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# THE STATISTICS OF METEORS IN THE EARTH'S ATMOSPHERE

*by* Gerald S. Hawkins *and* Richard B. Southworth


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# The Statistics of Meteors in the Earth's Atmosphere

By Gerald S. Hawkins[1] and Richard B. Southworth[2]

The heights of occurrence and the velocities of meteors in the atmosphere are of considerable interest to workers both in pure research and in technical problems of the upper atmosphere. From such studies we not only learn facts relating to astronomy and the physics of the upper atmosphere, but we also establish values of some of the environmental parameters above the stratosphere. Numerous data have been collected at Harvard College Observatory from photographic programs using conventional cameras and the Baker Super-Schmidt cameras, and the data have been analyzed by Whipple (1943, 1954), Whipple and Jacchia (1957a), and others. Previous work emphasized the measurement of the deceleration of the meteoroid, both to obtain accurate orbits and to estimate the density of the upper atmosphere. Since this emphasis might possibly have biased the sample of reduced meteors in favor of the longer, brighter trails, we decided to analyze a random sample of about 300 trails by an accurate reduction method.

Before presenting the results of the analysis, it is convenient to summarize contemporary meteor theory to provide a background for interpreting the meteor statistics.

### Basic theory of the meteoric processes

Basic meteor theory as it exists today results from the work of a number of people, including particularly Marris, Sparrow, Hoppe, Öpik, and Whipple (see Whipple, 1943).

Let us suppose that a meteoroid of mass $m$, irregular dimensions, and internal density $\rho_m$, enters the upper atmosphere with velocity $v$. Because of the high velocity, the kinetic energy of the incoming body exceeds the internal energies necessary to pulverize, melt, or vaporize the material.

Air particles are trapped momentarily on or near the surface of the meteoroid, imparting to it the energy of collision and decreasing its forward momentum. The air particles are given a forward velocity while the meteoroid suffers a deceleration, $dv/dt$, so that by the principle of conservation of momentum we may write

$$m\frac{dv}{dt}=-\Gamma S\rho v^2, \tag{1}$$

where $\rho$ is the density of the atmosphere, $\Gamma$ is the drag coefficient and $S$ is the effective cross-sectional area of the meteoroid. It is convenient to eliminate one variable from this equation by expressing the cross section as a function of the mass $m$. If, for example, the meteoroid were a sphere of density $\rho_m$, the cross sectional area $S$ could be written,

$$S=\left(\frac{9\pi}{16}\right)^{1/3}\rho_m^{-2/3}m^{2/3}. \tag{2}$$

In general, the meteoroid will be an irregularly shaped object, and we must replace the $(9\pi/16)^{1/3}$ by a general dimensionless shape factor $A$ which for bodies of simple shape, such as cones, ellipsoids, and short cylinders, is of the order of unity. With this transformation we can establish the first fundamental equation in the meteor theory, the drag equation:

$$\frac{dv}{dt}=-\Gamma A\rho_m^{-2/3}m^{-1/3}\rho v^2. \tag{3}$$

From the principle of the conservation of energy we may equate the energy imparted by

[1] Boston University and Harvard College Observatory.
[2] Harvard College Observatory.

the colliding particles to the energy required for ablation (vaporization, melting, or fragmentation) of the meteoroid, since the kinetic energy lost by deceleration of the meteoroid is negligible. Thus

$$\zeta \frac{dm}{dt} = -\frac{1}{2}\Lambda A \rho_m^{-2/3} m^{2/3} \rho v^3, \tag{4}$$

where $\zeta$ is the energy required to ablate one gram of the meteoroid and $\Lambda$ is the efficiency of the energy exchange. The second fundamental equation, the mass equation, is obtained by dividing equation (4) by equation (3), which gives

$$\frac{1}{m}\frac{dm}{dt} = \frac{\Lambda}{2\Gamma\zeta} v \frac{dv}{dt}. \tag{5}$$

The material ablated from the surface of the meteoroid collides with the particles of the atmosphere with the forward velocity $v$, and hence each meteor atom has a kinetic energy of from 100 to 1000 electron volts. This energy is sufficient to ionize and excite the air particles with consequent emission of light. If the fraction of the kinetic energy converted into light is $\tau$, then the luminous intensity $I$ may be expressed as

$$I = -\frac{1}{2}\left(\frac{dm}{dt}\right) v^2 \tau. \tag{6}$$

Similarly, if $\beta$ is the probability that an evaporated meteor atom will produce an ion pair, then the number $q$, of ion pairs per cm of track, is given by the expression,

$$q = -\frac{dm}{dt}\frac{1}{v}\frac{\beta}{\mu}, \tag{7}$$

where $\mu$ is the mean mass of an evaporated atom.

Thus we have four basic equations in the meteor theory, equations (3), (5), (6), and (7), with mass, velocity, and time as three variables. There are six unknown quantities, $\Gamma$, $\Lambda$, $\rho_m$, $\zeta$, $\tau$, and $\beta$, which are approximately constant. Two of the variables, $v$ and $t$, can be evaluated observationally, but $m$ at present is unknown. From the four equations we can evaluate three additional quantities, and this represents the crucial problem facing meteor theory at present. We choose to evaluate the following groups of constants: $\tau/\rho_m^{2/3}(\Gamma A)^3$, $\Lambda/2\Gamma\zeta$, $\tau/\beta$. To evaluate $\tau/\rho_m^{2/3}(\Gamma A)^3$, we use the fact that the mass at time $t$ is given by integrating equation (6) from $t$ to $t_e$ (the end of the meteor); and on substituting this value of $m$ in the drag equation, we find that

$$\frac{\tau}{\rho_m^{2/3}}(\Gamma A)^3 = -2\left(\frac{1}{\rho v^3}\frac{dv}{dt}\right)^3 \int_t^{t_e} \frac{I}{v^3}\, dt. \tag{8}$$

In practice, $v$ is found to be approximately constant and may be brought outside the integral sign. The intensity $I$ is found from the estimated visual magnitude $M_v$ from the expression given by Öpik (1937):

$$M_v = 24.6 - 2.5 \log_{10} I. \tag{9}$$

The quantity $\sigma = \Lambda/2\Gamma\zeta$ is found in a similar way by inserting $m$ and $dm/dt$ in the mass equation:

$$\frac{1}{\sigma} = \frac{2\Gamma\zeta}{\Lambda} = -\frac{v}{I}\frac{dv}{dt}\int_t^{t_e} I\, dt. \tag{10}$$

To express $\tau/\beta$ in terms of measured quantities, we eliminate the mass between equations (6) and (7) obtaining the relation, $I = qv^3\mu\tau/2\beta$. Substitution for $I$ in equation (9) yields the radar-magnitude relationship

$$M_v = 80.35 - 2.5\,(3\log_{10} v + \log_{10}\frac{\tau}{\beta} + \log_{10} q) \text{ (c.g.s. units)} \tag{11}$$

from which $\tau/\beta$ can be found.

For computational work and for theoretical reasons it is useful to develop subsidiary equations from the basic theory. For example, we may eliminate $dm/dt$ between equations (6) and (4), to obtain the intensity equation, which expresses the intensity of light as a function of air density and meteor velocity:

$$I = \frac{\Lambda A m^{2/3}}{4\zeta \rho_m^{2/3}} \tau \rho v^5. \tag{12}$$

By logarithmic differentiation we may then determine the air density, $\rho_{max}$, at which the meteoroid attains its maximum luminosity:

$$\rho_{max} = \frac{\rho_m^{2/3} m_{max}^{1/3} \cos Z_R}{5H\Gamma A\left\{\frac{\Lambda v^2}{15\Gamma\zeta} + 1\right\}}. \tag{13}$$

It will be noticed that the differential $d\rho/\rho dt$ has been evaluated by assuming an isothermal atmosphere with a scale height $H$, and that the meteor enters the atmosphere at an angle $Z_R$ to the vertical with negligible deceleration. Since $\Lambda v^2/15\Gamma\zeta \gg 1$, equation (13) simplifies to the form,

$$\rho_{max}=\frac{3\rho_m^{2/3} m_{max}^{1/3} \zeta \cos Z_R}{\Lambda H A v^2}. \quad (14)$$

We may express the mass of the meteor in terms of its height $h$ in the atmosphere and its mass $m_\infty$ outside the atmosphere by integrating equation (4):

$$m^{1/3}=m_\infty^{1/3}+\frac{\Lambda A v^2}{6\zeta\rho_m^{2/3}\cos Z_R}\int_{+\infty}^{h}\rho dh. \quad (15)$$

Evaluating the integral by assuming an isothermal atmosphere, and substituting for $\rho_{max}$ from equation (14), we may deduce the simple relationship

$$m_{max}=\frac{8}{27}m_\infty. \quad (16)$$

The intensity of a meteor is given a simple formulation if an isothermal atmosphere is again assumed and $\rho_{max}$ is substituted in the intensity equation. By neglecting deceleration it can be shown that

$$\frac{I}{I_{max}}=\frac{q}{q_{max}}\simeq\frac{9}{4}\frac{\rho}{\rho_{max}}\left[1-\frac{\rho}{3\rho_{max}}\right]^2. \quad (17)$$

Thus within the limits of the approximation, the normalized light curves of all the meteors are identical when plotted as a function of height, and are independent of velocity, angle of approach, and any physical characteristics of the meteoroid. The integrations involved in equations (12) to (17), of course, are not valid if the meteoroid explodes or produces flares of light along its path, which are frequent occurrences in the brighter photographic meteors, or where the atmospheric scale height varies with height.

It must be emphasized that the theory just outlined has been developed on the assumption of a single meteor body. Recent research has indicated that meteors are composed of collections of fine fragments (Jacchia, 1955), and the theory may require revision to account for the behavior of such conglomerates. In the extreme case of fragmentation, however, it can probably be stated that the above theory applies to each individual fragment, and can be extended to cover the case of a fragmenting meteor if account can be taken of all the individual particles.

### Selection and method of reduction

The meteors were selected from the Baker Super-Schmidt photographs taken from stations at Doña Ana and Soledad, New Mexico, from February 1952 to July 1954. These photographs form a homogeneous and fairly continuous record of the night sky, the major interruptions being caused by periods of moonlight. The principle of the classical decimation process was used to ensure the selection of a random sample, every tenth meteor being chosen for analysis. It was found that some 13 percent of the selected meteors had previously been reduced by Jacchia (unpublished), by the method of Whipple and Jacchia (1957b); these results, marked by an asterisk, have been incorporated in tables 1 and 2. Occasionally the "tenth" meteor selected by our system could not be used, because one of the trails had less than five measurable dashes, or because both images of the meteor cut the edge of the film. In such cases, amounting to less than 10 percent of the total sample, another meteor, immediately preceding (or immediately following) the original choice, was used as a substitute. A group of 13 meteors photographed between December 11 and December 13, 1952, was omitted from the analysis as they were thought to be members of the Geminid stream which is adequately represented in the sample. Careful inspection later showed that 10 of these meteors were actually Geminids. The omission of the three non-Geminids, of course, will bias the sample to some small extent.

The original sample comprised 292 meteors. During the analysis, one of these was rejected when we found that the two photographic images were not of the same meteor. Subsequently, we reduced an additional 69 meteors, selected from the same films that recorded those first chosen. This process, of course, interferes with the original method of selection, but does not appreciably alter the essential ramdomness of the method. The total sample, therefore, contained 361 meteors.

The "short trail" method of reduction was used as described by Hawkins (1957).

### The data

The fundamental data for each meteor are summarized in table 1, which gives sporadic meteors, and table 2, giving meteors in the recognized streams. Meteors are listed in order of their time of appearance and the date is given in days and fractions of days in universal time. To obtain the time of appearance in local mean time at the Doña Ana Station, 0.29667 must be subtracted from the date given in the table. It should be remembered that 10 meteors have been omitted from table 2 (see page 351), with characteristics similar to the Geminid meteors already listed in that table; and that 3 other meteors have been omitted during the same period.

