TWENTY-THREE ASTEROIDS LIGHTCURVES AT OBSERVADORES DE ASTEROIDES (OBAS): 2015 OCTOBER - DECEMBER

Amadeo Aznar Macías
Isaac Aznar Observatory, Valencia, SPAIN
POP-Punto Observación de Puzol, Valencia, SPAIN
obas@minorplanet.es

Alfonso Carreño Garcerán
Zonalunar Observatory,Valencia, SPAIN

Enrique Arce Mansego
Vallbona Observatory, Valencia, SPAIN

Pedro Brines Rodriguez
TRZ Observatory, Valencia, SPAIN

Juan Lozano de Haro
Elche Observatory, Alicante, SPAIN

Alvaro Fornas Silva, Gonzalo Fornas Silva
Oropesa Observatory, Castellón, SPAIN

Vicente Mas Martinez
CAAT, Centro Astronómico del Alto Turia, SPAIN

Onofre Rodrigo Chiner
Bétera Observatory, Valencia, SPAIN

(Received: 2016 January 15 Revised: 2016 January 29)

We report on the photometric analysis results for 23 main-belt asteroids (MBA) done by Observadores de Asteroides (OBAS). This work is part of the Minor Planet Photometric Database that was initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate, complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

In this issue we publish the results for 23 asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). This project is focused on collecting lightcurves for main-belt asteroids using photometric techniques. This database shows graphic results of the data, mainly lightcurves, with the data phased to a given period. We invite all astronomers to consult this database.

Observatory	Telescope (meters)	CCD
Zonalunar	0.10 refractor	Atik 383L+
OIA,Obs Isaac Aznar	0.35 SCT	SBIG STL1001E+AO
POP-Puzol	0.25 SCT	SBIG ST9-XE+AO
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+
CAAT	0.43 DK	SBIG STX-11K

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

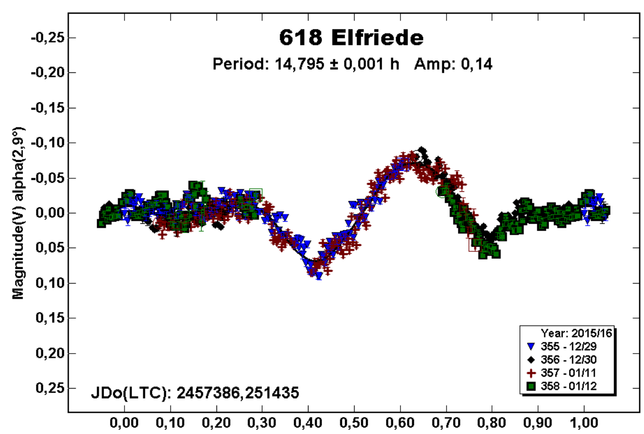
Table I shows the equipment at the observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) web site at *http://www.MinorPlanet.info/call.html*, paying special attention to keeping 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.

The image scale at each observatory was optimized to the average seeing at the given location. All images were binned 1x1 and were guided. Exposure times ranged from 60 to 200 seconds. *MPO Canopus* was used to measure the images by employing differential aperture photometry. The images were calibrated with bias, dark, and flat frames before measurement. Star subtraction was used where necessary and possible to minimize the effects on the asteroid measurements (Aznar, 2013).

Table II lists the individual results along with the range of dates for the observations and the number of nights that observations were made.

<u>618 Elfriede</u>. This MBA has an estimated diameter of 120 kilometers. Behrend (2004) found a period of 14.75 h and amplitude of 0.17 mag. Warner (2006) reported P = 14.801 h, A = 0.12 mag. Carbo *et al.* (2008) found a period of 14.85 h and amplitude of 0.12 mag.

We observed Elfriede on four nights during the period of 2015 Nov 11 to Dec 20. We found a synodic rotation period of 14.795 ± 0.001 h and lightcurve amplitude of 0.14 mag. These are consistent with the previous results.

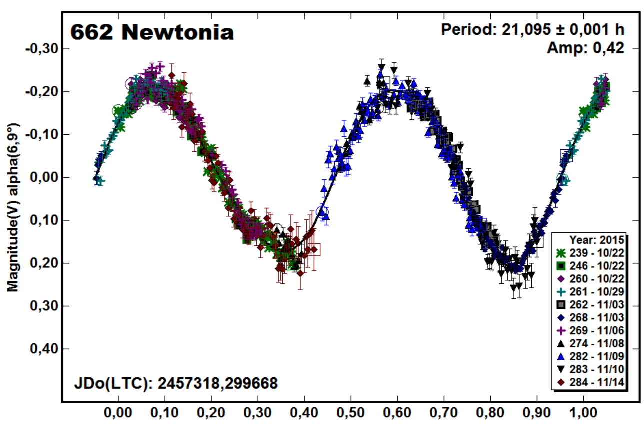


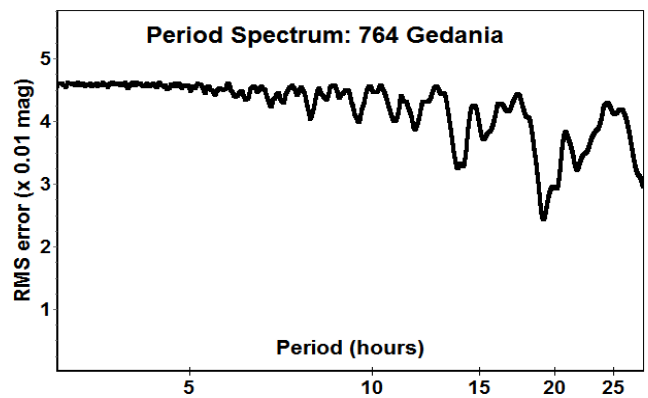
<u>662 Newtonia</u> is a main-belt with H = 10.3. The IRAS database (Tedesco *et al.*, 2004) indicates a diameter of 23.6 km and albedo of 0.1999 based on H = 10.5. Behrend (2006) found a period of 16.46 h based on incomplete coverage of the lightcurve. Other results include Chang *et al*. (2014; 20.6 h) and Waszczak *et al.* (2015; 21.4285 h).

