : 50	11	27	2.18	3.56
2	248.40	46. 11. 30	04 : 46	05 : 46	3	61	4.00	2.98
3	251.36	45. 12. 3	20 : 15	21 : 45	3	41	2.00	2.98
4	251.40	46. 12. 3	03 : 33	04 : 33	7	37	3.43	3.03
5	252.58	44. 12. 4	19 : 50	20 : 28	1	20	3.00	3.00
6	253.61	44. 12. 5	19 : 44	21 : 13	6	71	4.00	2.90
7	254.63	45. 12. 6	01 : 45	03 : 48	19	79	1.11	3.22
8	256.86	48. 12. 8	01 : 35	02 : 35	10	28	3.10	3.04

Continuation Table IX

No.	⊙	Date	T_1	T_2	N_+	N_-	$\bar{M}_+$	$\bar{M}_-$
9	257.93	48. 12. 9	02 : 45	03 : 45	9	35	2.89	3.20
10	258.87	44. 12. 10	00 : 39	01 : 11	10	14	1.60	2.86
11	259.42	46. 12. 11	00 : 34	02 : 34	54	40	2.59	2.73
12	259.75	44. 12. 11	19 : 37	23 : 24	81	68	2.67	3.24
13	259.98	48. 12. 11	03 : 10	04 : 10	46	31	3.26	3.55
14	260.18	47. 12. 12	21 : 50	04 : 30	487	234	2.91	3.60
15	260.54	49. 12. 12	21 : 42	23 : 23	136	46	2.84	2.85
16	260.77	45. 12. 12	01 : 23	05 : 55	906	277	3.07	3.01
17	260.96	44. 12. 12	01 : 49	02 : 42	48	18	2.63	3.39
18	261.38	46. 12. 13	19 : 05	04 : 00	831	124	2.65	3.10
19	261.58	49. 12. 13	21 : 33	00 : 33	353	40	2.65	3.38
20	261.68	53. 12. 13	00 : 12	04 : 05	517	183	2.59	3.13
21	261.73	44. 12. 13	19 : 09	21 : 02	216	49	3.00	3.27
22	261.75	48. 12. 13	20 : 05	22 : 05	67	8	0.90	2.25
23	262.38	46. 12. 14	20 : 59	01 : 12	96	66	2.29	3.14
24	262.53	49. 12. 14	20 : 40	21 : 32	30	14	2.77	3.21
25	262.69	53. 12. 14	01 : 12	02 : 12	66	52	2.82	3.56
26	263.34	46. 12. 15	21 : 26	22 : 00	3	22	3.33	3.73
27	263.79	44. 12. 15	20 : 18	21 : 15	5	21	3.00	4.05
28	264.34	46. 12. 16	20 : 57	21 : 57	6	31	4.17	3.81
29	264.84	44. 12. 16	18 : 58	00 : 24	24	74	3.46	3.19
30	265.12	47. 12. 17	20 : 57	21 : 57	3	29	2.00	3.86
31	265.90	44. 12. 17	21 : 50	23 : 34	15	43	3.40	3.60
32	266.17	47. 12. 18	21 : 40	22 : 43	1	29	4.00	3.55
33	267.94	44. 12. 19	22 : 15	23 : 15	2	18	3.00	3.06

Table X

Shower meteors

M	Lyr	η Aqr	δ Aqr	Per	Ori	Leo	Gem	Σ
—13	0	0	0	0	0	0	2	2
—7	0	0	0	13	0	0	0	13
—6	4	0	0	5	0	0	0	9
—5	0	0	0	16	0	0	4	20
—4	0	0	0	32	0	0	4	36
—3	0	0	0	70	5	0	13	88
—2	3	0	2	164	1	0	41	211
—1	8	4	2	440	5	2	86	547
0	5	3	16	909	21	14	190	1158
1	34	5	57	2019	63	29	294	2501
2	85	19	130	4459	228	52	772	5745
3	171	19	186	6022	364	74	1319	8155
4	160	13	150	3943	230	53	987	5536
5	37	3	40	1271	98	10	356	1815
6	0	0	1	44	0	0	4	49
Σ	507	66	584	19407	1015	234	4072	25885

different altitudes meteors are observed down to the same limiting apparent magnitude which, however, due to the varying slant range and extinction corresponds to a varying absolute (zenithal) magnitude. This effect displaces the maximum of occurrence and the mean altitude of meteors towards the zenith if the ratio $\varkappa$ increases.

A procedure based on this effect was applied to naked-eye observations by Millman and Burland (1956) who obtained the best agreement with $\varkappa_- = 3.7$. Levin (1956) treated the problem more broadly, but without comparing the theory with

Table XI

Sporadic meteors

M	Lyr	η Aqr	Per	Ori	Leo	Gem	Σ
—8	3	0	0	0	0	0	3
—7	0	0	4	0	0	0	4
—6	0	0	0	0	0	0	0
—5	0	0	4	0	0	3	7
—4	0	0	6	0	0	0	6
—3	2	0	12	3	2	1	20
—2	5	0	25	7	8	13	58
—1	3	0	129	10	0	10	152
0	0	6	287	29	7	41	370
1	32	6	795	83	18	85	1019
2	103	62	2546	262	92	272	3337
3	283	105	5408	570	179	642	7187
4	281	122	5204	468	172	590	6837
5	106	14	2202	253	69	267	2911
6	2	0	69	8	0	6	85
Σ	820	315	16691	1693	547	1930	21996

Table XII

	M_+	$\varkappa_+$	M_+	$\varkappa_-$
Lyrids	2.97	2.88	3.30	3.52
η Aquarids	2.47	2.32	3.18	3.26
δ Aquarids	2.87	2.74	3.16	3.22
Perseids	2.58	2.42	3.25	3.41
Orionids	2.95	2.86	3.23	3.37
Leonids	2.63	2.47	3.20	3.30
Geminids	2.77	2.62	3.23	3.37
all showers	2.64	2.48	3.24	3.40

the observations. Using a number of models for $\varkappa$ (in some of them $\varkappa$ is assumed to change with the magnitude) he computed the respective altitude distributions. Unfortunately, Levin's results cannot be directly applied to our data for the following reasons:

(a) Levin does not compute the number but the density of meteors in different altitudes. If we were to construct analogous curves from the observation, individual meteors would have widely different weights. The densities are referred just to the region of the zenith where the observed number of meteors is low.

(b) The variation of the perception coefficients with the altitude, depending on the position of the centre of the field of view, is not taken into account.

(c) Also the local conditions, in particular the local extinction factors, could not be included in a general solution. Unfortunately, it is just the region immediately above the horizon, where the difference may be considerable, that is most sensitive to the change of $\varkappa$.

For our purpose it is most reasonable to determine the expected dependence of the number of observed meteors on the altitude for different ratios $\varkappa$ and to compare this with the observed altitude distribution. The expected relation between the number of observed meteors and the altitude may be written as

$$N(H)\,\mathrm{d}H \sim \varrho(H)\sigma(H)P(H)\varkappa^{-\Delta M(d)-\Delta M(e)}\,\mathrm{d}H, \tag{12}$$

where $N(H)$ denotes the number of meteors at the altitude H, $\varrho(H)$ the correction factor for the coverage of the parallel of altitude H by the true horizon, $\sigma(H)$ the relative size of the area in the atmospheric layer, in which meteors appear at the altitude H, $P(H)$ the probability of observation of a meteor appearing at the altitude H, $\Delta M(d)$ the difference between the apparent and absolute (zenithal) magnitude of the meteor corresponding to its slant range d, and $\Delta M(e)$ the change of the apparent magnitude by the atmospheric extinction. Individual factors appearing in formula (12) are derived as follows:

(I) The factor $\varrho(H)$

This factor takes into account the extent of the coverage of individual parallels of altitude by the true horizon. Denoting by $\lambda(H)$ the shielded portion of the parallel (in radians, referred to the geometrical horizon) we have

$$\varrho(H) = 1 - \frac{\lambda(H)}{2\pi}. \tag{13}$$

For the Skalnaté Pleso observatory measurement of the horizon's contour by a theodolite was supplemented by a panoramatic set of photographs taken from the seats of the meteor observers. The resulting contour was shifted down by 3° to take into account the angular lengths of the meteors and from the values of $\lambda(H)$, determined graphically, the factors $\varrho(H)$ were found using (13). These are given in the second column of Table XVI.

(II) The factor $\sigma(H)$

Owing to the earth's curvature this factor depends upon the height of the meteors. Although the height varies with geocentric velocity, and thus systematically differs for different showers and sporadic meteors, we may adopt a uniform height of 100 km without any serious loss of accuracy. Expressing all distances in terms of the earth's radius, denoting the height by y, the slant range by d and the angle formed by the directions from the earth's centre to the observer and to the meteor by ϑ, we have

$$\sigma(H)\,\mathrm{d}H \sim d^2 \cos H \operatorname{cosec}(H + \vartheta)\,\mathrm{d}H. \tag{14}$$

From the sine formula we obtain the relation

$$\cos(H + \vartheta) = \frac{\cos\vartheta}{1 + y} \tag{15}$$

which may be used for the elimination of the angle ϑ from (14). After simple adaptations we have

$$\sigma(H) \sim \frac{(1 + y)\,d^2}{\sqrt{(1 + y)^2 \sec^2 H - 1}}. \tag{16}$$

The distance d is obviously equal to

$$d = \sqrt{\sin^2 H + 2y + y^2} - \sin H. \tag{17}$$

Inserting selected altitudes H and a uniform height $y = 0.0157$ into (16) we obtain the values of $\sigma(H)$ given in Table XVI; the relative collecting area at $H_0 = 45°$ is here adopted as a unit.

(III) The factor $P(H)$

The derivation of this factor is most difficult as it depends upon the probabilities of perception of the meteors appearing in different positions with respect to the centre of the field of view. The relation between H and $P(H)$ has to be derived empirically, from the same series of observations that have been used in section 4 to find the relation between M and $P(M)$. It is necessary to find first how the probability of witnessing a meteor changes with its distance from the field's centre D, no discrimination according to the magnitudes being required.

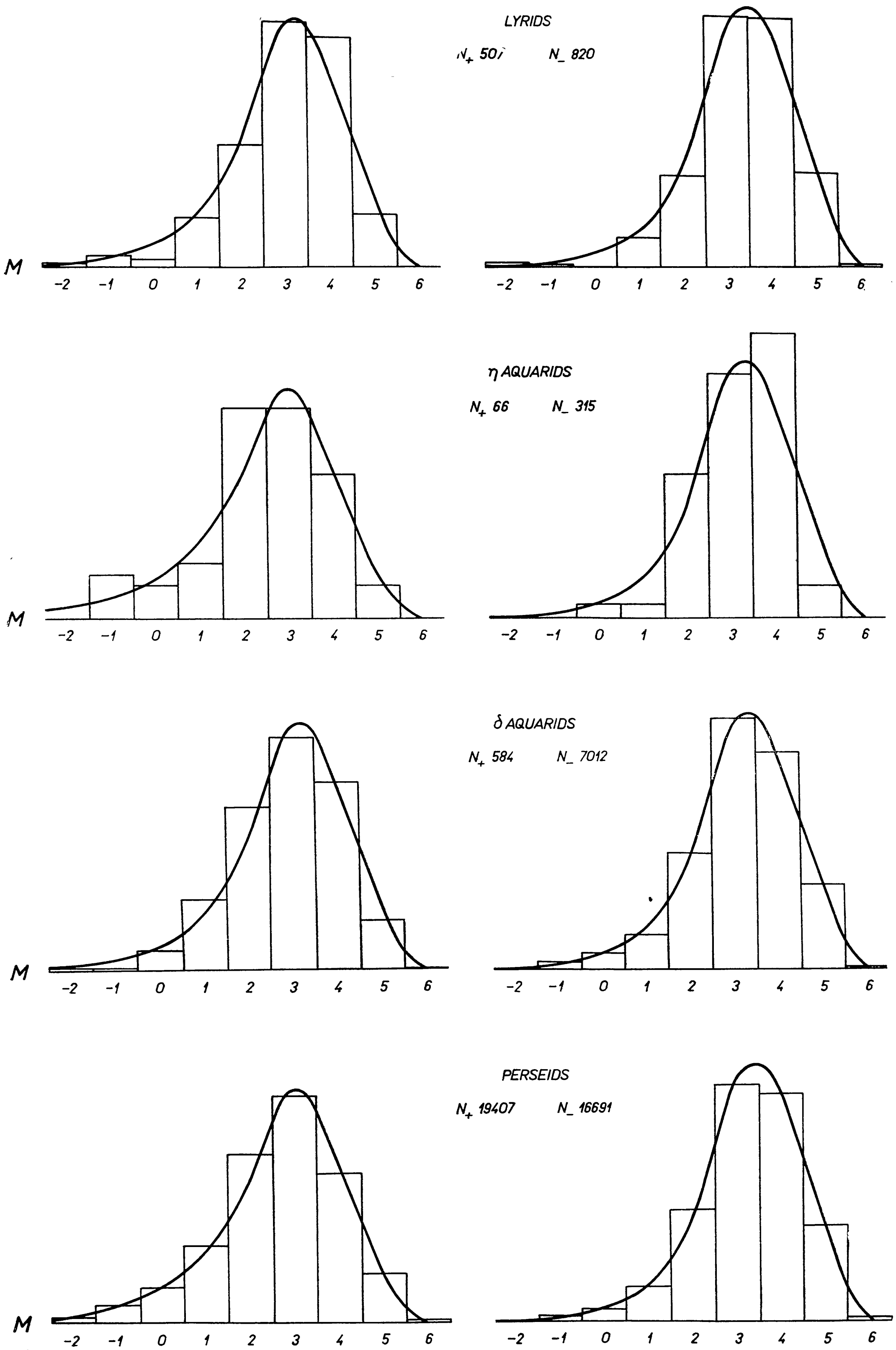
From 1344 distances D, estimated to the nearest 5°, the number of meteors within the annular spaces described around the centre of the field of view was determined. The diameter of the central spherical cap and the width of the other ring-like zones was 10°; the numbers of meteors $\overline{N}(D)$ within individual zones were computed from the frequencies of individual distances $N(D)$, i.e.

