

References

- Đurech, J.; Tonry, J.; Erasmus, N.; Denneau, L.; Heinze, A.N.; Flewelling, H.; Vančo, R. (2020). "Asteroid models reconstructed from ATLAS photometry." *Astron. Astrophys.* **643**, A59.
- Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gytis." *Icarus* **57**, 251-258.
- JPL (2021). Small-Body Database Browser - JPL Solar System Dynamics web site. Last accessed: 11 July 2021.
<http://ssd.jpl.nasa.gov/sbdb.cgi>
- Schmadel, L.D. (2012). *Dictionary of Minor Planet Names (3rd edition)*. pp. 216, 288, 317, 807, 815. Springer, Berlin.
- Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2021 June.
<https://minplanobs.org/MPInfo/php/lcdbsummaryquery.php>
- Warner, B.D. (2016). *Collaborative Asteroid Lightcurve Link website*. Last accessed: 26 September 2018.
<http://www.minorplanet.info/call.html>
- Warner, B.D. (2017). MPO Software, *MPO Canopus* version 10.7.10.0. Bdw Publishing.
<http://www.minorplanetobserver.com/>

DETERMINING THE LIGHTCURVES AND ROTATIONAL PERIODS OF FIVE MAIN BELT ASTEROIDS

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Lightcurves and rotational periods were determined for the following five main belt asteroids: 3942 Churivannia, 2.516 ± 0.002 h; 4673 Bortle, 2.643 ± 0.001 h; 5186 Donalu, 3.154 ± 0.001 h; 8441 Laponica, 3.285 ± 0.001 h; and 12259 Szukalski, 5.986 ± 0.001 h.

Introduction

The objective of this research was to determine the rotational periods for the following five asteroids: 3942 Churivannia, 4673 Bortle, 5186 Donalu, 8441 Laponica, and 12259 Szukalski, by plotting their lightcurves derived from photometric data taken over several nights. These lightcurves were analyzed to determine the asteroid's rotational period and from the shape of the lightcurve create a possible model of the asteroid.

Asteroid 3942 Churivannia was discovered by Chernykh, N. at the Crimean Astrophysical Observatory in 1977. It has an orbital eccentricity of 0.197 and a semi-major axis of 2.39 AU (JPL). Asteroid 4673 Bortle was discovered by Shoemaker, C.S. at the Palomar Observatory in 1988. The asteroid has an orbital eccentricity of 0.057 and a semi-major axis of 2.55 AU (JPL). Asteroid 5186 Donalu was discovered by Roman, B. at the Palomar Observatory in 1990. It has an orbital eccentricity of 0.084 and a semi-major axis of 2.58 AU (JPL). Asteroid 8441 Laponica was discovered by C.J. van Houten and I. van Houten-Groeneveld at the Palomar Observatory in 1977. It has an orbital eccentricity of 0.139 and a semi-major axis of 2.19 AU (JPL). Asteroid 12259 Szukalski was discovered by E.W. Elst at the European Southern Observatory in 1989. It has an orbital eccentricity of 0.161 and a semi-major axis of 2.19 AU (JPL).

Asteroids were selected through the website which catalogs all known asteroids (CALL). The asteroid's apparent magnitude, declination, and opposition date, were the criterion used to choose these asteroids. Asteroids at or near opposition were chosen to ensure the maximum amount of data each night. For the ideal signal to noise ratio, asteroids with magnitude of 16 or brighter were chosen. When observing asteroids in the northern hemisphere, asteroids with more positive declinations were chosen and when observing in the southern hemisphere, asteroids with more negative declinations were chosen.

Method

Two different telescopes were used to observe the asteroids. One telescope was the Texas A&M University-Commerce 0.7-m CDK 700 Planewave telescope equipped with an Andor iKon-XL CCD Camera located in Commerce, TX at a latitude of 33°N. The CCD camera was thermoelectrically cooled to -40°C to reduce background noise. The other telescope was part of the Southern Associate for Research in Astronomy (SARA) consortium. The SARA-CT 0.6-m telescope is also equipped with an Andor Ikon CCD Camera located in the southern hemisphere at the Cerro Tololo Observatory in Chile at a latitude of 30°S. The camera was cooled to -85°C to reduce background noise.

