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Collisional disruption of sintered dust aggregates

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Planets are formed in a protoplanetary nebula consisting of gas and dust grains. The first step of planetary formation is coagulation of dust grains, leading to the formation of dust aggregates. Further growth of the dust aggregates is promoted by mutual collisions between them. The motion of dust aggregates gradually decouples from that of the gas as aggregates grow. Dust aggregates drift inward due to gas drag. If the inward drift is faster than aggregate growth, solid components in a protoplanetary nebula disappears and planets cannot be formed. To prevent infalling, many mechanisms have been proposed (Kretke & Lin 2007, Lyla et al.2009, Sandor et al.2011). Fast collisional growth during the infalling of icy dust aggregates (Okuzumi et al. 2012) is another possibility. These studies are based on the assumption that the motion of aggregates decouples from gas. The infalling velocity is on the order of 1m/s when substantial decoupling is attained. Aggregates should grow to the sizes corresponding to the infalling velocity. Is it possible?

Experimentally, collisional breakup velocity of micron-sized SiO2 dust aggregates is on the order of 1m/s(Blum 2010). Breakup velocity for H_2O ice aggregates is also on the same order(Shimaki & Arakawa 2012). However, it is difficult to produce highly porous dust aggregates experimentally due to the Earth's gravity. I conducted two-dimensional numerical simulation of sintered dust aggregates in this study. It has been pointed out that sintering of H_2O ice proceeds in wide region of a protoplanetary nebula (Sirono 2013). As sintering proceeds, a neck between adjacent grains grows and mechanical interactions between grains greatly change. The effects of sintering are taken into account by changing breaking forces of a contact. The interactions between non-sintered contacts (Dominik & Tielens 1997) are adopted for newly formed contacts.

If sinterng proceeds sufficiently such that a neck is disappeared, catastrophic disruption was observed at low collision velocities (~10cm/s). This is because a contact is broken by rolling of a grain. On the other hand, catastrophic disruption at low collision velocities was not realized for less-sintered aggregates. This is due to immediate reconnection between grains with a non-sintered mode. These results depends on the tensile strength of H_2O ice. The breakup velocity increases as the strength increases. From the results obtained in this study, the evolution of icy dust aggregates is various, depending on the location in a protoplanetary nebula.

Keywords: dust aggregate, protoplanetary nebula, collisional disruption, sintering