$$\overline{N}(D) = \frac{1}{2} N(D - 5°) + N(D) + \frac{1}{2} N(D + 5°). \tag{18}$$

The relative frequency per unit area is obtained if $\overline{N}(D)$ is divided by the area of the zone which, expressed in thousands of square degrees, equals

$$S(D) = 206.3\,[\cos(D - 5°) - \cos(D + 5°)]. \tag{19}$$

Obviously, the actual density of meteors varies even along each zone but these differences essentially cancel out in the total, in particular for the inner zones where $P(D)$ is high. Putting



LYRIDS
N_+ 507
N_- 820
η AQUARIDS
N_+ 66
N_- 315
δ AQUARIDS
N_+ 584
N_- 7012
PERSEIDS
N_+ 19407
N_- 16691
M
-2 -1 0 1 2 3 4 5 6

Figure 5a

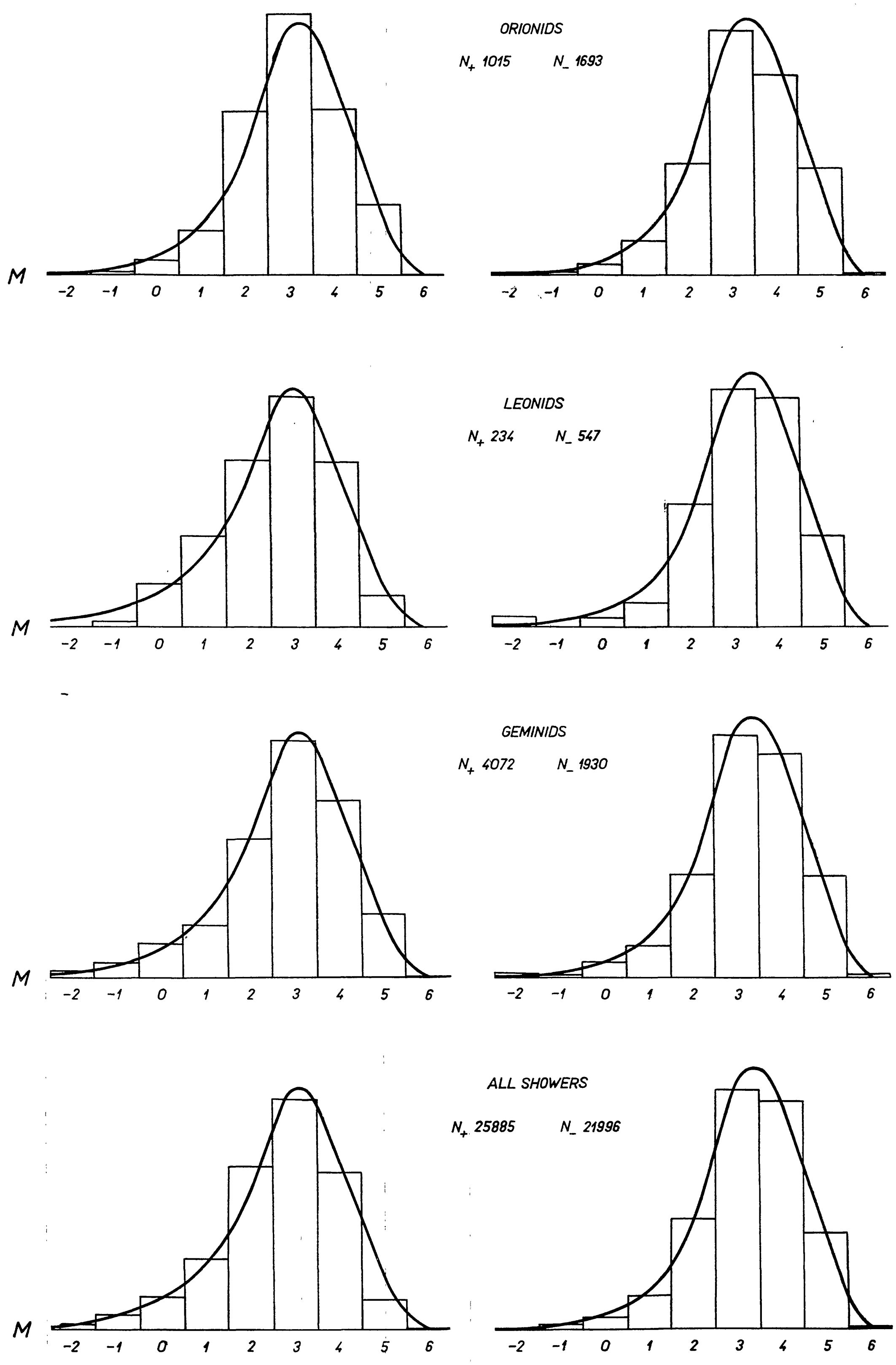

ORIONIDS
N_+ 1015 N_- 1693
LEONIDS
N_+ 234 N_- 547
GEMINIDS
N_+ 4072 N_- 1930
ALL SHOWERS
N_+ 25885 N_- 21996
M
-2 -1 0 1 2 3 4 5 6

Figure 5b

$P(0) = 1$ we may define the relative probability of perception referred to the probability at the field's centre as

$$P(D) = \frac{S(0)\overline{N}(D)}{S(D)\overline{N}(0)}\,. \qquad (20)$$

All quantities entering the determination of $P(D)$ are shown in Table XIII; the result is graphically represented in Figure 6 where a smooth curve of $P(D)$ is fitted to the histogram of the a posteriori probabilities $P(D)_0$ derived from the observation.

Table XIII

D	$N(D)$	$\overline{N}(D)$	$S(D)$	$\frac{\overline{N}(D)}{S(D)}$	$P_0(D)$	$P(D)$	$P_0(D)-P(D)$
0	9+	27+	0.079	34.2	0.90	1.00	—0.10
5	45	132	0.313	42.2	1.10	0.99	+0.11
10	165	249.5	0.624	40.0	1.05	0.94	+0.11
15	124	274.5	0.931	29.5	0.78	0.85	—0.07
20	136	290	1.230	23.6	0.62	0.74	—0.12
25	184	368.5	1.519	24.3	0.64	0.63	+0.01
30	233	410	1.798	22.8	0.60	0.52	+0.08
35	170	365	2.062	17.7	0.47	0.41	+0.06
40	157	276.5	2.311	12.0	0.32	0.30	+0.02
45	69	157.5	2.542	6.20	0.16	0.19	—0.03
50	20	62.5	2.754	2.27	0.06	0.08	—0.02
55	16	30.5	2.945	1.04	0.027	0.028	—0.001
60	9	20.5	3.114	0.66	0.018	0.017	+0.001
65	7	11.5	3.259	0.35	0.009	0.009	0.000
70	0	3.5	3.379	0.10	0.003	0.003	0.000
75	0	0	3.473	0.00	0.000	0.000	0.000

In order to convert the probabilities $P(D)$ to $P(H)$ it is necessary to integrate $P(D)$ along the individual parallels of altitude. The distance D from the centre of the field of view (altitude H_0, azimuth A_0) to a point with the co-ordinates H, A is given by

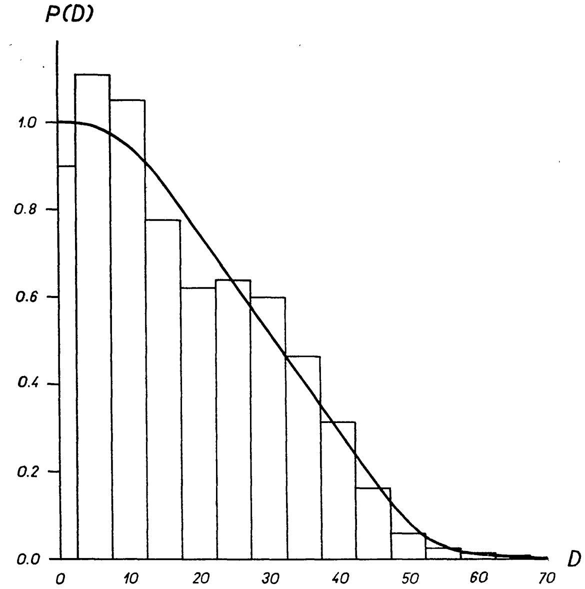


Figure 6

$$\cos D = \sin H \sin H_0 + \cos H \cos H_0 \cos (A - A_0) \qquad (21)$$

or, in our specific case where $H_0 = 45°$,

$$\cos D = 2^{-\frac{1}{2}}[\sin H + \cos H \cos (A - A_0)]. \qquad (22)$$

The distances $D(A, H)$ are given in Table XIV; the probabilities $P(A, H)$ corresponding to them according to Table XIII are given in Table XV. Figure 7 shows the relation between the azimuthal displacement of the meteor and the relative probability of perception for different altitudes if

Table XIV

Distance

$A - A_0$ \ H	0	10	20	30	40	50	60	70	80	90
0	45.00	35.00	25.00	15.00	5.00	5.00	15.00	25.00	35.00	45.00
10	45.86	36.04	26.33	16.94	8.90	8.39	16.15	25.49	35.19	45.00
20	48.36	39.00	29.98	21.72	15.52	14.35	19.16	26.91	35.73	45.00
30	52.24	43.46	35.19	27.89	22.54	20.72	23.28	29.08	36.61	45.00
40	57.20	48.99	41.34	34.65	29.60	27.15	27.97	31.82	37.77	45.00
50	62.97	55.22	48.01	41.65	36.61	33.51	32.90	34.92	39.17	45.00
60	69.31	61.90	54.96	48.72	43.50	39.74	37.89	38.24	40.73	45.00
70	76.00	68.84	62.02	55.74	50.22	45.80	42.84	41.65	42.41	45.00
80	82.95	75.89	69.07	62.62	56.73	51.64	47.64	45.05	44.14	45.00
90	90.00	82.95	76.00	69.30	62.97	57.20	52.24	48.36	45.86	45.00
100	97.05	89.89	82.73	75.69	68.87	62.44	56.57	51.50	47.54	45.00
110	104.00	96.63	89.16	81.71	74.38	67.28	60.56	54.43	49.13	45.00
120	110.69	103.03	95.19	87.28	79.42	71.67	64.18	57.07	50.58	45.00
130	117.03	108.96	100.68	92.30	83.90	75.55	67.35	59.40	51.87	45.00
140	122.80	114.25	105.50	96.64	87.73	78.84	70.03	61.37	52.96	45.00
150	127.76	118.70	109.49	100.18	90.84	81.49	72.17	62.93	53.84	45.00
160	131.64	122.11	112.49	102.82	93.12	83.42	73.73	64.07	54.48	45.00
170	134.14	124.26	114.36	104.45	94.53	84.60	74.68	64.77	54.87	45.00
180	135.00	125.00	115.00	105.00	95.00	85.00	75.00	65.00	55.00	45.00

