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SOME MODELS OF THE GEMINIDS METEOR STREAM FORMATION

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Further development of methods of investigations of meteor shower structure and a great deal of observational data have made it possible to obtain a precise flux density profile along the Earth's orbit for the Geminids meteor shower. This curve proved to be adequately described by a exponential law. The information obtained by ground observations is insufficient for construction of the exact picture of the flux density distribution in a stream cross-section. But we can make some assumptions. Namely, in a normal cross-section plane of Geminids, the lines of equal flux density (for particles with fixed mass) will be represented by a family of nested ellipse-like curves. The curves are stretched more toward the inside of the stream orbit. The flux density decreases exponentially from the maximum point to the periphery.

In this connection it is interesting to find out the following:

1. Which ejection model will fit the observed shower structure: a single ejection, an ejection over a certain orbital arch of the parent comet, a destructive impact, etc; and

2. To what extent the subsequent process of evolution modifies the formed structure.

Ejection from cometary nucleus.

The ejection from a cometary nucleus was modeled for particles of equal mass and size (radius = 0.1 cm, density = 0.8 g/cm^3). A sample of 5,000 particles was enough for construction of a qualitative picture of the stream cross-section in the ecliptic plane. The ejection speed of the dust was determined by the Whipple's formula (Whipple, 1951). The effect of radiation pressure was also taken into account (Burns et al., 1979).

The ejection at a certain point of the cometary orbit and around this orbit was simulated. Such models were considered by Fox, Williams and Hughes but for other purposes. The mean orbit of the Geminids from Fox et al., (1983) was chosen as a reference.

The model Geminids cross-section in the ecliptic plane with ejection at perihelion is shown in Fig. 1b. A distinctive ellipse was obtained. The size and compression of the ellipse changes depending on the true anomaly of the ejection point at the orbit of the parent comet but the qualitative picture is the same. It is clear that this model does not represent reality.

The second model simulates ejection around the cometary orbit. (See Fig. 1a). Ejection points are distributed around the orbit at random [rectangular distribution]. The ejection speed is fixed at every point. As we can see, the stream cross-section is of a rhombic rather than an

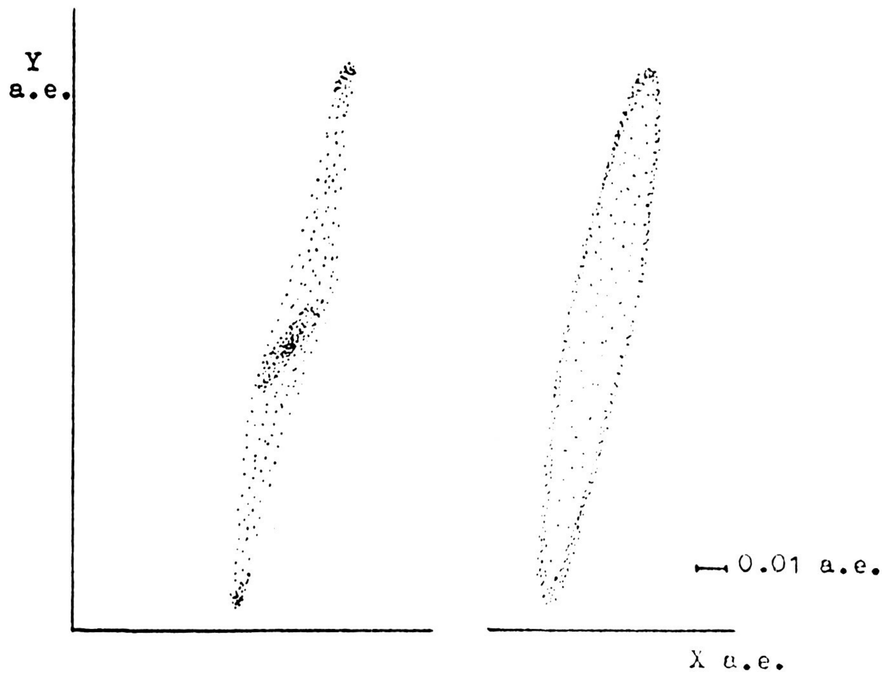

Fig. 1 Models of the Geminid cross-section in the eliptic plane. a) The ejection points are distributed randomly and uniformly around the orbit, b) The ejection from the perihelion point.

elliptical shape. A dense central core and distinctive concentrations at edges, so-called "wings", can be clearly seen.

Integrated rate curves, which are defined as the number of cross-section particles on some straight line (usually the X or Y axes of the standard heliocentric ecliptic frame), can be used for a qualitative study of the cross-sections. Fig. 2 shows the integrated curve along the X axis for ejections all around the orbit. An exponential density variation becomes apparent here.

