Thermal Inertia Estimates of Four Near-Earth Asteroids from Spitzer Space Telescope Spectral Observations

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Introduction

- Thermal inertia estimates for near-Earth asteroids (NEAs) are paramount to upcoming asteroid sample-return missions (e.g. NASA's OSIRIS-REx, & JAXA's Hayabusa-2)
- Thermal Inertia estimates build a foundation for the possibility of sending humans to asteroid surfaces in the near future.
- Asteroids with thermal inertias of <750 (J $m^{-2}s^{-0.5}K^{-1}$) likely support fine-grained regolith, the presence of which can be a significant factor in mission planning.
- The goal of the present work is to estimate thermal inertia values, albedos, and diameters for four near-Earth asteroids.
- We hypothesize that these objects will have high thermal inertias because of their small size.

Observations/Data Reduction

- Observed four near-Earth asteroids with NASA's Spitzer Space Telescope, Table 1.
- Used Spitzer's InfraRed Spectrograph (IRS) instrument to collect thermal infrared data (5.2 to 38 μm)
- Calibration corrections (e.g. flats, darks) applied by the Spitzer Science Center.
- We subtract background emission and extract into one-dimensional spectra.
- Different wavelength intervals of each spectrum are combined and scaled together.

Table 1. Observational circumstances and date.

Asteroid	Date (UT)	Start-End (hh:mm UT)	r (AU)	Δ (AU)	(S-T-O) Angle	Period (hours)
1580 Betulia	2005-Mar-11	1:27-1:49	1.92	1.75	31.2	6.13
1685 Toro	2004-Jul-14	14:39-14:45	1.14	0.37	61.5	10.2
1620 Geographos	2005-Nov-17	17:27-18:28	1.24	0.77	54.5	5.22
1866 Sisyphus	2006-Apr-19	9:08-9:17	1.64	1.35	37.5	2.40

Thermal Modeling

- Thermal inertia values computed from infrared observations over a range of wavelengths.
- Use the Near-Earth Asteroid Thermal Model (NEATM) to calculate a beaming parameter, η, which is adjusted to fit the model to the data, Fig. 1.
- Model temperature distribution of surface while varying thermal inertia to produce a spectrum that matches observations, Fig. 2.
- Incorporate surface roughness and asteroid shape to model temperature distribution that matches observations, Fig 3.

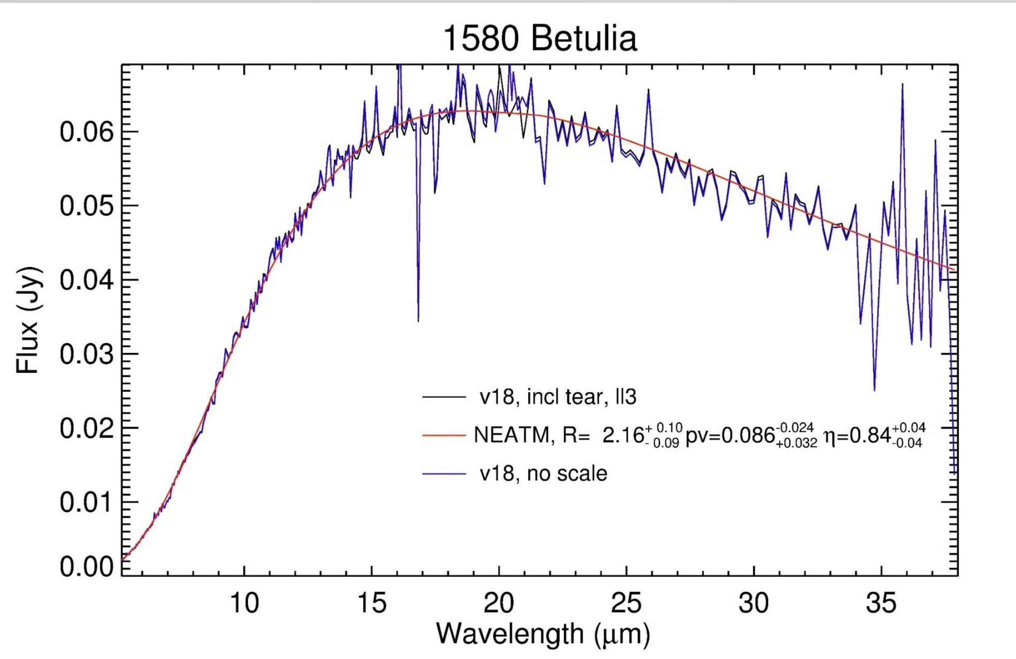

Fig. 1. Thermal emission spectrum showing results from the NEATM.

