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ON THE SPATIAL STRUCTURE OF THE PERSEIDS METEOR STREAM

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The paper deals with the analysis of radar observations of the Perseid meteor stream conducted at the ionospherical laboratory of the Astrophysics Institute of the Tajik Academy of Sciences in the period from 1964 to 1981.

The Perseids meteor rates were determined by the fluctuation method (ANDREEV and LAZAREV, 1979). Analysis of their hourly distributions showed that the stream maximum position is different for different years, i.e., the stream nodal position is constantly changing. Assuming the effect as real, the observed apparent nodal "regression" could be accounted for by the stream's complex structure (LEVIN, 1958). As for the true regression, it can be found only upon long-term observations. Later we shall show that the long-term Perseids nodal regression is very small, indeed. With due account taken of planetary perturbations, it amounts to something on the order of 2.10^{-4} deg. yr^{-1} for the last 15-20 millenia, which is confirmed by visual data (HUGHES, 1973). Therefore, since the narrow central condensation of the stream has been observed for at least a century we may conclude that this compact part is distributed all along its orbit but with a width that is obviously less than 1°. Consequently the thickness and width of this core are 0.016 a.u. and 0.0028 a.u. respectively.

The mean value of the solar longitude of the observed rate maximum has been 139.0 ± 0.2° for all the years of observation. It agrees well with most of the recent data obtained elsewhere. It is necessary to note that regardless of radioecho duration (i.e., particle mass) over a range from 1 to 20 sec, the maximum rate falls on the same solar longitude.

About 80 individual values of the mass index S have been found for this stream using the radio signal duration in the range of 0.7 to 60 sec. These are plotted in Fig. 1 as a function of the solar longitude (epoch 1950.0). It should be noted that the standard deviations in S for the Perseids are a little greater than for the Geminids and Quadrantids (ANDREEV et al., 1984 and ANDREEV et al., 1985). We believe a great portion of the spread in $S(\lambda_o)$ is due to a systematic mass index increase of about 0.01 a year (1964 to 1981). This increase can be explained by the ejection of mainly small particles from the comet surface during the last perihelion passage. The mean minimum value of S equals 1.94 ± 0.2 for the longitude of 139.0 ± 0.2°.

We found the Perseid flux density Q(m) by the modified Kaiser Belkovich method (ANDREEV et al., 1984). The physical model of the meteor phenomena selected was that of BELKOVICH et al., (1982). The particle density was taken as equalling 0.3 g cm^{-3}. For $m \geq 10^{-3}$ g, Fig. 1 gives the smoothed curve Q(m, λ 1950.0) obtained by averaging individual values with the step of about 0.7° in the solar longitude. Fig. 1 shows that the flux density maximum $q(10^{-3}) = 3.10^{-3}$ particles km^{-2} h^{-1} coincides with that of large particles. For $m \geq 10^{-3}$ g, the stream width at half maximum density is 1.8°. Analysis of the $Q(m, \lambda_o)$ shows that there is no

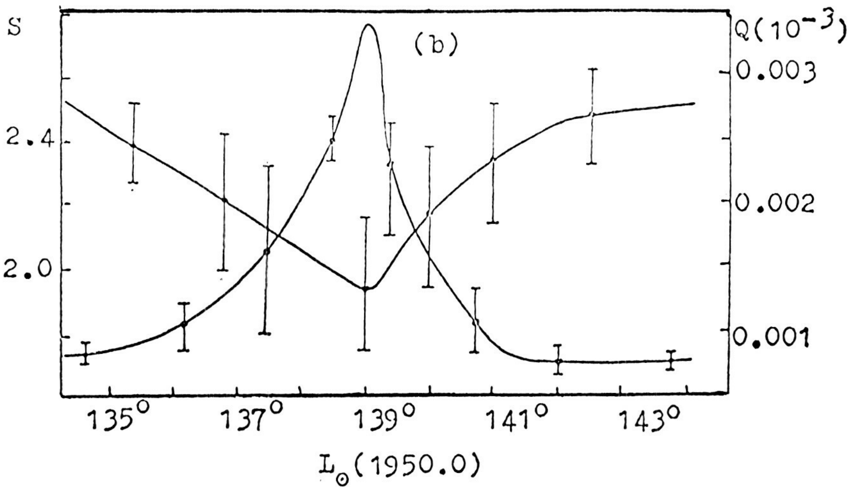

Fig. 1 Flux density Q(10^{-3}g)/km^{-2}h^{-1}/and index S versus solar longitude (epoch 1950.0).

displacement of the stream flux density position in the Perseids for the mass particle variation in the range of 10^{-4} to 10^{2} g.

On the basis of the obtained values of Q(m) and index S the meteor matter influx on the Earth during the Perseids activity time was estimated. For the range of masses from 10^{-5} to 10^{3} g the total influx amounted to 0.42 ton, half that amount striking the longitude range of 138 to 140°.

To define the total particle number in the stream and the stream mass, we derived the equation of the projection of the Earth's path on the nodal cross-sectional plane and determined the shower density distribution of particles with different mass along this projection. Studying these data, we discovered that the shower density distribution was asymmetrical to the mean orbital plane. It means that the area between equal density lines above the mean orbital plane are greater than the analogous area below it. The angle between the projection of the Sun direction and the major semi-axis of the cross-section is 27°. Hence, known gravitational and non-gravitational forces could not have caused this effect. The only possible explanation is a peculiarity of stream formation. The estimate of the total number of particles intersecting the cross-section of the Perseid stream at its node was obtained by integration of the flux density with the help of the ANDREEV and SUKHOTIN (1982) method. For the masses from 10^{-3} to 10^{3} g, the particle flux through the cross-section appeared to amount to $1.6 \cdot 10^{12}$ h^{-1} while the total number of particles in the stream was $1.7 \cdot 10^{18}$ and the stream mass less than $14 \cdot 10^{16}$ g.

