Satellite formation via pebble accretion in circumplanetary disks

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The four icy satellites around Jupiter called "Galilean satellites" are considered to have formed in a circumplanetary disk. In Shibaike et al. in prep., we calculated the growth and drift of dust particles in a steady circumplanetary disk and investigated the success condition of satellitesimal formation. We found that the dust-to-gas inflow mass flux ratio has to be higher than unity for the satellitesimal formation in the circumplanetary disk by the collisional growth of the dust particles and that the all dust particles drift to Jupiter in other conditions. However, it is difficult to achieve this success condition.
Recently, a new planetary formation model called "pebble accretion" has been attracted attention. In this model, several protoplanets accrete a lot of cm-sized dust particles (called "pebbles") drifted from the outer region of the protoplanetary disk and grow rapidly to planets.
In this work, we applied this "pebble accretion" model to satellite formation. We calculated the growths of the protosatellites accreting the dust particles growing and drifting in the circumplanetary disk. Figure 1 represents the growths of the protosatellites on the fore fixed current Galilean satellites' orbits when the gas inflow mass flux is $0.14 M_J/\mathrm{Myr}$ and the strength of turbulence in the viscous accretion disk is $\alpha=10^{-4}$. We found that there is a possibility that the protosatellites can grow to the planets with the mass of the Galilean satellites, 10^{23} kg, within 10^5-10^7 years even in the case with that the dust-to-gas mass inflow flux ratio is 0.01. Figure 2 represents the timescales of the growths of the protosatellites and the inward drifts by Type I migration. Our estimate suggested that the protosatellites drift to Jupiter by the Type I migration because the growth timescales become longer than the drift timescales when their mass reach 10^{21} kg. We used a simple model assuming steady states in these estimates. We will discuss the satellite formation in unsteady states, in other words, the evolutions of the circumplanetary disk and the orbits of the protoplanets in our talk.

Keywords: Satellite, Pebble accretion, Protosatellite, Circumplanetary disk, Galilean satellites, Type I migration