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The formation probability of the binary planet

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Binary planet is a system in which two planets revolve around a central star while rotating around each other. In the case of gaseous planets, a planet can capture the other planet by the tidal force when they closely approach during the planet scattering process. We study the closest distance between the planets during the scattering phase and determine the probability of binary planets formation.

It is known that the amount of energy dissipated by dynamical tides significantly depends on the distance between the planets. For two planets to be captured as a binary planet, it is necessary that the planets approach within several times of their physical radii. How multiple planets approach can be calculated only by mutual gravitational interactions, regardless of the details of the tidal model. In addition, the encounters of planets do not occur continuously unlike the encounter of the central star and the planet. Previous studies suggest that the formation of binary planets takes place immediately after the start of the orbital instabilities. We stop our calculations by 10000 Keplerian orbits, but perform 10000 simulations, which allow the statistical discussion. We compare Jacobi integral and the tidal energy to be dissipated at their closest encounter.

Results of our simple approach are almost consistent with the previous study, which performed orbital calculations including tidal dissipations (Ochiai et al. 2014). We find that the probability of binary planet formation was about 10%, independent of the semi-major axis. We vary the strength of tides as a parameter. We find that when the tidal dissipation is four times stronger, the formation probability of the binary planet becomes approximately two times larger. The probability of formation becomes 1/4 when the tides are 1/4.

Keywords: binary planet, N-body simulation