

LIGHTCURVE ANALYSIS OF MAIN-BELT ASTEROIDS FROM BMO AND DRO IN 2016: I

Julian Oey

Blue Mountains Observatory (MPC Q68)
94 Rawson Pde. Leura, NSW, AUSTRALIA
julianoey1@optusnet.com.au

Roger Groom

Darling Range Observatory
Perth, West Australia

(Received: 2018 Jun 30)

Photometric observations of selected asteroids were done from Blue Mountains Observatory (BMO) and Darling Range Observatory (DRO) in 2016. The observations were made during a favorable apparition for each asteroid as part of the Photometric Survey of Asynchronous Binary Asteroids (PSABA) program.

CCD photometric observations of several asteroids were made in 2016 from Blue Mountains Observatory by Oey and supported by Groom at Darling Range Observatory. Five telescope systems were used for the observations (Table I). Further information of the instruments used at BMO can be found at BMO (2016). Table II shows the absolute magnitude (H) and the instruments used for each asteroid.

Obs	Scope	Ap (m)	f	Camera	Pixel	Bin	Scale
DRO	D12	0.30	7.4	ST-8XME	9.0	1x1	0.84
BMO	B14	0.35	6.0	ST-8XME	9.0	1x1	0.88
BMO	B5	0.12	7.5	ST-8300M	5.4	3x3	3.51
BMO	B24	0.61	6.8	U42	13.5	1x1	0.70
BMO	B14E	0.35	11	U6	24	1x1	1.28

Table I. Equipment specifications. The Scope column gives the code used in Table II. Pixels sizes are in microns. The Scale is arcsec/pixel. BMO = Blue Mountains Observatory. DRO = Darling Range Observatory.

Number	H	Group	Comment
832	8.30	MB-O	B5, B12
910	10.50	MB-O	B5, B14
1741	11.50	MB-O	B24
2827	12.10	MB-I	B24, D12
2656	13.30	MB-F	B14
2956	12.10	MB-O	B24
3002	12.80	MB-F	B24, B14
3363	12.10	MB-O	B24
3738	12.90	MB-I	B24, B14
4022	13.10	MB-V	B14, D12
5129	13.06	MB-I	B14, B24, D12

Table II. The H values are from the MPC. The orbital groups are from the LCDB (Warner et al., 2009a). MB-I/O = Main-belt Inner/Outer, -V = Vestoid, -F = Flora

Unless otherwise specified, all images were taken unfiltered with exposures of 300 s to maximize SNR but at the same time provide sufficient data point frequency for most main-belt asteroid rotation periods.

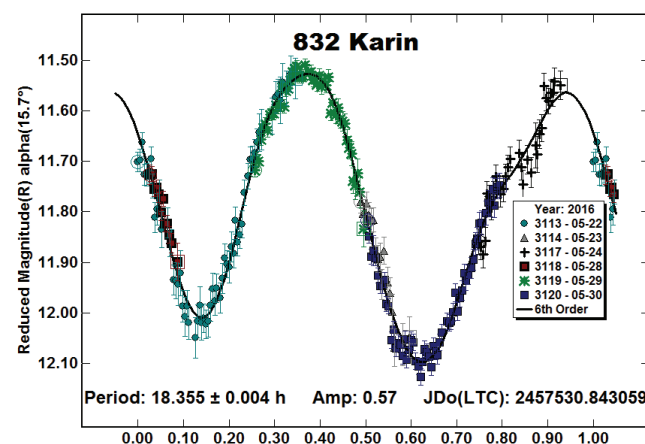
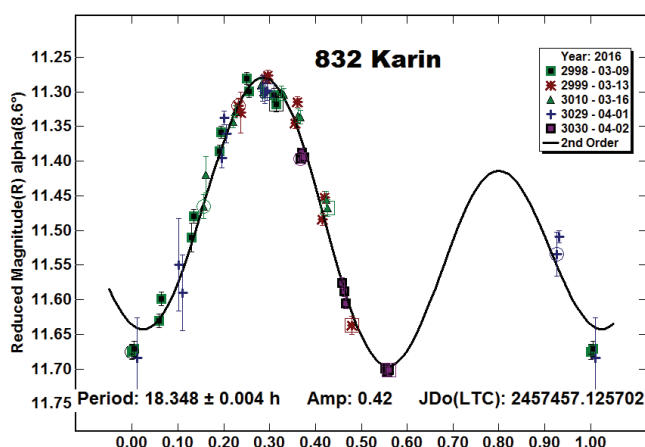
The raw data from B14 and DRO were subtracted with a library of flats, darks, and bias frames using *CCDSOFT* v5 while the raw data from B24 and B14E were obtained using *The SkyX* and subsequently reduced using a library of flats, darks, and bias frames in *Maxim DL* v6. Data measurement and reduction were done using *MPO Canopus* v10, which uses the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989).