The various quantities appearing in the tables have the following probable errors:

Date, universal time: ± 0.00001 (±1 second of time).

Height above sea level in km, $h$: ±0.5 km (uncertainty ± 1 shutter segment).

Apparent radiant, epoch 1950: ±7 minutes of arc.

Cosine of the angle between the observed apparent radiant and the zenith of Doña Ana Station, cos $Z_{AR}$: correct to 3 decimals.

Velocity corrected for the deceleration in the atmosphere in km/sec, $V_\infty$: the probable error is given individually. This error includes the effects of uncertainties in determining the radiant position and measuring the segments of the trail. It also takes account of the average shutter flutter to be expected and includes a term for the uncertainty introduced by adopting a standard value of $\sigma(= 10^{-11.3})$. No probable errors are given for the meteors previously analyzed by Jacchia, because these were long trails, of superior quality, for which the error in $V_\infty$ was less than 0.1 km/sec.

Maximum absolute photographic magnitude, $M_{pm}$: ±0.3. To obtain the absolute visual magnitude, an index varying between 1.8 for bright meteors and 1.0 for faint ones must be added to the photographic magnitude (Jacchia, unpublished).

$\Delta M$, the rise of the meteor magnitude above plate limit: ±0.2.

### Discussion

*Velocity distribution.* Figure 1 is a histogram showing the velocity distribution of all shower and sporadic meteors in our sample. The distribution is bimodal and shows a peak at a velocity of 22 km/sec and another at 67 km/sec. The minimum between 45 and 55 km/sec represents meteors in either of two types of relatively unlikely orbits. One type consists of retrograde orbits with small inclinations to the ecliptic and semimajor axes between 0.7 and 2.5. Orbits of this shape are rare in the photographic records and it is difficult to visualize a process by which meteors could be injected into these orbits, or move into them under the action of perturbations. The second type meets the earth's orbit nearly perpendicularly, and has a

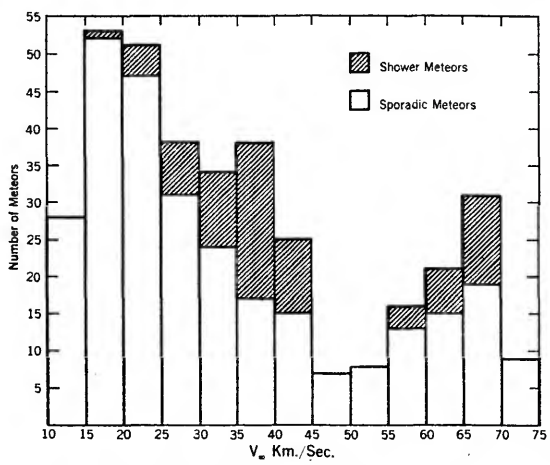


FIGURE 1.—Distribution of corrected velocities, $V_\infty$, for 285 sporadic and 74 shower meteors.

semimajor axis between 2 and ∞. Meteors of this second group, which also have radiants near the ecliptic, are almost linear oscillators and the probability is high of their colliding with the sun or the outer corona.

Shower meteors have been indicated separately in the diagram; they clearly tend to be concentrated in two ranges, between 25 and 45 km/sec and between 55 and 70 km/sec. These effects are caused in part by the Geminid stream with a mean velocity of 36.2 km/sec, and by the Orionid stream with a velocity of 67.7 km/sec. There is a noticeable dearth of showers with a velocity less than 25 km/sec. The velocity distribution determined photographically here differs to a small extent from the distribution that may be deduced from the published results of brighter meteors (Whipple, 1954). The present analysis has been carried out to a fainter limiting magnitude, namely +4.5 visual, and there has been no attempt to select brighter meteors or those of longer

duration. The distribution shown here is therefore more representative of photographic meteors than previous results.

*Dependence of height on velocity.* From equation (14) it can be seen that the simplified theory predicts

$$\log_e \rho_{max}=\log_e\frac{K_1}{v^2}, \tag{18}$$

where

$$K_1=\frac{3\rho_m^{2/3}\zeta m_{max}^{1/3}\cos Z_R}{\Lambda HA}. \tag{19}$$

Now for an isothermal atmosphere,

$$\rho_{max}=\rho_0 e^{-\frac{h_{max}}{H}}, \tag{20}$$

and when we substitute for $\rho_{max}$ in equation (18),

$$h_{max}=H\log_e\rho_0-H\log_e\frac{K_1}{v^2}. \tag{21}$$

The mean height of beginning, maximum light, and end have been evaluated for various velocities and are shown in figure 2. From the atmosphere established by the Rocket Panel (1952) we may deduce that $H=6.38$

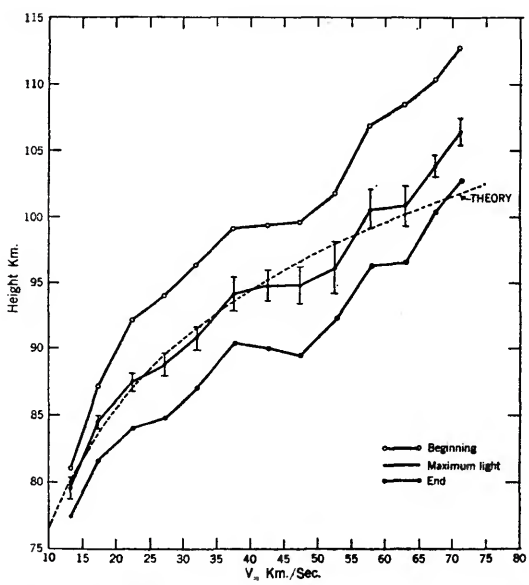


FIGURE 2.—Mean heights of beginning, maximum light, and end for sporadic meteors of various velocities. Broken line indicates theoretical height-curve.

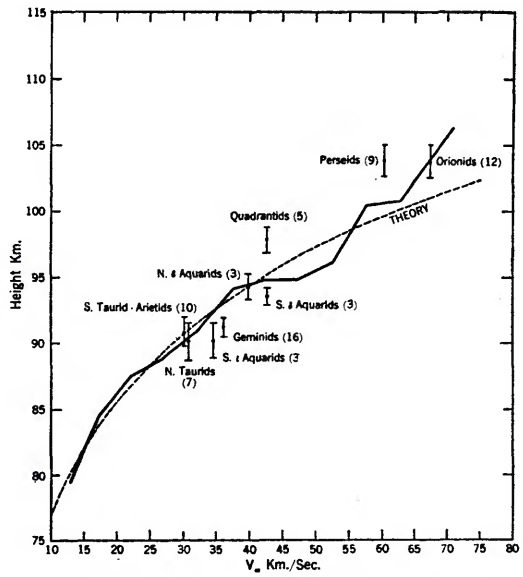


FIGURE 3.—Heights of maximum light for shower and sporadic meteors.

and $\log_e \rho_0=-5.128$. The constant $K_1$ cannot easily be evaluated in terms of the variables in equation (19), and so $K_1$ was adjusted numerically until the theoretical curve gave the best fit with the observations. The theoretical curve shown in figure 2 is obtained by adopting $\log_e K_1=-12.55$. There is obviously good general agreement between the theory and the observational data, although towards the high velocities, $V_\infty>60$ km/sec, the observed heights are somewhat greater than we would expect. This may indicate a difference in composition of the group of sporadic meteors having these velocities.

In figure 3, the height of maximum light of shower meteors has been compared with the height for sporadic meteors. It can be seen that the showers differ noticeably: the Quadrantids and Perseids appear about 5 km higher, and the Geminids, southern $\iota$ Aquarids and southern $\delta$ Aquarids some 3 km lower, than the corresponding sporadic meteors. These differences in heights have been attributed by Jacchia (1956a, 1956b) to differences in composition of the meteoroids.

*Relation between intensity and cos $Z_{AR}$.* If we substitute $\rho_{max}$ from equation (14) and

$m_{max}$ from equation (16) into equation (12), we find that

$$\log_{10} I_{max}=\log_{10}\left(\frac{2}{9}\frac{m_\infty v^3\tau}{H}\right)+\log_{10}\cos Z_{AR}. \quad (22)$$

Substitution for $I$ from equation (9) yields the expression

$$M+2.5\log_{10} m_\infty v^3=K_2-2.5\log_{10}\cos Z_{AR}, \quad (23)$$

where

$$K_2=22.9-2.5\log_{10}\left(\frac{2\tau}{9H}\right), \quad (24)$$

and where $\tau$, in equation (24), has the value assumed in computing $m_\infty$.

Thus we may check the dependence of the intensity of maximum light on the zenith angle of the radiant by plotting the quantity $M+2.5\log_{10} m_\infty v^3$ against $\log_{10}(\cos Z_{AR})$. In figure 4 these values have been plotted for all meteors. For comparison a straight line has been drawn having the gradient predicted by the theoretical equation (23). The scatter of individual points is wide, but the general tendency is in fair agreement with the predictions of theory.

*The theoretical light curve.* A simplified form of the normalized light curve is given in equation (17). If we substitute for the isothermal atmosphere from equation (20), and for the relation between intensity and magnitude from equation (9), we find that

$$\frac{2.303}{2.5}\left(M_{max}-M\right)=\log_e\frac{9}{4}+\frac{h_{max}-h}{H}+2\log_e\left[1-1\frac{1}{3}\exp\left\{\frac{h_{max}-h}{H}\right\}\right]. \quad (25)$$

In this analysis the magnitude of the meteor was measured at three points, the position of maximum light, and at the beginning and end of the trail when the magnitude of the meteor equalled the limiting magnitude of the plate, $M_{lim}$. Thus

At the beginning of the trail:
$h=h_B$, $M_{lim}-M_{max}=\Delta M$.
At the end of the trail:
$h=h_e$, $M_{lim}-M_{max}=\Delta M$.

It is therefore possible to check the theory by plotting $\Delta M$ against $h_{max}-h_B$ and against $h_{max}-h_e$. This has been done in figure 5 for

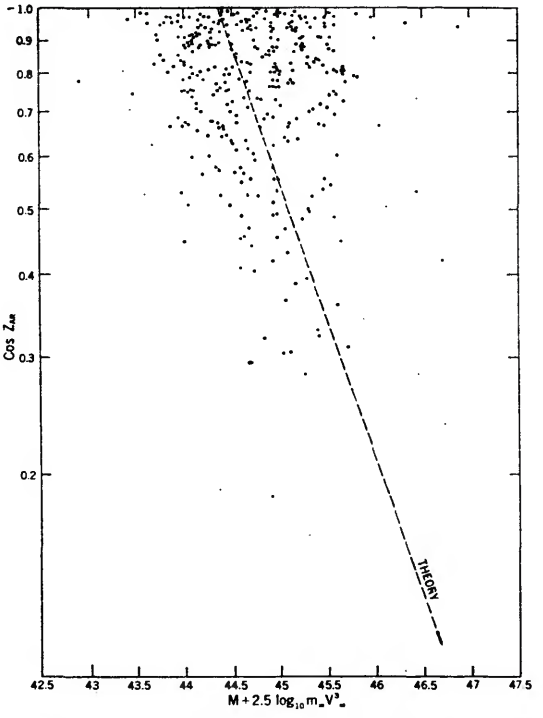


FIGURE 4.—Intensity of maximum light for all meteors, plotted against cos $Z_{AR}$. Straight line indicates gradient predicted by theory.

the beginning and end of each of the meteors measured in the present program; the theoretical light curve as given by equation (25) is shown for comparison. Almost all of the meteor measurements are seen to lie within the theoretical light curve, illustrating the fact that the length of a meteor trail is considerably shorter than that predicted by the theory. Jacchia (1955) has suggested that this discrepancy can be accounted for by the phenomenon of fragmentation of the meteoroid. The results of any investigations, such as the study of meteors by radar, which have been based on the validity of the normalized curve must therefore be treated with the utmost reserve.

