Photometric study and 3D modeling of two asteroids using inversion techniques

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Abstract

New photometric observations of the asteroids 616 Elly and 901 Brunsia were obtained during February and July 2014 in Bareket Observatory, Israel. The light curves showed synodic periods that matched previous studies. Using these light curves and other observations by different observers , sophisticated 3D models were constructed using inversion techniques along with sidereal rotation times and spin axis pole coordinates.

Introduction

The goal of this research was to model an asteroid's shape and spin characteristics by the inversion of photometric light curves. The research aimed to determine the asteroid's synodic period, sidereal period, spin axis pole coordinates, and generate a rough model of its shape.

I chose to study two asteroids selected from Warner et al.'s list of asteroid candidates for fulfilling the following criteria: magnitude brighter than 15 mag (to ensure high SNR), a previously known synodic period shorter than 6 hours (I had a limited amount of telescope time), amplitude larger than 0.3 mag (asteroids with high amplitudes are easier to analyze), and previous observations from at least two other apparitions. The last is especially important, because the modeling process requires data from more than one apparition to work reliably. The asteroids chosen were 616 Elly, and 901 Brunsia.

Methods

Observations were taken using the Bareket Observatory's Cassegrain Internet telescope with a cooled robotic SBIG ST10 MXE CCD camera. All images were taken through filter V, and calibrated using bias, flat-field, and dark master frames.

Due to cloudy weather, I managed to observe 616 Elly only on two nights: February 20-21, and obtained 330 images. I observed 901 Brunsia on four nights: July 22-24, August 6, and obtained 255 images. The lightcurves were made using derived photometry with MPO Canopus (Warner, 2012). In each image, 3 or more comparisons were measured along with the asteroid. For each comparison star, the asteroid's magnitude was calculated relative to the comparison star, using the following formula:

Dm=Im(target)-Im(comparison)+V(comparison)

Where: Dm = derived magnitude, Im = instrumental (measured) magnitude, V = magnitude from catalog

The average of the derived magnitude calculated from each of the comparison stars was then reduced to unity distance using the formula:

$$\Delta M = -5 * \log(rR)$$

Where: M = magnitude to be reduced, r = distance of asteroid from earth, R = distance of asteroid from sun (both in AU)

The time of each image was then corrected for light-time, using the formula

$$\Delta t = -0.005778\ r$$

The derived magnitudes were then plotted versus time, and a Fourier transform was applied to find the synodic periods.

These lightcurves, along with lightcurves from different observers during different apparitions, were then analyzed using LCInvert (Warner, 2010b). The following table lists the different lightcurves I used:

Asteroid	Year	Observer	Reference
616 Elly	2010	B. D. Warner	(Warner, 2010)
	2010	R. I. Durkee	(Durkee, 2010)
	2014	R. D. Stephens	(Stephens, 2014)
	2014	D. A. Klinglesmith et al.	(Klinglesmith, 2014)
901 Brunsia	2008	G. Vander Haagen	(Haagan, 2009)
	2011	M. Audejean, R. Behrend	(Behrend, 2011)

I started by running a period search finding the ChiSq value for each sidereal period in a range of periods close to the synodic one. After that, I ran a similar search for the spin axis pole. I then refined the search, finding the best period and pole parameter in the "area" of the previous ones I found (best meaning "with smallest ChiSq value"). During these searches, the shape of the asteroid was also determined, and the final step was to generate a 3D model of the asteroid. The math behind these steps can be found in M. Kassalainen et al.'s articles (M. Kassalainen, 2001).

Results

Below are the final results of my research. Pictures of the model are at the end.

Asteroid	Synodic period	Synodic period error[1]	Sidereal period	Spin pole axis	RMS error of model[2]
	Hours	Hours	Hours	Degrees (λ,β)	
616 Elly	5.28150	0.00230	5.29566897	(274, 14.7)	0.0390
901 Brunsia[3]	3.13574	0.00015	3.13641517	(165.2, -16.3)	0.0170
			3.13640349	(331.5, 2.4)	0.0193

[1] Synodic period error – the probable error given by the Fourier transform

[2] RMS error of model – after the model is determined, lightcurves of the model are generated for the same times as the observed lightcurves. The RMS is calculated for these modelled lightcurves against the originals.

