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Geophysical constraints on the past spin states of Itokawa

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Abstract

Itokawa has two distinct terrain types, rough highlands and smooth lowlands. The lowlands formed by the movement of fine-grained materials from the highlands into topographic lows [1]. The topography of asteroids is a function of the interior density, shape, and spin rate. Under faster spin periods (9 hours or less) the northern topographic low, Sagamihara, changes location. The location of the lowlands could be used as a constraint on the past spin periods of Itokawa if the time scale for the migration of the fines is longer than the time scale for the spin period change.

1. Introduction

The asteroid 25143 Itokawa is a small rubble-pile asteroid that is 535 x 294 x 209 m in size [1]. Itokawa's size and location in the solar system makes it a candidate for YORP modifications to its spin period [1]. Analysis of the high-resolution shape model predicted that the spin period of Itokawa should be increasing, i.e., that Itokawa should be spinning down [2]. In contrast, more recent observations from light-curve data found that Itokawa was spinning up, ie the spin period is decreasing, which was explained by a density difference between Itokawa's two lobes [3].

The Muses-Sea and Sagamihara regions on Itokawa are smooth lowlands surrounded by rough highlands [1]. Fine-grained material has flowed into topographic lows covering up the rougher large boulders [4]. Here, we use the current location of the lowlands as a possible constraint on the past spin states of Itokawa

2. Methods

We used a 49,152 plate shape model for Itokawa and calculate the gravity of an irregular asteroid using the approach in [5], to generate maps of the topography, height above the geopotential. We calculated the topography of Itokawa with constant density of 1.95 kg m^{-3} [1] and for a density difference between the head (2.44 kg m^{-3}) and body (1.93 kg m^{-3}) [6]. We calculated the global topography at the present spin rate, 12-hours, and at other spin rates from 6 to 24 hours in 2-hour increments. The resulting topography was projected onto a shape model of the asteroid (Panel 1).

3. Results

From maps of the topography of Itokawa, we observe that the topographic lows related to the Muses Sea and Sagamihara are in the same location for the 12- and 24-hour spin period. For a spin period of 6 hours, Muses Sea is still a topographic low, but Sagamihara's shifts away from the Itokawa's neck region to a location we denote as S2 (Panel 1).

We quantified this observation by looking at the difference in mean topography between highlands and lowlands with different spin periods (Figure 1). At 9-hour spin and below, we observe that the region S2 has a larger topographic difference compared to the highlands than Sagamihara for both the uniform and non-uniform density scenario. This implies that the material would be more likely to flow into S2 than Sagamihara at that spin rate.

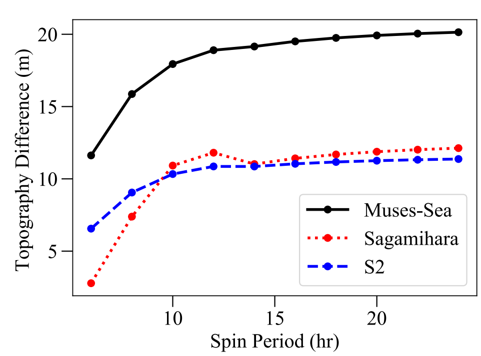

Figure 1. A plot of the difference in topography for the uniform density scenario between the lowlands and

highlands. A positive topographic difference represents the change in mean topography of the highlands compare to the mean topography of the lowland region of interest.

4. Summary and Conclusions

In this study, we performed analysis of the topography of Itokawa for different spin periods. Preliminary analysis for the timescale of fine-grain migration indicates that the timescale required for the downslope diffusion of a 2-10 m regolith layer [4] driven by global seismic shaking (< 0.01 Myr, [7,8]) is smaller than the timescale for YORP spin modification (~0.5 Myr [3]) required for the inversion of topographic low from Sagamihara to S2 (12 to 9 hours). These early results are the first documented geophysical evidence of Itokawa's recent YORP modifications and the results imply that Itokawa is unlikely to have spun faster than 9 hours in its recent past. Another possibility is that global impact-induced seismic diffusion, driven by impacts, is not as efficient a process as has been previously suggested [8], and the size segregation of grains on the surface of Itokawa requires an alternative mechanism.

References

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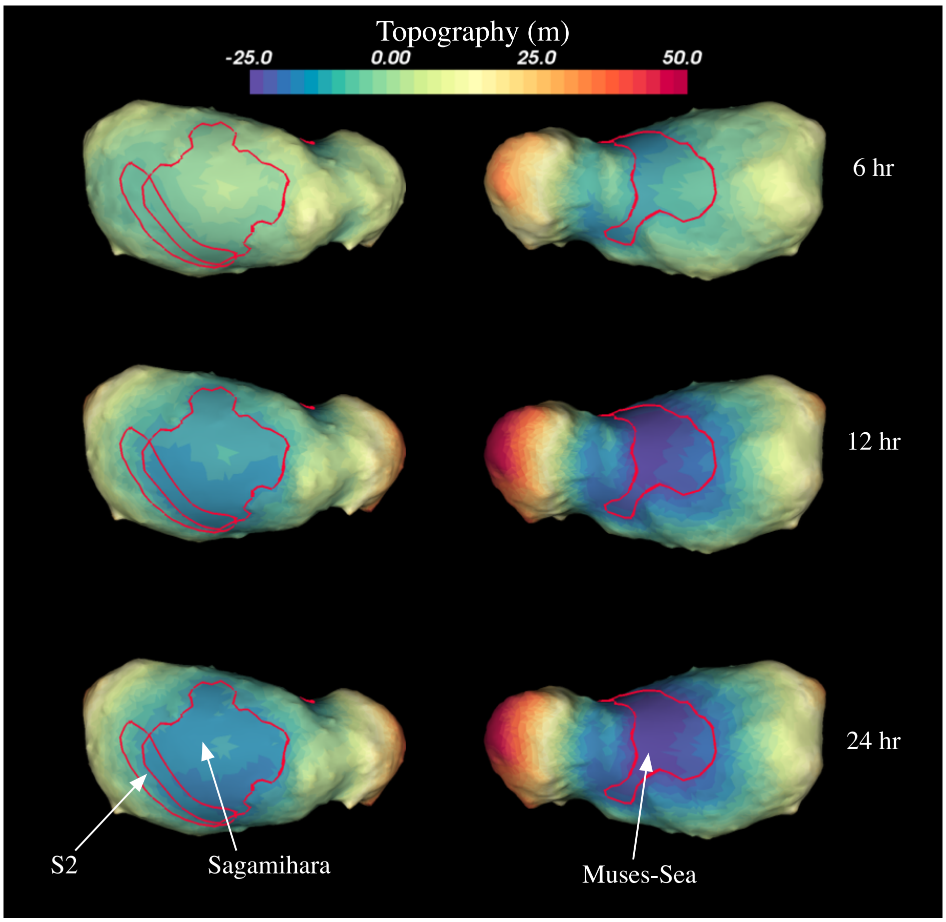

Panel 1. A north (left) and south view (left) of the topography of Itokawa calculated for three different spin periods. Red outlines of the Muses-Sea and Sagamihara were mapped at the 12-hour spin period using topography and slow maps. The red outline of the S2 region was mapped at the 6-hour spin period.