RETENTION OF SMALL DUST IN PROTOPLANETARY ENVIRONMENTS

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Introduction: The collisional evolution of solid material in protosolar nebula is a crucial initial step in the formation of comets, planetesimals and planets. Although the dense protoplanetary disk environments favour fast dust coagulation, there are several factors that limit the straightforward pathway from interstellar-like sub-micron grains to pebble-size agglomerates. The microphysical factors like grain charging [1], bouncing [2] and fragmentation [3], as well as global dust dynamics [4] affect the grain size distribution at the end of disk evolution, which may be imprinted in the properties of primitive meteorites.

The observations of protoplanetary disks reveal the presence of both small (μm-size; [5]) and large (mm-size; [6]) grain populations. It was suggested, that the presence of small grains can be explained by their replenishment in destructive collisions of larger aggregates [7]. On the other hand, the large grain population can be kept in dust traps [8], which prevents their fast radial drift to the central star [4]. Interestingly, the similar bidisperse size distribution manifests itself in primitive meteorites as matrix and chondrules.

Coagulation of charged dust: We study an alternative explanation of small dust retention due to non-zero grain charge, which naturally arise in weakly ionized media. Even the small ionization fraction of $<10^{-10}$ provides enough free electrons and ions to strongly charge dust grains. As electrons are more mobile than ions, grains acquire net negative charge and, hence, experience electrostatic repulsion in mutual collisions. The severity of the electrostatic barrier depends on the location in the disk, grain size and the strength of non-thermal sources of grain-grain relative velocities. We study the coagulation of charged dust by solving the Smoluchowski equation [9] consistently with the equations on grain charging in weakly ionized media [10]. We focus on the possibility of electrostatic barrier overcoming at specific positions of a typical protoplanetary disk and neglect dust drift and fragmentation.

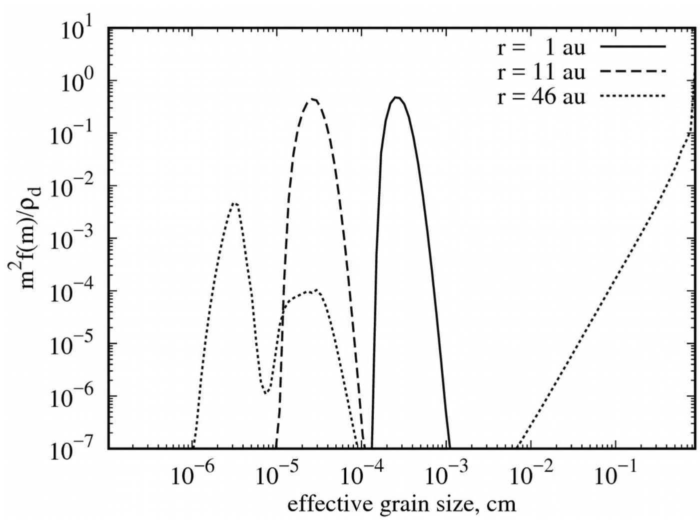

Figure 1. *Grain size distribution after 0.9 Myr of in situ coagulation in the midplane of a protoplanetary disk. The electrostatic repulsion keeps 0.1–10 μm grains from rapid coagulation into centimeter-size aggregates in the inner disk.*

Results: In Figure 1 we show the grain size distribution at several radial positions in the disk midplane after 0.9 Myr of charged dust coagulation. The dust densities at the considered positions of 1, 11, and 46 au are $2{\cdot}10^{-12}$, $9{\cdot}10^{-15}$, and $3{\cdot}10^{-16}$ g cm^{-3}, correspondingly. The dust aggregates are supposed to be fractal with fixed fractal dimension of D=2.1 and coagulate due to Brownian and turbulence-induced collisions. The turbulence parameter $\alpha=10^{-3}$ is assumed for active regions and 10^{-6} for a dead zone. It is seen, that dust is effectively trapped in 0.1–10 μm size range due the electrostatic barrier in the inner disk (1 and 11 au) and breaks to the cm-size regime in the outer disk (46 au). The subsequent inward radial drift of macroscopic dust may ensure the presence of large aggregates in the inner disk.

While the dust fragmentation is likely to occur in protoplanetary disks, it is not needed for the *replenishment* of small dust population as the electrostatic barrier may effectively *keep* the small dust in 0.1–10 μm size range.

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