Table XV

Probability

$A - A_0$ \ H	0	10	20	30	40	50	60	70	80	90
0	0.184	0.408	0.634	0.852	0.987	0.987	0.852	0.634	0.408	0.184
10	0.165	0.384	0.604	0.812	0.951	0.957	0.829	0.623	0.404	0.184
20	0.113	0.318	0.521	0.708	0.842	0.865	0.765	0.591	0.391	0.184
30	0.051	0.217	0.404	0.569	0.690	0.730	0.673	0.542	0.372	0.184
40	0.022	0.101	0.265	0.416	0.530	0.586	0.567	0.480	0.345	0.184
50	0.011	0.028	0.120	0.258	0.372	0.442	0.455	0.410	0.314	0.184
60	0.004	0.012	0.029	0.106	0.216	0.301	0.343	0.335	0.278	0.184
70	0.001	0.004	0.012	0.026	0.081	0.166	0.231	0.258	0.241	0.184
80	0.000	0.001	0.004	0.011	0.023	0.059	0.128	0.183	0.202	0.184
90	0.000	0.000	0.001	0.004	0.011	0.022	0.051	0.113	0.165	0.184
100	0.000	0.000	0.000	0.001	0.004	0.012	0.023	0.061	0.130	0.184
110	0.000	0.000	0.000	0.000	0.001	0.006	0.015	0.032	0.099	0.184
120	0.000	0.000	0.000	0.000	0.000	0.002	0.009	0.022	0.075	0.184
130	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.017	0.056	0.184
140	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.013	0.043	0.184
150	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.011	0.036	0.184
160	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.009	0.032	0.184
170	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.008	0.030	0.184
180	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.008	0.029	0.184

$H_0 = 45°$. A numerical integration yields the desired relation between $P(H)$ and H; this is presented in Figure 8 and in the last column of Table XVI.

It was the neglect of the factor $P(H)$ which led to some disagreement between the observation and theory in the work of Millman and Burland (1956). Figure 5 of their paper shows a distinct excess of observed meteor numbers in mean altitudes combined with a lack in the highest and lowest altitudes, which fact agrees well with our Figure 9. Nevertheless Millman and Burland obtained a good value of $\varkappa$ because they sagaciously restricted the examination to the altitudes $H > 25°$ where the effect becomes less significant and the decrease of $P(H)$ to the lower altitude limit adopted becomes roughly counterbalanced by the defect around the zenith. Levin (1956) also does not consider this effect. The present results suggest, however, that the effect is of substantial importance and its evaluation unavoidable for a correct determination of the ratio $\varkappa$ from the visual counts of meteor altitudes.

Table XVI

H	$\varrho(H)$	$\sigma(H)$	$P(H)$
0	0.00	378	0.026
5	0.35	131	0.047
10	0.48	47.3	0.071
15	0.67	19.9	0.098
20	0.80	9.80	0.127
30	1.00	3.27	0.185
40	1.00	1.42	0.233
50	1.00	0.721	0.258
60	1.00	0.393	0.251
70	1.00	0.212	0.224
80	1.00	0.0936	0.192
90	1.00	0.0000	0.184

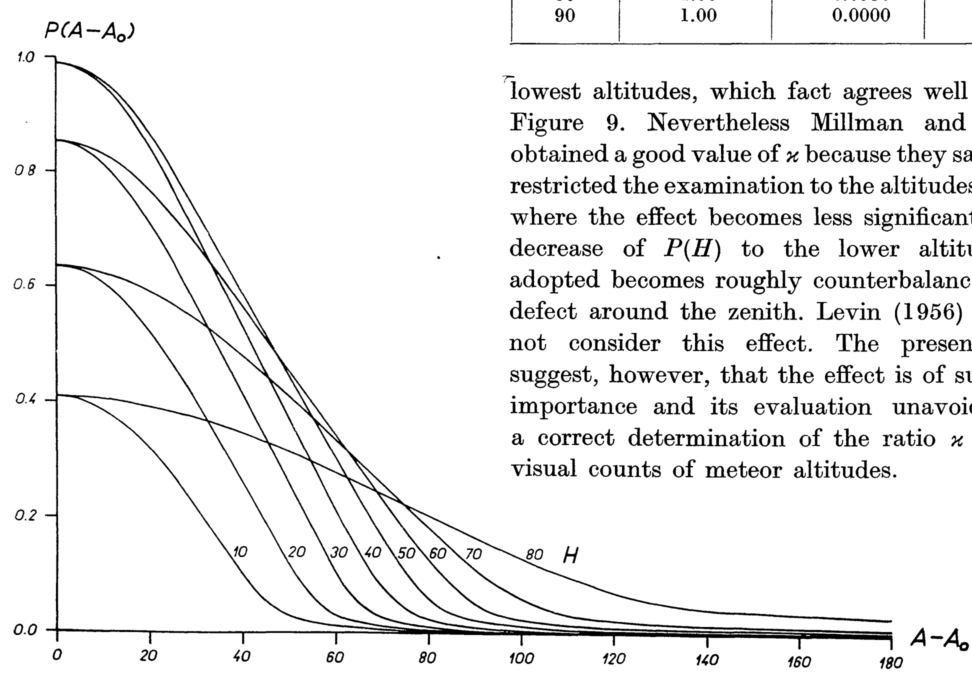


Figure 7

It must be pointed out that the function $P(D)$, and hence also the function $P(H)$, to some extent depends upon the magnitudes function of meteors under observation. Our numerical results have been derived from a period without any significant shower activity; as was demonstrated in section 5, $\varkappa$ is essentially invariable in such periods throughout the year. If we apply the factors $P(H)$ to meteor showers where $\varkappa$ is different, some systematic departures may appear. These are, however, not very significant and have the same sign in both tails of the $P(H)$ curve. If we deduce the magnitude function from the average altitudes we may reasonably expect that these systematic departures remain negligible.

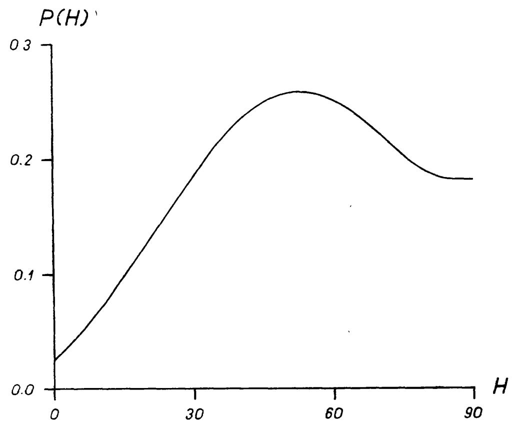


Figure 8

(IV) The exponent $\Delta M(d)$

This factor expresses the decrease of the apparent brightness with increasing slant range of the meteor. We have

$$\Delta M(d) = 5\,(\log d - \log y) \tag{23}$$

where d denotes the slant range and y the standard height of 100 km to which the absolute magnitudes are reduced. Assuming again a uniform height of 100 km for all meteors the numerical values of Table XVII are obtained.

Table XVII

H	$\frac{d}{y}$	$\Delta M(d)$	$\Delta M(e)$
90	1.000	0.00	0.00
80	1.015	0.03	0.00
70	1.063	0.13	0.01
60	1.152	0.31	0.02
50	1.298	0.57	0.05
40	1.539	0.94	0.09
30	1.956	1.46	0.16
20	2.771	2.21	0.31
10	4.774	3.39	0.74
0	11.331	5.27	

(V) The exponent $\Delta M(e)$

This factor expresses the diminution of the apparent brightness by atmospheric extinction. Denoting by p the transmission factor and by $F(H)$ the air mass we have, according to the well-known formula

$$\Delta M(e) = -2.5 \log p\,[F(H) - 1]. \tag{24}$$

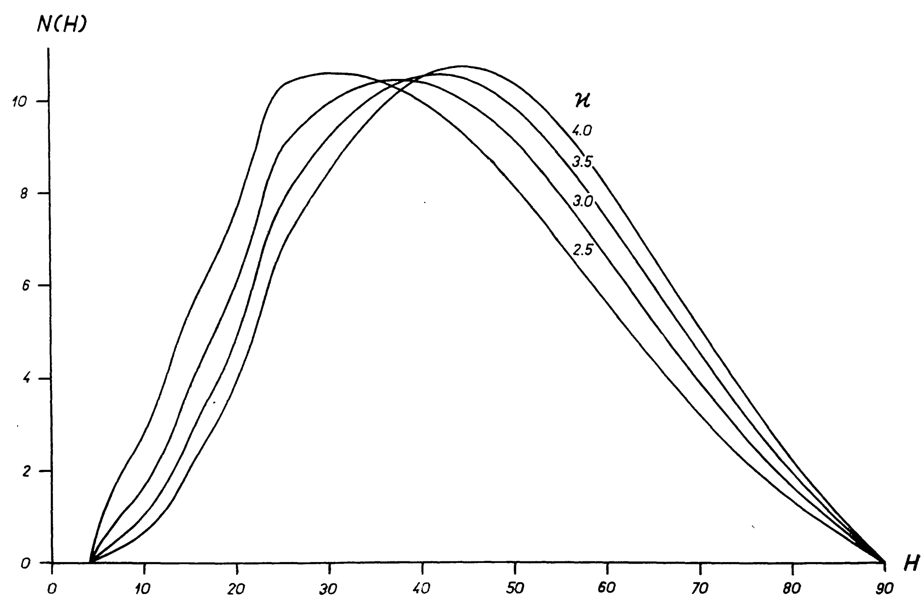


Figure 9

The transmission factors of the Skalnaté Pleso Observatory were measured by Lexa (1958) who obtained a close agreement with Abbot's (1911) extensive measurements at the Mount Wilson Observatory; the agreement is comprehensible with regard to the almost identical height above sea-level (1783 m and 1780 m, respectively). We adopted Abbot's value interpolated for the wave-length of 5100 Å corresponding to the maximum sensitivity of the human eye adapted to the night, $p = 0.862$. The air masses were found from Bemporad's Tables (Schoenberg 1929). The resulting values of $\Delta M(e)$ are given in the last column of Table XVII.

In order to obtain the expected altitude distributions for different ratios $\varkappa$ the factors (I) to (V) for selected values of H are inserted into formula (12), a numerical integration of $N(H)dH$ being necessary for converting the relative abundances into percentages. The results are given in Table XVIII and Figure 9 for $\varkappa = 2.5$, 3.0, 3.5 and 4.0. The discontinuity below $H = 25°$ is due to the factor $\psi(H)$ and comes from the partial coverage of the horizon at Skalnaté Pleso. Analogously to our procedure with the magnitude distribution, the average altitudes $\overline{H}$, median altitudes H_{med} and altitudes of maximum occurrence H_{max} were computed for $\varkappa$ interpolated to 0.1, and listed in Table XIX. Table XIX demonstrates that this method is more sensitive for lower values of $\varkappa$; H_{max} is the distribution parameter most affected by the changes of $\varkappa$. The principal potential sources of uncertainty are, firstly, systematic errors of the altitude estimates and, secondly, the factors $P(H)$ found empirically. In general the method is less sensitive than that based on direct magnitude estimates.

