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Thermal properties of slowly rotating asteroids

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Abstract

Thermal properties of asteroids: thermal inertia, size, albedo, and surface roughnes require physical properties like spin axis position, rotation period and shape to be known before they can be determined. We focus on slowly rotating main belt asteroids to decrease selection effects in their spin and shape properties, but also in thermal inertia values, which are largely missing for slow rotators. Using multi-mission infrared data we apply our models from lightcurve inversion in the thermophysical modelling process. As a result we obtain scaled shape models with thermal properties determined. We find both large and small values of thermal inertia, what indicates distinct properties of surface regolith.

1. Selection effects

1.1. Spins and shapes

Slowly rotating asteroids (P > 12 hours) are challenging in spin and shape modelling, requiring large amounts of observing time in order to register their full optical lightcurves, especially when slow rotation is coupled with small amplitude of brightness variations. As a result the sample of spin and shape modelled asteroids is now dominated by short-period and large-amplitude targets - those with elongated shapes and extreme values of spin axis obliquity [9].

This bias might influence studies of e.g. evolution of asteroids under Yarkovski and YORP effects [12], [5], or the outcomes of impacting events [11].

1.2. Thermal properties

This selection effect also propagates to studies of asteroid thermal properties, which cannot be reliably determined without precise spin and shape models. Our recent study has shown that combining data from a network of ground based observatories with data from infrared space telescopes (mainly from IRAS, AKARI, and WISE) has a huge potential in asteroid physical studies, providing detailed shape models with absolute size scales, albedos and thermal inertia values [10]. Such thermophysical models have been obtained for around 200 of asteroids so far, and among them only a small fraction rotate slowly [2], [6].

It has not been much investigated yet if thermal inertia of very slow rotators can ever be determined. Relatively small distance between sub-solar point and the warmest, afternoon part of the asteroid surface might challenge such determinations. On the other hand, if it can (and we found that true in most studied cases), then it should contain information on the material properties of deeper, sub-regolith layers of the surface [7]. This way the density and thermal conductivity of such layers, and also regolith grain size and packaging tied to the surface roughness can be studied [4].

2. Results

Our photometric observing campaign resulted in a substantial number of spin and shape models of slowly rotating asteroids based on dense lightcurves. To create the models we used convex inversion method [8] and in some cases also non-convex SAGE algorithm [1]. We then applied thermophysical models (e.g.[2]) to determine their sizes and albedos, with thermal inertia and indication of the level of surface roughness. It is worth noting that internally consistent good fits were simultaneously obtained for data from a few different infrared space observatories, giving more confidence to our results. One example is shown in Fig. 1

In a few cases a mirror pole symmetry was broken, as one of two solutions for the pole gave clearly better fit to thermal data. Found thermal inertia values are often large (up to 125 SI units), as expected. Sizes of main belt targets in our sample range from 20 to 130 km. So far mostly relatively large Γ values have been observed in this size range [2].

However in some cases Γ values that we found are surprisingly small (around 10 SI units), indicating a fine, mature regolith on their surfaces. Alternatively,

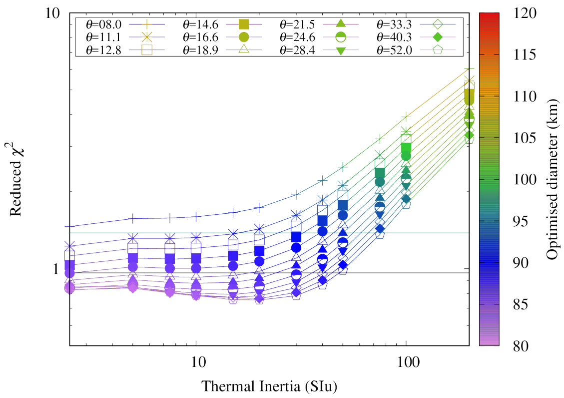

Figure 1: χ_2 plots versus thermal inertia values for asteroid 195 Eurykleia (P=16.52179 h). The different surface roughness levels are shown with different point types, and the best-fitting diameter for each model is coded in the colour palette. The horizontal lines mark the 1-sigma (lower) and 3-sigma (upper) limits below which models can be considered to fit the data acceptably.

small thermal inertia might be an indicator of colder temperatures of deeper subsurface layers, to which a heat wave can penetrate in case of long-period targets, provided the density does not change with depth [3].

3. Summary and Conclusions

By studying slow rotators we are filling the gaps in a few areas of asteroid physics. We debias the set of known spin and shape parameters, providing precise models based on dense lightcurves for targets that cannot be studied otherwise (e.g. where available sparse data from large surveys are often insufficient). This way we also provide largely missing type of targets for thermophysical modelling, and find a wide range of thermal inertias, indicating large differences of the regolith type on the surface or in subsurface material properties. In the near future we are going to verify various hypotheses concerning thermal inertia dependence on the rotation period, by studying more targets with periods longer than 20 hours.

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