DENSITY VARIATIONS OF METEOR FLUX ALONG THE EARTH'S ORBIT

N.T. Svetashkova

Tomsk State University
Tomsk, USSR

No model of distribution of meteor substance is known to explain the observed diurnal and annual variations of meteor rates, if that distribution is assumed to be constant during the year. A prediction of diurnal variation of rates carried out using statistical modeling (KOSTYLEV and SVETASHKOVA, 1977) for the meteor radar station in Mogadishu on the assumption that the distribution of the flux density of meteor bodies does not change during the year gives nearly the same average rates for all the different months. The analysis of the results of actual observations obtained from Mogadishu shows that the actual average rate of meteors reaches its maximum in July and minimum in March with the ratio of 5.7. Such a difference between the results of observations and the prediction leads to the conclusion that the density of the orbits of meteor bodies changes with the motion of the Earth along its orbit.

In the present paper, the distributions of the flux density over the celestial sphere are obtained by the method described previously (SVETASHKOVA, 1984). The system of equations of the form $Ax = u$ are constructed on the basis of the observational results and adequately formulated prediction equations, where A is the matrix whose elements are hourly rates for separate areas of the celestial sphere obtained as a result of prediction; u is the vector of the observed rates; x is the unknowns vector whose elements represent the meteor bodies flux density normalized for the assigned density in the prediction model. The solution of systems with inaccurately assigned u components and the unknown coefficient matrix is performed by the Tikhonov regularization method. Radar observations in Mogadishu covering the interval from December 1968, to May 1970, are used. The observations are taken for four azimuths (0°, 90°, 180°, 270°) with the time step of $\Delta t = 30$'s. The celestial sphere is subdivided into 76 areas. In the prediction algorithm of the meteor rates, a physical model of interaction of the meteor body with the Earth's atmosphere suggested by Tokhtasyev is employed. The distribution of the flux density parameter S over the celestial sphere is determined by the Pupyshev formula: $S(\varepsilon) = 1.0 + 0.12\varepsilon + 0.01\varepsilon^2$ where ε is the elongation angle from the apex in radians and the geocentric and heliocentric distributions of velocities are taken from the paper by ANDREEV et al., (1982). It is supposed for simplicity that half of the meteor bodies have the mean density of 2 g/cm^3 while the other half - that of 0.2 g/cm^3.

Variations of the average for the celestial sphere flux density of meteor bodies with masses over 10^{-3} g are in the geocentric system of coordinates and the flux density changes about four times a year, the minimum values being observed in March: $Q(10^{-3}g) = 4.67 \times 10^{-4}$ $km^{-2}h^{-1}sr^{-1}$; the maximum - in July: $Q(10^{-3}g) = 1.83 \times 10^{-3} km^{-2}h^{-1}sr^{-1}$. The character of hourly rate variation is determined completely by the variations of the geocentric flux density during the year. This conclusion can only be valid provided the physical model of a meteor phenomenon and models of mass and velocity distribution over the celestial sphere remain invariable when the results of homogeneous observations for different months are interpreted. The average annual value of the influx in the interval of masses from 10^{-12}g to 10^{2}g is 10 tons a day. The average annual flux density reduced

to the mass M = 5×10^{-6}g (1.80×10^{-9}m^{-2}s^{-1}) agrees well with the estimates of ELFORD (1967) (2 x 10^{-9}m^{-2}s^{-1}) and Pupyshev (6-9 x 10^{-9}m^{-2}s^{-1}). The estimates of other authors obtained on the basis of radar observations are of the order of 10^{-8} or 10^{-10}.

The minimum of the flux density in the heliocentric system of coordinates shifts to February, the maximum being observed in September-October. The maximum-minimum ratio is 3.6.

1.   Distribution of the flux density over the ecliptic longitude.

a)   The geocentric system of coordinates. The region of highest flux density is in the interval of longitudes from $\lambda - \lambda_0$ = 165° to $\lambda - \lambda_0$ = 15°, where the flux density value varies within the limits of approximately one order of magnitude reaching the maximum value at $\lambda - \lambda_0$ = 225 to 255°. A characteristic feature is the lowering of the flux density in the immediate proximity to the apex (with the exception of August-September). The region of the lowered flux density lies within the interval of longitudes $\lambda - \lambda_0$ = 45 to 135°. The ratios of the flux density in the regions of the apex and anti-apex are 10^2 to 10^3. The results show that the geocentric distributions of the flux density over ecliptic longitude can be considered symmetrical to the plane of the ecliptic for all months except March and the period of July to November.