The Comp Star Selector (CSS) feature in *MPO Canopus* was used to select comparison stars. Calibration of the data was done using the *MPO Canopus* MPOSC3 catalog. The R_C magnitudes for the comparison stars were converted from 2MASS J-K values. This resulted in internal consistency of < 0.05 mag. However, due to interstellar reddening, the conversion is inconsistent and some adjustments in the nightly zero points were required during period analysis (Warner, 2007).

Most of the targets in this paper were observed to support the Photometric Survey of Asynchronous Binary Asteroids (PSABA; Pravec, 2016). Unless noted otherwise, the description of the lightcurve elements was described in Oey et al. (2015).

832 *Karin* was selected from CALL website (Warner, 2016) because it was reaching a favourable opposition. Recent work by Yoshida (2016) found that the period 18.346 ± 0.96 h was consistent with our refined period. This is the primary body of the Karin family, which is thought to have been formed by a collision 5.8 My ago. In this regard, it was suggested that the asteroid might have the tell-tale signs of fresh impact on its surface detectable as a color difference over its rotational cycle.

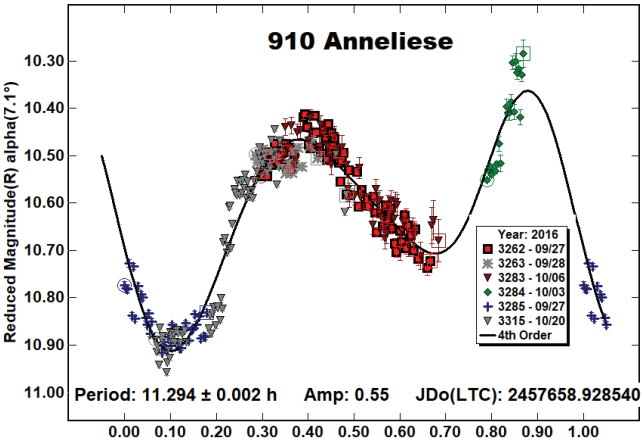
The data from 2016 March and May were plotted separately to show the change in amplitude due to the increase in phase angle.



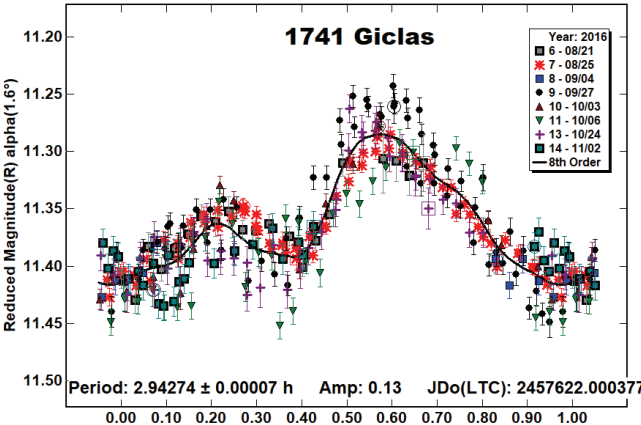
910 *Anneliese* was worked previously by Alvarez and Manuel (2015), who obtained a rotation period of 11.2863 ± 0.0002 h. Their data set was comprehensive, having about 3200 data points. The period reported here is based on relatively sparse data with no double coverage of the lightcurve. Even so, the result is consistent with that found by Alvarez and Manuel.

