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The Effect of Surface Roughness on the Yarkovsky and YORP Effects

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Abstract

We demonstrate the importance of the thermal infrared beaming effect caused by surface roughness on modeling the Yarkovsky and YORP effects acting on asteroids. Previous models have completely neglected or dismissed thermal infrared beaming by assuming lambertian thermal emission from asteroid surfaces. By using the new rough surface thermophysical model *ATPM* we will show that thermal infrared beaming affects both the Yarkovsky and YORP predictions by several tens of percent. The results have implications for reconciling observations and predictions for the few asteroids for which these effects have been detected.

1. Introduction

In addition to collisions and gravitational forces, it is now becoming widely accepted that photon recoil forces resulting from absorbed, reflected, and thermally re-radiated solar radiation are primary mechanisms governing the evolution of asteroids. The Yarkovsky effect causes an asteroid's orbit to drift and the YORP effect causes an asteroid's rotation rate and pole orientation to change. The two effects are coupled and result from the asymmetric reflection and thermal re-radiation of absorbed sunlight from an asteroid's surface. They have a number of important implications in asteroid dynamics including [1]: moving main belt asteroids into resonances potentially leading to Earth-crossing orbits, dispersing asteroid families, making the orbits of potentially hazardous asteroids difficult to predict [2], modifying asteroid rotation rates and pole orientations over short timescales, and have the potential to form binary asteroids from continued spin up of rubble pile asteroids [3].

Currently, there have been two confirmed detections of the Yarkovsky effect (Golevka [4] and 1992 BF [5]) and four confirmed detections of the YORP effect (YORP [6], Apollo [7], Geographos [8], and Eger [9]) in the near Earth asteroid population. Many models have predicted the detection of the YORP effect acting on Itokawa but so far there is no evidence of it in current photometric observations [10]. For the selection of YORP detected asteroids the models generally overestimate the YORP effect acting on them when compared to the observations.

Recent modeling has shown the YORP effect to be sensitive to inhomogeneous density distributions inside the asteroid [11] and slight variations in their global shape model representation [12] in attempts to reconcile the differences between observations and predictions. However, all previous models have assumed lambertian thermal emission from asteroid surfaces, and have either neglected or dismissed thermal infrared beaming caused by surface roughness at scales that are smaller than the global shape model resolution. Thermal infrared beaming has the tendency to re-radiate absorbed solar radiation back towards the Sun in a non-lambertian way, and affects the observed asteroid thermal flux used in asteroid diameter determination [13]. It has also been well observed in directional resolved thermal emission measurements of the lunar surface [14], and in images taken of Comet 9P/Tempel 1 by Deep Impact [15].

2. Application of the *ATPM* Model

A new thermophysical model has been produced, the *Advanced Thermophysical Model* (*ATPM*), to investigate the effects of surface roughness on planetary thermal emission and has been verified by accurately reproducing the lunar thermal infrared beaming observations [16]. The model accepts global shape and surface topography models in the triangular facet formalism. For each global facet and surface roughness subfacet a 1D heat conduction equation is solved throughout an asteroid rotation to determine the surface temperature distribution. A surface boundary condition is imposed that includes direct and multiple scattered solar radiation, shadowing, and re-absorbed thermal radiation from interfacing facets. The Yarkovsky and YORP effects acting on an asteroid are then determined by summing the photon recoil forces and torques over each global facet and surface roughness subfacet, and then averaged over an asteroid rotation and orbit. Re-absorbed thermally emitted and reflected photons from interfacing facets are excluded from the calculations since they have no overall effect on the asteroid. To represent the surface roughness we use hemispherical craters as they have been shown to accurately reproduce the lunar thermal infrared beaming effect [16].

3. The Effect of Surface Roughness

To demonstrate the effects of surface roughness on the Yarkovsky and YORP effects we consider the following examples: a 1 km spherical asteroid, an asymmetric wedge, and several real case asteroids. We ran the *ATPM* model for a range of thermal inertia values and varied the fraction of the surface covered with hemispherical craters. The results show that both effects are sensitive to the thermal infrared beaming effect caused by surface roughness by several tens of percent.

4. Summary and Conclusions

The new rough surface thermophysical model *ATPM* has been used to demonstrate the importance of surface roughness and thermal infrared beaming on modeling the Yarkovsky and YORP effects. In general, surface roughness affects the Yarkovsky and YORP effect predictions by several tens of percent. This has implications for reconciling the current differences between observations and predictions for detected asteroids. The results will be discussed in detail at the conference.

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References

[1] Bottke, Jr. W. F. *et al.*: Annual Review of Earth and Planetary Sciences, Vol. 34, pp. 157-191, 2006.

[2] Giorgini, J. D. *et al.*: Icarus, Vol. 193, pp. 1-19, 2008.

[3] Walsh, K. J. *et al.*: Nature, Vol. 454, pp. 188-191, 2008.

[4] Chesley, S. R. *et al.*: Science, Vol. 302, pp. 1739-1742, 2003.

[5] Vokrouhlický, D. *et al.*: The Astronomical Journal, Vol. 135, pp. 2336-2340, 2008.

[6] Lowry, S. C. *et al.*: Science, Vol. 316, pp. 272-274, 2007.

[7] Kaasalainen, M. *et al.*: Nature, Vol. 446, pp. 420-422, 2007.

[8] Durech, J. *et al.*: Astronomy and Astrophysics, Vol. 489, pp. L25-L28, 2008.

[9] Durech, J. *et al.*: American Astronomical Society, DPS Meeting 41, Abstract 56.04, 2009.

[10] Durech, J. *et al.*: Astronomy and Astrophysics, Vol. 488, pp. 345-350, 2008.

[11] Scheeres, D. J. and Gaskell, R. W.: Icarus, Vol. 198, pp. 125-129, 2008.

[12] Statler, T. S.: Icarus, Vol. 202, pp. 502-513, 2009.

[13] Delbo, M. *et al.*: Icarus, Vol. 190, pp. 236-249, 2007.

[14] Saari, J. M. *et al.*: The Moon, Vol. 5, pp. 179-199, 1972.

[15] Groussin, O. *et al.*: Icarus, Vol. 187, pp. 16-25, 2007.

[16] Rozitis, B. and Green, S. F.: EPSC Abstracts, Vol. 5, EPSC2010-196, 2010.