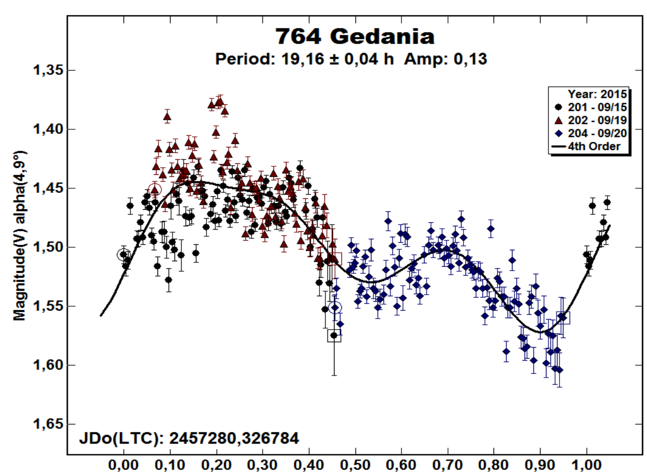
Our analysis found a period of 21.095 ± 0.001 h and amplitude of 0.42 mag, which is in good agreement with the Waszczak *et al.* period, especially given that it based on a limited number of data points. Because the phase angle was more than 25°, the shape and amplitude of the lightcurve may have been affected by shadowing effects.

Number	Name	Date Range 2015 mm/dd	Nights	Period (h)	Error (h)	Amp	Phase
618	Elfriede	11/11 - 12/30	4	14.795	0.001	0.14	-13.9,+3.1
662	Newtonia	10/22 - 11/14	11	21.10	0.001	0.42	-30.6,-25.0
764	Gedania	09/15 - 11/20	3	19.16	0.04	0.13	+4.9,+18.4
838	Seraphina	11/08 - 11/16	5	17.62	0.001	0.13	-4.2,-0.8
1001	Gaussia	11/17 - 11/28	5	20.99	0.01	0.11	+2.3,+5.5
1013	Tombecka	11/23 - 11/29	4	6.05	0.001	0.44	+5.7,+8.0
1018	Arnolda	11/18 - 11/20	4	14.57	0.01	0.39	+5.6,+6.3
1242	Zambesia	09/25 - 10/29	6	15.72	0.14	0.15	-14.5,+6.2
1343	Nicole	11/16 - 11/18	3	14.76	0.01	0.38	-1.1,+0.8
1480	Aunus	12/17 - 12/29	2	3.10	0.01	0.32	-16.5,-15.4
1531	Hartmut	12/19 - 12/24	8	25.4	0.01	0.26	+15.5,+17.3
2104	Toronto	11/18 - 11/19	3	8.97	0.01	0.26	-2.4,-2.2
2118	Flagstaff	10/16 - 10/29	5	15.17	0.01	0.35	+8.1,+14.4
2343	Siding Spring	11/03 - 11/16	3	2.11	0.01	0.15	+3.4,+11.7
2947	Kippenhahn	11/19 - 11/28	2	10.43	0.001	0.43	-2.2,+5.4
3433	Fehrenbach	11/30	1	3.922	0.001	0.28	+4.8
3606	Pohjola	11/28 - 12/04	4	2.92	0.01	0.11	-2.0,+1.3
3811	Karma	09/25 - 10/29	4	13.23	0.01	0.33	-9.5,+10.5
4212	Sansyu-Asuke	10/22 - 11/08	6	15.94	0.01	0.09	-5.1,+4.8
4272	Entsuji	10/15 - 11/03	8	2.81	0.01	0.07	-3.9,+11.9
6350	Schluter	10/29 - 11/08	3	13.19	0.001	0.31	+7.2,+10.4
10064	Hirosetamotsu	11/29 - 12/01	4	8.06	0.01	0.74	+12.0,+13.2
10907	Savalle	11/12 - 11/14	2	608	0.001	0.07	+1.3,+2.3

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, respectively, the phase angle on the first and last dates in the range at 0h UT. Pre-opposition phase angles are negative; post-opposition phase angles are positive.





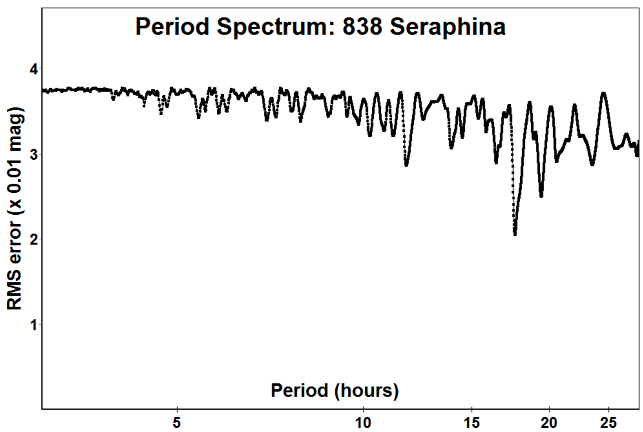


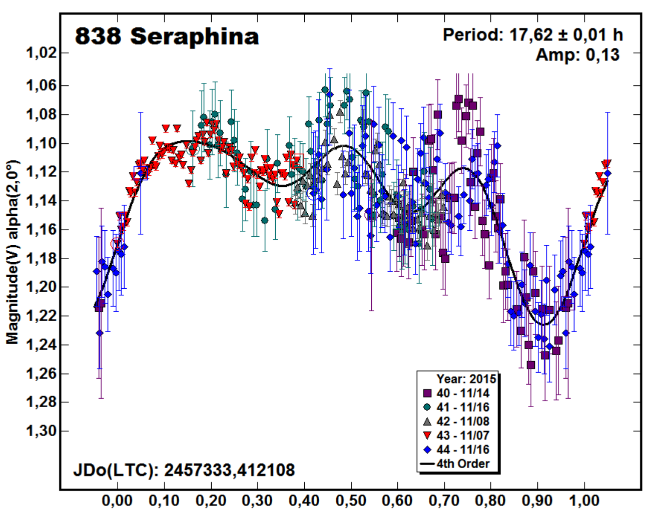
764 Gedania is a C-type main-belt asteroid with H = 9.6. The estimated diameter is 58.3 km and albedo is 0.0840 (Tedesco *et al.*, 2004). There were two rotation periods reported prior to our observations. The first one was 24.817 h (Brinsfield, 2010), based on observations in 2009, and the other was 24.9751 h (Behrend, 2006).

The OBAS group obtained a rotation period of 19.13 ± 0.01 h and amplitude of 0.1 mag. Looking at the period spectrum, we conclude that this is not a secure solution. Observations at future oppositions will be required to find a more secure period.

