Collision simulation of dust aggregates with monomer size distributions

Koji Wada[1], Hidekazu Tanaka[2], Toru Suyama[3], Hiroshi Kimura[4], Tetsuo Yamamoto[2,4]

[1]PERC, Chiba Institute of Technology, [2]ILTS, Hokkaido Univ., [3]Nagano City Museum, [4]CPS

In protoplanetary disks planetesimals are believed to be formed from dust aggregates consisting of submicron grains, but their growth process is unclear so far. One of the main problems with planetesimal formation is the feasibility of dust growth through collisions at velocities up to several tens of m/s [e.g., 1]. Recently we performed numerical simulations of dust aggregate collisions and found that dust aggregates can grow through high-velocity collisions even at 50 m/s if they consist of ice particles [2]. However, silicate dust aggregates are still difficult to grow through collisions since their critical collision velocity for collisional growth is only several m/s. We need to seek some kind of promising mechanism to enable silicate dust growth. One of factors we have not yet taken into account in our numerical simulation is the size distribution of monomer particles. According to a particle-interaction model, so-called JKR theory [3], the critical collision velocity for sticking of two monomers is proportional to their reduced radius to the power of -5/6, suggestive of an increase in the growth possibility of dust aggregates consisting of smaller particles. In fact, interstellar extinction observation suggests a power-law size distribution of interstellar dust grains with an exponent of -3.3 to -3.6 in a range of 0.025 – 0.25 micron radius [4]. Such a particle size distribution may contribute to enhancement of collisional growth of dust aggregates. On the other hand, energy to break up a pair of particles in contact is proportional to their reduced radius to the power of 4/3. This means connections between small particles are weaker than those between large ones. In that sense, a power-law size distribution of constituent particles has a negative effect for collisional dust growth. In this study, we carry out numerical simulations of aggregate collisions to investigate the influence of particle size distributions on the collisional growth of dust aggregates. Based on the numerical results, we will discuss the possibility of planetesimal formation through direct collisions of dust aggregates in protoplanetary disks. Preliminary results indicate that particle size distributions tend to encourage dust growth. Furthermore, the size distribution of fragments at collisional disruption of dust aggregates is expected to be affected by the size distribution of constituent particles. Fragment size distribution is an important factor in observing protoplanetary or debris disks. We will also check the fragment size distributions obtained from our simulations.

[1] Weidenschilling, S. J., & Cuzzi, J. N. (1993), in Protostars and Planets III, 1031. [2] Wada, K., Tanaka, H., Suyama, T., Kimura, H., & Yamamoto, T. (2009), ApJ 702, 1490. [3] Johnson, K. L. (1987), Contact Mechanics. [4] Mathis, J. S., Rumpl, W., & Nordsieck, K. H. (1977), ApJ 217, 425.