Number	Name	2016 mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
832	Karin	05/22-05/30	229	15,17	194	-1	18.355	0.004	0.57	0.02
832	Karin	03/09-04/02	53	8,0	192	-1	18.348	0.04	0.42	0.02
910	Anneliese	05/06-05/09	291	7,13	227	1	11.294	0.002	0.55	0.03
1741	Giclas	08/21-11/02	289	2,21	332	-4	2.94274	0.00007	0.13	0.02
2656	Evenkia	03/05-03/12	74	8,4	176	4	7.0855	0.0006	0.58	0.01
2827	Vellamo	30/02-03/07	330	13,10	189	-3	3.7392	0.0005	0.19	0.01
2956	Yeomans	11/03	61	2	44	-3	3.72	0.07	0.26	0.02
3002	Delasalle	04/26-05/04	188	12,8	231	9	6.5357	0.0004	0.35	0.02
3363	Bowen	05/17-05/18	229	4	228	3	3.016	0.003	0.19	0.03
3738	Ots	03/07-03/12	108	4,1	173	0	4.1717	0.0005	0.73	0.01
4022	Nonna	04/02-04/08	221	8,5	205	-7	2.5872	0.0004	0.08	0.01
5129	Groom	09/21-10/05	181	6,3	9	-5	3.3797	0.0003	0.23	0.02

Table III. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. If there are three values, the middle value is for the minimum during the range. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

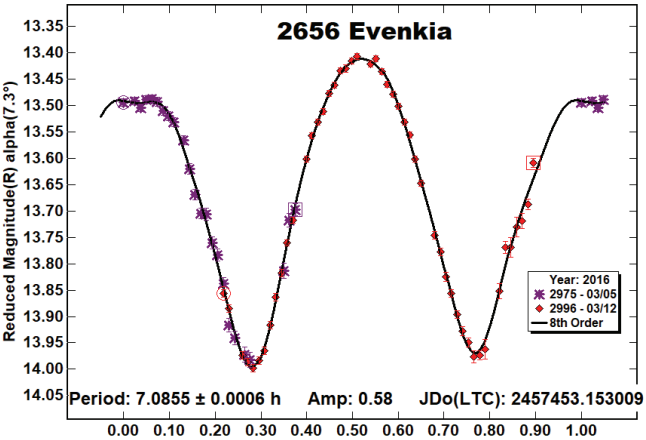


1741 Giclas is the primary of a paired asteroid within the search parameters of the PSABA project. According to Pravec *et al.* (2010), the primaries of binary and paired asteroids that have small secondaries ($D_s/D_p < 0.4$) have very similar, fast spin rates. Consequently, it was possible that 1741 Giclas would be a binary since its rotation period was within the range common among the primary body of binary asteroids. Our data showed no signs of a satellite.

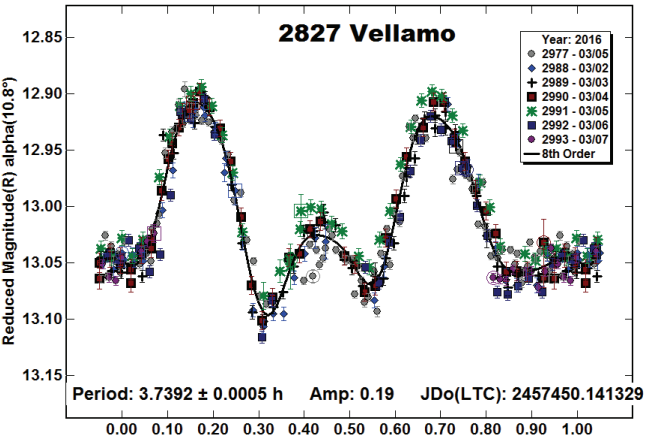


The result reported here is based on data from 2016 Aug-Nov. The changing observing geometry shift was apparent from the scatter seen in this the lightcurve. Four other sessions (June 28-29 and July 2-3) were excluded from this plot because of incorrect time stamps. Oey *et al.* (2015) obtained a period of 2.9426 h, which is consistent with the period found for the 2016 apparition.