838 Seraphina. Seraphina is a main-belt asteroid that has been studied several times in the past. Tedesco *et al*. (2004) found a dimeter of 59.8 km and albedo of 0.0455. It has been classified as a taxonomic type P asteroid. Reported periods include 15.67 h from Behrend (2005) and 16.2 h from Binzel (1987). Both results are based on less than full coverage.

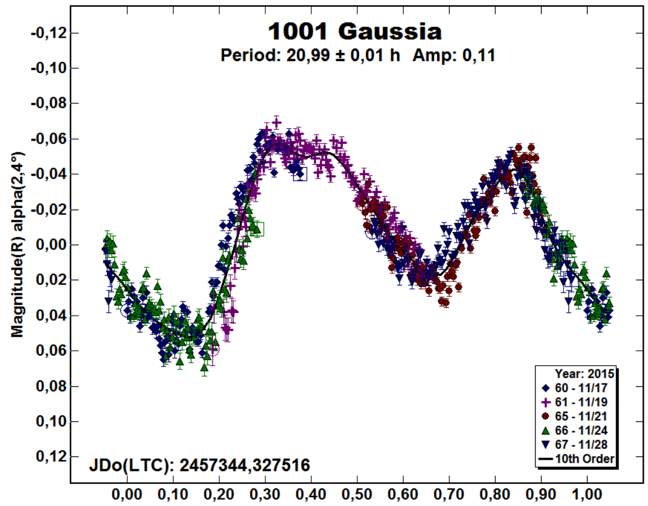
Using our data and the resulting period spectrum, we conclude that the rotation period could be 17.62 ± 0.01 hours. The amplitude of the lightcurve is 0.13 magnitudes. This amplitude does not match with the other amplitudes found by Behrend (0.07 mag) or Binzel (0.30 mag), but this could be due to different view aspects (polar vs. equatorial views) at the different oppositions.





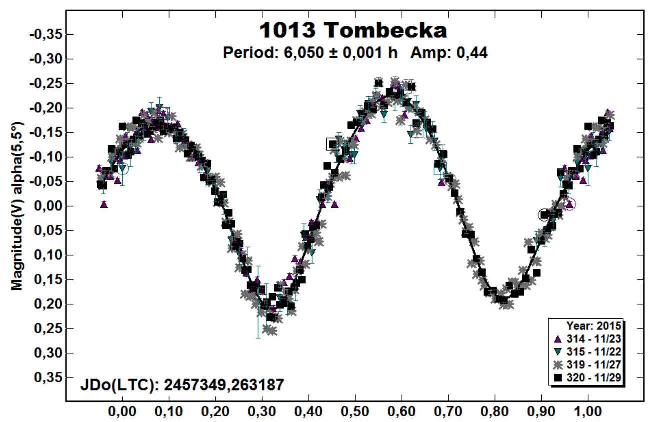
1001 Gaussia. The IRAS database (Tedesco *et al.*, 2004) gives a dimeter of 74.6 km and albedo of 0.0392 for this main-belt asteroid. As of 2015 December, only two rotation periods had been reported. The first one (Behrend, 2005) is 4.08 hours with an amplitude of 0.04 mag. This result was given U = 1 (likely wrong) in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). The second rotation period was obtained by Bonzo and Carbognani (2009). They found P = 9.17 h and A = 0.16 mag. This result is rated U = 2– in the LCDB. These results are based on less than full coverage, which is the reason why we selected this object to improve the rotation period solution.

The rotation period calculated by OBAS in this campaign is 20.99 ± 0.01 h. The lightcurve shows a bimodal shape with a maximum lightcurve amplitude of 0.11 magnitudes.



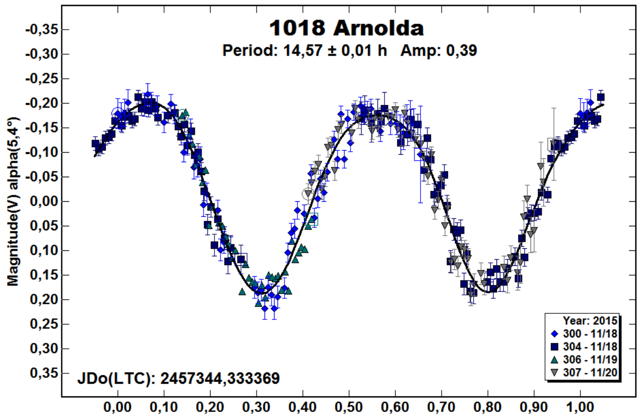
1013 Tombecka. This is a medium-sized main-belt asteroid (31.93 km) with an albedo of 0.1552 (Tedesco *et al.*, 2004).

We selected this asteroid in order to check the quality of results found by a new OBAS member since the period is well-known. The analysis done by the new member found a rotation period of 6.050 ± 0.001 hours and amplitude of 0.44 mag. These closely match previous results from Behrend (2006; 6.0508 h) and Fauerbach *et al*. (2008; 6.053 h)



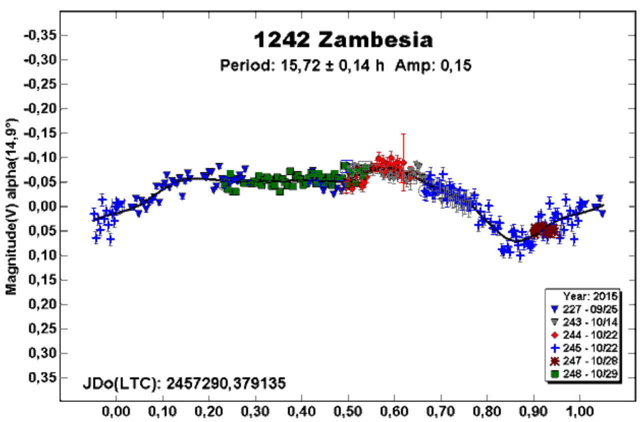
1018 Arnolda. This is a medium-sized main-belt asteroid (16.42 km) with an albedo is 0.3701 (Tedesco *et al.*, 2004). Binzel (1987) found a period of 11.97 h. More than 20 years later, two other results were published: 10.00 h (Behrend, 2011) and 14.617 h (Pligge *et al.*, 2011). The lightcurve obtained by OBAS has a period of 14.57 ± 0.01 hours, similar to that of Pligge *et al.*

The lightcurve shows a bimodal shape with a maximum amplitude of 0.39 magnitudes, which also nearly matches Pligge *et al*. This is not surprising because the phase angle bisector longitude (Harris *et al.*, 1984) in 2015 was almost 180° away from the longitude in 2010 when Pligge *et al.* observed the asteroid. This means that the viewing aspects were along the same line but looking at different hemispheres of the asteroid. Observations at a longitude about 90° from those in 2015, or about 140°, might result in a lightcurve with a much different shape or amplitude. This would give an idea of the direction that the spin axis of the asteroid points.

