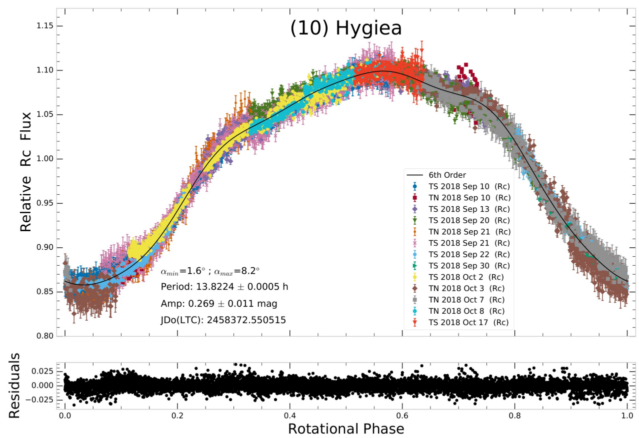

Figure 2. The lightcurve phased using the new period of 13.8224 h.

Acknowledgements

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LIGHTCURVE ANALYSIS OF L4 TROJAN ASTERIODS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2020 OCTOBER TO DECEMBER

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(Received: 2021 Jan 9)

Lightcurves for six L4 Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2020 October to December.

CCD photometric observations of six Trojan asteroids from the L_4 (Greek) Lagrange point were obtained at the Center for Solar System Studies (CS3, MPC U81). For several years, CS3 has been conducting a study of Jovian Trojan asteroids. This is another in a series of papers reporting data analysis being accumulated for family pole 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 two 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 and will be published at a later date.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

Telescope	Camera
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.40-m f/10 Schmidt-Cass	Fli Microline 1001E
0.35-m f/10 Schmidt-Cass	Fli Microline 1001E

Table I. List of telescopes and CCD cameras used at CS3.

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.

To reduce the resetting nightly zero points, we use the ATLAS r′ (SR) magnitudes. Those adjustments are mostly ≤ 0.03 mag. The occasions where larger corrections were required may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms.

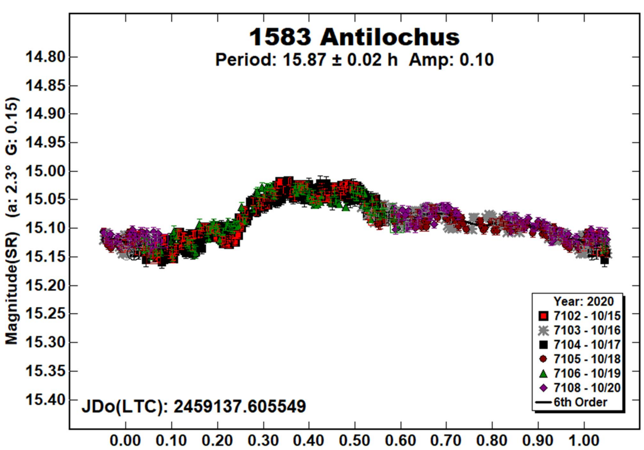
Unless otherwise indicated, the Y-axis of lightcurves gives ATLAS SR "sky" (catalog) magnitudes. During period analysis, the magnitudes were normalized to the phase angle and value for *G* given in the parentheses. The X-axis rotational phase ranges from –0.05 to 1.05.

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.

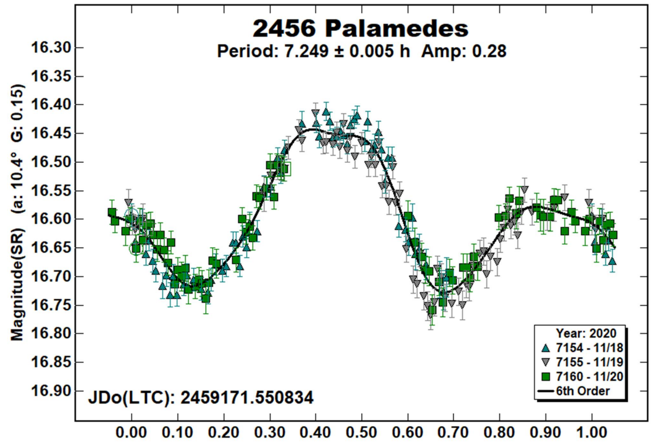
Targets selected for this L_4 observing campaign were mostly based upon the availability of dense lightcurves acquired in previous years. We obtained two to four lightcurves for most of these Trojans at previous oppositions. For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

To evaluate the quality of the data obtained and to determine how much more data might be needed, preliminary pole and shape models were created for all of these targets. Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-2 (2020) site. These sparse data were combined with our dense data as well as any other dense data found in the ALCDEF asteroid photometry database (*http://www.alcdef.org/*) using *MPO LCInvert*, (Bdw Publishing). This Windows-based program incorporates the algorithms developed by Kassalainen and Torppa (2001) and Kassalainen et al. (2001) 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.

