The YORP Effect on Asteroids with Heterogeneous Distribution of Surface Thermophysical Properties

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Introduction

The YORP effect is caused by torques created by scattering or by emission of thermal radiation from small irregular bodies in the Solar System – asteroids. The main consequences of YORP are change of the rotation period and change of the orientation of rotation axis.

Until now, YORP has been studied only on bodies with homogeneous distribution of surface materials, thus with uniform optical and thermophysical properties. However, asteroids are not homogeneous, see Asteroid surfaces section, figures (a), (b) and (c).

We applied several different methods to create heterogeneous surfaces on 200 artificial asteroids and then evaluated whether the presence of heterogeneities influences YORP significantly compared to the homogeneous case or not.

Asteroid surfaces

Asteroid surfaces are not optically and thermophysically homogeneous, as can be seen from pictures taken by interplanetary probes. Landslide uncovering fresh material in (a) one of Eros’s craters (Murdoch et al., 2015), (b) Lintoc crater (Thomas et al., 2011) and (c) Stickney crater on Phobos (Basilevsky et al., 2014).

Model

We use artificial asteroid models that are composed of triangular facets. Modelling of surface heterogeneities is done in three ways:

- An impact crater with higher albedo regolith (not influenced by space weathering) is placed on a regolith-covered asteroid → reflected radiation.
- Higher albedo (unweathered) regolith appears on steep slopes (slope angle of a triangular facet \( \alpha > 35^\circ \) – angle of repose of loose materials) → reflected radiation.
- Properties of bare rock (with different thermal parameters) are attributed to the areas of steep slopes → thermal radiation.

Then we evaluate the influence of torques by means of statistics. For computation of YORP we use already existing model by Čapek and Vokrouhlický, 2004.

The last part of our research is based on a comparison of behaviour of sets of homogeneous asteroids with different covering materials.

Distribution of properties

If a facet has slope \( \alpha \) (angle between inner normal \( n \) and vector sum of centrifugal \( a \) and gravitational \( g \) acceleration) greater than the angle of repose \( \epsilon_{\text{max}} \) of regolith that was on the facet originally tends to slide away from it and lower layers of regolith (with higher albedo) or bare rock (with different thermal conductivity, density etc.) than the rest of the surface) are uncovered.

Asteroid models

Different rotation periods (\( T_{\text{crit}} \) denotes the critical period) cause different centrifugal acceleration, and hence the final distribution of materials differs:

- Impact crater: majority of asteroids end with rotation axis perpendicular to the orbital plane (type I) or lying in it (type II); no preference to accelerate/decelerate rotation speed or to be prograde/retrograde rotator.
- Landslides uncovering unwethered regolith: majority of asteroids are of type I or II, very probable deceleration of rotation.
- Landslides uncovering bare rock: more than 87% of asteroids are of type II (axes perpendicular to the orbital plane), we can see statistically non-significant prograde rotation tendency in the sample, just critically rotating asteroids tend to decelerate rotation (on border of significance).

Results

- Heterogeneous distribution of optical or thermal properties on asteroid surfaces does not influence the final YORP effect substantially.
- The higher is the conductivity of surface layer of the asteroid, the more probable is its convergence to the state of prograde rotation.

References


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