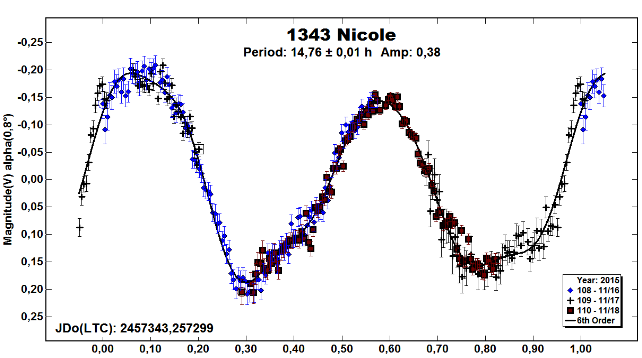


1242 Zambesia. Tesdesco *et al*. (2004) give this main-belt a diameter of 47.7 km and geometric albedo as 0.0708. Pozzoli (2003) reported a period of 17.305 h and amplitude of 0.24 mag. However, the lightcurve was not published and so this result cannot be considered certain.

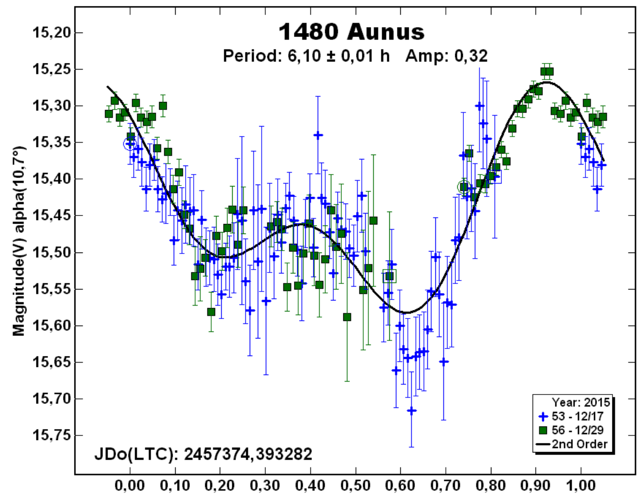
The OBAS team analyzed this asteroid during its 2015 opposition and the result is not definitive. The lightcurve shows a rotation period of 15.72 ± 0.14 hours and an amplitude of 0.15 magnitudes. Cloudy weather prevented additional observations beyond the six nights we did observe.



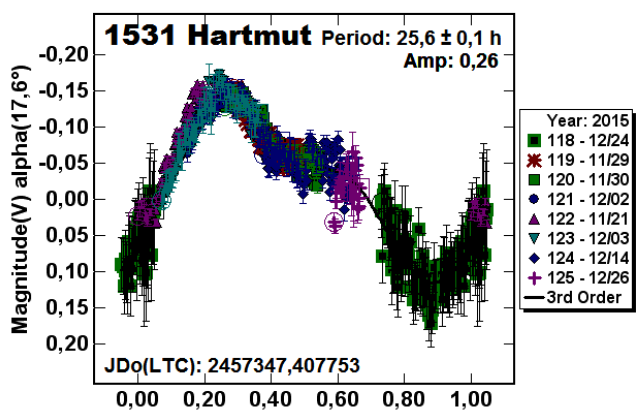
1343 Nicole. Nicole is a main-belt asteroid of about 24 km diameter and H = 11.0. Warner (2009) found a period of 14.77 hours based on less than full coverage and said that the period could be wrong. The OBAS team observed Nicole on three nights in 2015 November. Our analysis found a period of 14.76 ± 0.01 h, which is very similar to the one reported by Warner. The lightcurve has an amplitude of 0.38 mag.



1480 Aunus. This main-belt asteroid was discovered in 1938 by Vaisala. There were no entries in the LCDB. Analysis of our data obtained on two nights in 2015 December found a bimodal lightcurve with a period of 6.10 ± 0.01 hours and amplitude of 0.32 mag.

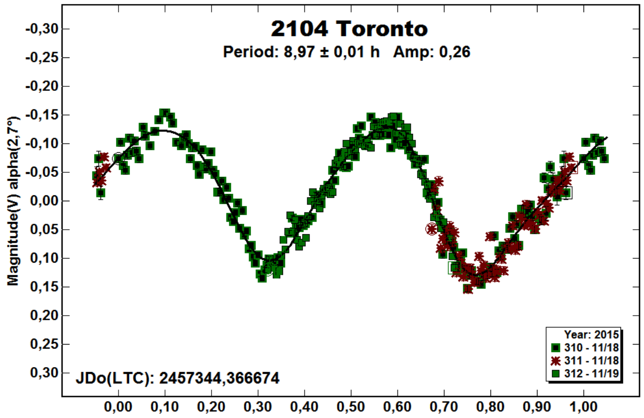


1531 Hartmut. The only other period for this main-belt asteroid was reported by Klinglesmith *et al*. (2016), who reported a period of 25.57 h and amplitude of 0.21 mag based on observations in 2015 November. Our data, obtained on eight nights in 2015 December led to a rotation period of 25.63 ± 0.01 hours and a maximum lightcurve amplitude of 0.26 magnitudes. The period is very similar to the one found by Klinglesmith *et al.* (2016).



2104 Toronto. This MBA was found to have a rotation period of 8.9669 h by Oey (2006) at Blue Mountain Observatory. His lightcurve was almost complete, missing only a small portion. However it was rated U = 2+ because of large gaps between observing sessions and the small missing section. This rating indicates that the period is very likely correct, but not absolutely so. It is "almost secure."