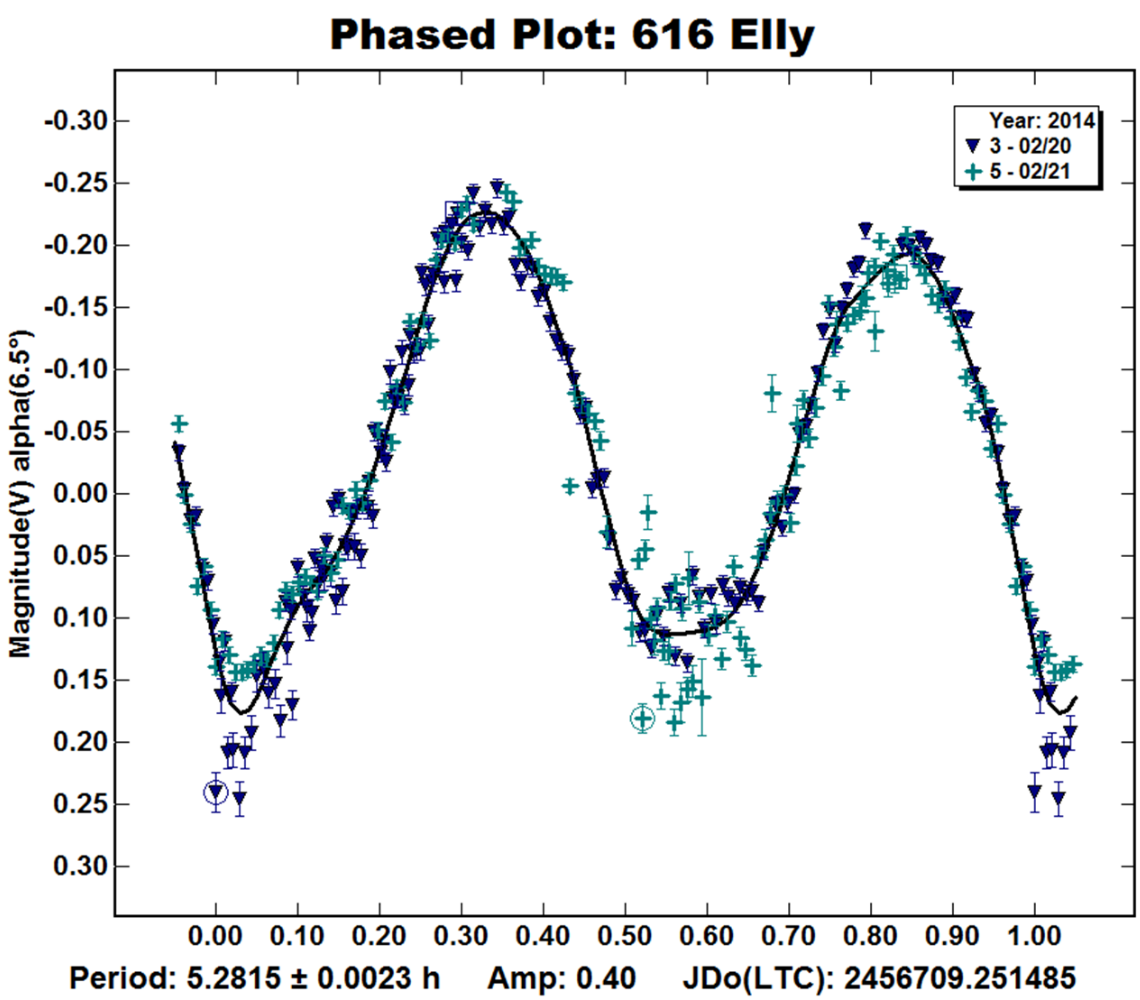
[3] The inversion process revealed two likely models for this asteroid. Both are shown in separate lines.

The models found are the first models found for these asteroids. They were made using relatively few observations, and therefore are a rather rough representation of the real asteroids. These models may be used as a basis for further research, and more observations can be used to further refine these models. All data is available online in the Lightcurve Database (Warner et al., 2009), and DAMIT (Durech et al., 2010).

