TWENTY-ONE ASTEROID LIGHTCURVES AT GROUP OBSERVADORES DE ASTEROIDES (OBAS): LATE 2015 TO EARLY 2016

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We report on the photometric analysis result of 21 main-belt asteroids (MBA) done by Observadores de Asteroides (OBAS). This work is part of the Minor Planet Photometric Database task initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as additional incomplete lightcurves to help analysis at future oppositions. This is a compilation of lightcurves obtained during last quarter of 2015 and first quarter of 2016.

In this paper we publish the result of 21 asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*), which is focused on collecting lightcurves of main-belt asteroids using photometric techniques. This database shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

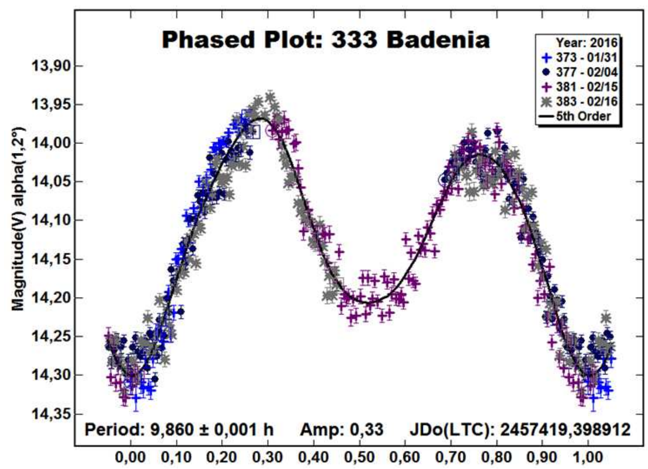
Table I shows the equipment at the observatories that participated in this work. Table II lists the individual results along with the range of dates for the observations, the number of nights that observations were made, and the phase angles.

We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the CALL website (CALL, 2015), making sure to keep the asteroid's magnitude within reach of the telescopes being used. We tried to observe asteroids at a phase angle of less than 15°, but this was not always possible. Images were measured using *MPO Canopus* (Bdw Publishing) using differential photometry. For more information about technical topics see Aznar *et al*. (2015).

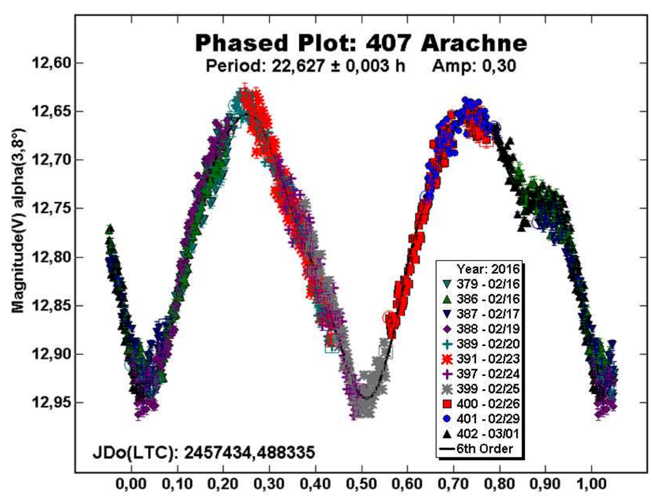
Observatory	Telescope	CCD
OIA,Obs Isaac Aznar	0.35 SCT	SBIG STL1001E+AO
POP-Puzol	0.25 SCT	SBIG ST9-XE+AO
Zonalunar	0.10 refr	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 SCT	Atik 414L+

Table I. List of instruments used for the observations. SCT is Schmidt-Cassegrain. R-C is Ritchey-Chrétien. DK is Dall-Kirkham. Refr is refractor.

333 Badenia. The rotation period for this MBA has been measured many times, *e.g.*, Behrend (2006), who found a period of 8.19 hours. OBAS observed this asteroid during four nights from 2016 Jan 31 to Feb 16. We obtained a rotation period of 9.86 ± 0.001 h and amplitude of 0.33 mag. This result is consistent the rotation period of 9.96 h and an amplitude of 0.30 mag found by Denchev *et al.* (2000).