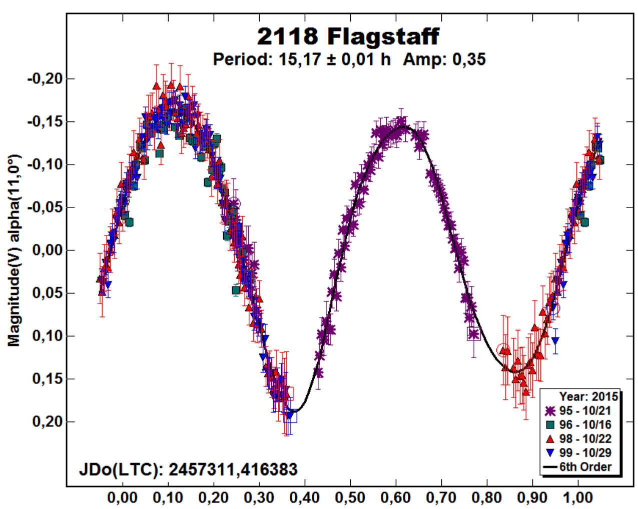
The asteroid was included in this project in order to get a more certain determination of the period. Based on a complete bimodal lightcurve, we found a period of 8.97 ± 0.01 h with an amplitude of 0.26 mag. The period is almost identical to the period found by Oey (2006).



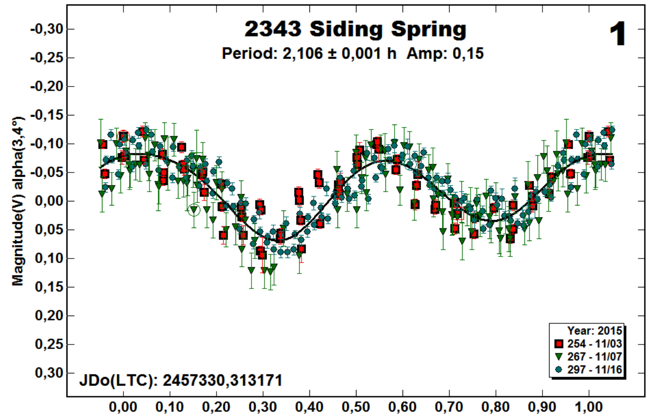
2118 Flagstaff. This MBA was analyzed in 2007 by Vander Haagen (2008). He reported a rotation period of 15.1557 hours with only a small gap in the lightcurve. The LCDB gives a U = 2+ rating, which means that the solution is very likely correct. Vander Haagen kindly provided his data to Aznar for additional analysis. After reprocessing all the Vander Haagen sessions, we concluded that the rotation period in 2007 was 15.19 ± 0.01 hours and the lightcurve amplitude obtained was 0.25 magnitudes.

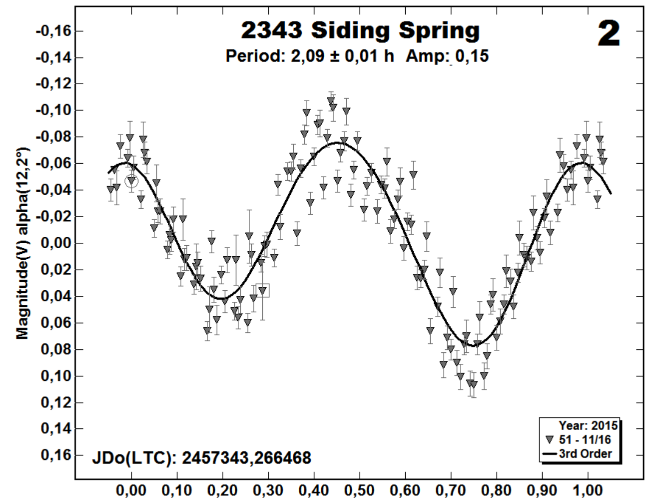
The OBAS team selected this object in order confirm the earlier results. Our complete lightcurve shows a rotation period of 15.17 hours, consistent with the result determined by Vander Haagen in 2008.

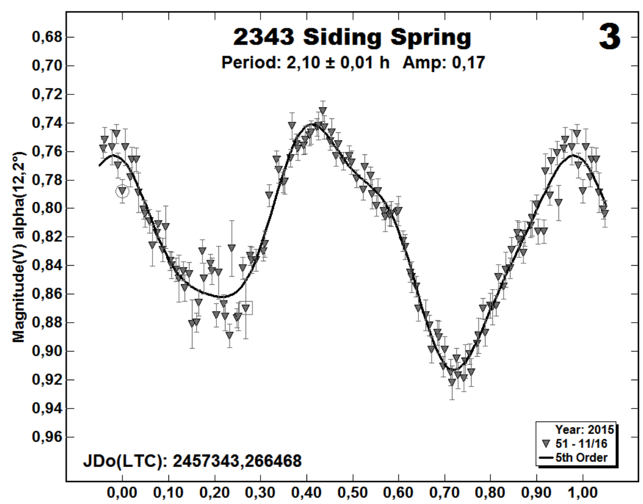
Both lightcurves show a similar period but they have maximum amplitudes that differ by about 0.1 magnitudes. This difference can be explained in part by the difference in phase angles at the time of the observations. The Vander Haagen observations were at about 13° while the OBAS observations were at about 23°. Another reason could be that the phase angle bisector longitudes differed by about 20 degrees between the two oppositions (Brian D. Warner, private communications) and so the viewing aspects were not the exactly the same.



2343 Siding Spring. This is a binary main-belt asteroid. The satellite was detected in 2015 by Pollock *et al.* (2015). The effective diameter of the system is about 5 km and the primary's rotation period is 2.10637 h. The satellite has an orbital period of 11.789 h and an effective diameter of about 0.19 that of the primary (Pollock *et al.*, 2015). The group also reported a secondary period of 20.01 h, which they attribute to a possible third member of the system.





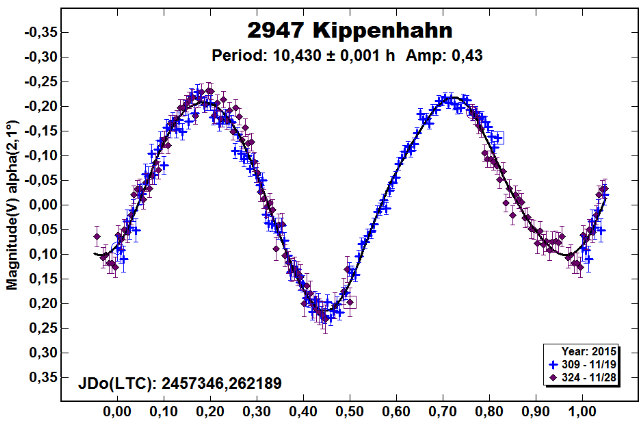


Plot "1" shows the lightcurve using the data from the three observatories that followed the asteroid: TRZ, Betera, and Isaac Aznar. Although two observatories of OBAS team detected the effect of the secondary asteroid in the lightcurve (Betera and Isaac Aznar) we used only the Isaac Aznar Observatory data for computing the rotation period and lightcurve amplitude of the primary. The analysis found $P = 2.10 \pm 0.01$ h and $A = 0.17$ mag.

