THERMAL INERTIA OF ASTEROIDS FROM MULTI-EPOCH OBSERVATIONS BY WISE

Eric MacLennan[1,2], Josh Emery[1], David Trilling[2]

[1]*Department of Earth and Planetary Sciences, University of Tennessee* (emaclenn@utk.edu)

[2]*Department of Physics and Astronomy, Northern Arizona University*

INTRODUCTION

The ability of a material to resist changes in temperature is called the thermal inertia. Determination of this quantity can give clues as to the physical properties of the surface of an asteroid, such as composition and the presence of a regolith (Muller 2007). Thermal inertia is proportional to the square root of the thermal conductivity, which may take on a large range of values among asteroid surfaces. In general, bare rock surfaces have a higher thermal conductivity and thus correspond to a large thermal inertia while the presence of small grains will decrease the bulk thermal conductivity and lower the thermal inertia. Compositionally speaking, metals have a much higher thermal conductivity than other materials that may exist on asteroid surfaces (e.g. silicates) and may yield relatively higher thermal inertia values.

The presence of asteroid regolith has been hypothesized to be the effect of surface impacts throughout the lifetime of an object (Housen & Wilkening 1982). A series of impacts could not only generate regolith particles, but also pulverize existing regolith into smaller particles. Larger asteroids have a higher surface gravity and also longer collisional lifetimes (Bottke et al. 2005), so it is expected that small particle regolith is more abundant on larger-sized bodies due to their longevity and impact frequency.

Thermal inertia has been measured for large solar system bodies, such as the Moon (Spencer et al. 1989) and Mercury (Emery et al. 1998), and also a few dozen small bodies by (Delbo & Tanga 2009) using data from the Infrared Astronomical Satellite. An inverse relationship between diameter and thermal inertia was found by (Delbo & Tanga 2009) over diameters ranging four orders of magnitude, which supports the theory of regolith generation via impacts. However, the thermal inertia of many asteroid surfaces remains to be determined. The thermal inertia for a large set of asteroids could reveal trends among or between dynamical and compositional groups. Such information will lead to a better understanding of the impact history within in the inner solar system.

OBSERVATIONS

- Wide-Field Infrared Explorer (WISE)
- Moving object catalog (NEOWISE) (Mainzer et al. 2011)
  - 157,000 solar system objects found
- 12 and 22µm bands
  - Dominated by thermal emission

ACKNOWLEDGEMENTS

This publication makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration.

