Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

PEM032-01 Room: Exibition hall 7 subroom 1 Time: May 24 13:45-14:02

Importance of dust charging in planet formation

Satoshi Okuzumi[1*]

[1]GSHES, Kyoto University

It is a widely accepted idea that the fist step of planet formation is the growth of micron-sized dust particles into kilometer-sized solid bodies (planetesimals). A protoplanetary disk, a gas disk around a young star, consists primarily of $H_2$and He gas, with approximately 1% by mass of micron-sized dust grains. It is still an open issue how such microscopic particles evolve into kilometer-sized bodies. To address this issue, we need to identify all physical processes that determine the evolution of dust in protoplanetary disk.

In this talk, I discuss the roles of dust charging in planet/planetesimal formation. It is theoretically considered that protoplanetary disks are weakly ionized by a variety of nonthermal ionization sources (e.g., Galactic cosmic rays, stellar X-rays). The fact that dust charges up negatively in ionized gases---although well known in plasma physics---has been totally ignored in the theory of planet(esimal) formation. In addition, protoplanetary disks are characterized by very low ionization degrees, which are easily affected by dust charging.

Dust charging affects planet formation processes both directly and indirectly. A direct effect is electrostatic repulsion between dust particles. With an analytical model on dust charging in a weakly ionized gas, we have first examined how strongly the electrostatic repulsion could halt the collisional growth of dust particles. Surprisingly, we find that the repulsion is so strong and could halt dust growth in the most of the planet formation region (1-100 astronomical units from the central star). This implies that planet formation might be triggered by dust growth far away from the central star.

An indirect effect of dust charging is the stabilization of MHD turbulence. It is well known in astrophysics that a magnetized, differentially rotating gas disk is unstable (magnetorotational instability, MRI). The MRI saturates at nonlinear levels and provides MHD turbulence in the disk. Turbulence can be a barrier against planetesimal formation since it induces high-speed collisional fragmentation of macroscopic dust particles. However, the MRI does not operate in a region where microscopic dust particles are abundant, because they efficiently lower the ionization degree of ambient gases and make the region decoupled from magnetic fields. This fact implies that dust charging is a key to circumvent the turbulence-induced fragmentation barrier against dust growth. In this talk, I show the results of simple model simulations that take into account dust growth and MRI-driven turbulence consistently, and demonstrate that the stabilization of the turbulence due to dust charging is a powerful mechanism that allows us to go beyond the fragmentation barrier.

Keywords: dust, charging, planet formation, weakly ionized gases, MHD, turbulence