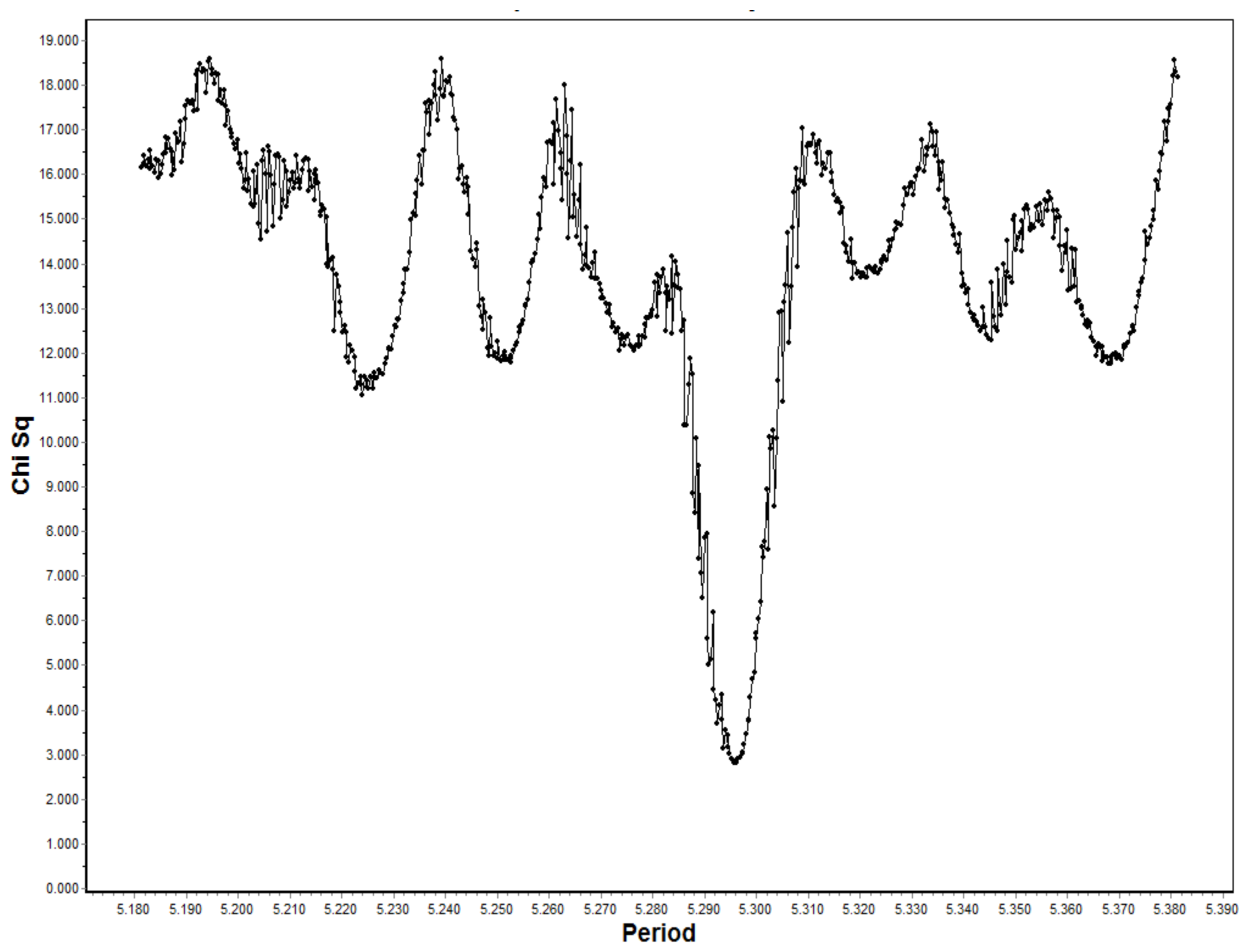
Graphs

Following are the lightcurves I made, along with graphs of the different searches I made as part of the modeling process.

