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Dust movement and chemical evolution of proto-solar disk

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Origin and evolution of the protoplanetary system have been developed mostly from the dynamic point of view, which includes two competing theories, and whichhas been improved by astrophysical observation of exoplanets and extrasolar planetary systems. On the other hand, examination of meteorites and samples by planetary explorations such as lunar samples, cometary particles, and regolith particles of the asteroid Itokawa enable us to gain insight into the evolution of the Solar System. Although those primitive materials give various information, they are not linked to the physical processes in the primary Solar System.

The purpose of this study is to demonstrate how chemical composition distribution evolves over time in the early stage of the proto-solar disk. In order to combine physical processes and chemistry, we have developed a new model consisting of chemical equilibrium calculation and particle tracking equations. At first, we calculate the chemical composition of starting particles at each position in the protoplanetary disk, to track their each motion in the evolving disk, and to analyze the bulk composition of particles that came from various positions in particular time and space. Then, the dynamic evolution of individual particles is calculated in one-dimensional steady-state disk model. In an early stage, particle located in the inner region of the disk have a composition rich in refractory components and those outside have unfractionated CI-like composition. Particles in average move inward by the angular momentum conservation, but a little fraction of them move outward by the turbulent diffusion. Therefore, mixing of refractory particles from inside and CI-like materials from outside takes place, and the mixing ratio vary with time and space.

Because of inward movement of many particles, the relative fraction of particles from outside increases with time for one particular region in the disk, that is, the bulk chemical composition of particles is getting more CI-like. Similarly, the bulk chemical composition of particles at particular place is getting more CI-like with time. Calculations with model parameters of higher temperature of the disk suggest that longer time is needed to replace refractory-rich compositions by a CI-like composition. It is because the radial distance between fractionated particles with refractory-rich composition and unfractionated CI-like materials is longer in a high temperature disk.

Comparing these results and the composition of CM, CO, CV chondrites, it is concluded that CV composition can be reproduced at the most inner region, CO in the next, and CM most outer region in the disk. The present work shows that the composition of carbonaceous chondrites were formed at the asteroid belt region at the early stage of disk evolution with the wide spread of high temperature region.

Keywords: protoplanetary disk, chemical evolution, dust movement, chemical equilibrium