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LIGHTCURVE ANALYSIS OF L4 TROJAN ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2021 JULY TO SEPTEMBER

Robert D. Stephens
Center for Solar System Studies (CS3) / MoreData!
11355 Mount Johnson Ct., Rancho Cucamonga, CA 91737 USA
rstephens@foxandstephens.com

Brian D. Warner
Center for Solar System Studies (CS3) / MoreData!
Eaton, CO

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Lightcurves for 11 Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2021 July to September.

For several years, the Center for Solar System Studies (CS3, MPC U81) has been conducting a study of Jovian Trojan asteroids. This paper reports CCD photometric observations of nine Trojan asteroids from the L_4 (Greek) Lagrange point and two from the L_5 (Trojan) Lagrange point from 2021 July to September.

All observations were made using a 0.4-m f/10 Schmidt-Cassegrain telescope and an FLI Proline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. The exposures were 180 seconds.

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). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs and are the "native" magnitudes of the catalog.

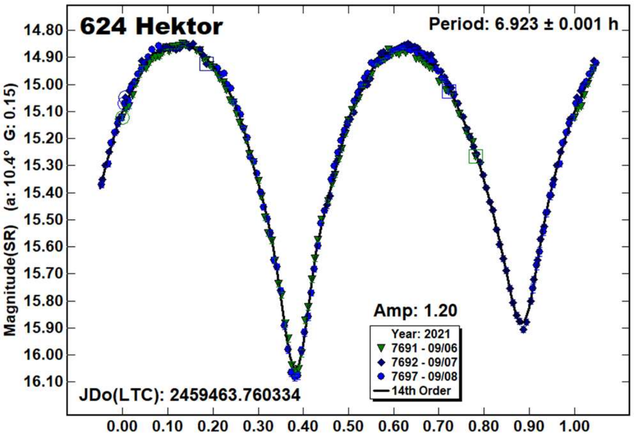
The Y-axis of lightcurves gives ATLAS SR "sky" (catalog) magnitudes. During period analysis, the magnitudes were normalized to the phase angle and value for *G* given in the parentheses. The X-axis rotational phase ranges from –0.05 to 1.05.

The amplitude indicated in the plots (e.g., Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

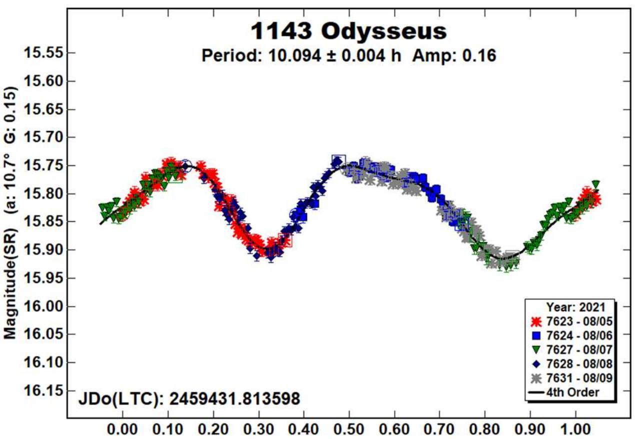
For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

<u>624 Hektor</u>. The LCDB shows that many synodic periods for Hektor were found in the past, all about 6.92 h. Hektor has also been previously found to be a binary asteroid (Marchis et al., 2006) with a primary that might have a bilobated shape approximately 350×210 km and a secondary estimated to be 15 km in size. Marchis et al. found a pole position with ecliptic coordinates of λ_1 = 332° and β_1 = –32°. Pole positions have also been independently found a number of times over the years, the latest by Hanuš et al. (2015), which is similar to the Marchis et al solution. Most of the pole solutions reported a sidereal period of 6.92051 h.

The synodic period found this year produced a classic bimodal lightcurve consistent with rotational periods found in previous years.

