Condition of the efficient formation of dense dust clumps due to the streaming instability

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Planetesimal formation is the key process for the planetary system formation. There are, however, many theoretical difficulties to form planetesimals. The fragmentation barrier is one of the most serious problem for planetesimal formation (Blum & Munch, 1993). The maximum size of dust particles is limited to about millimeters to centimeters by this barrier. We need a model to connect these small dust particles or pebbles to planetesimals.

The streaming instability is one of the promising process to form planetesimals (Youdin & Goodman, 2005; Johansen et al., 2012). This instability can form the dense dust clumps consisting of millimeter- or centimeter-sized particles. These dense dust clumps are sometimes gravitationally bound and are considered to form planetesimals by subsequently self-gravitational collapse.

Whether the streaming instability can form dense dust clumps depends on the particle size and the dust-to-gas ratio of protoplanetary disks. Carrera et al. (2015) conducted a parameter survey to find the critical dust-to-gas ratio for strong clumping due to the streaming instability at each particle size.

In this study, we focus on the efficiency of the formation of dense dust clumps. We conducted 2D simulations of dust-gas system like Carrera et al. (2015). We investigated how much dust particles contribute to clumping in the parameter space where indicated as being appropriate for formation of dense dust clumps by Carrera et al. (2015). Then we compared the mass of the entire dust particles that contributed to clumping with the mass of solar system planets, looking for conditions suitable for solar system formation. We found that a sufficient amount of particles contribute to clumping when dust-to-gas ratio is 0.04 even though the dust particles have relatively small radius about 1 mm.

キーワード：原始惑星系円盤、微惑星形成、惑星系形成
Keywords: Protoplanetary disk, Planetesimal formation, Planetary system formation

