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Temporary capture of planetesimals by a planet

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When planetesimals encounter with a planet, the typical duration of close encounter during which they pass within or near the planet's Hill sphere is smaller than or comparable to the planet's orbital period. However, in some cases, planetesimals are captured by the planet's gravity and orbit about the planet for an extended period of time, before they escape from the vicinity of the planet. This phenomenon is called temporary capture. Temporary capture may play an important role in the origin and dynamical evolution of various kinds of small bodies in the Solar System, such as short-period comets and irregular satellites. Recently, temporary capture of planetesimals by a planet from heliocentric orbits has been investigated in detail using three-body orbital integration (Iwasaki & Ohtsuki 2007). In the case of planetesimals initially on circular orbits, the rate of temporary capture was evaluated, and it was found that it increases with increasing semi-major axis of the planet, because the size of the planet's Hill sphere relative to its physical size increases with increasing distance from the sun. The rate of temporary capture in the case of low random velocity was also examined and shown to increase with increasing orbital eccentricity. However, cases of large orbital eccentricities were not examined in detail. Moreover, the above calculations assumed that planetesimals and a planet were initially in the same orbital plane, and effects of orbital inclination were not studied. In the present work, we examine temporary capture of planetesimals initially on eccentric and inclined orbits about the Sun.

We examine temporary capture using three-body orbital integration (i.e. the Sun, a planet, a planetesimal). We integrate Hill's equation for planetesimals with various initial orbital elements, using the eighth-order Runge-Kutta integrator. The initial azimuthal distance between planetesimals and the planet was taken to be large enough to neglect their mutual gravity. Planetesimals are uniformly distributed radially, and in the case of initially eccentric or inclined heliocentric orbits, their initial horizontal and vertical phase angles are also uniformly distributed. Orbital integration is terminated when the distance between the planetesimal and the planet becomes large enough again, or a collision between them is detected.

We found that the rate of temporary capture increases with increasing eccentricity, in agreement with the previous calculation with a limited range of parameters. In the case of low initial random velocity, temporary capture in the retrograde direction is common, and prograde capture is very rare. On the other hand, both prograde and retrograde captures become possible for large initial eccentricities. Also, shapes of the orbits during temporary capture are different between cases of prograde and retrograde orbits about the planet.

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