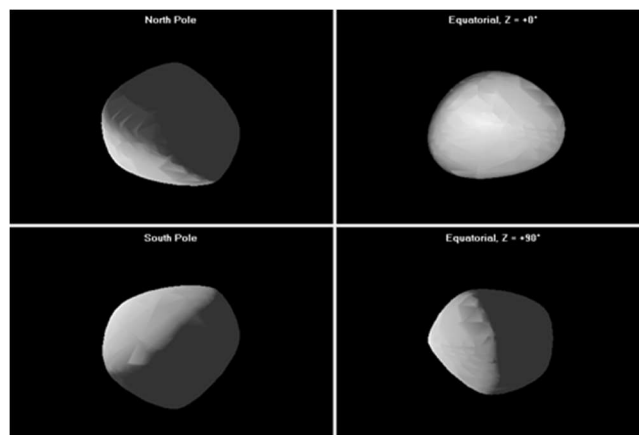
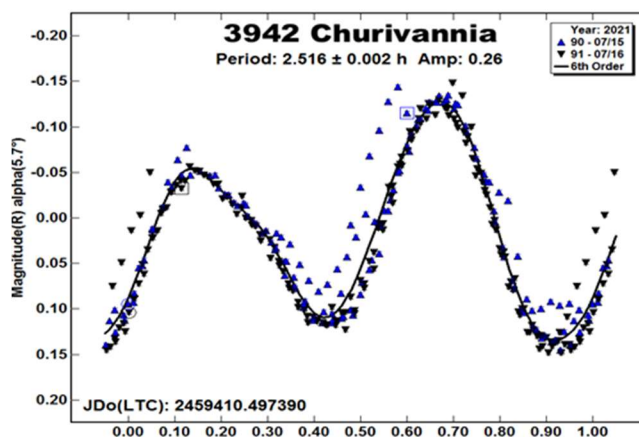
To calibrate the images, dark, flat, and bias frames were obtained at the beginning of each night. Dark frames were taken using the same exposure length as the respective light images, three minutes for each telescope. Flat field images were taken against the twilight sky at exposure times between five and thirty seconds were used. The flat field images were used to correct for anomalies in the optical path and non-uniformities across the chip. Both telescopes had a luminance filter between the telescope and camera. The luminance filter transmits most of the visible light from the target but blocks the infrared.

Images were reduced and aligned using the software *MaxIm DL* (Diffraction Limited). Once the images were reduced, the program *MPO Canopus v.10.3.0.0*. (Warner, 2011) was used to perform differential photometry. For each night of observations, five comparison stars were chosen within each of the images. Aperture photometry was then used to determine the brightness of the asteroid and the comparison stars. The average difference in mag. between the stars and asteroids was found for each image and then plotted versus time, to produce a lightcurve. When the asteroid passed a nearby star those observations were deleted from the lightcurve. A Fourier transform was then applied to the lightcurve to determine the asteroid's rotational period and associated error.

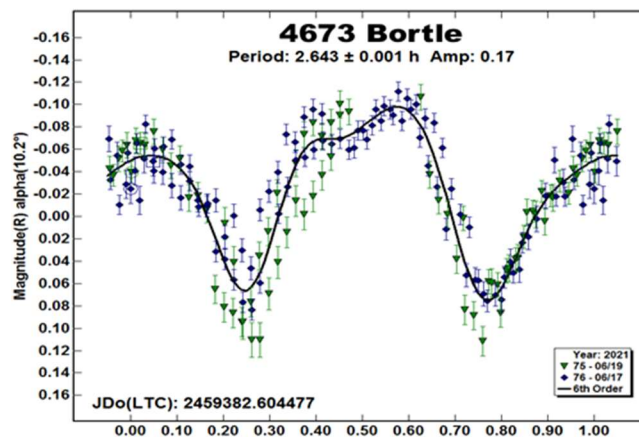
The processed lightcurve files were then exported into *MPO LCInvert* (Warner, 2011) to create notional 3D models for all five asteroids. The reduced and light-time corrected *MPO Canopus* files were converted into "Kaasalainen files" since they have a specific format utilized by the inversion algorithms of the program. A search was done with *MPO LCInvert* for the rotational period with the lowest chi-squared value, indicating the best period. For all five asteroids, the rotational periods found for the 3D models were within 0.01 hours of the original lightcurve periods. However, despite the seemingly accurate depiction of the 3D models, limited solar phase angle variations and limited ecliptic longitude coverage in the data means these shape models are simply initial estimates to encourage future observations. We can expect that these models may be subject to significant revision as more data become available.