Plot “2” shows the lightcurve without removing the effects of the satellite. Plot “3” shows the primary asteroid lightcurve after removing the effects of the satellite.

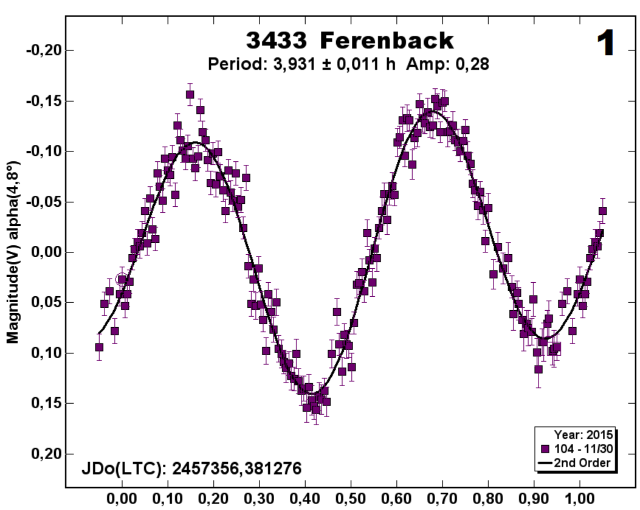
2947 Kippenhahn. This is an MBA discovered in 1955. It was previously analyzed by Chiorny *et al*. (2011). Their analysis was based on absolute photometry of small main-belt asteroids from which they found a rotation period of 10.5 hours and amplitude of 0.42 magnitudes. They also found a color index of V–R = 0.507. Because these results were based on incomplete coverage of the lightcurve, we chose this asteroid in order to get the full lightcurve and find a secure period.

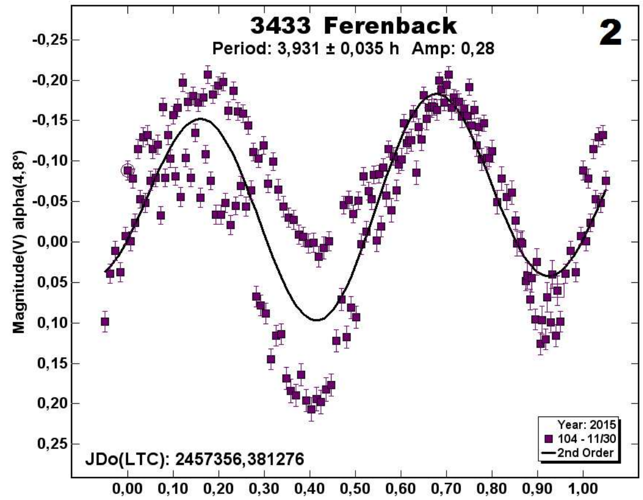
Based on two nights of observations, we found that the rotation period is 10.430 ± 0.001 hours and the lightcurve amplitude is 0.35 mag.



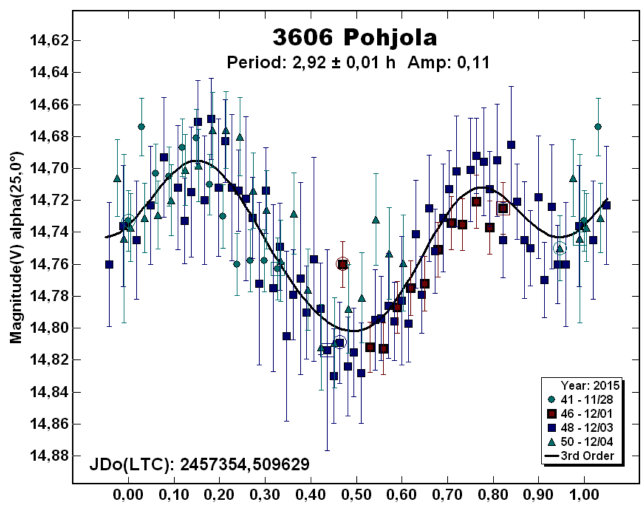
3433 Fehrenbach. This is a binary MBA discovered in 1963. The satellite was discovered by Pray *et al*. (2015), who found the primary rotation period to be 3.9160 h; the satellite is tidally-locked to its orbital period of 19.665 h, *i.e.*, its rotation period is also its orbital period.

We observed the asteroid on one night and found the main lightcurve period of 3.922 hours with an amplitude of 0.28 mag. Plot “1” shows the data from Isaac Aznar Observatory with the effects of the satellite removed while Plot “2” shows the data set without subtracting the effects of the satellite.

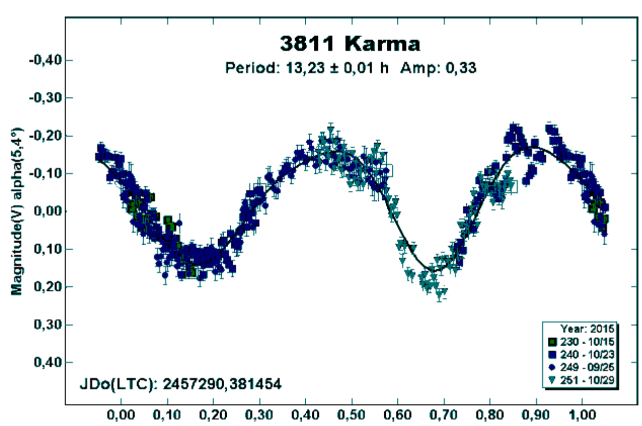




3606 Pohjola. There were no previous entries in the LCDB (Warner *et al.*, 2009) for this main-belt asteroid. Our solution indicates a slightly asymmetric bimodal lightcurve with a period of 2.92 ± 0.01 h and a maximum amplitude of 0.11 magnitudes.

