of a random distribution of the radiants over the sky. The fastest meteors come from the apex, where the radiant density actually is higher, and the slowest ones from the neighbourhood of the north pole (field of view of the telescope), where the density is reduced due to the ecliptical concentration of the radiants. The better agreement in the observations and computations in Fig. 8 in comparison with Fig. 7, and the preponderance of observed radiants on the hemisphere of the apex (Fig. 4) confirm this explanation.

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DYNAMIC AND PHOTOMETRIC MASS OF METEORS

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The difference of the dynamic and photometric mass of the meteors cannot be explained by differences in the constants of equations (1) and (2) only. The exponents at ϱ, v, $\mathrm{d}v/\mathrm{d}t$, which fit these equations best for the complete material of Jacchia-Verniani-Briggs meteors (1965), are far from the theoretical values. Thus the result of Verniani (1965) for the mean meteoroid density (0·25 gr/cm^3) based on the theoretical values of exponents is not correct. The distribution of the k_B-parameter (equation (5)) and orbital elements for the Jacchia-Verniani-Briggs sporadic meteors completely confirm the results of the previous paper (Ceplecha 1966) based on the less accurate values of McCrosky-Posen meteors. Similar statistical groups (A, B, C) as previously found using the k_B-parameter are also present in the distribution of differences of the dynamic and photometric mass. Thesre is a relation between independant k_B and log (m_{ph}/m_d). (Fig. 7.). The exponents at ϱ, v, $\mathrm{d}v/\mathrm{d}t$, which fit best the equations (1) and (2) for the groups A, B, C separately, are much closer to the theoretical values than is the case for the complete material. The deviations from the theory increase with decreasing density of the meteoroid. The meteoroid densities: A-group $\varrho_m = 4{\cdot}0$ gr/cm^3, B-group $\varrho_m = 2{\cdot}2$ gr/cm^3, C-group $\varrho_m = 1{\cdot}4$ gr/cm^3 estimated in the previous paper (Ceplecha 1966) are probably much closer to the reality than the mean value 0·25 gr/cm^3 computed by Verniani (1965) for all the meteors.

Динамическая и фотометрическая масса метеоров. Разхождение между динамической и фотометрической массой метеоров нельзя объяснить только различием постоянных в уравнениях (1) и (2). Экспоненты при ϱ, v, $\mathrm{d}v/\mathrm{d}t$, которые найлучше соответствуют наблюдательному материалу Jacchia, Verniani, Briggs (1965), далеко от теоретических. Поэтому результат Verniani (1965) по средней плотности метеорных частиц (0,25 гр/см^3), вычисленной при помощи теоретических экспонентов, не верен. Статистическое распределение параметра k_B (уравнение (5)) и орбитальных элементов для спорадических метеоров Jacchia, Verniani, Briggs полностью потвертждают результаты предыдущей работы (Ceplecha 1966) основанной на не так точных данных по метеорам McCrosky, Posen. Одинаковые статистические группы (A, B, C), каторые найдены в предыдущей работе при помощи параметра k_B, были тоже найдены для статистического распределения расхода динамической и фотометрической массы. Естественным является отношение между независимыми k_B и log (m_{ph}/m_d). (Рис. 7.) Экспоненты при ϱ, v, $\mathrm{d}v/\mathrm{d}t$, которые найлучше удовлетворяют уравнениям (1) и (2) для отдельных групп A, B, C, много ближе к теоретическим, чем для всего материала. Расхождение с теорией увеличивается с уменьшением плотности метеорной частици. Плотности метеорных частиц, определенные в предыдущей работе (Ceplecha 1966), для группы A: $\varrho_m = 4{,}0$ гр/см^3, для группы B: $\varrho_m = 2{,}2$ гр/см^3, для группы C: $\varrho_m = 1{,}4$ гр/см^3, находятся с большой вероятностью ближе к естественным плотностям, чем величина средней плотности 0,25 гр/см^3, которую вычислил Verniani (1965) для всех метеоров.

1. *Introduction*

The meteor mass can be computed in two different ways:

a) Dynamic mass computed from the measured deceleration using the drag equation:

$$(1) \qquad {}^{*)}\; m_d = \frac{(\Gamma A)^3}{\varrho_m^2} \left(\frac{\varrho v^2}{\dfrac{\mathrm{d}v}{\mathrm{d}t}} \right)^3 .$$

b) Photometric mass computed from the measured

*) For list of symbols used see end of paper.

light curve:

$$m_{ph} = \frac{2}{\tau_{op}} \int_t^{t_E} \frac{I_p}{v^3} \, dt \,. \tag{2}$$

These relations are usually used for the data obtained from double-station photographs of meteors. It is a well known fact that the results from (1) and (2) usually differ by more than one order, if one value of the meteoroid density is used for the whole material. This basic fact is analyzed in this paper using the best, most extensive and homogeneous material of Super-Schmidt meteors published by Jacchia, Verniani and Briggs (1965).