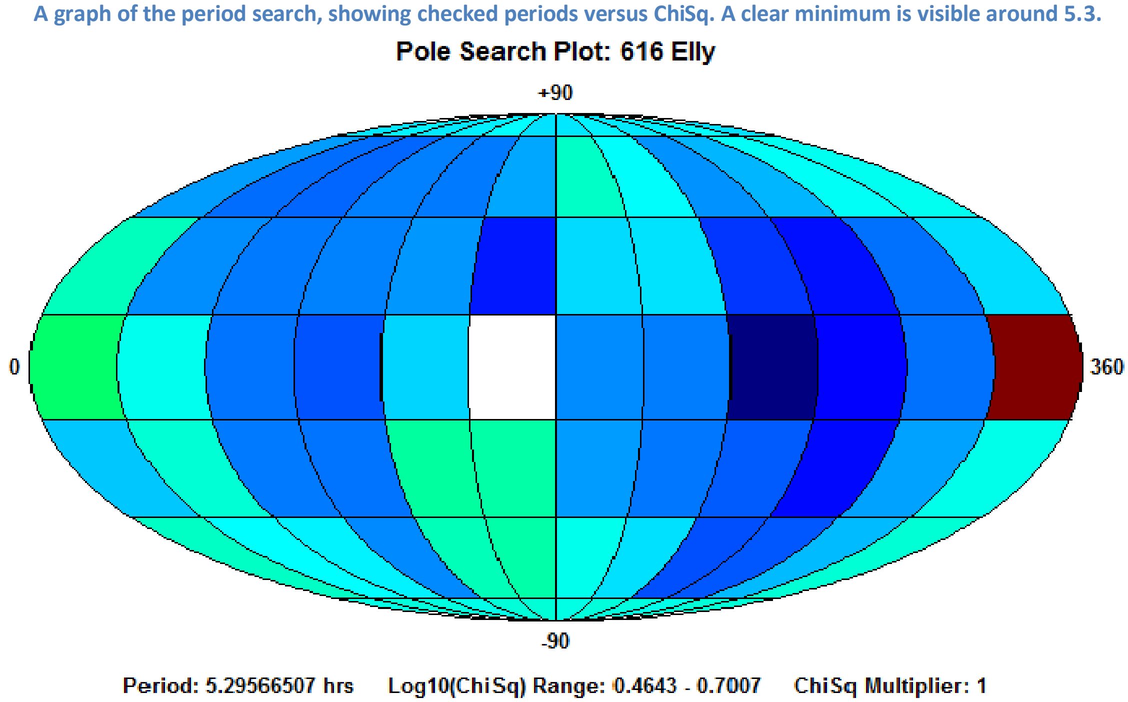
616 Elly



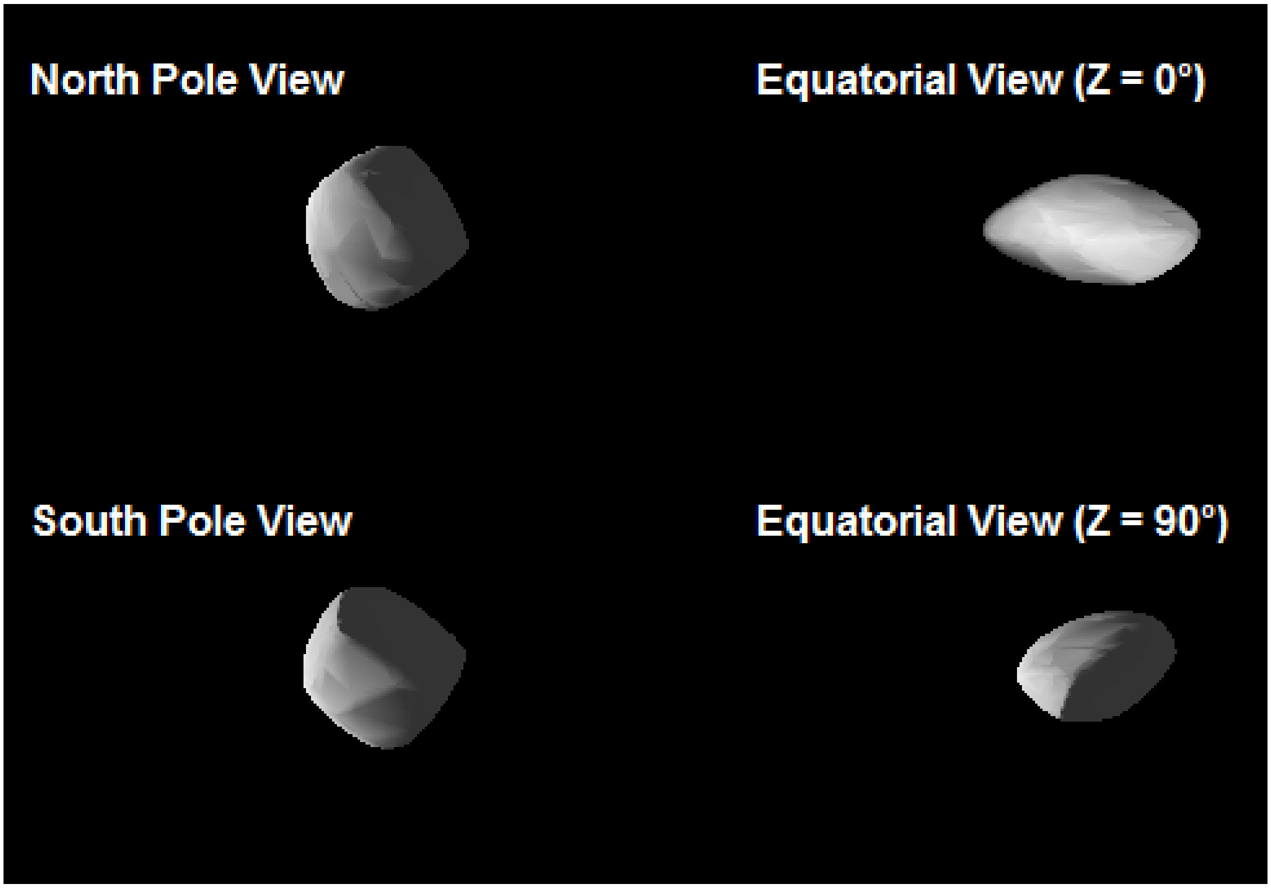
Phased lightcurve plot showing derived magnitude of the asteroid versus one period cycle



