82. STATISTICS OF THE ORBITS OF METEOR STREAMS AND COMETS

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Abstract. From radar observations carried out during 1967–1968 a catalogue of 20 000 orbits was obtained. A method has been developed for identifying meteor streams and associations, and the orbits of the meteors recorded during January–April 1968 have been analysed. Among them 163 streams have been identified, and these contain 33.5% of the total number of orbits. Comparison with the orbits of the short-period comets of $q < 1.1$ AU shows considerable differences.

Radar measurements of the radiants and velocities of individual meteors were carried out at the Institute for Experimental Meteorology from September 1967 to August 1968 using the method described by Korpusov and Lebedinets (1970). The basic radar parameters were: wavelength 11.9 m, transmitter pulse power 75 kW, pulse repetition frequency 20 μs, transmitting and receiving antenna gain 16, maximum sensitivity of the basic receiver 0.5×10^{-14} W. The meteors recorded were mainly between magnitudes 5 and 8. As a result of these measurements the orbits of 20 000 meteoroids were calculated.

One of the main purposes of this work was the study of the orbits of meteor streams and associations. We developed a special method for the computer selection of meteor orbits in order to reveal the existence of meteor streams. In this method a meteor orbit is represented as a point in four-dimensional space $1/a$, e, i, ω. The orbits of sporadic meteoroids form a continuous background in the portion of this space satisfying the condition of collision with the Earth; inside a sufficiently small volume of the space the distribution of the sporadic background can be considered as accidental. Groups of orbits of meteoroids that are members of meteor streams are superimposed on the sporadic background.

The accidental $(\mathrm{O}-\mathrm{C})$ deviations of the radiants of individual meteors from the mean radiants for a number of known streams were evaluated according to the results of photographic observations (Whipple and Wright, 1954); see Table I. The $(\mathrm{O}-\mathrm{C})$ values are proportional to the stream-width and are several times less than the mean

TABLE I

$(\mathrm{O}-\mathrm{C})$ deviations of radiants of individual meteors from mean radiants for known streams

Stream	O – C	Stream	O – C
Draconids	0°12	Southern Taurids	0°57
Leonids	0.22	Perseids	0.68
Geminids	0.22	Northern Taurids	1.05
Orionids	0.38	δ Aquarids	0.80

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that $\tilde{P}$ is usually smaller than $\tilde{P}_0$; moreover, the calculations show that about one-third of the initial particles reach parabolic velocity, i.e., after about 3000 yr almost 30% of the initial particles leave the solar system.

The fraction q of the initial meteoroids crossing the parabolic limit in unit time at the instant t may be determined from (Chandrasekhar, 1943)

$$q(x, t) = \frac{x}{t} \frac{1}{(4\pi D t)^{0.5}} \exp\left(-\frac{x^2}{4Dt}\right), \tag{4}$$

where $x = u_p - u_0 = 0.6$ km s^{-1}, u_p being the parabolic velocity (42 km s^{-1}), and $D = \frac{1}{2}nu^2$, n being the number of 'steps' (revolutions) of the particle in unit time and $u=$ 0.14 km s^{-1} is the average change in velocity. For the time unit we may choose the mean revolution period (about 100 yr), in which case $n=1$, $D=0.01$. By $t=30$ we obtain $q\,(0.6, 30) \approx 0.007$; i.e., in the 30th century of the stream existence some 0.7% of the initial particles leave the solar system as a consequence of random perturbations.

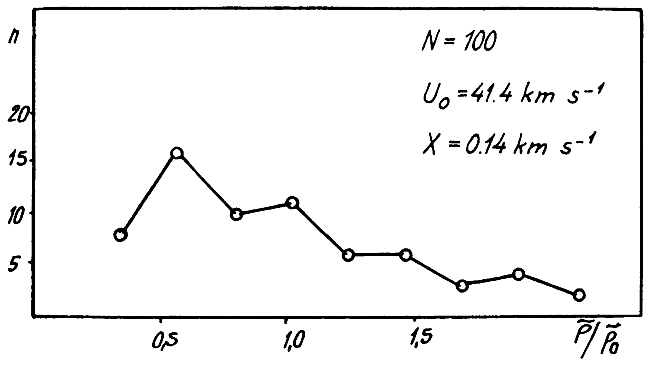

Fig. 4. The theoretical age of the Perseids.