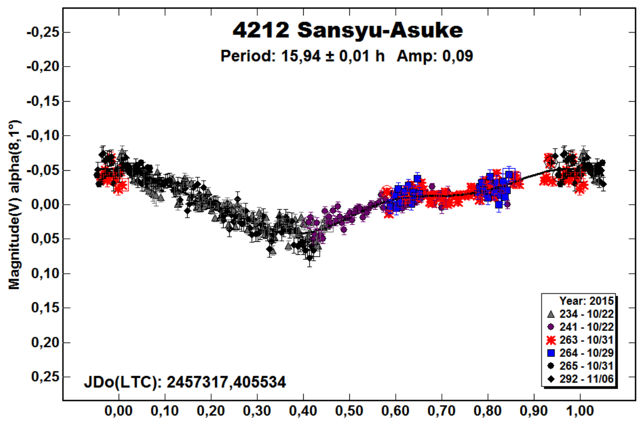


3811 Karma. The only previously reported period for Karma is from Behrend (2007), who found a period of 11.52 h and amplitude of >0.20 mag. This result is based on less than full coverage. We were able to obtain a complete lightcurve in 2015. Our analysis found a period of 13.23 ± 0.01 h and amplitude of 0.33 mag.



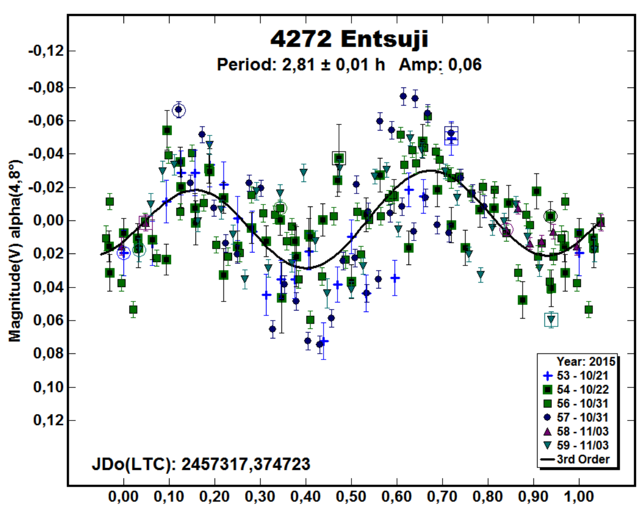
4212 Sansyu-Asuke. This MBA was discovered in 1987. It appears that this is the first reported lightcurve for Sansyu-Asuke. We followed the asteroid for eight nights. Cloudy weather did not allow collecting more observations, so our result must be considered preliminary.

Our lightcurve does not show a bimodal shape, maybe because it has a long period asteroid or the viewing aspect was nearly pole-on. Our analysis found a rotation period of 15.94 ± 0.01 h and amplitude of 0.09 mag.

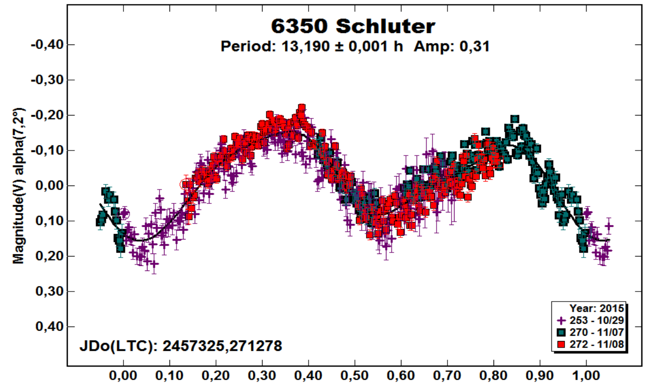


4272 Entsuji. This is a binary MBA discovered in 1977. The satellite was discovered by Benishek *et al*. (2015). They reported a primary rotation period of 2.8087 h and the satellite's orbital period as 15.94 hours, which is also probably its rotation period. They estimated the effective diameter ratio of the two bodies to be *Ds/Dp* = 0.18.

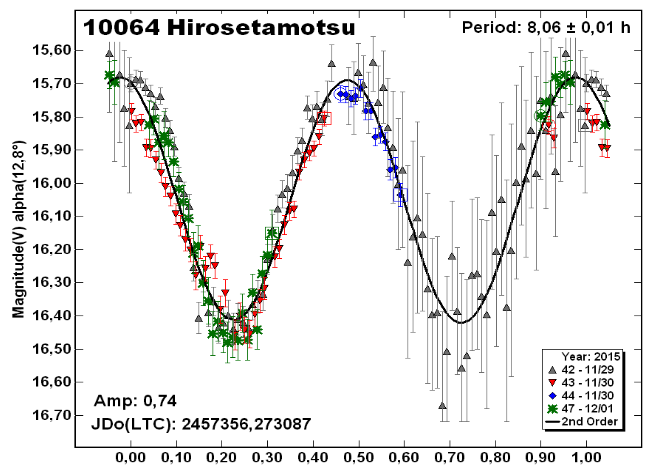
The analysis of our data from 2015 September shows a rotation period of 2.81 ± 0.01 h, which is consistent with the results from Benishek *et al*. (2015). The lightcurve amplitude is 0.06 magnitudes. We did not see any signs of the satellite because of the short time we observed the asteroid.



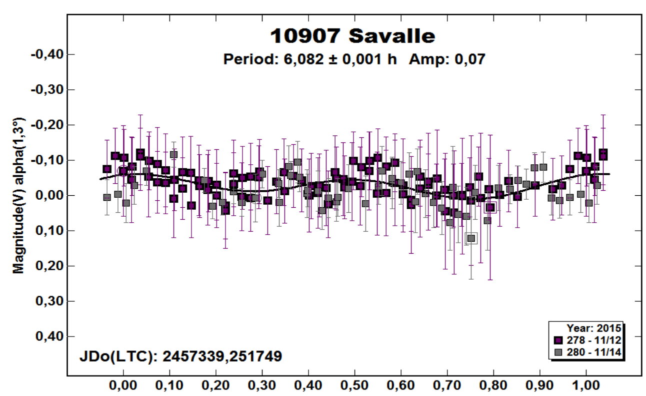
6350 Schluter. This MBA was discovered in 1960. Tedesco *et al.* (2004) found a diameter of 24.6 km and albedo of 0.0671. There were no entries in the LCDB for Schulter. We observed the asteroid for three nights in 2015 October and November. The resulting lightcurve has a bimodal shape and period of 13.190 ± 0.001 h and maximum amplitude of 0.31 mag.



