Planetesimal Formation by Collisional Growth of Dust Aggregates in Disk Formation Phase

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Introduction: Planets are thought to be formed from planetesimals, though the formation process of planetesmals has not been understood well. Some proposed mechanisms include the gravitational instability of the dust layer, the streaming instability, and the successive collisional growth of dust aggregates. It is not clear if required conditions for these mechanisms are met in real protoplanetary disks or in the early solar nebula.

Recent astronomical observations of protoplanetary disks suggest that planets start to form in the class 0 phase, i.e., the disk formation phase, in which the mass accretion from a parental molecular cloud core to the disk continues [1]. If this is the case, planetesimals should be formed in the disk formation phase, too. Theoretically, however, it was suggested that the planetesimal formation seems difficult in the disk formation phase [2], mainly because the disk temperature in the class 0 phase is so high that dust aggregates are likely to drift into the central star due to the gas drag.

In the previous study [2], the disk was assumed to be a viscous accretion disk in which turbulence and viscous energy dissipation are present in the whole disk. This disk tends to have a higher temperature structure. On the other hand, it is known that when the ionization degree of the disk is low enough, the region becomes “dead” and neither turbulence nor dissipation takes place. In the disk with the dead zone, the temperature becomes lower than that of the “active” disk. Then, it is expected that the radial drift of dust aggregates is suppressed. In this study, we examine the temperature structure of the disk in the class 0 phase with the dead zone, and see if dust aggregates can grow to planetesimals or not.

Dust Growth in Dead Zone: We theoretically modeled and obtained the temperature structure of the disk with the dead zone and examined if the dust aggregates can grow to planetesimals with some physical parameters such as the mass accretion rate in the disk and the distance from the central star. We found that with a typical parameter range, it is hard for dust aggregates to grow to planetesimals. However, when the mass accretion rate in the disk is as low as 10^{-7} M_{sun} yr^{-1} or lower, planetesimal may be formed through collisional growth. Those parameter sets may be realized in a quiescent phase of the FU Ori phenomenon.

References:

[1] e.g., Ansdell, M. *et al.* (2016) *Astrophysical Journal* **828**, 46.

[2] Homma, K. and Nakamoto, T. (2018) *Astrophysical Journal* **868**, 118.

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