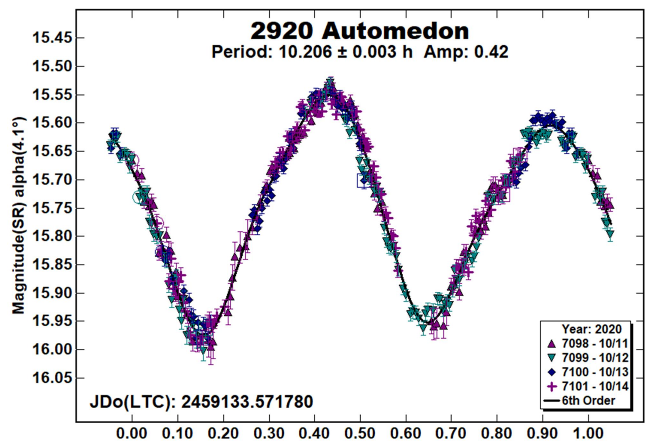
1583 Antilochus. We obtained rotational rates for this Trojan five times in the past (Stephens and Warner, 2020; and references therein), each time finding a period near 15.8 h. The 2020 results are in good agreement. In addition to our six dense lightcurves, we used sparse data from the AstDyS-2 site to find a preliminary shape model with a sidereal rotational period of 15.771329 ± 0.00001 h.



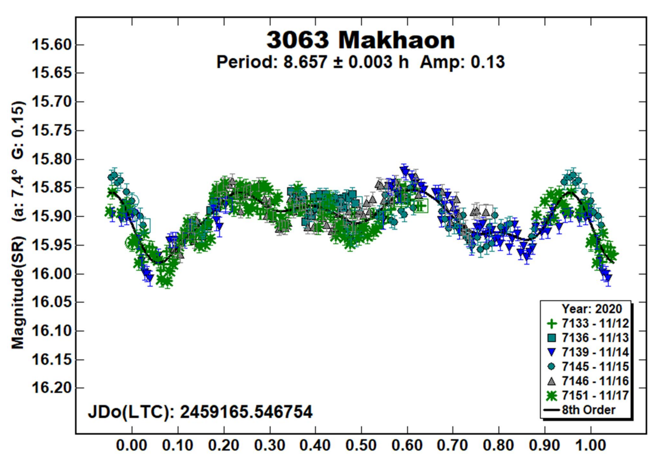
2456 Palamedes. We had only observed this Trojan once in the past (Stephens 2010), finding a rotational period of 7.24 h. Mottola et al. (2011) found a similar period of 7.258 h. Observations were made in 2020 in hope of being able to determine a shape model and pole solution. Our period is in good agreement with previous results.



2920 Automedon. We have observed this Trojan three times in the past (Stephens and Warner, 2020; and references therein). In addition to these dense lightcurves, we used sparse data from the AstDyS-2 site to create a preliminary shape model with a sidereal rotational period of 10.212444 ± 0.00001 h.



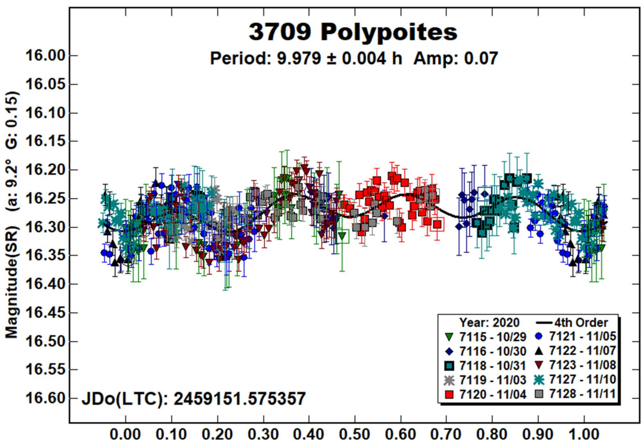
3063 Makhaon. We observed this L_4 Trojan twice in the past (French et al., 2011; Stephens et al., 2016). Mottola et al. (2011) also observed it twice. Our results from 2020 are in good agreement with those findings. Despite having only three dense lightcurves and some sparse data from the AstDyS-2 site, we were able to create a preliminary shape model with a sidereal rotational period of 8.63422 ± 0.0001 h.



