Shape Up

A Physical Model of Asteroid 2015 DP155

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Introduction

Asteroid shapes and spin states provide insight into Solar System formation and evolution. Knowing asteroids' physical characteristics aids in planning spacecraft visits for study or redirection[1,2].

Arecibo Observatory's (AO) planetary radar program collects data on near-Earth asteroids (NEAs) which can be used to make detailed physical models.

We developed a shape model of potentially hazardous asteroid 2015 DP155 using radar and lightcurve data.

Observations

- 2015 DP155 passed .023 au from Earth in June 2018 and will not be close enough for observations of comparable quality until 2080
- Radar data taken at AO in June 2018
- Lightcurves measured at Northolt Branch Observatories and European Southern Observatory in June and July 2018
- Previously published lightcurves measured by Terskol Observatory[3] and CS3-PDS[4] in May 2018

Model Creation

- Used the 'SHAPE' software[5], which constrains asteroid shape and spin rate by adjusting model parameters and checking against data
- Began with grid search of rotation pole directions using capsule template (**Fig. 1**) with floating principal axis lengths
- Let individual vertices float for later models to adjust shape
- Encountered issues such as unrealistically high radar scattering coefficients, large spikes in model, and optimization stuck in local chi-squared minima

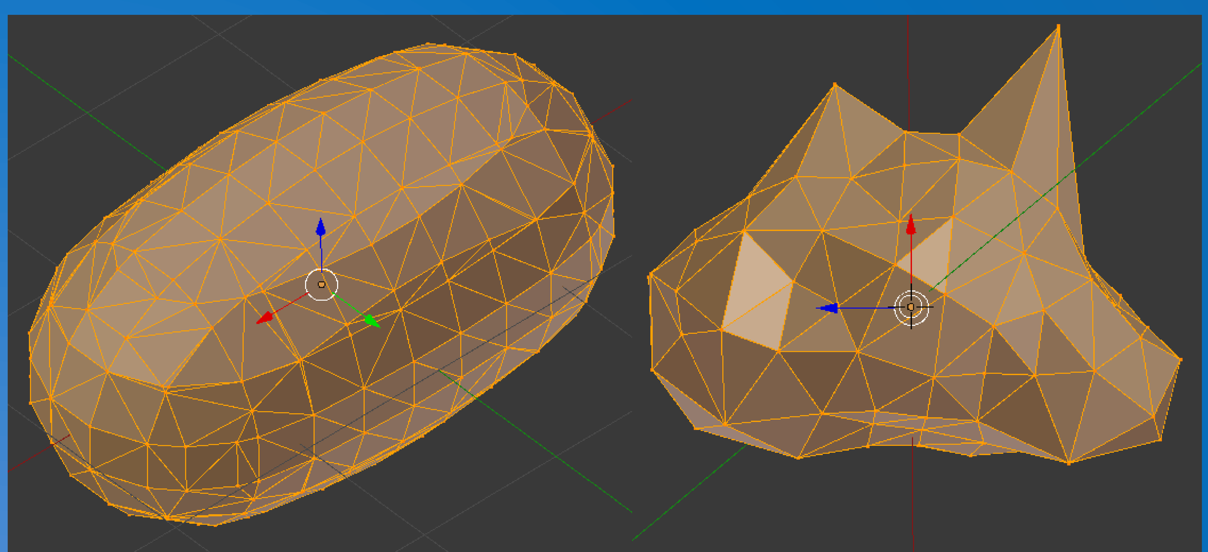

Figure 1. The capsule template we made in the animation software Blender[6, 7] (left) and a model which fit the data well but had unrealistic spikes (right).