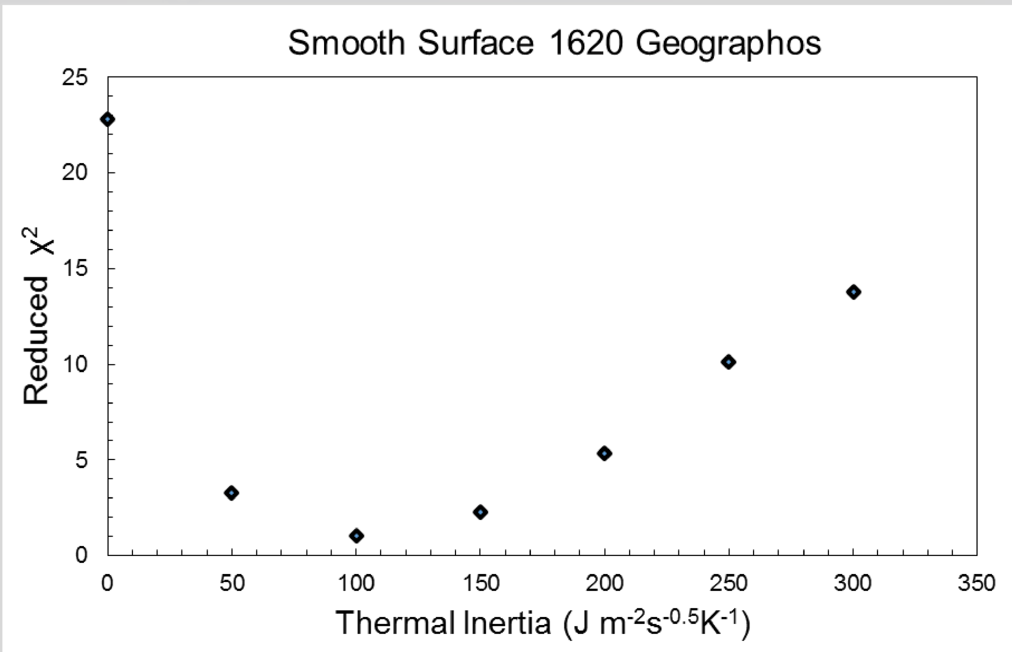

Fig. 2. Thermal model for 1620 Geographos. The lowest chi squared value occurs at a thermal inertia of 100.