A graph of the period search, showing checked periods versus ChiSq. A clear minimum is visible around 5.3.

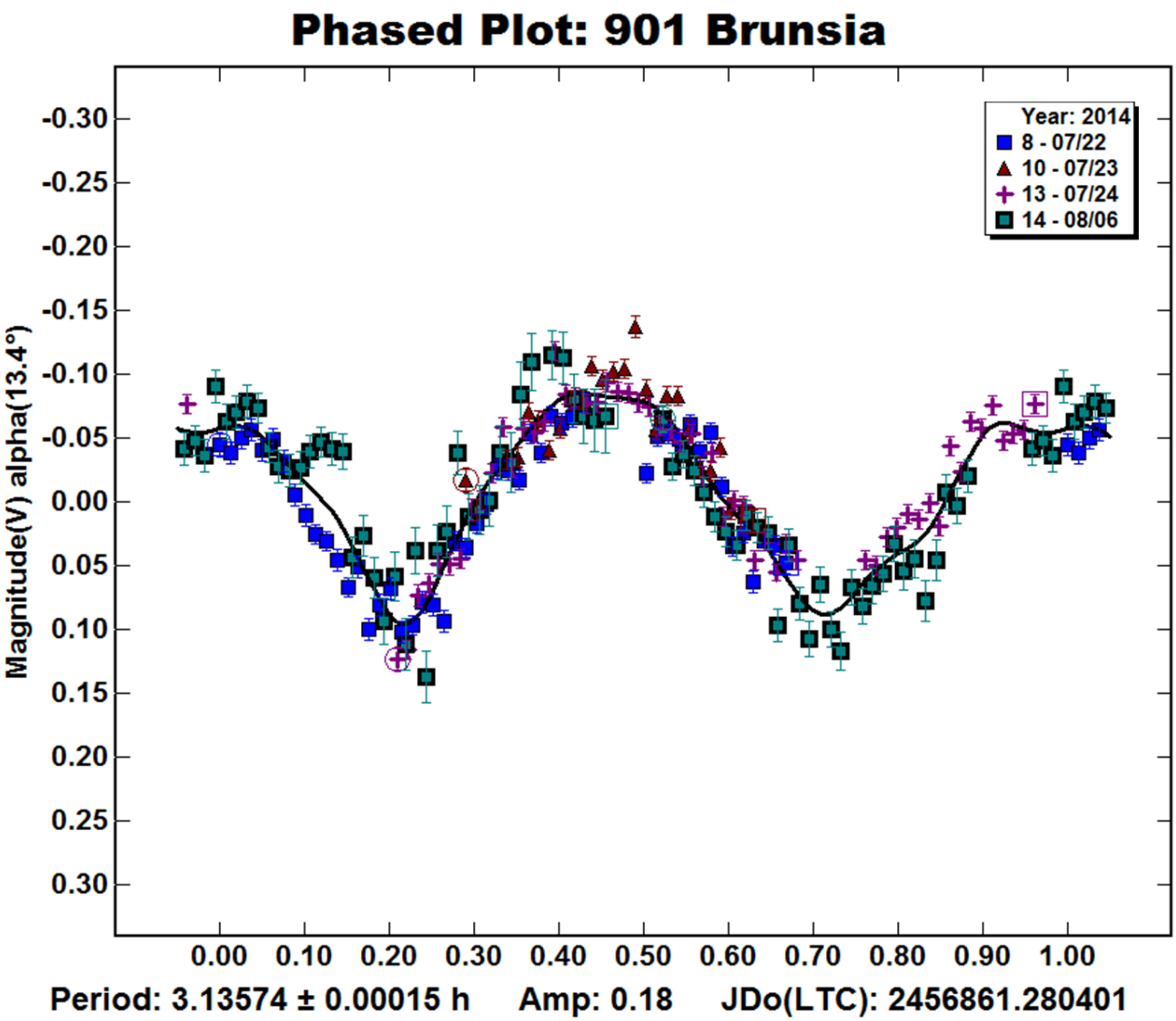


The initial pole search, showing lower ChiSq values in dark blue, and higher ones in red. The minimum is around (240,0)