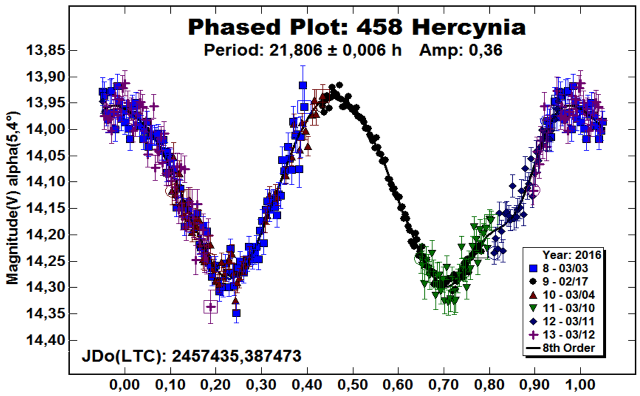


407 Arachne. Behrend (2005) found a period of 22.62 hours and amplitude of 0.31 mag. Weidenschilling, (1990), based on incomplete coverage of the lightcurve, found P = 44.0 hours.

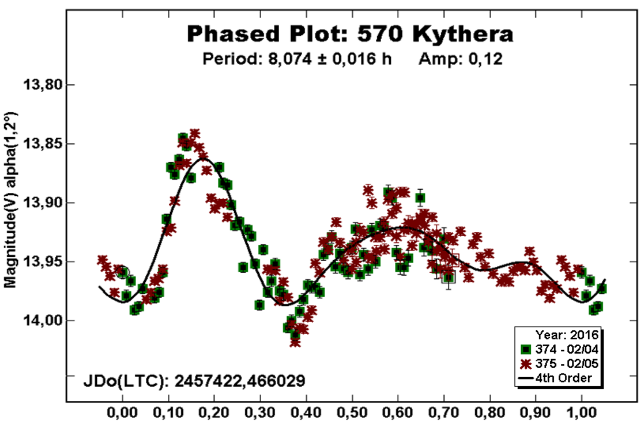


Based on ten nights of data, the analysis by the OBAS group determined a period of 22.627 ± 0.003 h, very close to Behrend's, and an amplitude of 0.30 magnitudes.

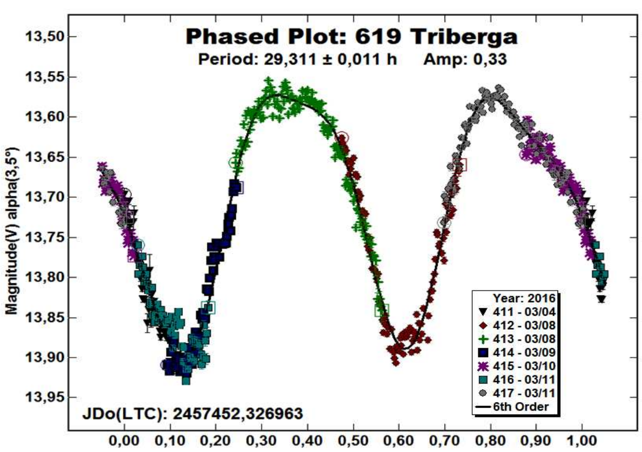
458 Hercynia. Four different rotation periods have been reported for this asteroid. We observed it on six nights in 2016 February and found a rotation period 21.806 ± 0.006 h. The lightcurve amplitude is 0.36 mag. This result is similar to Binzel (1987) who reported a period of 22.3 h and amplitude of 0.33 mag.



570 Kythera. There is no consensus on the rotation period of this asteroid. Up to five periods have been found. The most recent (Chavez, 2014) indicates a period of 10.5 h and amplitude of 0.2 mag. We found a period of 8.074 ± 0.016 h and amplitude of 0.12 mag. This result is similar only to Behrend (2004; 8.120 h).

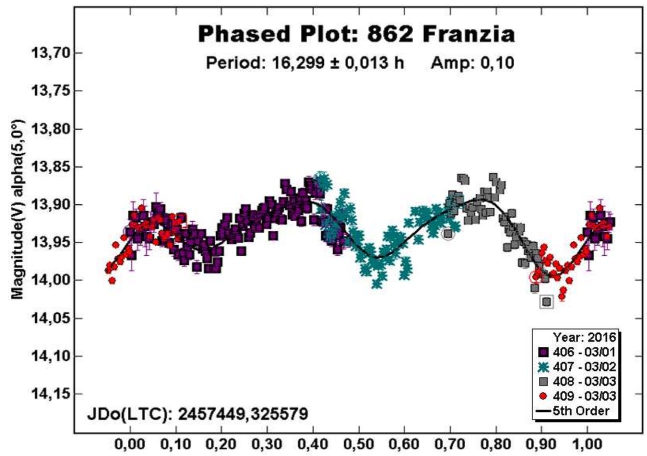


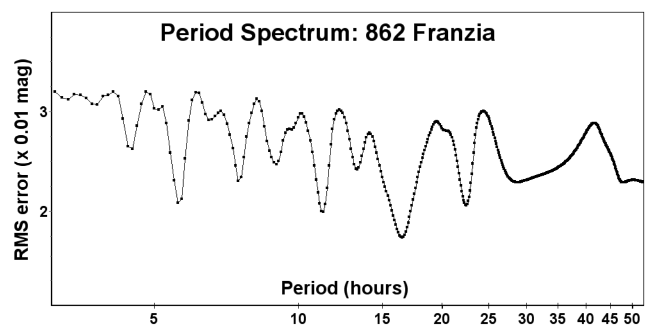
619 Triberga.