**Acknowledgments**

The photographic equipment used for this work was constructed and operated under contracts with the Air Force Cambridge Research Center and the Office of Naval Research. A few of the meteors included in the sample for statistical homogeneity have been previously re-

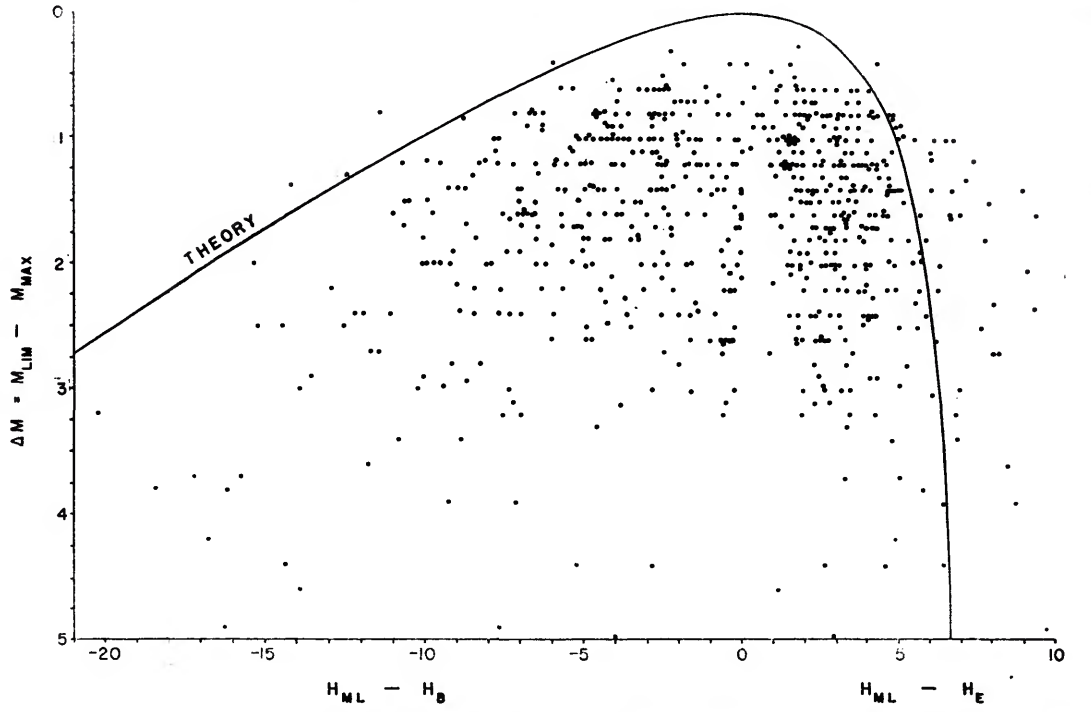


FIGURE 5.—Theoretical light curve compared with beginning and end points of observed light curves of meteors (see p. 354). Key: $H_{ML}$, height at maximum light; $H_B$, height at beginning of observed trail; $H_E$, height at end of observed trail.

duced by Dr. L. G. Jacchia under contract with the Office of Ordnance Research. Dr. F. L. Whipple has directed the entire program of the Meteor Department at Harvard College Observatory and his advice on details and general planning of the Short Trail Reduction Program has been greatly appreciated. The assistance of Miss F. W. Wright has been invaluable in organizing the classification of photographic plates and the search for meteor trails. Much of the measurement and reduction has been carried out by Mrs. M. E. Greber, Mrs. D. Underhill, Mrs. V. Krotkov, Mr. R. F. Kandel, Mr. R. S. Calusdian, and Mr. P. Asch. Dr. R. E. McCrosky has assisted in supervising the work of the program. The measurements, reductions, and final preparation of the data were supported jointly by the Army, Navy, and Air Force, under contract with the Massachusetts Institute of Technology.

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TABLE 1.—*Fundamental data for sporadic meteors*