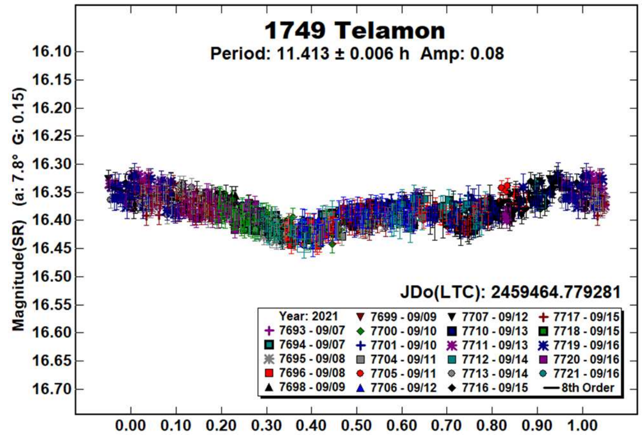


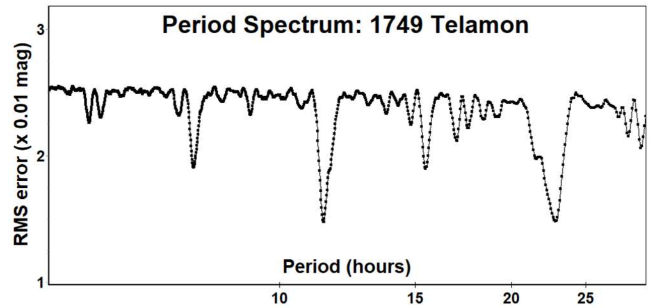
1143 Odysseus. Odysseus has been observed many times in the past. Molnar et al. (2008), Mottola et al. (2011), Shevchenko et al. (2012), Stephens et al. (2014), Waszczak et al. (2015), Ryan et al., (2017), and Szabó et al. (2017), and Stephens and Warner (2020b) each found a period near 10.11 h. The found this year is similar to those found in the past.

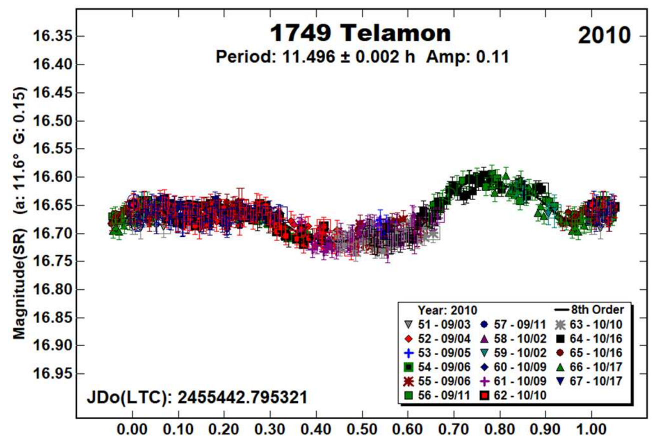


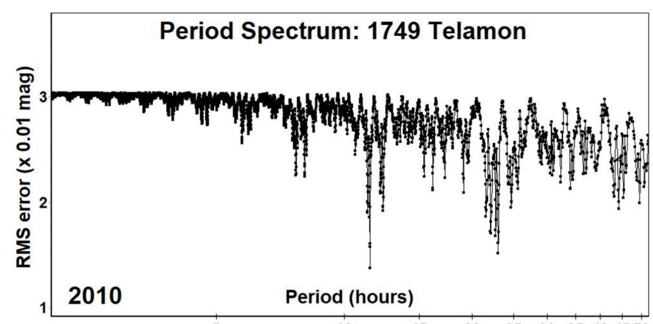
1749 Telamon. Because of its low amplitude, a period for this L_4 Trojan has been difficult to resolve in the past (Mottola et al. 2011) reported a period of 11.187 h. French et al. (2011) found a result of 16.975 h. Using data from the K2 mission of the Kepler Space Telescope, Ryan et al. (2017) found a period of 22.613 h and Szabó et al. (2017) found a period of 11.331 h or a possible 22.662 h period.

The results this year favored the 11 h period. The French et al. images obtained in 2010 were remeasured using field stars from the ATLAS catalog with careful attention to make sure that background stars were not in the measurement annulus. The remeasured 2010 data also showed a strong preference for the 11 h solution, given its asymmetric lightcurve.