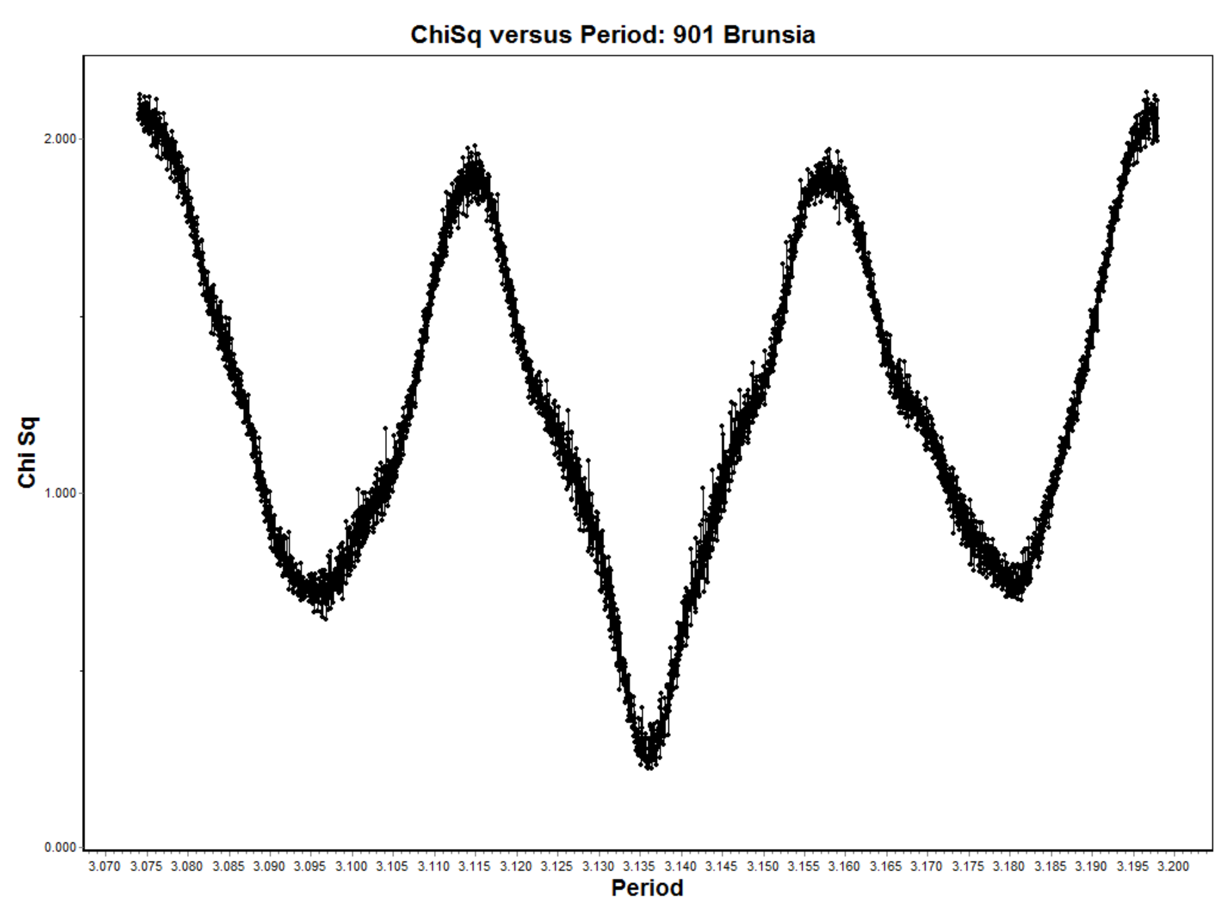


Final model, shown from different angles.

