Astrometry, orbit determination, and thermal inertia of the Tianwen-2 target asteroid (469219) Kamo`oalewa

Kamo`oalewa is a small super-fast rotator with low thermal inertia

Background: The small near-Earth asteroid (469219) Kamo`oalewa is the most stable known Earth quasi-satellite. Lightcurve measurements revealed a rotation period of about 28 minutes (Sharkey et al. 2021), and VIS-NIR spectrum suggests a classification as S-type asteroid. Kamo`oalewa has been selected as the target of the sample-return Tianwen-2 mission by the China National Space Administration.

New observations and orbit determination

We imaged Kamo`oalewa in March 2024 from the **Loiano Station** (Italy) and the **Calar Alto Observatory** (Spain). We also re-measured precovery observations by the **Sloan Digital Sky Survey** (SDSS) from 2004.

We accurately computed the orbit of Kamo`oalewa with the ESA Aegis orbit determination software (Fenucci et al. 2024), and determined the **Yarkovsky effect** drift at $\dot{a} = (-67.3 \pm 4.7)\ \mathrm{au\ My^{-1}}$ with a SNR of 14.

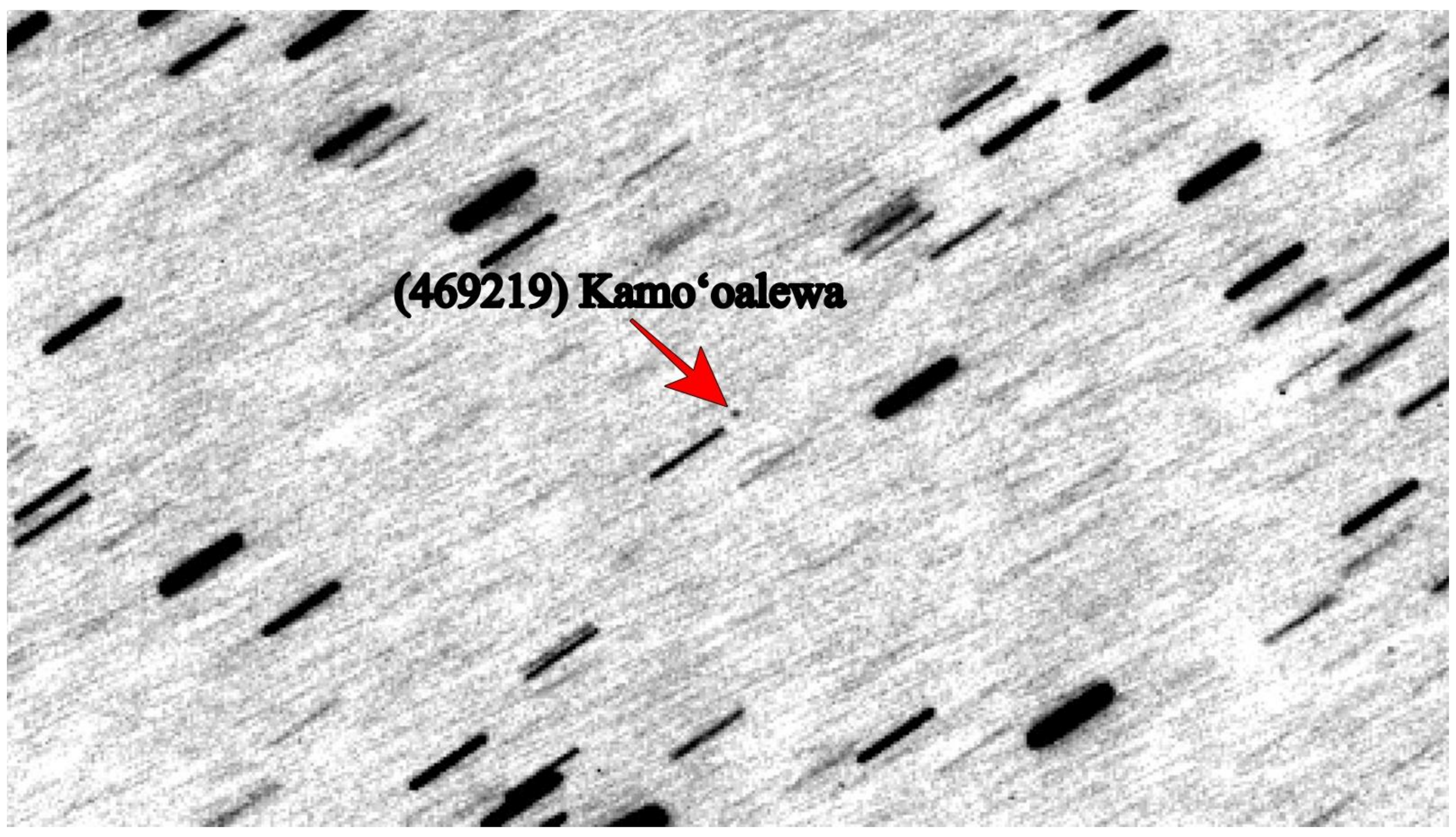

Fig 1 – Detection of (469219) Kamo`oalewa from the Loiano Station (MPC Code 598) on 2024-03-07.

ASTERIA method for thermal inertia estimation

