# Numerical simulation of collisions between sintered icy dust aggregates

*Sin-iti Sirono[1], Haruta Ueno

1.Department of Earth and Planetary Sciences, Nagoya University

Collision of dust aggregates is a critical step in planetary formation. In the outer regions of a protoplanetary nebula, the main component of a dust grain is ice. Because ice is volatile material, it sublimes and recondenses in a protoplanetary nebula. Dust grains are connected by surface tension, leading to formation of a neck between grains. A neck has a concave surface, in contrast to the other parts of a grain having a convex surface. The equilibrium vapor pressure depends on the shape of surface. A concave surface has a lower vapor pressure than a convex surface. Because the gas pressure is uniform around a dust aggregate, ice molecules sublime from convex surface and recondense on concave surface. This process is called sintering. Sintering induces growth of a neck between grains. A grain can roll against the neighboring grain keeping a connection between grains. This rolling efficiently dissipate the kinetic energy and enables sticking in a collision. However, the rolling requires breakup of a grown neck after sintering. Therefore, it can be expected that sintering strongly affects collisional outcome of icy dust aggregates.
We performed 2-D collision simulations including the effects by sintering. A neck is approximated by an elastic cylinder. The degree of sintering corresponds to the radius of a neck. Head on collisions are simulated. Aggregates without sintering can stick if the collision velocity is less than 50 m/s. We investigated this critical velocity below which collisional growth is possible. When the colliding aggregate is produced by BCCA(Ballistic Cluster Cluster Aggregation) algorithm and sintering degree is high (neck radius/grain radius=0.7), the critical velocity decreases to around 20 m/s. If the degree of sintering is low (neck radius/grain radius=0.2), the necks are broken efficiently and reconnect through non-sintered necks. Then the difference in collisional outcomes is negligible.
When the packing fraction of an aggregate is high, the critical velocity is around 1 m/s. Above this velocity, collisional outcome is bouncing. This is because elasticity of an aggregate is high in this case. The induced stress is higher than the strength of contacting region on the aggregate surface, and the colliding aggregates bounce. When the collision velocity is higher than 20 m/s, Fracturing proceeds around the contacting region and fragments are produced. The amount of fragments is a few % when the collision velocity is 20 m/s.
From these results, sintering hinders collsional growth of icy dust aggregates. Aggregates infall to the central star due to gas drag. Within a sintering region, the infalling velocity differs from that in non-sintering region because the maximum aggregate size is limited by sintering. This velocity contrast produces a contrast in surface density in a protoplanetary nebula. The heterogeneity in solid component might affect planetary formation processes.

Keywords: sintering, dust aggregate, collision

 