If a large enough statistical sample is available, then not only the variances, but also the theoretical and observational distribution laws can be compared.

To a first approximation the perturbations may be taken as proportional to the attractive force by the perturbing planet when the particle crosses the ecliptic plane. Let R be the mean heliocentric distance of the perturbing planet, r the heliocentric distance of the particle at the node, and ρ the distance of the planet from the node (assuming that the planet moves in a circular orbit in the plane of the ecliptic). We suppose that the heliocentric angle θ between the directions to the node and to the planet is a uniformly distributed random quantity in the range $(0, 2\pi)$. This means that at the instant the meteoroid crosses the ecliptic plane the planet can occupy any point in its orbit with equal probability. The probability density of random perturbations is then

$$p_1(W) = p[\theta(W)] \left| 2 \frac{\mathrm{d}\theta}{\mathrm{d}W} \right|, \tag{5}$$

where

$$p(\theta) = 1/2\pi \tag{6}$$

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and

$$W = \frac{A}{\rho^2} = \frac{A}{R^2 + r^2 - 2Rr\cos\theta}, \tag{7}$$

where A is a constant. Hence

$$p_1(W) = \frac{1}{\pi W}\left\{\left[2\frac{W}{A}(R^2 + r^2) - \frac{W^2}{A^2}(R^2 - r^2) - 1\right]^{1/2}\right\}^{-1}. \tag{8}$$

This is the first approximation to the theoretical distribution law of perturbations for a single meteoroid passing through the ascending node. For the Perseids we may assume $r = 11$ AU, $R = 10$ AU (in the case of Saturn), and if we suppose for simplicity that $A = 1$, then $W_{\max} = (R - r)^{-2} = 1$; the corresponding distribution curve is given in Figure 5. From elementary calculations it follows that the probability

$$p_1(W < 0.01\ W_{\max}) > 0.65 \text{ and } p_1(W < 0.1\ W_{\max}) > 0.90;$$

i.e., insignificant perturbations prevail in the distribution.

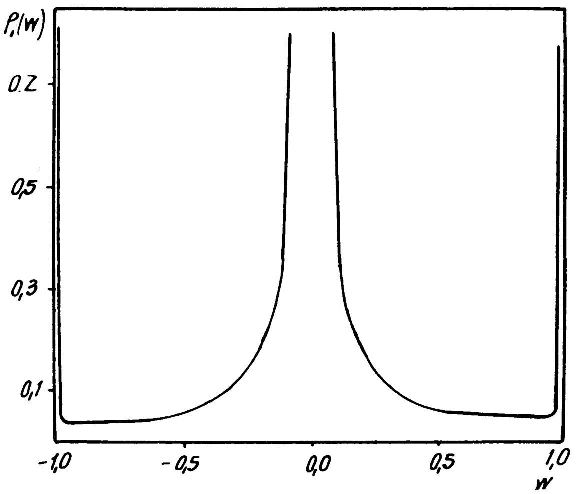

Fig. 5. Theoretical distribution of perturbations on the Perseids.

The distribution of random perturbations after k passages through the ascending node is complicated and more easily calculated by the Monte-Carlo method. Preliminary results show the probability of random perturbations after 30 revolutions of the Perseid meteoroids to be $p_k(|W| > |2\ W_{\max}|) < 0.1$. Thus the gravitational perturbations after 3000 yr cannot disturb the stream to the observed extent, and either the ejection velocity from the comet is higher than commonly assumed or the stream has been perturbed by factors other than gravitational ones.

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