

Size dependence of the Merging Criteria for Planetesimal Collision

*Sota Nakahara¹, Keisuke Sugiura², Keiji Ohtsuki¹

1. Graduate School of Science, Kobe University, 2. Tokyo Institute of Technology, Earth-Life Science Institute

Most of N-body simulations for orbital evolutions in planetary systems assume perfect accretion of colliding bodies, but it was shown that hit-and-run collisions can occur in high-velocity and oblique cases. Thus, some attempts have been made to derive merging criteria for collisions between protoplanets to incorporate into N-body simulations. Previous studies investigated the critical impact velocity, i.e., the transitional velocity between merging and hit-and-run collision, of protoplanets by treating them as self-gravitating fluid bodies, and found that the critical impact velocity scaled by the two-body escape velocity (v_{esc}) does not depend on the size of protoplanets (Genda et al. 2012). However, merging criteria under the effects of material strength and friction have not been examined so far. In this study, we performed impact simulations considering strength and friction for rocky material to investigate the dependence of the merging criteria on the size of protoplanets.

We used Smoothed Particle Hydrodynamics (SPH) method that could treat rock fracture and friction in damaged rock (Sugiura et al. 2018). We carried out impact simulations for equal-sized protoplanets using 100,000 SPH particles in total, changing the size of the protoplanets from 10-km to 6000-km radius. For each protoplanet size, we varied the impact velocity in the range of 1.0-2.4 v_{esc} , and obtained the critical impact velocity for merging and hit-and-run collision. We found that the critical impact velocity scaled by the escape velocity depends on the size of the protoplanet: it is about $2.0v_{\text{esc}}$ and $1.4v_{\text{esc}}$ for small and large protoplanets, respectively; and for intermediate cases, the critical velocity scaled by v_{esc} decreases with increasing size, making hit-and-run collision more easily take place. This dependence reflects the fact that, for the same value of the impact velocity scaled by v_{esc} , larger protoplanets have larger impact energies, which results in higher degrees of particle melting and weaker frictional effect.