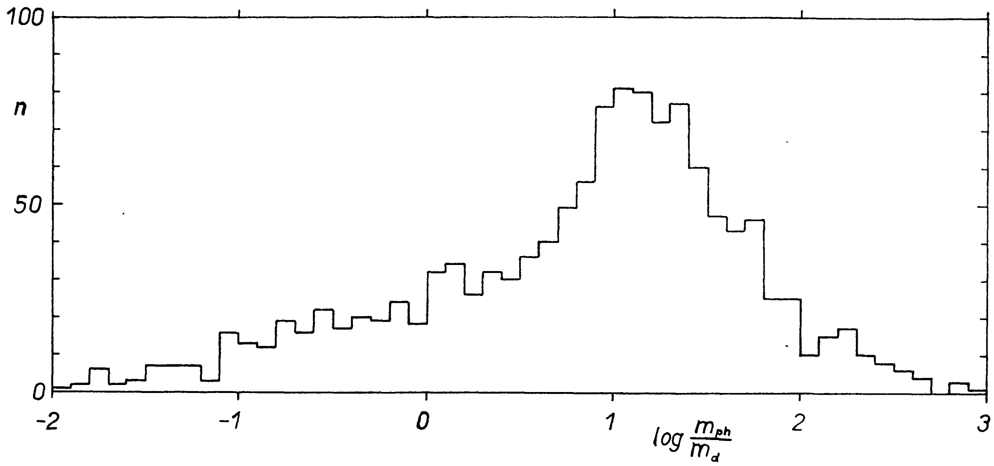

Fig. 1. Histogram of $\log (m_{ph}/m_d)$ shows superposition of more than one distribution.

2. *Relations between m_d and m_{ph} for the complete observational material*

The photometric mass computed from (2) is directly published in Table 1.2 of the paper by Jacchia, Verniani and Briggs (1965) (there it is denoted m_1). The dynamic mass used here was computed with the value of $(\Gamma A)^3/\varrho_m^2 = 1$ and with the values of h, v, dv/dt of Table 1.2 of the mentioned paper. The US Standard Atmosphere (1962) was used to connect h with ϱ. The decadic logarithm of m_d and m_{ph} are used. Thus $\log m_d$ is determined with an unknown constant to be added.

The histogram of all $\log (m_{ph}/m_d)$ is plotted in Fig. 1. At first sight the distribution is not a simple one. The distribution in the vicinity of the main maximum at the 1·0 interval corresponds to much narrower distribution (crossing about 2 orders) than is observed for the whole material. Especially the left part at negative values of $\log (m_{ph}/m_d)$ points to a superposition of other distribution curves than only the main one.

The position of the main maximum at the 1·0 interval could be shifted to the position of $\log (m_{ph}/m_d) = 0$ by choosing another value of the constant, which we previously assumed to be 1. If the total difference is caused by this constant only, it is possible to compute the mean meteoroid density ϱ_m by equalizing m_d with m_{ph}. The resulting value $\varrho_m = 0{\cdot}43$ gr/cm^3 (assuming $\Gamma = 1{\cdot}1$ and $A = 1{\cdot}21$) is close to the value obtained by Verniani (1965).

This simple assumption, that the difference of the maximum position in Fig. 1 from zero is completely caused by the constant $(\Gamma A)^3/\varrho_m^2$ is somewhat arbitrary especially with such non-regular distribution as in Fig. 1. There is no guarantee that equations (1) and (2), applied to the complete observational material with the same constants Γ, A, τ_{op}, ϱ_m, define the same physical value. But we can examine this problem by the following simple procedure:

We choose the exponents in equation (1) quite generally

$$\log m_d = X \log \varrho + Y(2 \log v) + Z(-\log (-dv/dt)) + U \,. \tag{3}$$

Thus the theoretical values of (3) corresponding to equation (1) are

$$X = Y = Z = 3 \,.$$

If m_{ph} defined by (2) has the same physical meaning as m_d, we have

$$\log m_{ph} = X \log \varrho + Y (2 \log v) + Z(-\log (-dv/dt)) + U \,. \tag{4}$$

The solution of (4) by the method of least squares, applied to the complete observational material, gives (c. g. s. system of units):

$$X = 0{\cdot}69, \; Y = -0{\cdot}13, \; Z = 1{\cdot}03, \; U = 11{\cdot}39, \; n = 1277.$$

(A few extreme values of $\log (m_{ph}/m_d)$ less than —2 and greater than 3 were omitted in this solution.)

The quadratic mean residuum for one case is $\sqrt{\sum \Delta^2/(n-4)} = \pm 0{\cdot}41$ for this solution. The distribution of residuals is shown in Fig. 2, where it is also evident that the least squares method was applied to superposed distributions of $\log (m_{ph}/m_d)$. The computed exponents X, Y, Z are too far from the theoretical value 3. There is a tendency to very little dependence of m_{ph} on ϱ, v, and dv/dt, which speaks for a smoothing process of applying simple theoretical distribution (least squares) to the multiple observed distribution.