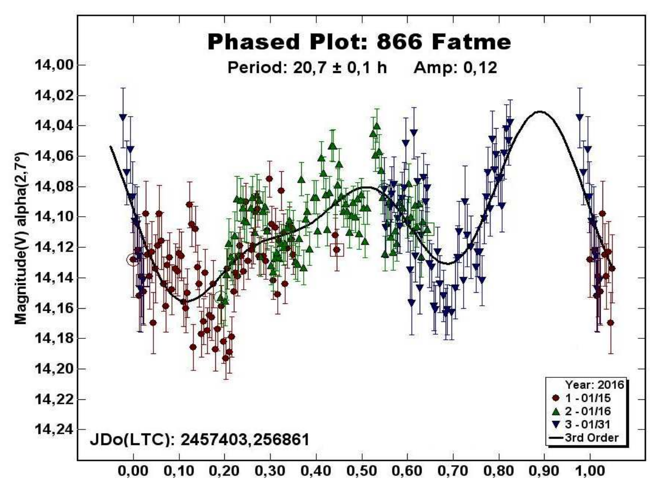
We observed Trigbera for five nights in 2016 March, which allowed us to form a complete composite lightcurve that shows a typical bimodal shape. Our analysis found a rotation period of 29.311 ± 0.011 h and amplitude of 0.12 mag. This is consistent with other previously reported periods, *e.g.*, Pray (2006a; 29.412 h), Behrend (2006; 29.411 h), and Oliver (2008, 29.37 h).

862 Franzia. This asteroid has been analyzed on many occasions. Warner (2005) found an ambiguous solution of 15.05 h, but could not rule out one of about 7.6 h. He later revised the period using the same data to 7.65 h (Warner, 2010) as well as reporting a period of 7.52 h based on data obtained in 2000. Brinsfield (2011) found 5.041 h for the period while Behrend (2011, 2015) reported 5.05 h both times. Our data from three nights in 2016 March led to a period of 16.299 ± 0.013 h with a trimodal shape and amplitude of 0.10 mag.



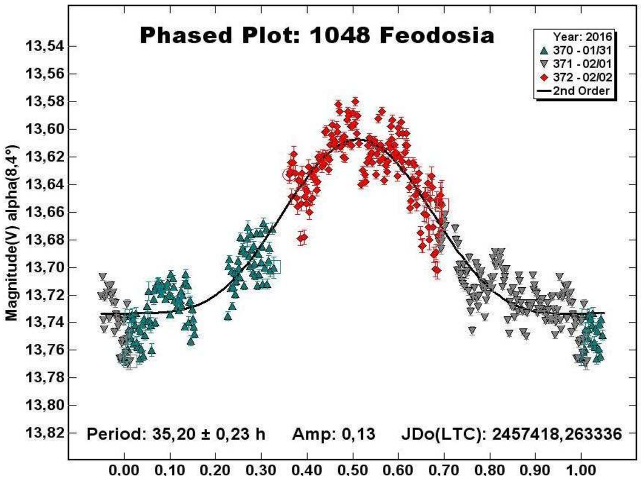


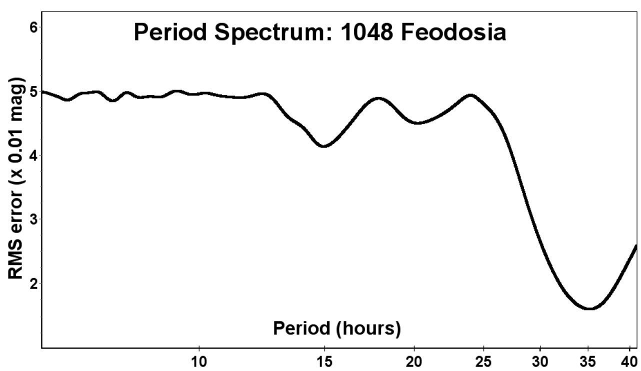
866 Fatme.



We observed Fatme on three nights between 2016 Jan 15-31. Analysis of the data found a rotation period of 20.7 ± 0.1 h. The lightcurve shows a maximum amplitude of 0.12 mag. The period is similar that reported by Stephens (2002; 20.03 h), but there is a gap on our lightcurve. We recommend working this asteroid at future oppositions.

