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# Retrospective evolution and age of a meteoroid stream

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## Retrospective evolution method

The retrospective evolution method implies that evolution of a parent body orbit and the orbits of meteoroids of its meteoroid stream are traced back in order to find the moment of their convergence. This method was very popular 20–30 years ago until researchers realized that it is not reliable, since any method for the numerical integration of the equations of motion is sensitive to the inaccuracy of the initial conditions, and this inaccuracy is large even for the most precise photographical orbits of meteors. In addition the physical parameters of the meteoroids are not well known, so non-gravitational perturbations, which are significant for meteoroids, are not well known also.

It so happened that, ascertaining in unreliability of the method, almost no one published the results of their studies. A single publication exists [1], where the authors revised the results of their earlier studies after they had analyzed the influence of the initial conditions on the results of integration. To calculate the orbital evolution, Kramer and Shestaka [1] used the Gauss method. Their results were later confirmed using the Everhart numerical integration method [2]. Ryabova [2] showed that, most likely, the problem of determining the error in estimating the age of a stream cannot be solved at present.

Time passed, and the unpublished, but "known to all" results have been forgotten. The purpose of this work is to demonstrate that errors of the initial parameters do not allow to determine the moment of a model stream formation. The study was fulfilled for several model examples of the Geminid, Orionid, Perseid, Quadrantid, and Leonid meteor showers.

As a measure of the distance between two orbits we used the Southworth-Hawkins *D*-criterion [3], Drummond *D*-criterion [4], and the minimal value of distances between two points lying on two given ellipses [5–6].

## Modelling method

We simulated the ejection of 1000 meteoroids from a parent body at a specified moment. The ejection was isotropic and the ejection velocities have been determined using the Whipple [7] formula. The ejection of meteoroids was simulated during one revolution of the parent comet; the true anomalies of the ejection points were distributed proportionally to $r^{-3} - r^{-4}$, where $r$ is the heliocentric distance.

The evolution of the orbits was calculated from the ejection moment to January 1, 2000. After that, the errors were introduced into the elements of the orbits of the model meteoroids, and the "impaired" orbits were integrated back, but 1000 years further than the ejection moment. Non-gravitational effects were ignored. The phase distances $D$ and the Euclidian distance were calculated between the orbits of the parent body and model meteoroids with some time step. The errors we introduced to the orbital elements are the real errors of the observations, taken from the Dutch Meteor Society catalog [8].

## Results

We considered the following models: the Geminid stream (age ≈2000 years), the Quadrantid stream (age ≈1000 years), the Orionid stream (ages ≈ 700 and 2200 years), the Perseid stream (ages ≈ 900 and 2100 years), and the Leonid stream (ages ≈ 400 and 1100 years). It was found that the age of none of the considered model streams has been reliably determined.

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