THERMOPHYSICAL MODELING FOR BINARY ASTEROIDS AND APPLICATION TO DIDYMOS.
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Introduction: Thermophysical models are widely used to support the thermal observations in order to obtain physical properties of asteroids [1]. Observations from infrared ground-based telescopes and measurements from infrared cameras on-board spacecraft can be used in combination with numerical simulations to derive the physical properties of asteroids, such as density, conductivity, surface emissivity, grain size, but also their shape, and spin axis. (65803) Didymos is a binary system of asteroid. The main body Didymos is ~800m in diameter and the moon Dimorphos ~160m [2]. The secondary was orbiting the primary in ~12hours before the kinetic impact of the DART spacecraft which occured on the 26 September 2022 [3]. The Hera mission will rendez-vous with Didymos in 2026 [2]. Binary asteroids are particularly interesting celestial objects to study for their formation and further understanding of the formation of the Earth. Individual components from both bodies may have different physical properties and their interaction can affect the overall thermophysical characteristics of the system.

Thermophysical Model: The current state of the simulator developed at the Royal Observatory of Belgium supports the thermophysical modeling of binary asteroids. The one-dimensional heat transfer equation is numerically solved for each surface element of both asteroids. Ground fluxes are transferred until a certain depth where an adiabatic condition is assumed. Shadows are computed using the shape models which creates two mutual events: the primary and secondary eclipses. The solar flux is considered as the main source of heating. Mutual heating is implemented to simulate the interaction between the two bodies of the binary system. Self heating between the facets of a single body is also implemented for cratering and rough surface.

Results: We have simulated the surface temperature of the binary system of asteroids Didymos and Dimorphos over the period of close proximity operations of the Hera spacecraft in 2027. All orbital parameters, physical properties and shape models were taken as the one assumed before the impact of DART using ground-based observations. For the parameters we considered a thermal inertia of 500 J/m^2/s$^{1/2}$/K, ground density of 2146 kg/m^3, heat capacity of 600 J/K/kg, bond albedo of 0.1 and emissivity of 0.9. The highest temperature is expected at the sub-solar latitude which depends on orbital conditions of the asteroid. If the obliquity of the spin axis is zero, it is on the equator. The top panel of figure 1 shows the heliocentric distance and sub-solar latitude variation with time. Between February-July 2027 the change of surface temperature can be up to 100K. The bottom panel shows a drop of 80K in temperature resulting from Didymos eclipsing Dimorphos from the Sun for about 1 hour and 10 minutes (the mutual event is called secondary eclipse). Figure 2 shows the surface temperature of the binary system in a scene rendered in 3D and projected in 2D. Clear changes in temperature can be observed around the secondary and primary eclipses. The primary eclipse is visible in panels C6&7 at longitude/latitude ~0°/-40°.

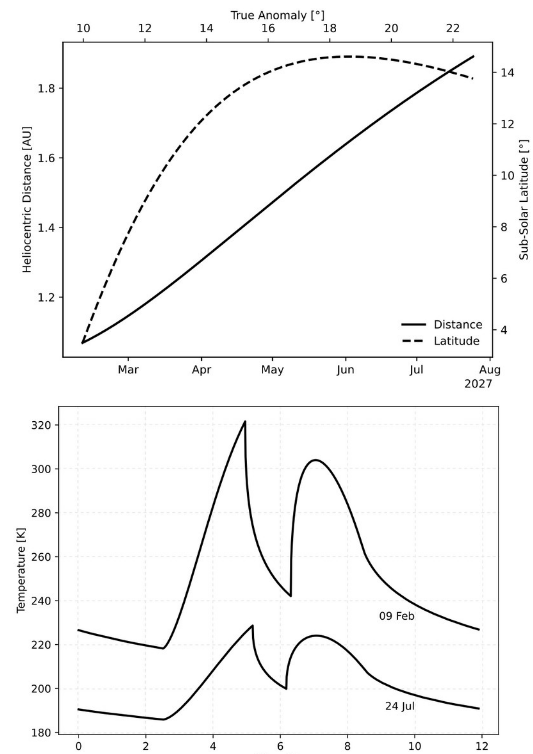

Figure 1: Top panel: Evolution of the heliocentric distance and sub-solar latitude of Dimorphos from February 9th to July 24th 2027. Bottom panel: Dimorphos equator daily surface temperature on the February 9th and July 24th 2027.

Further work: The next study will be focused in preparation for the Hera mission rendez-vous with Didymos on applying the model on the recent orbital properties and shape models of Didymos and

Dimorphos that were derived after the DART spacecraft kinetic impact and imaging from its framing camera DRACO and the cubesat LICIACube. For this exercise, ground roughness will be investigated further as well as three-dimensional heat transfer using finite element method.

