Accretional Shock on the Protoplanetary Disk Surface

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We have examined the physical and chemical processes of gas and dust grains that pass through a shock wave on the protoplanetary disk surface. Our study is mainly relevant to the high-density accretion shocks that are associated with the supersonic infall of material from a molecular cloud core at the period of protoplanetary disk formation. We would be able to discuss the chemical evolution of materials in the disk and the model of formation of chondrule precursors by this study.

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Although there are many studies on the physical and chemical processes of molecular astrophysical gas that passes through a shock front in the interstellar medium (e.g. Hollenbach & McKee 1979,1989), which is the low density region, there is not yet much investigation into the high density region like a protoplanetary disk. There are many unclear things about dense accretion shocks. For example, according to Neufeld & Hollenbach (1994) the maximum grain temperature is about 580K (grain radius is 0.1 micron), while according to Ruzmaikina & Ip (1994) it is over 1600K (grain radius is 1mm).

We investigated systematically the physical process which governs the structure of shock waves formed at the protoplanetary disk surface, and the thermal evolution of dust grains passing through the shock wave, which concerns with the chondrule formation. We carried out numerical simulations of the shock taking account 35 species of molecules, atoms, and ions, about 200 chemical reactions, gas-dust interactions, and radiative heating of dust grains. We found that two temperature plateaus at about 7000K and 500K are formed due to the lack of efficient coolant and the balance between the CO cooling and the molecular hydrogen formation heating, respectively. In particular, in the second plateau, the gas density rises and the dust grain is heated drastically due to the drag heating.