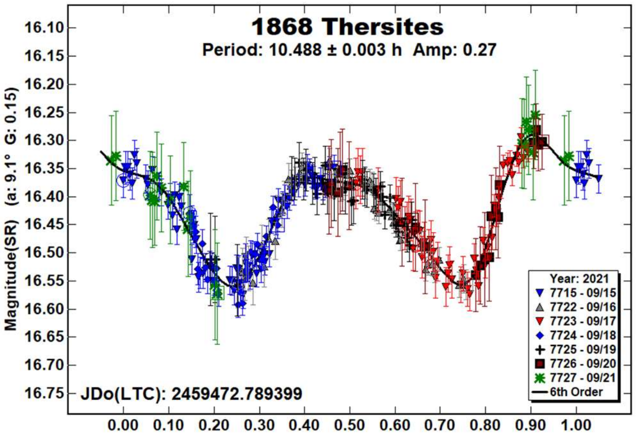




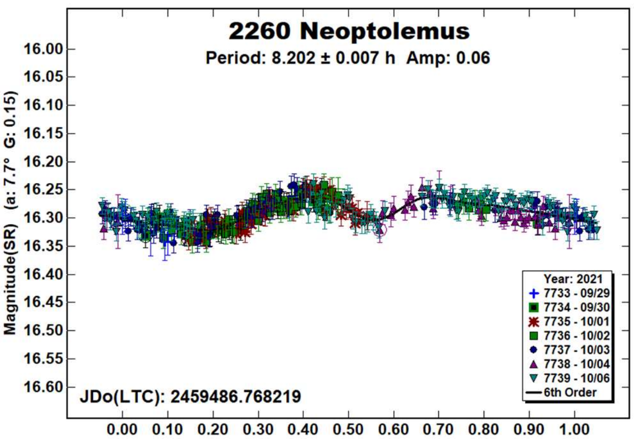




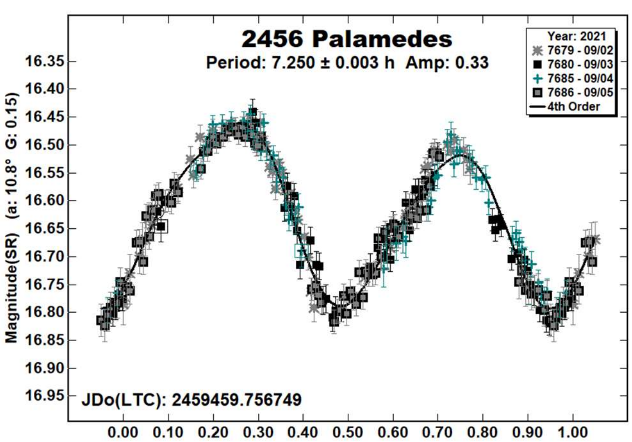
1868 Thersites. A period for this L_4 Trojan has been reported four times in the past (Stephens and Warner, 2020a; and references therein), The result this year is in good agreement with past findings.



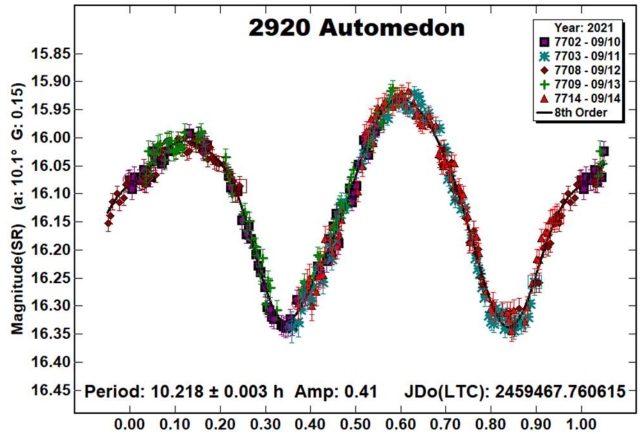
2260 Neoptolemus. A period for this L4 Trojan has been reported four times in the past. Mottola et al. (2011) reported two periods of 8.180 h. Stephens et al. (2016a and 2016b) reported periods of 8.18 h and 8.199 h. The result this year is in good agreement with those prior findings.



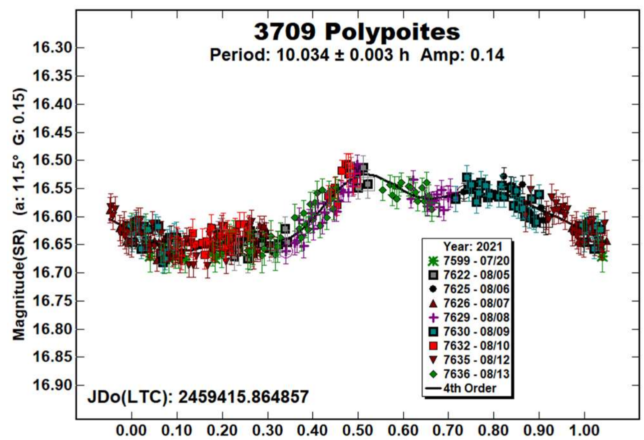
2456 Palamedes. This L4 Trojan has been observed three times in the past (Stephens and Warner, 2021; and references therein), each time finding a rotational period near 7.25 h. Our period at this opposition is in good agreement with those previous results.



