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Numerical Simulations of Catastrophic Impacts Resolving Shapes of Remnants

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Asteroids have a variety of shapes that are probably formed through asteroidal collisions. Recent high-velocity impacts mainly result in catastrophic disruption and also the formation of asteroid families. Therefore, if we clarify asteroidal shapes formed through catastrophic disruption and compare them with those of family asteroids, we may extract valuable information on the past collisional events.

We conduct numerical simulations of catastrophic impacts using Smoothed Particle Elastic Dynamics (SPED: Sugiura & Inutsuka 2017) method with the self-gravity and the models of fracture of rock (Benz & Asphaug 1994) and friction of damaged rock (Jutzi 2015). We use basaltic spheres as impacting asteroids. The radius of target asteroids, the friction angle of damaged rock, the total number of SPED particles for each simulation, and the impact angle are set to 50 km, 40°, 4 million, and 15°, respectively. We conduct the three simulations with $v_{\rm imp} = 350\,{\rm m/s}$ and $M_i/M_t = 1$, $v_{\rm imp} = 700\,{\rm m/s}$ and $M_i/M_t = 1/4$, and $v_{\rm imp} = 1.7\,{\rm km/s}$ and $M_i/M_t = 1/16$, where $v_{\rm imp}$ is the impact velocity, M_t and M_i show the mass of targets and impactors, respectively.

We select the collisional remnants composed of more than 5,000 SPED particles resulting from the simulations, and analyze their shapes. As a result, we find that the remnants produced through catastrophic impacts mainly have spherical and bilobed shapes (Fig. 1). Spherical remnants are firstly formed through reaccumulation of fragments, and then coalescence of two spherical remnants produces bilobed remnants. However, flat shapes are difficult to form (hereafter, "flat" means the shapes with the ratio of the minor to major axis lengths less than 0.6 and the ratio of the intermediate to major axis lengths larger than 0.8): There are only two flat remnants among 106 remnants produced in the simulations.

We also analyze the shape models of asteroids with diameters larger than 10 km obtained from DAMIT database (Ďurech *et al.* 2010), and compare the shape distribution of non-family asteroids with that of asteroids belonging to families produced through catastrophic disruption. Here, we use AstDyS-2 database (http://hamilton.dm.unipi.it/astdys/) to distinguish between family and non-family asteroids. For non-family asteroids, there are 49 flat asteroids among 573 asteroids; the fraction of flat shapes is 8.6%. For family asteroids, there are 9 flat asteroids among 237 asteroids; the fraction of flat shapes is 3.8%. Thus the fraction of flat shapes for non-family asteroids is more than twice as large as that for family asteroids. This implies that catastrophic disruption is difficult to produce flat asteroids and supports the results of our simulations.

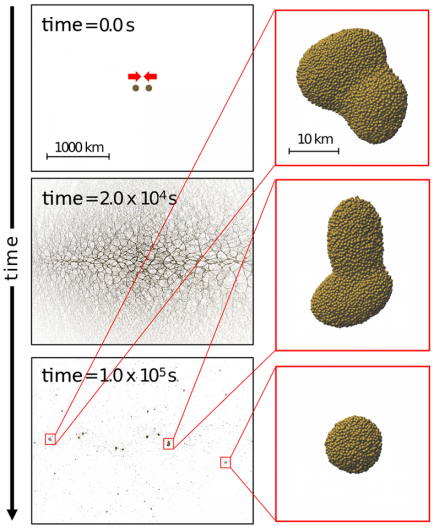

Figure 1. Snapshots of the impact simulation with $v_{\rm imp} = 350\,{\rm m/s}$ and $M_i/M_t = 1$.

References

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