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Capture of Small Bodies After Tidal Disruption

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Abstract

The subject of the current work is the phisical and dynamical evolution of the small comets group formed by tidal disruption of the protocomet while passing near the large body (Sun, Jupiter). The equations of motion were integrated numericaly. In case of the Sun the evolution of the sun-grazing orbits were discussed and the typical lifetime of such comets was estimated. Nongravitational acceleration and the size reduction of fragments due to sublimation were taking into account.

1. Introduction

A long-standing problem in cometary astronomy is the mechanism of capture of Halley-type comets from near-parabolic flux. There is the difficulty of explaining the apparent over abundance of Jupiter-family comets compared with predictions based on capture from the observed near-parabolic comets flux. In this paper we try to solve these problems by Opics capture of icy fragments (the capture by the massive body after tidal disruption of large protocomet). The large comet could be disrupted by the tidal forces during the close approach to the Sun or a giant planet. This is one of the main hypothesis of the Kreutz comet group formation [4]. In such case the cloud of comet fragments of different sizes is formed. Their further trajectories can be described as independent. The fragments' positions are very close to each other in the perihelion. However the comet cloud stretches sufficiently while moving to aphelion. The orbits of the fragments can evolve in different ways under influence of the planets' gravitational perturbations and the sublimation jet force.

The evolution of near-parabolic orbits was previously discussed by researchers [2]. It is noticed that the high-eccentricity orbits are more likely to evolve in the inner regions of the Solar System if they had initially small perihelion distance. The sun-grazing orbits are interesting as an extreme case of such orbits. Besides the close approach to the Sun is typical for many of the asteroids approaching the Earth [1]. So the evolution of sun-grazing orbits can be considered as a potential source of near-Earth objects.

2. Orbit evolution

We considered two model problems, namely, the disruption near the Sun and near Jupiter. The differential equations of motion were integrated numerically. The planets' motion was considered as nonperturbed in both cases.

2.1. Disruption near the Sun

In case of the Sun the protocomet moved on the near-parabolic orbit with the eccentricity equal to 0.99993 and the semi-major axis equal to 100 AU. The disruption took place in the perihelion in the distance of 0.007 AU from the Sun. The fragments which appeared closer to the Sun passed to less elliptical orbits because they kept the speed the parent body had.

The sublimation acceleration was calculated according to the Marsden formula[3]. The comets were considered as ice spheres. The change in size of the comet was taken into account.

Without close approaches to planets the complete combustion of a comet on sun-grazing orbit takes several thousands of years.

Also we considered the occasion when the comet cloud after disruption at the perihelion is passing close to Jupiter. It should be noted that if the initial size of the cloud was 100 km it would be about 0.1 AU while crossing the Jupiter's orbit. In this case the gravitational influence of Jupiter was enough to capture some of comets to the low-eccentricity orbits.

2.2 Disruption near Jupiter

In case of Jupiter large protocomet moved on the hyperbolic orbit with perihelion in the close vicinity of Jupiter. The disruption occured on the distance of

0.0005 AU from the planet. We modeled the different configurations in terms of the Sun-Jupiter-comet position. The 100 km cloud after passing the Jupiter sphere of influence was stretched in size up to 0.02 AU.

Part of these comets moved on a such distance from the Sun so the sublimation effect was small or even neglectable. First of all it means that comets does not burn down quickly and can exist for cosmogonic time.

3. Summary and Conclusions

The main result of this work is the cloud of the protocomet's fragments become very dispersed right after disruption. The sun-grazing orbits are not likely to evolve in the inner regions of the Solar System because the sun-grazers burn down too fast.

However a giant protocomet disrupted near the Jupiter might be a source of the small bogies on long existing orbits.

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