Table XVIII

Expected percentage $N(H)$

H \ $\varkappa$	2.5	3.0	3.5	4.0
0	0.00	0.00	0.00	0.00
5	0.85	0.37	0.18	0.09
10	2.80	1.66	1.05	0.68
15	5.44	3.82	2.76	2.06
20	7.62	6.05	4.86	3.96
25	10.32	8.97	7.80	6.81
30	10.59	9.92	9.17	8.45
35	10.47	10.40	10.11	9.72
40	9.99	10.42	10.56	10.52
45	9.20	9.99	10.48	10.75
50	8.15	9.16	9.88	10.40
55	6.91	7.99	8.82	9.48
60	5.61	6.63	7.47	8.17
65	4.35	5.25	6.01	6.66
70	3.21	3.92	4.55	5.10
75	2.20	2.72	3.18	3.61
80	1.34	1.67	1.97	2.24
85	0.62	0.78	0.92	1.04
90	0.00	0.00	0.00	0.00

Table XIX

$\varkappa$	$\overline{H}$	H_{med}	H_{max}
2.50	39.92	38.4	31.0
2.60	40.56	39.1	32.6
2.70	41.16	39.8	34.1
2.80	41.73	40.5	35.4
2.90	42.26	41.1	36.6
3.00	42.76	41.7	37.7
3.10	43.23	42.2	38.7
3.20	43.68	42.7	39.6
3.30	44.11	43.2	40.4
3.40	44.51	43.7	41.1
3.50	44.89	44.1	41.8
3.60	45.25	44.5	42.4
3.70	45.60	44.9	43.0
3.80	45.94	45.3	43.5
3.90	46.26	45.7	44.0
4.00	46.58	46.0	44.5

7. *Magnitude function derived from statistic of altitudes*

Our observational data, to which the results of the preceding section are applicable, are about 40 % less comprehensive than those concerning the magnitude distribution: they consist of 14468 altitudes of shower meteors and 13490 altitudes of sporadic meteors of the background. The shower of η Aquarids was omitted from the elaboration because there were relatively few data and, moreover, they referred to the time when the radiant is close to the horizon and the meteor trails are extraordinarily long. The observations of the Perseids were divided into two: (A) those from the period 1944—1949 and (B) those from the period 1950—1954. As there were some changes in the composition of the team of observers, this division should provide a check on the possible systematic errors of the altitude estimates.

The observed altitude distribution within individual showers is shown in Table XX, that of their sporadic background in Table XXI. In the last column of the latter table the sporadic meteors from the δ Aquarid period are omitted because these were identical with the sporadic meteors from the earlier part of the Perseid period. From the basic data of Tables XX, XXI the average values $\overline{H}_+$ and $\overline{H}_-$ were computed; they are given, together with the corresponding values

Table XX

Shower meteors

H	Lyr	δ Aqr	Per A	Per B	Ori	Leo	Gem	Σ
5	0	7	15	14	1	0	4	41
10	5	17	102	102	9	2	45	282
15	24	27	203	187	52	12	128	633
20	19	31	259	206	50	7	209	781
25	29	24	274	225	58	13	152	775
30	41	64	443	447	112	15	375	1497
35	50	30	372	348	77	20	265	1162
40	35	60	569	508	118	18	450	1758
45	39	49	461	491	69	14	247	1370
50	82	66	450	511	106	19	412	1646
55	27	7	228	168	25	6	117	578
60	58	25	285	195	42	15	223	843
65	29	19	190	113	34	10	78	473
70	19	19	237	197	32	10	153	667
75	6	16	89	109	27	6	48	301
80	29	21	145	110	21	3	76	405
85	8	4	58	44	10	0	28	152
90	2	8	44	57	4	0	11	126
0—90	502	494	4424	4032	847	170	3021	13490

Table XXI

Sporadic meteors

H	Lyr	δ Aqr	Per A	Per B	Ori	Leo	Gem	Σ
5	2	33	33	13	0	1	7	56
10	9	100	104	77	8	4	35	237
15	20	196	207	115	43	7	47	439
20	43	311	331	193	57	18	63	705
25	51	390	414	216	64	14	92	851
30	75	658	666	378	120	24	165	1428
35	102	513	530	330	109	26	110	1207
40	127	798	867	493	137	34	215	1873
45	101	630	763	371	105	35	128	1503
50	118	695	797	413	124	47	210	1709
55	53	308	355	177	60	12	51	708
60	64	371	458	233	78	18	108	959
65	39	298	336	128	70	13	40	626
70	68	373	460	165	79	7	70	849
75	19	191	249	80	36	6	15	405
80	38	224	272	138	35	13	48	544
85	19	119	124	68	22	1	12	246
90	7	74	73	32	2	0	9	123
0—90	955	6282	7039	3620	1149	280	1425	14468

Table XXII

	$\overline{H}_+$	$\varkappa_+$	$\overline{H}_-$	$\varkappa_-$
Lyrids	46.93	4.11	46.74	4.05
δ Aquarids	42.70	2.99	45.60	3.70
Perseids	43.68	3.20	45.91	3.79
Orionids	42.23	2.89	46.04	3.83
Leonids	43.44	3.15	44.37	3.37
Geminids	42.79	3.01	43.43	3.14
all showers	43.47	3.15	45.63	3.71

of $\varkappa_+$ and $\varkappa_-$ (found by interpolation in Table XIX), in Table XXII.

It is interesting to note that the mean value of $\varkappa_-$ perfectly agrees with that derived from the altitude distribution by Millman and Burland (1956). Both the values of $\varkappa_+$ and $\varkappa_-$ are systematically higher than those based on the magnitude estimates; the difference corresponds to an average overestimation of the altitudes by about 3°. Considering that the systematic differences among the altitude estimates of individual observers amount to 4° (see p. 78) and that additional discrepancies may arise from the uncertainty of the probability factors $P(M)$ and $P(H)$, this difference is not so high as to cast doubts on the correctness of the method applied. The method based on the altitude distribution is evidently inferior to that based on the magnitude distribution. Nevertheless the main conclusion that the ratio is systematically lower for shower meteors than for sporadic meteors is confirmed beyond doubt. For the total data the ratio $\varkappa_+/\varkappa_-$ obtained from the magnitude distributions is 0.73, that obtained from the altitude distributions is 0,85.

Adopting the values of $\varkappa$ given in Table XXII we may construct the expected altitude distributions and compare them with the observation; this is done in Figure 10. Since Tables XX and XXI show the preference of some observers to round off the altitudes to the nearest 10° instead of 5° (this is naturally most striking in the region $50° \leqq H \leqq 70°$ where the accuracy of the estimates is less than elsewhere) the summed numbers $N(H)$ from the neighbouring pairs of H were used as the frequencies in 5° intervals. The agreement between observation and theory is good. Some random fluctuations become apparent where the number of meteors is relatively low; in addition to this a depression of the histogram below the curve between $H = 50°$ and $H = 70°$ appears in most cases. We have already noted that just in this region the errors of the altitude estimates are greatest. It may be reasonably assumed that an excessive proportion of the meteors from this region was erroneously distributed into the neighbouring zones, $H = 40°$ to $50°$ and $70°$ to $80°$, where an excess is actually observed. This explanation is confirmed by the fact that the depression is most pronounced for the Perseids B where some observations are due to two teams of observers simultaneously active, the greater part being composed of less experienced observers.

8. *Dependence of magnitude function on position within stream*

As was mentioned in the introduction, there are two principal effects which may produce variations of $\varkappa$ with the position of the earth:

(I) The changes of the magnitude function in the direction from the stream's centre towards its boundary.

(II) The changes of the magnitude function from the inner to the outer boundary (relative to the Sun), in the orbital plane.

The former effect could be observable in each stream, but in particular where the earth passes near to the orbit of the parent comet. It should be more pronounced in the streams with steep curves of activity; inasmuch as the threshold observable frequency of each shower is practically the same, the chance of establishing this effect increases with the peak hourly rate. The latter effect, associated with the potential operation of the Poynting-Robertson and corpuscular drag, may appear only in the streams with moderately inclined orbital planes ($i \neq 90°$), met by the earth far enough from the perihelion ($q \neq 1$ $\omega \neq 0°$ or $180°$). The conditions are most favourable in old, widely dispersed streams, with the orbits not approaching closely to the orbits of major planets which would effectively intermingle the meteors by the perturbations.

In order to judge these two effects each shower was divided into four parts along the path traversed by the earth through the stream:

(a) from the beginning of the activity to the point where the shower attains one half of its maximum frequency (reduced to the radiant in the zenith),

(b) from this point to the point of maximum frequency,

(c) from this point to the point where the frequency drops again to one half of the maximum,

(d) from this point to the end of the shower's activity.

The adopted solar longitudes of the limiting points are given in Table XXIII. The number of nights n, the number of shower and sporadic meteors N_+, N_-, the average magnitudes $\overline{M}_+$, $\overline{M}_-$, the corresponding ratios $\varkappa_+$, $\varkappa_-$ according to Table VIII, and the differences of the average magnitudes $\overline{M}_+ - \overline{M}_-$ are given in Table XXIV. The results obtained for individual showers require the following comments:

The Lyrids. The gradual increase of $\varkappa_+$ is accompanied by a simultaneous increase of $\varkappa_-$; this indicates that it is likely due to random changes of observing conditions. There is no evidence of any systematic changes of $\varkappa_+$ with the position within the stream, although some concentration of brighter meteors towards the stream's centre is not excluded.

Table XXIII

	Solar longitudes		
	(a) (b)	(b) (c)	(c) (d)
Lyrids	30.5°	31.0°	31.5°
η Aquarids	41.0	44.5	50.0
δ Aquarids	123.0	125.0	127.0
Perseids	138.0	139.5	140.5
Orionids	205.0	209.0	212.0
Leonids	233.5	234.0	234.5
Geminids	259.0	261.0	262.5

The η Aquarids. The data are insufficient for drawing any dependable conclusion. The exceptionally positive difference $\overline{M}_+ - \overline{M}_-$ in subgroup (c) deserves no attention, being based on three shower meteors only. The only remarkable feature is a distinctly lower value of $\varkappa_+$ than that found for the other shower associated with Comet Halley—the Orionids.

The δ Aquarids. The values of $\overline{M}_-$ and $\varkappa_-$ are very stable, owing to the comprehensive data on the sporadic background. For the shower meteors the variations are much greater but without any distinct tendency.

The Perseids. Here the data are extensive enough in all subgroups, and all quantities computed are much less affected by random variations than in other cases. The differences $\overline{M}_+ - \overline{M}_-$ show regular variations of low amplitude, indicating a moderate concentration of brighter meteors to the stream's centre. The reality of this effect is supported if the innermost region (12 observations between $\odot = 139.0°$ and $140.0°$) is analogously elaborated: here we get $\overline{M}_+ = 2.37$, $\varkappa_+ = 2.3$ and $\overline{M}_+ - \overline{M}_- = -0.76$. It appears that $\varkappa_+$ of the Perseids is about 0.2 lower in the centre than at the boundary of the stream.

The Orionids. In the subgroups (a)—(c) no changes of the magnitude function are apparent, but in subgroup (d) both $\varkappa_+$ and $\overline{M}_+ - \overline{M}_-$ increase abruptly. As the subgroup (d) corresponds to the inner boundary of the stream, the effect qualitatively agress with the potential separation of smaller particles by the Poynting-Robertson drag. The differences $\overline{M}_+ - \overline{M}_-$ suggest, like in the case of the Perseids, some concentration