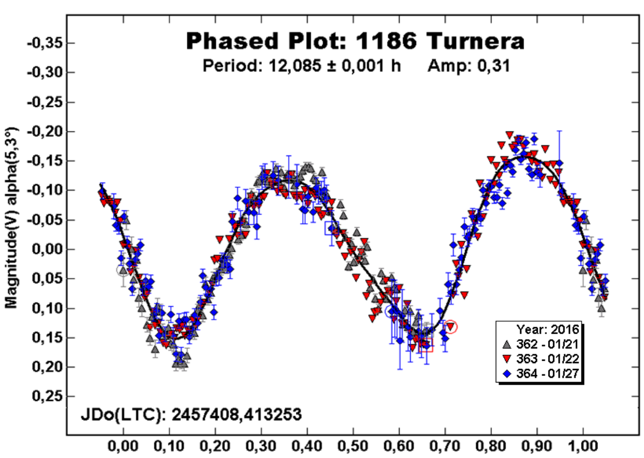
1048 Feodosia. If we assume a monomodal shape, the phased plot shows an incomplete lightcurve, with a rotation period of 35.20 ± 0.23 hours and amplitude of 0.13 magnitudes.





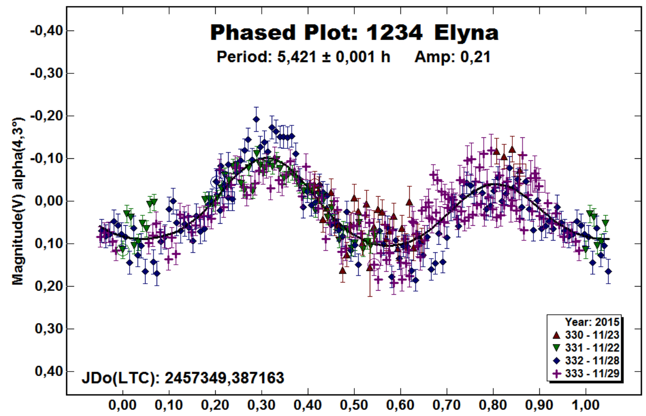
The period spectrum shows that this is the best approach. Nevertheless, this is inconsistent with other rotation periods of 10.46 h (Schober *et al*., 1994) and 23 h (Behrend, 2007). We suggest observations of this object at future oppositions.

1186 Turnera.

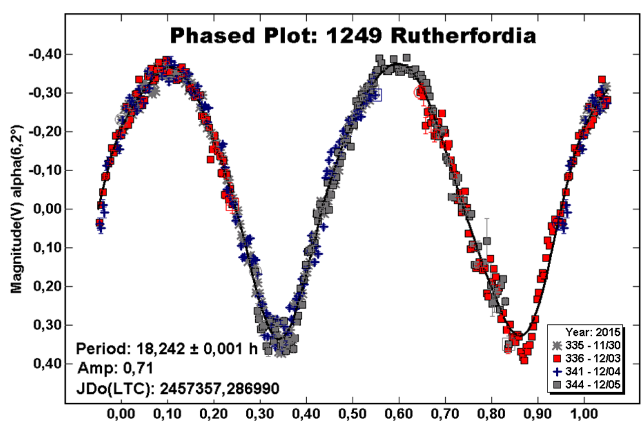


Previous periods include those from Barucci (1992; 9.41 h), Behrend (2006; 15.00 h), and Warner (2006; 12.066 h). The new OBAS observations taken during 2016 January define a period of 12.085 ± 0.001 h with an amplitude of 0.31 mag.

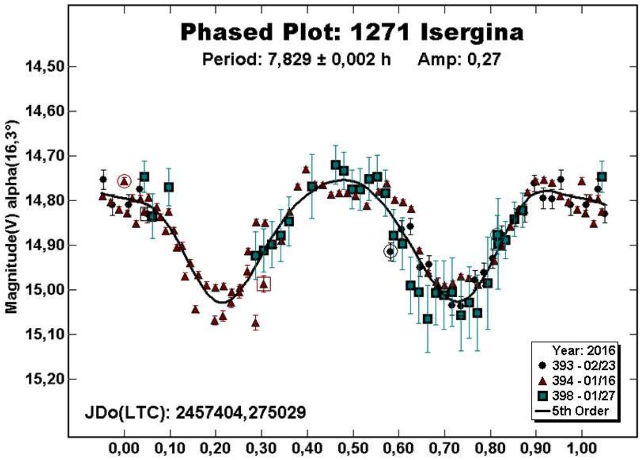
1234 Elyna. Behrend (2005) reported a rotation period of 5.9981 hours. Almost eighteen years before, Binzel (1987) reported a period of 17.6 hours. The OBAS group observed the asteroid on four nights during 2015 November. We found a rotation period of 5.421 ± 0.001 h with amplitude of 0.21 mag. The observations were made at phase angles +18.4° to +19.2° (post-opposition).



