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Could the Geminid meteoroid stream be the result of long-term thermal fracture?

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Abstract

The previous models by Ryabova have shown that the Geminid meteoroid stream has cometary origin, so asteroid (3200) Phaethon (the Geminid's parent body) is probably a dead comet. Recently (in 2009 and 2012) some week activity was observed (see Jewitt & Li, 2010, AJ, 140), but it was not the cometary activity. Recurrent brightening of Phaethon in perihelion could be the result of thermal fracture and decomposition. In this study we model the long-term dust release from Phaethon based on this mechanism.

1. The reason for the study

1.1 First qualitative model

Some time ago the work on the *qualitative* model of the Geminid meteoroid stream was completed [1, 2]. The main discovery was that the stream has two layers, and the peculiar bimodal shape of the observed activity profile conforms to *cometary scenario* of the stream origin. To calculate orbital evolution of meteoroids the method of nested polynomials was used, which is about 10^6 times faster than numerical integration, so it was possible to use statistically-rich models in 10 millions of meteoroid orbits.

1.2 Second numerical model

However the use of approximations has some shortcomings, considered in detail by Ryabova [1]. In the result the model stream turned out to be shifted in space and more compact relatively the real stream. The next step was the *quantitative* model. Numerical integration is expensive: to calculate a frugal model in 30 000 of particles a usual desktop computer has to make calculations about one month; therefore it is reasonable to begin with a preliminary model [3, 4]. It was found that the stream width increased insignificantly, so gravitational perturbations and encounters with the planets are not responsible for the mentioned discrepancy. The shower maximum in the numerical model is still shifted about one day relatively the observed one. We again come to Lebedinets [5] hypothesis that the parent body orbit underwent the drastic transformation during rapid release of the volatiles. Such transformation explains both discrepancies. Unfortunately, it is hardly possible to calculate the initial parent body orbit, if it is the case.

1.3 (3200) Phaethon activity

The Geminid's parent body asteroid (3200) Phaethon was discovered in 1983. Since then no activity was observed until 2009, when Jewitt & Li [6] found evidence of week activity. The same was observed in 2012 [7]. In both years the scenario was identical: about 0.5 days after perihelion passage Phaethon brightened very fast by 1 mag, and the brightness returned to its normal level within 2 days.

Jewitt & Li [6, 7] have analyzed four possible reasons for the brightening, and considered that the most plausible is the dust production by thermal fracture and decomposition. They estimated the ejected mass as $4\times10^8 a_{\mathrm{mm}}$ kg, where a_{mm} is the effective dust radius in mm. The mass of the Geminid stream according to highly uncertain estimates is 10^{12} to 10^{13} kg [8, 9]. So theoretically the stream could be produced by this periodical replenishment during several thousand years.

As it was mentioned above, the results of the Geminid modelling lead us to cometary origin of the stream. Moreover, they suggest that the dust release has happened during very short time — from one half and up to several orbital revolutions. Nevertheless, I believe that simulation the contrary scenario could clarify the situation.

2. Model

The method of modelling was described in details by Ryabova [1]. Taking into account that the Geminid's age is about 2 thousand years [10], and that from all ejected particles only small amount is registered on the Earth, it is not advisable to use numerical modelling. The main idea is simple: to simulate particles ejection in perihelion every several revolutions and follow their evolution till the present time.

On the moment of this abstract presenting there are no results to analyse. I could only predict that the model activity curve should be very different from the observed Geminid profile of activity.

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