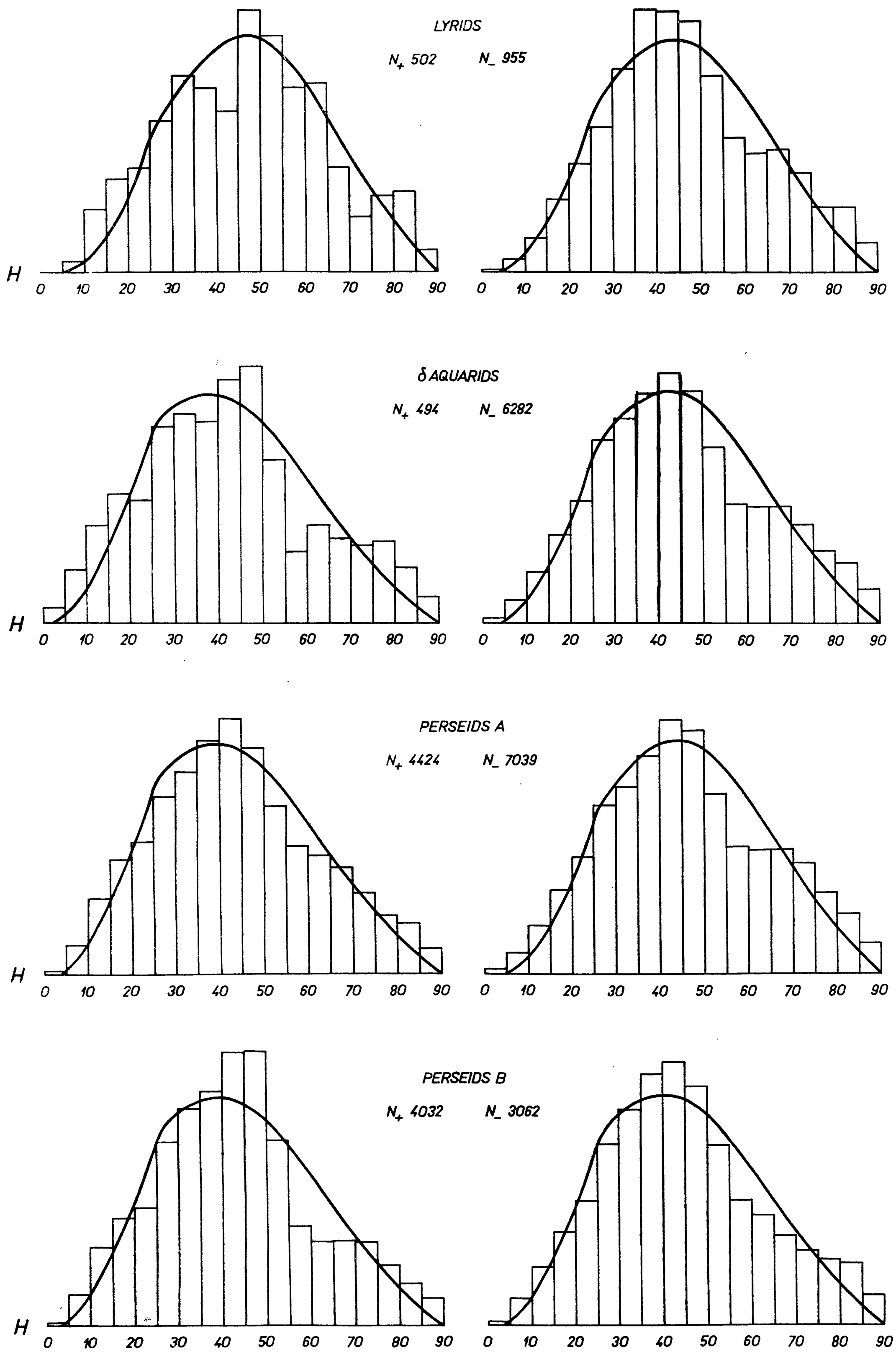

LYRIDS
N+ 502
N_ 955
δ AQUARIDS
N+ 494
N_ 6282
PERSEIDS A
N+ 4424
N_ 7039
PERSEIDS B
N+ 4032
N_ 3062
H
0 10 20 30 40 50 60 70 80 90

Figure 10a

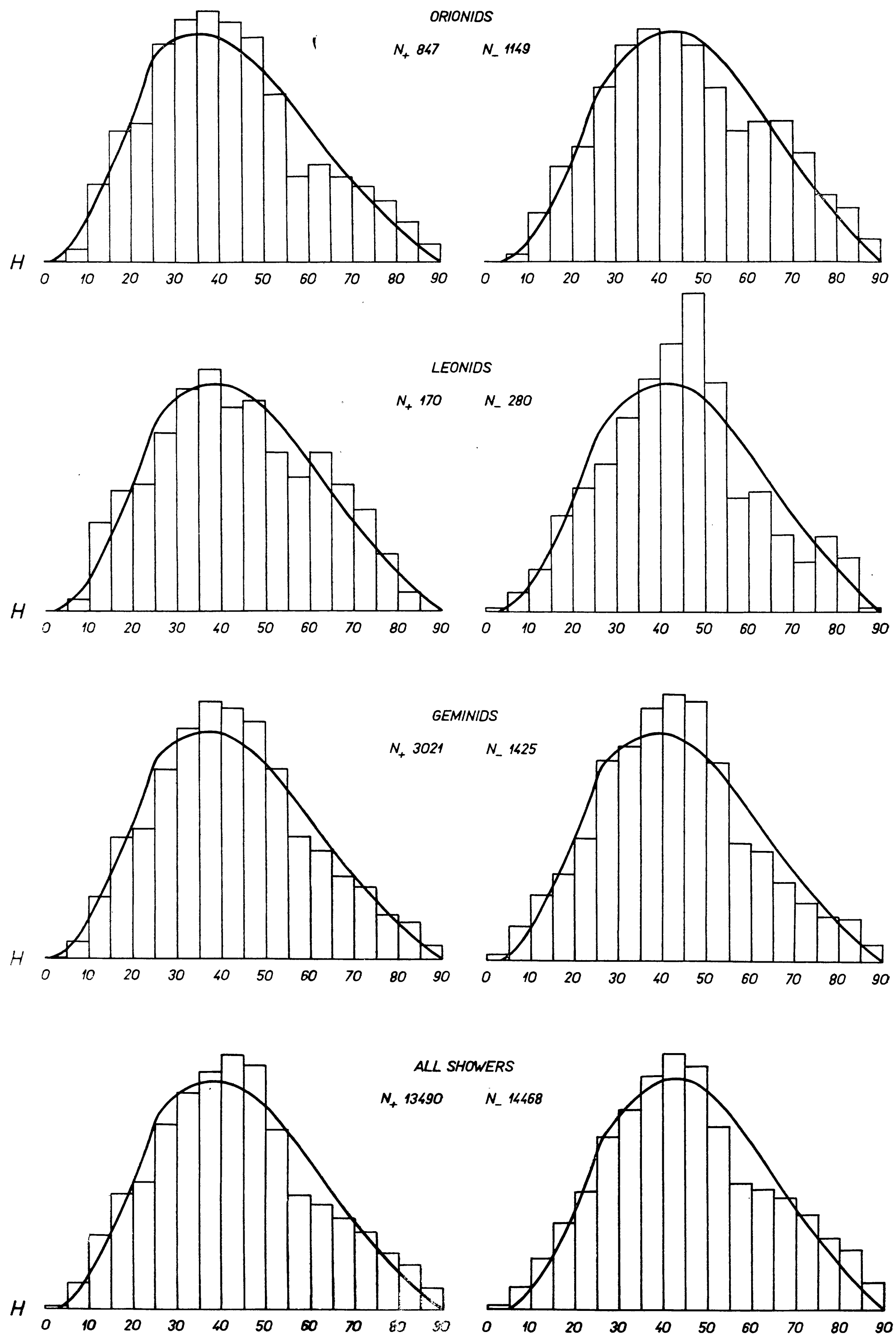

ORIONIDS
N_+ 847
N_- 1149
LEONIDS
N_+ 170
N_- 280
GEMINIDS
N_+ 3021
N_- 1425
ALL SHOWERS
N_+ 13490
N_- 14468
H
0 10 20 30 40 50 60 70 80 90

Figure 10b

Table XXIV

region	nights	N_+	N_-	$\overline{M}_+$	$\overline{M}_-$	$\varkappa_+$	$\varkappa_-$	$\overline{M}_+ - \overline{M}_-$
				Lyrids				
(a)	6	70	344	2.81	3.20	2.7	3.3	−0.39
(b)	2	101	185	2.43	3.36	2.3	3.7	−0.93
(c)	1	282	160	3.18	3.39	3.3	3.8	−0.21
(d)	6	54	131	3.04	3.40	3.0	3.8	−0.36
Σ	15	507	820	2.97	3.30	2.9	3.5	−0.33
				η Aquarids				
(a)	2	10	66	2.80	3.36	2.7	3.7	−0.56
(b)	5	53	217	2.34	3.15	2.2	3.2	−0.81
(c)	2	3	32	3.67	3.06	.	3.0	+0.61
(d)	0	0	. 0	.	.	.	.	.
Σ	9	66	315	2.47	3.18	2.3	3.3	−0.71
				δ Aquarids				
(a)	7	61	871	2.74	3.14	2.6	3.2	−0.40
(b)	11	119	1335	3.04	3.19	3.0	3.3	−0.15
(c)	6	205	1091	2.70	3.05	2.5	3.0	−0.35
(d)	24	199	3715	2.97	3.19	2.9	3.3	−0.22
Σ	48	584	7012	2.87	3.16	2.7	3.2	−0.29
				Perseids				
(a)	76	5769	10070	2.64	3.23	2.5	3.4	−0.59
(b)	19	6339	1814	2.47	3.16	2.3	3.2	−0.69
(c)	11	4629	1256	2.57	3.29	2.4	3.5	−0.72
(d)	32	2670	3551	2.75	3.31	2.6	3.5	−0.56
Σ	138	19407	16691	2.58	3.25	2.4	3.4	−0.67
				Orionids				
(a)	9	169	592	2.91	3.15	2.8	3.2	−0.24
(b)	12	684	778	2.91	3.22	2.8	3.4	−0.31
(c)	5	91	144	2.96	3.46	2.9	4.0	−0.50
(d)	2	71	179	3.48	3.35	4.0	3.6	+0.13
Σ	28	1015	1693	2.95	3.23	2.9	3.4	−0.28
				Leonids				
(a)	8	118	389	2.59	3.13	2.4	3.2	−0.54
(b)	1	6	3	2.33	2.67	2.2	2.5	−0.34
(c)	1	34	27	2.29	3.41	2.2	3.8	−1.12
(d)	3	76	128	2.86	3.38	2.7	3.7	−0.52
Σ	13	234	546	2.63	3.20	2.5	3.3	−0.57
				Geminids				
(a)	10	79	413	2.37	3.07	2.3	3.1	−0.70
(b)	7	1758	714	2.97	3.23	2.9	3.4	−0.26
(c)	6	2080	470	2.60	3.14	2.4	3.2	−0.54
(d)	10	155	333	3.03	3.53	3.0	4.2	−0.50
Σ	33	4072	1930	2.77	3.23	2.6	3.4	−0.46

of bright meteors towards the stream's centre, but the random variations are too great to allow of a definite conclusion.

The Leonids. Even for this stream some concentration of brighter meteors towards the centre is indicated. Unfortunately, there are few observations from the central region of the stream.

The Geminids. In spite of a sufficient number of magnitude estimates, $\varkappa_+$, $\varkappa_-$ and $\overline{M}_+ - \overline{M}_-$ vary rather irregularly within a wide range. None of the two effects anticipated is apparent.

The results obtained on different streams may be summarized as follows:

(1) A difference between the inner and outer boundary of a stream was found merely in the case of the Orionids, where it qualitatively agrees with the potential operation of the Poynting-Robertson drag. Additional observations, in particular between the solar longitudes 212—215°, are necessary for confirming this effect; telescopic and radio-echo investigations of the magnitude function of this shower would be of special interest.

(2) The two short-periodic showers with a low inclination and a small perihelion distance which are represented in our data, the Geminids and δ Aquarids, show considerable variations of the magnitude function. These variations, however, are not systematically associated with the position within the stream. This agrees with the suggestion of Kaščejev and Lebedinec (1959) that the Geminid stream contains isolated regions where the number of greater particles is relatively increased.

(3) The long-periodic showers of great inclination—the Perseids, Orionids, Lyrids and Leonids—yield a lower value of $\varkappa_+$ near the stream's centre. For the Perseids the diminution is moderate (about 0.2) but, owing to the great extent of the data, it appears well established. For the other streams the number of observations is too low to allow a decided conclusion; however, the qualitative agreement among them makes the effect rather probable.

(4) The reality of this effect is supported by comparing the results obtained for the Orionids and Aquarids. These two showers are associated with the same comet, but the η Aquarids move much nearer to the orbit of the parent comets, the minimum distances being 0.07 and 0.15 A.U., respectively. As a matter of fact, the ratio $\varkappa$ comes out considerably smaller for the η Aquarids than for the Orionids.

(5) The decrease of $\varkappa$ in the centre of the streams is in our data considerably less pronounced than in the examples quoted by Levin (1956). It must be remembered, however, that the cases referred to by Levin are mostly observations of extraordinarily strong displays, not represented in our data.

9. Changes of ratio $\varkappa$ with magnitude

In the preceding sections we have assumed that the ratio $\varkappa$ remains constant throughout the whole magnitude range investigated. As a matter of fact, only for brighter naked-eye meteors (down to about 3^m) could the probability factors $P(M)$ be determined with an accuracy sufficient for confirming this assumption. The upper magnitude limit for which the independence of $\varkappa$ upon M may be checked on the basis of the present observations depends on the number of magnitude estimates available. It amounts to about -5^m for the Perseids, -4^m for the sporadic meteors, -3^m for the Geminids, but only to 0^m for the Orionids, δ Aquarids, Leonids and Lyrids.

