Estimation of Interior Density Distribution for Asteroid Itokawa

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Itokawa is considered to be a rubble pile object based on high porosity of approximately 40 percent (Fujiwara, et al., 2006). However, internal structure and formation process of the sub-kilometer-sized rubble pile are still open questions. Interior density distribution of Itokawa gives us an important clue to understand the formation process. It is possible that Itokawa has interior structure derived from processes of collisional breakup and reconfiguration.

Light curve observation and thermophysical simulation for Itokawa suggested the center-of-mass (COM) is displaced from the center-of-figure (COF) by approximately 21m (Lowry, et al., 2014). Such a great offset between the COM and COF can be explained by a significant difference of bulk density between two lobes, "head" and "body". The COM offset is important evidence of density inhomogeneity within the asteroid. The goal of this study is to make a determination on the density distribution of Itokawa from a different view point, focusing on the shape and the gravity field.

We remodeled a conventional gravity simulation of a constant-density polyhedron (Werner and Scheeres, 1997) so as to represent density inhomogeneity within a 3D shape model of Itokawa. We verified an interior density map, where the head part of Itokawa has a higher density value than the remaining body part. We calculated the gravity potential all over the surface of Itokawa and obtained potential variance as an index of density distribution estimation. We searched for a minimum value of potential variance assigning different density values to the head and body part. The minimum of potential variance was recognized as an estimation solution of density distribution. Our estimation is based on the assumption that the surface terrain of the asteroid comes close to the equi-potential surface over sufficient time due to erosion and resurfacing processes (Richardson and Bowling. 2014).

This study implied new evidence of internal density inhomogeneity of asteroid Itokawa. Potential variance through the global surface was minimized where the head density was approximately 2,750 kg/m^3. The head part of such a high density corresponds to a density value of 1,870 kg/m^3 in the remaining body part and a COM offset by 16 m toward the head of Itokawa. If both the head and body of Itokawa consist of LL-chondrites whose bulk density is 3,190 kg/m^3, it is found that Itokawa has porosity widely ranging from approximately 14% to 41% between two lobes. It is possible for the head of Itokawa to have a more coherent and monolithic structure in comparison with the other regions. It is possible that the head part of Itokawa is composed of large fragments derived from a parent body.

Keywords: Asteroid Itokawa, Gravity Field, Polyhedron Gravity Simulation, Density Inhomogeneity, Interior Structure