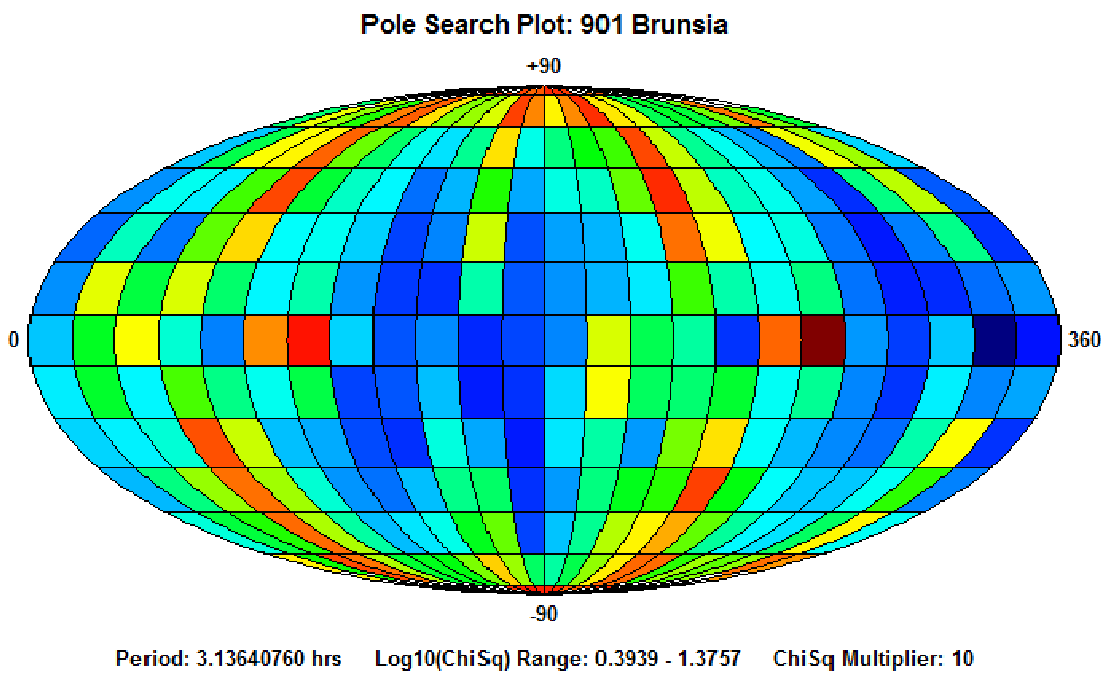
901 Brunsia



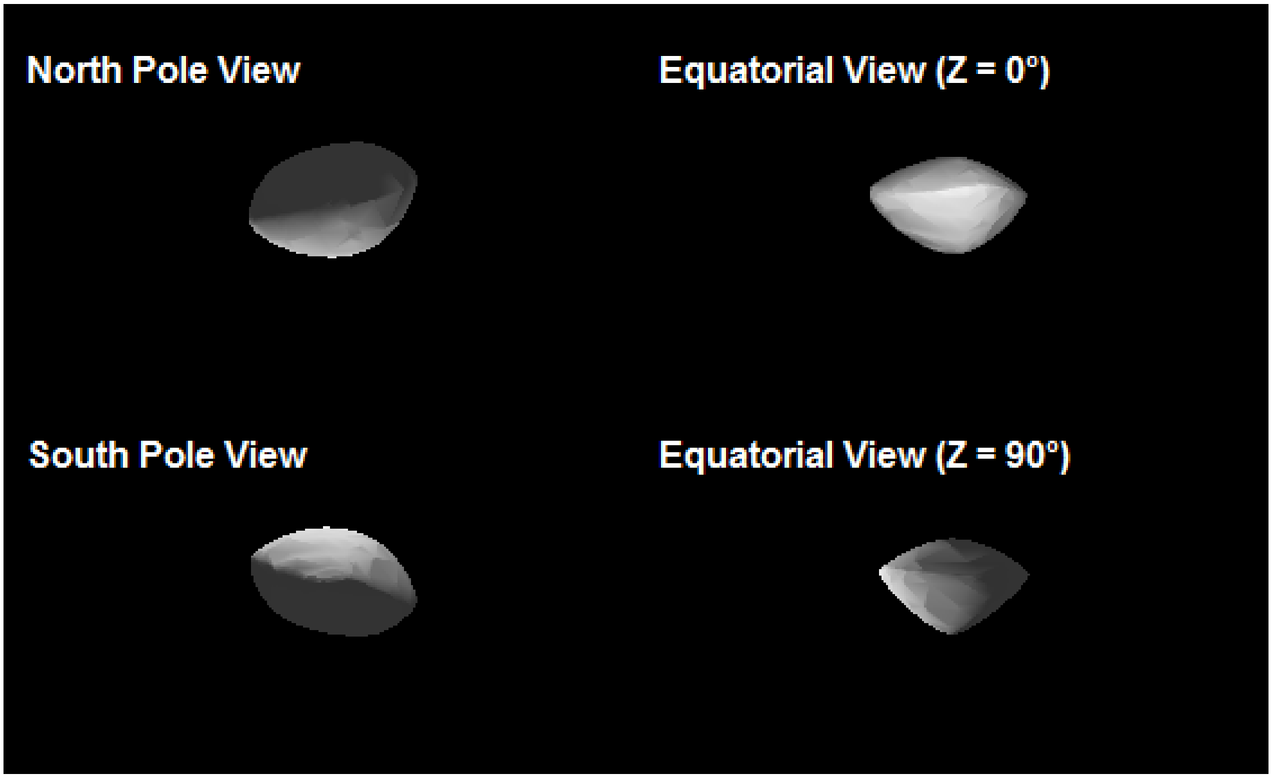
Phased lightcurve plot showing derived magnitude of the asteroid versus one period cycle



