

THE TANDEM PLANETESIMAL FORMATION IN THE ACCRETION DISK AROUND A PROTOSTAR.

Y. Imaeda¹ and T. Ebisuzaki¹, ¹Riken (2-1 Hirosawa, Wako, Saitama 351-0198, Japan, Email: y.imaeda@gmail.com).

We obtained steady-state solutions of accretion disk around a protostar. We include the following physical processes:

- Viscous heating + Irradiative heating
- Ionization by the cosmic ray, the radioactive nuclei, and the thermal collisions
- Magneto-rotational Instability as the switch of viscous state

We use the a disk model by Shakura and Snyaev [1], adopting $\alpha=0.01$ for MRI active region and $\alpha=0.001$ for MRI inactive region. We calculated the ionization degree as the function of the distance from the central star, taking into account the above ionization sources.

We found that the accretion disk is divided into three parts, inner turbulent region (ITR), MRI inactive region (MIR), and outer turbulent region (OTR) [e.g. 2]. The transition from ITR to MIR (inner MRI front) occurs around 0.3-1AU, while the transition from MIR to OTR (outer MRI front) occurs around 3-10AU, depending on the mass accretion rate. The inner MRI front shifts considerably outward compared with the previous works [3] due to the viscous heating and the thermal ionization.

The drift velocity of the solid particles turns out to be outward around the inner MRI front, because of the positive pressure gradient. This causes a strong concentration of solid particles around the inner MRI front

boundary. They undergo gravitational instability to form rocky planetesimals in the thin pebbles sub-disk [4]. Since the temperature of inner MRI front is around 1000K-1300K, the planetesimals are likely to be almost volatile free. Such water-free planetesimal formation may explain the suitable amount of water on the rocky planet, which is required by the Habitable-Trinity environment for the initial life [5].

On the other hand, icy particles can rapidly grow and eventually undergo gravitational instability around the outer MRI front around 10 AU outside snowline [6]. Some remaining icy particles drift inward to pass the snowline. They are likely to undergo metamorphism to clay minerals. They form a thin pebbles sub-disk and further drift inward to reach the inner MRI front, the other planetesimal formation sites, described above. Such tandem planetesimal formation at the two MRI fronts may explain the distribution of terrestrial planets as well as gas giants.

References:

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