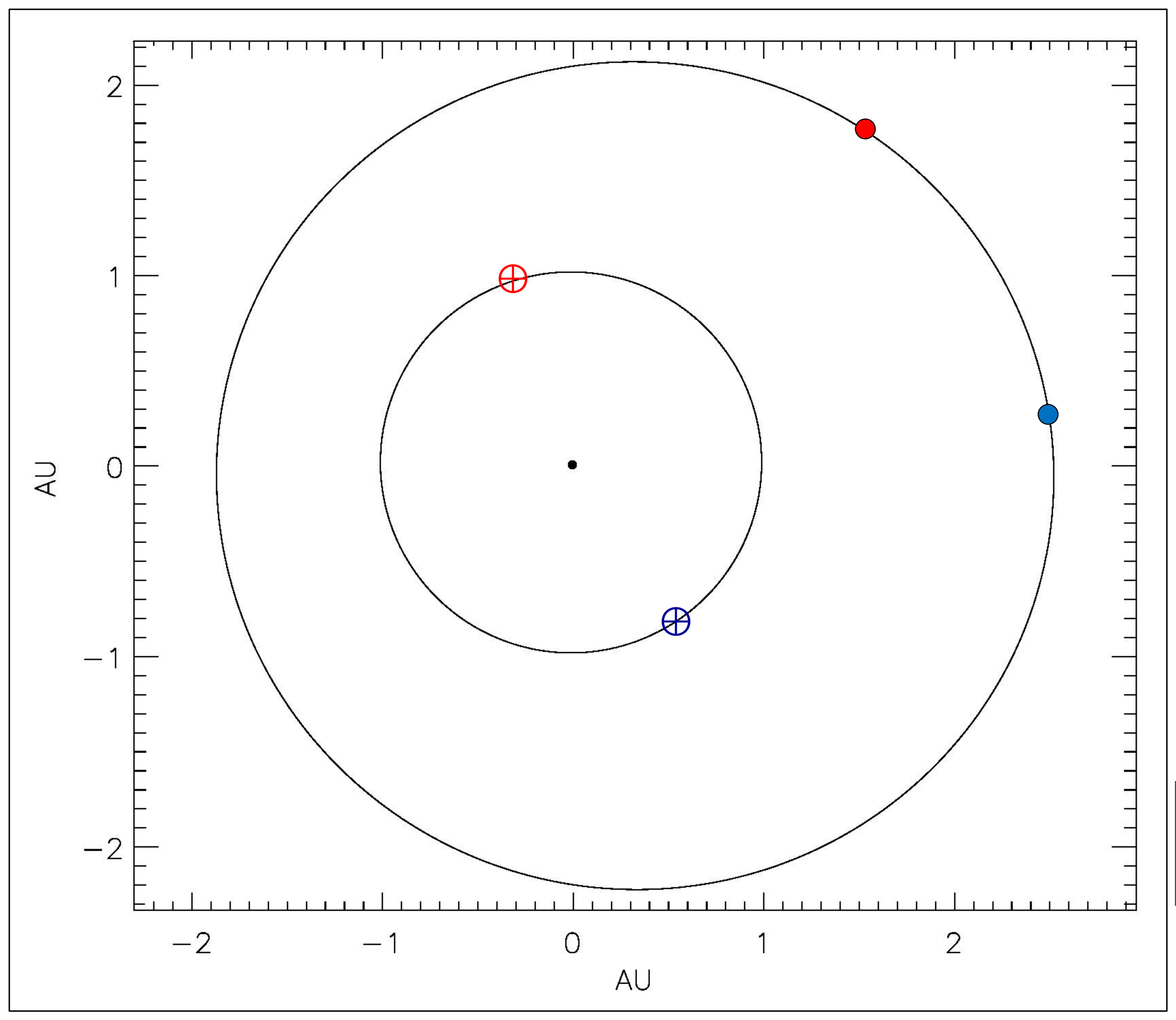

Figure 1. Diagram showing the position of Earth and asteroid 270 Anahita during observations by WISE in two separate epochs.

RESULTS

The expected afternoon flux for the first epoch (dark blue curve) and morning flux from the second epoch (light red curve) give the same thermal inertia range for 270 Anahita (220-350 J m^{-2} K^{-1} s$^{-1/2}$; figure 3). For this range, the best-fit value for the diameter is 60 - 66 km, and albedo is 0.12 - 0.16. Although the exact spin pole cannot be derived here, given the position of 270 Anahita at each sighting by WISE, it can be said that the rotation is prograde with respect to its orbit.

