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

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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, 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.

(3200) Phaethon activity

The Geminid's parent body asteroid (3200) Phaethon was discovered in 1983. Since then no activity was observed until 2009 [1] and 2012 [2]. 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. A hypothesis explaining this scenario (i.e. why 0.5 days after perihelion, and why only 2 days) was proposed in [3]: the combination of extremely high obliquity (~88°) of the Phaethon pole and very small perihelion distance (0.14 au)

Jewitt & Li [1] 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 and found that the stream could be produced by this periodical replenishment during several thousand years.

Geminid meteoroid stream modelling

Some time ago the work on the *qualitative* model of the Geminid meteoroid stream was completed [4, 5]. 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.

However the use of approximations has some shortcomings [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 [6]. This numerical model did not improve the situation. The model 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 still was shifted about one day relatively the observed one.

However, careful comparison the model activity profile with observations has shown that the Geminids have rather narrow core, which is comparable with the model one, and very extended low-level activity. This 'tail' is practically absent in the model. 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. During this catastrophic release of volatiles the cometary orbit could be drastically transformed. Another possibility is that the core of the stream was generated by this catastrophic dust release, and the wide low-level 'tail' by long-term recurrent perihelion activity.

Long-term thermal fracture modelling

The method of modelling was described in details in [4]. The main idea is simple: to simulate particles ejection with 'thermal' speed (~100 $\mathrm{m\,s^{-1}}$) in perihelion every several revolutions and follow their evolution till the present time. We used Halphen-Goryachev method to calculate the particles' orbital evolution.

We found that it is not probable that the Geminid meteoroid stream (or its low-active wide tail) was generated by long-time thermal fracture.

References

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