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YORP-Yarkowski evolution of asteroid families

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Abstract

According to [2], the coupling between obliquity and spin rate evolution drives the rotation state of small bodies into complex paths that may end up into equilibria. This behaviour not only significantly influences the spin dynamics of asteroids but it also affects their orbital evolution via the Yarkovsky effect which strongly depends on the obliquity of the body. To have a full picture of this dynamics it is essential to consider, in addition to the 'normal' Yorp (NYORP), also the so-called Tangential YORP (TYORP), caused by asymmetric light emission by boulders or other structures on the surface of an asteroid, and mutual collisions which cause step changes in the spin of asteroids. Introducing these effects in a model which tracks the coupled orbital and rotational evolution of asteroid families, under the action of the Yarkowsky (diurnal and seasonal), YORP and collision effects, we are able to recover the characteristic V-shape configuration in the semimajor axis vs absolute magnitude (H) space. The time evolution of a number of synthetic families is explored with this model looking in detail at different size regimes. Looking at time snapshots of the V-shape evolution the YORP-eye hypothesis of [4] is probed too.

1. Introduction

An evolutionary model was developed to simulate the time evolution of the asteroid families considering the semimajor axis mobility due to the Yarkowsky effect. The influence of the YORP effect on the Yarkowsky evolution of the objects' semimajor axis, due to the evolution of the rotation axis obliquity, is accurately modelled and, finally, the influence of the collisions on the rotation state of the asteroids is included as well.

1.1. The model

The process is the following. A synthetic family is generated with a distributions of diameters D derived from a collisional code. An ejection velocity vector V and a spin vector S are assigned at each member. In addition, assuming they have irregular shapes, to each of them we assign different NYORP and TYORP coefficients which may change during the evolution once the body either reaches a breakup or tumbling state or a collision occurs (with a large enough projectile).

We focus on a Koronis–like family in terms of initial orbital parameters of the parent body. Once the family is generated, we evolve the semimajor axis of all individual family members under the Yarkovsky effect with a drifting rate of the same order of magnitude of that adopted by [1]. The drift rate is properly scaled for the size and semimajor axis of the fictitious fragments considered in our model. The YORP effect on the evolution of the magnitude and direction of the spin vector is computed following the method described in [3] and [2]. In particular, the YORP-driven obliquity evolution is computed, according to the model described in [2], tracking the spin axis displacement along the YORP cycles from 0 to π. Both NYORP and TYORP (caused by asymmetric light emission by boulders or other structures on the surface of the asteroid) are taken into account. Finally, the change in the angular momentum and obliquity due to impacts, against a population of potential impactors (derived from the SDSS size distribution of asteroids and distributed over logarithmic size bins), is computed, again using the model described in [3].

2. First tests

To test the code we have first investigate the evolution of a putative family under the effects of Yarkovsky–YORP only. In particular, we tested the relevance of TYORP on the orbital distribution of the family after 1 Gyr. For this purpose, at each asteroid, member

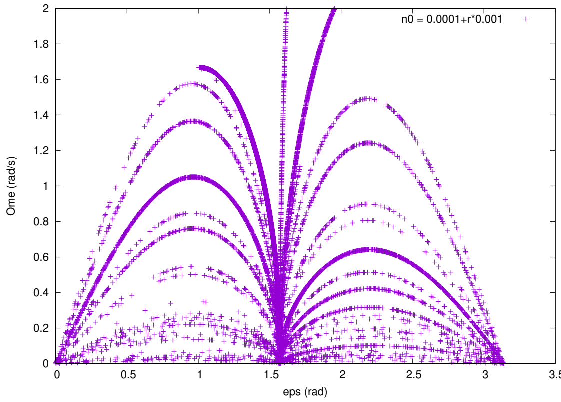

Figure 1: Example of the obliquity evolution of a single member (r=1km) of the putative family under NYORP and TYORP over 1 Gyr.

of the family, is assigned a different random value of the constant n_0 which is proportional to the number of boulders on the surface [2].

In Figure 1 we show the evolution of the obliquity and rotation rate of a single small asteroid under the effects of NYORP and TYORP. In Figure 2 we illustrate the evolution in semimajor axis of a sample of fragments of the family for different ranges of values of the TYORP coefficient n_0. The higher dispersion for lower values of n_0 is due to the trapping of some members in obliquity equilibrium state where the Yarkovsky driven migration is faster. For stronger TYORP these equilibrium states are altered and the family appears more compact.

3. Summary and Conclusions

The next stage of the modeling consists in the inclusion of collisions with background asteroids which should reset the YORP obliquity evolution due to 1) a impulsive change in the spin vector and then in the YORP state 2) a variation of the shape and boulder surface distribution. Both these effects put the body on a different NYORP+TYORP track. It will be possible in this way to test how the family distribution changes in the semimajor axis vs. eccentricity distribution.

The results of the complete modelling, on different sysnthetic families, will be presented at the meeting.

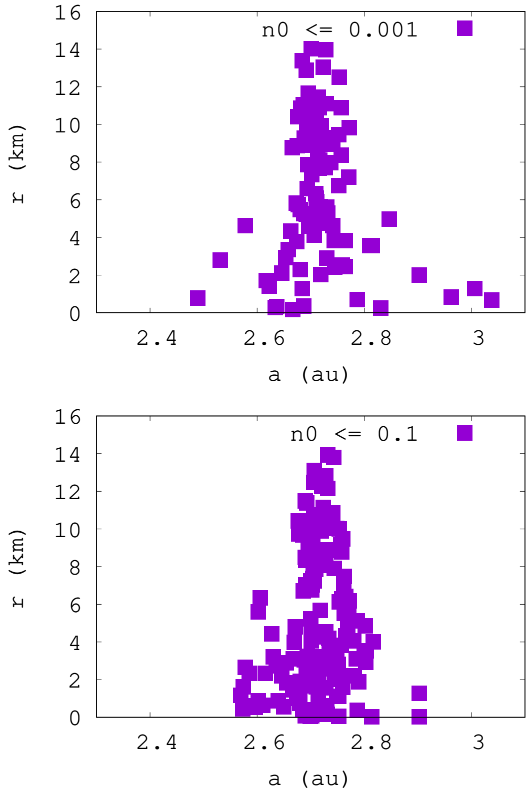

Figure 2: Evolution of a subsample of family members under NYORP+TYORP. In the upper case the coefficient n_0 is randomly selected from values lower than 0.001 while in the bottom case from values lower than 0.1.

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