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Temporary capture of planetesimals by a giant planet

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Gravitational interaction between planets and planetesimals plays an important role not only in planet formation but also in the origin and dynamical evolution of small bodies in the Solar System. When planetesimals encounter with a planet, in most cases they experience either gravitational scattering by the planet or collision onto it. However, in some cases planetesimals can be 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, and may have played an important role in the origin of irregular satellites and Kuiper-belt binaries, as well as dynamical evolution of short-period comets.

Recently, we investigated temporary capture of planetesimals initially on eccentric orbits, and found that temporary capture orbits can be classified into four types (Suetsugu et al. 2011). Their orbital size and direction of revolution around the planet change depending on planetesimals' initial eccentricity and energy. When initial eccentricity is so small that Kepler shear dominates relative velocity between planetesimals and the planet, temporary capture typically occurs in the retrograde direction in the vicinity of the planet's Hill sphere, while large retrograde capture orbits outside the Hill sphere are predominant for large eccentricities. Long prograde capture occurs in a very narrow range of eccentricity and energy of planetesimals. We obtained rates of temporary capture of planetesimals and found that the rate of long capture increases with increasing eccentricity at low and high eccentricity but in intermediate values of eccentricity decreases with increasing eccentricity.

In the above study, we performed three-body orbital integrations under Hill's approximations, where the masses of the planet and planetesimals are assumed to be much smaller than the solar mass. In this case, the effect of the curvature of their guiding-center orbits are neglected.

This assumption is valid for the case of low mass planets, but the effect of curvature may be important for temporary capture by a high mass planet, like Jupiter. Previous global orbital integration that investigated temporary capture focused on long-term evolution of small bodies under the influence of multiple giant planets (Kary & Dones 1996).

In the present work, we use a simple three-body system that consists of the Sun, a planet, and a test particle, and perform global orbital integration to examine effects of a high mass planet on temporary capture. We will discuss the characteristics of temporary capture obtained by our global calculation and compare them with our previous results of local three-body calculation.

Keywords: planets, satellites