2016 GE1: AN EXTREME EXAMPLE OF SUPER-FAST ROTATOR WITH VERY LOW THERMAL INERTIA.

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Introduction: Near-Earth asteroids (NEAs) pose a significant threat to people and infrastructure, because they could impact our planet. On the other hand, NEAs carry key information for understanding the formation of planets and the early conditions of the Solar System. Internal and surface properties of NEAs need to be determined to assess their potential threat, to evaluate the effectiveness of an eventual mitigation strategy, and for the design of lander and sample-return missions. However, physical properties are not easy to determine, and often they can be inferred only from space-born observations or from in-situ spacecraft visits.

Despite the level of detail obtained through this kind of data, space-born observations can be performed only for a limited number of asteroids, especially for the case of spacecraft visits. On the other hand, surface properties and internal composition of asteroids are very diverse, and knowledge derived from a limited number of objects typically can not be safely applied to a large number of objects. For these reasons, an alternative approach that permits to constrain critical parameters (such as diameter, density, and surface thermal inertia) for a large number of NEAs would still provide a significant scientific return.

In [1], we developed a preliminary method for the determination of physical properties of NEAs, that uses only ground-based observations. Small and super-fast rotators are particularly interesting objects, because little is known about their surface and internal structure. In [1], we found an unexpectedly low thermal inertia for 2011 PT, an asteroid rotating in only 11 minutes. In this abstract, we present the results obtained for 2016 GE1, an extreme case of small and super-fast rotator.

Methods: The Yarkovsky effect is a thermal recoil force due to solar radiation that causes a drift in semi-major axis, and today it is commonly measured from astrometric observations [2]. On the other hand, the semi-major axis drift depends on several orbital and physical properties, and mathematical models can be used to estimate its magnitude [3]. Our Monte Carlo-like method to constrain NEAs physical parameters is based on the comparison between the measured and the model-predicted Yarkovsky effect.

Input parameters of the Yarkovsky model are treated as follows. The rotation period P and the Yarkovsky drift $(\mathrm{d}a/\mathrm{d}t)_\mathrm{m}$ are assumed to be measured, and their error to be normally distributed. Density and diameter are usually unknown, and they are modeled by using general NEAs population models. To this purpose, a distribution of the albedo p_V is first produced by using the models by [4] and [5]. Assuming that p_V gives an indication on the composition, the albedo is converted into a distribution of density ρ. Additionally, by using the absolute magnitude H measurements, the albedo is converted into a distribution of diameter D. The obliquity γ can be either estimated from observations, or modeled with a population distribution [6]. Finally, the semi-major axis a, the eccentricity e, and the heat capacity C are fixed to nominal values. Once the input distributions are defined, the modeled vs. observed Yarkovsky drift equation

$$\left(\frac{\mathrm{d}a}{\mathrm{d}t}\right)(a,\, e,\, D,\, \rho,\, K,\, C,\, \gamma,\, P) = \left(\frac{\mathrm{d}a}{\mathrm{d}t}\right)_\mathrm{m}$$

is solved for K over a set of randomly sampled input parameters, where the left hand side of the equation is a computed through a semi-analytical Yarkovsky model that takes into account the effect of the eccentricity. Then, the thermal inertia is computed as $\Gamma = \sqrt{\rho K C}$, and a probability density function (PDF) is reconstructed.

Results: 2016 GE1 is a faint (H = 26.7 mag) NEO with semi-major axis a = 2.0613 au, eccentricity e = 0.5203, and inclination i = 10.727 deg. It is an extreme case of small super-fast rotator, since the estimated rotation period extracted from the lightcurve is of only 33 s. It is also affected by a large Yarkovsky drift of $(\mathrm{d}a/\mathrm{d}t)_\mathrm{m} = -0.0583\pm0.0178$ au My^{-1}, reported in the JPL Small Body Database. By applying our Monte Carlo method of thermal inertia estimation to this object, we obtained a bi-modal distribution of Γ (see Fig. 1), with two most likely values at around 2 and 18 J m^{-2} K^{-1} s$^{-1/2}$. Overall, we obtained a probability of 0.99 for Γ to be smaller than 100 J m^{-2} K^{-1} s$^{-1/2}$. Additionally, our method permitted to get estimations of the density ρ, and the diameter D (see Fig. 1).

We constrained the diameter D to values between 5 m and 20 m, with a most likely value of about 12 m. The median value of the density distribution is at 1346 kg m^{-3}, with a most likely value at 1020 kg m^{-3}. The extremely low thermal inertia, coupled with a density comparable to very porous carbonaceous asteroids [7], are an indication that this extreme super-fast rotator could be a pubble-pile.

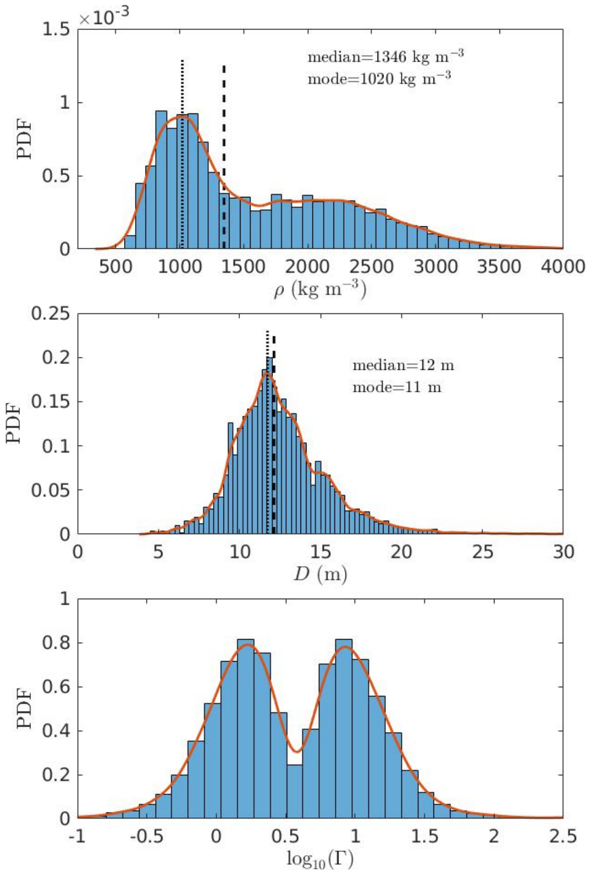

Fig. 1 Distribution of density (top panel), diameter (central panel), and thermal inertia (bottom panel) of 2016 GE1.

Summary and conclusions. We determined physical and thermal properties of the super-fast rotator 2016 GE1. We found a diameter of about 12 m, a density comparable to that of porous carbonaceous asteroids, and we constrained the thermal inertia to values smaller than 100 J m^{-2} K^{-1} $s^{-1/2}$ with 0.99 probability. The most likely values of thermal inertia are at 2 and 18 J m^{-2} K^{-1} $s^{-1/2}$, that are both unexpectedly low for a super-fast rotator. These results are an indication that 2016 GE1 has a rubble-pile internal structure.

Low thermal inertia solutions have been found already for the super-fast rotator 2011 PT [1]. Preliminary observations suggest similar results for 1998 KY26 [8], the target of the extended Hayabusa2 mission, that could be confirmed by new observations during the 2024 close approach. 2016 GE1 is an extreme example of super-fast rotator, and it is the one with the lowest thermal inertia found so far.

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