b)   The heliocentric system of coordinates. Taking into account (according to the Levin technique) the motion of the Earth around the Sun, we obtain the distribution of the flux density in a heliocentric system of coordinates (Fig. 1). The regions of the maximum heliocentric flux density are actually located near the geocentric anti-apex. Though right at that point ($\lambda - \lambda_0$ = 105 to 135° in Fig. 1) there is for many months, a flux density reduction comparable in value with the minimum that now appears in the geocentric apex direction. The average annual distribution of the heliocentric flux density near the plane of the ecliptic can be imagined in the form of two petals about 60° wide, the maxima falling on $\lambda - \lambda_0$ = 45° and 165°. The ratio of the mean values of the heliocentric flux density in the geocentric anti-apex region to the geocentric apex regions is about 3 x 10^2. The asymmetry of distributions over the plane of ecliptic is especially noticeable in January and in the period of July to October. In August to October, the heliocentric flux density in the geocentric apex region of the Northern hemisphere is only about one order of magnitude higher than in other months and therefore the excess number of orbits with direct motion is 10 to 40, which is below what is considered normal. In the Southern hemisphere, a rise in heliocentric flux density of about one order of magnitude is observed in January and July. Thus, the distribution of the flux density over ecliptic longitude is not constant during the year. For sporadic meteors, a heliocentric component in the geocentric anti-apex direction near the ecliptic plane is thus always present. In January and July, the Earth similarly crosses a complex of meteors with retrograde motion whose radiants are located in the geocentric apex hemisphere at ecliptic latitudes 0° to 20°. In the Southern hemisphere meteor bodies going from the geocentric apex also have a high flux density in June, August and February. In August-October an analogous component of meteor bodies is present in the latitudes of 0° to 20°.
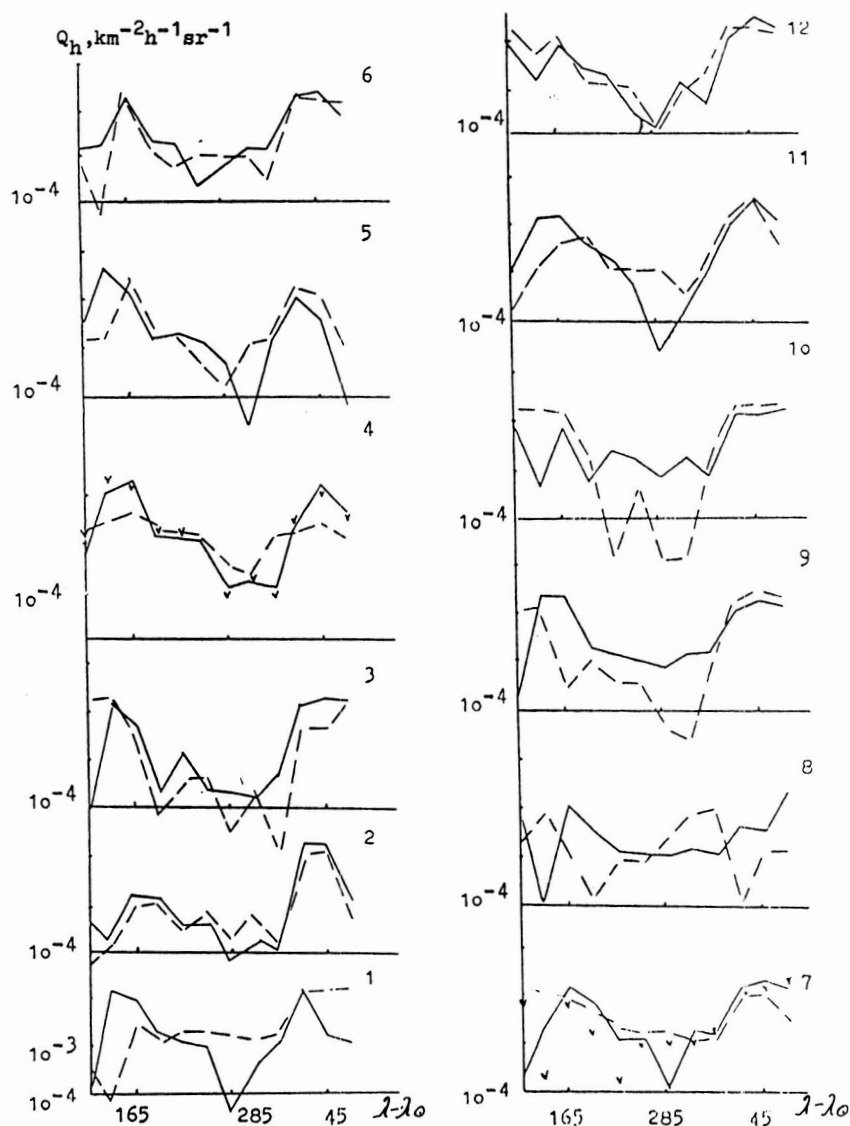
Fig. 1   Distribution of the heliocentric flux density of meteoric bodies with the masses greater than 10^{-3} g over the ecliptic longitude. The figures denote the number of a month.   The continuous line shows distributions for latitudes 0° to 20° and the dashed lines represent 0° to -20°.   A v symbol represents distributions with seasonal latitudinal variations of the density of the atmosphere being taken into account.