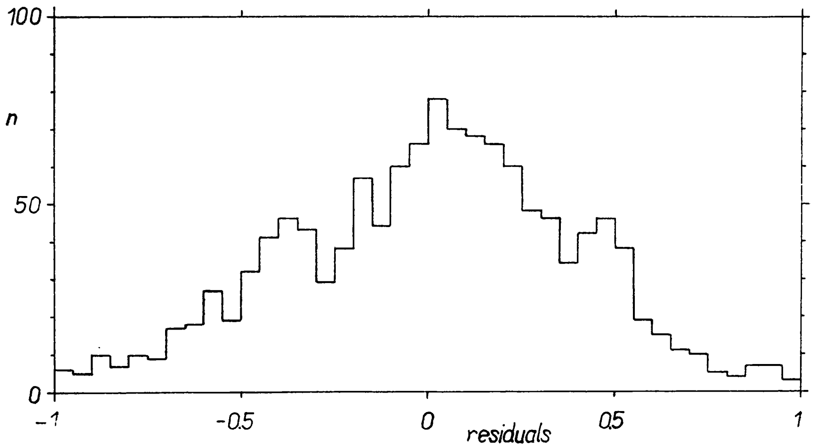

Fig. 2. Histogram of residuals of the least squares solution of equation (4) applied to the complete observational material of Jacchia-Verniani-Briggs meteors shows a superposition of more than one distribution.

The simple assumption that the difference of the maximum position in Fig. 1 from zero is completely caused by the constant $(\Gamma A)^3/\varrho_m^2$ (or U) is not valid. Thus the meteoroid density computed on this assumption ($X = Y = Z = 3$) from the complete material has no physical meaning.

3. k_B-parameter

Before a further detailed analysis of the results of chapter 2, we are obliged to explain some previously published results (Ceplecha 1966). The parameter k_B is defined by

$$k_B = \log \varrho_B + 2{\cdot}5 \log v_\infty - 0{\cdot}5 \log\cos z_R \,, \tag{5}$$

where B means that the values are to be computed for the beginning of the meteor. The velocity exponent 2·5 was verified using the McCrosky-Posen observational material (1961). In my paper (1966) three groups of meteors were found with different intervals of k_B and at the same time with different orbits. k_B was examined as a very good criterion speaking about the meteoroid composition (heat conductivity and density).

The distribution of k_B for the Jacchia-Verniani-Briggs Super-Schmidt meteors is presented in Fig. 3. It is of course not so good as for the extensive McCrosky-Posen material, but the results are principally the same: three groups of meteors can be separated: A-group with maximum at k_B interval 7·6, B-group with maximum at k_B interval 7·1, and C-group with maximum at k_B interval 6·9.

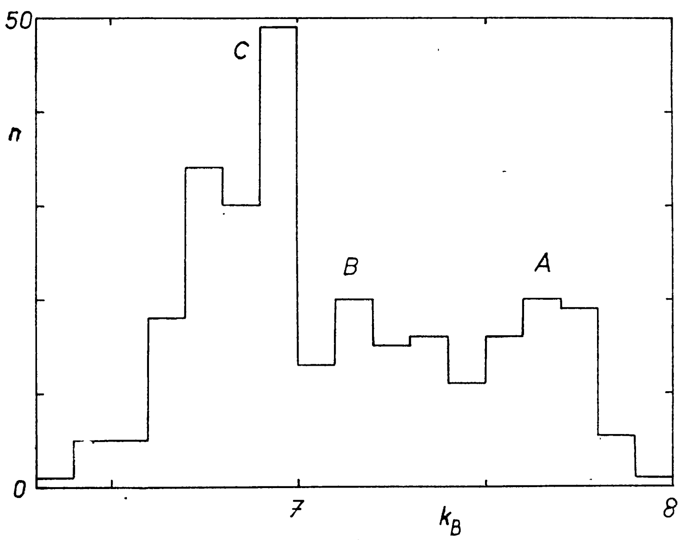

Fig. 3. Distribution of k_B-parameter for Jacchia-Verniani-Briggs sporadic meteors. The same statistical groups as previously found for the McCrosky-Posen sporadic meteors are evident. The distribution is similar to that for small camera meteors with predominant C-group.

It is interesting that the distribution of Jacchia-Verniani-Briggs bright Super-Schmidt meteors is much more similar to the distribution of the small camera meteors than to the McCrosky-Posen weak meteors. Especially the C-group is more extensive for the small camera meteors and for the Jacchia-Verniani-Briggs bright Super-Schmidt meteors than for the McCrosky-Posen weak meteors. This means that the greater brightness was the main criterion when 413 meteors were separated from the complete Super-Schmidt sample by Jacchia, Verniani and Briggs (1965). Thus the mean features derived from the Jacchia-Verniani-Briggs meteors are closer to the C-group features than in the case of McCrosky-Posen meteors.

The orbital element distribution of Jacchia-Verniani-Briggs meteors is in complete agreement with the results of my previous paper (1966). The spread in the distributions for individual groups is much less than it was for the McCrosky-Posen meteors, which corresponds to precise reductional methods and measurements used by Jacchia, Verniani and Briggs (1965). The distributions of orbital elements for sporadic meteors of Jacchia-Verniani-Briggs Super-Schmidt meteors are plotted in Figs. 4, 5, 6.

