Evolution of optical property of protoplanetary disks due to dust growth

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Optical property of dust grains plays an important role in the analysis of observational data of protoplanetary disks. In the present study, we performed numerical simulations of dust growth in protoplanetary disks and examined evolution of optical property of the disks. Although similar simulation of dust growth have already done by Nakagawa et al. (1981), they mainly focused on the dust layer and planetesimal formation. However, a small amount of micron sized dust grains which remains floating above the dust layer would have a large contribution on the optical thickness of protoplanetary disks. In order to clarify the amount of the floating dust, we performed highly accurate simulations of dust growth for various protoplanetary disks. In this study, laminar protoplanetary disks are assumed and the sticking probability of grains is regard as a parameter.

Our results are summarized as follows:

(1)As a result of dust growth and settling, a dust layer is formed on the equatorial plane of the protoplanetary disk within a few thousand Keplerian periods. At this stage, the optical thickness of the protoplanetary disk rapidly decreases. After the formation of the dust layer, the disk optical thickness is determined by a small amount of the floating dust grains and the contribution of the dust layer is negligible. This would mean that, in observations of protoplanetary disks, only the floating dust grains are detectable.

(2)As for the floating dust grains, larger ones settle to the dust layer earlier. The size distribution of the floating dust grains is given by a power-law distribution with the index -3, which does not depend on the disk model. The coefficient of the power-law distribution is also independent of the disk surface densities of gas and dust. Due to the dust settling, the upper limit of the power-law size distribution decreases. In the minimum-mass solar nebula model proposed by Hayashi (1981), the settling time of micron sized grains is about 10^6 years, which is almost consistent with the "disk life time" obtained from observations of protoplanetary disks.

(3)Since the amount of detectable floating dust grains is not proportional to the disk surface densities of gas and dust, we should not determine the disk surface density directly from observational data of the disk optical thickness. Our results would be essential in deriving information of protoplanetary disks such as the disk surface density from observational data.