

DETERMINING THE ROTATIONAL PERIODS AND LIGHTCURVES OF MAIN BELT ASTEROIDS

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(Received: 2020 Feb 21 Revised: 2020 March 20)

Lightcurves and rotational periods are presented for six main-belt asteroids. The rotational periods determined are 970 Primula (2.777 ± 0.001 h), 1103 Sequoia (3.1125 ± 0.0004 h), 1160 Illyria (4.103 ± 0.002 h), 1188 Gothlandia (3.52 ± 0.05 h), 1831 Nicholson (3.215 ± 0.004 h) and (11230) 1999 JV57 (7.090 ± 0.003 h).

The purpose of this research was to create lightcurves and determine the rotational periods of six asteroids: 970 Primula, 1103 Sequoia, 1160 Illyria, 1188 Gothlandia, 1831 Nicholson and (11230) 1999 JV57. Asteroids were selected for this study from a website that catalogues all known asteroids (CALL). For an asteroid to be chosen in this study, it has to meet the requirements of brightness, declination, and opposition date. For optimum signal to noise ratio (SNR), asteroids of apparent magnitude of 16 or lower were chosen. Asteroids with positive declinations were chosen due to using telescopes located in the northern hemisphere. The data for all the asteroids was typically taken within two weeks from their opposition dates. This would ensure a maximum number of images each night.

Asteroid 970 Primula was discovered by Reinmuth, K. at Heidelberg in 1921. This asteroid has an orbital eccentricity of 0.2715 and a semi-major axis of 2.5599 AU (JPL). Asteroid 1103 Sequoia was discovered in 1928 by Baade, W. at Bergedorf. This asteroid has an orbital eccentricity of 0.0945 and a semi-major axis of 1.9339 AU (JPL). Asteroid 1160 Illyria was discovered in 1929 by Reinmuth, K. at Heidelberg. This asteroid has an orbital eccentricity of 0.1169 and a semi-major axis of 2.5606 AU (JPL). Asteroid 1188 Gothlandia was discovered in 1930 by Comas Sola, J. at Barcelona. This asteroid has an orbital eccentricity of 0.1807 and a semi-major axis of 2.1902 AU (JPL). Asteroid 1831 Nicholson was discovered in 1968 by Wild, P. at Zimmerwald. This asteroid has an orbital eccentricity of 0.1279 and a semi-major axis of 2.2392 AU (JPL). Asteroid (11230) 1999 JV57 was discovered by LINEAR at Socorro in 1999. This asteroid has an orbital eccentricity of 0.1378 and a semi-major axis of 2.1777 AU (JPL).

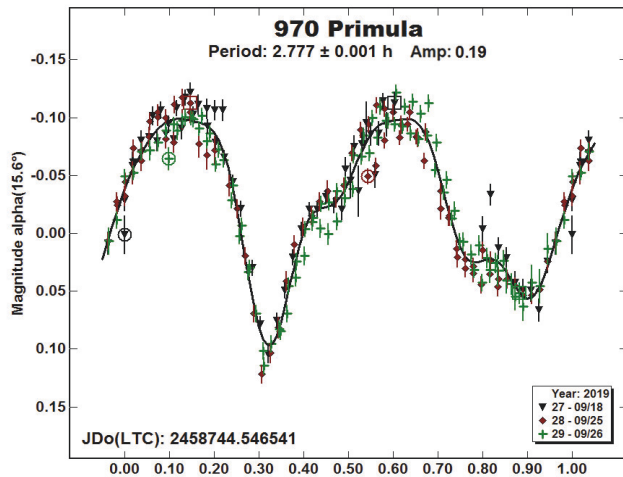
Two different telescopes were used to collect data for this research. The first one is part of the Southeastern Association for Research in Astronomy (SARA). The SARA-ORM 1.0-m telescope is equipped with an Andor Ikon-L CCD camera and is located at the Observatorio de Roque de los Muchachos located on the island of La Palma in the Canary Isles. The second telescope used was the Texas A&M University-Commerce (TAMUC) 0.7-m telescope equipped with an Andor Ikon-L CCD Camera located at the Research Observatory in Commerce, Texas.

