Planetesimal Bow Shocks: Hydrodynamics Simulations with H_2 Dissociation and Recombination.

Fumika Yamazaki[1] and Taishi Nakamoto[1], [1]Tokyo Institute of Technology; fyamazaki@geo.titech.ac.jp.

Introduction: Many meteorites include mm-sized silicate particles, which are called chondrules. They are formed about 4.5 billion years ago in the solar nebula. There are evidences that chondrules have experienced heating and melting, but the details of the heating event are still unknown. One of the ideas for heating mechanism is the shock wave heating model [e.g., 1, 2]. The model explains that, when the precursor dust grains run into the shock, they experience the gas drag heating, and dust temperature exceeds the melting point. Based on this idea, numerical hydrodynamics simulations of planetesimal bow shocks were conducted [3, 4] and bow shocks were examined as a chondrule formation site. In those simulations it was assumed that the gas consists of hydrogen molecules and the gas changes adiabatically; the effects of H_2 dissociation and recombination were ignored. However, the calculated temperature behind the shock front was 4000 K or more [4], so H_2 dissociation is expected to occur. Once the dissociation of H_2 takes place, the resultant temperature of the gas would be different.

It is considered that the bow shocks would cause not only chondrule formation but also planetesimal evaporation [5]. Assuming that the planetesimals consist of ice, the bow shocks could heat the gas, and the planetesimals would be heated by the surrounding gas, and eventually may evaporate. The planetesimal evaporation is sensitive to the surrounding gas temperature.

To understand these phenomena, the detailed profile of the gas flow around planetesimals is needed, and it should be investigated hydrodynamics simulations with H_2 dissociation and recombination.

Calculation Method: We conduct 2-D hydrodynamics simulation with H_2 dissociation and recombination around planetesimals. We develop an equilibrium calculation code of H_2 dissociation/recombination and add it to the ZEUS-2D code [6].

Results: Our simulation results show that the gas temperature is lower and the density is higher in front of planetesimals than the results by adiabatic calculations. This can be understood as a result of the H_2 dissociation. Moreover, in the region where the recombination occurs, the temperature is higher than the one of adiabatic calculation. Also the positions and the figurations of the shock fronts are slightly different between both calculation results.

These results suggest that the H_2 dissociation and recombination may affect the heating of chondrule precursors. That is because the gas drug heating is susceptible to the gas density. So, the thermal history of dust particles under the effect of H_2 dissociation and recombination should be investigated in the future.

Summary: We conduct hydrodynamics simulation with H_2 dissociation and recombination around supersonic planetesimals. From the comparison of the calculation results to adiabatic calculation results, we found that (1) behind the shock front, the gas temperature is lower and density is higher because of dissociation, (2) in the region where the recombination occurs, the gas temperature is higher because of recombination, (3) shapes of those shock fronts are slightly different.

References:

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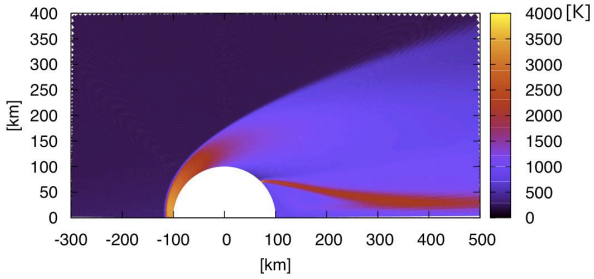

Figure 1: Gas temperature profile calculated without H_2 dissociation/recombination. The planetesimal radius R = 100 km, initial gas speed V =10 km s^{-1}, and the gas density ρ =10^{-8} g cm^{-3}.

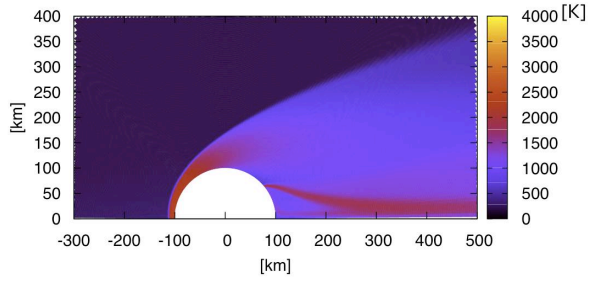

Figure 2: Gas temperature profile calculated with H_2 dissociation/recombination. The settings are the same as Figure 1.