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Numerical simulation of planetesimal-forming gravitational instability using a thin dust layer model with dust settling

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There are two models for planetesimals formation; one is the growth through mutual sticking of dust aggregates, another is the gravitational instability in the dust layer. When the perturbed self-gravity of the dust layer exceeds the perturbed Coriolis force, the dust layer becomes gravitational unstable. Many authors investigated the conditions for attaining the critical dust spatial density of the gravitational instability, but few did how the dust layer evolves after it. Yamoto and Sekiya (2006) performed numerical simulations to investigate the density evolution in the dust layer due to the gravitational instability and the dust settling toward the midplane. With the assumption that the dust layer is axisymmetric with respect to the rotation axis, they figured out when the nondimensional gas friction time (product of the gas friction time and Keplerian angular velocity) equal to 0.01, the gravitational instability grows faster than dust the settling.

Although, Yamoto and Sekiya (2006) made the assumption of the axisymmetry for simplicity, it is known that nonaxisymmetric modes of the gravitational instability grow faster than axisymmetric ones in various astrophysical systems (e.g. Salo 1995, Laughlin and Rozyczka 1996). In order to elucidate more precise way of planetesimals formation by the gravitational instability including nonaxisymmetric modes, we have to perform 3D numerical simulation. For the sake of anticipating some results of 3D simulation, we here perform numerical simulation using a 2D thin dust layer model, in which the radial and azimuthal directions are taken as independent variables. In vertical direction hydrostatic equilibrium approximation is adopted. In this work, we take the dust settling into account. We set the initial perturbations using pseudo-random numbers. We adopt the shearing box boundary condition.

The results of our numerical simulations show that the gravitational instability grows not in axisymmetric modes, but in nonaxisymmetric modes.