Thermal inertia was estimated by using the **ASTERIA method** (Novaković et al. 2024), which is a Monte Carlo method based on the **measured vs. modelled Yarkovsky drift** equation. **Different models** of physical properties of Kamo`oalewa were used to compute the modelled Yarkovsky drift. Two scenarios for **albedo** and **obliquity** were chosen. The bulk density was set according to properties of S-type asteroids.

Parameter	Value	Reference
Absolute magnitude	24.28 ± 0.18	Estimated
Albedo	0.1 ± 0.03 / 0.24 ± 0.05	Assumed
Bulk Density	2720 ± 540 kg m^{-3}	Assumed
Rotation period	0.4716 ± 0.03 h	Sharkey et al. 2021
Obliquity	107 ± 10 deg / NEO population	Zhang et al. 2025

Tab 1 – Some of the physical parameters used for the modelling of Kamo`oalewa. The NEO population obliquity distribution is the one obtained by Tardioli et al. 2017.

Thermal inertia and grain size constraints

With the new determination of the Yarkovsky effect, we estimated the thermal inertia at a value of $\mathbf{150^{+90}_{-45}}$ **J m^{-2} K^{-1} s$^{-1/2}$**. The result is stable with respect to changes in the physical properties modelling. Regolith models based on LL chondrite analogues suggest that Kamo`oalewa may have surface regolith with size **between 0.1 and 3 mm**, with a maximum size of 3 cm.