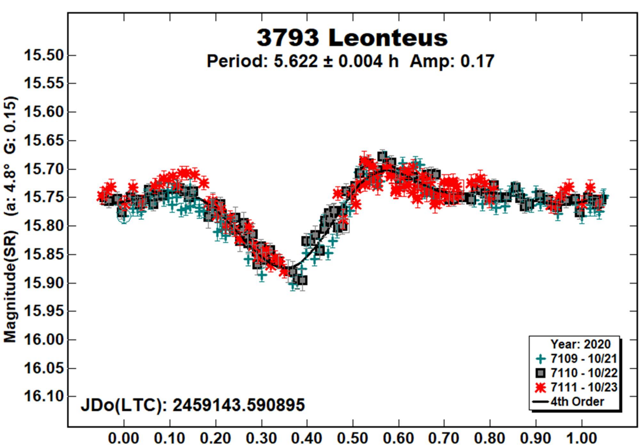
Number	Name	2020 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1583	Antilochus	10/15-10/20	2.3,2.2	25	10	15.87	0.02	0.10	0.01
2456	Palamedes	11/18-11/20	10.4,10.6	358	9	7.249	0.005	0.28	0.02
2920	Automedon	10/11-10/14	4.2,4.5	8	16	10.206	0.003	0.42	0.02
3063	Makhaon	11/12-11/17	7.4,8.0	12	13	8.657	0.003	0.13	0.01
3709	Polypoites	10/29-11/11	9.2,10.3	345	6	9.979	0.004	0.07	0.02
3793	Leonteus	10/21-10/23	4.9,5.2	5	6	5.622	0.004	0.17	0.02

Table II. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema 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).

3709 Polypoites. We have observed this Trojan six times in the past (Stephens and Warner, 2020; and references within). The result from the 2020 data is a little faster than these previous findings, no doubt noise from the nearly flat, four extrema lightcurve. Even with this slightly different period, we were able to use our seven dense lightcurves to create a preliminary shape model with a sidereal rotational period of 10.037046 ± 0.00001 h.



3793 Leonteus. This is another L_4 Trojan that we have observed six times in the past (Stephens and Warner, 2020; and references therein). Adding our seventh dense lightcurve allowed us to create a preliminary shape model with a sidereal rotational period of 5.621931 ± 0.0001 h.



Acknowledgements

Observations at CS3 and continued support of the asteroid lightcurve database (LCDB; Warner et al., 2009) are supported by NASA grant 80NSSC18K0851. This work includes data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. ATLAS is primarily funded to search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen's University Belfast, the Space Telescope Science Institute, and the South African Astronomical Observatory. The purchase of a FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar year 2020 are encouraged to report them to this author on or before 2021 April 1. This will be the deadline for receipt of reports, for which results can be included in the “General Report of Position Observations for 2020,” to be published in *MPB* Vol. 48, No. 3.

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2020 SEPTEMBER TO 2021 JANUARY

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(Received: 2021 Jan 10)

Lightcurves of 22 Near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2020 October to early 2021 January were analyzed for rotation period, peak-to-peak amplitude, and signs of satellites or tumbling.

CCD photometric observations of 22 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2020 September to early 2021 January. Table I lists the telescopes and CCD cameras that were combined to make observations.

Up to nine telescopes can be used for the campaign, although seven is more common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel.

Telescopes	Cameras
0.30-m *f*/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m *f*/9.1 Schmidt-Cass	FLI Proline 1001E
0.40-m *f*/10 Schmidt-Cass	SBIG STL-1001E
0.40-m *f*/10 Schmidt-Cass	
0.50-m *f*/8.1 Ritchey-Chrétien	

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

All lightcurve observations were unfiltered since a clear filter can cause a 0.1-0.3 mag loss. The exposure duration varied depending on the asteroid’s brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid.

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. To reduce the number of times and amounts of adjusting nightly zero points, we use the ATLAS catalog r′ (SR) magnitudes (Tonry et al., 2018). Those adjustments are usually ≤ ±0.03 mag. The rare greater corrections may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction. Another cause may be selecting what appears to be a single star but is actually an unresolved pair.

The Y-axis values are ATLAS SR “sky” (catalog) magnitudes. The two values in the parentheses are the phase angle (a) and the value of *G* used to normalize the data to the comparison stars used in the earliest session. This, in effect, had all the observations made at a single fixed date/time and phase angle, leaving any variations due only to the asteroid’s rotation and/or albedo