2920 Automedon. The synodic period found in 2021 agrees with previous synodic results (Stephens and Warner, 2019; and references within), all of which were near 10.21 h.

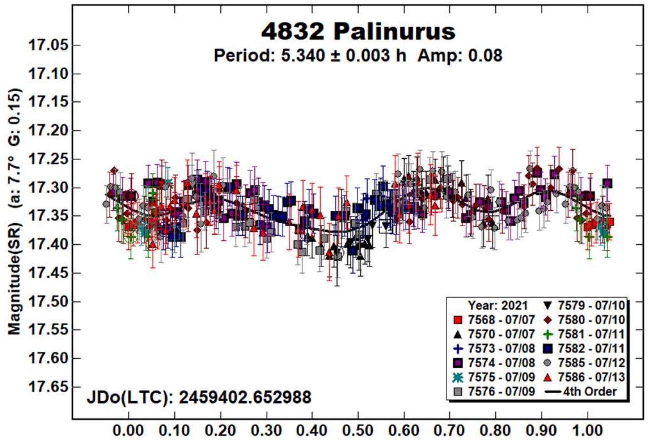


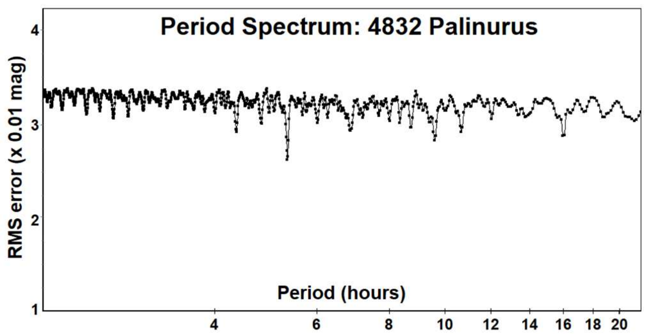
3709 Polypoites. This L4 (Greek) Trojan has been observed seven times in the past (Stephens and Warner, 2021; and references within). The result from the 2021 data is in good agreement with those previous findings.



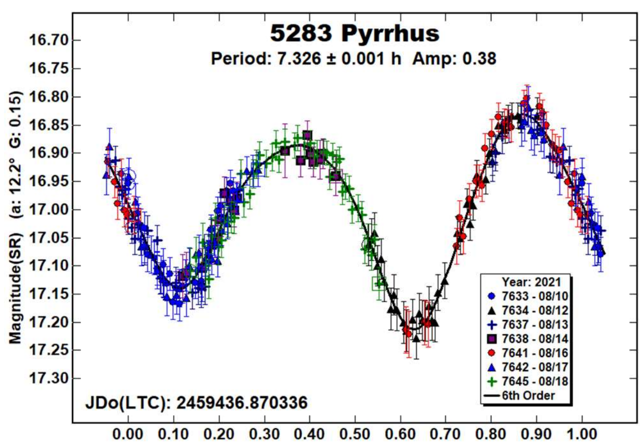
4832 Palinurus. This L5 Trojan has been observed twice in the past. Mottola et al. (2011) found a period of 5.319 h with an amplitude of 0.09 mag from a sparse bimodal lightcurve they regarded as tentative. Stephens et al. (2015) found a period of 5.85 h. However, this period is rated U=1 and is considered unreliable. In those images from 2015, a bright field star cast internal reflections throughout the field of view.

The observations in 2021 are similar in longitude to the Mottola observations from 2010 and resulted in a period of 5.342 h. As expected from the similar longitude, the amplitude of our lightcurve of 0.08 mag is also near to the Mottola result. As noted by Harris et al. (2014), given the low amplitude, a bimodal solution cannot be assumed. Our observations in 2021 have three extrema in the lightcurve. The Period Spectrum shows another frequency near 10 h, which has an unlikely five extrema in the lightcurve. The next favorable opportunity to observe Palinurus is in 2022 July when the observing geometry should give a more certain solution.