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Maximum light ($h_{max}$) | End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 52 Feb 26.40208 | 94.6 | 86.7 | 85.3 | 164°33′ | +21°51′ | .908 | 22.1±.7 | +2.6 | 1.0 |
| 52 Mar 21.36111 | 99.6 | 93.2 | 91.3 | 205 52 | +58 48 | .906 | 23.9±.2 | +2.6 | 0.9 |
| 52 Mar 28.22500 | 92.2 | 89.3 | 86.7 | 267 21 | +70 46 | .484 | 24.2±.4 | +1.9 | 1.3 |
| 52 Mar 28.45222 | 99.8 | 93.7 | 90.0 | 274 3 | +22 36 | .864 | 52.5±.3 | +0.2 | 2.1 |
| 52 Apr 2.38125 | 93.9 | 90.5 | 85.7 | 261 47 | +58 5 | .809 | 30.1±.7 | +1.4 | 1.1 |
| 52 Apr 22.29792 | 95.7 | 88.6 | 86.9 | 219 12 | −11 0 | .732 | 31.5±.9 | +1.6 | 1.4 |
| *52 Apr 23.32587 | 105.4 | 94.8 | 89.6 | 266 5 | +42 47 | .811 | 40.8 | +1.3 | 1.5 |
| 52 Apr 26.28750 | 83.9 | 83.3 | 81.4 | 195 18 | −17 38 | .686 | 18.5±.3 | +1.1 | 2.2 |
| 52 May 19.21518 | 81.6 | 81.5 | 81.0 | 57 28 | +27 12 | .321 | 11.5±.2 | +2.2 | 1.3 |
| *52 May 21.36274 | 100.8 | 95.6 | 93.3 | 256 19 | −25 24 | .550 | 36.0 | +1.3 | 1.7 |
| *52 May 22.28093 | 85.7 | 83.0 | 77.0 | 219 36 | −9 40 | .779 | 17.3 | +2.2 | 1.1 |
| 52 May 24.35000 | 103.2 | 93.5 | 91.1 | 294 38 | +50 35 | .863 | 40.9±.3 | +1.0 | 1.6 |
| 52 May 31.38916 | 106.1 | 102.8 | 96.2 | 308 6 | +18 52 | .891 | 55.5±.3 | +0.9 | 1.3 |
| 52 Jun 17.36898 | 87.9 | 85.7 | 82.7 | 238 21 | +60 20 | .764 | 20.6±.2 | +0.1 | 2.2 |
| *52 Jun 21.42265 | 113.4 | 102.6 | 95.7 | 5 42 | +18 28 | .677 | 68.8 | −0.6 | 3.4 |
| 52 Jun 24.20301 | 87.2 | 83.7 | 78.4 | 257 49 | −10 25 | .727 | 21.0±.1 | +1.8 | 1.0 |
| *52 Jun 25.22215 | 101.3 | 87.4 | 86.2 | 278 5 | −10 22 | .632 | 30.4 | −1.6 | 4.6 |
| *52 Jul 24.34757 | 112.8 | 97.1 | 93.8 | 10 28 | +36 46 | .755 | 65.3 | −0.8 | 3.7 |
| 52 Jul 27.22387 | 87.2 | 85.5 | 82.8 | 297 34 | −2 17 | .795 | 24.4±.2 | +1.4 | 2.0 |
| 52 Jul 29.41137 | 111.8 | 104.7 | 95.9 | 14 2 | +45 27 | .915 | 58.4±.3 | −1.1 | 3.9 |
| *52 Aug 4.46209 | 92.3 | 92.1 | 87.1 | 262 9 | +74 52 | .488 | 28.2 | +0.5 | 2.5 |
| 52 Aug 16.32917 | 87.1 | 83.5 | 80.3 | 2 24 | −14 12 | .625 | 31.3±4.8 | +0.5 | 2.4 |
| *52 Aug 18.25543 | 103.7 | 96.4 | 93.2 | 273 28 | +65 37 | .781 | 31.0 | −0.3 | 3.0 |
| 52 Aug 18.44646 | 108.8 | 100.9 | 97.9 | 20 57 | +56 9 | .917 | 57.5±.3 | +0.7 | 2.0 |
| 52 Aug 21.23344 | 86.0 | 85.4 | 81.2 | 340 24 | −5 18 | .718 | 17.4±.5 | +2.0 | 2.0 |
| 52 Aug 22.20000 | 83.2 | 83.1 | 81.5 | 354 43 | +11 49 | .675 | 14.5±.3 | +1.5 | 2.0 |
| 52 Sep 12.11222 | 88.6 | 85.7 | 83.7 | 292 40 | +36 15 | .990 | 19.4±.5 | +2.5 | 0.8 |
| *52 Sep 14.23858 | 115.9 | 108.3 | 98.5 | 57 58 | +51 49 | .467 | 64.2 | −2.5 | 4.9 |
| *52 Sep 14.37389 | 92.4 | 84.9 | 80.6 | 2 30 | −15 41 | .665 | 25.0 | +0.3 | 3.2 |
| 52 Sep 16.33723 | 103.4 | 94.5 | 90.4 | 10 13 | +5 58 | .899 | 36.9±.8 | +0.5 | 2.2 |
| 52 Sep 16.33958 | 79.8 | 77.4 | 75.4 | 327 11 | −8 58 | .694 | 13.9±.3 | +3.0 | 0.8 |
| 52 Sep 17.47711 | 111.9 | 101.3 | 98.4 | 41 41 | +39 51 | .957 | 60.6±1.0 | +0.9 | 1.7 |
| 52 Sep 17.47750 | 103.5 | 99.8 | 97.6 | 90 12 | −15 9 | .578 | 59.3±2.1 | +1.3 | 1.0 |
| 52 Sep 19.23462 | 94.7 | 87.1 | 82.9 | 341 26 | −6 18 | .810 | 20.0±.8 | +2.0 | 1.7 |
| 52 Sep 20.28438 | 101.1 | 96.8 | 88.7 | 351 45 | −4 53 | .817 | 23.0±.2 | +0.9 | 2.3 |
| 52 Sep 20.29047 | 89.7 | 87.7 | 84.7 | 14 1 | −18 50 | .638 | 22.5±.2 | +2.3 | 1.0 |
| 52 Sep 20.37133 | 110.5 | 105.6 | 103.9 | 71 44 | +23 41 | .755 | 70.1±.5 | +1.0 | 1.0 |
| 52 Sep 25.17361 | 89.2 | 85.7 | 82.4 | 326 20 | +41 54 | .983 | 19.4±.3 | +1.4 | 1.7 |
| 52 Sep 25.17571 | 108.4 | 104.0 | 99.9 | 39 7 | +67 54 | .568 | 51.7±.2 | +0.8 | 1.4 |
| 52 Sep 25.36001 | 96.5 | 89.9 | 86.5 | 355 15 | +5 28 | .798 | 23.8±.2 | +2.5 | 0.8 |
| 52 Sep 25.36419 | 109.1 | 103.8 | 103.4 | 72 7 | +6 39 | .669 | 65.7±.7 | +1.1 | 1.1 |
| 52 Sep 25.47579 | 110.6 | 107.4 | 104.4 | 115 10 | −1 40 | .569 | 61.5±.3 | +1.7 | 0.6 |
| 52 Sep 26.33935 | 108.3 | 104.3 | 101.8 | 61 4 | +23 10 | .799 | 65.4±.5 | +1.8 | 0.8 |
| 52 Sep 26.43333 | 104.6 | 96.9 | 96.0 | 3 13 | +36 32 | .762 | 37.3±.7 | +1.7 | 1.0 |
| 52 Sep 27.30972 | 94.6 | 92.0 | 88.8 | 349 47 | +18 29 | .936 | 20.0±.2 | +2.7 | 1.2 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 52 Sep 27.43247 | 115.5 | 110.5 | 106.0 | 96°13′ | −2° 9′ | .616 | 68.7±2.0 | +0.9 | 1.2 |
| 52 Sep 28.33541 | 96.1 | 91.9 | 87.6 | 24 32 | −3 52 | .819 | 30.2±.4 | +2.3 | 0.8 |
| 52 Sep 28.33834 | 98.3 | 96.4 | 95.0 | 82 3 | +38 11 | .665 | 67.0±.3 | +1.6 | 0.4 |
| 52 Sep 28.48414 | 96.6 | 94.1 | 88.3 | 24 32 | +27 33 | .741 | 45.6±.4 | +0.9 | 1.9 |
| 52 Oct 9.19742 | 79.3 | 78.8 | 76.9 | 278 36 | +30 10 | .782 | 12.7±.2 | −0.2 | 3.2 |
| 52 Oct 9.19792 | 99.0 | 93.1 | 91.3 | 13 17 | +8 40 | .807 | 25.2±.2 | +1.9 | 1.2 |
| 52 Oct 12.33141 | 95.5 | 93.4 | 91.0 | 181 53 | +81 25 | .442 | 43.5±.2 | +1.7 | 0.8 |
| 52 Oct 13.27778 | 101.5 | 91.4 | 87.1 | 18 32 | +18 5 | .969 | 26.8±.3 | +2.2 | 1.7 |
| 52 Oct 14.26667 | 85.0 | 85.0 | 82.8 | 38 7 | +4 36 | .845 | 15.6±.7 | +3.3 | 0.7 |
| 52 Oct 14.34938 | 90.3 | 84.2 | 81.6 | 37 21 | −14 51 | .694 | 33.3±.2 | +0.7 | 2.6 |
| 52 Oct 14.35291 | 96.9 | 92.5 | 89.1 | 4 6 | +45 47 | .865 | 24.2±.3 | +2.3 | 1.0 |
| 52 Oct 16.21458 | 92.9 | 84.4 | 82.8 | 359 29 | −7 40 | .811 | 17.5±.4 | +2.6 | 1.3 |
| 52 Oct 16.33880 | 113.4 | 108.4 | 100.6 | 103 56 | +18 39 | .525 | 72.0±.2 | +0.1 | 1.8 |
| 52 Oct 17.40034 | 113.5 | 109.6 | 105.3 | 102 24 | +26 20 | .823 | 70.6±.4 | +1.0 | 1.6 |
| 52 Oct 19.38057 | 107.0 | 103.4 | 102.8 | 228 22 | +71 56 | .283 | 39.0±.1 | +2.0 | 0.8 |
| 52 Oct 19.44228 | 76.3 | 73.1 | 69.8 | 50 11 | −7 24 | .865 | 11.4±.2 | +2.3 | 1.8 |
| 52 Oct 19.44444 | 98.0 | 93.3 | 90.0 | 59 35 | +3 44 | .833 | 32.8±.3 | +1.4 | 2.6 |
| 52 Oct 19.44602 | 94.9 | 91.8 | 86.8 | 167 16 | +76 0 | .550 | 45.0±.2 | +0.0 | 2.2 |
| *52 Oct 21.27695 | 117.7 | 103.3 | 101.5 | 95 22 | +5 56 | .311 | 67.0 | −0.5 | 2.5 |
| 52 Oct 21.32905 | 95.3 | 93.3 | 89.6 | 52 43 | −9 34 | .736 | 38.9±.4 | +2.0 | 0.7 |
| 52 Oct 21.32940 | 87.7 | 86.0 | 84.7 | 22 37 | −10 27 | .753 | 18.1±.2 | +2.1 | 1.2 |
| *52 Oct 22.26372 | 118.9 | 109.8 | 107.1 | 104 15 | +26 32 | .306 | 70.6 | +0.1 | 1.9 |
| 52 Oct 22.33227 | 111.1 | 104.8 | 103.0 | 104 49 | +36 1 | .645 | 68.4±.3 | +1.4 | 0.8 |
| 52 Oct 23.49206 | 109.6 | 102.9 | 98.3 | 140 45 | +4 21 | .700 | 60.6±.5 | +0.7 | 1.6 |
| 52 Oct 23.49348 | 111.8 | 93.4 | 87.5 | 110 59 | +49 46 | .949 | 64.1±.2 | −1.0 | 3.8 |
| *52 Oct 24.27733 | 116.7 | 102.8 | 99.4 | 99 29 | +33 49 | .498 | 67.8 | −0.6 | 2.2 |
| 52 Oct 24.35000 | 84.3 | 82.6 | 81.0 | 21 23 | +0 34 | .778 | 20.7±.2 | +1.9 | 1.2 |
| 52 Oct 24.42292 | 89.5 | 83.9 | 81.1 | 61 3 | +34 54 | .973 | 36.2±.5 | +1.1 | 2.0 |
| 52 Oct 27.36228 | 102.9 | 94.2 | 90.3 | 102 32 | +74 27 | .689 | 50.3±.2 | +1.0 | 1.4 |
| 52 Oct 27.48226 | 108.3 | 103.4 | 97.8 | 130 46 | +60 0 | .838 | 58.6±.3 | −0.2 | 2.5 |
| 52 Nov 12.19033 | 91.0 | 81.8 | 78.6 | 342 10 | +22 5 | .903 | 15.6±.1 | +2.4 | 1.4 |
| 52 Nov 12.19349 | 89.8 | 85.8 | 83.8 | 339 51 | +22 26 | .908 | 14.4±1.0 | +2.3 | 0.7 |
| 52 Nov 12.26391 | 89.6 | 87.5 | 84.2 | 342 58 | +21 52 | .744 | 15.5±.4 | +2.2 | 0.7 |
| 52 Nov 15.41654 | 100.2 | 90.1 | 87.8 | 63 14 | −4 58 | .673 | 32.5±.1 | +1.4 | 1.4 |
| 52 Nov 18.50424 | 97.5 | 94.6 | 89.9 | 185 43 | +45 15 | .737 | 56.6±.2 | +1.1 | 1.4 |
| 52 Nov 20.33769 | 96.6 | 92.0 | 87.2 | 102 43 | +34 17 | .913 | 53.2±.3 | +2.1 | 0.8 |
| 52 Nov 21.37387 | 109.5 | 108.8 | 105.7 | 142 59 | +4 20 | .527 | 70.8±.9 | +0.7 | 1.2 |
| 52 Dec 9.26560 | 90.0 | 86.2 | 82.9 | 52 1 | +24 3 | .975 | 18.3±.2 | +1.6 | 1.6 |
| 52 Dec 9.26872 | 80.4 | 75.7 | 74.1 | 44 51 | +6 1 | .876 | 16.5±.1 | +1.4 | 2.0 |
| 52 Dec 10.22380 | 89.7 | 84.2 | 80.7 | 52 49 | +24 3 | .992 | 16.0±.2 | +2.5 | 1.4 |
| 52 Dec 11.18502 | 99.7 | 93.4 | 92.3 | 103 18 | +49 22 | .665 | 34.3±.2 | +1.9 | 1.1 |
| 52 Dec 14.25625 | 78.8 | 78.8 | 77.7 | 353 53 | +20 25 | .750 | 11.4±.9 | +1.8 | 1.6 |
| 52 Dec 14.51304 | 117.3 | 100.6 | 95.6 | 169 24 | +13 36 | .937 | 71.3±.3 | −1.6 | 4.2 |
| 52 Dec 14.51538 | 103.7 | 99.6 | 97.1 | 148 27 | +31 53 | .982 | 62.5±.5 | +1.8 | 1.2 |
| 52 Dec 16.50693 | 104.3 | 101.1 | 97.6 | 139 33 | −8 3 | .710 | 58.9±.4 | +1.9 | 1.1 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Maximum light ($h_{max}$) | End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 52 Dec 20.44578 | 89.3 | 89.1 | 83.5 | 100° 0′ | +27°10′ | .819 | 29.3±.2 | +0.8 | 2.1 |
| 53 Jan 13.29493 | 98.2 | 96.6 | 94.9 | 118 23 | +22 7 | .979 | 25.6±1.2 | +3.2 | 0.7 |
| 53 Jan 13.45089 | 94.6 | 82.5 | 79.6 | 122 57 | +41 48 | .825 | 27.0±.1 | +1.3 | 2.4 |
| 53 Jan 13.45411 | 91.0 | 85.8 | 79.3 | 122 22 | +33 11 | .801 | 27.6±.9 | −1.6 | 4.4 |
| 53 Jan 14.22500 | 85.8 | 82.5 | 77.7 | 125 29 | +38 58 | .868 | 21.4±.2 | +1.7 | 1.6 |
| 53 Jan 14.34632 | 108.4 | 98.3 | 94.7 | 140 44 | +5 34 | .882 | 47.8±.2 | +1.0 | 2.0 |
| 53 Jan 15.21244 | 92.8 | 81.4 | 76.2 | 65 17 | +19 18 | .955 | 16.0±.6 | +3.0 | 0.8 |
| 53 Jan 15.40959 | 98.0 | 97.2 | 94.1 | 111 36 | +34 37 | .840 | 22.3±.2 | +2.5 | 0.8 |
| 53 Jan 16.40208 | 110.3 | 106.8 | 105.1 | 154 58 | −26 3 | .530 | 57.1±1.1 | +0.6 | 1.8 |
| 53 Jan 16.40235 | 103.2 | 98.5 | 91.8 | 152 40 | +33 25 | 1.000 | 42.1±.5 | +1.7 | 1.0 |
| 53 Jan 17.20082 | 89.1 | 86.6 | 83.1 | 301 26 | +83 44 | .533 | 21.8±.2 | +0.6 | 2.7 |
| 53 Jan 19.19278 | 97.2 | 95.8 | 91.5 | 105 32 | +31 53 | .939 | 20.1±.2 | +2.4 | 1.2 |
| 53 Jan 19.42292 | 111.7 | 106.8 | 102.0 | 189 8 | +17 12 | .887 | 65.8±.6 | +0.6 | 1.8 |
| 53 Jan 19.42292 | 104.0 | 93.0 | 88.9 | 156 0 | +40 44 | .986 | 34.4±.4 | +2.0 | 1.6 |
| 53 Jan 21.37852 | 96.1 | 91.4 | 89.4 | 105 55 | +24 52 | .822 | 20.0±.2 | +2.7 | 0.8 |
| 53 Jan 21.47209 | 82.0 | 81.3 | 79.7 | 121 38 | +85 42 | .732 | 13.4±.3 | +2.5 | 1.0 |
| 53 Jan 21.47354 | 93.5 | 91.1 | 88.0 | 148 35 | +6 34 | .756 | 41.4±.4 | +0.8 | 2.0 |
| *53 Jan 23.38956 | 95.8 | 86.3 | 84.4 | 117 52 | +14 0 | .810 | 22.7 | +1.7 | 2.0 |
| 53 Jan 24.44375 | 87.8 | 86.4 | 84.6 | 121 6 | −20 11 | .432 | 16.9±.1 | +2.1 | 1.4 |
| *53 Feb 5.14883 | 102.2 | 93.4 | 88.6 | 147 15 | +12 27 | .486 | 31.7 | −0.1 | 3.4 |
| *53 Feb 10.27808 | 104.9 | 74.4 | 68.8 | 142 14 | +38 51 | .985 | 27.4 | −2.9 | 5.6 |
| 53 Feb 12.38367 | 91.6 | 87.5 | 84.2 | 167 34 | +24 44 | .989 | 29.8±.4 | +1.3 | 2.1 |
| 53 Feb 12.50846 | 101.6 | 87.7 | 85.7 | 219 22 | +19 49 | .976 | 61.0±.3 | −0.3 | 3.0 |
| 53 Feb 17.20441 | 98.0 | 92.0 | 89.5 | 147 0 | +9 42 | .799 | 25.0±.5 | +1.2 | 1.8 |
| 53 Feb 17.20626 | 89.5 | 89.2 | 82.9 | 162 54 | +26 12 | .753 | 26.6±.2 | −0.0 | 2.6 |
| 53 Feb 18.35000 | 96.5 | 86.6 | 84.7 | 154 38 | +17 43 | .956 | 24.1±.3 | +1.8 | 1.5 |
| 53 Feb 20.37820 | 82.0 | 81.7 | 80.4 | 156 37 | +1 7 | .855 | 14.2±.3 | +2.0 | 1.2 |
| 53 Feb 20.41300 | 96.7 | 93.3 | 90.8 | 185 3 | +3 59 | .880 | 34.9±.3 | +1.4 | 1.5 |
| *53 Feb 21.46448 | 108.0 | 94.5 | 90.4 | 254 53 | +8 53 | .690 | 64.4 | −0.6 | 2.9 |
| 53 Mar 12.17613 | 94.6 | 92.0 | 90.3 | 150 27 | −15 9 | .685 | 17.1±.7 | +1.8 | 1.0 |
| 53 Mar 12.27841 | 92.1 | 89.0 | 85.6 | 153 12 | +12 11 | .942 | 18.7±.2 | +2.5 | 0.6 |
| 53 Mar 13.29792 | 83.5 | 83.5 | 82.6 | 143 0 | −6 34 | .748 | 14.6±.3 | +1.6 | 1.6 |
| 53 Mar 13.29824 | 83.3 | 82.7 | 80.2 | 130 20 | +47 37 | .883 | 15.4±.3 | +0.6 | 2.6 |
| 53 Mar 13.37773 | 93.2 | 90.6 | 84.6 | 218 16 | +24 19 | .950 | 41.0±.3 | +1.6 | 1.4 |
| 53 Mar 14.16204 | 74.4 | 72.0 | 70.3 | 80 37 | +0 15 | .791 | 12.9±.3 | +2.6 | 0.6 |
| 53 Mar 14.34103 | 83.4 | 81.7 | 78.9 | 167 39 | −3 6 | .802 | 20.6±.2 | +3.1 | 0.3 |
| 53 Mar 14.44147 | 77.7 | 77.3 | 74.3 | 204 30 | +14 26 | .961 | 11.9±.2 | +1.9 | 1.8 |
| 53 Mar 14.44426 | 106.5 | 100.7 | 96.0 | 270 37 | +30 56 | .783 | 48.8±.4 | +0.9 | 1.4 |
| 53 Mar 14.44737 | 109.2 | 105.2 | 101.4 | 235 52 | −10 41 | .720 | 64.2±.7 | +1.3 | 1.2 |
| 53 Mar 18.33889 | 83.8 | 81.8 | 78.5 | 161 50 | +31 47 | .943 | 15.6±.2 | +0.1 | 2.8 |
| 53 Mar 18.33892 | 85.4 | 85.4 | 83.6 | 174 44 | −2 48 | .828 | 18.6±.4 | +1.2 | 1.9 |
| 53 Mar 18.44619 | 109.6 | 107.1 | 105.2 | 287 52 | +0 59 | .446 | 65.8±.5 | +1.0 | 1.2 |
| *53 Mar 19.31853 | 86.6 | 81.0 | 78.6 | 174 46 | +26 20 | .988 | 21.6 | +1.9 | 1.7 |
| *53 Mar 19.39518 | 99.8 | 87.4 | 82.7 | 172 12 | +20 1 | .821 | 24.7 | +2.1 | 1.3 |
| 53 Mar 20.42303 | 87.9 | 87.8 | 86.1 | 159 17 | −9 1 | .412 | 19.0±.3 | +2.2 | 1.0 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Maximum light ($h_{max}$) | End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 53 Mar 21.40029 | 94.5 | 90.1 | 84.0 | 183°43′ | +13° 0′ | .839 | 26.0±.2 | +2.1 | 1.0 |
