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Asteroid spin properties derived from thermal data

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Abstract

Multiple optical lightcurves of asteroids are widely used to derive the object's shape and spin properties via standard lightcurve inversion methods. Thermal measurements are key ingredients for radiometric methods to derive size, albedo, and thermal properties of a given asteroid. However, thermal infrared data also contain crucial information about the object's spin properties. Depending on the amount of available thermal data and their quality, one can determine the object's sense of rotation or even constrain the spin-axis orientation. The thermal data also allow to verify shape solutions, and in some cases it is also possible to improve shape solutions. This is important for objects where the lightcurve inversion is ambiguous or fails completely. We present our methods and discuss possibilities and limitations of the new approach.

1. Introduction

Thermal infrared measurements typically comprise individual photometric points, sometimes multi-filter measurements (like from IRAS, AKARI or WISE), and only in very rare cases thermal ligthcurves coming from Spitzer or Herschel. These data are widely used to determine the size and albedo of small bodies via radiometric techniques. It is also possible to constrain the object's thermal properties and estimate surface roughness properties or even grain size distributions ([1] and references therein). However, in cases where thermal observations cover different aspect angles - preferentially also different phase angles and wavelengths - it is also possible to constrain the object's spin properties from thermal data alone (e.g., [8, 6]). A new method by Ďurech et al. [2] even allows to combine optical and thermal data to constrain multiple object properties simultaneously (see results on Ryugu by [11]). The combined approach is still difficult since it requires a careful weighting of data and a profund knowledge of the information content of a given (optical or thermal) data set. Here, we go one step back to look at the possibilities and limitations of radiometric techniques in the context of constraining the object's spin properties.

2. Applications

We use all available thermal data for a given object to find out if the object's spin properties can be identified. The combined data are analysed via a powerful thermophysical model code [3, 4, 5].

First, we look at a sample of large and well-known main-belt asteroids which only have a few thermal data points typically from the survey missions IRAS, AKARI, MSX and/or WISE, but only very few targeted thermal measurements from ground or space. For these poorly observed objects (at thermal wavelengths), our method allows to estimate at least the sense of rotation. We compare our results with the true spin properties as listed in the DAMIT database[1].

Other cases, like Bennu [8], Itokawa [10] and Ryugu [11], and also a few main-belt asteroid, have many more thermal data, covering different aspect angles, phase angles, and wavelengths. Here, the thermal data can put very strong constraints on the actual spin-axis orientation.

And even for Centaurs and trans-Neptunian objects it is often possible to distinguish between objects seen pole-on from objects seen equator-on. The thermal measurements in those cases are coming either from Herschel and/or Spitzer, for some near Centaurs also from WISE.

The comparison with "ground truth" - whenever available - shows the large scientific potential of thermal data in the context of asteroid spin properties. But

[1] http://astro.troja.mff.cuni.cz/projects/asteroids3D

it is important to understand the spin information content imprinted in thermal data before one can use them in a more general application where all available optical and thermal data are combined. For the full exploitation it is necessary to understand the wavelength, phase-angle and aspect-angle related effects, and to have a deeper understanding of the relative and absolute errors of a given measurement. We'll present our results and discuss the possiblities and limitations of the different approaches.

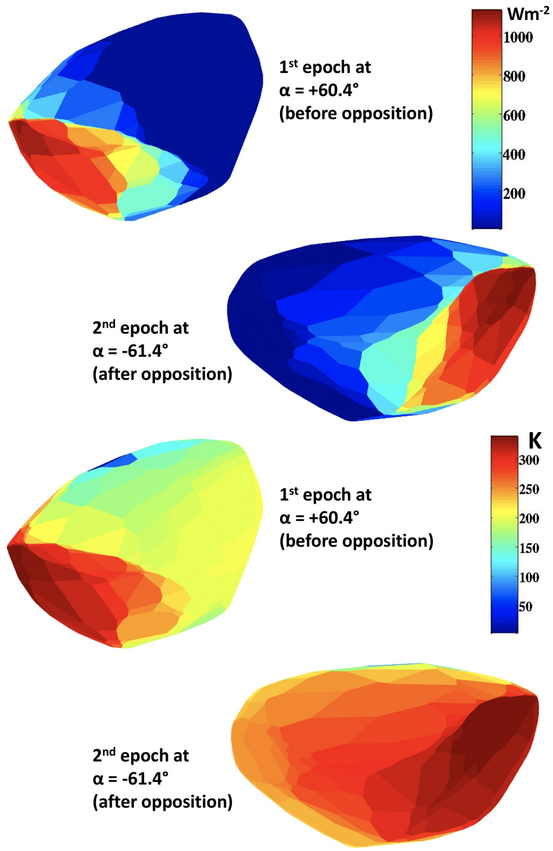

Figure 1: Top: The two figures show the insolation for the NEA 99942 Apophis before (left) and after (right) opposition, almost at exactly the same phase angles of around 61°. Bottom: The corresponding surface thermal pictures are very different, caused by the combined spin and thermal inertia properties. This example shows that thermal measurements contain information about the sense of rotation and in some cases can also constrain the spin-axis orientation. Figures adapted from [9].

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