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Evaporation of planetesimals due to bow shocks: heating by line emissions of water molecules

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In protoplanetary disks, planetesimals grow to planets through mutual collisions and accumulations. The gravitational interactions among planetesimals increase the eccentricities of their orbits. When the relative velocity between a planetesimal and the disk gas exceeds the speed of sound of the gas, a bow shock is produced on the leading side of the planetesimal.

In the previous study, we have shown that the bow shocks lead to the heating and evaporation of icy planetesimals in the stage of formation of protoplanets, where strong bow shocks are produced by gravitational perturbations by the protoplanets [1]. We also showed that the evaporation time of planetesimal depends strongly on the Stanton number, the efficiency of heat conduction from the gas to the planetesimal surface.

In this study, we evaluated the radiative heating due to the line emissions of gas molecules in order to investigate planetesimal evaporation in more detail.The shock velocity of the planetesimal in the stage of the oligarchic growth is 1 km s^{-1} $<$vp $<$5 km s^{-1}, which leads to an increase in gas temperature in the post-shock region. In such a temperature region ($<$ 1000 K), line emissions due to the vibrational motions of H_2O molecules become effective.

The emission rate from H_2O molecules is given as a function of temperature and gaseous density [2]. We estimated the radiative flux from the gas by integrating the line emissions in the post-shock region around the planetesimals, where we used temperature and density distribution obtained from two-dimensional fluid simulations of planetesimal bow shocks [3]. We found that the heating rate due to line emission of water molecules is comparable or larger than the heat conduction from gas.

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[2] H. Miura, and T. Nakamoto, Icarus, 2005, 175, 289
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