| 53 Mar 21.40331 | 88.4 | 82.4 | 78.2 | 169 5 | +14 13 | .739 | 20.2±.2 | +2.5 | 0.4 |
| *53 Apr 4.17230 | 86.4 | 80.8 | 76.8 | 175 48 | +57 23 | .878 | 18.0 | +1.8 | 2.2 |
| *53 Apr 7.28372 | 103.9 | 93.7 | 86.7 | 218 22 | +7 54 | .819 | 32.7 | +0.0 | 3.0 |
| 53 Apr 7.35030 | 93.6 | 91.1 | 89.4 | 203 28 | −10 52 | .732 | 30.2±.3 | +2.1 | 0.5 |
| 53 Apr 9.29081 | 89.8 | 87.2 | 86.6 | 184 45 | +20 55 | .976 | 19.0±.4 | +2.4 | 0.8 |
| 53 Apr 9.35927 | 93.8 | 88.5 | 84.5 | 209 51 | +27 38 | .989 | 22.4±.2 | +3.0 | 0.6 |
| 53 Apr 10.24583 | 83.6 | 82.3 | 79.3 | 185 24 | +53 42 | .951 | 14.6±.7 | +3.1 | 1.2 |
| 53 Apr 11.14238 | 76.0 | 75.5 | 73.4 | 108 1 | +15 54 | .932 | 10.6±.3 | +2.8 | 1.4 |
| 53 Apr 11.22535 | 93.7 | 85.7 | 79.9 | 186 20 | +8 57 | .909 | 19.6±.8 | +2.0 | 2.0 |
| *53 Apr 11.34984 | 86.6 | 83.8 | 79.2 | 194 52 | +1 24 | .819 | 21.9 | −0.6 | 4.4 |
| 53 Apr 13.25625 | 96.2 | 91.9 | 87.1 | 212 58 | +33 27 | .928 | 25.9±.3 | +1.8 | 0.9 |
| 53 Apr 13.25916 | 99.1 | 96.3 | 94.9 | 224 22 | −15 34 | .525 | 37.0±.9 | +1.8 | 0.8 |
| 53 Apr 13.46416 | 109.9 | 102.2 | 98.2 | 282 5 | −7 8 | .720 | 66.7±1.6 | +0.7 | 1.1 |
| 53 Apr 14.28612 | 84.9 | 83.8 | 82.5 | 190 57 | +1 23 | .878 | 18.8±.3 | +2.2 | 1.2 |
| 53 Apr 15.24583 | 86.5 | 84.2 | 81.5 | 178 55 | −5 41 | .822 | 18.8±.9 | +2.1 | 1.2 |
| 53 Apr 15.24742 | 78.0 | 77.2 | 74.4 | 137 48 | +14 1 | .886 | 11.0±.3 | +3.4 | 0.9 |
| 53 Apr 15.35235 | 87.5 | 87.1 | 85.3 | 92 51 | +81 4 | .557 | 18.0±.3 | +2.2 | 0.8 |
| 53 Apr 15.45282 | 104.3 | 99.2 | 95.1 | 294 59 | +38 4 | .873 | 39.3±.3 | +1.5 | 1.0 |
| 53 Apr 15.45366 | 116.1 | 104.4 | 95.8 | 314 8 | −0 25 | .492 | 67.3±.3 | −1.8 | 3.6 |
| 53 Apr 15.45669 | 108.5 | 102.0 | 98.8 | 277 49 | +8 29 | .877 | 61.8±.5 | +0.9 | 1.5 |
| 53 Apr 16.28881 | 96.3 | 89.9 | 84.5 | 210 27 | +14 48 | .946 | 23.4±.3 | +2.9 | 1.0 |
| 53 Apr 16.42532 | 87.5 | 85.7 | 83.2 | 256 35 | +59 48 | .894 | 29.6±.3 | +1.5 | 1.3 |
| 53 Apr 21.36042 | 101.9 | 97.7 | 95.8 | 263 21 | +61 3 | .827 | 32.4±.3 | +1.8 | 0.9 |
| 53 Apr 21.36280 | 85.7 | 78.6 | 75.3 | 222 32 | +42 40 | .979 | 24.5±.2 | +1.4 | 1.6 |
| *53 Apr 21.44645 | 100.5 | 91.6 | 88.6 | 347 23 | +25 20 | .323 | 47.2 | +0.1 | 1.9 |
| *53 May 5.28417 | 104.5 | 96.1 | 91.4 | 239 7 | −22 13 | .546 | 36.8 | +0.8 | 2.2 |
| *53 May 6.28495 | 90.2 | 85.1 | 81.1 | 214 42 | −14 51 | .720 | 21.4 | +1.4 | 1.7 |
| 53 May 7.22324 | 93.1 | 88.6 | 85.9 | 211 2 | −10 35 | .751 | 20.4±.2 | +2.6 | 0.8 |
| 53 May 7.33659 | 88.9 | 88.9 | 86.6 | 249 42 | +32 30 | .987 | 24.1±.5 | +2.1 | 1.4 |
| 53 May 7.33958 | 85.1 | 82.5 | 78.4 | 231 38 | +40 25 | .988 | 17.6±.2 | +1.0 | 2.4 |
| 53 May 7.33977 | 95.2 | 94.1 | 84.7 | 250 4 | −0 39 | .830 | 40.2±.3 | +1.1 | 1.6 |
| 53 May 8.26605 | 82.0 | 81.3 | 78.7 | 224 5 | +7 15 | .918 | 15.9±.8 | +1.4 | 2.4 |
| 53 May 8.38998 | 83.3 | 82.8 | 80.1 | 231 47 | +41 28 | .943 | 16.2±1.2 | +0.5 | 2.6 |
| 53 May 9.35808 | 99.1 | 94.9 | 91.0 | 222 40 | +2 6 | .806 | 23.7±.2 | +1.0 | 1.8 |
| 53 May 9.42072 | 81.5 | 81.0 | 78.4 | 341 45 | +63 52 | .726 | 14.7±.3 | +1.1 | 2.6 |
| 53 May 12.26313 | 91.4 | 89.2 | 85.9 | 246 40 | −5 6 | .712 | 25.2±.3 | +1.1 | 1.7 |
| 53 May 12.26667 | 96.8 | 89.1 | 86.1 | 226 10 | +20 2 | .972 | 21.3±.6 | +2.2 | 1.0 |
| 53 May 13.16348 | 81.3 | 81.1 | 79.6 | 178 2 | +15 4 | .971 | 13.6±.3 | +2.5 | 1.2 |
| 53 May 18.41332 | 83.7 | 81.9 | 77.0 | 258 59 | +28 59 | .972 | 18.1±.31 | +1.4 | 2.3 |
| 53 Jun 2.22566 | 98.0 | 91.0 | 86.8 | 255 40 | +18 14 | .865 | 23.9±.2 | +1.0 | 1.9 |
| *53 Jun 4.20432 | 96.9 | 92.1 | 89.1 | 262 22 | −25 53 | .360 | 30.8 | +1.2 | 1.6 |
| 53 Jun 5.17987 | 90.3 | 87.8 | 85.3 | 161 1 | +49 3 | .842 | 14.8±.3 | +2.1 | 1.1 |
| 53 Jun 6.19792 | 91.3 | 88.8 | 87.0 | 143 30 | +57 53 | .669 | 17.2±.5 | +2.4 | 0.6 |
| 53 Jun 8.28370 | 93.7 | 91.5 | 87.4 | 293 45 | +22 9 | .784 | 47.2±.3 | +1.2 | 1.7 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 53 Jun 8.28750 | 93.9 | 89.8 | 87.0 | 255°30′ | +37°53′ | .995 | 25.0±.3 | +1.7 | 1.0 |
| 53 Jun 8.29039 | 96.5 | 94.6 | 91.9 | 240 16 | −9 27 | .763 | 20.8±.3 | +1.9 | 0.9 |
| 53 Jun 8.37832 | 92.6 | 90.1 | 86.7 | 266 16 | −25 51 | .513 | 32.4±.2 | +1.3 | 1.3 |
| 53 Jun 9.33150 | 102.8 | 99.3 | 96.0 | 280 24 | −22 20 | .580 | 38.4±.3 | +1.4 | 1.0 |
| 53 Jun 9.33275 | 79.9 | 79.3 | 78.3 | 196 43 | +1 17 | .564 | 12.8±.2 | +0.6 | 2.7 |
| 53 Jun 13.26806 | 92.4 | 88.6 | 79.7 | 253 4 | +46 50 | .972 | 24.1±.2 | +1.9 | 1.4 |
| *53 Jun 13.36281 | 111.1 | 95.8 | 90.9 | 322 9 | +10 56 | .764 | 63.0 | −0.4 | 2.0 |
| 53 Jun 16.30529 | 95.5 | 92.8 | 90.9 | 264 59 | −28 36 | .526 | 27.4±.3 | +2.0 | 0.6 |
| 53 Jun 16.31098 | 89.7 | 88.0 | 86.9 | 269 44 | −28 24 | .524 | 29.0±.2 | +1.6 | 1.0 |
| 53 Jun 20.35000 | 87.0 | 86.8 | 84.0 | 258 35 | +50 23 | .906 | 21.2±.4 | +1.6 | 1.7 |
| 53 Jun 20.43325 | 88.7 | 88.3 | 88.1 | 261 40 | −47 31 | .166 | 16.5±.3 | +2.2 | 0.4 |
| 53 Jul 10.31681 | 95.8 | 92.6 | 90.7 | 287 45 | +60 52 | .888 | 26.3±.3 | +1.3 | 1.7 |
| 53 Jul 10.40023 | 109.1 | 104.4 | 101.2 | 23 8 | +27 8 | .646 | 67.6±.6 | +0.4 | 1.2 |
| 53 Jul 15.23777 | 88.2 | 88.2 | 86.3 | 25 56 | +62 36 | .453 | 17.8±.2 | +2.1 | 1.1 |
| 53 Jul 15.28729 | 83.7 | 81.7 | 79.4 | 263 20 | +50 47 | .927 | 16.0±.3 | +0.9 | 2.4 |
| 53 Jul 15.42229 | 95.1 | 90.2 | 88.5 | 337 52 | +18 2 | .969 | 54.8±.4 | +0.1 | 2.6 |
| 53 Jul 16.40248 | 105.8 | 103.0 | 100.8 | 11 44 | +22 17 | .805 | 67.1±.7 | +1.6 | 0.6 |
| 53 Jul 24.43319 | 110.1 | 107.3 | 103.1 | 352 37 | +42 32 | .984 | 57.3±.6 | +1.0 | 1.7 |
| 53 Aug 4.22721 | 111.6 | 107.2 | 102.7 | 5 43 | +34 52 | .454 | 63.3±.3 | +0.4 | 1.6 |
| *53 Aug 5.35035 | 90.6 | 89.1 | 83.5 | 343 40 | −16 28 | .675 | 25.5 | +1.0 | 2.3 |
| *53 Aug 5.43212 | 100.8 | 93.8 | 85.9 | 59 33 | +83 10 | .601 | 43.6 | +1.3 | 1.5 |
| 53 Aug 6.16985 | 83.0 | 82.8 | 79.3 | 272 19 | −27 21 | .637 | 15.5±.2 | +0.3 | 3.0 |
| 53 Aug 6.17192 | 94.8 | 94.0 | 91.6 | 331 55 | −13 5 | .304 | 30.9±.4 | +1.4 | 1.1 |
| 53 Aug 6.30833 | 93.4 | 91.2 | 86.9 | 341 4 | +45 42 | .929 | 47.1±2.2 | +2.1 | 0.8 |
| *53 Aug 7.39845 | 83.4 | 82.9 | 80.6 | 253 58 | +11 34 | .330 | 13.7 | +0.5 | 3.1 |
| 53 Aug 9.23255 | 91.6 | 89.3 | 85.8 | 257 5 | +38 46 | .898 | 17.4±.2 | +1.7 | 1.6 |
| *53 Aug 10.22697 | 80.7 | 71.6 | 69.3 | 266 52 | −6 35 | .794 | 14.5 | +1.0 | 2.8 |
| 53 Aug 13.35836 | 82.5 | 82.2 | 81.2 | 302 27 | −23 44 | .600 | 13.6±.3 | +1.3 | 2.1 |
| 53 Aug 13.36031 | 108.7 | 105.9 | 104.7 | 40 8 | +36 41 | .701 | 68.6±.6 | +0.3 | 1.1 |
| *53 Aug 13.42525 | 84.2 | 80.2 | 77.4 | 280 8 | +26 33 | .421 | 17.7 | −1.5 | 5.0 |
| 53 Aug 13.45457 | 109.7 | 104.6 | 103.0 | 45 0 | +12 49 | .854 | 72.1±.6 | +0.9 | 1.0 |
| 53 Aug 13.45561 | 97.8 | 96.5 | 84.5 | 341 16 | +30 17 | .857 | 47.8±.3 | −0.0 | 2.4 |
| 53 Aug 13.45625 | 95.5 | 91.7 | 89.1 | 59 8 | +65 58 | .756 | 54.6±.4 | +2.3 | 0.6 |
| 53 Aug 14.44728 | 108.0 | 101.6 | 97.9 | 37 7 | +5 20 | .838 | 68.7±.8 | +0.1 | 2.2 |
| 53 Aug 14.45417 | 109.2 | 92.0 | 87.1 | 2 56 | +43 38 | .959 | 56.8±.7 | −1.0 | 2.2 |
| 53 Aug 15.42275 | 88.0 | 87.3 | 86.9 | 270 12 | +38 51 | .410 | 16.9±1.2 | +2.6 | 0.6 |
| 53 Aug 22.41119 | 100.2 | 92.6 | 88.9 | 343 7 | +10 48 | .846 | 29.6±.2 | +1.9 | 1.2 |
| 53 Oct 2.20670 | 93.3 | 92.8 | 88.4 | 20 21 | −15 59 | .491 | 28.5±.3 | +1.4 | 1.3 |
| 53 Oct 2.31090 | 99.0 | 89.8 | 83.5 | 5 21 | +7 43 | .907 | 24.8±.2 | +1.3 | 2.0 |
| 53 Oct 3.25367 | 83.7 | 81.4 | 79.7 | 345 1 | +28 31 | .991 | 16.5±.3 | +1.3 | 2.1 |
| 53 Oct 3.29383 | 83.0 | 82.8 | 80.0 | 343 7 | +10 23 | .886 | 15.7±.3 | +1.2 | 2.2 |
| 53 Oct 3.44375 | 106.1 | 100.8 | 95.3 | 79 21 | +38 29 | .972 | 68.1±1.0 | +0.8 | 2.0 |
| 53 Oct 6.28447 | 91.1 | 90.2 | 86.5 | 16 54 | +1 58 | .870 | 24.1±.3 | +1.6 | 1.4 |
| *53 Oct 7.39307 | 87.5 | 78.9 | 76.4 | 9 18 | +0 18 | .699 | 20.6 | +0.6 | 2.9 |
| 53 Oct 9.24410 | 87.7 | 86.2 | 81.5 | 24 42 | +15 34 | .878 | 28.8±.3 | +0.9 | 2.0 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| *53 Oct 9. 31647 | 112. 4 | 103. 8 | 102. 5 | 123° 8′ | +66°42′ | . 454 | 58. 0 | +0. 6 | 1. 7 |
| 53 Oct 10. 21343 | 105. 1 | 93. 4 | 85. 2 | 36 0 | +16 36 | . 708 | 37. 4±. 1 | −0. 3 | 2. 7 |
| 53 Oct 10. 31215 | 95. 0 | 93. 2 | 91. 0 | 12 16 | −9 33 | . 766 | 21. 2±. 4 | +2. 4 | 0. 7 |
| 53 Oct 12. 33162 | 108. 5 | 101. 7 | 96. 8 | 52 33 | +45 5 | . 941 | 52. 9±. 3 | +1. 3 | 0. 9 |
| 53 Oct 16. 42579 | 110. 9 | 104. 5 | 100. 8 | 98 36 | +26 48 | . 909 | 70. 5±. 5 | +0. 6 | 1. 6 |
| 53 Oct 31. 24399 | 79. 1 | 78. 7 | 76. 8 | 29 25 | +18 48 | . 970 | 14. 8±. 4 | +1. 0 | 2. 6 |
| 53 Nov 2. 35675 | 105. 7 | 104. 6 | 103. 5 | 97 39 | +83 34 | . 624 | 43. 0±. 3 | +1. 3 | 0. 7 |
| 53 Nov 2. 36021 | 102. 3 | 92. 5 | 87. 9 | 57 45 | +16 3 | . 958 | 35. 0±. 3 | +1. 7 | 1. 2 |
| 53 Nov 6. 33041 | 82. 8 | 81. 2 | 78. 6 | 15 50 | −15 29 | . 593 | 16. 8±. 1 | −0. 0 | 3. 0 |
| 53 Nov 9. 27016 | 100. 0 | 98. 6 | 93. 1 | 84 34 | −19 59 | . 387 | 41. 4±1. 0 | +1. 2 | 1. 0 |
| 53 Nov 11. 44044 | 92. 3 | 85. 1 | 82. 3 | 71 19 | +48 45 | . 889 | 44. 1±. 3 | −0. 6 | 3. 1 |
| 53 Nov 13. 24583 | 83. 4 | 81. 7 | 80. 1 | 29 29 | +0 35 | . 884 | 16. 6±1. 4 | +0. 5 | 2. 4 |
| 53 Nov 13. 41988 | 109. 1 | 99. 8 | 94. 8 | 104 1 | +8 5 | . 904 | 61. 6±. 6 | −0. 8 | 3. 0 |
| 53 Nov 16. 41339 | 94. 9 | 90. 7 | 86. 8 | 80 1 | +30 29 | . 971 | 39. 1±. 3 | +0. 1 | 2. 5 |
| 53 Dec 4. 35998 | 98. 9 | 93. 3 | 86. 6 | 77 19 | +18 52 | . 940 | 29. 0±. 4 | +0. 6 | 1. 6 |
| 53 Dec 4. 43333 | 99. 5 | 91. 4 | 85. 4 | 69 38 | −6 2 | . 508 | 26. 5±. 3 | +1. 3 | 1. 2 |
| 53 Dec 8. 31711 | 91. 2 | 87. 4 | 83. 7 | 74 31 | +15 13 | . 952 | 24. 3±. 6 | +1. 5 | 1. 2 |
| 53 Dec 9. 40208 | 102. 9 | 90. 2 | 83. 3 | 126 33 | +2 34 | . 853 | 58. 2±1. 0 | −0. 4 | 1. 7 |
| 53 Dec 10. 51604 | 105. 2 | 98. 3 | 94. 4 | 101 36 | +7 40 | . 555 | 43. 9±. 3 | +1. 0 | 1. 7 |
| 53 Dec 11. 32126 | 82. 0 | 80. 3 | 78. 7 | 81 23 | +14 26 | . 965 | 14. 4±. 3 | +1. 5 | 1. 6 |
| 53 Dec 12. 29396 | 86. 6 | 84. 5 | 79. 8 | 94 28 | +28 40 | . 972 | 36. 4±. 3 | +0. 4 | 1. 4 |
| 53 Dec 12. 40883 | 96. 2 | 95. 4 | 90. 7 | 206 51 | +58 12 | . 503 | 44. 7±. 2 | +0. 3 | 1. 4 |
| 53 Dec 13. 50766 | 106. 3 | 99. 3 | 97. 5 | 128 24 | −9 31 | . 644 | 58. 2±. 4 | +0. 9 | 1. 5 |
| 53 Dec 15. 49848 | 106. 2 | 102. 0 | 98. 6 | 198 6 | +24 17 | . 795 | 64. 8±. 5 | +0. 9 | 0. 9 |
| 53 Dec 27. 20060 | 91. 7 | 84. 5 | 80. 6 | 100 24 | +9 17 | . 743 | 27. 5±. 2 | +0. 9 | 1. 2 |
| 53 Dec 30. 36336 | 84. 4 | 81. 5 | 78. 4 | 113 16 | +25 19 | . 985 | 30. 7±. 6 | +1. 6 | 1. 0 |
| 53 Dec 31. 33958 | 82. 9 | 80. 6 | 77. 1 | 109 26 | +57 21 | . 926 | 17. 7±. 4 | +1. 1 | 1. 5 |
| *54 Jan 1. 44056 | 96. 5 | 85. 1 | 75. 7 | 19 49 | +68 57 | . 423 | 18. 9 | +0. 5 | 2. 7 |
| 54 Jan 3. 44375 | 108. 7 | 104. 2 | 99. 2 | 175 55 | +24 23 | . 940 | 64. 6±. 5 | +0. 7 | 1. 4 |
| 54 Jan 4. 49735 | 112. 0 | 102. 0 | 99. 1 | 202 58 | +7 21 | . 812 | 71. 4±. 6 | −0. 3 | 2. 0 |
| 54 Jan 5. 39088 | 110. 1 | 109. 2 | 107. 3 | 197 39 | −23 23 | . 190 | 68. 9±. 6 | +0. 4 | 1. 3 |
| 54 Jan 6. 26510 | 93. 8 | 91. 2 | 87. 6 | 105 58 | −20 32 | . 607 | 32. 4±. 2 | +1. 4 | 1. 4 |
| 54 Jan 13. 51791 | 83. 9 | 82. 8 | 80. 2 | 207 14 | +44 59 | . 962 | 17. 3±. 3 | +0. 4 | 2. 6 |
| 54 Jan 28. 17159 | 84. 6 | 84. 6 | 82. 2 | 114 25 | +37 48 | . 899 | 21. 0±. 6 | +0. 7 | 1. 4 |
| 54 Feb 2. 48125 | 77. 9 | 77. 7 | 76. 0 | 165 48 | +55 1 | . 910 | 12. 8±. 3 | +2. 1 | 1. 5 |
| 54 Feb 3. 35977 | 105. 8 | 99. 0 | 92. 3 | 175 47 | +33 35 | . 956 | 44. 7±. 3 | +0. 3 | 1. 6 |
| 54 Feb 4. 51289 | 106. 5 | 102. 2 | 96. 3 | 240 7 | +39 12 | . 915 | 51. 0±. 7 | +0. 1 | 1. 8 |
| 54 Feb 6. 38914 | 93. 2 | 76. 1 | 71. 0 | 152 3 | +30 29 | . 973 | 29. 0±. 1 | −1. 3 | 3. 7 |
| 54 Feb 6. 42292 | 91. 8 | 87. 8 | 82. 6 | 145 24 | +16 49 | . 830 | 28. 1±. 8 | +3. 0 | 1. 0 |
| 54 Feb 8. 42292 | 92. 3 | 86. 7 | 81. 1 | 251 35 | +59 32 | . 642 | 32. 1±. 7 | +0. 2 | 2. 0 |
| 54 Feb 10. 40343 | 91. 1 | 90. 8 | 81. 4 | 171 7 | +37 27 | . 993 | 34. 9±. 3 | +0. 5 | 2. 1 |
| 54 Feb 11. 42659 | 81. 6 | 81. 0 | 79. 3 | 106 24 | +36 31 | . 629 | 13. 9±. 2 | +1. 1 | 1. 9 |
| 54 Feb 26. 30579 | 87. 0 | 84. 9 | 83. 5 | 153 14 | +3 10 | . 885 | 22. 3±. 5 | +2. 4 | 1. 0 |
| 54 Mar 1. 36968 | 93. 0 | 81. 9 | 79. 7 | 159 17 | +23 29 | . 931 | 20. 7±. 2 | +0. 2 | 2. 5 |
| 54 Mar 5. 29565 | 84. 3 | 78. 2 | 74. 1 | 113 33 | +12 36 | . 805 | 13. 2±. 1 | +1. 7 | 2. 0 |

