Formation of Low-Mass Multiple Satellites

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In this paper, we investigate the evolution of a debris disk and accretion of satellite(s) from the disk by N-body simulations.

In a context of the lunar origin, it was shown that a single satellite would be formed from a relatively massive debris disk, which is initially confined within the Roche limit (Ida et al. 1997). We performed N-body simulations of less massive disks, and found that a multiple satellite system is formed from a less massive disk.

A multiple satellite system is formed as follows. Within the Roche limit, no satellite is formed from the disk due to tidal effect of the planet. However, the disk spreads due to its viscosity, and a satellite grows outside the Roche limit with disk material which spreads beyond the Roche limit. On the other hand, gravitational interaction between the satellite and disk particles works as if it were repulsive. Thus, when the satellite mass reaches a certain value, disk-satellite repulsion overwhelms the viscous spreading of the disk, and a gap is formed between the satellite and the disk, and growth of the satellite stops. As a result, mass of a satellite becomes proportional to a square of the disk mass. If the mass of the satellite is small compared with the remaining disk, the satellite migrates outward by satellite-disk interaction, and the disk spawns a new satellite near the Roche limit.

We found that a multiple satellite system is formed from a disk with mass less than about $0.03 M_{c}$, where M_{c} is mass of the planet. In the course of disk evolution, disk material tends to pile up in resonance location of the satellite, and a new satellite tends to be formed from that material. In the parameter range of our simulations, satellites are in 2:1 orbital resonance if two satellites are formed.