EPSC Abstracts
Vol. 10, EPSC2015-895-2, 2015
European Planetary Science Congress 2015
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Sensitivity of the YORP effect to small perturbations of the asteroid shape

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Abstract

We study YORP for an asteroid modelled as a triaxial ellipsoids slightly perturbed by spherical harmonics. The analyticaly obtain the YORP torque as a series in terms of spherical function coefficients. Then we analyze sherical fuction and determine, which spherical functions give vanishing contributions due to symmetries. We find that the largest contribution to the YORP effect is provided by harmonic Y_{42}. We developed a program computing YORP torque for several specific asteroids, whose shapes are determined observationally. Results of the program are used to estimate the error in the YORP effect, produced by neglecting small-scale structures.

1. Introduction

The reemitted lite from the assymetric asteroid surface recoil pressure which could produce the asteroid rotation. As it was shown by [1] that torque can be caused by external geometry of the body. The body must have a certain amount of "windmill" asymmetry. Thus the discribed effect was named as windmill effect. It is not difficult to recignize that figures of revolution or even triaxial ellipsoids wouldn't be spun up.

Yarkovsky, O'Keefe, Radzievskii and Paddack developed paradigm of non-gravitational forces acting on asteroids [3]. And the mechanism for changing the spin state of asteroids is colled Yarkovsky–O'Keefe–Radzievskii–Paddack effect (YORP effect for short). It is significant for kilometer- and smaller-sized asteroids, especially in the near-Earth region.

As the torque depends on asteroid shape it is interesting to research the sensitivity of torques to different scales of shape irragularity [2].

2 YORP of perturbed triaxial ellipsoids

In order to explore dependence of the YORP torque of an asteroid on different scales of shape irregularity we research a specific asteroid model. Persume asteroid as a sphere perturbed by spherical harmonics and stretched along three mutually orthogonal axes. The obtained spheroidal issue is close to a triaxial ellipsoid. Consider the problem of analytical calculation of the YORP effect for it. Fortunaly total YORP effect turns in linearly series of YORP torques of spherical functions.

$$T_z = \sum_{l,m} \tau_{lm} a_{lm} \quad (1)$$

, here τ_{lm} – YORP torques of spherical functions (or YORP coefficients), a_{lm} –coeffients of decomposition. From the sherical fuction analyze it is not difficult to recognize multiplicity of harmonics which give vanishing contributions due to symmetries. It was found that the largest contribution to the YORP effect is provided by harmonic Y_{42}. Found stong dependence of YORP torque on asteroid elongation.

3 Decomposition of observed shape models into spherical harmonics

We take existing shape models of asteroids obtained either via lightcorve inversion method, or from radar observations, or from direct in situ observations by spacecraft. We fit a triaxial ellipsoid to each shape model, and decompose the residual into spherical harmonics, finding coefficients a_{lm}. The coefficients of the decomposition are assumed to be Gaussian random variables, whose power spectrum is determined via averaging of coefficients of several spherical harmonics.

Then each asteroid appears to be just one single realization of an ansamble of asteroids with the same power spectrum.

For small l the observationally determined power spectrum is very uncertain, because here no meaningful averaging procedure can be applied. For big l the power appears to bee very small, because small features on the asteroid remain unresolved in the shape model. Still, a power-law extrapolation can be done to this area.

4 Sensitivity of YORP to unresolved features

We substitute the power spectrum of a_{lm} determined in Section 3 and YORP coeffients τ_{lm} determined in Section 2 into Eq. 1. To estimate the error in Eq. 1 due to unresolved features of the surface, we must quadratically add errors due all terms beyond resolution of the shape model. In each of these terms the YORP coeffient τ_{lm} is taken from Section 2, and the variance of a_{lm} is taken from the power spectrum.

The obtained results depend on the validity of extrapolations of the power spectrum to big l. But filtering out high harmonics and calculating the YORP for a smoothed model of an asteroid allows us to make a more rigorous error estimate of the YORP effect.

References

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