1) Velocity distribution variation effects

The fixed ejection velocity for the given orbital point is an idealization. The gas flow speed (according to Whipple's model) is considered as a mean speed. It cannot be the same all over the cometary nucleus. Moreover, real particle cross-sections are different because of their irregular shape and this leads to variations in the ejection speeds. Therefore, it is more appropriate to study models where the ejection speed is distributed according to a certain law. Certainly, in the case of a destructive impact of the parent body, the notion of a velocity distribution must necessarily be applied.

Assuming a Gaussian distribution of ejection velocities we have obtained the following results:

1. In ejection all around the orbit there were the following changes: The "wings" vanished, while the exponentially grew more pronounced (Fig. 2).

2. But ejection only at perihelion produced striking changes as compared with the case of the fixed but random ejection velocity (Fig. 3). The structure of the cross-section in the ecliptic plane became similar to those observed in ejection all around the orbit. However, for this to occur the value of σ (the parameter of Gaussian distribution) must be no less than 0.4c, where c is the mean ejection velocity.

We have also examined the case of a random [rectangular] distribution of ejection velocity. Fig. 4 shows the integral rate curve along the X-axis for the isotropic ejections at perihelion and for a rectangular distribution of the ejection velocities in the interval from 0 to 1.33634 km/s. A detailed study of this curve leads to the conclusion that the density decrease from the cross-section center appear to depart from one that is strictly exponential. The integral curve for ejection around the orbit did not change appreciably. However, we have every reason to assume that the exponential dependence was also disturbed here and so this case requires further study.

The previous models have been considered in the assumption that the ejections take place during one comet revolution. When ejections occur during several revolutions, it is easy to foresee the resulting cross-section structure. The new integral rate curve, for example, can be obtained by adding several single revolution sets shifted along the axis, one towards the other. The width of the stream increases by 1.5 times for 100 years.

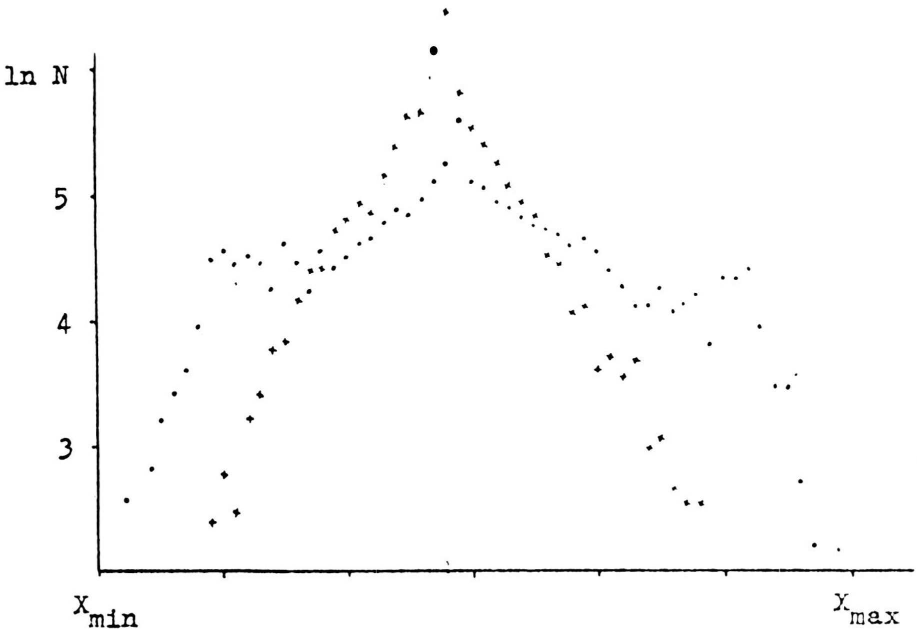

Fig. 2 The integral rate curves. The curve for the ejection around the orbit with the fixed ejection velocity is shown by dots, and the one with the Gaussian distribution of ejection velocities by crosses.

