Estimation of Interior Density Distribution for Small Solar System Bodies

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Density distribution within a small solar system body encodes information about interior inhomogeneity. Small bodies such as asteroids and comet nuclei have experienced collisional events. A rubble-pile object is of low density and high porosity because fragments of its parent body is loosely packed by the self-gravity after a catastrophic collision. For example, asteroid Itokawa, which is visited by the Hayabusa spacecraft, is of about 40 percent porosity and considered to be a rubble pile asteroid (Fujiwara et al., 2006). In addition, a great offset between its center-of-figure and its center-of-mass is predicted by a light curve observation and a thermophysical simulation (Lowry et al., 2014). This is associated with density variation in two distinct lobes of Itokawa, "head" and "body". Interior density distribution is an important clue to understand its structure and origin for various types of small bodies.

In this study, we propose a technique to make a constrain on interior density distribution based on a shape model of a small body and the equilibrium state of the surface topography. Regolith migration in the down-slope direction is a dominant process to refresh the asteroid surface. If there are enough amount of loose regolith, the surface topography becomes close to a kind of the equi-potential surface over sufficient time (Richardson and Bowling, 2014). We calculated the gravity potential on the surface of asteroid Eros and Itokawa, and investigated which density distribution makes the surface potential closest to this state.

The gravity measurement by the NEAR spacecraft showed that Eros had a coherent interior (Miller et al., 2002). Mean density of Eros was evaluated as 2,670 kg/m^3. We confirmed that the variance of the surface potential represented a minimum when all regions of Eros have the same density with the mean density. The potential variance minimization technique reproduced homogeneous density distribution of Eros. We applied this technique to asteroid Itokawa, whose density distribution is unknown. In contrast to Eros, the potential variance represented a minimum if Itokawa’s "head" is of higher density than its "body", or the "head" has a high density core in it. If the potential variance minimization technique can properly work for this sub-kilometer sized asteroid, it is possible for Itokawa to have great density inhomogeneity within it.

If we measure the gravity harmonics coefficients up to several degrees and orders, we can use them to constrain density distribution within a small body (Takahashi and Scheeres, 2014). However, it is not easy to measure the gravity harmonics coefficients up to enough degree and order in a small body mission. Our technique is a potential way to constrain asteroid interior even if the gravity measurement is not enough. The combination of these techniques to estimate density distribution is helpful for future small body missions not only to constrain an internal structure but also to estimate the exterior gravity field of target bodies more precisely.

Keywords: Small solar system body, Gravity potential, Shape model, Interior structure, Asteroid 433 Eros, Asteroid 25143 Itokawa