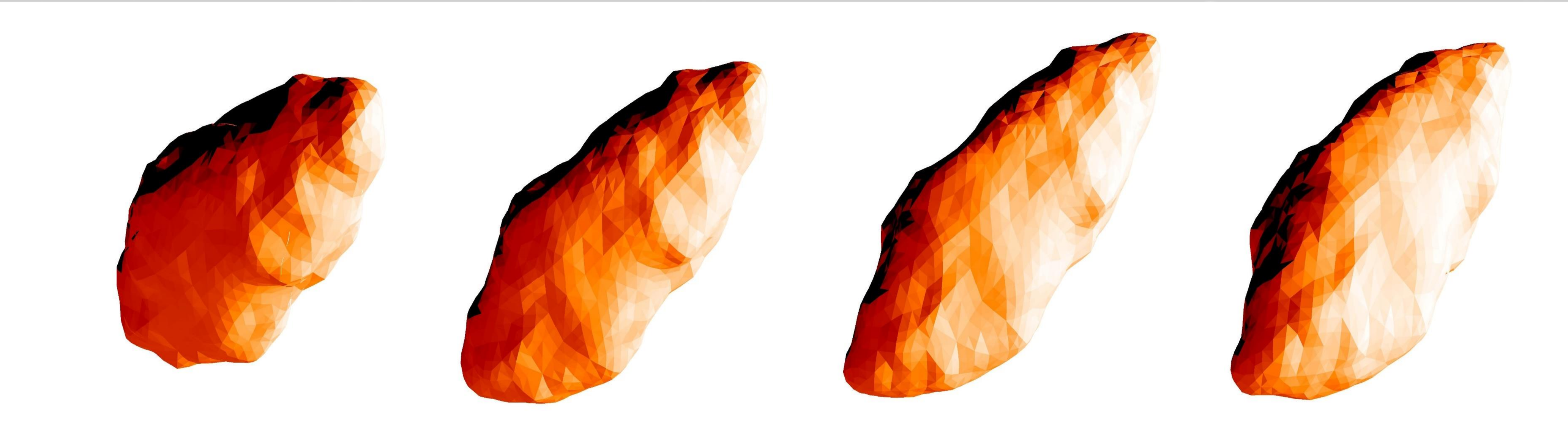

Fig. 3. Radar shape model of asteroid 1620 Geographos showing the temperature distribution across the surface [1].

Results

- Both shape and roughness thermophysical models calculate a chi squared minimum at Γ=100 (J $m^{-2}s^{-0.5}K^{-1}$) for 1620 Geographos, Fig. 4.
- No published spin pole solution for 1866 Sisyphus thus we solved for a series of possible spin pole axes, Fig. 5. We calculated a spin pole of 0,70.
- Shape model calculates chi squared minimum of Γ=980 (J $m^{-2}s^{-0.5}K^{-1}$) for 1685 Toro, Fig 6. Smooth surface thermophysical model calculates a chi squared minimum at Γ=1450 (J $m^{-2}s^{-0.5}K^{-1}$), Fig. 7.
- All thermophysical models calculate chi squared minimum at Γ≤50 (J $m^{-2}s^{-0.5}K^{-1}$) for 1580 Betulia, Table 2.

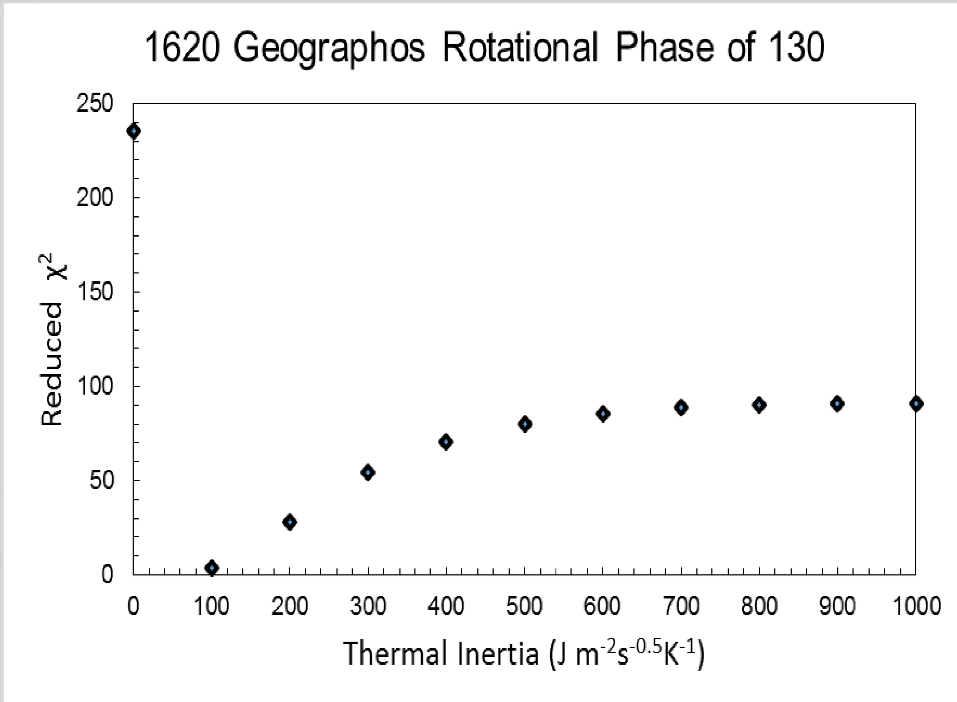

Fig. 4. Chi squared minimum occurs at a thermal inertia of Γ=100 for Geographos. The lowest chi squared minimum value occurs at a rotational phase of 130˚.

