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Physical Characterization of Potentially Hazardous Asteroid (1566) Icarus

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A critical component of planetary defense is accurately assessing the size and surface properties of potentially hazardous asteroids and impactors. Observations and modeling of an asteroid's thermal emission, which depends on its surface temperatures, lead to a direct size determination [1]. Characterizing surface properties such as thermal inertia and roughness provides insights into regolith cohesion (surface strength) and internal structure (bulk density) [2]. Low thermal inertia values indicate surfaces that are dominated by finer particles, whereas higher thermal inertias suggest a higher fraction of boulders [3].

Characterization of surface properties lends to accurate modeling of the surface temperature distribution, which depends on several factors. Key factors include the asteroid's shape and spin parameters. Thermophysical models (TPMs) calculate surface temperatures based on shape and spin parameters, incorporating subsurface heat conduction and small-scale topographic effects (i.e., roughness) that cause shadowing and self-heating effects that influence the surface temperatures [4]. When the asteroid's visual brightness is measured or estimated, its albedo can also be derived with the size calculated from infrared observations. Depending on the data quality and observing geometry, the thermal inertia and surface roughness can be constrained to some degree.

We present preliminary results for the shape, size, and thermal inertia of the potentially hazardous near-Earth asteroid (1566) Icarus. Lightcurve inversion modeling gives a top-spin shape that is characteristic of fast rotators [5]. Discovered in 1949, Icarus is rarely observed due to its small size and orbital

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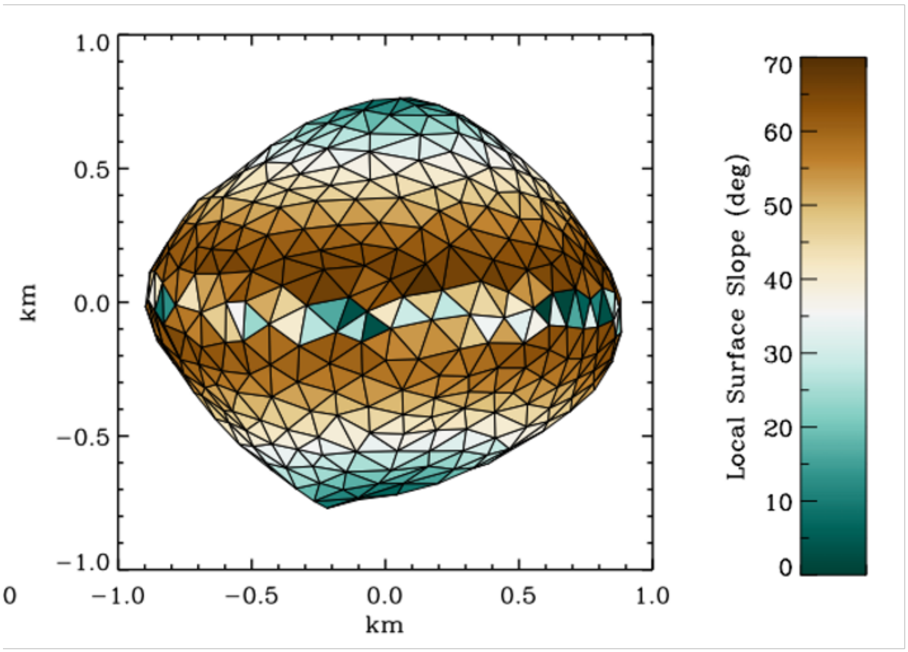

Figure 1: Effective gravitational slopes calculated using a rotation period of 2.12 hr, a bulk density of $\rho_{bulk} = 2280$ kg m^{-3}, and size of 1.5 km.

configuration, which results in close Earth approaches only every 9, 19, or 28 years. Ground-based radar observations in 2015 [6] resulted in an orbital drift measurement as a result of the Yarkovsky Effect [7]. We incorporate this measurement into our shape and thermophysical modeling of thermal observations to constrain Icarus's bulk density ($\rho_{bulk} = 2280^{+180}_{-150}$ kg m^{-3}). From these parameters, we model its surface gravitational slopes shown in Figure 1. Larger surface slopes found near the equatorial region are more susceptible to landslides and mass ejection [8].

Using the MIRSI instrument at NASA's Infrared Telescope Facility we obtained new thermal infrared observations in June 2024 when Icarus approached Earth to within 0.21 au. Even at this close distance the total thermal emission was too weak to be detected from individual, sky-subtracted MIRSI frames. But the optical brightness was sufficient at visible wavelengths allowing us to guide the telescope using the MIRSI Optical Camera. By employing blind stacking of frames acquired over several hours on three separate nights, we were able to detect and measure its thermal emission at 10-μm. Using a TPM along with pre-existing shape and spin parameters, we estimate the asteroid's size and surface thermophysical properties. We also obtained simultaneous absolute optical photometry with the IRTF's Opihi telescope/camera, enabling lightcurve observations that will be used to refine the shape model.

Comments:

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