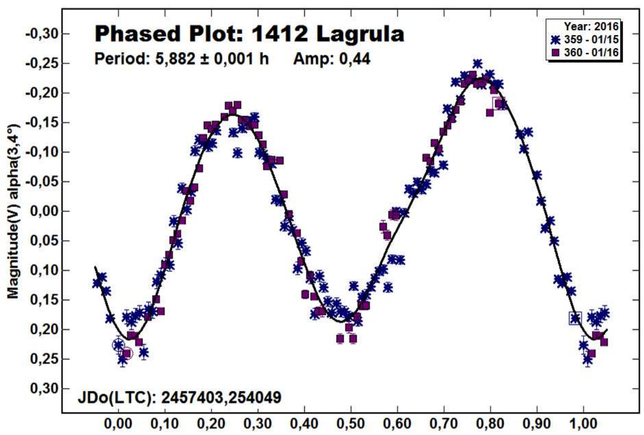
1249 Rutherfordia. The last published observations were made in 2008 (Kryszczyska *et al*., 2012), who found a period of 18.220 h. The OBAS team observed Rutherfordia during four nights in 2015 November and December. Our analysis found a period of 18.242 ± 0.001 h with an amplitude of 0.71 mag. The period is similar to Kryszczyska *et al.* and Berhrend (2001, 2004) who found periods of 18.20 and 18.24 h, respectively.



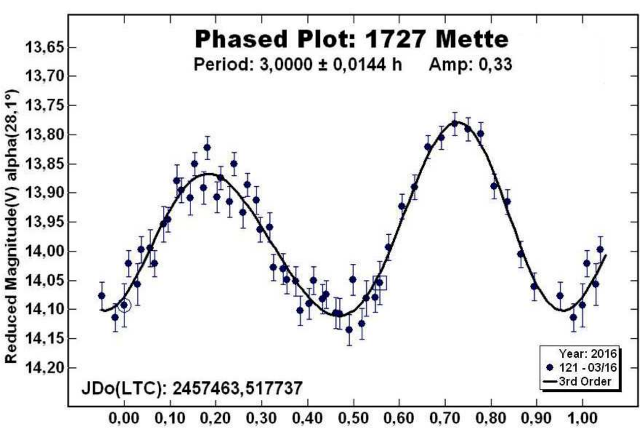
1271 Isergina. This main-belt asteroid did not have any previous entries in the LCDB. The OBAS team observed it on three nights in 2016 January and February. The phase angle ranged between +5.3° and +16.2° (post-opposition). The lightcurve shows a typical bimodal shape and has a period of 7.829 ± 0.002 h. The maximum amplitude is 0.27 mag.



1412 Lagrula. Casalnuovo (2013) found a rotation period of 5.9176 hours. In 2016 January we calculated a rotation period of 5.882 ± 0.001 hours. The lightcurve has a bimodal shape with a maximum amplitude of 0.44 mag.



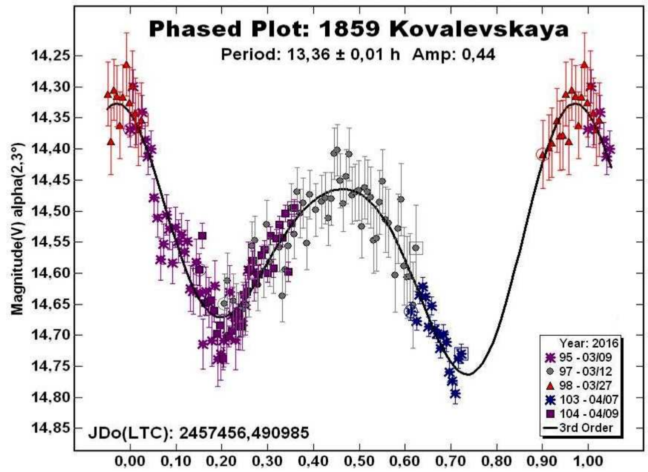
1727 Mette. This is a binary asteroid (Warner and Stephens, 2013). Its primary rotation period was first measured by Wiseniwski *et al*. (1987) and then several times after before the satellite was discovered.



