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Temporary capture of asteroids by Jupiter/Saturn

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Abstract

Irregular satellites observed around giant planets are thought to be object that were initially in the heliocentric orbits and later been captured into their current orbits around their host planets. To clarify the possibility of their origin in the asteroid belt, we calculated the orbit of mass-less particles initially distributed around the outer asteroid belt under the perturbations by Jupiter and Saturn. We found that the asteroids can be the candidates for the irregular satellites, not only of Jupiter but also of Saturn.

1. Introduction

The irregular satellites might not be formed by accretion in a circumplanetary disk, as were the regular satellites. The inclination distribution and large semimajor axes of the irregular satellites tell us that they must have formed elsewhere and later been captured into their current orbits around their host planets (e.g., [1]). The recent study on their origin in the framework of the Nice model proposed that the irregular satellites are the icy planetesimals originally formed outside the giant planets [2]. In this model, the planetesimals could be captured by the planets via 3-body interactions during the planet migration. On the other hand, their low albedo (<~0.05) derived from the observations may indicate that they are physically similar to asteroids rather than Kuiper belt objects. However, the possibility of the Main Belt Asteroids (MBAs) being the irregular satellites, especially those of Saturn and the outer giant planets have not been examined. Furthermore, the effect of another planet on the capture process has not been clarified, despite the process of temporary capture of particles by a giant planet has been investigated by many authors (e.g., [3]).

2. Model and Method

2.1 Setup

How effective/ineffective is Saturn in the capture of asteroids by Jupiter? To answer the questions we calculated the orbit of mass-less particles initially distributed around the asteroid belt (2.5-4.5AU) under the perturbations by Jupiter and Saturn. Jupiter and Saturn have their current masses and in circular orbits with their current semimajor axes. These two planets have no gravitational interaction between them (so-called restricted circular 4-body problem). The equation of the motion we solved using the 4th-order Hermite scheme is

$$\frac{d^2\mathbf{r}}{dt^2} = -\frac{GM_{Sun}}{r^3}\mathbf{r} - \frac{Gm_J}{r_{Jp}^3}\mathbf{r}_{Jp} - \frac{Gm_S}{r_{Sp}^3}\mathbf{r}_{Sp} - \frac{Gm_J}{r_J^3}\mathbf{r}_J - \frac{Gm_S}{r_S^3}\mathbf{r}_S \qquad (1)$$

where G is the gravitational constant, M_{Sun}, m_J, m_S are the masses of the Sun, Jupiter, and Saturn, respectively, and $\mathbf{r}$, $\mathbf{r}_J$, and $\mathbf{r}_S$ are the position vectors of the particle, Jupiter, and Saturn, respectively. The subscripts Jp and Sp of $\mathbf{r}$ denote the directions from the particle to Jupiter and Saturn, respectively.

2.2 Candidates

During the calculation, we counted the number of the irregular satellite candidates. To count the irregular satellite candidates, we used two definitions of the candidates. First, it is called an “encounter”. It is defined only by the minimum distance between the particle and the potential host planet. When the minimum distance is less than one Hill radius of the planet, this event is counted as an “encounter”. Second, it is defined by the distance and the time; if a particle spends time longer than one Kepler period of the potential host planet within its three Hill radii, the event is counted as a “temporary capture”.

3. Results

We found that (1) asteroids can be transported near both Jupiter and Saturn, (2) the number of J-candidates is about three times larger than that of S-candidates, and (3) the existence of Saturn is ineffective in the temporary capture by Jupiter and changes the favoured conditions for capture. The favoured condition is overlapping Hilda asteroid region on the semimajor axis (a) and eccentricity (e) plane. Figure 1, which shows the *a* and *e* of the particles just before the temporary capture (the distance between the particle and the planet is exactly three Hill radii), indicates the favoured region on the *a*-*e* plane. Figure 2 compares two examples of the orbits on the rotational coordinates centred on the host planet. The particle captured via the favoured region (red) is tightly bound to the host planet compared to the other. The total number of the temporary capture event and the ratio of the temporary capture via L_2 point are smaller than the case without Saturn. These negative effects of Saturn will be analyzed in detail and presented on the poster at the EPSC/DPS meeting 2011.

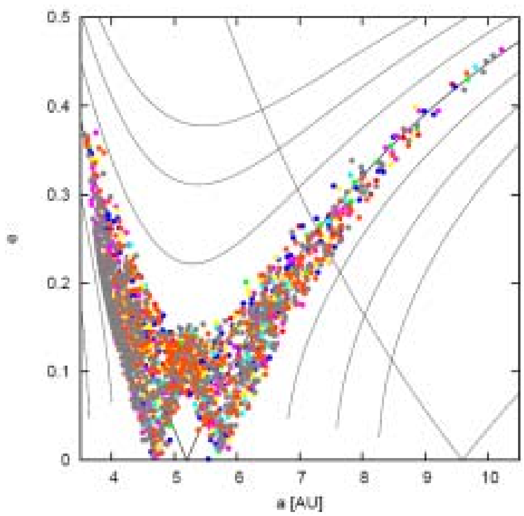

Figure 1: Distribution of the particles just before the temporary capture on the *a*-*e* plane.

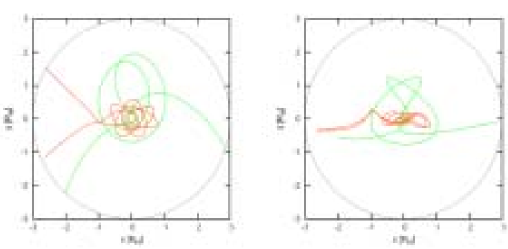

Figure 2: Examples of orbits on the rotating coordinate centered on the host planet.

References

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