Dust dynamics during the early disk evolution in the star formation process and implication for planet formation

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論 文 名　：Dust dynamics during the early disk evolution in the star formation process and implication for planet formation
（星形成過程の円盤初期進化段階におけるダストのダイナミクスと惑星形成への示唆）

区　　分　：　甲

論 文 内 容 の 要 旨

Stars form in molecular cloud cores composed of gas and dust grains. It is considered that planet embryos, which are aggregates of dust grains, appear within the rotationally supported disks that form in the star formation process. The star formation process has been investigated in both theoretical and observational studies. Although gas dynamics in the star formation process have been well investigated in such studies, dust dynamics are poorly understood because of the uncertainty of dust properties.

In this study, we proposed a method for calculating the trajectories of dust particles and implemented it in previously developed nested grid code in which the local gas physical quantities of the gas fluid are used to calculate dust dynamics and dust grains are treated as Lagrangian particles. We performed a three-dimensional MHD simulation that included the trajectory calculation of dust particles and investigated dust dynamics in a collapsing cloud with different sized dust grains. We confirmed that our results are qualitatively and quantitatively consistent with previous studies that adopted one- or two-fluid approximation with the Eulerian approach. We found that dust grains that satisfy $a_d \leqq 10\mu m$ (where, a_d is the dust grain size) are coupled with the gas during the gravitational collapse at least until the protostellar mass reaches about 8 per cent of the initial cloud core mass. This coupling condition is consistent with previous studies. We showed that the trajectory calculation adopted in this study is appropriate for tracing dust dynamics in the star formation process.

In addition, we focused on the trajectories of the dust grains in the disk. Dust grains with an initial large θ (θ is the zenith angle) enter the disk from the equatorial plane rather than from the above. Such dust grains do not fall into the central star with a spiral structure, while they move in a circular motion without falling. The gas within 10 au loses its angular momentum. On the other hand, the gas beyond 10 au receives the angular momentum because of the gravitational torque. Thus, the dust grains, which are strongly coupled with the gas, move in a circular motion around 10 au.