Oral | Symbol P (Space and Planetary Sciences) | P-PS Planetary Sciences

[P-PS21_29AM2]Planetary Sciences

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Tue. Apr 29, 2014 11:00 AM - 12:45 PM 416 (4F)

We call for general interest papers for Planetary Sciences. Planetary Sciences consist of a variety of studies on the past, present, and future of our solar system and exoplanetary systems. Discussions based on various backgrounds are encouraged.

12:30 PM - 12:45 PM

[PPS21-P10_PG]An improved fragmentation model on outcome of planetesimal collisions

3-min talk in an oral session

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Collisions between planetesimals or a planetesimal and a protoplanet are thought to occur frequently in the stage of planet formation, and these planetary bodies grow up through these collisions. However, if destructive collisions between them occur frequently, these bodies break up into fragments rather than promote the growth of them. Therefore, in order to understand the process of the growth for planetesimals and protoplanets, it is important to know the impact conditions under which a collision is destructive. The critical specific impact energy for catastrophic disruption Q_D^*, where the largest remnant has half the target mass, has been well investigated under various conditions so far (Holsapple et al., 2002; Benz &Asphaug, 1999; Leinhardt &Stewart, 2009). Such catastrophic impacts have been regarded as important process for planet formation. The values of Q_D^* which has been referred and used most frequently were calculated by Benz and Asphaug (1999). Although they performed many impact simulations to determine Q_D^*, the resolution of their numerical simulation were quite low and they did not check the resolution convergence of Q_D^*. In addition, recent studies (Kobayashi &Tanaka, 2010; Kobayashi et al., 2010) have suggested that non-disruptive small-scaled impacts were also important to the growth of protoplanets, because these small-scaled impacts are much more frequent than disruptive impacts. In order to discuss more correctly the growth of planets, a correct value of Q_D^* and the relation between ejecta mass and impact energy for small-scaled impacts should be required. In this thesis, I investigate the resolution dependence of Q_D^* and obtain a correct value of Q_D^* for planetesimal collisions by numerical impact simulations with sufficient resolution. I also investigate small-scaled impacts, and formulate the relation between the ejecta mass and impact energy.Using the smoothed particle hydrodynamics method (SPH) with self-gravity and without strength, I systematically perform the hydrodynamic simulations of collisions between rocky planetesimals. I consider collisions of 10 km and 100 km rocky targets and various sized impactors under various conditions such as impact velocity, impact angle and resolution.I found that the value of Q_D^* depended on resolution. This is because distribution ratio of initial impact energy to kinetic and internal energy of a target differs depending on resolution due to shear flows which appears during propagation of shock wave and rarefaction wave and ejection process. This energy distribution ratio, probably also Q_D^*, converges in using 7.5×10^7 particles.

The resolution in Benz &Asphaug (1999), where they performed impact simulations with $5x10^4$ particles, was insufficient. The Q_D^* obtained by higher-resolution simulations is about a half order of magnitude smaller than that of Benz and Asphaug (1999). This means collisions between planetesimals or a planetesimal and a protoplanet are more destructive than previously thought. I applied improved Q_D^* to the growth of protoplanets using analytical method proposed by Kobayashi et al. (2010). As a result, the mass of the finally formed protoplanet is a half smaller than the case for previous Q_D^*. In addition, I derived the formulation of scaling law representing the relation between ejecta mass and impact energy from small-scaled impacts to destructive impacts. I found that this relation can be scaled by target size, impact energy normalized by Q_D^*, and impact velocity, but it depend on impact angle. With Q_D^* and the scaling law obtained in this study, the final grown mass of a protoplanet is 0.058 M_{earth} at 1AU and 0.17M_{earth} at 5 AU, where M_{earth} represents the Earth mass.