Thus the main results of my paper (Ceplecha 1966) fully agree with the results from Jacchia-Verniani-Briggs precisely reduced photographic meteors and can be briefly repeated:

The sporadic meteors can be separated into 4 groups. Three groups A, B, C can be separated using the k_B-parameter. The A-group has the greatest density, the C-group the smallest. The C-group can

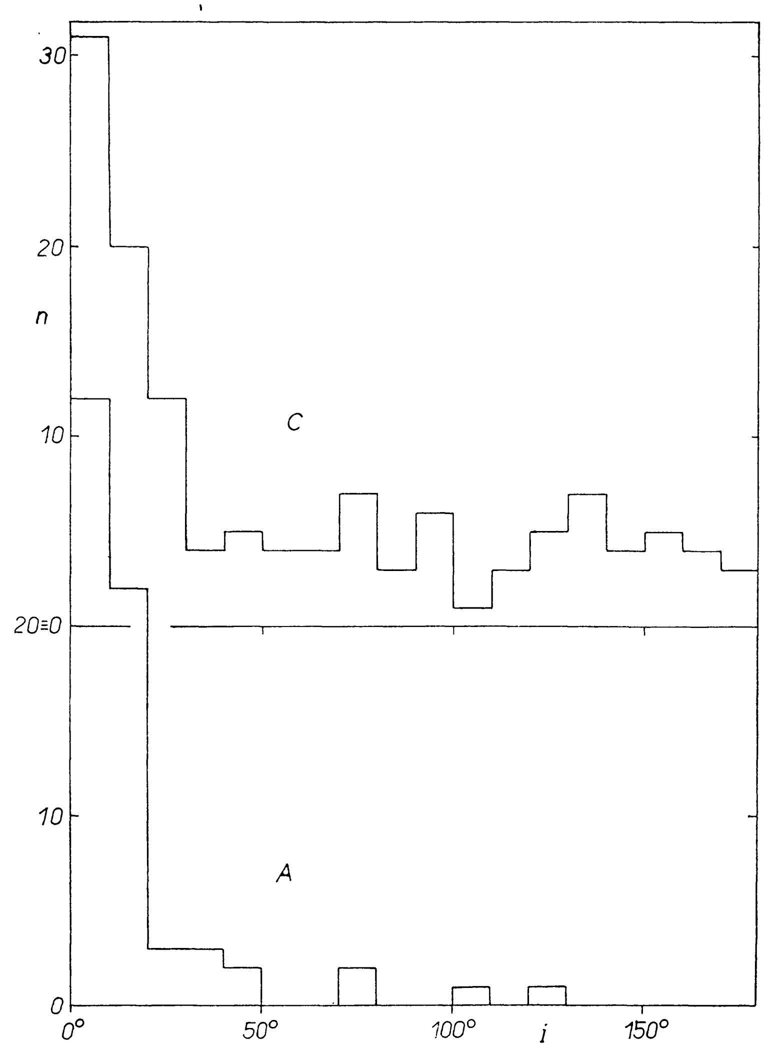

Fig. 4. Distribution of orbital inclination for the A-group ($k_B =$ $= 7{\cdot}50$ to $7{\cdot}79$) and for the C-group ($k_B = 6{\cdot}70$ to $6{\cdot}99$). If the C-group, which contains an enormous number of high inclined orbits, is divided into C_1-group with $i < 50°$ and C_2-group with $i \geqq 50°$, the double maximum distribution of the semi-major axis (Fig. 5) is separated into two distributions with a single maximum. Almost all orbits of the A-group are with $i < 50°$ (Jacchia-Verniani-Briggs sporadic meteors).

be further separated into C_1- and C_2-groups according to the semimajor axis and orbital inclinations. Characteristcis: The A-group: the greatest meteoroid density, short-period orbits with small eccentricities and ecliptical concentration. The C_1-group: the smallest meteoroid density, short-period orbits, but with longer semimajor axis and with greater eccentricities than the A-group, ecliptical concentration. The C_2-group: density identical with the C_1-group, long-period orbits with eccentricities near 1 and without any ecliptical or other concentration. The B-group: density between the A- and C-group, short-period orbits with great eccentricities and ecliptical concentration, small perihelion distan. ces.

4. k_B-parameter and $\log(m_{ph}/m_d)$

The results of chapter 2 point to the possible existence of different statistical groups in the distribution of $\log(m_{ph}/m_d)$. If such groups have something to do with the meteoroid composition, then there must be some correlation between the k_B-parameter and $\log(m_{ph}/m_d)$, which are independant values computed from different observational data. The observed values of k_B and $\log(m_{ph}/m_d)$ are plotted in Fig. 7. as the x and y axes. Though there is large scatter especially in the y-axis, the dependence of $\log(m_{ph}/m_d)$ on k_B is evident. Thus $\log(m_{ph}/m_d)$ can be considered as a similar criterion of meteor composition as k_B. The greater scatter in $\log(m_{ph}/m_d)$ is evidently caused by more observational values contained in $\log(m_{ph}/m_d)$ than in the simple definition of k_B. The deceleration contained in (1) is probably the main reason of the great scatter. As $\log(m_{ph}/m_d)$ and k_B are completely independent, Fig. 7 and Fig. 8 are a good verification that there exist groups of meteoroids of different composition.

