SPH calculations of Mars-scale collisions: the role of the Equation of State, material rheologies, and numerical effects

Harrison Agrusa

Based on the paper by Emsenhuber et al. (2018)

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Abstract

Giant impacts during late stages of planet formation can explain a variety of solar system phenomenon. The most well known theory is the the formation of Earth's moon via giant impact (Hartmann and Davis (1975), Cameron and Ward (1976)). Giant impacts can also explain Mercury's thin mantle, through large grazing impacts that could have stripped the material away (Asphaug and Reufer (2014)) A giant impact may have formed the Pluto-Charon system as well as Pluto's smaller moons (Canup (2011)) Finally, the motivaiton for this work is that a giant impact could also be responsible for Mars' hemispheric dichotomy (Marinova et al. (2008))

In this work, the authors do a series of SPH calculations of a 200 km diameter boject impacting a Mars size target. They use two different equations of state (ANEOS and Tillotson), two rheologies (solid and liquid), two different numerical schemes, and two different impact angles. All 16 simulations are done in 3D with over 1 million SPH particles. It is generally thought that material strength is negligible in these types of gravity dominate collisions, however they argue that their strength model has a substantial effect on the impact outome. They also explore numerical effects due to well known problems with SPH codes, namely surface discontinuities and rotational instabilities in rigid body rotation.

To extend their work, I will repeat some of their simulations with `spheral++`, a parallel Adaptive Smoothed Particle Hydrodynamics with an oct-tree based N-body solver (Owen (2018)). The code can model solids and fluids as well as damage and fractures. Although the code is open-source, some parts (namely the fancy Equations of State) are not. Most likely, I will have to use some of the simpler EOS that `spheral++` is already built with. In that case, I will try to match the initial conditions as best as possible (an exact match is impossible), and then see how my results vary with a simpler equation of state. Right now I am thinking of using Murnaghan equation of state, because it is quite simple and has been used for shock physics and and Earth science before. I am still waiting to here back from my undergraduate collaborators and the developer of `spheral++` before I decide on what EOS I can use, which will determine exactly what I do with this project.

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