

LIGHTCURVE ANALYSIS OF TROJAN ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES 2016 OCTOBER - DECEMBER

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(Received: 2017 Jan 11 Revised: 2017 Feb 12)

Lightcurves for six Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2016 October to December.

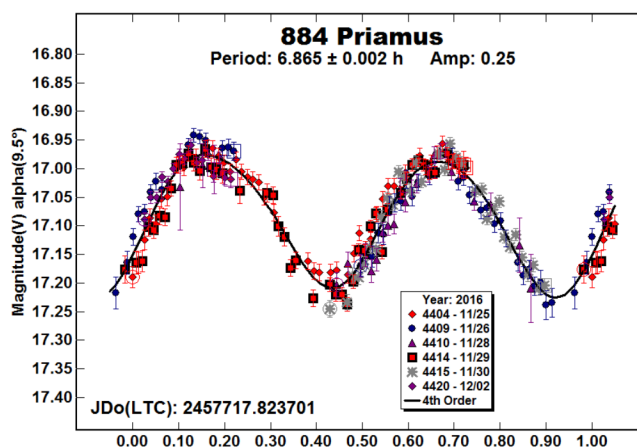
CCD Photometric observations of six Trojan asteroids were obtained at the Center for Solar System Studies “Trojan Station” (CS3, MPC U81). For three years, CS3 has been conducting a study of Jovian Trojan asteroids. As part of this study, data are being accumulated for family rotational and shape model studies. It is anticipated that for most Jovian Trojans, two to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed and can be supplemented with reliable sparse data for the brighter Trojan asteroids. For most of these targets, we were able to get preliminary pole positions and create shape models from sparse data and the dense lightcurves obtained to date. These preliminary models will be improved as more data are acquired at future oppositions.

All images were made with a 0.4-m SCT using an FLI ML-Proline 1001E or a 0.35-m SCT with a FLI ML-Microline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Night-to-night calibration of the data (generally $< \pm 0.05$ mag) was done using field stars from the CMC-15 catalog or the MPOSC3 catalog. The MPOSC3 catalog converted to approximate Johnson V magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

In the lightcurve plots, the “Reduced Magnitude” is Johnson V corrected to a unity distance by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$. The X-axis rotational phase ranges from -0.05 to 1.05.

The amplitude indicated in the plots is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

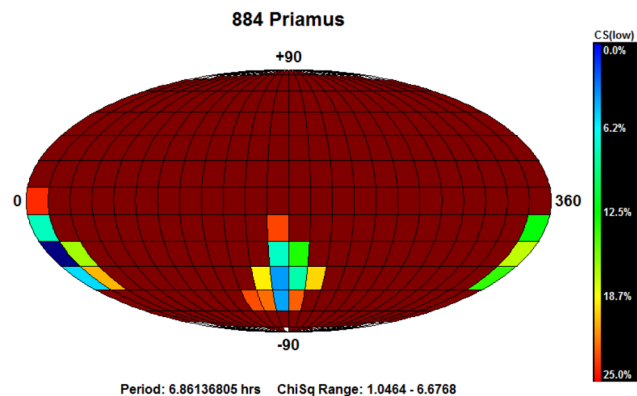
884 Priamus. This large Trojan has been well studied over the years. Mottola *et al* (2011), French *et al* (2011b), and Stephens *et al* (2015, 2016b) each found synodic rotational periods near 6.86 h. When the data was combined with our previous data and sparse data we were able to create a preliminary shape model with a sidereal rotational period of 6.86137 ± 0.00001 h.



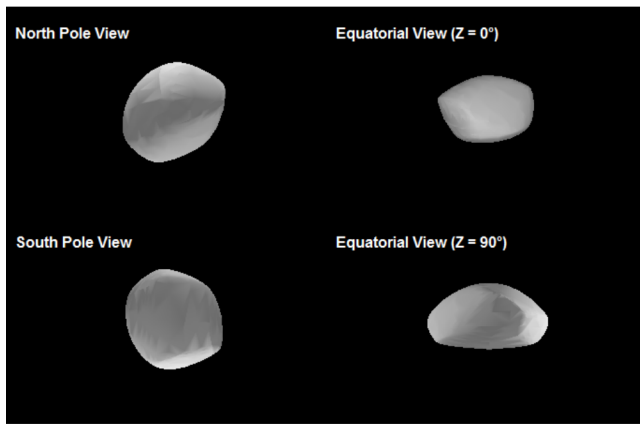
The sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (<http://hamilton.dm.unipi.it/asdys2/>). This sparse data was combined with our dense data from 2010, 2015 and 2016 using *MPO LCInvert*, (Bdw Publishing) a Windows-based program that incorporates the algorithms developed by Kallalainen *et al.* (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values.