In order to calibrate the CCD images, a set of flats, bias, and dark calibration images were taken each night. The flat field images were taken against the twilight sky at exposures of five to fifteen seconds to ensure proper signal to noise ratio and no shutter artifacts. The darks were exposed for the same time as the

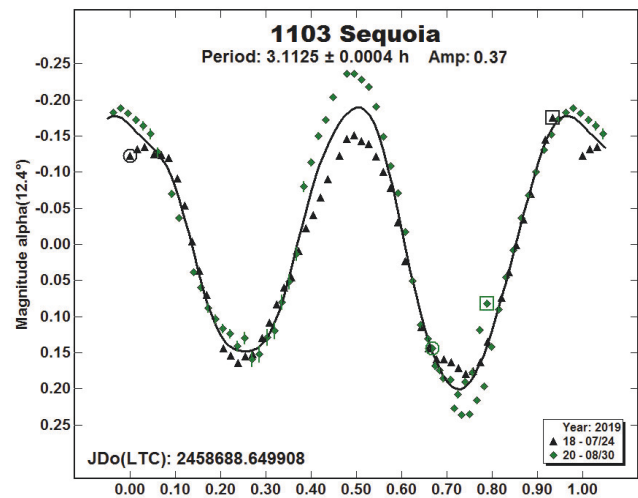
respective light images, with exposures ranging from two minutes to three minutes. The filter used for the SARA-ORM telescope was an IR-blocking and the one for TAMUC telescope was a luminance filter. Both filters transmit the visible portion of the spectrum but block the infrared.

The astronomical software *MaxIm DL* was used to reduce and align all the images to correct for minor image shifts. Afterwards, the program *MPO Canopus v10.2.1.0* (Warner, 2011) was used to perform differential photometry on the reduced data. For each reduced image, five stars were used for brightness comparison to the asteroid. Aperture photometry was used to determine the brightness of these comparison stars and the asteroid. The average of the difference in brightness between the stars and the asteroid was found for each image and then plotted versus time to create a lightcurve. A Fourier transform was then applied to the lightcurve to determine the rotational period and associated error.

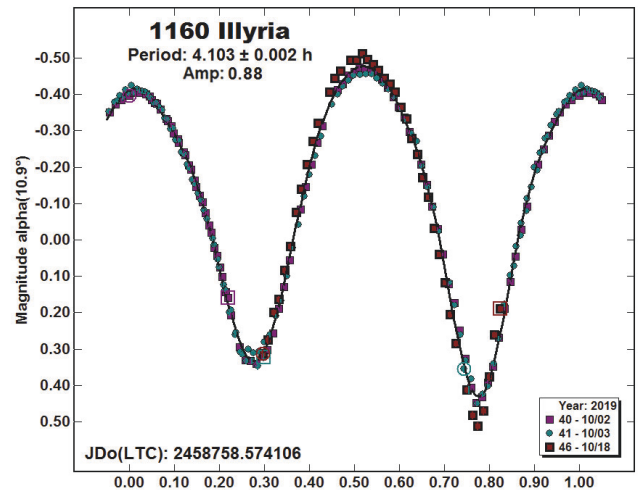
970 Primula. The asteroid 970 Primula was imaged 86 times on 2019, September 18, 82 times on 2019, September 25, and 97 on 2019, September 26. All three nights used the TAMUC telescope and the data resulted in a rotational period of 2.777 ± 0.001 h with an amplitude of 0.19 mag. A previous study found a similar rotation period of 2.777 h with an amplitude of 0.18 mag (Sada et al., 2004).



1103 Sequoia. The asteroid 1103 Sequoia was imaged 68 times on 2019, July 24 and 67 times on 2019, August 30. Both nights used the TAMUC telescope and the data resulted in a rotational period of 3.1125 ± 0.0004 h with an amplitude of 0.37 mag. A previous study found a similar rotation period of 3.04 h with an amplitude of 0.34 mag (Lecrone et al., 2004).



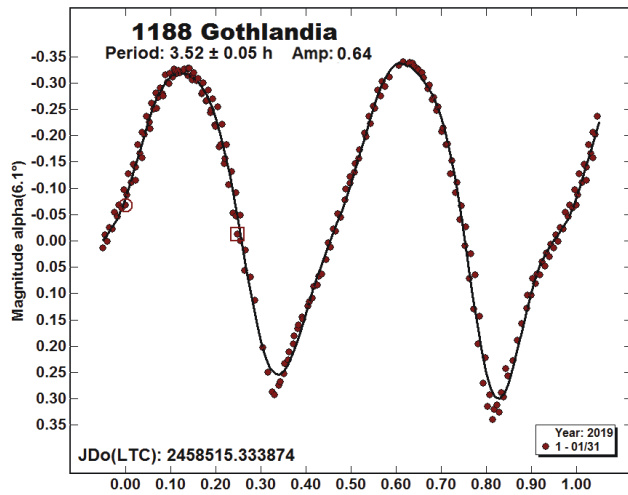
1160 Illyria. The asteroid 1160 Illyria was imaged 92 times on 2019, October 2, 120 times on 2019, October 3, and 42 times on 2019, October 18. All three nights used the TAMUC telescope and the data resulted in a rotational period of 4.103 ± 0.002 h with an amplitude of 0.88 mag. A previous study found a similar rotation period of 4.1040 h with an amplitude of 0.58 mag (Bennefeld, et al., 2009).