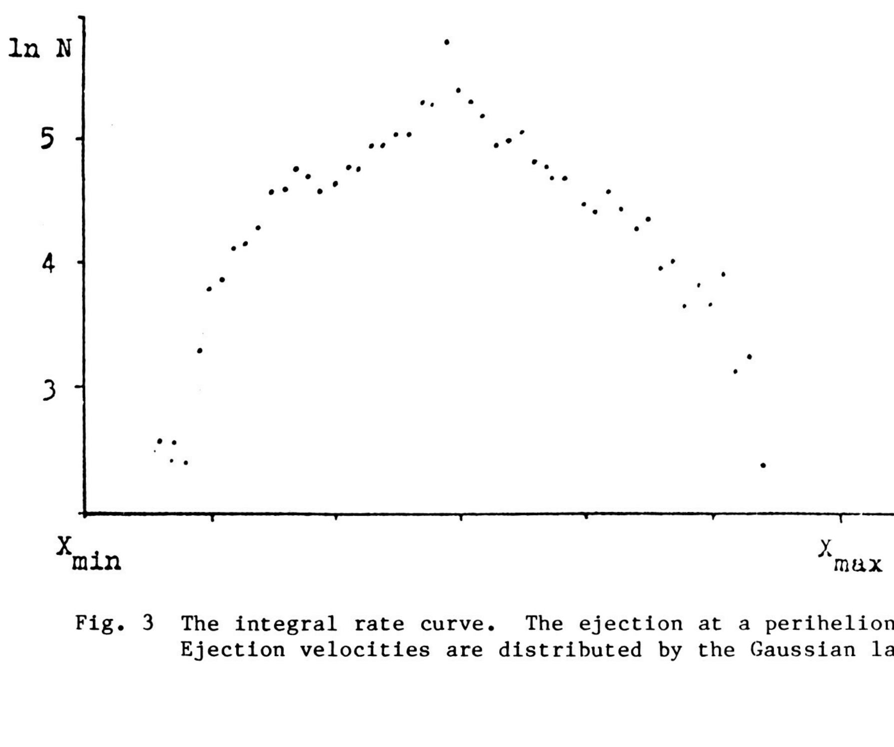

Fig. 3 The integral rate curve. The ejection at a perihelion. Ejection velocities are distributed by the Gaussian law.

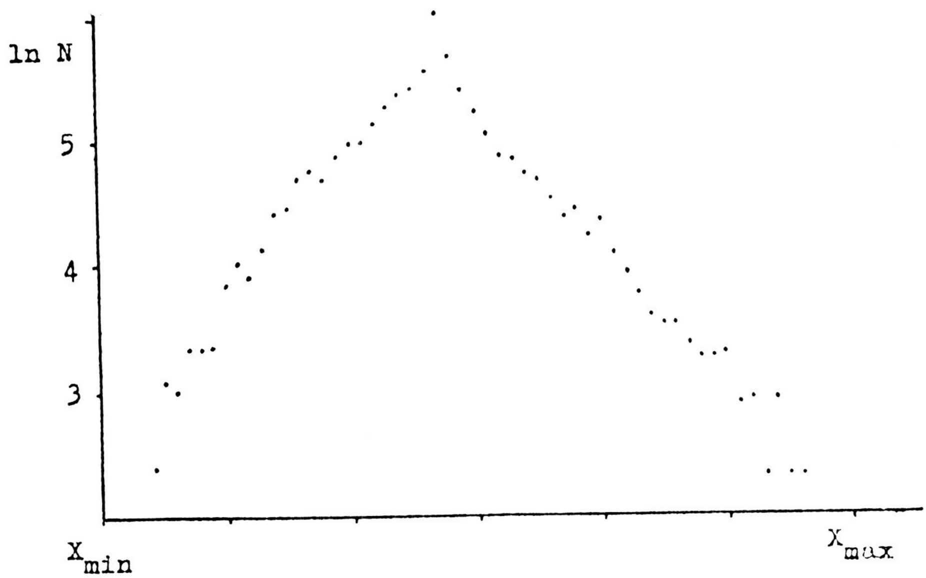

Fig. 4 The integral rate curve. The ejection at a perihelion. The distribution of the ejection velocity is uniform in the interval from 0 to 1.33634 km/s.

2) Cross-section changes due to the secular gravitational perturbations

A simple model to reveal the influence of secular gravitational perturbations on the cross-section structure changes is considered. A sample of 5,000 particles was ejected from the parent body around its orbit at random and rectangularly. The ejection velocity was determined by the Whipple's formula (WHIPPLE, 1951). The particles crossing the ecliptic plane along semi-major and semi-minor axes of the cross-section ellipse were chosen (Fig. 5, t=0). Then we traced the orbital evolution of those chosen (Fig. 5, t=0). Then we traced the orbital evolution of those particles for 8,500 years ahead by the Halphen-Goryachev method. It is sufficient to consider Jupiter's influence only on this model. The previously obtained ellipse-like shape of the stream cross-section is maintained for no more than 1,500-2,000 years (Fig. 5). The initial ellipse deforms gradually with the extension into the stream orbit increasing. The stream width remains about the same but due to stretching along the semi-major axis the mean space density of the stream decreases with time. However, the central core persists.