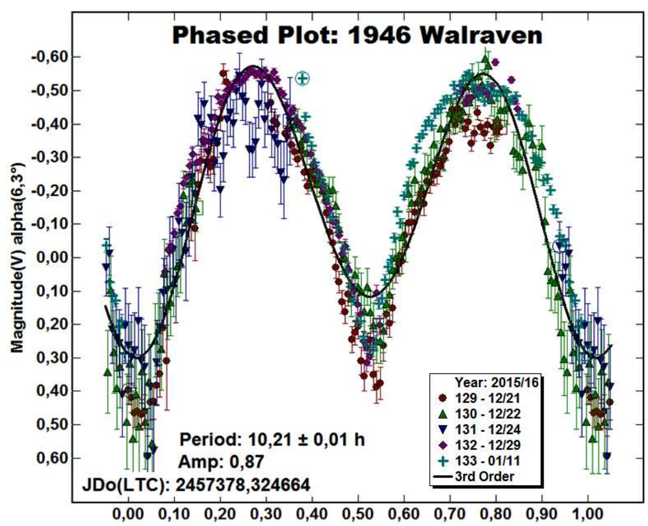
Warner *et al*. (2015a) observed the asteroid again in 2014 and found no signs of the satellite. Observations of Mette were made at the Isaac Aznar Observatory in 2016 to see if there were any deviations that would be due to a satellite. The analysis found a period of 3.0000 ± 0.0144 h with an amplitude of 0.33 mag. The data were taken on one night and there were no obvious deviations.

At the time of this writing, the asteroid was in pre-opposition phase. It will be analyzed again using more data collected during the apparition.

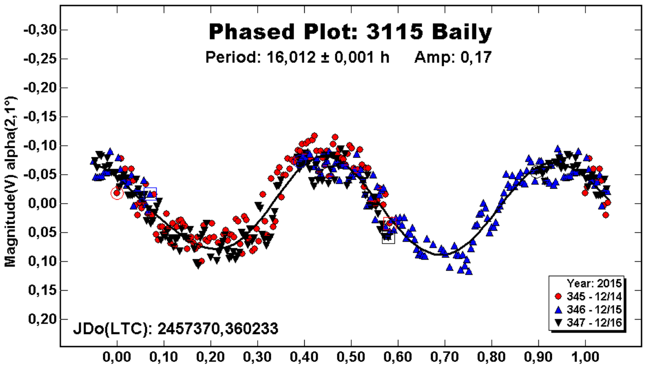
1859 Kovalevskaya. Waszczak *et al.* (2015) found a period of 11.1084 h. In 2016, we calculated a rotation period of 13.36 ± 0.01 hours with an amplitude of 0.44 magnitudes. Observations at future oppositions are needed to improve the period solution.



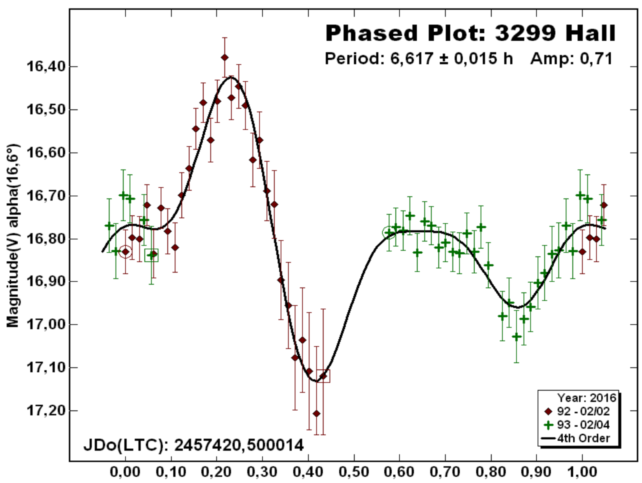
1946 Walraven. Folberth *et al*. (2012) reported a synodic rotation period of 10.22 h. The OBAS group observed the asteroid for five nights in 2015 December to 2016 January. Analysis of the data led to a period of 10.21 ± 0.01 h and maximum amplitude is 0.87 mag; both are similar to Folberth *et al.*



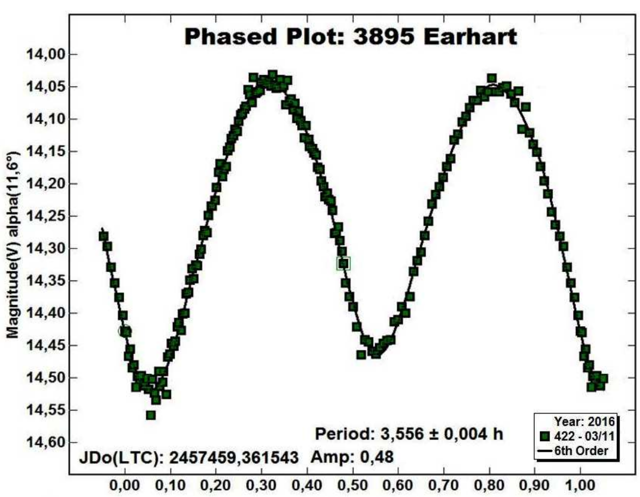
3115 Baily. This asteroid was observed by the OBAS group for three nights in 2015 December. We conclude that it has a period of 16.02 ± 0.001 h and amplitude of 0.17 mag. This is in good agreement Behrend (2006; 16.28 h) and Warner (2007; 16.22 h).