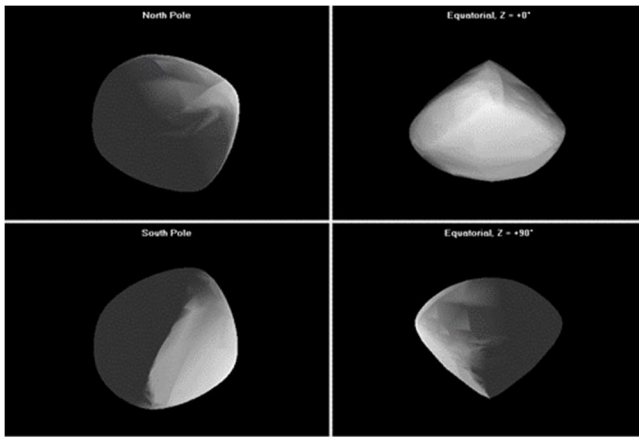
Results

3942 Churivannia was imaged 170 times on 2021, July 15, and 172 times on 2021, July 16. Both nights used the SARA-CT telescope and the data resulted in a rotational period of 2.526 ± 0.002 h with an amplitude variance of 0.26 mag. No previous studies regarding the rotation period were found in either the JPL Small-Body Database or the Minor Planet Light Curve Database.

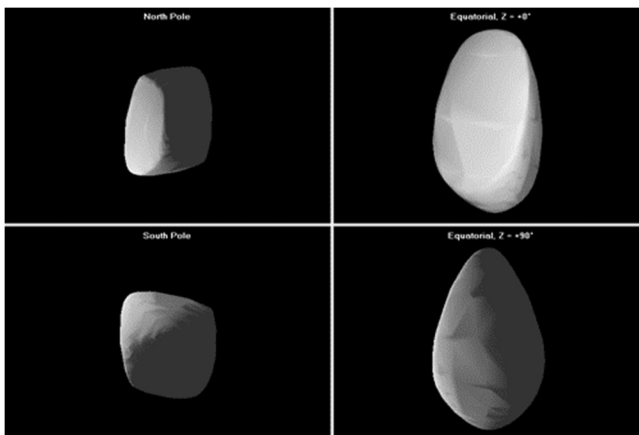
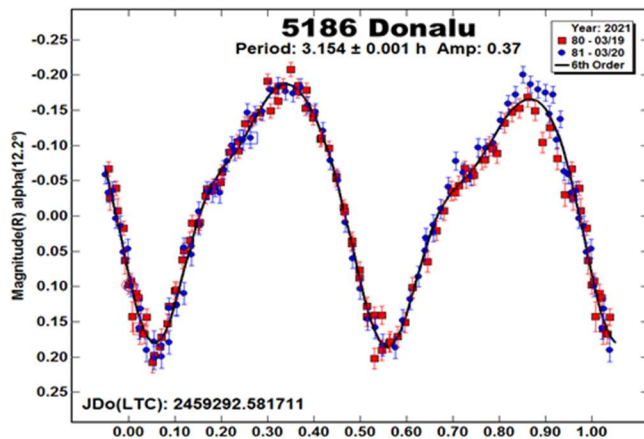


4673 Bortle Asteroid 4673 Bortle was imaged 101 times on 2021, June 17, and 97 times on 2021, June 19. Both nights used the TAMUC telescope and the data resulted in a rotational period of 2.643 ± 0.001 h with an amplitude variance of 0.17 mag. Behrend (2008web) found a similar period of 2.639 ± 0.00002 h with an amplitude of 0.16 mag. Kim et al. (2014) found a similar period of 2.64 ± 0.01 h with an amplitude of 0.16 mag. Behrend (2016web) found a similar period of 2.639 ± 0.0006 h with an amplitude of 0.15 mag. Pal et al. (2020) found a similar period of 2.640 ± 0.00005 h with an amplitude of 0.09 mag.