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References: [1] M. Delbo et al. (2015) Asteroid IV. [2] P. Michel et al. (2022) *PSJ, 3:160*. [3] R.T. Daly et al. (2023) Nature, in revision.

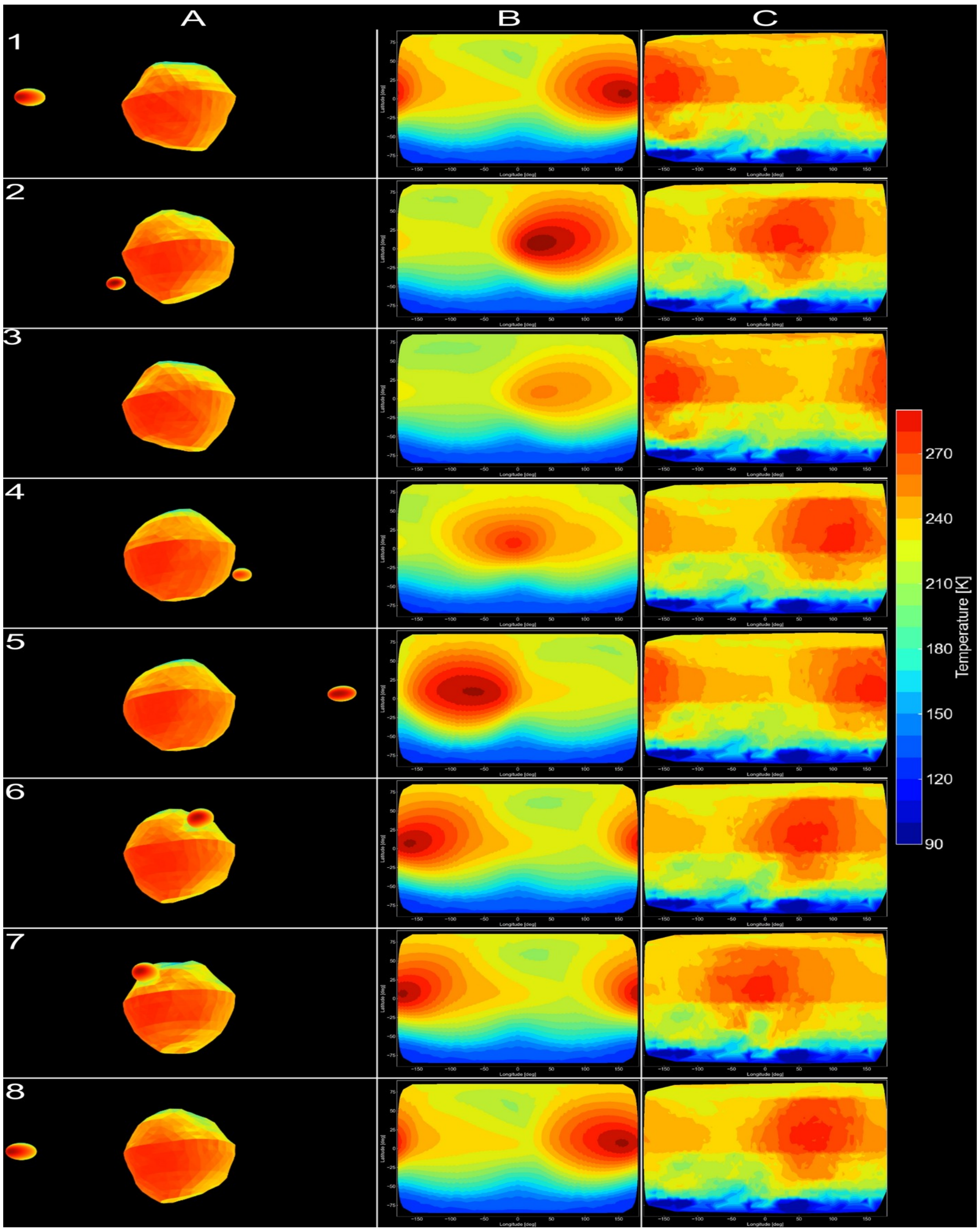

Figure 2: Evolution of the surface temperature of Didymos (C) and Dimorphos (B) over a full rotation of the moon around the primary. In this simulation, Dimorphos is assumed synchronously locked, thus also covers a full day of Dimorphos. The first column of panels (A) shows the binary system with the Sun behind the observer, Dimorphos orbiting around Didymos and both asteroids spinning around their rotation axis.