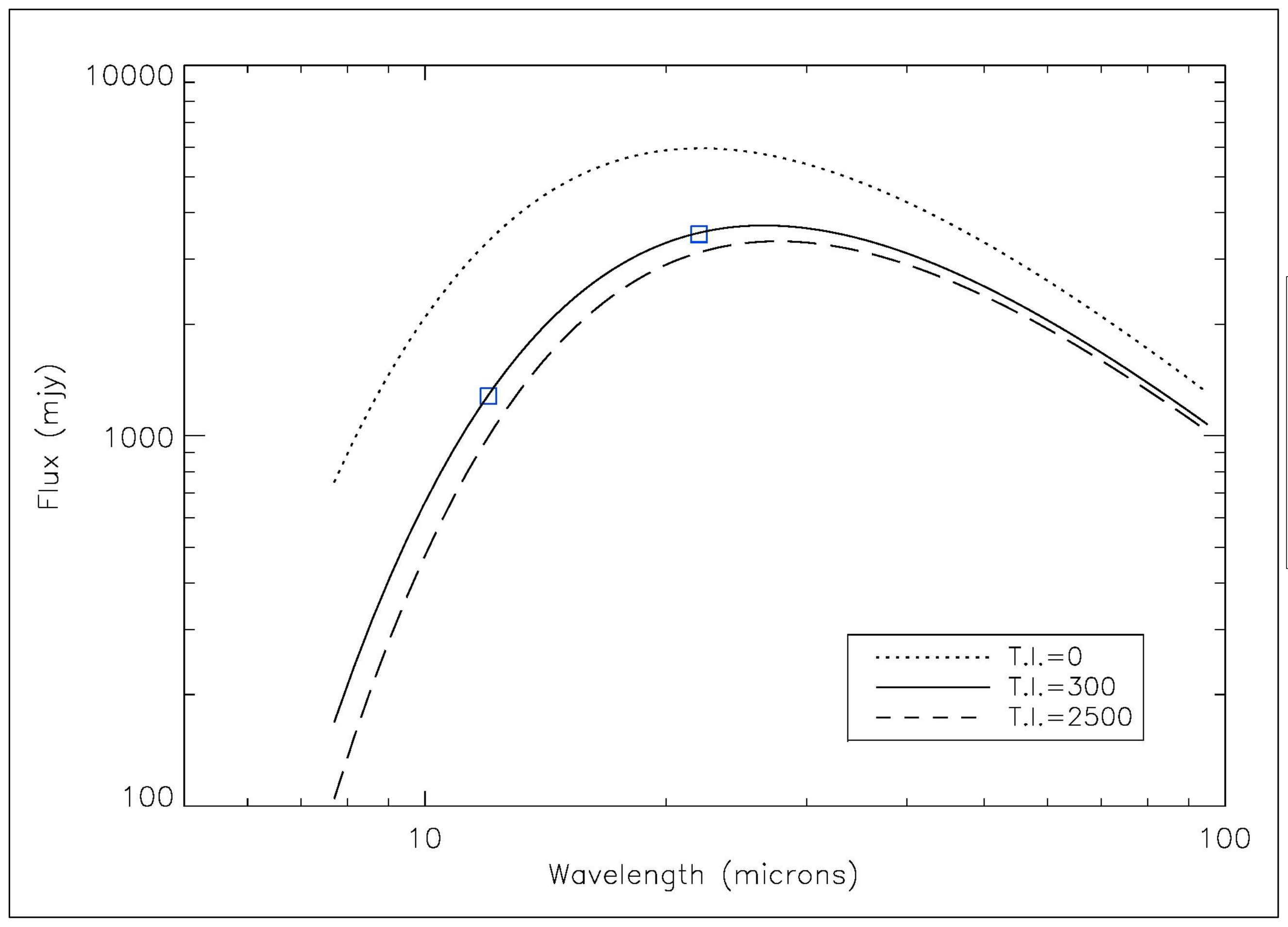

Figure 2. A plot showing the energy emitted as a function of wavelength from the asteroid 270 Anahita. 12 and 22 micron flux measurements by WISE from first epoch observations are plotted along with the modeled flux for different values of thermal inertia (T.I.).