Now if we connect the k_B-groups of Fig. 3 with the $\log(m_{ph}/m_d)$-groups evident in Fig. 7, we can define the following areas of the groups

Table 1

Interval / Group	k_B	$\log(m_{ph}/m_d)$	Number of points inside
A	7·40 to 7·79	−0·20 to −0·79	46
B	7·00 7·39	−0·09 0·49	67
C	6·60 6·99	0·80 1·49	343

The values inside the given intervals have the greatest probability that they belong to the corresponding group of composition as defined by the k_B-parameter only. If we now apply the least squares solution to equation (4), using the points contained inside the intervals given in Table 1, we have the results:

Table 2

Group	X	Y	Z	U	n	ε
A	2·65 ±0·20	2·67 ±0·26	2·61 ±0·15	−1·00 ±1·38	46	±0·15
B	2·24 ±0·22	2·01 ±0·32	2·35 ±0·23	3·27 ±1·81	67	±0·12
C	2·06 ±0·02	1·65 ±0·03	2·27 ±0·02	6·77 ±0·15	343	±0·21
Complete material	0·69 ±0·04	−0·13 ±0·06	1·03 ±0·03	11·39 ±0·48	1277	±0·41
Theoretical values	3	3	3	—	—	—

We see that the values are much closer to the theoretical value and that the mean quadratic error (residuum) of one observation is substantially less than it is for the complete material. This is a good verification that a substantial part of the discrepancy between the dynamic and photometric mass is caused by the superposition of at least 3 different distributions evidently belonging to groups of different meteoroid composition and density.

The resulting exponents X, Y, Z are much closer to the theoretical values for the solution inside the defined composition groups A, B, C than for the solution of the complete material. But there still remains a difference from the theory, which could be explained as deviations from the simple theoretical equations (1) and (2). It is quite to be expected that neither equations (1) or (2) fit the observations quite exactly. The complicated process of light emission is only very roughly approximated by equation (2). The same holds for the drag equation (1). It is interesting that the deviations from the simple theory of a single body increase from A- to the C-group. The density of the meteoroid decreases from the A- to the C-group, thus we see that denser particles give better agreement with the single body theory.

5. *Verniani's results on meteoroid density*

Verniani (1965) on page 145 uses relation (11) for computing the ratio τ_p/ϱ_m^2. As also Verniani writes, he admitted the equality of the dynamic

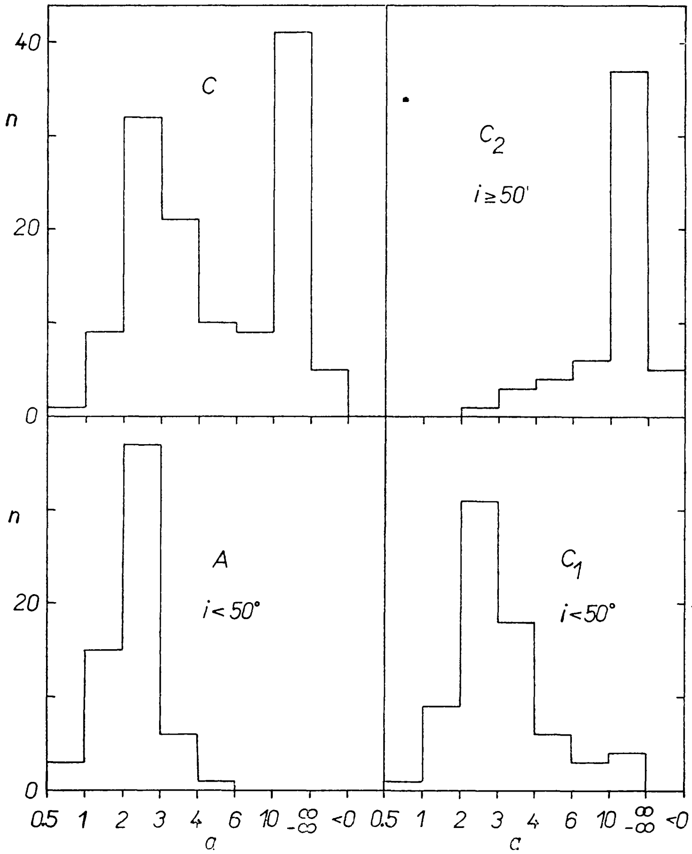

Fig. 5. Distributions of semi-major axis show clearly the difference of orbits of groups defined by the k_B-parameter. Maximum for the A-group is $a = 2·3$ a. u., for the C_1-group 2·8 a. u., and for the C_2-group between 10 a. u. and ∞. The separation of the C-group into C_1-group and C_2-group by the inclination corresponds well to the separation of the two maxima of the C-group a-distribution. (Jacchia-Verniani- Briggs sporadic meteors.)

