Dust Growth in Star-Forming Regions and its Possible Impacts on Galaxy Evolution

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Dust grains are considered to have large impacts on galaxy evolution. The effect important in the early evolutionary stage is dust cooling: With a sufficient amount of dust, dust cooling is able to induce fragmentation into subsolar mass cores. This means that dust cooling induce a transition from massive Pop III stars to low-mass Pop II stars [1, 2]. On the other hand, dust properties are also modified in the star-forming enviromentns through coagulation (grain–grain sticking). The modification of grain sizes may affect the efficiency of cooling.

We investigate if dust coagulation affects the thermal properties of star-forming clouds. We calculate coagulation in collapsing pre-stellar cores with different metallicities by considering the thermal motions of grains. We show that coagulation does occur even at low metallicity $\sim 10^{-6}$ $Z_\odot$. However, we also find (i) that the H_2 formation rate on dust grains is reduced only after the majority of H_2 is formed and (ii) that the dust opacity is modified only after the core becomes optically thick. Therefore, we conclude that the effects of dust coagulation can safely be neglected in discussing the temperature evolution of the pre-stellar cores for any metallicity as long as the grain motions are thermal [3].

Some observations in the Milky Way show "pre-growth" of dust grains in dense molecular cloud cores. Recent *Spitzer* observations have found the mid-infrared emission from deep inside a number of dense cores, the so-called "coreshine," which is thought to come from scattering by micron (μm)-sized grains [4, 5]. Based on numerical calculations of coagulation starting from the typical grain size distribution in the diffuse interstellar medium, we obtain a lower limit to the time t to form μm-sized grains: $t/t_{\rm ff} > 5.5(5/S)(n_{\rm H}/10^5\ {\rm cm}^{-3})^{-1/4}$ (where $t_{\rm ff}$ is the free-fall time at hydrogen number density $n_{\rm H}$ in the core, and S the enhancement factor to the grain-grain collision cross-section to account for grain fluffiness). At the typical core density $n_{\rm H} = 10^5$ cm^{-3}, it takes at least several free-fall times to form the μm-sized grains responsible for coreshine. The implication is that those dense cores observed in coreshine are relatively long-lived entities in molecular clouds, rather than dynamically transient objects that last for one free-fall time or less [6].

The possibility of "pre-growth" in dense clouds (at least in the solar metallicity environments) indicates that we should reconsider the initial condition for the grain size distribution in collapsing pre-stellar cores. Moreover, if such μm-sized grains are somehow dispersed into the diffuse interstellar medium, dust growth in dense molecular cores is an important source of big dust grains. We also discuss these points in the context of galaxy evolution.

References

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