Upon finding a period, a search for the spin pole axis is made by forcing the pole solution to one of 315 distinct longitude-latitude pairs allowing the period to “float”. This creates a plot which is an equal area projection of the ecliptic sphere. The colors range from deep blue (lowest χ^2) to red which represents χ^2 values greater than 10 percent of the lowest χ^2 solutions. In a perfect solution, there is one or two small islands of blue in a sea of reds. Often there are two solutions that differ by 180° in longitude because it is not certain when the viewing aspect at a given time is looking at the north or the south pole.

The preliminary shape model for 884 Priamus shows two possible pole solutions approximately 180° apart. The preferred solution is at 0.5° longitude and -32.3° latitude. Additional data at future oppositions should improve on this pole solution.

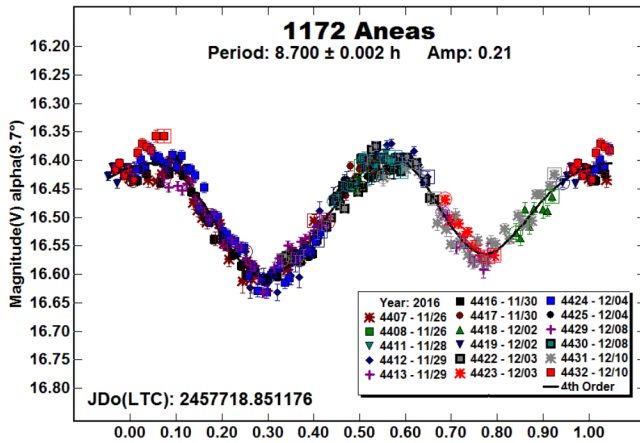


The pole search plot shows the sky in equatorial coordinates in 312 discrete regions that are $15 \times 15^\circ$. The region representing the pole solution with the lowest χ^2 value is dark blue. As the colors move from blue to green to red, the difference, in percent from the lowest χ^2 value increases. Those regions that are dark red (maroon) are $> 1.25 \times$ the lowest value.

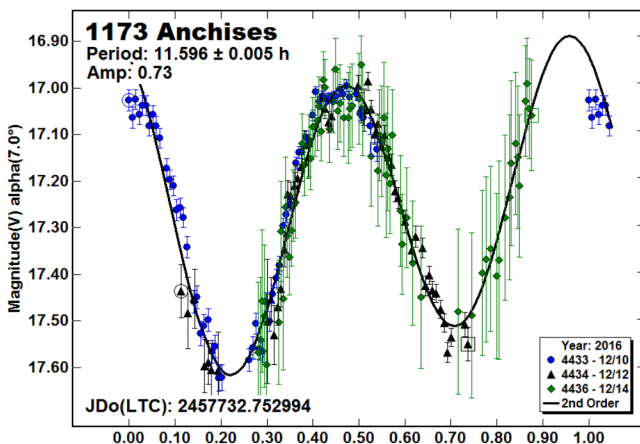


The preliminary model for 884 Priamus shows an elongation of about 1.5 to 1.

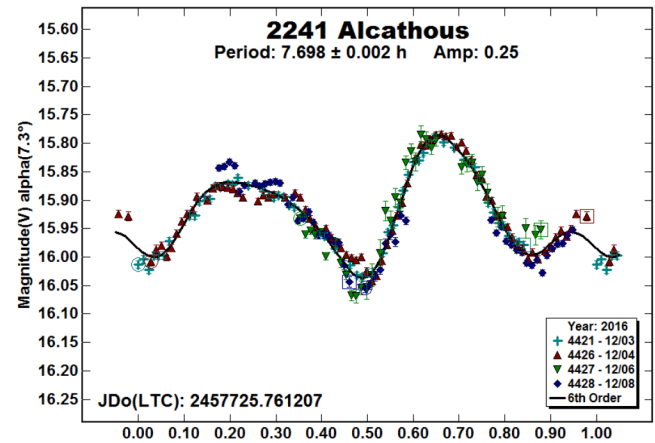
1172 Aeneas. The synodic period found using CS3 data from 2016 for this large Trojan is in good agreement with previous results (Mottola 2011, French 2011a, Stephens 2015 and 2016a). When combined with sparse data and our previous data, we were able to create a preliminary shape model with a sidereal rotational period of 8.70297 ± 0.00001 h.