10064 Hirosetamotsu is a main-belt asteroid discovered in 1988. Hanus *et al*. (2015) reported a sidereal period based on lightcurve inversion of 12.128 hours. Behrend (2015) and Casalnuovo (2016) found almost identical periods of 8.05 hours. Our lightcurve shows a bimodal shape with a period of 8.06 ± 0.01 h and amplitude of 0.74 mag. The 12-hour solution is almost exactly 1.5 times the period found by three different observers using lightcurve photometry analysis. This may indicate a miscount of the number of rotations over the time of the data in either the Hanus *et al.* (2015) or our solution.



10907 Savalle. There were no previous entries in the LCDB (Warner *et al.*, 2009) for this main-belt asteroid that was discovered in 1997. Our bimodal lightcurve with an amplitude of only 0.07 mag indicates a rotation period of 6.08 hours. The low amplitude could be caused by viewing the asteroid nearly pole-on or it being nearly spheroidal in shape. The large scatter in the data made the analysis difficult. Future observations are encouraged.



Acknowledgements

We would like to express our gratitude to Brian Warner for supporting the CALL web site and his suggestions made to OBAS group. We also thank Gary Vander Haarden for contributing his data

References

Aznar. A. (2013). "Lightcurve of 3422 Reid using star subtraction techniques." *Minor Planet Bull*. **40**, 214-215.

Barucci, M.A., Capria, M.T., Harris, A.W., Fulchignoni, M. (1989). "On the shape and albedo variegation of asteroids - Results from Fourier analysis of synthetic and observed asteroid lightcurves." *Icarus* **78**, 311-322.

Behrend, R. (2004, 2005, 2006, 2007, 2011, 2015). Observatoire de Geneve web site.
http://obswww.unige.ch/~behrend/page_cou.html

Benishek, V., Pollock, J., Hawkings, R., Pravec, P., Pray, D., Chiorny, V., Reichart, D., Haislip, J., Smith, A. (2015). "(4272) Entsuji." *CBET* **4158**.

Binzel, R.P. (1987). "A photoelectric survey of 130 asteroids." *Icarus* **72**, 135-208.

Brinsfield, J.W. (2010). "Asteroid Lightcurve Analysis at the Via Capote Observatory: 2009 3rd Quarter." *Minor Planet Bull.* **37**, 19-20.

Carbo, L., Kragh, K., Krotz, J., Meiers, A., Shaffer, N., Torno, S., Sauppe, J., Ditteon, R. (2009). "Asteroid lightcurve analysis at the Oakley Southern Sky Observatory: 2008 September and October." *Minor Planet Bull.* **36**, 91-94.

Casalnuovo, G.B. (2016). "Lightcurve Analysis for Nine Main-belt Asteroids." *Minor Planet Bull.* **43**, 112-115.

Chang, C.-K., Ip, W.-H., Lin, H.-W., Cheng, Y.-C., Ngeow, C.-C., Yang, T.-C., Waszczak, A., Kulkarni, S.R., Levitan, D., Sesar, B., Laher, R., Surace, J., Prince, T.A. (2014). "313 New Asteroid Rotation Periods from Palomar Transient Factory Observations." *Ap. J.* **788**, A17.

Chiorny V., Galad, A., Pravec, P., Kusnirak, P., Hornoch, K., Gajdos, S., Kornos, L., Vilagi, J., Jusarik, M., Kanuchova, Z., and 9 coauthors. (2011). "Absolute photometry of small main- belt asteroid in 2007-2009." *Planetary and Space Science* **51**, 1482-1489.

Fauerbach, M., Marks, S.A., Lucas, M.P. (2008). "Lightcurve Analysis of Ten Main-belt Asteroids." *Minor Planet Bull*. **35**, 44-46.

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.

Hanus, J., Durech, J., Oszkiewicz, D.A., Behrend, R., Carry, B., Delbo, M., Adam, O., Afonina, V., Anquetin, R., Antonini, P., and 159 coauthors. (2015). "New and updated convex shape models of asteroids based on optical data from a large collaboration network." *Astron. Astrophys.*, in press. arXiv:1510.07422.

Klinglesmith III, D.A., Hendrickx, S., Madden, K., Montgomery, S. (2016). "Lightcurves for Shape/Spin Models)." *Minor Planet Bull*. **43**, 124-129.

Oey, J. (2006). "Lightcurves analysis of 10 asteroids from Leura Observator." *Minor Planet Bull*. **33**, 96-99.

Pligge, Z., Monnier, A., Pharo, J., Stolze, K., Yim, A., Ditteon, R. (2011). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2010 May." *Minor Planet Bull*. **38**, 5-7.

Pollock, J., Caton, D., Hawkings, R., Pravec, P., Pray, D., Cooney, W., Gross, J., Terrell, D., Oey, J., Benishek, V., Galad, A., Gajdos, S., Groom, R., Stranger, K., Chiorny, V,. Reichart, D., Haislip, J., Smith, A. (2015). "(2343) Siding Spring." *CBET* **4206**.

Pozzoli, V. (2003). Posting on CALL web site.
http://www.MinorPlanet.info/call.html

Pray, D.P., Pravec, P., Marchini, A., Salvaggio, F., Papini, R., Pollock, J., Caton, D., Hawkins, R., Benishek, V., Smith, A., Reigchart, D., Haislip, J. (2015). "(3433) Fehrenbach." *CBET* **4201**.

Tedesco, E.F., Noah, P.V., Price, S.D. (2004). "IRAS Minor Planet Survey." IRAS-A-FPA-3-RDR-IMPS-V6.0. NASA Planetary Data System.

Vander Haagen, G.A. (2008). "Lightcurves of Minor Planets 2118 Flagstaff (15161) 2000 FQ48, and (46436) 2002 LH5." *Minor Planet Bull*. **35**, 49.

Warner, B.D. (2006). Asteroid lightcurve analysis at the Palmer Divide Observatory: March-June 2006." *Minor Planet Bull*. **33**, 85-88.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updates available at *http://www.minorplanet.info/lightcurvedatabase.html*

Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Astron. J.* **150**, A75.

Zappala, V., Cellini, A., Barucci, A.M., Fulchignoni, M., Lupishko, D.E. (1990). "An analysis of the amplitude-phase relationship among asteroids." *Astron. Astrophys*. **231**, 548-560.