Thus, we can draw the following conclusions:

1. When studying the mechanism of formation of meteor streams, it is necessary to take into consideration the velocity distribution of particles that have been ejected from the parent body.

2. On the basis of the observed density variations, it is impossible to determine (at any rate at present) what kind of ejection takes place: a single ejection or that around an orbital arch.

3. The original structure of the Geminids cross-section persists for no more than 1,500-2,000 years.

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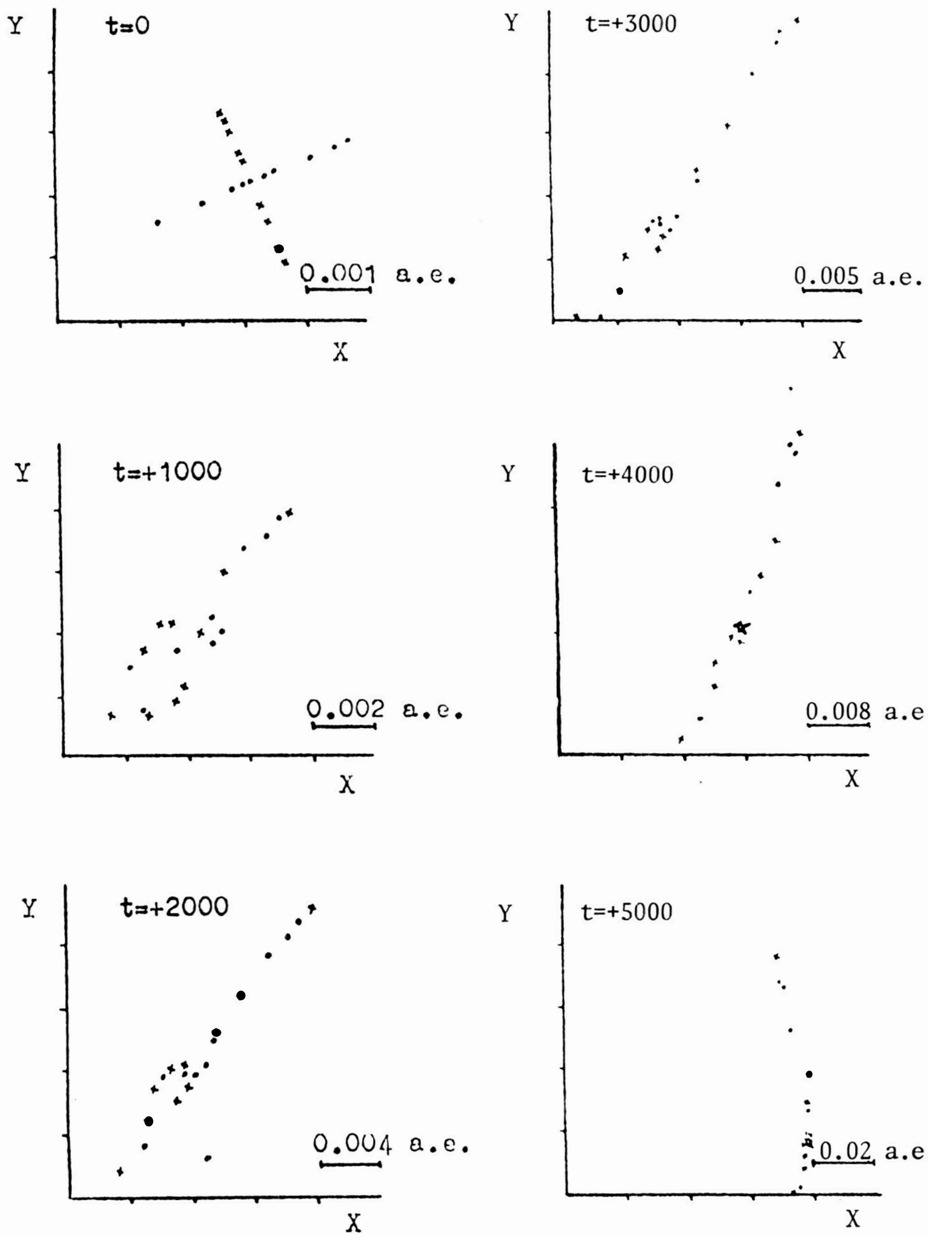

Fig. 5 The influence of secular gravitational perturbations on the shape of the Geminid cross-section in the ecliptic plane.