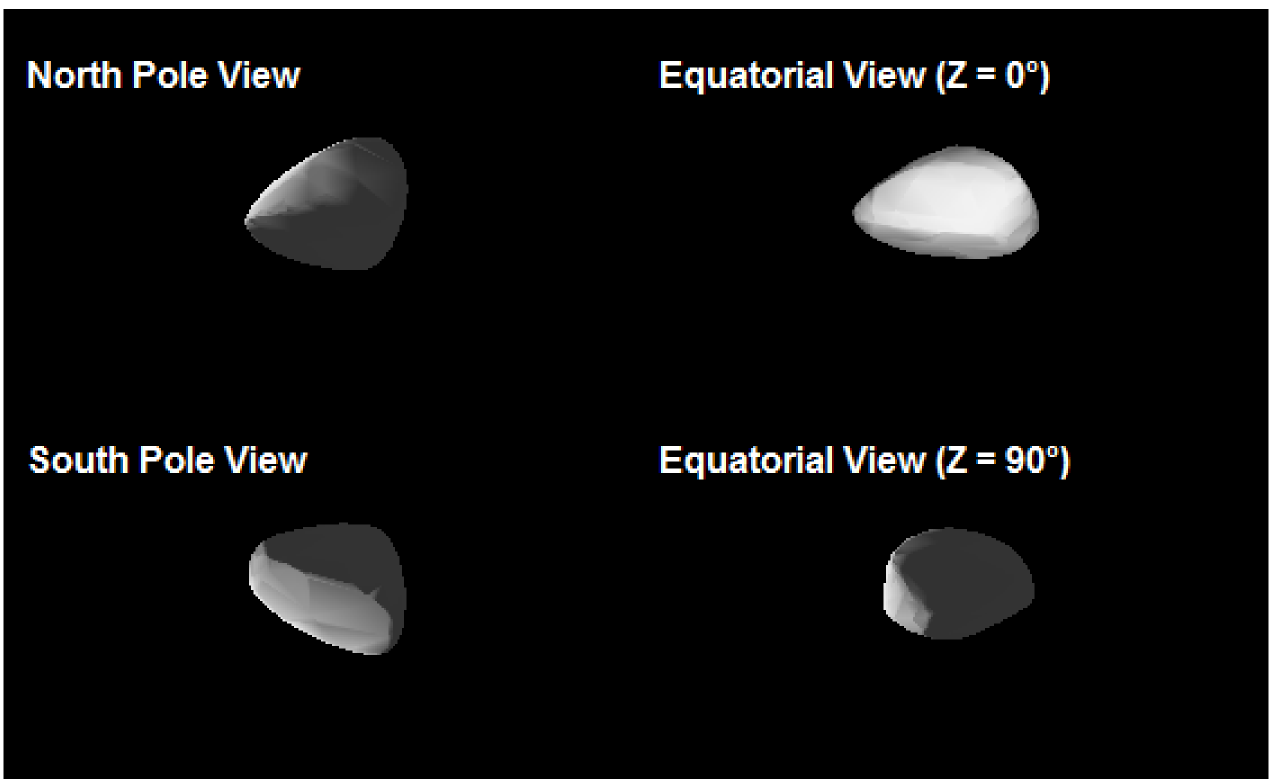
A graph of the period search, showing checked periods versus ChiSq. The minimum isn't as pronounced as I would wish, but it does peak arounf 3.135



The initial pole search, showing lower ChiSq values in dark blue, and higher ones in red. There are two likely poles: around (330,0) and (165,-30)



Final model 1, shown from different angles.



Final model 2, shown from different angles.

References

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