*Previously reduced by Jacchia.

TABLE 1.—*Fundamental data for sporadic meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) |
|---|---|---|---|---|---|---|---|---|---|
| 54 Mar 5.44662 | 87.7 | 83.0 | 80.2 | 179° 6′ | +39°45′ | .877 | 26.4±.2 | +0.9 | 1.4 |
| 54 Apr 24.15182 | 100.9 | 92.0 | 82.3 | 220 43 | −20 12 | .240 | 32.4±.2 | −0.3 | 2.4 |
| 54 Apr 28.30873 | 86.9 | 86.8 | 85.3 | 313 46 | +68 20 | .599 | 16.6±.2 | +2.0 | 1.0 |
| 54 Apr 29.13439 | 85.6 | 81.5 | 79.1 | 117 58 | +28 50 | .846 | <30 | +0.9† | 1.2 |
| 54 Jun 3.25929 | 78.8 | 76.9 | 76.6 | 76 55 | +62 47 | .539 | 12.2±.5 | +1.6 | 0.9 |
| 54 Jun 4.24583 | 83.9 | 83.9 | 81.8 | 244 59 | +50 32 | .950 | 18.2±.3 | +0.8 | 2.1 |
| 54 Jun 4.35000 | 94.8 | 93.4 | 86.9 | 271 9 | −28 51 | .501 | 38.4±.7 | +1.1 | 1.0 |
| *54 Jun 5.26538 | 98.2 | 89.0 | 82.5 | 105 11 | +58 35 | .284 | 19.3 | −0.5 | 3.9 |
| 54 Jun 8.32663 | 91.7 | 88.1 | 83.8 | 288 22 | −19 25 | .577 | 39.6±.4 | −0.1 | 2.3 |
| 54 Jun 9.37083 | 99.0 | 95.2 | 92.2 | 267 41 | +56 39 | .905 | 26.7±.5 | +1.9 | 0.9 |
| 54 Jun 11.38442 | 89.4 | 84.9 | 80.1 | 255 54 | +51 44 | .871 | 24.4±.3 | +2.4 | 0.8 |
| 54 Jun 23.21042 | 94.0 | 91.1 | 88.7 | 267 49 | +66 56 | .804 | 25.9±.3 | +2.4 | 0.8 |
| 54 Jun 24.23159 | 99.6 | 98.6 | 97.4 | 286 22 | −16 15 | .508 | 36.6±.3 | +1.4 | 0.6 |
| 54 Jun 25.24461 | 83.8 | 81.0 | 78.3 | 237 49 | +46 21 | .959 | 18.8±.2 | +0.7 | 3.0 |
| 54 Jun 29.33144 | 83.6 | 81.9 | 80.2 | 300 18 | +54 17 | .936 | 17.0±.3 | +0.2 | 2.6 |
| 54 Jul 3.17241 | 87.4 | 87.3 | 84.4 | 277 28 | +1 7 | .670 | 25.2±.2 | +0.4 | 1.7 |

