Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS21-23 会場:304 時間:5 月 20 日 17:15-17:30

ダスト－円盤ガス－惑星間の重力相互作用
Planetary Migration in Dust-Rich Disks

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There are still serious problems in the theory of planet formation. One of the problems is how to keep protoplanets with Earth-masses in a disk for a sufficiently long time until the disk gas is dispersed. A protoplanet growing in a disk interacts with a gas disk gravitationally and, as a result, changes the radial distance from the central star. This process is called the type I migration of a protoplanet. A variety of structures of extrasolar planetary systems might be a natural outcome resulted from the type I migration. The corotation torque and the Lindblad torque act on a protoplanet, leading to the type I migration of the protoplanet. The migration velocity of the protoplanet is determined by the sum of the torques. Recently, Yamada & Inaba (2012) showed that the magnitude of the torques depends on a thermal structure of a disk. The positive corotation torque acting on a protoplanet in a disk inside of the ice line becomes large enough to cancel the negative Lindblad torque. Protoplanets might accumulate at the location of the ice line of a disk with small viscosity.

Once dust particles grow, they move in a disk interacting with gas. Particles lose angular momentum and migrate inward toward the inner region of a disk. The particle density in the inner region of a disk is increased with time. Birnstiel et al. (2012) studied the evolution of the particle surface density considering the growth and fragmentation of particles and the radial motion of the particles as well. They showed the greatly increased particle-to-gas ratio in an inner region of a disk with small viscosity in 1Myr. We study the effect of particles on the type I migration of a protoplanet. We compare the torques acting on a protoplanet by disks with and without dust particles. Parameters in this model are particle radius (0.1mm to 1cm) and particle-to-gas mass ratio (0.01 to 0.1). We find that the magnitude of the positive corotation torque acting on a protoplanet is dependent on the particle size and increases with an increase in the particle-to-gas mass ratio. A protoplanet may be prone to migrate outward in dust-rich disks.

キーワード: タイプ I 移動, 密度波, ダスト, 惑星系, 重力相互作用, 共回転共鳴トルク
Keywords: type I migration, density wave, dust, planetary system, corotation torque, gravitational interaction