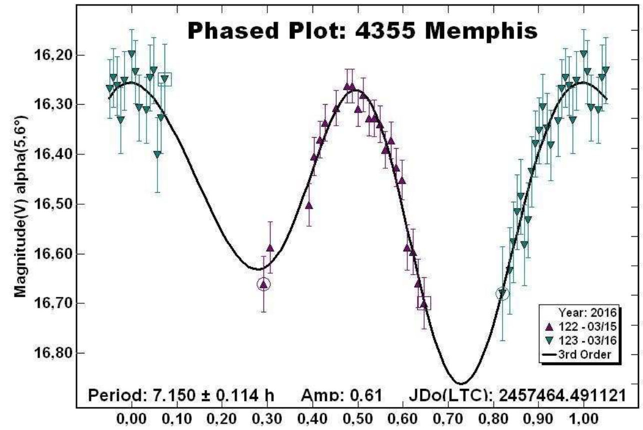
3299 Hall. This main-belt asteroid, discovered in 1980, had no published period that we could find. It was observed on two nights during 2016 February, when the angle phase was +17.0. As the plot shows, the lightcurve is incomplete. Therefore, the rotation period of 6.617 ± 0.015 h is only an approximation found by using the FALC Fourier analysis algorithm (Harris *et al.*, 1989).

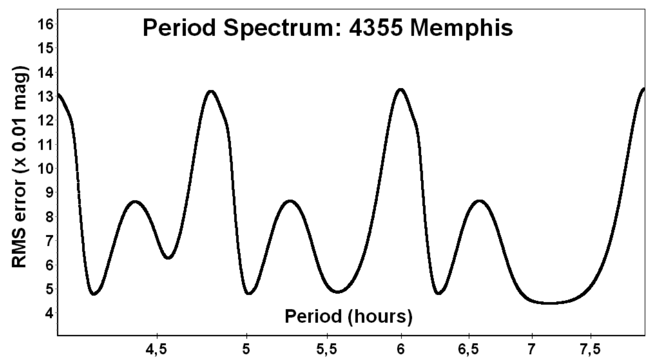


3895 Earhart. The OBAS team observed this main-belt asteroid for one night in 2015 November. Our analysis determined a period of 3.556 ± 0.004 hours. The amplitude is 0. 48 magnitudes. This result is similar with Warner (2009; 3.564 h).



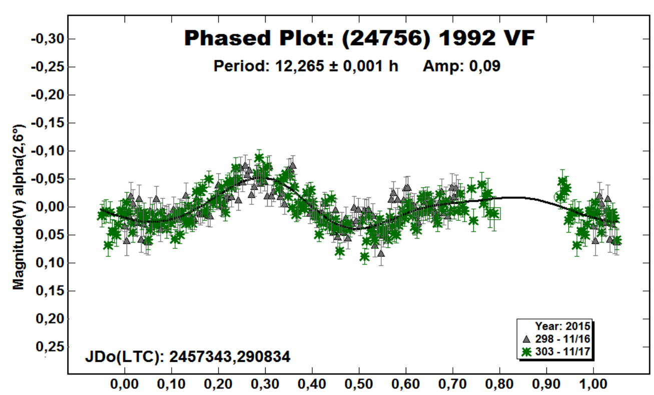
4233 Memphis. This is a main-belt asteroid discovered in 1960. There were no previous entries in the LCDB (Warner *et al.*, 2009a) for this asteroid.





Our data were obtained on two nights in 2016 March. The bimodal lightcurve, with an amplitude of 0.61 mag, indicates a rotation period of 7.150 ± 0.114 h. Although the data were not enough to get the complete lightcurve, the period spectrum shows that this could be a possible solution and so is the one we accept here.

(24756) 1992 VF. This is MBA was discovered in 1992. There were no previous entries in the LCDB. The OBAS group observed the asteroid for two nights in 2015 November. Our analysis found a period of 12.265 ± 0.001 h with and amplitude of 0.09 magnitudes.



Acknowledgements

We would like to express our gratitude to Brian Warner for supporting the CALL web site and his suggestions made to OBAS group.

