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Structure of the accretion disk around a protostar and the planetesimal formation (II)

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We constructed steady-state protoplanetary disk models that can explain the local concentration of the solid materials in the disk. The enhancement of the particle to gas ratio in the disk is favorable for the planetesimal formation scenario through the gravitational instability (Youdin and Shu 2002).

We considered one dimensional viscous accretion disk in steady-state as the disk model. The disk structure is determined by the balance of the angular momentum flux and the viscous torque, the balance of the viscous heating, the irradiative heating, and the radiative cooling as the function of mass accretion rate. The viscous process is determined by the Magnetorotational Instability (MRI). Whether MRI is active or inactive is determined by the ionization degree. In addition to the galactic cosmic rays and the radioactive nuclei, we take into account the thermal ionization as the ionization source in this study, which brings the inner disk becomes MRI active. The previous works (Balbus and Hawley 2000) showed that this thermal ionization boundary was located very close to the central star (0.1AU or less). We, however, found that the viscous heating of the disk sifts the front location outward to nearly 1 AU for the case of mass accretion rate, 10^{-7} Ms/yr.

In this transition region (inner MRI front), the drift velocity of the solid particles turns out to be outward because of the positive pressure gradient at the mid-plain of the disk. This change in drift direction leads the concentration of solid particles around the boundary. Since the drift velocity is size dependent, this concentration mechanism is also size dependent. Small particles larger than 1cm can be trapped, but less than 1mm pass this front. The temperature of this region is around 1000K-1300K. The planetesimals are likely to be almost volatile free, if they formed in such a high temperature. We discuss our disk model and the implications to the planetesimal formation and the chemical compositions of meteorites in more detail in the presentation.

Keywords: protoplanetary disk, planetesimal formation, magnetorotational instability