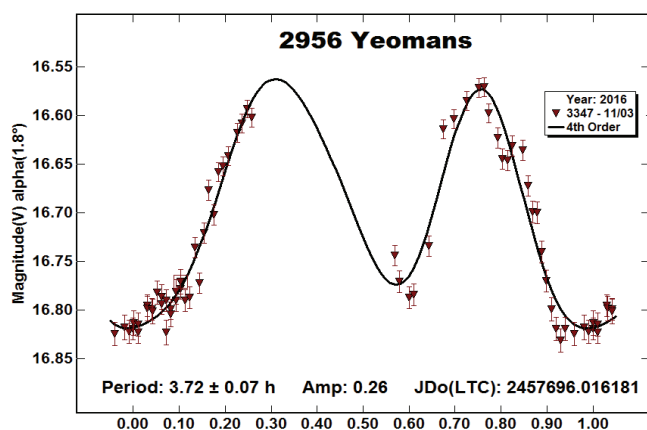
2656 Evenkia was also reported by Lang *et al.* (2016) during the same apparition. They found the same synodic period of 7.0870 h.



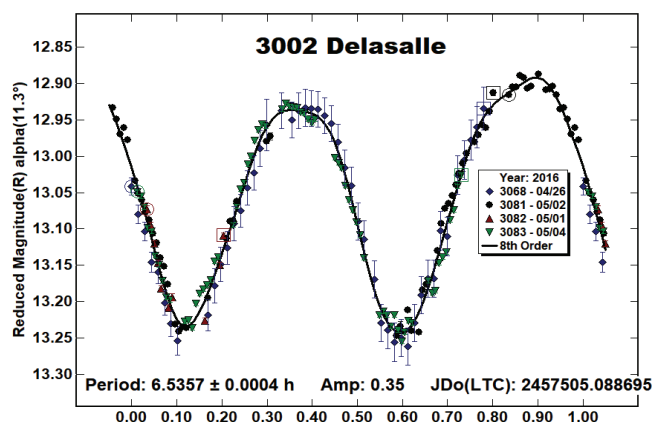
2827 Vellamo was done the through PSABA program (Pravec, 2016). The period is unique with no signs of being the asteroid being binary.



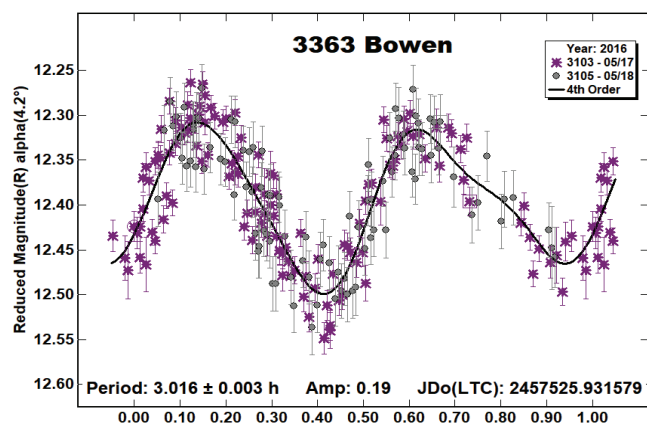
2956 Yeomans was a target of opportunity during the observations of 5112 Kusaji. Previous work done by Aznar (2015) from a single night light curve produced a $U = 2$ result and a period of 3.4 ± 0.1 h. His data were better than those used here in the sense that they produced a complete lightcurve.