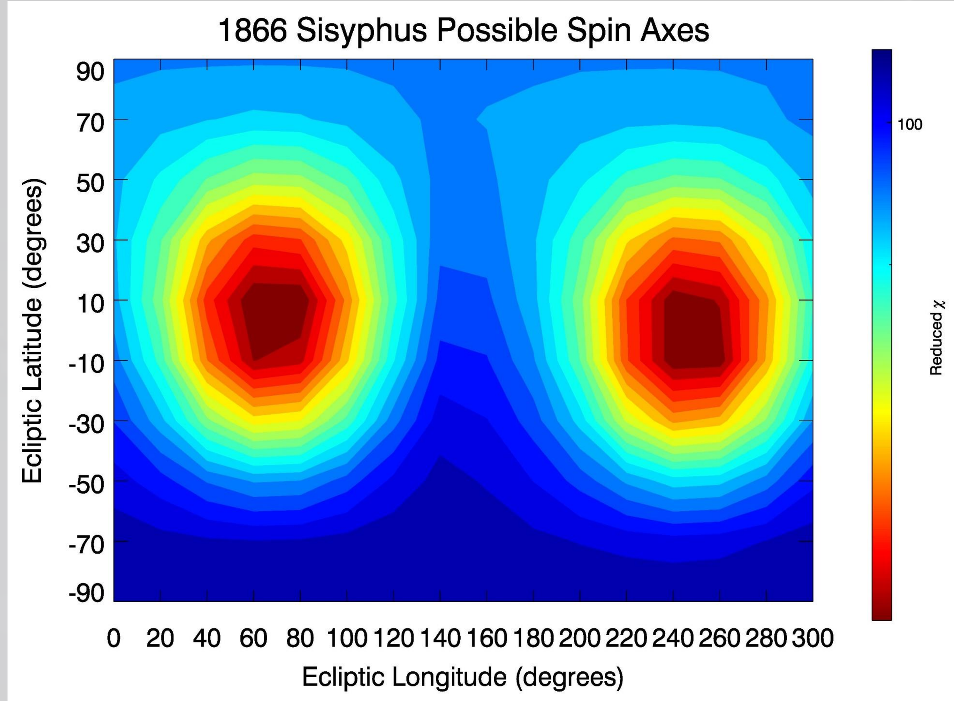

Fig. 5. Warm colors indicate a chi squared minimum and represent the location of Sisyphus' spin pole in latitude/longitude coordinates.

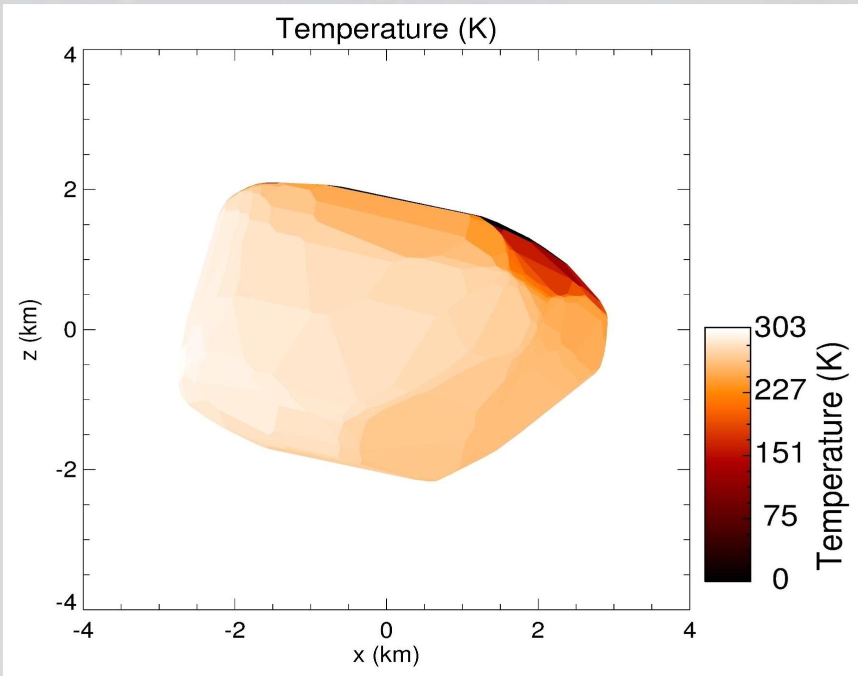

Fig. 6. Shape model of 1685 Toro pictured at a rotational phase of 67˚ [2]. Colors indicate asteroid surface temperature.

