Peculiar Betulia Re-visited: Checking thermal models of asteroids

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Harris, Mueller, Delbó, Bus, 2005, *Icarus*, in press.

This is a modified version of a talk given at the 37th mtg. of the DPS.

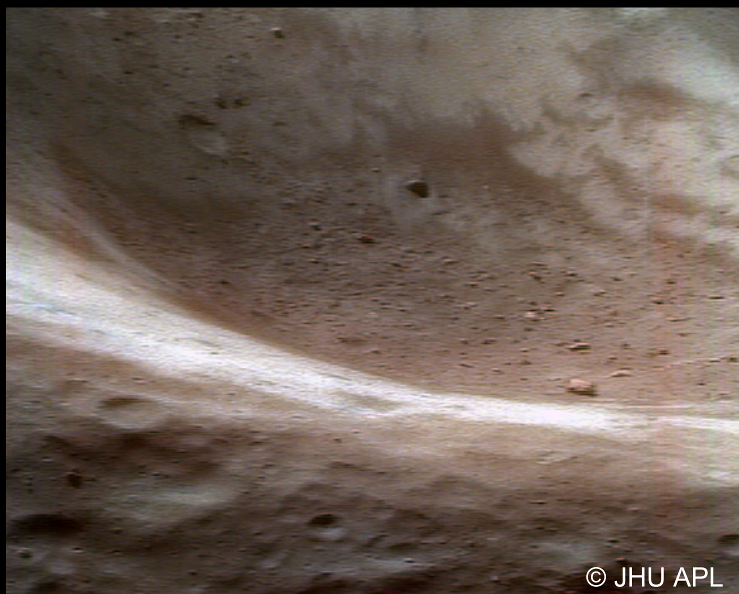
1580 Betulia

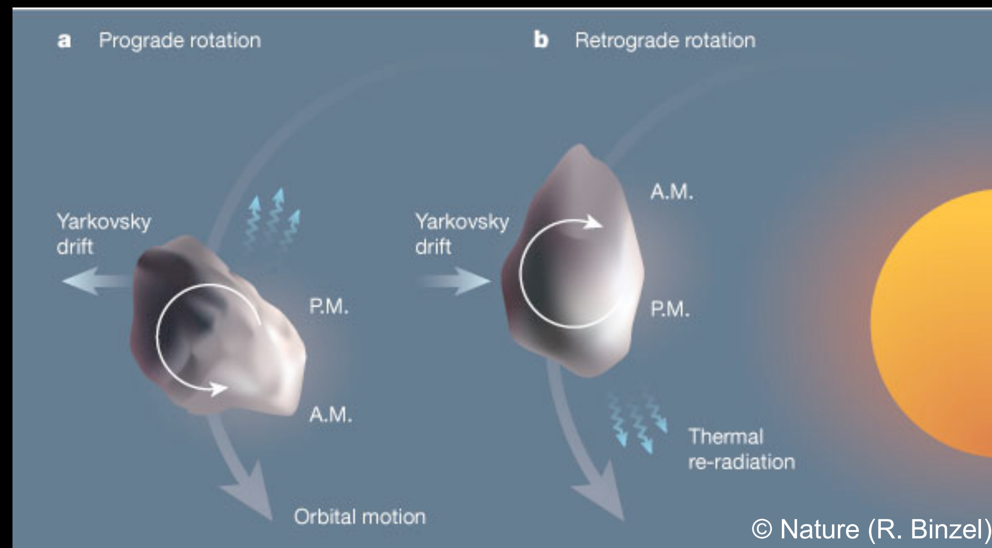
1580 Betulia is C-type near-Earth object (Amor)

Is Betulia peculiar?

- Lightcurve changes dramatically with solar phase angle, indicative of a highly irregular shape and/or unusual topographic features (important for models and data interpretation!).
- First asteroid for which thermal-IR observations (Lebofsky *et al*. 1978) apparently indicated surface of very high thermal inertia, consistent with bare rock.
- But recent observations indicate similarly sized asteroids have regolith. No convincing evidence yet for other bare-rock asteroids. Is Betulia unique or is the high thermal inertia an artifact of the thermal modeling?

Why is it Important to Know about the Surface Properties of Small Asteroids?





Knowledge of regolith coverage important for studies of spectral properties, space weathering, design of lander missions.

Knowledge of thermal inertia important for studies of Yarkovsky and YORP effects, which influence orbital evolution (e.g. of PHAs) and spin vectors.