Results

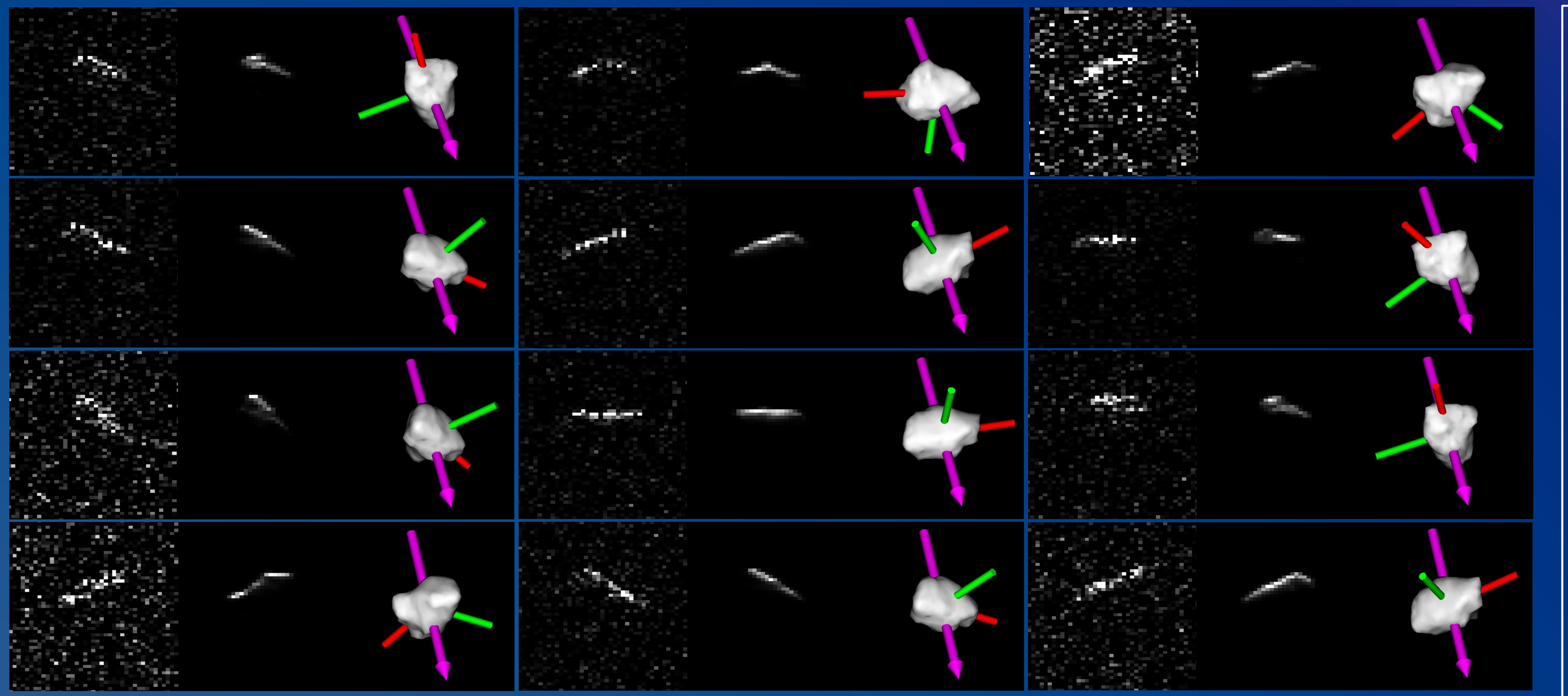

Figure 2. Sets of (left) delay-Doppler data of DP155, (center) synthetic radar images made using our model, and (right) our model as it would appear in the sky at the time of the corresponding observation frame. Each row features frames from a different day of observations from June 13th to June 16th, 2018. The three colored shafts show principal axes; the magenta shaft is also the axis of rotation. The radar delay resolution is 50 ns; the radar range resolution is 7.5m.

