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Chondrule Formation by Planetesimal Bow Shocks

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Chondrules are mm-sized silicate particles included in most meteorites. Though it is known from experiments and observations that they experienced flash heating and melting in the solar nebula, the heating mechanism is still unknown. To comprehend chondrule formation may lead to understanding the environment in the solar nebula and the solar system formation.

One of the ideas for heating mechanism is the shock wave heating model. 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 (e.g., Hood & Horanyi, 1991; Iida et al., 2001). In this study, we conduct detailed examination of dust heating by planetesimal bow shocks, which are the shocks occurring around eccentric planetesimals.

We carry out the calculation of 2-D grain trajectory and thermal history in the flow around the planetesimal taking account of melting and evaporation of the grains, which was not included in 2-D calculations of previous studies about planetesimal bow shock model (e.g., Nakajima, 2010, master thesis; Morris et al., 2012). Moreover, for detailed examination, we use the gas flow which is obtained by 2-D hydrodynamics simulations with H_2 dissociation and recombination as the background of grain motion.

Our results show that the grains avoid collision with the planetesimal thanks to the evaporation in some cases, and it affects the chondrule formation efficiency and the resultant size of heated grains. Using our calculations, the size distribution of chondrules and compound chondrule formation could be investigated and compared with the observations. We also show the chondrule formation condition by calculations with various nebula gas density and relative velocity of planetesimal to gas. Our results support the expectation that the solar nebula was more massive than MMSN model and that chondrules were formed in inner region of 3AU from the Sun.

Keywords: chondrule, bow shock, planetesimal, solar system formation, hydrodynamics simulations