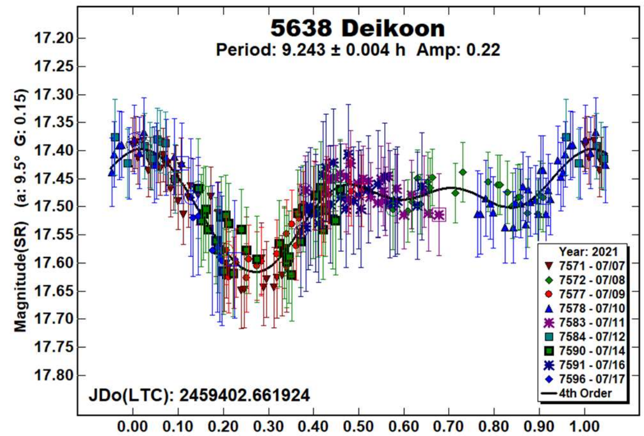


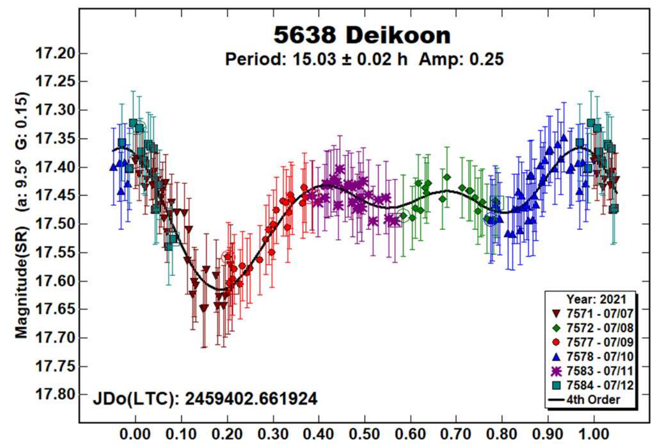


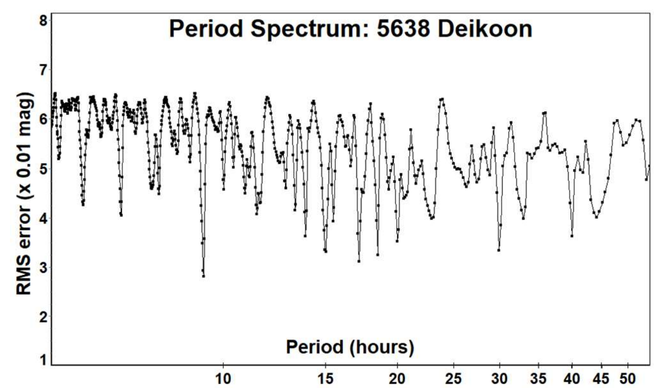
5283 Pyrrhus. A period for this L_5 Trojan has been reported only once in the past by Mottola et al. (2011), who found it rotated every 7.323 h. The result this year is in good agreement with the Mottola finding.



5638 Deikoon. This L_5 Trojan was observed twice in the past. Molnar et al. (2008), using somewhat sparse data, found a period of 19.4 h resulting in a bimodal lightcurve. Mottola et al. (2011), also with sparse data, found a period of 9.137 h based on a trimodal lightcurve. Our Period Spectrum shows the 15 and 19 h periods to be possible, but they are fit-by-exclusion. Our most likely period of 9.243 h is in agreement with the Mottola finding.







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Number	Name	2021/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
624	Hektor	09/06-09/08	10.4,10.3	49	17	6.923	0.001	1.20	0.01
1143	Odysseus	08/05-08/08	10.7,10.5	18	2	10.094	0.004	0.16	0.02
1749	Telamon	09/07-09/16	7.8,6.3	22	4	11.413	0.006	0.08	0.01
		2010/09/03-10/17	11.9,5.7	48	6	[r]11.496	0.002	0.11	0.01
1868	Thersites	09/15-09/21	9.1,8.2	36	-5	10.488	0.003	0.27	0.02
2260	Neoptolemus	09/29-10/06	7.7,6.6	41	-15	8.202	0.007	0.06	0.01
2456	Palamedes	09/02-09/05	10.8,10.5	36	13	7.250	0.003	0.33	0.02
2920	Automedon	09/10-09/14	10.1,9.6	42	5	10.218	0.003	0.41	0.02
3709	Polypoites	07/20-08/13	11.5,10.2	17	-2	10.034	0.003	0.14	0.02
4832	Palinurus	07/07-07/13	7.8,8.5	249	18	5.340	0.003	0.08	0.02
5283	Pyrrhus	08/10-08/18	12.2,11.7	26	-15	7.326	0.001	0.38	0.02
5638	Deikoon	07/07-07/17	9.5,10.7	242	12	9.243	0.004	0.22	0.03
						[a]15.03	0.02	0.25	0.03

Table I. Observing circumstances and results. [r]Restated previous period. [a]Alternative period. The phase angle is given for the first and last dates. If preceded by an asterisk, the phase angle reached an extremum during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).

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