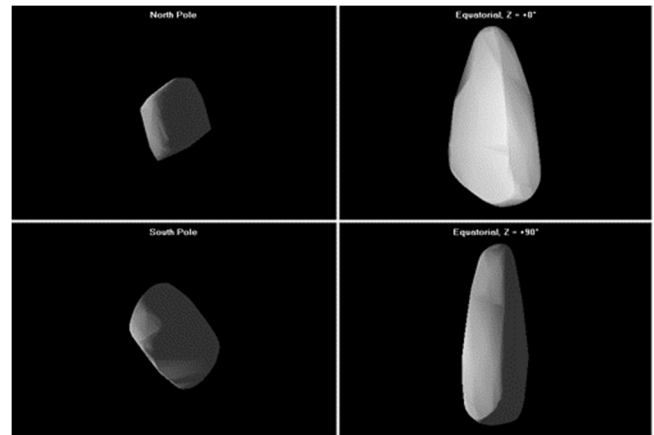
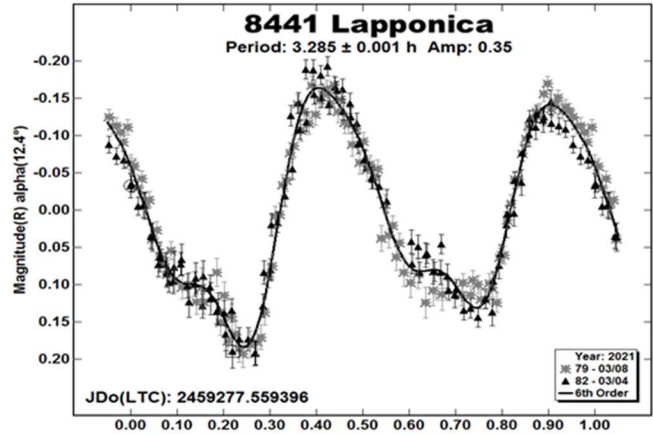




5186 Donalu was imaged 106 times on 2021, March 19, and 96 times on 2021, March 20. Both nights used the TAMUC telescope and the data resulted in a rotational period of 3.154 ± 0.001 h with an amplitude variance of 0.37 mag. Casalnuovo (2016) found a similar period of 3.15 ± 0.01 h with an amplitude of 0.25 mag. Benishek (2020) found a similar period of 3.153 ± 0.001 h with an amplitude of 0.36 mag. Durech et al. (2020) also found a similar period of 3.153 ± 0.000005 h.



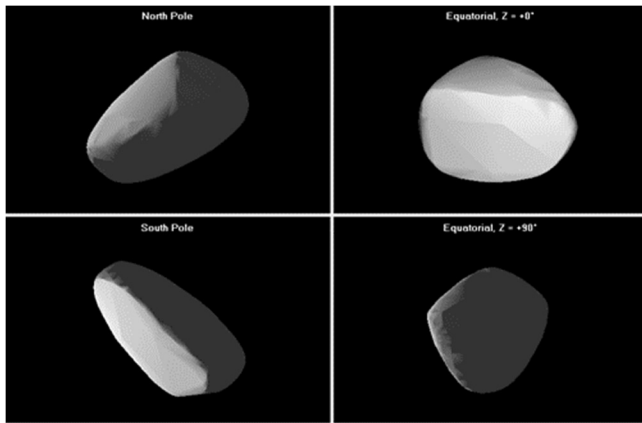
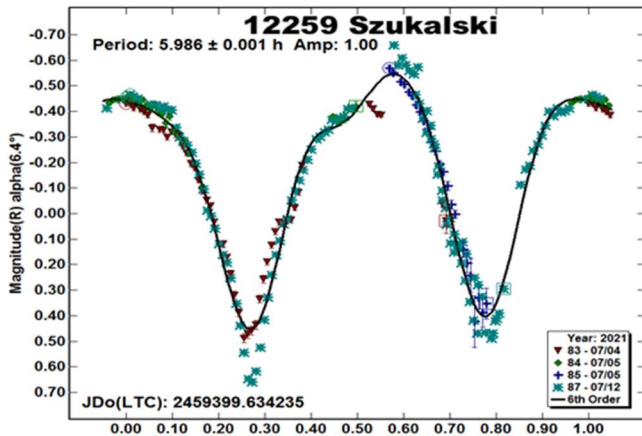
8441 Lapponica was imaged 120 times on 2021, March 4, and 125 times on 2021, March 8. Both nights used the TAMUC telescope and a rotational period of 3.285 ± 0.001 h was found with an amplitude variance of 0.35 mag. Behrend (2008web) found a similar period of 3.270 ± 0.01 h with an amplitude of 0.29 mag. Clark (2008) found a similar period of 3.275 ± 0.001 h with an amplitude of 0.50 mag. Benishek (2021) found a similar period of 3.285 ± 0.0003 h with an amplitude of 0.38 mag.