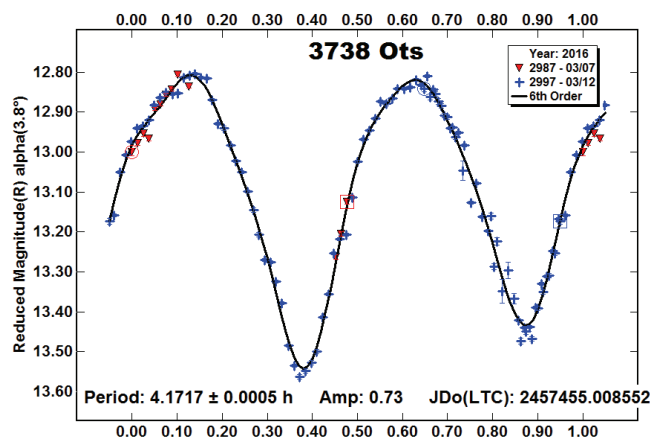
3002 Delasalle was part of the PSABA program (Pravec, 2016). The period is unique and consistent with previous work by Aznar (2016), who found a period of 6.537 ± 0.001 h.



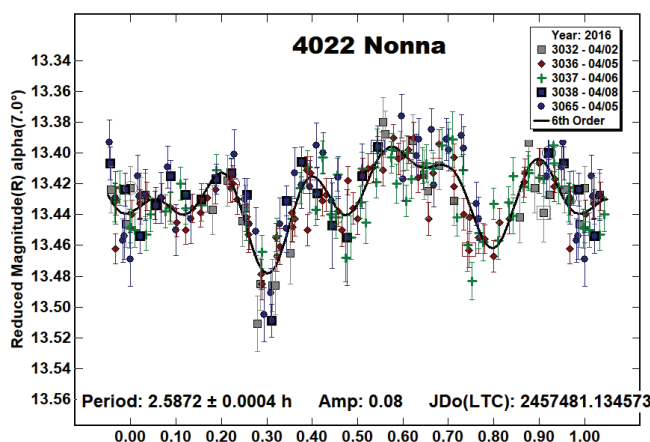
3363 Bowen was another PSABA target. The bimodal lightcurve amplitude is 0.20 mag. There was a considerable amount of scatter due to a full moon. Despite this, the resulting synodic period is consistent with that obtained from a previous apparition (Pravec, 2016), 3.0219 ± 0.0006 h.



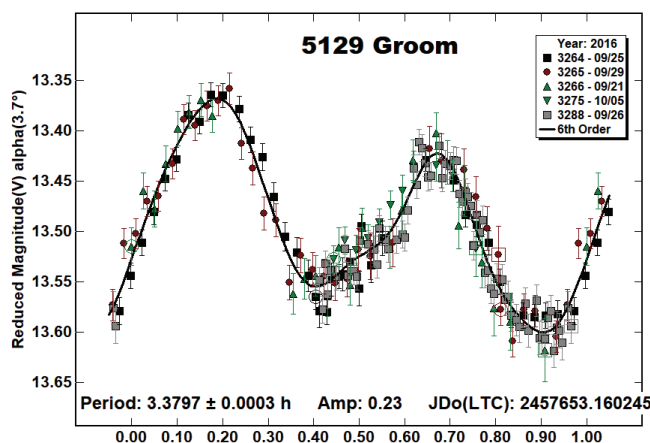
3738 Ots was part of the PSABA program. With the large amplitude of 0.73 mag and low phase angle, this asteroid can only be a prolate spheroid with a unique bimodal lightcurve (Harris et al., 2014). We found a synodic period of 4.1717 h.



4022 Nonna was previously studied through the PSABA program (Pravec, 2010) and by Behrend (2013). The result reported here is consistent with those previous works. It is noted here that the apparent multimodal lightcurve with the low 0.09 mag amplitude may be caused by concavities in the roughly spherical shaped asteroid.



5129 Groom was previously observed in the PSABA project (Pravec, 2016). This is the fourth apparition of this “prime suspect” observed by the PSABA team (Oey et al., 2015).



