Accretion of gas and dust onto giant planet systems and implication for satellite formation

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The principal satellites of giant planets, such as Galilean satellites and Titan, are considered to be formed by accretion of solid materials in the gaseous disk around a giant planet, i.e., circumplanetary disk. Although building blocks of the satellites are likely to be supplied from the protoplanetary disk into the circumplanetary disk, there are many unknowns in the supply process. Recent numerical studies show that three-dimensional gas flow around a planet significantly influence the supply of solid materials (Tanigawa et al. 2012, 2014; Homma et al. 2020). On the other hand, it is not well understood yet how the process depends on planetary mass. In this work, we performed hydrodynamic simulations in the local region around a giant planet for various planetary masses, and integrate the orbits of solid particles taking the obtained gas flow into account. Then we investigate the dependence of the supply process of gas and small particles to the circumplanetary disk on the planetary mass.

From our hydrodynamic simulations, we found that the source region of the gas accreting into the circumplanetary disk, i.e. “accretion band”, expands in radial direction in proportion to the planetary mass. Using this result and considering the effect of gap formation, we semi-analytically estimated and found that solid mass accretion rate onto a circumplanetary disk depends on the -2/3 power of the planetary mass in the limit of the small size of particles. Orbital integration of solid particles showed that the capture rates of particles with a sufficiently small Stokes number increase with increasing planetary mass, under the assumption that particles are mixed well with the gas in the vertical direction. When particles are stirred vertically enough due to strong turbulence, solid mass accretion rates are found to be consistent with the semi-analytical solution obtained based on hydrodynamic simulations. We also investigated the radial distributions of supplied particles in the circumplanetary disk, and found that they are mainly supplied in the region exterior to the current orbits of the Galilean satellites. We will discuss implication for satellite formation around a giant planet based on the above results.

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