The probabilities $P(M)$ for the faintest naked-eye meteors that the ratio $\varkappa_-$ is obtained for brighter sporadic meteors may be extrapolated into this magnitude range. For this reason it is impossible to obtain idependently the variation of $\varkappa_+$ with M; we may only search for relative changes of $\varkappa_+$ against $\varkappa_-$.

The changes of the ratio $\varkappa$ may be most conveniently represented using the logarithmic form of the magnitude function. If $N(M)$ denotes the actual relative number of meteors of magnitude M an $N(M)_0$ the observed number, we have

$$\log N(M) = \log N(M)_0 - \log P(M) = \\ = M \log \varkappa + C. \tag{25}$$

The graphical representation of this equation may be compared with a point-to-point plot of log $N(M)$ against M. The changes of $\varkappa$ with M will then appear as a curvature of the observed relation against the computed straight line.

Such a comparison is presented in Figure 11 where the slope of the dashed line corresponds to $\varkappa = 3.4$ (a value found for sporadic meteors in section 5) and the full line to $\varkappa = 2.5$. The vertical scales are adjusted by fixing the constant C so as to yield $N(M)_0 = 100$ for $M = 3$. The difference between the magnitude functions of sporadic and shower meteors is apparent at first glance. As regards the curvature of the magnitude functions the evidence is not so clear. In considering this effect we must remember that

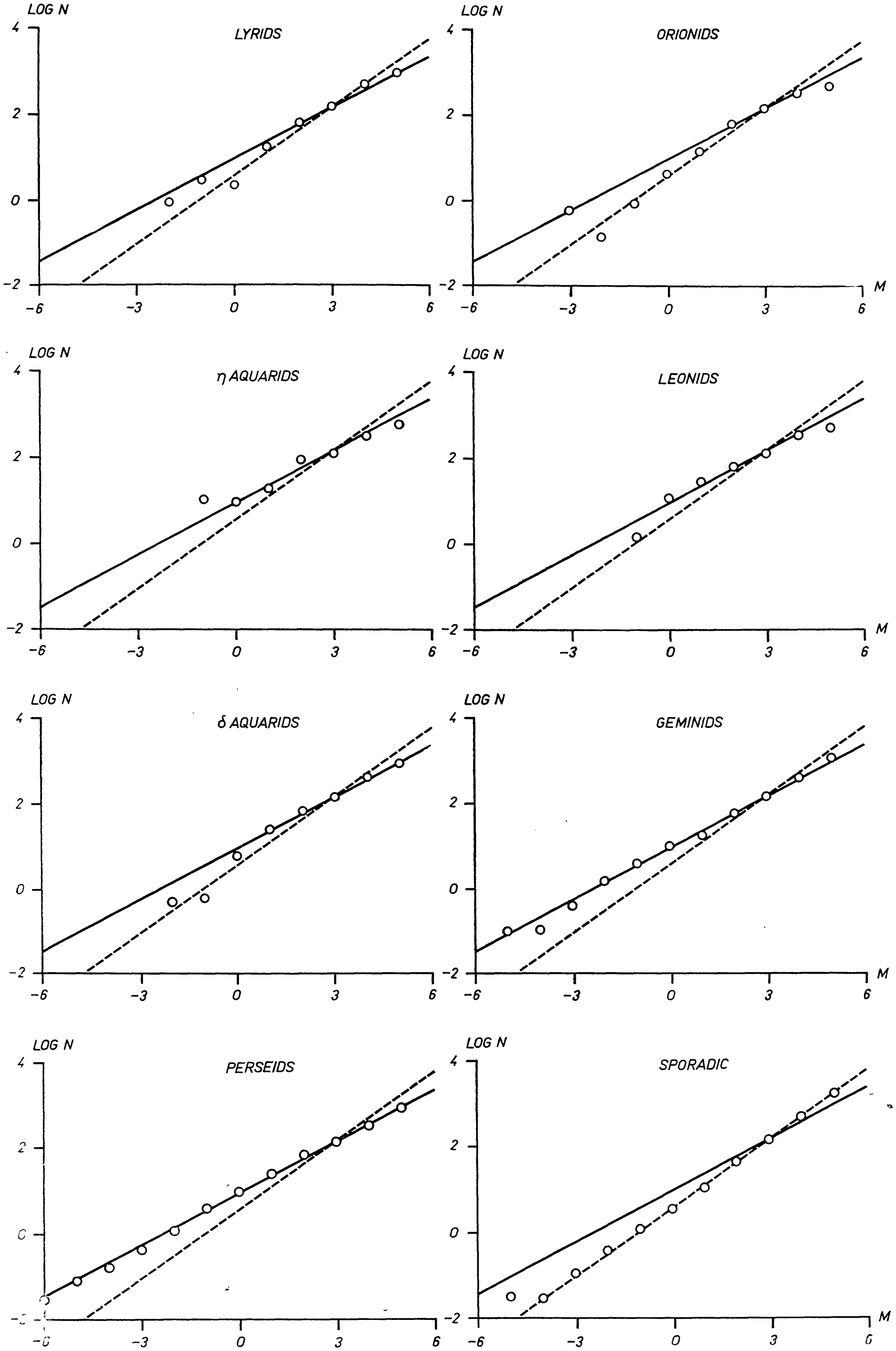

LOG N
M
LYRIDS
ORIONIDS
η AQUARIDS
LEONIDS
δ AQUARIDS
GEMINIDS
PERSEIDS
SPORADIC
4
2
0
-2
-6
-3
0
3
6

Figure 11

Table XXV

M	log $N(M)$							
	Lyr	η Aqr	δ Aqr	Per	Ori	Leo	Gem	Spor
—8	—∞	—∞	—∞	—∞	—∞	—∞	—∞	—1.86
—7	—∞	—∞	—∞	—1.16	—∞	—∞	—∞	—1.74
—6	—0.10	—∞	—∞	—1.52	—∞	—∞	—∞	—∞
—5	—∞	—∞	—∞	—1.09	—∞	—∞	—0.99	—1.49
—4	—∞	—∞	—∞	—0.77	—∞	—∞	—0.98	—1.54
—3	—∞	—∞	—∞	—0.38	—0.25	—∞	—0.44	—0.98
—2	—0.09	—∞	—0.33	0.07	—0.86	—∞	0.14	—0.44
—1	0.44	1.03	—0.22	0.60	—0.07	0.17	0.57	0.08
0	0.32	0.98	0.76	0.99	0.64	1.10	0.99	0.54
1	1.20	1.26	1.37	1.39	1.17	1.47	1.24	1.04
2	1.79	1.92	1.81	1.83	1.82	1.81	1.74	1.65
3	2.16	2.09	2.14	2.13	2.19	2.14	2.14	2.15
4	2.69	2.49	2.60	2.50	2.55	2.55	2.58	2.69
5	2.96	2.76	2.93	2.91	3.08	2.73	3.04	3.22
6	—∞	—∞	3.38	3.52	—∞	—∞	3.16	3.74

the random errors of log $N(M)_o$ rapidly increase to the left of the diagrams, owing to a lack of data on brighter meteors and to the application of the logarithmic scale. The missing circles correspond to $N(M)_o = 0$, or $\log N(M)_o = —\infty$. For the genuine curvature of the magnitude function the last few circles at the right are decisive.

From this point of view only the curvature of the magnitude function of the Orionids appears well established; it is conspicuous that just for this stream some magnitude separation was found (see p. 101). A slight indication of curvature is yielded by the Leonids, δ Aquarids and Lyrids; for the η Aquarids the data are insufficient for any conclusion. It is significant that just the two showers which are best represented in our data, the Perseids and Geminids, fail to show any curvature with respect to the magnitude function of the sporadic background. On the other hand, it is interesting to note that in all other cases the curvature has always the same sign, suggesting a decrease of $\varkappa_+$ with decreasing brightness.

A confirmation of this decrease may be obtained only from telescopic observations. Unfortunately, it is rather difficult to observe telescopic shower meteors in sufficient numbers for a statistical treatment. Even using the types of telescopes most suitable for meteor observations the hourly rates generally remain much lower than in naked-eye observations. For the shower meteors the conditions are even worse than for sporadic meteors because the relative rate varies with $(\varkappa_+/\varkappa_-)^{\Delta M}$, where ΔM is the gain in magnitude. This effect may be illustrated by a simple example. For the Skalnaté Pleso telescopic observations (Kresák and Kresáková 1965) the rates of sporadic meteors are about 4 times lower than those obtained from the naked-eye observations; the difference of the mean magnitudes M is 4.5^m; the average ratio $\varkappa_+/\varkappa_-$ from Table XII is 0.73. Accordingly, a shower yielding an hourly rate of 10 meteors in the naked-eye range should yield only $10 \times 0.25 \times 0.73^{4.5} = 0.6$ meteors per hour in the telescopic range, provided that $\varkappa_+$ does not decrease with decreasing brightness, and otherwise even less. For most major showers the peak naked-eye frequency is 10 to 30 meteors per hour, i.e. not more than one or two telescopic meteors per hour. Moreover, the greater proportion of sporadic background meteors makes the discrimination of shower meteors less reliable. It may be concluded that in our latitude zone no permanent streams, except the Perseids and the Geminids, promise to yield statistical data capable of a serious statistical analysis. Even for the Perseids and the Geminids it would be very difficult to collect observations of, say, 100 telescopic shower meteors.

At Skalnaté Pleso and Bratislava telescopic observations of some meteor showers were attempted, some results of which have been reported elsewhere. From the Perseid observations on August 6/7, 8/9, 9/10, 10/11 and 15/16, 1956, the writer (Kresáková 1958) has found the ratio of shower to sporadic meteors as $N_+/N_- = 0.155 \pm \pm 0.035$, with the average magnitude $\overline{M} = 7.8$. For the same nights from different years we find from Table IX the naked-eye ratio $N_+/N_- = 0.98$. The observing conditions, in particular the average zenith distance of the radiant which affects the observed frequency of shower meteors, were almost identical, only the average brightness was considerably higher, $\overline{M} = 2.9$. Denning's comprehensive series of naked-eye observations (1899), obtained under worse atmospheric conditions and thus with a still higher average brightness of meteors recorded, yield $N_+/N_- = 1.5$; from the Harvard photographic observations (Wright and Whipple 1953), with $\overline{M} \simeq -2$, we get $N_+/N_- = 2.2$. This is an additional proof that the ratio of shower to sporadic meteors actually decreases with decreasing brightness. Obviously, this may be explained if the ratio $\varkappa_+$ is appropriately lower than $\varkappa_-$ without requiring that $\varkappa_+$ decreases with increasing $\overline{M}$.

If we adopt for the Perseids the ratio $\varkappa_+/\varkappa_- = 0.74$ (see Table XII) in an unlimited magnitude range the expected ratios $(N_+/N_-)_c$ may be computed from the relation

$$\left(\frac{N_+}{N_-}\right)_c = \left(\frac{\varkappa_+}{\varkappa_-}\right)^M \tag{26}$$

and compared with the observed ratios $(N_+/N_-)_o$.

Table XXVI

M	$\left(\frac{N_+}{N_-}\right)_o$	$\left(\frac{N_+}{N_-}\right)_c$	$\left(\frac{N_+}{N_-}\right)_o : \left(\frac{N_+}{N_-}\right)_c$
—3	5.8	7.3	0.80
—2	6.6	5.4	1.22
—1	3.4	4.0	0.85
0	3.2	3.0	1.07
1	2.5	2.2	1.14
2	1.75	1.63	1.07
3	1.11	1.20	0.92
4	0.76	0.89	0.85
5	0.58	0.66	0.88
7.8	0.224	0.155	0.69

This is done in Table XXVI for naked-eye meteors; in the last line the result of the telescopic observations is added. It is shown that the ratio of observed to computed values is practically constant for brighter meteors (fluctuations among the brightest ones being due to random sampling errors) but slightly decreases for fainter meteors. It cannot be excluded that the activity of the Perseids in 1956 differed from the mean activity from the years 1944—1954. If we assume that this was not the case, we should conclude that the ratio $\varkappa$ of the Perseids drops by about 0.2 (from 2.6 to 2.4) within an interval of 5 magnitudes (from +3 to +8).