Acknowledgement

The purchase of the Apogee U42 camera was made possible by a 2015 Shoemaker NEO Grant.

References

- Alvarez, E., Manuel, E. (2015). "Rotation period and H-G parameters determination for 910 Anneliese." *Minor Planet Bull.* **42**, 252-253.
- Aznar, M.A. (2015). "Asteroid lightcurve analysis at Isaac Aznar Observatory Aras De Los Olmos, Valencia Spain." *Minor Planet Bull.* **42**, 4-6
- Aznar, M.A. (2016). "Parameters of rotation and shapes of Main-Belt asteroids from APT observatory group: second quarter 2016". *Minor Planet Bull.* **43**, 350-353.
- BMO (2016). Blue Mountains Observatory website. bluemountainsobservatory.com.au/asteroid/observatory.html
- Behrend (2013). Observatoire de Geneve web site. <https://obswww.unige.ch/~behrend/r004022a.png>
- Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gypsis." *Icarus* **57**, 251-258.
- Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H.J., Debehogne, H., Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.
- Harris, A.W., Pravec, P., Galad, A., Skiff, B.A., Warner, B.D., Vilagi, J., Gajdos, S., Carbognani, A., Hornoch, K., Kusnirak, P., Cooney, W.R., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.
- Lang, K., Jacobsen, J., Kristensen, L.H., Larsen, F.R. (2016). "Synodic rotation period of 2656 Evenkia." *Minor Planet Bull.* **43**, 344-346.
- Oey, J., Williams, H., Groom, R., Pray, D., Benishek, V. (2015). "Lightcurve analysis of binary and potential binary asteroids in 2015." *Minor Planet Bull.* **43**, 200-204.
- Pravec P., Vokrouhlický D., Polishook, D., Scheeres, D. J., Harris, A.W., Galád, A., Vaduvescu, O., Pozo, F., Barr, A., Longa, P., Vachier, F., Colas, F., Pray, D., Pollock, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A., Kušnirák, P., Henych, T., Marchis, F., Macomber, B., Jacobson, S. A., Krugly, Yu N., Sergeev A. V., Leroy, A. (2010) "Formation of asteroid pairs by rotational fission". *Nature* **466**, 1085-1088.
- Pravec, P. (2016). "Photometric Survey of Asynchronous Binary Asteroids." <http://www.asu.cas.cz/~asteroid/binastphotosurvey.htm>
- Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bull.* **34**, 113-119.
- Warner, B.D. (2016). CALL web site. <http://minorplanet.info/call.html>
- Yoshida, F., Ito, T., Dermawan, B., Nakamura, T., Takahashi, S., Ibrahimov, M.A., Malhotra, R., Ip, W.-H., Chen, W.-P., Sawabe, Y., Haji, M., Saito, R., Hirai, M. (2016). "Lightcurves of the Karin family asteroids." *Icarus* **269**, 15-22.

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2018 APRIL-JUNE

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

(Received: 2018 July 12)

Lightcurves for 39 Near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June were analyzed for rotation period and signs of satellites or tumbling. In addition, re-examination of data for 2014 UR taken in 2014 shows that the rotation period is 0.2300 h and not the 2.37 h that was originally reported.

CCD photometric observations of 39 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June. In addition, re-examination of data obtained in 2014 of the NEA (25916) 2001 CP44 revised the original period (Warner, 2014a) from 4.208 h to 4.608 h.

Table I lists the telescope/CCD camera combinations that were used. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

Desig	Telescope	Camera
Squirt	0.30-m f/6.3 Schmidt-Cass	ML-1001E
Borealis	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
Eclipticalis	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Australius	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Zephyr	0.50-m f/8.1 R-C	FLI-1001E

Table I. List of CS3-PDS telescope/CCD camera combinations.

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. Catalog magnitudes were taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs.

The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach >0.1 mag. There is a systematic offset between the two catalogs and so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris et al., 1989).

In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distances by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU.