P154-005 **Room: 201B** **Time: May 16 9:52-10:05**

Dusty vortices in protoplanetary disks

satoshi inaba[1]

[1] SILS Waseda university

In some recent models of protoplanetary disks, turbulence is powered by MHD instabilities like the Magneto-Rotational instability. However, gas couples to the magnetic field only in ionized regions of the disk. Ionization is effective in the low density outer regions due to cosmic ray interactions and in the high density inner regions due to collisions. It is, however, too weak to generate turbulence in the intermediate region which is located at 1-10 AU from the star and is known as the dead-zone. Turbulence produced by the instability transports angular momentum outward and carries gas inward toward the inner region of the disk. Gas transferred from the outer region tends to piles up in the dead zone where the density can match the initial conditions for the Rossby Waves instability (RWI). Recent hydrodynamic simulations by Varniere & Tagger (2006) show, indeed, that the conditions for the RWI are satisfied near the dead-zone of an accretion disk.

In this paper we perform hydrodynamic 2D simulations with initial conditions consistent with the pile up mechanism near the dead-zone of a protoplanetary disk and study the formation and evolution of anticyclonic vortices when the gaseous component is fully coupled to the solid particles. The code we use in this paper was developed in a previous work (Inaba et al. 2005), in which gas and solid particles are treated as two phases of fluid and are interacting with each other through gas drag force.

Modified by a bump in the radial distribution of the surface density, the disk is unstable to random perturbations with the propagation of Rossby waves and the formation of anticyclonic vortices. The occurrence of the instability has been studied for different values of the amplitude and width of the bump. The disk is unstable for amplitudes larger than a critical value or for widths thinner than the scale height of the disk. After the formation of 5 small vortices and a stage of successive merging, a single large anticyclone is formed, of which stability and lifetime depend on particle size and concentration. The vortex is stable until the end of the simulation (for 2000yrs) when the disk is composed only of gas.

When solid particles are included in the disk, they sink toward the center of the vortex pushed by the Coriolis force. This motion also depends on the friction parameter or degree of coupling between the gas and the solid particles. Small particles are nearly glued to the gas and take long time to sink toward the center of the vortex. On the other hand, large particles are less coupled to the gas and rapidly accumulate at the center of the vortex. The surface density of the solid particles can be enhanced by order of magnitude, so that the back reaction of the particles onto the gas can play a significant role. The solid material is able to change and, even, to drive the motion of the gas. The anticyclonic motion of the gas is weakened by the back reaction of the solid particles. Therefore, a dusty vortex keeps its shape on a shorter time than a gaseous vortex.

Persistent anticyclonic vortices could play a crucial role in the evolution of the protoplanetary disks: (i) they can capture very effectively the solid particles and could make easier the formation of the planetesimals and the giant planet cores; (ii) they can transfer the disk angular momentum outward, modifying our understanding of the protoplanet migration and, consequently, of the exoplanet statistical distribution.