†Assuming $V_\infty = 25$
*Previously reduced by Jacchia.

TABLE 2.—*Fundamental data for shower meteors*

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) | Shower |
|---|---|---|---|---|---|---|---|---|---|---|
| *52 Jun 29. 43208 | 98. 9 | 88. 4 | 86. 2 | 299°18′ | −16° 4′ | . 602 | 32. 1 | +1. 5 | 1. 5 | S. ιAquarid |
| *52 Jul 25. 44425 | 97. 3 | 93. 8 | 86. 1 | 335 53 | −17 4 | . 613 | 43. 0 | +0. 1 | 2. 5 | S. δAquarid |
| 52 Jul 27. 22705 | 99. 7 | 93. 0 | 89. 9 | 323 49 | −6 49 | . 554 | 38. 5±. 2 | +2. 0 | 0. 8 | N. ιAquarid |
| *52 Jul 28. 31172 | 96. 8 | 92. 3 | 88. 9 | 339 39 | −16 28 | . 572 | 42. 7 | −0. 7 | 3. 3 | S. δAquarid |
| 52 Jul 29. 40913 | 96. 1 | 94. 5 | 91. 7 | 340 10 | −16 35 | . 662 | 42. 2±. 3 | +1. 6 | 0. 8 | S. δAquarid |
| 52 Aug 22. 20417 | 98. 4 | 95. 6 | 91. 9 | 321 9 | −2 9 | . 772 | 24. 3±. 6 | +2. 2 | 1. 0 | α Capricornid |
| 52 Aug 25. 35970 | 100. 0 | 94. 0 | 89. 9 | 354 16 | +4 42 | . 889 | 39. 0±. 2 | +0. 6 | 2. 4 | N. δAquarid |
| *52 Sep 17. 31692 | 97. 5 | 85. 6 | 83. 8 | 10 39 | +1 24 | . 857 | 33. 8 | +0. 8 | 2. 4 | S. Taurid† |
| 52 Sep 19. 37056 | 93. 9 | 91. 6 | 89. 9 | 16 48 | +1 12 | . 862 | 26. 5±. 3 | +2. 9 | 0. 3 | S. Taurid† |
| 52 Sep 20. 28367 | 98. 6 | 89. 2 | 86. 9 | 12 29 | +2 13 | . 834 | 26. 9±. 2 | +2. 1 | 1. 2 | S. Taruid† |
| 52 Sep 25. 36076 | 100. 4 | 93. 4 | 86. 4 | 22 51 | +3 59 | . 885 | 31. 8±. 2 | +2. 0 | 1. 6 | S. Taurid† |
| 52 Oct 13. 28086 | 101. 1 | 95. 4 | 91. 7 | 34 51 | +9 12 | . 879 | 31. 4±. 4 | +2. 7 | 0. 6 | S. Taurid† |
| 52 Oct 14. 35000 | 100. 2 | 94. 4 | 86. 9 | 41 24 | +12 13 | . 938 | 31. 8±. 3 | +1. 9 | 1. 2 | S. Taurid† |
| 52 Oct 16. 33975 | 105. 4 | 82. 8 | 79. 4 | 39 40 | +17 26 | . 967 | 35. 7±. 1 | +0. 5 | 3. 2 | N. Taurid |
| 52 Oct 19. 26487 | 96. 1 | 89. 1 | 84. 2 | 36 3 | +10 7 | . 880 | 29. 2±. 1 | +1. 8 | 1. 4 | S. Taurid† |
| 52 Oct 19. 38343 | 100. 8 | 91. 9 | 87. 0 | 38 51 | +19 38 | . 936 | 28. 6±. 1 | +1. 6 | 1. 4 | N. Taurid |
| 52 Oct 21. 37795 | 112. 7 | 107. 7 | 103. 1 | 95 12 | +16 15 | . 803 | 67. 8±. 4 | +1. 1 | 1. 2 | Orionid |
| 52 Oct 21. 43514 | 112. 5 | 100. 0 | 96. 8 | 95 30 | +15 41 | . 926 | 67. 8±. 4 | +0. 0 | 2. 5 | Orionid |
| 52 Oct 22. 40394 | 111. 6 | 101. 5 | 97. 6 | 95 9 | +16 11 | . 880 | 67. 8±2. 6 | −0. 3 | 2. 9 | Orionid |
| *52 Oct 22. 47095 | 101. 4 | 86. 2 | 80. 1 | 33 37 | +7 26 | . 535 | 27. 9 | +0. 4 | 2. 5 | S. Taurid |
| 52 Oct 23. 32858 | 115. 7 | 92. 5 | 90. 4 | 96 43 | +16 21 | . 633 | 68. 0±. 2 | −1. 9 | 4. 5 | Orionid |
| 52 Oct 23. 37987 | 116. 1 | 107. 9 | 102. 6 | 95 14 | +16 19 | . 825 | 69. 4±. 7 | −0. 9 | 2. 8 | Orionid |
| 52 Oct 23. 38440 | 110. 5 | 103. 9 | 100. 6 | 96 48 | +17 3 | . 829 | 68. 0±. 4 | +0. 4 | 1. 6 | Orionid |
| 52 Oct 23. 45296 | 112. 4 | 108. 0 | 101. 6 | 96 41 | +15 37 | . 947 | 68. 3±. 5 | +0. 1 | 2. 2 | Orionid |
| 52 Oct 23. 45794 | 110. 7 | 103. 7 | 96. 9 | 94 50 | +16 55 | . 960 | 66. 5±. 3 | −0. 6 | 3. 2 | Orionid |
| 52 Oct 23. 49375 | 111. 4 | 104. 4 | 100. 2 | 96 3 | +15 42 | . 953 | 67. 2±. 5 | +0. 4 | 2. 4 | Orionid |
| 52 Oct 23. 49586 | 110. 6 | 104. 7 | 100. 9 | 97 1 | +15 50 | . 954 | 68. 3±. 6 | +0. 7 | 1. 6 | Orionid |
| 52 Oct 24. 42326 | 112. 1 | 103. 8 | 99. 7 | 95 24 | +16 54 | . 927 | 66. 9±. 9 | +1. 0 | 1. 2 | Orionid |
| 52 Oct 27. 35625 | 98. 1 | 94. 2 | 89. 3 | 52 30 | +12 32 | . 942 | 33. 3±. 5 | +2. 1 | 1. 0 | S. Taurid |
| 52 Oct 27. 35799 | 100. 8 | 93. 7 | 89. 0 | 42 34 | +18 55 | . 951 | 31. 1±. 5 | +2. 6 | 0. 8 | N. Taurid |
| 52 Nov 7. 10870 | 96. 8 | 87. 1 | 83. 0 | 22 55 | +27 33 | . 806 | 20. 9±. 2 | +1. 2 | 2. 0 | Bielid |
| 52 Nov 12. 19596 | 98. 9 | 89. 0 | 85. 8 | 58 22 | +22 58 | . 782 | 30. 7±. 2 | +0. 9 | 2. 0 | N. Taurid |
| 52 Nov 12. 37045 | 98. 8 | 87. 8 | 81. 9 | 57 7 | +22 7 | . 941 | 29. 8±. 1 | +0. 7 | 2. 4 | N. Taurid |
| 52 Nov 12. 37333 | 106. 8 | 93. 0 | 86. 7 | 63 3 | +25 4 | . 973 | 32. 0±. 5 | +2. 4 | 0. 9 | N. Taurid |
| 52 Dec. 11. 25625 | 97. 4 | 91. 9 | 91. 0 | 110 11 | +33 5 | . 798 | 36. 3±. 3 | +1. 3 | 1. 2 | Geminid |
| 52 Dec 14. 15038 | 99. 4 | 92. 1 | 89. 8 | 113 25 | +32 8 | . 394 | 36. 6±. 0 | +0. 5 | 2. 4 | Geminid |
| 52 Dec 14. 25344 | 100. 8 | 86. 4 | 83. 8 | 113 36 | +32 17 | . 784 | 36. 2±. 1 | −1. 2 | 4. 4 | Geminid |
| 52 Dec 14. 25988 | 96. 0 | 90. 7 | 88. 4 | 112 43 | +32 10 | . 811 | 37. 0±. 2 | +1. 5 | 1. 7 | Geminid |
| 52 Dec 14. 44600 | 99. 4 | 91. 7 | 87. 9 | 113 27 | +32 18 | . 948 | 36. 1±. 1 | +0. 8 | 2. 4 | Geminid |
| 52 Dec 14. 51668 | 97. 6 | 94. 3 | 91. 4 | 113 13 | +32 5 | . 771 | 36. 2±. 2 | +0. 8 | 1. 5 | Geminid |