Observations and Data Analysis

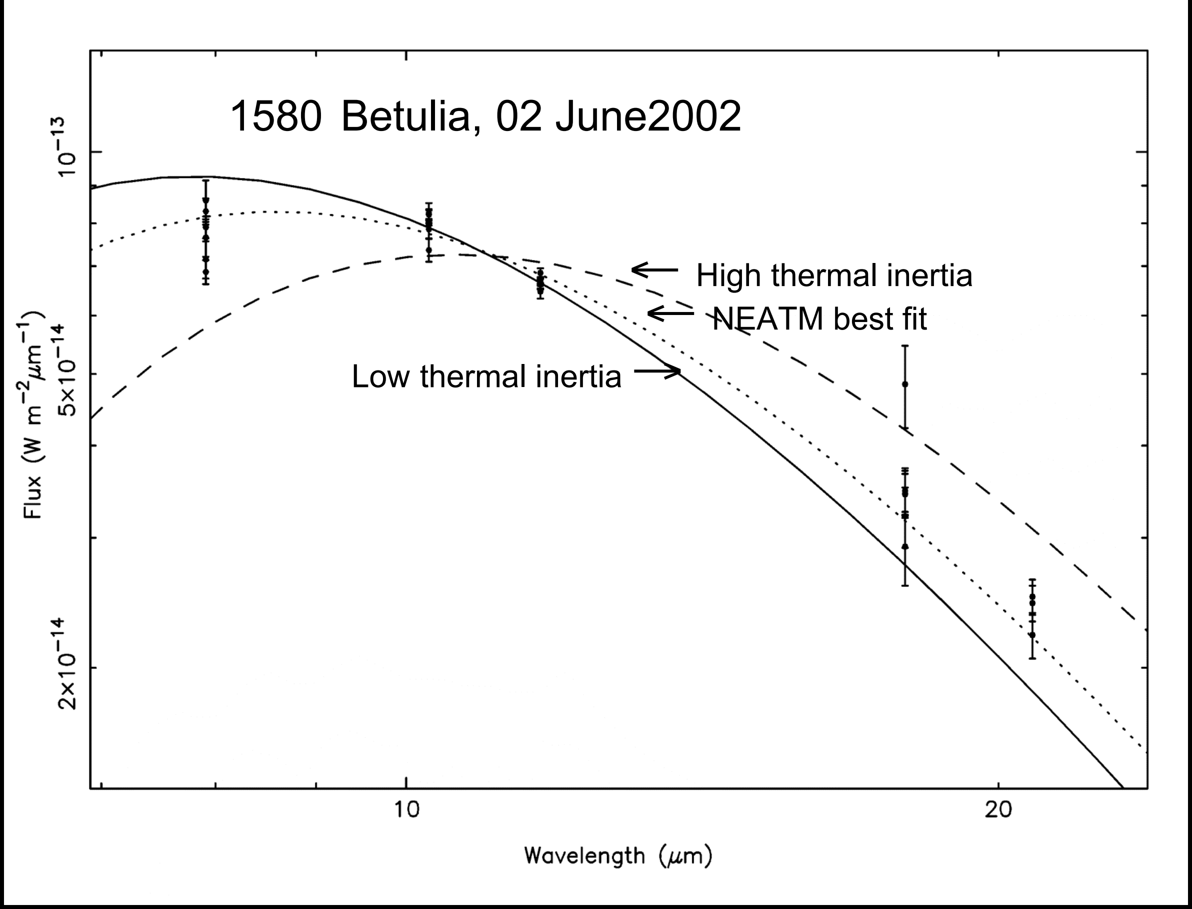
- Harris, Mueller, Delbó, Bus, 2005, *Icarus*, in press:
  - 3-m IRTF observations at 5 wavelengths between 8 and 20 µm.
  - Thermophysical model and NEATM used.
  - Models give D_{eff} of 3.8-4.6 km.
  - Derived intermediate thermal inertia => has regolith.

- Compare to Lebofsky *et al*. 1978:
  - 0.7 m Mt. Lemmon; observations at 10.6 µm only.
  - Used two simple thermal models: zero thermal inertia and for very high thermal inertia (bare rock)
  - The high-thermal-inertia model gave diameter (7.4 km) consistent with radar and polarimetry.
  - Concluded Betulia has a surface of bare rock.

Near-Earth Asteroid Thermal Model (NEATM) Continuum Fit

Our NEATM fit to the complete set of light curve-corrected N- and Q-band data indicates Betulia has intermediate thermal inertia.

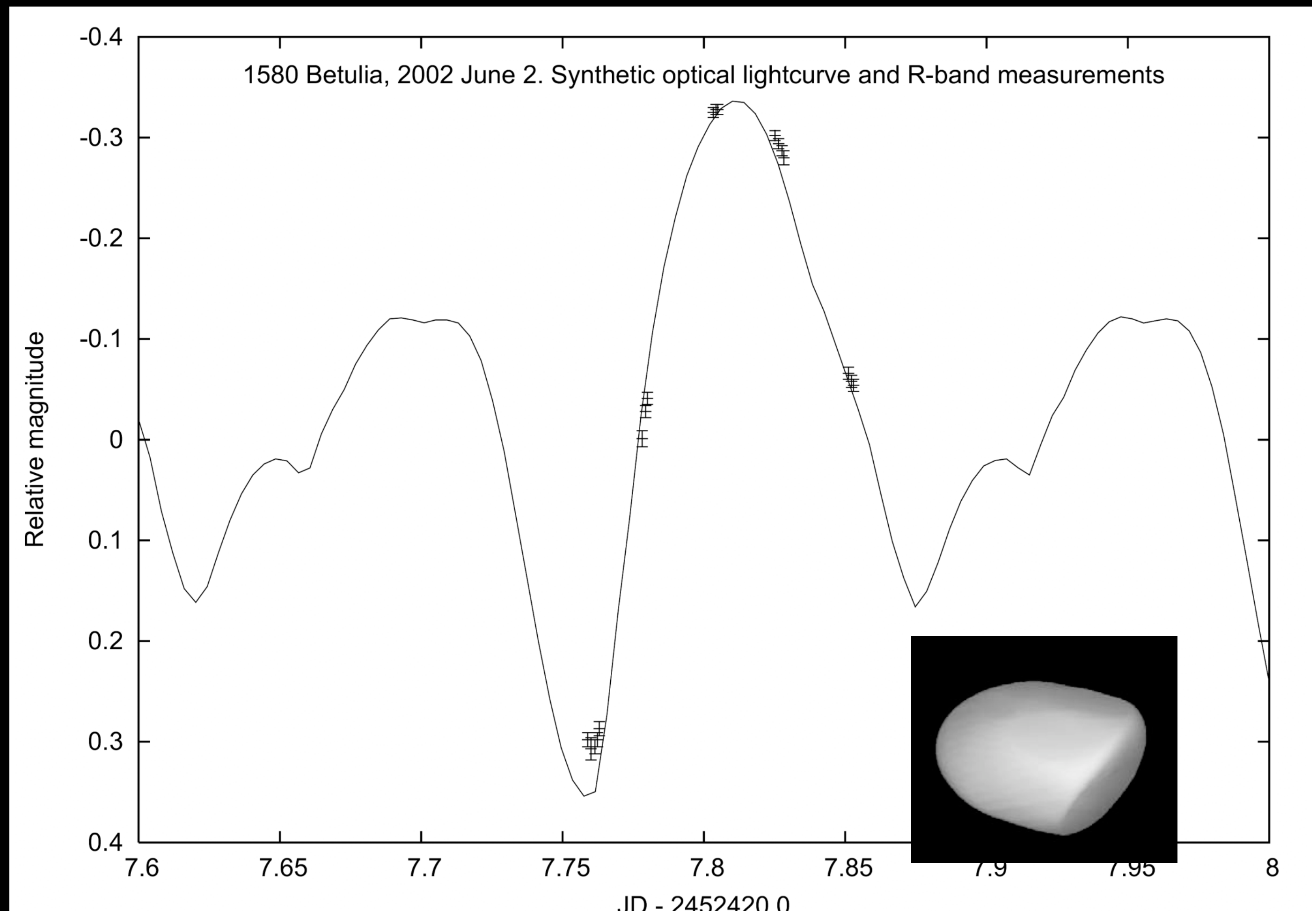
The high-thermal-inertia curve is a very poor fit to the data.



Shape Model

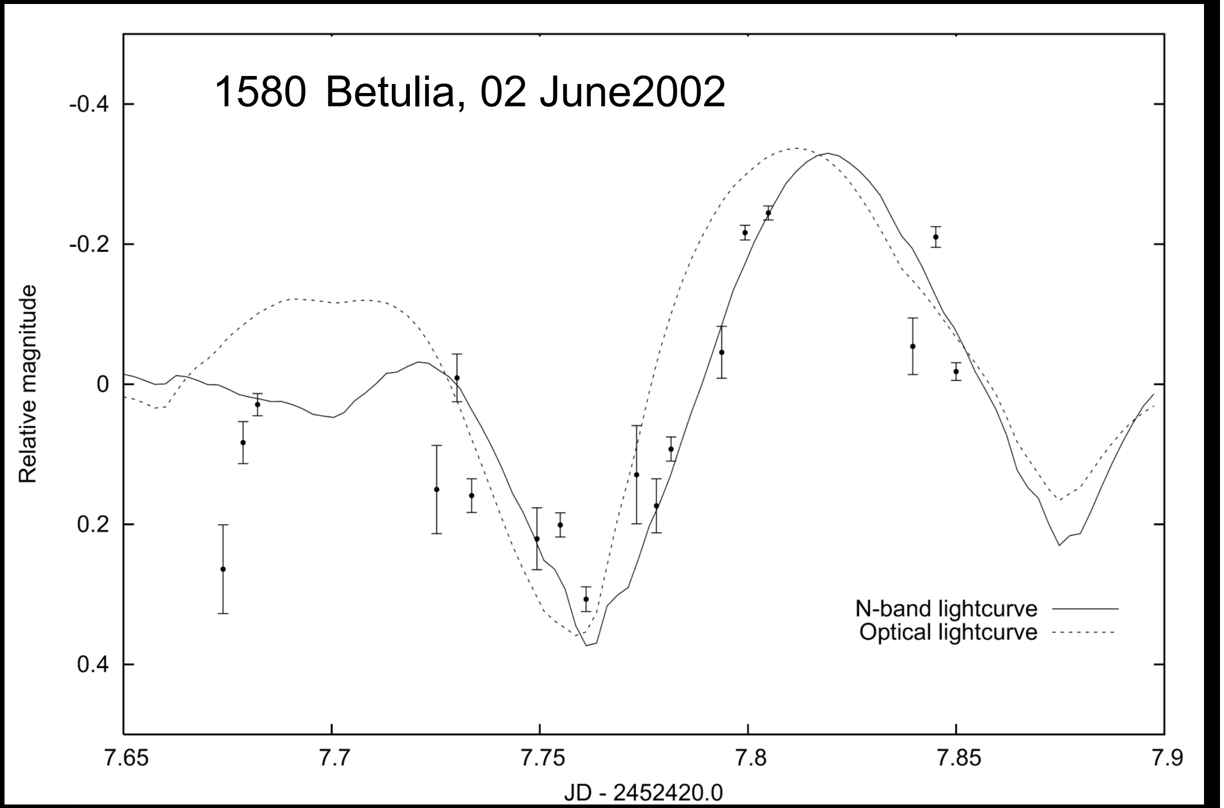
Synthetic optical light curve generated from the shape model compared to optical measurements.

The shape model forms the basis of the thermophysical model.



Thermophysical Model

- Requires shape model, knowledge of spin-axis orientation.
- Thermal inertia modeled by 1-D vertical heat diffusion algorithm.
- Surface roughness (cratering) modeled by hemispherical indentations.



Plotted points are the N-band data from the IRTF.

Results (from Thermophysical Model)

- D_{eff} = 4.6 ± 0.5 km, p_v = 0.08 ± 0.015
- Thermal inertia = ~180 $Jm^{-2}s^{-0.5} K^{-1}$
  - significantly larger than that of the Moon (50) but at least an order of magnitude below that of bare rock (~2500)
- Betulia is smaller than the earlier Lebofsky et al. models indicated and it has a significant thermally-insulating regolith.

These results are consistent with other work that indicate NEOs generally have moderate thermal inertias and surfaces largely covered in thermally insulating regolith or dust.

Summary

Observations of asteroids in the thermal infrared are the main source of information on their sizes, albedos, and thermal inertias. Knowledge of these parameters is crucial for many aspects of asteroid research, including size distribution and impact hazard of NEOs, the taxonomic composition of populations of asteroids, the physical properties of asteroid surfaces and regolith, and calculations of the Yarkovsky effect.

<u>The work presented here shows the importance of non-spherical shape models combined with more realistic assumptions of thermal inertia and surface roughness.</u>