Planetary Society Step Grant project: Demystifying Near-Earth Asteroids

Bojan Novaković[1 [0000−0001−6349−6881]], Marco Fenucci[1,2 [0000−0002−7058−0413]], Dušan Marčeta[1 [0000−0003−4706−4602]], and Debora Pavela[1 [0000−0001−7008−4367]]

[1] University of Belgrade, Faculty of Mathematics, Department of Astronomy, Belgrade, Serbia bojan@math.rs
[2] ESA Near-Earth Objects Coordination Centre, Frascati (Roma), Italy

Abstract. Here we present the novel approach for characterizing the surface thermal properties of asteroids. The idea is based on the Yarkovsky effect, and the model relies predominantly on ground-based observations.

Keywords: solar system · asteroids · near-Earth objects.

1 Introduction

Knowledge of the physical and surface properties of most NEAs lags far behind the current rate of their discoveries. Still, asteroid surfaces and internal structures are very diverse, and knowledge derived from a limited number of asteroids typically could not be reliably extrapolated to a large number of objects. The Demystifying Near-Earth Asteroids (D-NEAs) is the Planetary Society STEP Grant 2021 project aiming to develop an alternative method to characterize surface thermal properties mainly from ground-based data.

2 Methodology

The idea is based on the Yarkovsky effect, a non-gravitational phenomenon that causes objects to undergo orbital semi-major axis drift. The effect joins the asteroid's orbital dynamics, composition, and physical properties. Our idea to derive the surface thermal properties of near-Earth objects is built around these facts. Theoretical models of the Yarkovsky effect allow predicting the semi-major axis drift, assuming a set of input parameters is available. On the other hand, astrometric observations and orbit determination procedures allow detecting the asteroid's semi-major axis drift in motion. Therefore, at least one asteroid's property that determines the drift rate could be estimated by comparing the model's predicted da/dt and measured $(da/dt)_m$ magnitude of the effect, as given by Eq. 1:

$$\frac{da}{dt}(a, e, D, \rho, K, C, \gamma, P) = (\frac{da}{dt})_m \tag{1}$$

Especially critical are the thermal conductivity uncertainties that span a range of about four orders of magnitude [1]. It is also a key for thermal inertia estimation, which is diagnostic of surface porosity and cohesion.

3 Results

The first results obtained by Fenucci et al. [2] are encouraging but also intriguing at the same time. As shown in Fig. 1, a small super-fast rotator, near-Earth asteroid (499998) 2011 PT, is characterized by the very low thermal conductivity K, which is highly unexpected for such bodies.

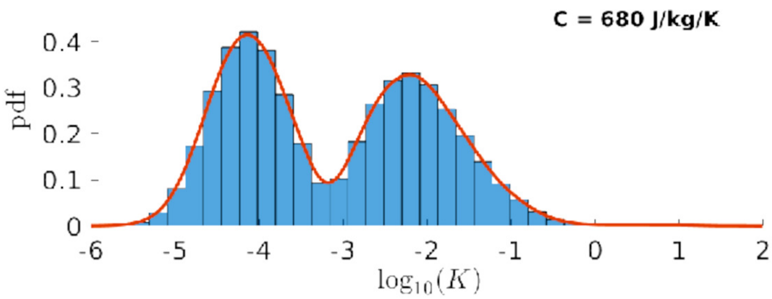

Fig. 1. The thermal conductivity K probability distribution for asteroid 2011 PT, obtained with our Monte Carlo model.

4 Perspectives

This exciting result opens the possibility for further studies. There are, however, several essential features that are not included in the preliminary model. To fully exploit the potential of our approach, it is necessary to extend the model by including, for instance, Yarkovsky correction for eccentric orbits, heterogeneity in object density, or variable thermal inertia along the orbit [3]. The model incorporating all these features is underdevelopment within the D-NEAs project. It should ensure a more robust model, applicable to many asteroids.

Acknowledgements We appreciate support from a Planetary Society STEP Grant, made possible by the generosity of The Planetary Society' members..

References

1. Delbo, M., Mueller, M., Emery, J. P., Rozitis, B., Capria, M. T.: Asteroid Thermophysical Modeling. In: Asteroids IV, pp. 107–128. University of Arizona Press, Tucson (2015)
2. Fenucci, M., Novaković, B., Vokrouhlický, D., Weryk, R.: Low thermal conductivity of the superfast rotator (499998) 2011 PT. Astronomy and Astrophysics **647**, A61 (2021)
3. Rozitis, B., Green, S. F., MacLennan, E., Emery, J. P.: Observing the variation of asteroid thermal inertia with heliocentric distance. MNRAS **477**, 1782–1802 (2018)