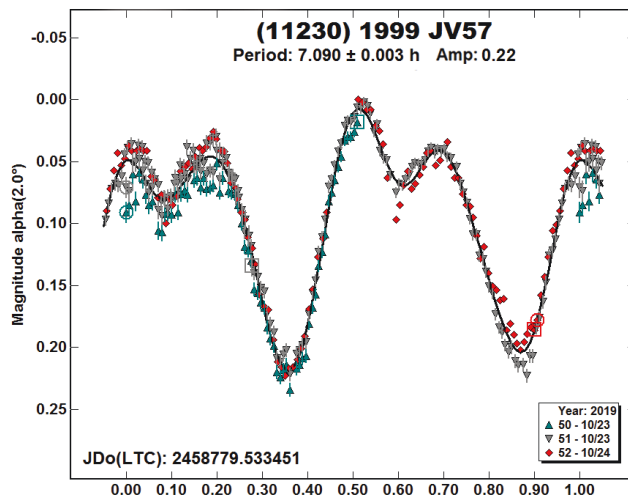
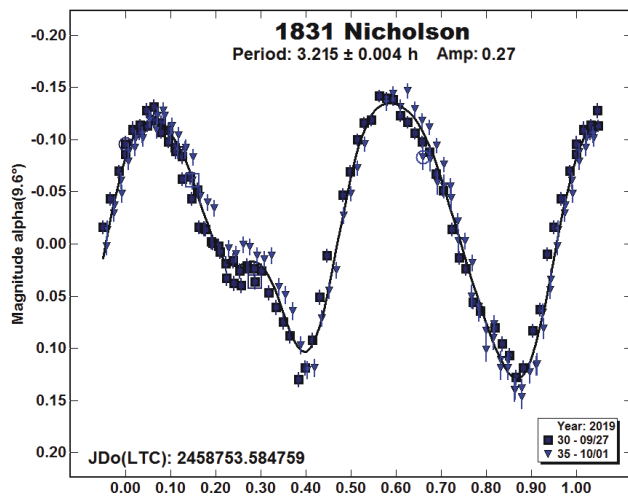
1188 Gothlandia. The asteroid 1188 Gothlandia was imaged 200 times on 2019, January 31. This night used the SARA-ORM telescope and the data resulted in a rotational period of 3.52 ± 0.05 h with an amplitude of 0.64 mag. A previous study found a similar rotation period of 3.4916 h with an amplitude of 0.59 mag (Baker et al., 2012).

Number	Name	2019 mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
970	Primula	09/18-09/26	15.4, 18.8	327	+2.9	2.777	0.001	0.19	0.03	MB-I
1103	Sequoia	07/24-08/30	12.3, 28	295	+16.6	3.1125	0.0004	0.37	0.04	H
1160	Illyria	10/02-10/18	10.8, 17.3	349	-2.6	4.103	0.002	0.88	0.02	EUN
1188	Gothlandia	01/31	6.0	121	+5.8	3.52	0.05	0.64	0.02	FLOR
1831	Nicholson	09/27-10/01	9.5, 11.2	384	-7.6	3.215	0.004	0.27	0.03	FLOR
11230	1999 JV57	10/23-10/24	1.9, 2.5	27	-0.7	7.090	0.003	0.22	0.02	

Table I. Observing circumstances and results. The phase angle is given for the first and last date. 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). Some data is from the JPL SBN website (JPL, 2017). Additional data is from *MPO Canopus v10.2.1.0* (Warner, 2011).



1831 Nicholson. The asteroid 1831 Nicholson was imaged 82 times on 2019, September 27 and 90 times on 2019, October 1. Both nights used the TAMUC telescope and the data resulted in a rotational period of 3.215 ± 0.004 h with an amplitude of 0.27 mag. A previous study found a similar rotation period of 3.2551 h with an amplitude of 0.27 mag (Benishek, 2016).



(11230) 1999 JV57. The asteroid 11230 1999 JV57 was imaged 172 times on 2019, October 23 and 116 times on 2019, October 24. The first night used the TAMUC telescope and the second night used the SARA-ORM telescope. This data resulted in a rotational period of 7.090 ± 0.003 h with an amplitude of 0.22 mag. An investigation of the lightcurve database showed no previous lightcurve data (LCDB). A search of JPL's Small Body Database also produced no other lightcurve data on this asteroid (JPL).

Acknowledgements

This research used observations from the SARA Observatory 1.0-m telescope at the Observatorio de Roque de los Muchachos located in the Canary Isles, which is owned by the Southeastern Association for Research in Astronomy at saraobservatory.org. One of the authors (S.G.) would like to give a special thanks to Kent Montgomery at Texas A&M University-Commerce for the continued support and the necessary training of the TAMUC telescope; he also provided the training of the multiple software programs listed. This author would like to also give a special thanks to Cristo Sanchez at Texas A&M University-Commerce for the training of how to operate the SARA-ORM telescope.

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