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Sensitivity of Tangential YORP Effect to Shapes and Arrangement of Boulders

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1. Abstract

In this work, we investigate the sensitivity of the tangential YORP (TYORP) effect on the geometry and arrangement of boulders. Firstly, we compute the TYORP force created by isolated boulders with 3D shapes ranging from simple to realistically irregular geometries. We then study the total TYORP force due to a set of boulders. In particular, we examine the effects of shadowing and self-heating for various configuration of the boulders. We compare the results to the predictions of the analytic theory of Golubov (2017). Finally, we integrate the TYORP effect over a population of boulders of different sizes to obtain an improved estimate of the total TYORP effect. The results are compared to the values of the TYORP effect expected for asteroids (25143) Itokawa and (101955) Bennu.

2. Introduction

The tangential YORP effect, or TYORP, is a torque experienced by an asteroid due to asymmetric thermal radiation by relatively symmetric boulders lying on its surface [1]. It has been estimated that for many asteroids this effect can be comparable to the normal YORP caused by the global shape asymmetry of the asteroid, and thus precise computation of TYORP is needed to reliably study asteroids' evolution and to correctly interpret the observational data on YORP [2,3,4].

TYORP has been studied numerically only in several simple geometries: for 1-dimensional walls [2,4], for spherical boulders [3,5], and for one particular boulder of a more complex shape [4]. On the theoretical side, a general estimate of TYORP created by boulders of any shape has been proposed, as well as a somewhat cumbersome expression for TYORP of an ensemble of boulders of different sizes [6]. Although acceptable as a temporary measure to bridge the gap between the few available numeric simulations and the TYORP expressions required for asteroid modeling, the accuracy of this approach is severely limited by the numerous simplifications performed to construct the analytic estimate in [6].

Here, we aim to extend the scope of the numeric simulations such that they can supersede the previous analytic estimates, and advance the state of modeling of asteroid evolution.

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