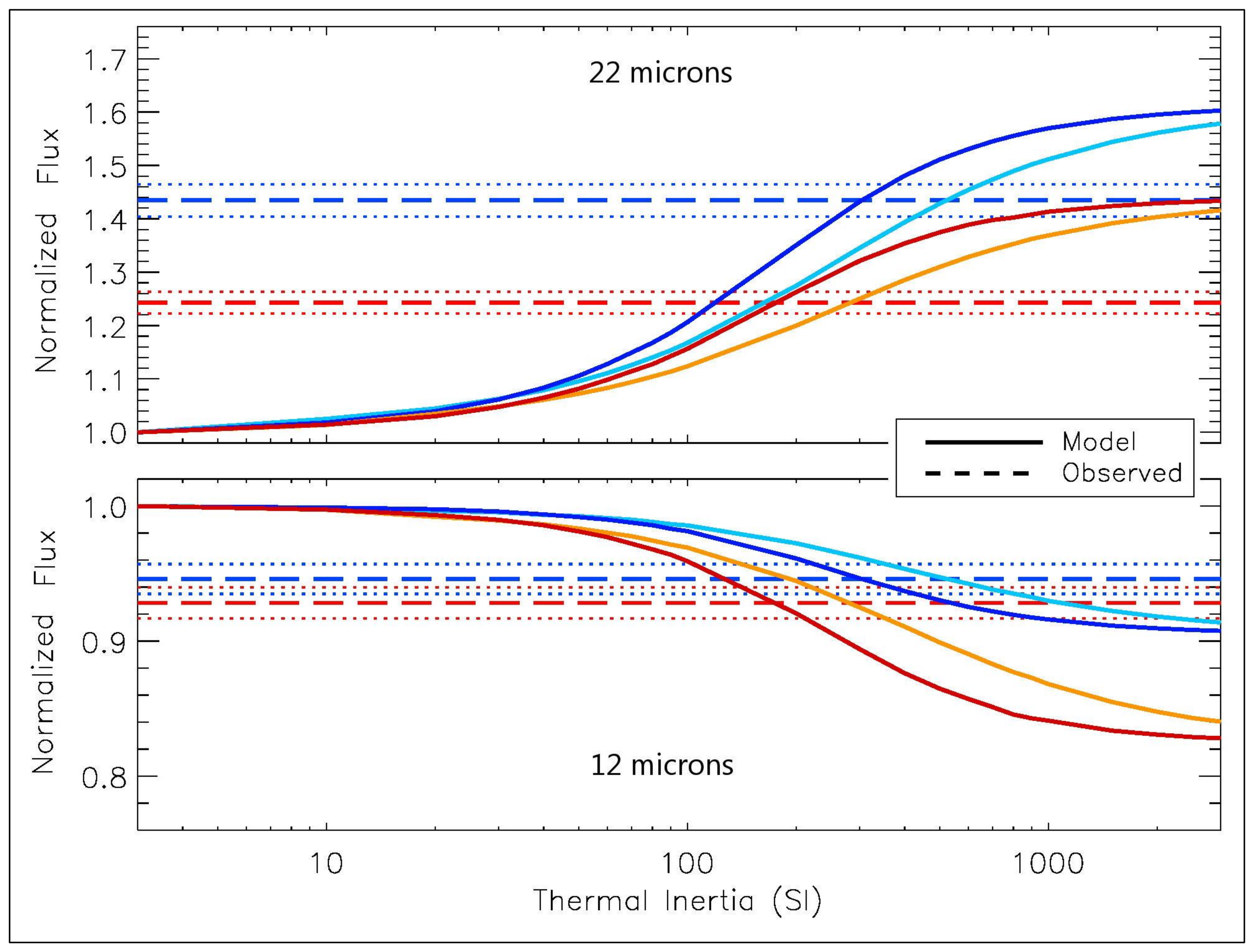

Figure 3. Best-fit model fluxes for each thermal inertia value and four cases, as described before, for 270 Anahita. Top panel shows the 22 micron WISE band and bottom panel shows the 12 micron WISE band. Bold lines are the expected flux for different thermal inertia, and dashed lines give the measured flux from WISE and range given by dotted lines. Blue and red lines correspond to the first and second epoch, respectively, with darker shades giving the expected afternoon flux and lighter shades corresponding to morning fluxes.

OBJECT SELECTION

- Asteroids with a known spin pole solution

  and/or

- Asteroids observed in more than one epoch, with a known rotation period

THERMOPHYSICAL MODEL

- One-dimensional time-dependent heat diffusion equation
- Smooth, spherical asteroid
- 12 and 22µm flux computed from surface temperatures
- Thermal Inertia varied: 0 – 3000 J m^{-2} K^{-1} s$^{-1/2}$
- Best-fit gives albedo and diameter for each value of thermal inertia

