Shock heating of dusts and icy planetesimals and recondensation of icy grains

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In protoplanetary disks, 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. It is proposed that planetesimals perturbed by Jovian mean-motion resonances are the promising source of shock waves that form chondrules in chondritic meteorites because the shocks give short-time-scale heating of dust grains, which is appropriate for the formation of chondrules [1]. In the previous studies on planetesimal excitation, however, the velocities obtained were at most 8 kms^{-1} in the asteroid belt, which is insufficient to account for the ubiquitous existence of chondrules. Recently we reexamined the effect of Jovian resonances, taking into account the secular resonance in the asteroid belt caused by the gravity of the gas disk [2]. We found that the velocities relative to the gas disk of planetesimals exceed 12 kms^{-1} and the heating region is restricted to a relatively narrowband (1.5-3.5 AU). Our results suggest that chondrules were produced effectively in the asteroid region.

The planetesimal shocks also lead to heating of the planetesimal itself. Because of the strong shock heating, icy planetesimals with radius larger than 100 km suffers a significant evaporation even outside the snow line [3]. The evaporation reduces the mass of the planetesimal. The evaporation time is much shorter than the disk lifetime of 10^6 yr. The evaporated vapor from the planetesimal surface recondenses as it cools and form a large amount of icy fine grains. During the evaporation, the silicate dusts are also expected to be released from the planetesimal surface by the strong flow of the disk gas. This process provides a large amount of chondrule precursors. The planetesimal bow shocks also leads to chemical reactions among evaporated molecules. There is a possibility that we can diagnose the shock heating and evaporation of icy planetesimals in the protoplanetary disks, using observations of lines of molecules evaporated from the planetesimals.

[1] Weidenschilling et al. (1998), *Sci*. **279**, 681. [2] Nagasawa et al. (2014) *ApJL*, **794**:L7. [3] Tanaka et al.(2013) *ApJ*, **764**, 120.