Number	Name	Date Range yy/mm/dd	Nights	Period (h)	Error (h)	Amp (Mag)	Phase
333	Badenia	16/01/31 – 16/02/16	4	9.860	0.001	0.33	+1.4,+4.9
407	Arachne	16/02/16 – 16/03/01	10	22.627	0.003	0.30	+4.2,+9.8
458	Hercynia	16/03/03 - 16/03/12	6	21.806	0.006	0.36	+5.4,+8.6
570	Kythera	16/02/04 - 16/02/05	5	8.074	0.016	0.12	+1.5,+1.8
619	Triberga	16/03/04 – 16/03/11	5	29.311	0.001	0.66	-3.5,+5.1
862	Franzia	16/03/01 - 16/03/03	3	16.299	0.013	0.10	-3.6,+3.5
866	Fatme	16/01/15 - 16/02/20	4	7.93	0.001	0.05	+2.4,+13.3
1048	Feodosia	16/02/20 - 16/02/02	3	35.751	0.001	0.13	+8.3,+8.6
1186	Turnera	16/01/21 - 16/01/27	3	12.085	0.001	0.31	-5.1,-4.5
1727	Mette	16/03/16	1	3.00	0.0144	0.33	+28.1
1234	Elyna	16/11/23 - 16/11/29	4	5.421	0.001	0.21	+18.4,+19.2
1249	Rutherfordia	15/11/30 - 15/12/05	4	18.242	0.001	0.71	-6.8,-3.9
1271	Isergina	16/01/16 - 16/02/23	3	7.829	0.002	0.27	+5.3,16.2
1412	Lagrula	16/01/15 - 016/01/16	2	5.882	0.001	0.44	+3.4,+3.6
1859	Kivalevskaya	16/03/09 - 16/04/09	5	13.36	0.001	0.44	+2.3,+13.0
1946	Walraven	15/12/21 - 16/01/11	5	10.21	0.001	0.87	-6.3, +11.8
3115	Baily	15/12/14 - 15/12/16	3	16.012	0.001	0.17	-2.1,-1.1
3299	Hall	16/02/02 - 16/02/04	2	6.617	0.015	0.71	+17.0,+17.8
3895	Earhart	16/03/11	1	3.556	0.0004	0.048	-11.5
4233	Memphis	16/03/15 - 16/03/16	2	7.086	0.042	0.63	+19.9
24756	1992 VF	15/11/16 - 15/11/17	2	12.265	0.01	0.09	+2.6,+3.1

Table II. Dates of observation, number of nights, and derived periods/amplitudes. The Phase column gives the phase angle. If there are two values, they represent the phase angle on the first and last date of observation, respectively.

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THE BINARY NATURE OF 8077 HOYLE

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Analysis of CCD photometric observations of 8077 Hoyle shows that it is a binary asteroid with a synodic period for the primary of 2.746 ± 0.001 h and an orbital period of 53.862 ± 0.026 h. The amplitude of the primary lightcurve is 0.18 mag.

CCD photometric observations of 8077 Hoyle were made at the Esctorn Campus Observatory (Klinglesmith and Franco, 2016) in 2016 March. We used one of three Celestron 0.35-m telescopes equipped with an SBIG CCD camera. The images were processed and calibrated using *MPO Canopus* 10.4.7.6 (Warner, 2015). The exposures were 420 seconds through clear filters. The multiple nightly data sets were combined with the FALC algorithm (Harris *et al.*, 1989) within *MPO Canopus* to search for the synodic period of the asteroid.

We selected 8077 Hoyle for follow-up observations from the list of spin/shape models from Warner *et al*. (2016) because it was listed as having a particularly favorable apparition. There had been three previously determined periods. Klinglesmith *et al.* (2012) reported a period of 2.746 ± 0.002 h with an amplitude of 0.20 ± 0.10 mag. Clark obtained periods of 2.270 ± 0.001 h with an amplitude of 0.20 ± 0.02 mag (2013) and 2.7296 ± 0.0004 h with an amplitude of 0.23 mag (2015). All three sets of observations were obtained over short intervals of dates and did not show indications of a satellite.

The most recent observations covered a wider range of dates, six nights from 2016 Feb 6-18, and revealed mutual events (eclipses). Using the dual period search in *MPO Canopus* (Warner, 2015), we were able to obtain a synodic period for the primary of 2.746 ± 0.001 hours and an orbital period of 53.862 ± 0.026 h. The amplitude of the primary lightcurve is 0.18 ± 0.03 mag. Petr Pravec (private communications) confirmed the determination with synodic period of 2.74574 h and an orbital period of 54.0 ± 0.1 h. The depth of the shallower eclipse gives a satellite/primary effective diameter ratio (D_2/D_1) of about 0.35, but this is uncertain due to insufficient coverage.

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