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Collision condition for compound chondrule formation I: Condition for coalescence

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Chondorules are mm-sized, spherical-shaped, silicate particles that are the main component of chondritic meteorites. They are thought to have been formed from the dust particles by some flash heating events, which can melt them in the early solar nebula. Compound chondrules, which are two or more chondrules fused together, also exist in the chondrite. Although, the fraction of compound chondrules is about 5% in all the chondrules, they are thought to offer crucial information about the chondrule formation itself because of their uniqueness. Some compound chondrules seem to be formed by collisions of two independent particles during their melting (heating) events. However, the probability of random collisions in solar nebula is too small to explain the observed fraction of compound chondrules because of the extremely low number density of chondrules and the short melting duration. Then, a lot of compound chondrule formation models proposed so far (Wasson et al. 1995, Sekiya and Nakamura 1996, Miura et al. 2008) estimated collision frequency and looked for conditions that can account for the observed fraction of compound chondrules.

However, they seldom noticed the collision conditions. If two melting dust experience the high-speed or grazing collision, the compound chondrule cannot be formed because they cannot coalesce. Moreover, if the viscosities of both components are too low to keep their external shapes during collision, they will fuse together and we cannot observe them as compound chondrules.

Thus it is important to consider the collision conditions, which consist of 'condition for coalescence' and 'condition for keeping their shapes' when we discuss compound chondrule formation.

In this study, we numerically examined the collision of two dust drops by using the three-dimensional hydrodynamics simulations. In particular, we examined 'condition for coalescence' for various parameters;the collision velocity, the collision angle, the size ratio of drops, and viscosities of drops. We can categorize the results of dust drops' collisions; 'Stretching separation', which occurred when the collision velocity is large, 'Fission', which occurred when the collision velocity is large and 'Coalescence'. If the dust drops have relatively lower viscosities (1poise), our results agree well with water and organic matter drops' collision experiments (Ashgriz and Poo 1990, Qian and Law 1997). In this case, the maximum velocity of 'Coalescence' is about 5 m/s (the collision angle is about 12 degree). On the other hand, in the larger viscosity case, because the kinetic energy is dissipated due to the viscous dissipation, the region of 'coalescence'is expanded to larger collision velocity and larger collision angle. For example, when the viscous coefficients are 10 poise and 100 poise, the maximum relative velocities for coalescence are about 15 m/s and 50 m/s, respectively. Moreover, when the size ratio is lower than 1, the region of 'coalescence'is expanded to large collision velocity and larger collision angle because the ratio of contact volume to not contact volume becomes small.

In addition, we found that the boundary of coalescence and separation can be expressed by comparing the kinetic energy, surface energy, viscous dissipation, and rotational energy, which is exited by the collision. Then we can obtain the 'condition for coalescence'for various collision velocity, collision angle, viscosity, and size ratio. If we add 'condition for keeping their shape' to these results, we will be able to obtain the collision condition for the compound chondrule formation.