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Diagnozing Evaporation of Icy Planetesimals due to Shock Heating in Protoplanetary Disks by ALMA Observations

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It is thought that eccentricities of planetesimals are excited due to gravitational interaction with protoplanets in protoplanetary disks. As a result, bow shocks are formed around the icy planetesimals and the ice is evaporated via the shock heating. Evaporation rates and orbital evolution of such planetesimals have been investigated (Tanaka et al. 2013, Nagasawa et al. 2014). In this work, we examine a possibility of diagnosing the shock heating and evaporation of icy planetesimals, using ALMA observations of lines of molecules evaporated from the planetesimals.

Evaporation of ice has been studied observationally and theoretically well, for example, at a shock front of outflows associated with young stellar objects. The evaporated molecules will be destroyed via chemical reactions with other species and/or depletion on dust grains. Destruction timescale via the reactions is about 10^4years, while depletion time onto grains is much less than 10^4years as far as the amount of grains is large enough. Therefore, the evaporated molecules can survive in gas-phase for around 10^4years in the region hotter than their evaporation temperatures, while they freeze out immediately in the cold region. As parent species evaporated from ice, saturated nitrogen- or sulphur-bearing species and organic molecules are often considered. The evaporation temperatures are different depending on species; for example, the evaporation temperature of complex molecules are as high as that of water. In this work we focus on sulphur-bearing species whose evaporation temperature is not very high and gas-phase abundances are not high without evaporation of ice.

Our calculations show that evaporated H_2S is destroyed via gas-phase reactions, and SO and then SO_2 are produced through reactions of atomic sulphur with molecular oxygen and OH. The timescale of these reactions is about 10^4years. Therefore, H_2S and SO are good tracers of shock heating and evaporation of icy planetesimals if it occurs in the region hotter than the evaporation temperatures of H_2S and SO. The evaporation temperature of SO_2 is higher than those of H_2S and SO. Thus, if the evaporation of icy planetesimals occurs in the region colder than the evaporation temperature of SO_2, the intensity of SO_2 lines will be a good tracer of dust density since the depletion time on grains depends on it.

Molecular lines of H_2S, SO, and SO_2 have not yet been detected towards protoplanetary disks by the previous radio observations. ALMA observations with high sensitivity and high spatial resolution, however, will make it possible to detect the lines of these molecules. Conditions that molecular lines of H_2S and SO becomes strong enough to be detected by ALMA observations will be discussed in the talk.

Keywords: protoplanetary disks, evaporation of icy planetesimals, astrochemistry