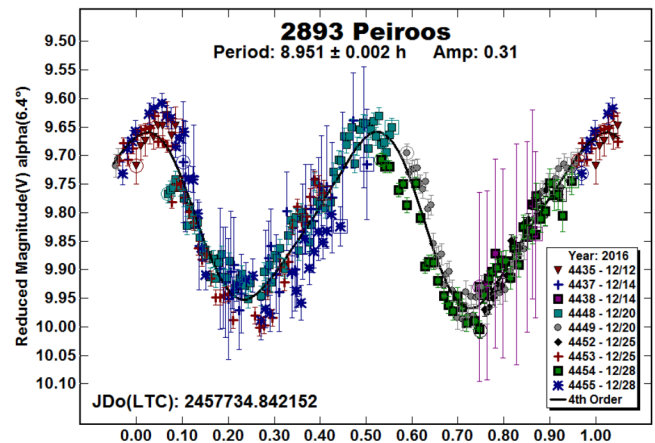
1173 Anchises. French (1987) found a synodic rotational of 11.60 h. We were able to extract the times and magnitudes from that paper and combine it with our data from last year (Stephens *et al* 2016a) and available sparse data to create a preliminary shape model and determine the sidereal period to be 11.609374 ± 0.000002 h.



2241 Alcahous. The synodic period found in 2016 using CS3 data agrees with previous synodic results (Mottola 2011, French 2011a, Stephens 2014, 2015, 2016a). The data collected this year, when combined with our previous data and available sparse data was used to create a preliminary shape model with a sidereal rotational period of 7.68988 ± 0.00001 h.



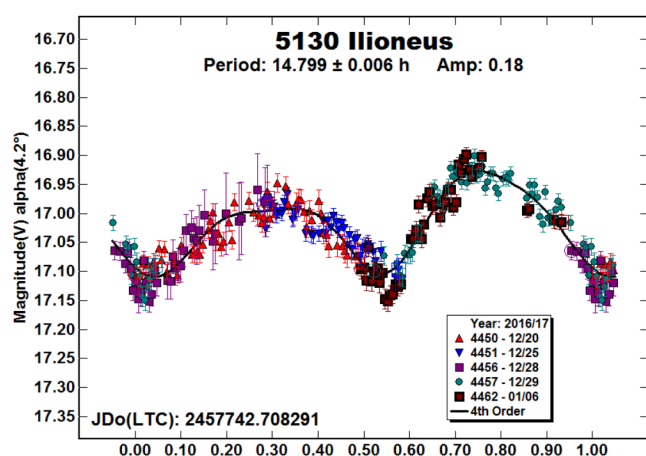
2893 Peiroos. Gonano *et al* (1991) observed this Trojan in 1989 finding a synodic rotational period of 8.96 h. We observed it last year (Stephens *et al* 2016a) finding a synodic rotational period of 8.99 h. When that data was combined with this year's data and sparse data, we were able to create a preliminary shape model with a sidereal period of 8.95310 ± 0.00001 h.



5130 Ilioneus. Mottola *et al.* (2011) observed this Trojan in 1994 reporting a synodic period of 14.768 h. Using sparse data from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a synodic rotational period of 14.7429 h. We observed it last year (Stephens *et al* 2016a) finding a synodic period of 14.783 h. This year's result is in good agreement with those previous findings, but we did not have sufficient sparse data to create a shape model.

Number	Name	2016 mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period	P.E.	Amp	A.E.	Grp
884	Priamus	11/25-12/02	211	9.5, 9.1	132	-1	6.865	0.002	0.25	0.02	TR-J
1172	Aneas	11/26-12/10	328	9.7, 9.0	164	-12	8.7	0.002	0.21	0.02	TR-J
1173	Anchises	12/10-12/14	180	7.0, 6.5	122	-2	11.596	0.005	0.73	0.04	TR-J
2241	Alcathous	12/03-12/08	225	7.3, 6.5	109	-6	7.698	0.002	0.25	0.02	TR-J
2893	Peiroos	12/12-12/25	323	6.4, 4.2	116	1	8.951	0.002	0.31	0.02	TR-J
5130	Ilioneus	12/20-01/06	249	4.2, 2.5	106	-12	14.799	0.006	0.18	0.02	TR-J

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



Acknowledgements

This research was supported by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grants AST-1210099 and AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (<http://svo2.cab.inta-csic.es/vocats/cmc15/>). The purchase of an FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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