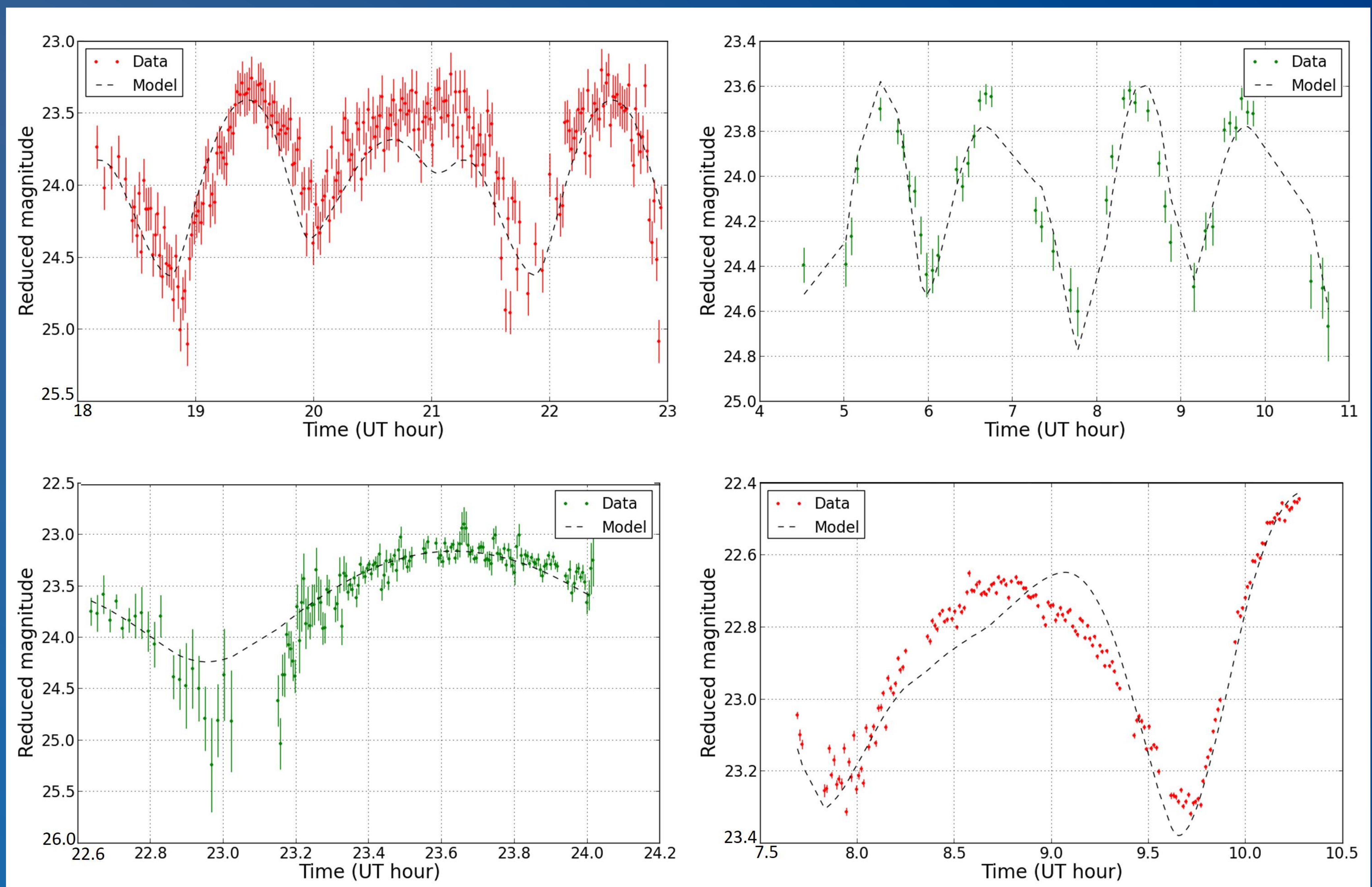

Figure 3. 2018 lightcurve data (points) plotted against what our model would produce (dashed line). From left to right, top to bottom, the data sets shown are from Terskol Observatory, May 3; CS3-PDS, May 17; Northolt Branch Observatories, June 10; and the Danish Telescope at La Silla Observatory (European Southern Observatory), June 25.

Dimensions	200m ± 20m 140m ± 15m 130m ± 30m
Equivalent Diameter	140m ± 15m

Rotation Pole Direction	Ecliptic (200°, -73°) ± 10°
Rotation Period	3.0973 ± .0002 hr