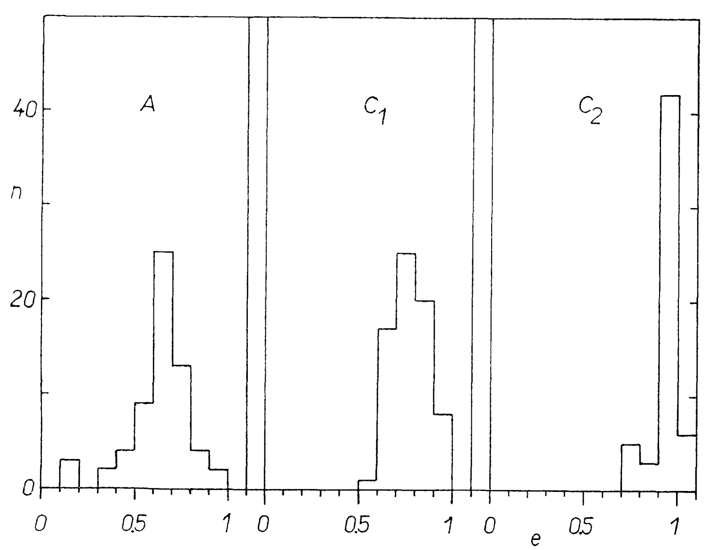

Fig. 6. Distributions of eccentricity for the groups defined by the k_B-parameter (Jacchia-Verniani-Briggs sporadic meteors).

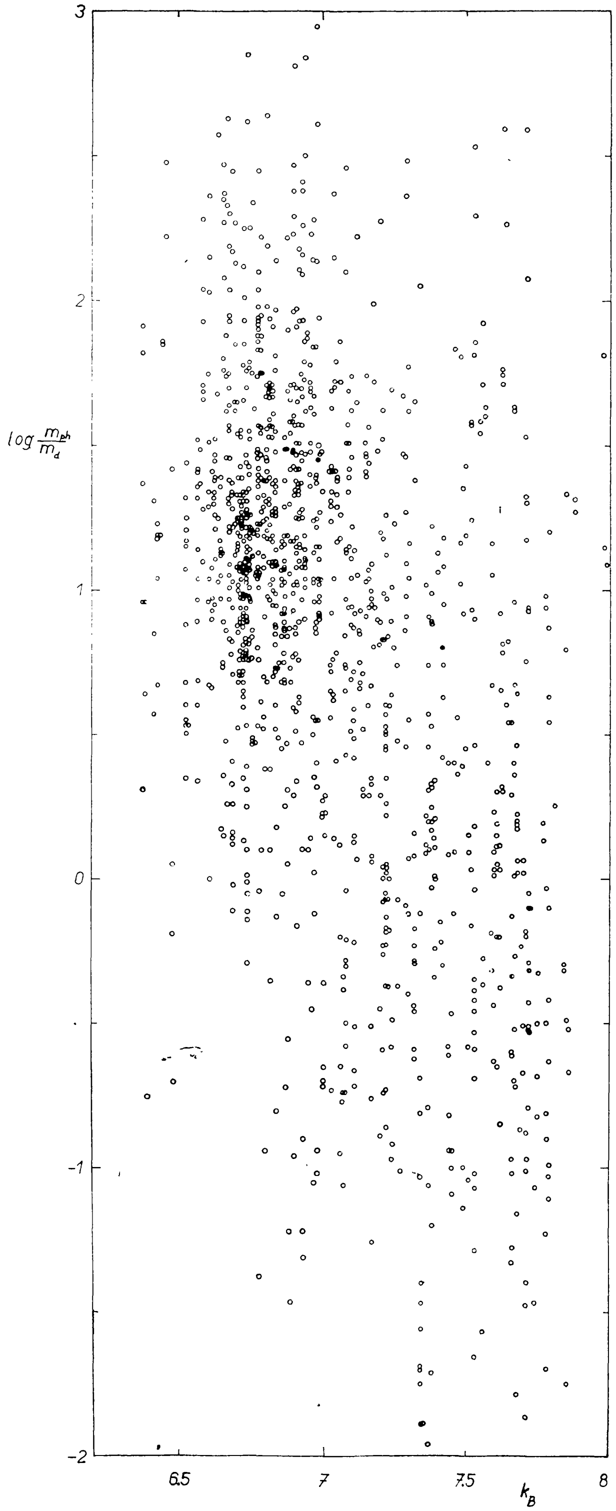

Fig. 7. All observed values of $\log (m_{ph}/m_d)$ are plotted against the observed values of the k_B-parameter. The dependence of these a priori independent values is evident, thus the difference of the photometric and dynamic meteor mass is a function of the k_B-parameter (i. e. also of the meteoroid density). The great scatter in the direction of $\log (m_{ph}/m_d)$ is evidently caused by more observational values (namely $\log (\mathrm{d}v/\mathrm{d}t)$) contained in the computation. The simple definition of the k_B-parameter is the reason for the substantially smaller scatter of these values. (All meteors published by Jacchia, Verniani, and Briggs; one meteor is represented by more points, if independent data on deceleration were published).

and photometric mass in deriving this equation. He writes also that this assumption is not right. But he assumed that the only effect, which causes the difference in the computed dynamic and photometric mass, is the fragmentation, and he believes that such effect can be eliminated by using the Jacchia's fragmentation index χ.