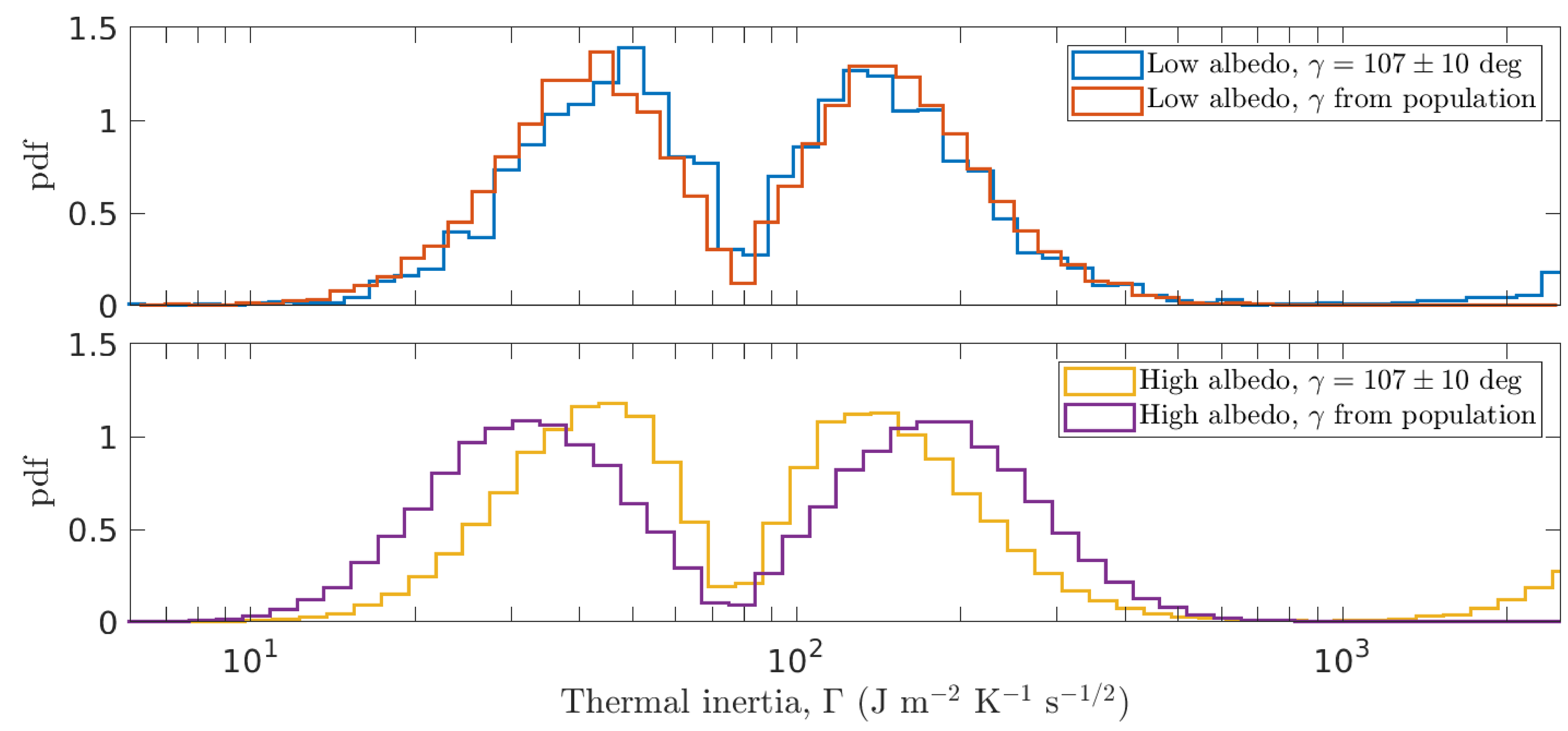

Fig 2 – Thermal inertia distribution of Kamo`oalewa estimated by ASTERIA, for different physical properties models. The top panel refers to results obtained with low albedo, while the bottom panel to those for high albedo. The bi-modal distribution is typical for the ASTERIA method. However, in this case the most likely thermal inertia is that corresponding to the second peak.