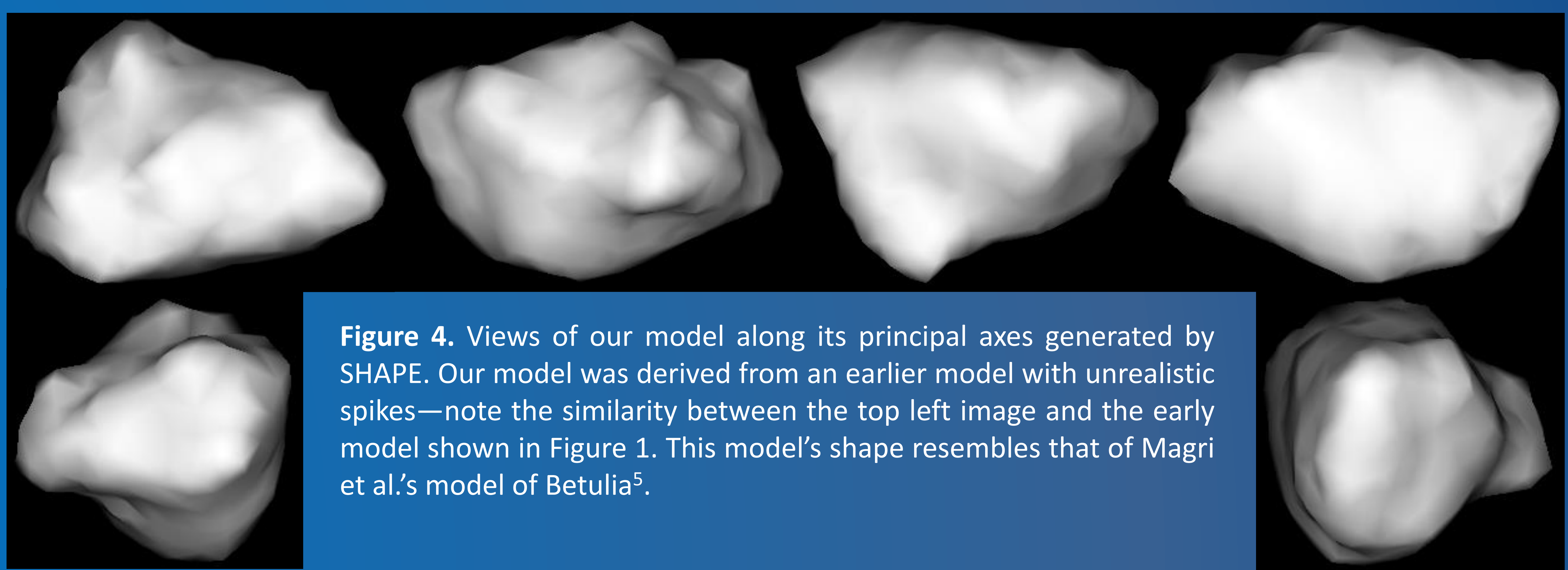

Figure 4. Views of our model along its principal axes generated by SHAPE. Our model was derived from an earlier model with unrealistic spikes—note the similarity between the top left image and the early model shown in Figure 1. This model's shape resembles that of Magri et al.'s model of Betulia[5].

Conclusions

- Model provides good fit to majority of radar & lightcurve data (**Fig. 2, 3**)
- Final model derived from earlier model that fit data well but had large spikes (**Fig. 1, 4**)
  - Manual adjustment in Blender and penalty functions increasing chi-squared for non-smooth models removed spikes; data still agreed
  - Pursuing promising but flawed models may be worthwhile for others developing shape models
- Shape may indicate deformation by YORP spin-up[8]
  - Not lobed, so not the result of a collapsing binary asteroid system
- Rotation period close to spin barrier[9], which could lead to future mass shedding

Future Work

- After developing this model to further improve its agreement with radar and lightcurve data, we will publish our finished version
- We will continue to monitor this NEA to detect YORP-induced rotational torques, and to monitor it for mass shedding events
- This model could help with detailed thermal modeling of 2015 DP155 using infrared observations from NASA's WISE spacecraft[10]

References:

- [1] Ostro et al. (2002). Asteroid Radar Astronomy. *Asteroids III.*
- [2] Cheng et al. (2018). *Planetary and Space Science,* 157, 104-115.
- [3] Reshetnyk V. et al. (2018). *The Astronomer's Telegram*, 11645.
- [4] Warner B. (2018). *The Minor Planet Bulletin*, 45, 366-379.
- [5] Magri et al. (2007). *Icarus*, 186, 152-177.
- [6] blender.org
- [7] Crowell et al. (2017). *Icarus,* 291, 254-267.
- [8] Sánchez P. and D. J. Scheeres (2018). *Planetary and Space Science*, 157, 39-47.
- [9] Warner et al. (2009). *Icarus,* 202, 134-146.
- [10] Mainzer et al. (2011). *The Astrophysical Journal*, 731:53 (13pp).

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