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MERGING CRITERIA FOR GIANT IMPACTS OF PROTOPLANETS : Dependence of Their Composition and Size

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At the final stage of terrestrial planet formation, collisions between Mars-sized protoplanets, called giant impact, occur frequently. Giant impacts have a large influence on the number and sizes of planets, the formation of the Moon and the large metal core of the Mercury, and so on (Kokubo and Genda 2010). Therefore, the investigation of impact phenomena of giant impacts is important for understanding the characters and early evolution of terrestrial planets in our solar system. These days many extrasolar planets have been discovered around other fixed stars. Recently, the planets with several times the mass of the Earth called super-Earths and the planets almost composed of H_2O have also been discovered. During formation of these planets, it is also considered that collisions between planetary sized objects occurr frequently (Ogihara and Ida 2009).

According to Genda et al. (2012), they focused on the giant impacts of protoplanets during terrestrial planet formation in our solar system, and investigated the merging criteria for collisions between protoplanets with the mass from Mars to Earth size composed of rocky mantle and irony core. As a result, they found that about a half of giant impact events that occurred during the giant impact stage was not merging events.

However, the merging criteria obtained by Genda et al. (2012) are not simply applied to the formation of extrasolar planets such as super-Earths and icy planets. In this study, we performed simulations of collisions between super-Earths and icy planets under various impact parameters. We investigated the merging criteria and compared our results with Genda et al. (2012).

We used Smoothed Particle Hydrodynamics method and performed several hundreds simulations under the various impact conditions such as the impact velocity, the impact angle, and the sizes and compositions of planets. As the composition and size of planets, we considered ice, rock, and iron materials, and the sizes with 0-10 times Earth mass.

As a result, in the case of the collision between two Mars-sized planets with icy mantle and rocky core, we found that the merging criteria were the same as the results of Genda et al. (2012). Similarly, in the case of the collision between two Mars-sized planets composed only of icy material and two Mars-sized planets composed only of rocky material, the results were the same. Hence, the merging criteria for giant impacts do not depend on composition of colliding planets if the planetary size is smaller than the Earth.

Additionally, we performed simulations of the collision between two planets with different composition, for example an icy planet and a rocky planet. In this case, we found that the merging criteria changed from that of Genda et al. (2012). Critical impact velocity is lower than the results of Genda et al. (2012). By observing the impact simulation, we noticed that the planet with higher density went through the other, which probably made merging of the two planets difficult.

In the case of the collision between two super-Earths with rocky mantle and irony core, we found that almost head-on collision with high impact velocity tended to be not merging although the other cases were similar to the previous work. As the reason why the results were different from that of Genda et al. (2012), the vaporization of rock is considered. In the case of the collision between super-Earths, a large amount of rocky material vaporizes, which prevents two planets from merging.

References

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Ogihara, M., Ida, S., N-Body Simulations of Planetary Accretion Around M Dwarf Stars, ApJ 699, 824-838, 2009.

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