But this is a very special assumption based on theoretical discussion only. As it has been shown in previous chapters directly on the observational material (the same as used by Verniani), the equality of the dynamic and photometric mass is a quite inadmissible assumption not only due to the constant term containing the meteoroid density but also due to the different exponents at ϱ, v, $\mathrm{d}v/\mathrm{d}t$ than the theoretical ones.

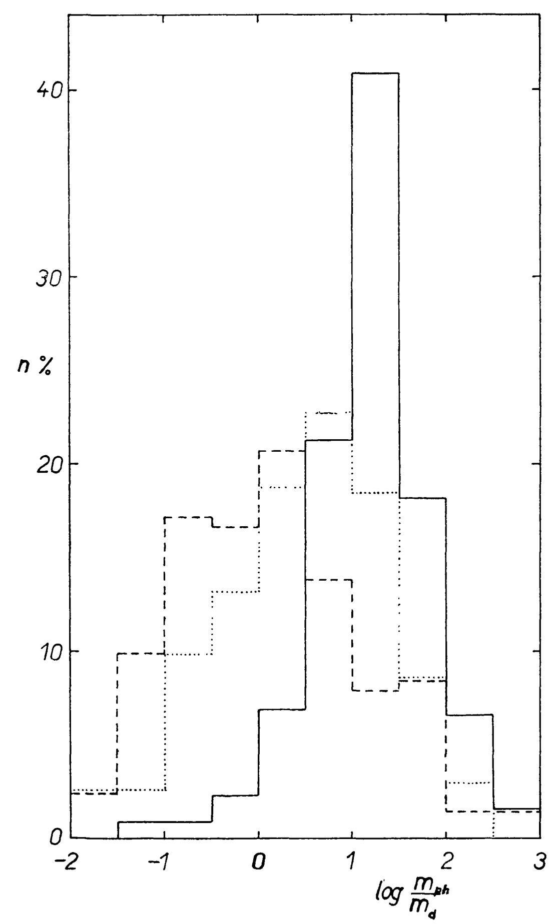

Fig. 8. The percentage distribution of $\log (m_{ph}/m_d)$ for different k_B-groups. — — — — A-group ($k_B = 6{\cdot}60$ to $6{\cdot}99$); . . . . . . B-group ($k_B = 7{\cdot}00$ to $7{\cdot}39$); ———— C-group ($k_B = 7{\cdot}40$ to $7{\cdot}79$). The fact that the difference of the photometric and dynamic mass continuously decreases with the increasing value of k_B is evident beyond any doubt. (All meteors of Jacchia-Verniani-Briggs).

Thus Verniani's equation (11) is not valid at all and cannot be used to obtain any reliable results. The discussion of the equalization od dynamic and photometric mass is made only theoretically by Vernian without any direct examination of this problem on the observational material. It is quite clear that for statistical discussions it is better to use the dynamic and photometric mass directly, than any other combined value computed with theoretical exponents and on assumption of equality of these two masses. Such a value is even τ_p/ϱ_m^2 used by Verniani.

6. *Verniani's criticizm of my results on the luminosity-equation velocity-exponent*

I agree with Verniani (1965 page 143) that the values of the velocity exponent in the luminosity equation derived by Ceplecha (1958) and Ceplecha, Padevět (1961) are not real. The same problem as discussed in this paper is contained in previous results: it is the computation of any real value of the meteor mass. But the value of the velocity exponent derived by Verniani using equation (11) on page 145 (1965) is also not real according to the results of this paper. It contains a mixture of exponents of ϱ, v, dv/dt in the drag equation and of v in the luminosity equation. The deviations of these exponents from the theoretical values are the reason that the value $n = 1$ computed by Verniani is of the same order of "precision" as my previous values of n.

I briefly mention the seven points, in which we were criticized. I use the same notation as in Verniani's paper (1965).

1. I use the theoretical relation between the intensity at maximum light I_m and the mass outside the atmosphere after a statistical verification of this relation by the same observational material (Ceplecha 1958, Fig. 7).
2. The relations of Levin (1956) have nothing to do with that of Herlofson (1948).
3. I completely agree with this point. The elimination of meteor mass by the theoretical equations, I used, was the main source of the resulting unreal values. The fragmentation is not the only cause, but the assumption of equalization of the dynamic and photometric mass is again passed over in silence. This is not correct.
4. I did not use any measured deceleration in the computations.
5. and 6. I completely agree.
7. I did not use any published value of meteor mass, but I use directly the meteor maximum magnitudes. There is a principal disagreement between point 3. and point 7. of the criticism: 3. speaks about elimination of the meteor mass and 7. speaks about the use of the published meteor masses.