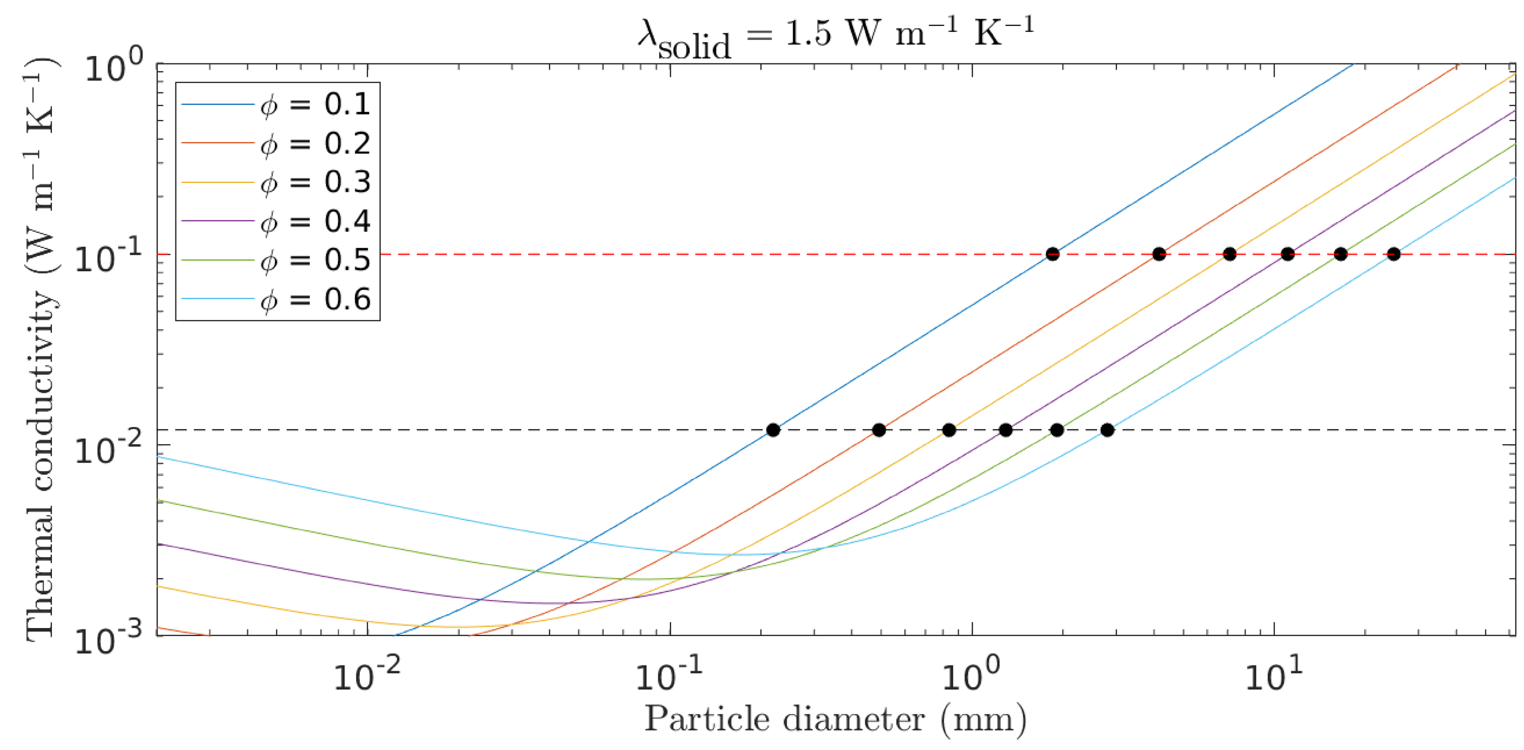

Fig 3 – Grain size estimation with the method by Gundlach & Blum (2013). Coloured curves are the values of thermal conductivity of a regolith model, for different filling factor values, as a function of the regolith size. The dashed black and red lines are the nominal and the upper thermal conductivity, respectively, as estimated by ASTERIA. Regolith size is estimated by the intersection of the coloured curves with the horizontal lines.

References

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Authors Information:

M. Fenucci[1], B. Novaković[2], P. Zhang[3], A. Carbognani[4], L. Faggioli[1], F. Gianotto[1], F. Ocaña[5], D. Föhring[1], J. L. Cano[6], L. Conversi[1], R. Moissl[1]

[1] Planetary Defence Office, NEO Coordination Centre, ESA/ESRIN, Largo Galileo Galilei, 1, 00044 Frascati (RM), Italy
[2] Department of Astronomy, Faculty of Mathematics, University of Belgrade, Studentski trg 16, Belgrade 11000, Serbia
[3] Center for Lunar and Planetary Sciences, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang (Guizhou), PR China
[4] INAF – Osservatorio di Astrofisica e Scienza dello Spazio, Via Gobetti, 93/3, 40129 Bologna, Italy
[5] Planetary Defence Office, ESA/ESAC, Bajo del Castillo s/n, 28692 Villafranca del Castillo, Madrid, Spain
[6] Planetary Defence Office, ESA/ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt, Germany

Presenter email: marco.fenucci@ext.esa.int