The Perseid stream formation is usually connected with the decay of comet 1862 III. Taking into account the orbital size, one may assume that the decay of this comet was taking place mainly close to its perihelion. In this case, it should be expected that there must exist a common intersection region of individual meteor orbits. The analysis of 356 photographical meteor orbits showed that the ecliptic coordinates of this region are $\lambda_c = 84.4 \pm 4.5°$; $\beta_c = 62.5 \pm 1.7°$; $r_c = 1.51 \pm 0.09$ a.u.; and its true anomaly $V_c = 274\ 284.1 \pm 4.4°$. These data confirm the hypothesis of Perseid stream formation due to a comet decay on a rather small arc of the orbit.

Since individual meteor orbits cannot be used for solution of the problem of the Perseid formation and evolution, we considered the comet orbital evolution first and selected possible favorable moments for its decay. Fig. 2 gives the results of the comet evolution calculations by the Halphen-Goryacheve method (ANDREEV and SUKHOTIN, 1982) under the following conditions: a) the orbits of the disturbing planets Jupiter, Saturn and Uranus are constant; b) secular perturbations up to the first order by these objects are taken into account; c) the same as in b) but with perturbations due to Neptune added; d) the same as in c) but with perturbations produced by the Earth added; e) the same as in d) but with periodic perturbations at the epoch of close approaches to the planets were considered using numerical methods. Fig. 2 shows that subsequent comet evolution depends primarily on integration conditions. The analysis shows that the main evolutionary transformations of the comet orbit were caused by the close approaches to Saturn (the first was up to 1.07 a.u. in 1859.9 and later - one for every 33 revolutions) and one catastrophic approach to Jupiter some 25 millenia ago. Discussing Fig. 2 we came to the conclusion

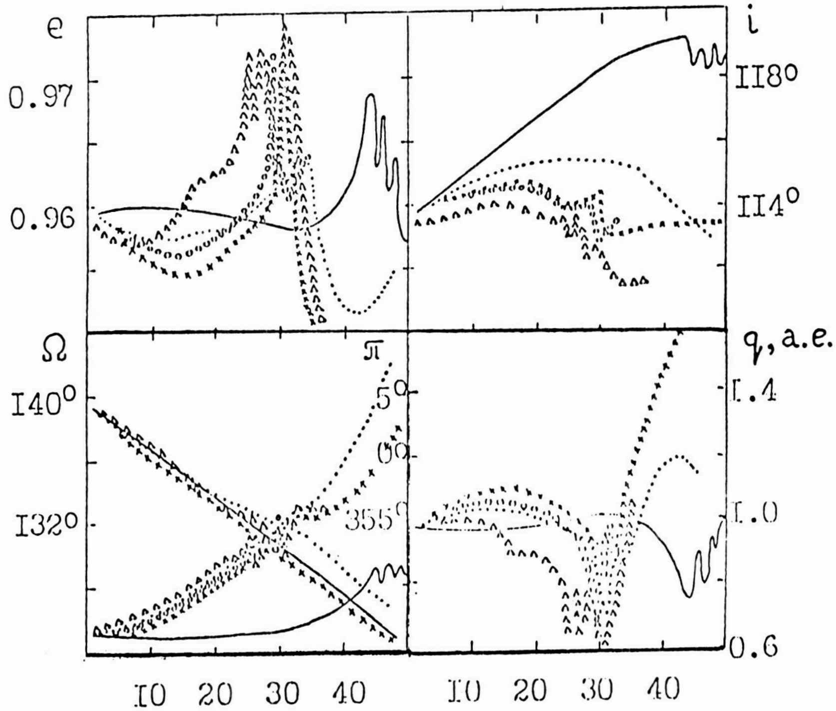

Fig. 2 Evolution of the comet 1862 III orbit. The curves correspond to the following integration conditions detailed in the text: a(---), b(●●●), c(xxx), d(ooo), and e(^^^).

that the comet 1862 III decay occurred most probably at the start of the comet onto its present orbit, i.e., 25 millenia ago. Special attention should be paid to the secular change of the true anomaly V_c of the common "point" in the Perseids orbits' approach. Irrespective of the integration conditions at the moment of approach to Jupiter, $V_c = 150 - 180°$. It means that for an interpretation of decay near the perihelion, the modern coordinates of λ_c, β_c are quite the opposite of the true ones.

In order to determine the decay velocities from the comet surface, various decay types (directed, isotropic, with different distribution of velocities and masses) were simulated. But none of the results satisfies either the observed deviation between the comet orbital elements and the elements of the stream's mean orbit nor the variance of the comet's modern orbital elements and the Earth's path length. Agreement with these decay models is possible only under the following conditions: a) if upon ejection practically all the particles pass through the sphere of influence of Jupiter (25 millenia ago) or Saturn (10-12 millenia ago); b) if the comet decayed near aphelia ~ 20-025 millenia ago and was of a collisional nature.

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