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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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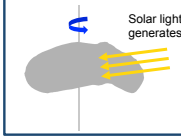
BACKGROUND

Internal Density Inhomogeneity

YORP Simulation (Scheeres et al., 2007)

✔ 3D shape models of Itokawa
✔ Constant-density assumption

⇒ Rotational Deceleration



COM Offset & YORP (Scheeres & Gaskell, 2008)

If the Center-of-Mass (COM) is displaced from the Center-of-Figure (COF) by 16 m or more

Reverse of YORP effect

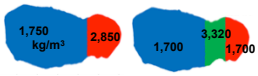
Light Curve Observation (Lowry et al. 2014)

⇒ Rotational Acceleration

COM offset ΔX: 21 ± 12 m

Significant density inhomogeneity

Possibility of high-density head or neck



AIMS

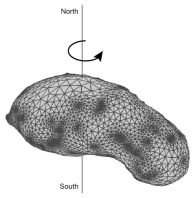
- **Remodeling gravity simulation so as to represent density inhomogeneity within 3D shape models**
- **Estimating the internal density distribution of Itokawa from the view point of surface topography and the gravity potential**

Physical characteristics of Itokawa (Fujiwara et al., 2006 and Abe et al., 2006)

Dimensions	535 × 294 × 209m (±1m)
Rotation period	12.132370 [hour]
Mass	(3.58 ± 0.18) × 10^{10} [kg]
Volume	(1.84 ± 0.09) × 10^{7} [m^3]
Bulk density	1,950 ± 140 [kg/m^3]
Bulk porosity	~ 40%

METHOD

Polyhedron Gravity Simulation

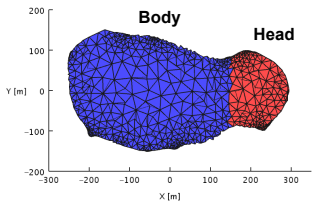


1 Meshing by Netgen Mesh Generator

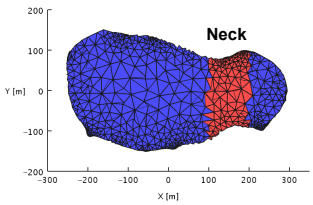
✔ Import a shape model of Itokawa consisting of 25,350 vertices and 49,152 facets (Gaskell et al., 2006)
✔ Generate surface elements and volume elements

2 Interior Density Map

Compressed Head Model



Compressed Neck Model

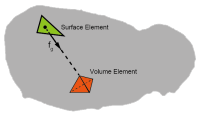


Total Mass Constraint

The total mass of Itokawa was fixed to 3.58×10^{10} kg. (Abe et al., 2006)

3 Gravitation 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
✔ Calculate it on every surface element



4 Effect of Rotation on the Surface Gravity Field

✔ Rotation Axis: Z axis of the shape model ✔ Rotation Period: 12.1324 hours (Fujiwara et al. 2006)

Estimation of Interior Density Distribution

Self-Correcting System

Down-slope regolith migration erodes the surface topography towards a **equi-potential surface** or a **low-slope state** (Richardson & Bowling, 2014).

Estimation Indicators

We calculated
1. Variance of the gravity potential, and
2. Average of slope angles

all over the surface as functions of density of the **head** or **neck** part.

At minimum…

Estimation solution of density distribution

Potential Variance

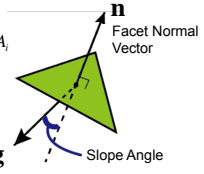
$$\sigma^2(\rho_{head}) = \frac{1}{N_s - 1} \frac{\sum A_i \left[\frac{U_i(\rho_{head})}{U_0(\rho_{head})} - 1 \right]^2}{\sum A_i}$$

where potential average is $U_{ave}(\rho_{mean}) = \sum_{i=1}^{N_s} A_i U_i(\rho_{mean}) \Big/ \sum_{i=1}^{N_s} A_i$

Area of ith surface element

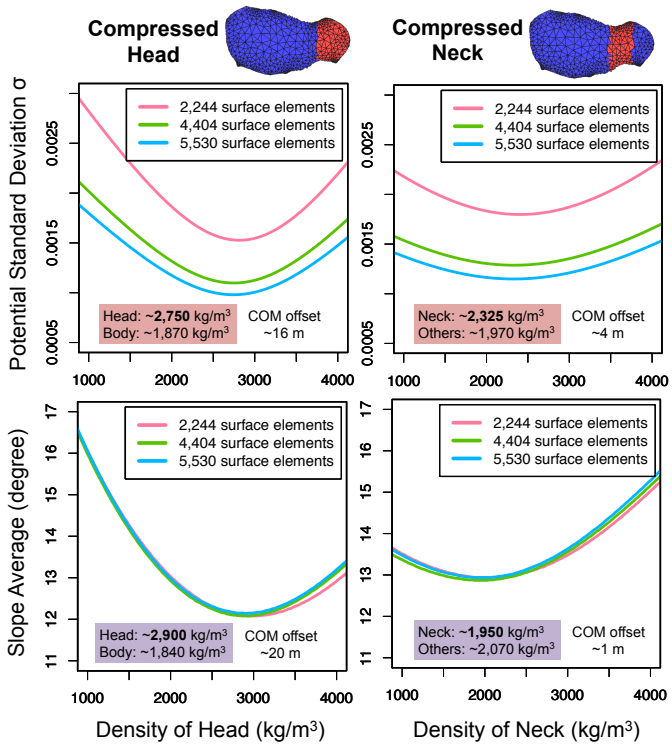
Slope Average

$$\varphi_{ave}(\rho_{head}) = \sum_{i=1}^{N_s} A_i \varphi_i(\rho_{head}) \Big/ \sum_{i=1}^{N_s} A_i$$

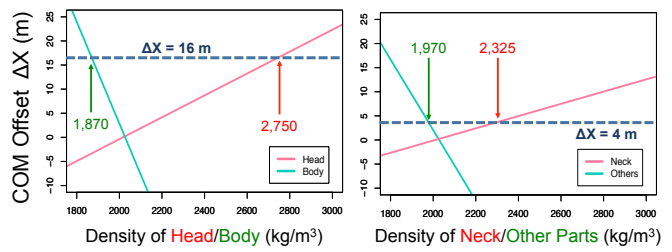


RESULT

Density Distribution Estimation

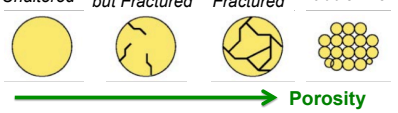


COM Offset

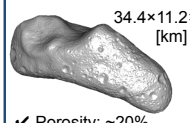


DISCUSSION

Internal fractures of an asteroid (Wilkison et al. 2002)

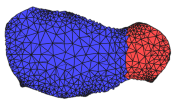


Asteroid 433 Eros



✔ Porosity: ~20%
✔ COM offset: 13 m
⇒ Coherent but fractured

New evidence of density Inhomogeneity within Itokawa!!



Body: 1,870 kg/m³ Head: 2,750 kg/m³

~41% in porosity **~14 %**

if both lobes are composed of the same LL-chondrites whose density of 3,190 kg/m³ (Abe et al., 2006)

✔ **It is possible for Itokawa to have the monolithic and coherent head, and the low-density body in structure of rubble pile.**

✔ **Were large fragments taken into the head part after a catastrophic disruption of the parent object?**