2. Distribution of the flux density over the ecliptic latitude.

Heliocentric distributions of the latitudinal flux density are presented in Fig. 2. In different months, 70-80 percent of meteor body orbits are located in the ecliptic latitudes $|\beta| < 35°$ and less than 10 percent in the latitudes $|\beta| > 50°$. The maximum flux density is observed near the ecliptic plane in the interval of latitudes $|\beta| < 20°$. Distributions over latitude can be considered symmetrical to the plane of ecliptic only for two months - namely December and January. Assymmetry becomes particularly apparent in February, April and May when the flux density of particles in the Northern hemisphere is 1.7, 1.9 and 1.7 times respectively higher than in the Southern one. On the contrary, in October, the Southern hemisphere is 1.5 times more active than the Northern one. Geocentric distributions of the flux density over latitude are also shown in Fig. 2. It can be seen that the Earth's motion along its orbit distorts the heliocentric distributions considerably.

The known seasonal and latitudinal variations of atmospheric conditions does not appear to significantly affect the value of the mean flux density of meteor bodies and the matter influx onto the Earth.

The analysis of the data obtained over the equator makes it possible to draw a conclusion that variations of meteor activity of the celestial sphere during the year are a reflection of variations of the meteor body flux density along the Earth's orbit.

References

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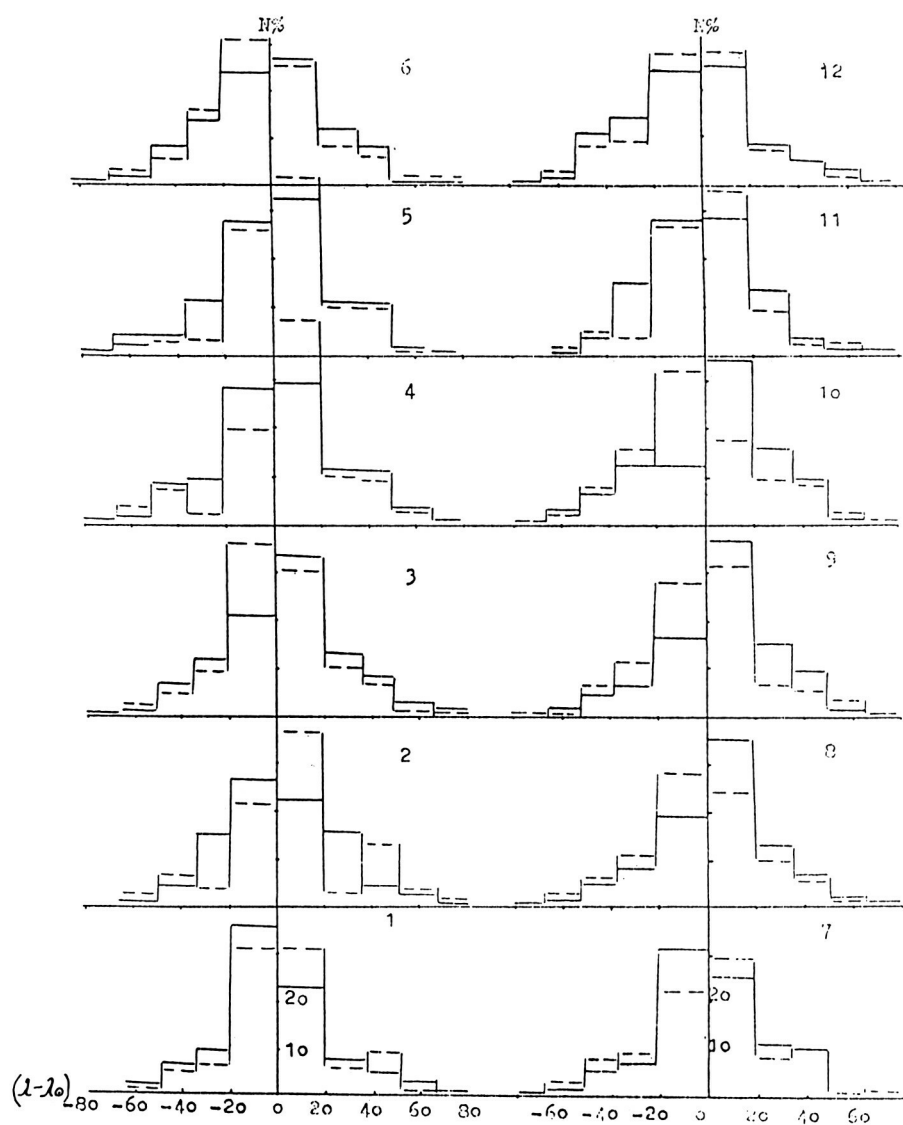
Fig. 2   Distributions of the flux density of meteoric bodies with masses greater than 10^{-3} g over the ecliptic latitude. The continuous line represents the geocentric distributions; the dotted line shows the heliocentric distributions.