†The Arietid stream, included in this category, appears to be indistinguishable from the Southern Taurids (see Wright and Whipple, 1950).
*Previously reduced by Jacchia.

TABLE 2.—*Fundamental data for shower meteors*—Continued

| Date (Universal time) | Height (km) at Beginning ($h_B$) | Height (km) at Maximum light ($h_{max}$) | Height (km) at End ($h_e$) | Corrected radiant (Eq. 1950.0) R. A. | Corrected radiant (Eq. 1950.0) Decl. | Cos $Z_{AR}$ | Corrected velocity ($V_\infty$) | Maximum photographic magnitude ($M_{pm}$) | Magnitude above plate limit ($\Delta M$) | Shower |
|---|---|---|---|---|---|---|---|---|---|---|
| 52 Dec 14.51848 | 97.9 | 93.0 | 90.3 | 114°50′ | +31°45′ | .779 | 35.8±1.3 | +0.9 | 1.4 | Geminid |
| 53 Jul 21.35918 | 92.1 | 89.3 | 86.7 | 328 34 | −13 54 | .700 | 35.9±.5 | +0.7 | 2.0 | S. ι Aquarid |
| 53 Aug 5.24597 | 103.2 | 96.2 | 91.6 | 36 8 | +55 14 | .359 | 61.0±.2 | +0.3 | 1.5 | Perseid |
| *53 Aug 8.19278 | 101.3 | 92.9 | 88.8 | 335 7 | −15 6 | .343 | 36.1 | +0.8 | 2.4 | S. ι Aquarid |
| 53 Aug 8.35862 | 108.6 | 102.3 | 101.3 | 42 19 | +56 41 | .659 | 60.7±.4 | +0.9 | 0.9 | Perseid |
| 53 Aug 8.36042 | 94.3 | 90.2 | 86.5 | 309 46 | −6 20 | .712 | 23.5±.3 | +2.2 | 0.9 | α Capricornid. |
| 53 Aug 8.36458 | 108.3 | 101.8 | 98.1 | 41 4 | +57 9 | .682 | 60.6±.3 | +0.9 | 0.8 | Perseid |
| 53 Aug 8.40951 | 110.5 | 108.0 | 103.9 | 43 48 | +60 54 | .753 | 58.6±.4 | +0.5 | 1.2 | Perseid |
| 53 Aug 10.35729 | 107.8 | 101.4 | 98.8 | 40 42 | +58 56 | .678 | 59.8±.4 | +0.3 | 1.7 | Perseid |
| 53 Aug 10.43442 | 97.4 | 93.2 | 89.9 | 342 48 | +0 29 | .779 | 40.5±.3 | +1.7 | 1.3 | N. δ Aquarid |
| 53 Aug 13.19186 | 98.1 | 95.8 | 94.7 | 342 59 | +2 32 | .470 | 40.0±.4 | +1.8 | 0.6 | N. δ Aquarid |
| 53 Aug 13.36156 | 110.4 | 107.2 | 104.1 | 48 13 | +59 5 | .658 | 59.5±.4 | +1.0 | 1.0 | Perseid |
| 53 Aug 14.36275 | 109.4 | 107.1 | 100.3 | 49 12 | +55 58 | .663 | 61.5±.3 | +0.1 | 1.4 | Perseid |
| 53 Aug 15.41947 | 110.3 | 106.5 | 100.3 | 52 36 | +52 22 | .791 | 63.3±.5 | −0.0 | 3.1 | Perseid |
| 53 Aug 15.44366 | 106.8 | 104.3 | 100.3 | 53 4 | +57 28 | .818 | 60.2±.5 | +1.0 | 0.8 | Perseid |
| *53 Oct 9.19222 | 103.8 | 96.3 | 90.6 | 270 56 | +47 14 | .669 | 20.2 | +0.1 | 1.6 | Giacobinid |
| 53 Oct 9.24725 | 99.8 | 89.7 | 87.5 | 34 8 | +7 44 | .772 | 30.4±.2 | +1.6 | 1.8 | S. Taurid |
| 53 Oct 19.42117 | 110.7 | 106.7 | 105.6 | 93 17 | +15 46 | .903 | 65.3±.8 | +1.6 | 0.4 | Orionid |
| 53 Nov 3.29681 | 101.6 | 92.9 | 88.7 | 47 35 | +21 17 | .978 | 28.8±.3 | +2.5 | 0.8 | N. Taurid |
| *53 Nov 7.46139 | 86.2 | 81.2 | 79.1 | 31 4 | +12 40 | .448 | 19.8 | +1.7 | 1.9 | Bielid |
| 53 Dec 12.34620 | 97.1 | 90.6 | 89.2 | 111 47 | +32 47 | .980 | 35.7±.3 | +1.2 | 1.2 | Geminid |
| 53 Dec 12.49241 | 99.6 | 91.2 | 88.5 | 111 27 | +32 17 | .848 | 35.9±.3 | +1.3 | 1.8 | Geminid |
| 53 Dec 13.31502 | 100.1 | 94.8 | 91.5 | 112 55 | +32 39 | .934 | 36.0±.2 | +1.4 | 1.1 | Geminid |
| *53 Dec 13.36370 | 98.4 | 87.0 | 79.4 | 112 6 | +32 39 | .994 | 36.3 | −0.2 | 2.2 | Geminid |
| 53 Dec 13.43578 | 100.8 | 93.2 | 87.5 | 111 53 | +32 49 | .962 | 36.5±1.0 | +0.2 | 2.2 | Geminid |
| 53 Dec 13.46534 | 95.7 | 91.9 | 89.9 | 112 31 | +32 24 | .914 | 35.6±.3 | +1.3 | 1.5 | Geminid |
| 53 Dec 14.37933 | 98.8 | 94.3 | 87.0 | 112 52 | +32 27 | 1.000 | 36.4±.2 | +1.0 | 1.4 | Geminid |
| *53 Dec 14.40912 | 100.3 | 84.1 | 70.6 | 113 9 | +32 20 | .991 | 36.2 | −2.5 | 4.9 | Geminid |
| 53 Dec 14.47656 | 97.3 | 92.2 | 88.4 | 111 54 | +31 5 | .876 | 36.4±.4 | +1.6 | 1.5 | Geminid |
| 54 Jan 2.37141 | 102.0 | 98.7 | 94.8 | 226 13 | +51 6 | .365 | 42.8±2 | −0.0 | 1.8 | Quadrantid |
| 54 Jan 3.36061 | 100.9 | 99.4 | 97.8 | 231 1 | +50 29 | .294 | 42.1±.3 | +0.7 | 1.1 | Quadrantid |
| 54 Jan 3.36219 | 101.0 | 99.4 | 96.9 | 230 4 | +49 12 | .295 | 42.7±.2 | +0.9 | 1.4 | Quadrantid |
| 54 Jan 3.47494 | 100.2 | 95.3 | 93.0 | 228 40 | +50 26 | .672 | 42.2±.3 | −0.2 | 2.0 | Quadrantid |
| 54 Jan 3.50625 | 99.6 | 96.6 | 93.4 | 229 29 | +48 26 | .755 | 43.4±.5 | +0.6 | 1.6 | Quadrantid |

*Previously reduced by Jacchia.


## *Abstract*

A random sample of 360 of the meteors doubly photographed by the Baker Super-Schmidt cameras has been taken. These meteors are fainter than those previously reduced, reaching a limiting photographic magnitude of +4. Their heights, velocities, radiants, and magnitudes have been accurately computed and are tabulated. Current meteor theory is briefly outlined, and certain of its predictions compared with statistics of the observed sample of meteors. The observed length of trail is less than that predicted by the single-body theory.


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