Collisional evolution of dust in planet formation

Hiroshi Kobayashi[1]

[1]*Department of Physics, Nagoya University*

Planets were believed to form via the accretion of planetesimals generated from dust grains in protoplanetary disks. However, the growth of planets is much slower than their migration due to disk-planet interaction. Comparably rapid growth via pebble accretion was then proposed, which requires very massive protoplanetary disks because most pebbles fall into the central star. Although planetesimal formation, planetary migration, and planetary growth have been studied with much effort, the full evolution path from dust to planets was uncertain. We have investigated full collisional evolution from dust to planets. For collisional evolution, collisional outcomes are not simply characterized as fragmentation, bouncing, etc. The impact simulations for dust aggregates showed the detailed outcomes. According to the outcome model, the growth of dust grains are not prevent from collisional fragmentation. We thus perform the full simulations (DTPSs) for collisional evolution from dust to planet in whole protoplanetary disks. Dust growth with high porosity allows the formation of icy planetesimals in the inner disk ($\leq 10\,\mathrm{au}$), while pebbles formed in the outer disk drift to the inner disk and there grow to planetesimals. The growth of those pebbles to planetesimals suppresses their radial drift and supplies small planetesimals sustainably in the vicinity of cores. This enables rapid formation of sufficiently massive planetary cores within 0.2-0.4 million years, prior to the planetary migration. However, such porous pebbles are unlikely to reproduce the polarized millimeter wavelength light observed from protoplanetary disks. We thus investigate gas-giant core formation with non-porous pebbles via DTPSs. Even non-porous bodies can grow into planetesimals and massive cores to be gas giants are also formed in several 10^5 years. The rapid core formation is mainly via the accretion of planetesimals produced by collisional coagulation of pebbles drifting from the outer disk. The formation mechanism is similar to the case with porous pebbles, while core formation occurs in a wider region ($5-10\,\mathrm{au}$) than that with porous pebbles. Although pebble growth and core formation depends on the disk temperature, core formation is likely to occur with disk temperatures in typical optical thick disks around protostars.