Planetesimal Impact Simulations by Godunov SPH Method for Elastic Dynamics with the Effects of Rocks

*Keisuke Sugiura[1], Shu-ichiro Inutsuka[1], Hiroshi Kobayashi[1]

1.NAGOYA UNIVERSITY Graduate School of Science

The earth and other rocky planets are supposed to be formed via collisional coalescences of planetesimals in protoplanetary disks. To understand the origins of rocky planets and characteristic shapes of asteroids we have to study the detail of outcomes of collisions between planetesimals. Laboratory experiments for disruptive collisions have been conducted, but they cannot treat objects larger than several ten centimeters or the velocity higher than several kilometers per second. Hence numerical simulation is powerful and effective method to study planetary collisions.

Many previous works on simulation of planetary collisions have used Smoothed Particle Hydrodynamics (SPH) method, which is one of the computational fluid dynamics methods using Lagrangian particles. However the most popular form of SPH method (the standard SPH method) has several problems. In particular, its spatial accuracy is lower than first order in disordered particle distribution; it utilizes artificial viscosity that tends to cause particle penetration in strong shock waves; the tensile instability, which is numerical instability, occurs in tension-dominated region. Moreover the effects of solids such as deviatoric stress are generally ignored in protoplanet collisions mostly in cases where self-gravity is dominant. The influence of the effects of solids for large protoplanet impacts is not fully discussed. Thus we should consider those effects, which requires us to develop an appropriate numerical simulation method.

Godunov SPH method (Inutsuka 2002) is proposed to solve the problems in the standard SPH method. The Godunov SPH method achieves second-order accuracy in space. To avoid the use of artificial viscosity it uses Riemann solver, which can introduce (possibly) minimum but sufficient physical viscosity. Moreover the Godunov SPH method can solve the tensile instability by selecting appropriate order of interpolation that is used in the equation of motion (Sugiura and Inutsuka 2016). We further extend the Godunov SPH method to elastic dynamics, and implement several models represent the effects of realistic solid material such as fracture. In this talk, we show the results of numerical simulations for planetesimal collisions that account for the effects of solid material, and discuss its influence.

Keywords: Planetesimals, collisional destruction, numerical simulation, elastic dynamics , Godunov SPH method

