Investigating the Effects of the Rotation and Interior Density Distribution on the Surface Gravity Field of Asteroid Itokawa

Estimation of Interior Density Distribution: The case of Itokawa

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BACKGROUND
Internal Density Inhomogeneity

YORP Simulation
(Scheeres & Gaskell, 2008)
- 3D shape models of Itokawa
- Constant-density assumption
- Rotational Deceleration

Light Curve Observation
(Scheeres et al., 2007)
- Rotational Acceleration

COM Offset & YORP
(Werner & Scheeres, 1997)
- Significance of YORP
- Possible high-density head or neck

Aims

• Remodeling gravity simulation so as to represent density inhomogeneity within 3D shape models
• Estimating the internal density distribution of Itokawa from the view point of surface topography and the gravity potential

METHOD
Polyhedron Gravity Simulation

1. Meshing by Netgen Mesh Generator
   - Import a shape model of Itokawa consisting of 25,350 vertices and 49,152 facets (Gaskell et al., 2005)
   - Generate surface elements and volume elements

2. Interior Density Map
   - Compressed Head Model
   - Compressed Neck Model

Total Mass Constraint
The total mass of Itokawa was fixed to $3.58 \times 10^{15}$ kg. (Krebs et al., 2008)

Gravity of Tetrahedron & Integration
- Calculate gravitation of every volume element using a constant-density polyhedron model (Werner & Scheeres, 1997)
- Sum gravitational contribution through all volume elements

Effect of Rotation on the Surface Gravity Field

• Rotation Axis: Z axis of the shape model
• Rotation Period: 12.1324 hours (Fukawa et al., 2006)

Estimation of Interior Density Distribution

Self-Correcting System
Down-slope regolith migration erodes the surface topography towards a zero-potential surface or a low-slope state (Richardson & Davies, 2014)

Potential Variance

$$
\sigma^2(\rho_{int}) = \frac{1}{N-1} \sum_{i=1}^{N} \left( \frac{U_i(\rho_{int})}{U_i(\rho_{ref})} - 1 \right)^2
$$

where potential average is

$$
U_{\rho_{int}}(\rho_{ref}) = \sum_{i=1}^{N} A_i \mathbf{g} \cdot \mathbf{n}
$$

Slope Average

$$
\psi(\rho_{int}) = \frac{1}{N} \sum_{i=1}^{N} \psi_i(\rho_{int})
$$

where

- $A_i$: Area of ith surface element
- $\mathbf{g}$: Gravity acceleration vector
- $\mathbf{n}$: Facet normal vector
- $\psi_i(\rho_{int})$: Slope angle at the ith surface element

Estimation Indicators

1. Variance of the gravity potential, and
2. Average of slope angles across the surface as functions of density of the head or neck part.

At minimum...

Estimation solution of density distribution

Potential average...

1. $U_i(\rho_{int}) = \sum_{i=1}^{N} A_i \mathbf{g} \cdot \mathbf{n}$

Slope Average

1. $\psi(\rho_{int}) = \frac{1}{N} \sum_{i=1}^{N} \psi_i(\rho_{int})$

Gravity Acceleration Vector

slope angle...