7. *Meteoroid densities*

We have now two methods of computation of the meteoroid mean densities. First Verniani's equation (11) (1965 page 145b), which corresponds to the assumption of the equalization of dynamic and photometric mass. But we see that the theoretical exponents of this relation (11) do not fit the complete observational material used by Verniani. If three different statistical groups A, B, C are used, the computed exponents are much closer to the theoretical one. There is of course the possibility of computing the density separately for these groups A, B, C using the least squares solutions. But still there is a discrepancy in the exponents, and if one wishes to keep the physical meaning of the absolute term U containing the density, one must use some transformation of the computed exponents X, Y, Z to the theoretical value, which is equal 3. This, and the great scatter of the computed ratio of the dynamic and photometric mass, are the reason that the results for the groups A, B, C separately, are still doubtful. Any direct comparison with data on a body of known density is also lacking.

The second method is the application of the k_B-parameter. In comparison with the first method, k_B-values have substantially less scatter. A great advantage is also the possibility of the direct comparison of k_B-values of bodies of known composition with the k_B-values of other observed meteors. Thus the method of using the k_B-value for the estimation of meteor density seems to be more representative than the method of Verniani. Thus the values of the mean meteoroid densities for the asteroidal A-group $\varrho_m = 4{\cdot}0$ gr/cm^3, for the B-group $\varrho_m = 2{\cdot}2$ gr/cm^3, and for the cometary C-group $\varrho_m = 1{\cdot}4$ gr/cm^3 estimated from the k_B-values (Ceplecha 1966) are probably much closer to reality than the value $\varrho_m = 0{\cdot}25$ gr/cm^3 computed by Verniani as the mean value for all the observed meteors.

Acknowledgements

The numerical computations were made using the ZUSE Z-23 electronic digital computer of the State Institute of Heat Engineering in Prague. The numerical data for the computer were kindly prepared by Miss M. Ježková.

List of mathematical symbols

m_d dynamic mass of the meteor (equation (1))
m_{ph} photometric mass of the meteor (equation (2))
Γ drag coefficient
A shape factor ($A = (9\pi/16)^{1/3}$ for the spherical shape)
ϱ_m meteoroid density
v meteor velocity
τ_{op} coefficient of the luminous equation
I_p photographic luminous intensity of the meteor
h height of the meteor
ϱ air density
X, Y, Z exponents of the drag equation (see definition (3))
U absolute term of equation (3)
n number of observations (in chapter 6: exponent $\tau_p = \tau_{op} v^n$)
k_B parameter defined by equation (5) is function of meteoroid density, heat conductivity and capacity
z_R zenith distance of the radiant of the meteor
ε mean quadratic error of one observation

Suffices:

B beginning of the meteor
E end of the meteor
∞ no atmosphere value

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THE INFLUENCE OF DIFFUSION ON THE RADIO DETERMINATION OF METEOR VELOCITIES

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The influence of diffusion on the determination of a meteor velocity by the diffraction method has already been discussed by Kaiser (1953), Kaščejev and Lebedinec (1961) and Dudnik, Kaščejev and Lebediněc (1962). The two sides arrived at somewhat different conclusions by insufficiently detailed analyses of this problem. Here it is shown that if the first maximum on the diffraction characteristic is neglected when evaluating the meteor velocity and if this characteristic is so long that it contains at least two minima, then the mean value of the error in the velocity does not exceed $\pm 4\%$ for values of $\nabla \leqq 2$.

Влияние диффузии на определение скорости метеоров радиолокационным методом. Влияние диффузии на определение скорости метеоров методом дифракции обсуждалось уже раньше Кайзером (1953), Кащеевым и Лебединцем (1961) и Дудником, Кащеевым и Лебединцем (1962). Обе стороны пришли не очень подробным анализом этой проблемы к несколько отличающимся заключениям. В настоящей работе показано, что если при обработке скорости метеора пренебречь первым максимумом на характеристике дифракции и когда эта характеристика настолько длинная, что содержит по крайней мере два минимума, то среднее значение ошибки определенной скорости не превысит $\pm 4\%$ для значения $\nabla \leqq 2$.

1. Introduction

In determining the velocities of meteors by the diffraction method the measurements are hampered by a series of errors. The influence of instrumental errors has already been discussed (Šimek 1966). Here we should like to deal with the influence of the diffusion coefficient on the form of the diffraction characteristic. It is one of the main factors causing a change in position of the extremes on Fresnel's characteristic and thus also an error in determining the velocity. This problem has already been dealt with by Kaiser (1953), Kaščejev and Lebediněc (1961), Dudnik, Kaščejev and Lebediněc (1962) and others. The above-mentioned authors solved this case for parallel polarization and $\alpha < 2{\cdot}4 \times 10^{12}$ el.cm^{-1}.