The reality of this decrease may be also checked in another effect, using the difference between the average magnitudes of shower and sporadic meteors. As is seen from Table VIII, the difference $\overline{M}_+ - \overline{M}_-$ increases with $\varkappa_+ - \varkappa_-$. For the naked-eye data from the Perseid period (Table XII) we obtain:

$$\overline{M}_+ = 2.58, \quad \overline{M}_- = 3.25, \quad \overline{M}_+ - \overline{M}_- = -0.67$$

For the telescopic observations of the Perseids 1956 we have:

$$\overline{M}_+ = 6.97, \quad \overline{M}_- = 8.06, \quad \overline{M}_+ - \overline{M}_- = -1.09.$$

Accordingly, $\varkappa_+$ of the telescopic Perseids should amount to 2.0 or 2.1 only. This figure is, however, subject to considerable uncertainty owing to the small number of shower meteors included. Our considerations are still based on the assumption that $\varkappa_-$ is a constant; if $\varkappa_-$ decreases with decreasing brightness, as indicated by some telescopic observations (Williams 1939, Kresáková and Kresák 1955), then $\varkappa_+$ decreases even more rapidly than $\varkappa_-$.

Another way of obtaining information on the reality of the decrease of $\varkappa_+$ consists in the comparison of the magnitude distributions of meteors derived from observations with different instruments. Such simultaneous observations were secured at the Skalnaté Pleso observatory during the 1959 Perseid return. They included 912 magnitude estimates, among them 712 observations with the naked-eye, 118 observations with the telescope AT-1 (diameter 5 cm, magnifying power 6), and 82 observations with the binoculars Somet-Binar (diameter 10 cm, magnifying power 25).

The respective magnitude distributions are shown in Figure 12. The naked-eye observations, where the discrimination of shower meteors is more reliable, were treated separately for shower and sporadic meteors. The upper two histograms reveal distinct differences between the magnitude distribution of the naked-eye Perseids and their sporadic background, apparent, in particular, in the shift of the maximum occurrence of the Perseids towards brighter meteors. The average magnitudes $\overline{M}_+ = 2.71$ and $\overline{M} = 3.19$, corresponding to the ratios $\varkappa_+ = 2.59$ and $\varkappa_- = 3.29$, are in excellent agreement with the results of Table XII.

The fourth histogram, obtained using 10 cm binoculars, reveals continuous changes of the number of meteors with the magnitude, similar to that obtained from naked-eye observations but considerably less skew. This could be explained by a lower ratio $\varkappa$ of sporadic meteors; however, an important selection effect is evidently responsible, at least partially, for the flatness of the distribution. The effective collecting area of a telescope depends on the angular length of the meteors and hence increases with increasing brightness (Kresáková and Kresák 1955). In addition the brightness of the faintest telescopic meteors may be systematically underestimated, as compared with the brighter ones, due to the effect of angular velocity (Öpik 1955). On the other hand, an underestimation of the brightness of the longest meteors, which are usually the brightest ones, is expected; this is due to the fact that the point of maximum light of long meteors more frequently falls outside the field of the telescope than that of the short ones (Grygar and Kohoutek 1958). The problem is rather complicated and its analysis is beyond the scope of the present article. At any rate, the fourth histogram evidently includes only a very low proportion of the Perseids and may be visualized as a continuation of the naked-eye distribution of sporadic meteors.

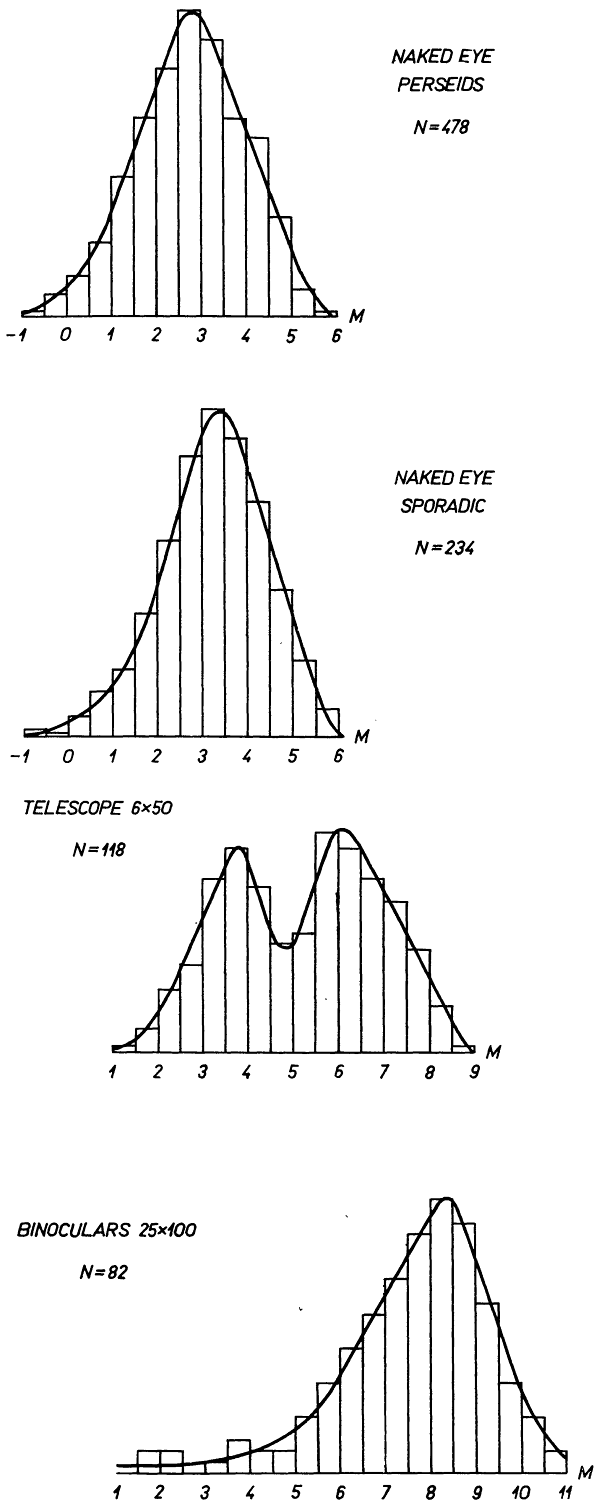


Figure 12

The third histogram from above, referring to the observations with a small telescope 6×50, is of special interest. Here, where the number of shower meteors should approximately equal that of sporadic meteors, a bimodal distribution, substantially different from the others, appears. The first maximum between 3.5 and 4^m may be tentatively identified as a result of the contribution of the Perseids, whereas the second maximum at about 6^m belongs to the sporadic background. The intermediate decline of meteor numbers suggests that an abrupt decrease of $\varkappa_+$ takes place at about $M = 5^m$.

The fact that the telescopic observations, unlike the naked-eye ones, indicate an abrupt decrease of $\varkappa_+$ may perhaps be attributed to a much narrower altitude range of telescopic meteors. In the naked-eye observations the wide altitude range covered by the observer introduces variable corrections of apparent to absolute magnitudes, which must partially smooth any curvature of the magnitude function. The results demonstrate that small, low-power telescopes are particularly suitable for the observation of meteor showers. More observations of this kind are required to confirm the anomaly found here.

The main results of this section may be summarized as follows:

(1) The relative contribution of shower meteors, as compared to the sporadic background, rapidly decreases with decreasing brightness owing to a lower ratio $\varkappa_+$.

(2) In addition to this effect, even the ratio $\varkappa_+$ alone seems to decrease as the range of telescopic meteors is approached. At the same time the ratio $\varkappa_-$ either remains constant or decreases too, but less rapidly than $\varkappa_+$.

(3) The low value of $\varkappa_+$ compared with $\varkappa_-$ shows little prospect of obtaining data on telescopic meteors from most major showers in sufficient numbers for a statistical analysis. The only exception in the northern latitude zone may be the Perseids and the Geminids; however, it is just these two showers that do not provide evidence of any decrease of $\varkappa_+$ in the naked-eye magnitude range.

(4) In spite of this, telescopic observations of the Perseids suggest a decrease of $\varkappa_+$ between $M = 3^m$ and 8^m. This decrease depicts independently in three series of observations, using different indicators of the mgnitude function, i.e.: (a) the variation of the ratio of shower to sporadic meteors with the magnitude, (b) the difference between the average magnitudes of shower and sporadic meteors in naked-eye and telescopic observations, respectively, (c) the form of the apparent magnitude distribution obtained by the observations with different telescopes.

(5) The observations of the Lyrids, δ Aquarids, Leonids, and especially Orionids suggest that a moderate decrease of $\varkappa_+$ takes place also within the naked-eye magnitude range of these showers. The present data are insufficient for confirming this with certainty for individual showers. However, from the qualitative agreement among all four cases it seems probable that the effect is genuine.

10. Conclusions

It was demonstrated that the ratio $\varkappa$ generally does not undergo appreciable variations with the magnitude, but is widely different for meteor showers and their sporadic background. For this reason it may be visualized as a characteristic feature of the internal constitution of individual meteor streams. It is conspicuous that this parameter divides the meteors into two groups—the members of the major showers and the sporadic meteors which inevitably include also minor showers and associations for which $\varkappa$ is indeterminate. The ratio $\varkappa$ of sporadic meteors does not undergo seasonal variations, being evidently independent of the geocentric velocity.

It was shown how the expected magnitude and altitude distributions for different ratios $\varkappa$ can be derived with the use of auxiliary multiple observations, yielding the probabilities of perception for meteors of different magnitudes appearing in different positions in the sky. By the comparison of the observed and expected distributions it was demonstrated that $\varkappa$ may be conveniently determined from the average magnitudes and altitudes, provided that homogeneous observations of a representative number of meteors is available. Minor changes of atmospheric conditions and personal factors may be accounted for by comparing the average magnitudes of shower meteors and sporadic meteors, owing to the seasonal invariability of the magnitude function of sporadic meteors.

Of the two independent methods, suggested for the determination of the magnitude function from naked-eye observations, the method based on the observed magnitude distribution is distinctly preferable to that based on the altitude distribution. Figures 13 and 14 present the final results concerning the relation between $\varkappa$, $\overline{M}$ and $\overline{H}$ for

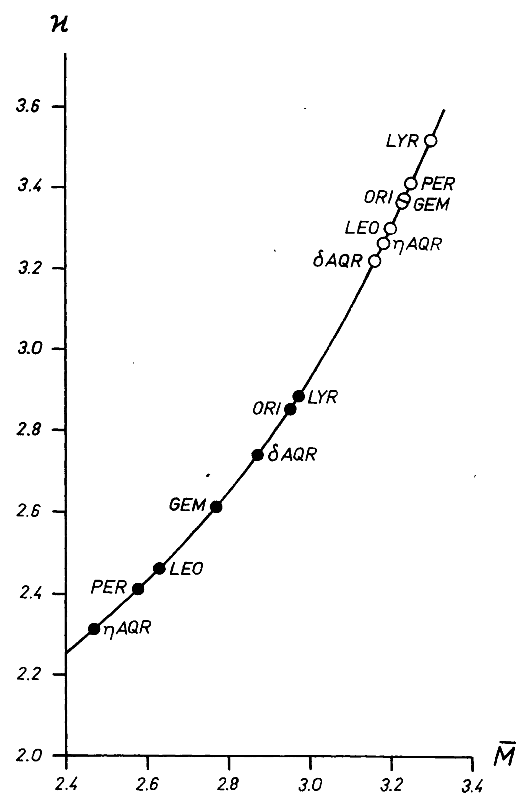


Figure 13

shower meteors (full circles) and their sporadic background meteors (blank circles). The lower sensitivity of $\varkappa$ to the altitude distribution is illustrated by a considerably greater dispersion of the points and, in particular, by the narrow range of average altitudes corresponding to appreciable changes of $\varkappa$; also systematic errors are more interfering in this case.