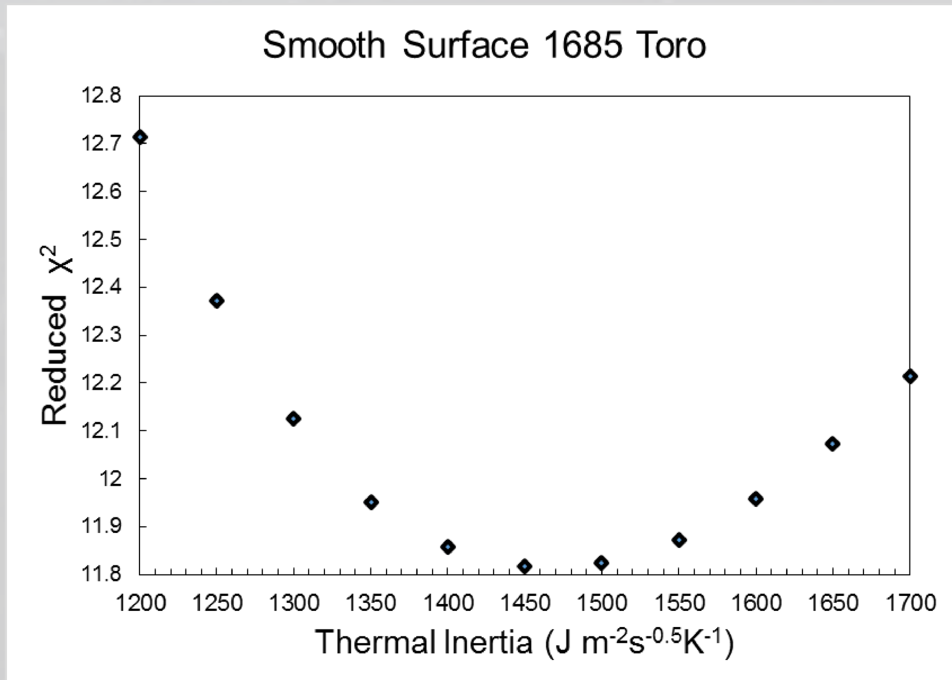

Fig 7. Chi squared minimum occurs at a thermal inertia of 1450 for 1685 Toro using a thermophysical model that assumes a smooth and spherical surface.

Table 2. List of the observed asteroids and the results from each thermal model. The thermal inertia value that corresponds to a chi squared minimum is shown. 1866 Sisyphus not shown because the thermal models have not been completed for this object.

Asteroid	Smooth Surface (Γ)	Nominal Roughness (Γ)	High Roughness (Γ)	Shape Model (Γ)	Radius (km)
1620 Geographos	100	150	200	100	1.03
1580 Betulia	0	50	50	50	2.16
1685 Toro	1450	2000	above 2000 (no min)	980	1.93

Discussion

- 1685 Toro has a high thermal inertia consistent with our hypothesis. The surface of Toro is more similar to that of exposed bedrock than a dusty fine grained regolith.
- 1620 Geographos and 1580 Betulia have low thermal inertia values indicative of surfaces with fine grained regolith.
- Calculated a spin pole of 0,70 for 1866 Sisyphus. The Spitzer Space Telescope observed part of the asteroid's spin pole which is consistent with the calculated beaming parameter of η = 1.04.
- More spin pole solutions and shape models are needed to increase our data set and continue to estimate thermal inertia values for NEAs.

Acknowledgements

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References

[1] Neese, C., Ed. Small Body Radar Shape Models V2.0. EAR-A-5-DDR-RADARSHAPE-MODELS-V2.0, NASA Planetary Data System, 2004.

[2] Josef Durech (personal communication). Shape derived from inversion of light curve data.