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TANGENTIAL YORP EFFECT

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ABSTRACT

YORP is a torque produced by recoil forces acting on the surface of an asteroid. On cosmologic timescales it can substantially alter the rotation state of a kilometer-sized asteroid, and thus present a major contribution to its rotational state evolution. Via disrupting fast rotators by centrifugal forces, YORP forms distribution of asteroids over sizes and shapes. Via changing obliquities and rotation periods of asteroids it can alter the strength of Yarkovsky effect. Due to all these factors good quantitative understanding of the YORP effect presents one of the major constituents of our understanding of the origin of near-Earth asteroids.

The heat conductivity process in the body of an asteroid is governed by two important distance scales. One of them is the thermal wavelength L_{wave} . The other is the heat conductivity length L_{cond} , which roughly corresponds to the distance at which the heat conductivity flux is equal to the infalling solar energy flux. (For precise definitions see Golubov & Krugly 2012.) The ratio of these two scales defines the thermal parameter, $\theta = L_{\text{cond}} / L_{\text{wave}}$.

In my talk I'll cover a range of topics related to the YORP effect. First, I'll discuss the case when the heat conductivity in the body of an asteroid can be considered 1-dimensional. This approximation holds if the surface of an asteroid is smooth on the scales L_{cond} , which is usually of the order of metres for stony surfaces. In this approximation the YORP acceleration of an asteroid is independent of the thermal model of the surface, and a simple analytic theory of the YORP acceleration can be constructed. The influence of YORP on the obliquity of an asteroid depends on the

thermal model of the surface, but a semi-analytic theory incorporating thermal properties of the surface, can also be proposed in this case. This case, when the YORP acceleration is produced by forces normal to the surface, is called normal YORP effect, or NYORP.

The major part of my talk will be dedicated to the tangential YORP effect, or TYORP. This effect appears if an asteroid has structures with sizes of order of L_{cond} (the most importantly, stones of these sizes). Then from solution of the heat conductivity problem in these stones, it can follow, that each stone emits more radiation westwards than eastwards, or vice versa. Then the surface of an asteroid, considered globally on scales much bigger than L_{cond} , will experience a net tangential drag. (But this drag is produced by summation of local forces, each of which is perpendicular to the local surface element.)

To get a rough estimate of this effect, it will be considered in a simplified model of 1-dimensional stones of thickness d . It will be shown, that the effect is the strongest, when $d \approx L_{\text{cond}} \approx L_{\text{wave}}$ (or, equivalently, $L_{\text{cond}}/d \approx 1$, $\theta \approx 1$). The normalized strength of the effect is shown in Fig. 1. We see that in most cases the effect is positive, thus TYORP tends rather to accelerate asteroids than to decelerate them. Numerical estimates of the TYORP torque will also be performed.

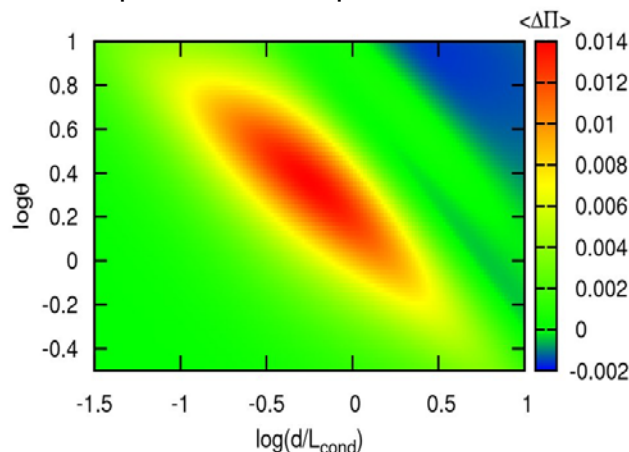


Fig. 1. Dimensionless TYORP drag acting on the surface color-coded as a function of the thicknesses of the stone d and the thermal parameter θ .

In reality NYORP and TYORP act simultaneously. The absolute amount of the tangential force is at least 2 orders of magnitude smaller than the absolute amount of the normal force. But, firstly, the normal force has a much smaller lever arm and, secondly, normal forces acting on opposite points of an asteroid largely compensate each others' torques, while tangential forces' torques can add up. Thus torques of NYORP and TYORP can be comparable. For example, TYORP could account for the discrepancy between the predicted and the observed torques of the asteroid 25143 Itokawa. Moreover, as TYORP depends on the rotation speed of an asteroid, many asteroids can tend to equilibrium, where TYORP and NYORP compensate each other, and no total acceleration is observed. And only understanding both TYORP and NYORP in concert, can we correctly describe dynamics of asteroids quantitatively and qualitatively.

References:

1. Golubov O., Krugly Yu., 2012, APJL, 752:L11