With regard to the unequal weight of the two determinations we may tentatively adopt, as the best value of $\varkappa$,

$$\varkappa = 0.8\varkappa(M) + 0.2\varkappa(H). \qquad (27)$$

These final values for individual showers are shown in Table XXVII, compared with Levin's

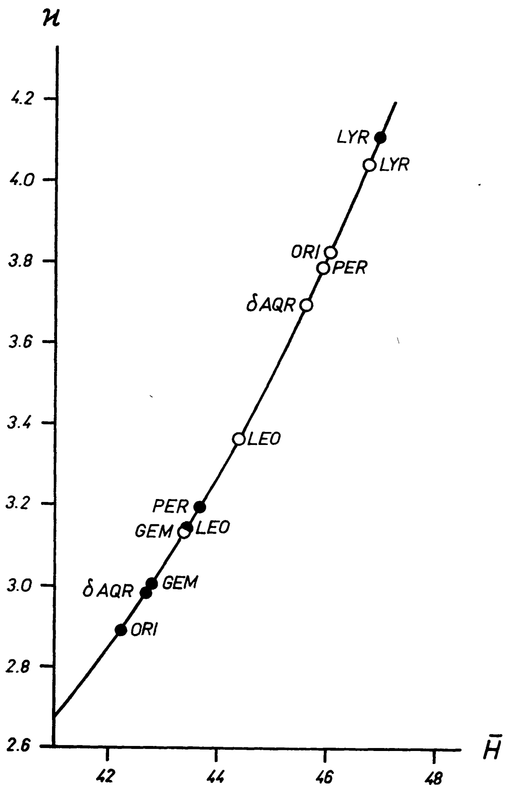


Figure 14

results (1953) based on Hoffmeister's data. The second part of the table gives the values of the mass exponent s, assuming that

$$s = 1 + 2.5 \log \varkappa. \qquad (28)$$

Table XXVII

	$\varkappa_+$	$\varkappa_-$	$\varkappa$ Levin (1953)	s_+	s_-	s Levin (1953)
Lyrids	3.1	3.6	1.7	2.25	2.40	1.60
η Aquarids	2.4	3.3	2.3	1.95	2.30	1.90
δ Aquarids	2.8	3.3	3.7	2.10	2.30	2.40
Perseids	2.6	3.5	2.5	2.05	2.35	2.00
Orionids	2.9	3.5	4.0	2.15	2.35	2.50
Leonids	2.6	3.3	2.4	2.05	2.30	1.95
Geminids	2.7	3.3	3.4	2.10	2.30	2.35
all shower meteors	2.6	.	2.3	2.10	.	1.90
all sporadic meteors	.	3.5	3.0	.	2.35	2.20

The agreement with Levin's figures is good only for the η Aquarids, Perseids and Leonids; other cases are rather discordant, in particular for the Lyrids and Orionids. The ratio $\varkappa_+/\varkappa_-$ for the total of shower and sporadic meteors agrees well: 0.77 (Levin) against 0.74 (this paper). In our data no shower with $\varkappa_+$ greater than $\varkappa_-$ is found, whereas in Levin's data three examples of this kind are present. It must be pointed out, however, that no discrimination among the sporadic backgrounds of different showers is made in Hoffmeister's data, and hence it was impossible to obtain a check on the variation of atmospheric conditions to which the observed magnitude distribution is sensitive. Some of Hoffmeister's observations were obtained during his expeditions into the southern hemisphere, apparently under different atmospheric conditions than the remainder. A seven times greater number of magnitude estimates used in the present study is perhaps another reason why our dispersion of $\varkappa$ for individual showers is much less than that found by Levin.

Our results agree fairly well with those of Grygar, Kohoutek and Kvíz (1962) as far as only naked-eye meteors are concerned. On the other hand, Kvíz and Mikušek (1958) find a much higher value of $\varkappa_-$ (about 5.6) from their telescopic observations. The reason of this discrepancy is obscure.

The study of the magnitude function within individual showers poses two main problems: (a) how the ratio $\varkappa$ varies with the position within the stream, and (b) how the ratio $\varkappa$ varies with the magnitude. A detailed account of our results in these directions need not be repeated here, as they are summarized at the end of sections 8 and 9. Unfortunately, none of the anomalies appears to lie far from the threshold of detectability by naked-eye observations. On the whole, it may be inferred that regions with an increased proportion of larger particles are actually present in many meteor streams. In long-periodic retrograde streams, which are not heavily perturbed by the major planets, these regions are generally situated around the parent comet's orbit. In short-periodic streams of low inclination, where the planetary perturbations affect the meteor orbits more permanently, these regions appear to be distributed within the stream rather irregularly. For the Orionids an increase of $\varkappa$ at the inner boundary of the stream, consistent with a separation by the Poynting-Robertson or corpuscular drag, is suggested. Assuming a constant ratio $\varkappa$ for sporadic meteors (this is reasonable with regard to their velocity dispersion) a slight decrease of $\varkappa$ with decreasing brightness is indicated in most showers. Even where the naked-eye observations yield a negative result (the Perseids) the telescopic observations suggest a decrease of $\varkappa$ leading to a relative lack of faint shower meteors.

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М. КРЕСАКОВА

РАСПРЕДЕЛЕНИЕ МЕТЕОРОВ ПО ЗВЕЗДНОЙ ВЕЛИЧИНЕ В МЕТЕОРНЫХ ПОТОКАХ

Исследуется распределение по звездной величине метеоров отдельных потоков. Работа основана на 48 000 определений звездной величины и 28 000 определений высот метеоров над горизонтом, полученных с 1944 г. наблюдателями Скальнате Плесо при 45 встречах с главными метеорными потоками (Лириды, η-Аквариды, δ-Аквариды, Персеиды, Ориониды, Леониды, Геминиды). Параллельные наблюдения позволили определить зависимость вероятности наблюдения от яркости и положения на небе отдельного метеора (рис. 1 и 3); эта зависимость использована для определения ожидаемого распределения наблюдаемых метеоров по звездной величине и высоте для разных $\varkappa$ функции светимости типа $\mathrm{d}N \sim \varkappa^M \mathrm{d}M$. Сравнение вычисленного и наблюдаемого распределений (рис. 4 и 8, табл. X, XI, XX и XXI) позволяет определить $\varkappa$ для отдельных потоков, которые после определения веса обеих методов приведены в табл. XXVII. Метод, основанный на статистике звездных величин, оказался существенно чувствительнее метода основанного на статистике высот метода.

Изменения значения $\varkappa$ при изменении звездной величины не существенны. С другой стороны выразительные различия оказались между величинами $\varkappa$ для метеоров главных потоков и для метеоров спорадического фона, в который включены также метеоры слабых потоков и асоциаций. Примечательно, что функция светимости спорадических метеоров в течение года не изменяется, что с одной стороны показывает на ее независимость от геоцентрической скорости, а с другой стороны предоставляет ценный контроль для определения функции светимости метеорных потоков из полученных при различных атмосферных условиях наблюдений. Численные значения $\varkappa$ для всех 7 исследованных метеорных потоков существенно меньше значения $\varkappa$ для метеоров их спорадического фона — приблизительно 2.7 и 3.5 соответственно — и обнаруживает для метеорных потоков больший разброс в сравнении со спорадическими метеорами. Этим результатом подтверждается также поразительное отсутствие метеоров потоков при телескопических наблюдениях.

С точки зрения эволюции метеорных потоков очень важны структурные различия в функции светимости для отдельных мест исследуемого потока и изменения крутизны функции светимости для различных звездных величин. Относительное число больших частиц медленно изменяется с положением в рое. Для долгопериодических роев с обратным движением, которые не так сильно возмущены планетами, большие частицы сосредоточены, главным образом, вдоль орбиты кометы-родоначальницы, в то время как у короткопериодических роев с небольшим наклонением орбит, у которых возмущения более постоянного характера, большие частицы создают скорее неправильным образом распределенные потоки. Повышение числа слабых метеоров на внутреннем краю роя, которое требуют эффект Пойнтинга-Робертсона и корпускулярный эффект, проявляется слабо только в рое Орионид, у которого одновременно наиболее выразительное падение $\varkappa$ с понижением звездной величины. Для большинства потоков оказывается тождественным общее понижение $\varkappa$ в направлении более слабых метеоров. Этот эффект не является достаточно вы-

разительным, чтобы на основании существующего материала оказалось возможным доказать его с уверенностью для отдельных потоков. Даже поток, для которого наблюдения невооруженным глазом наилучшим образом соответствуют постоянному значению $\varkappa$ (Персеиды), при телескопическом наблюдении показывает значительное понижение $\varkappa$ в области более слабых метеоров.

M. KRESÁKOVÁ

ROZDELENIE METEOROV PODĽA VEĽKOSTI V METEORICKÝCH ROJOCH

V práci sa skúma rozdelenie meteorov podľa veľkosti v rôznych meteorických rojoch. Za základ slúži asi 48 000 odhadov jasnosti a 28 000 odhadov výšok meteorov nad obzorom, ktoré sa získali na observatóriu na Skalnatom Plese od r. 1944, počas 45 návratov hlavných meteorických rojov (Lyridy, η Akvaridy, δ Akvaridy, Perzeidy, Orionidy, Leonidy, Geminidy). Ďalšie simultánne pozorovania umožnili odvodiť závislosť medzi pravdepodobnosťou zbadania meteoru, jeho jasnosťou a polohou na oblohe (obr. 1 a 3); táto závislosť sa použila na konštrukciu očakávaného rozdelenia pozorovaných meteorov podľa zdanlivých jasností a výšok pre rôzne funkcie jasnosti tvaru $\mathrm{d}N \sim \varkappa^M \,\mathrm{d}M$. Porovnanie výpočtu s pozorovaním (obr. 4 a 8, tab. X, XI, XX a XXI) dalo hodnoty $\varkappa$ pre jednotlivé meteorické roje, tak ako sú po uvážení oboch metód uvedené v tabuľke XXVII. Metóda založená na štatistike jasností sa ukázala podstatne citlivejšia ako metóda založená na štatistike výšok.

Zmeny veličiny $\varkappa$ s magnitúdou nie sú podstatné. Naopak, veľmi výrazné sú rozdiely v jej hodnote pre hlavné meteorické roje a ich sporadické pozadie, v ktorom sú pochopiteľne zahrnuté i slabšie roje a asociácie. Je pozoruhodné, že funkcia jasnosti sporadických meteorov sa v priebehu roka nemení, čo jednak svedčí o jej nezávislosti od geocentrickej rýchlosti, jednak poskytuje cennú kontrolu pri určovaní funkcie jasnosti rojových meteorov z pozorovaní pri rôznych atmosferických podmienkach. Pre všetkých 7 skúmaných meteorických rojov je numerická hodnota $\varkappa$ podstatne nižšia ako pre ich sporadické pozadie — okolo 2.7 proti 3.5 — a vykazuje medzi jednotlivými rojmi väčší rozptyl ako medzi sporadickými meteormi. Tento záver potvrdzuje i nápadný nedostatok rojových meteorov pri teleskopickom pozorovaní.

Pre problémy vývoja meteorických rojov sú dôležité štrukturálne rozdiely, prejavujúce sa odlišným priebehom funkcie jasnosti v rôznych častiach toho istého roja a vo zmenách tvaru funkcie jasnosti s veľkosťou meteorov. Ukazuje sa, že relatívne zastúpenie väčších čiastočiek sa mierne mení s polohou v roji. V dlhoperiodických retrográdnych rojoch, menej rušených planétami, zoskupujú sa väčšie čiastočky prevažne pozdĺž dráhy materskej kométy, kým v krátkoperiodických rojoch s málo sklonenými dráhami, kde poruchy majú trvalejší charakter, vytvárajú skôr nepravidelne rozložené prúdy. Zvýšenie počtu slabých meteorov na vnútornom okraji roja, aké vyžaduje Poynting-Robertsonov a korpuskulárny efekt, prejavuje sa mierne iba v roji Orioníd, kde je aj najvýraznejší celkový pokles faktoru $\varkappa$ s klesajúcou jasnosťou. Vo väčšine rojov sa zhodne ukazuje pokles $\varkappa$ smerom ku slabším meteorom. Tento efekt nie je dostatočne výrazný na to, aby sa na základe existujúceho materiálu dal bezpečne dokázať pre jednotlivé prípady. I roj, pre ktorý pozorovania prostým okom najlepšie vyhovujú konštantnému faktoru $\varkappa$ (Perzeidy), ukazuje pri teleskopickom pozorovaní zreteľný pokles $\varkappa$ v oblasti slabších meteorov.