12259 Szukalski was imaged 91 times on 2021, July 4, and 98 times on 2021, July 5 both nights using the TAMUC telescope and it was also imaged 150 times on 2021, July 12 using the SARA-CT telescope. The data resulted in a rotational period of 5.986 ± 0.001 h with an amplitude variance of 1.00 mag. No previous studies regarding the rotational period were found either in the JPL Small-Body Database or the Minor Planet Light Curve Database.

Number	Name	2021 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3942	Churivannia	2021 07/15-07/16	5.65, 5.93	289.1	-7.1	2.516	0.002	0.26	0.01	MB-I
4673	Bortle	2021 06/17-06/19	9.55, 10.18	247.9	11.2	2.643	0.001	0.17	0.02	MAR
5186	Donalu	2021 03/19-03/20	12.18, 12.54	150.8	-1.1	3.154	0.001	0.37	0.01	MB-I
8441	Lapponica	2021 03/04-03/08	10.21, 12.43	150.1	6.3	3.285	0.001	0.35	0.03	MB-I
12259	Szukalski	2021 07/05-07/11	6.10, 9.04	277.6	5.6	5.986	0.001	1.00	0.02	MB-I

Table I. 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). Grp is the asteroid family/group (Warner et al., 2009). Additional data is from *MPO Canopus v10.3.0.0*. (Warner, 2011).



Acknowledgements

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References

- Behrend, R. (2008web, 2016web) Observatoire de Geneve web site. http://obswww.unige.ch/~behrend/page_cou.html
- Benishek, V. (2020). "Photometry of 39 Asteroids at Sopot Astronomical Observatory: 2019 September - 2020 March." *Minor Planet Bulletin* **47**, 231-241.
- Benishek, V. (2021). "Lightcurve and Rotation Period Determinations for 25 Asteroids." *Minor Planet Bull.* **48**, 280-285.
- Casalnuovo, G.B. (2016). "Lightcurve Analysis for Nine Main Belt Asteroids." *Minor Planet Bulletin* **43**, 112-115.
- Clark, M. (2008). "Asteroid Lightcurve Observations." *Minor Planet Bulletin* **35**, 152-154.
- Collaborative Asteroid Lightcurve Link (CALL): Potential Lightcurve Targets. http://www.minorplanet.info/PHP/call_OppLCDBQuery.php
- Diffraction Limited MaxIm DL - Astronomy and Scientific Imaging Software. <https://diffractionlimited.com/product/maxim-dl/>
- Durech, J.; Tonry, J.; Erasmus, N.; Denneau, L.; Heinze, A.N.; Flewelling, H.; Vanco, R. (2020). "Asteroid models reconstructed from ATLAS photometry." *Astron. Astrophys.* **643**, A59, 5 pp.
- Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.
- JPL Small-Body Database Browser. <http://ssd.jpl.nasa.gov/sbdb.cgi#top>
- Kim, M.-J.; Choi, Y.-J.; Moon, H.-K. and 13 colleagues (2014). "Rotational properties of the maria asteroid family." *Astron. J.* **147**, A56.
- Minor Planet Light Curve Database (LCDB). <https://minplanobs.org/MPInfo/php/lcdbsummaryquery.php>
- Pal, A.; Szakats, R.; Kiss, C.; Bodi, A.; Bognar, Z.; Kalup, C.; Kiss, L.L.; Marton, G.; Molnar, L.; Plachy, E.; Sárneczky, K.; Szabo, G.M.; Szabo, R. (2020). "Solar System Objects Observed with TESS - First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey." *Ap. J. Supl. Ser.* **247**, id.26.
- Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2021 June. <http://www.minorplanet.info/lightcurvedatabase.html>
- Warner, B.D. (2011). MPO Canopus software Version 10.3.0.0. Bdw Publishing. <http://www.minorplanetobserver.com/>