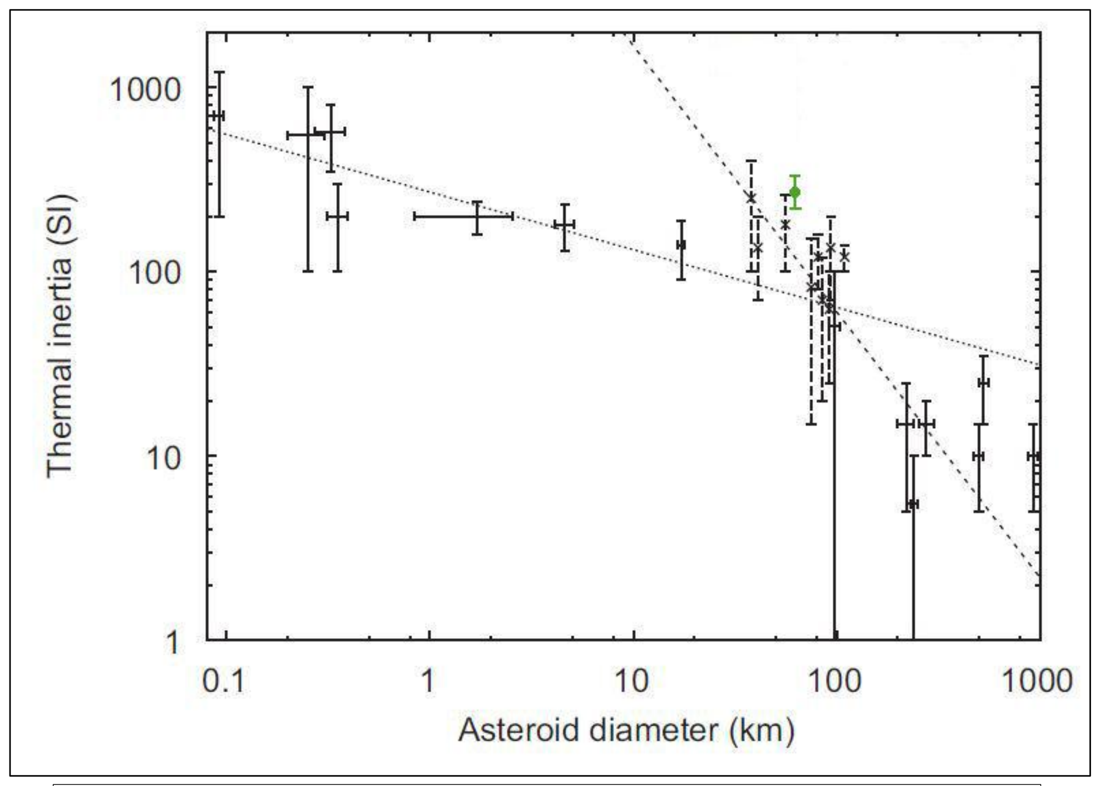

Figure 4. Modified from Delbo & Tanga (2009), the inverse relationship between thermal inertia and asteroid diameter with 270 Anahita plotted in green.

DISCUSSION/ FUTURE WORK

The thermal inertia calculated for 270 Anahita is typical for other main belt asteroids of the same size, as found in Delbo & Tanga (2009). An inverse relationship between diameter and thermal inertia was found by Delbo & Tanga (2009) which suggests that larger objects have a more developed regolith (figure 4).

This method can be used on hundreds of objects in the WISE catalog to compute thermal inertia values for asteroids with and without known spin pole solutions but with known rotation periods. In doing so, we can effectively constrain the spin pole orientation and because of this, it is possible to discern between two degenerate spin pole solutions for objects with intermediate thermal inertia.

With thermal inertia constraints on many objects, a better understanding of regolith evolution on asteroids can be achieved. A more sophisticated thermophysical model will be used in future work to better understand the regolith properties on asteroids.

WORKS CITED

[1] Muller M. (2007) *Ph.D. Thesis.* [2] Housen K. R. and Wilkening L. L. (1982) *Annu. Rev. Earth Planet. Sci., 10*, 355–376. [3] Bottke, W. F. et al. (2005) *Icarus*, 179, 63. [4] Spencer et al. (1989) *Icarus, 78*, 337-354. [5] Emery et al. (1998) *Icarus, 136*, 104-123. [6] Delbo, M. and Tanga, P. (2009) *Planet. Space Sci., 57*, 259–265. [7] Mainzer et al. (2011) *ApJ, 731*, 53.