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# THE ROTATION PERIOD OF 3977 MAXINE

Lorenzo Franco
Balzaretto Observatory, Rome, ITALY
lor_franco@libero.it

Angelo Tomassini, Maurizio Scardella
Associazione Tuscolana di Astronomia (D06)
Osservatorio Astronomico F. Fuligni
Via Lazio, 14 - località Pratoni del Vivaro – 00040
Rocca di Papa (RM) – ITALY

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Photometric observations of main-belt asteroid 3977 Maxine were made over five nights during 2013 July. Lightcurve analysis shows a synodic period $P = 3.081 \pm 0.001$ h with amplitude $A = 0.25 \pm 0.03$ mag.

The main-belt asteroid 3977 Maxine was selected from the "Potential Lightcurve Targets" web site (Warner, 2012a) and observed on five nights from 2013 June 30 to July 20. Observations were carried out from Balzaretto Observatory (A81) in Rome (Italy), using a 0.20-m Schmidt-Cassegrain (SCT) reduced to *f*/5.5 and equipped with a SBIG ST7-XME CCD camera with clear filter. Observations at the F. Fuligni Observatory near Rome (Italy) used a 0.35-m *f*/10 Meade Advanced Coma Free telescope and SBIG ST8-XE CCD camera with Bessel R filter. All images were calibrated with dark and flat-field frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012b). The large scatter of the session of July 20 is due to the hazy weather, which however did not affect the general trend of the lightcurve.

The derived synodic period was $P = 3.081 \pm 0.001$ h (Fig. 1, 2) with an amplitude of $A = 0.25 \pm 0.03$ mag.

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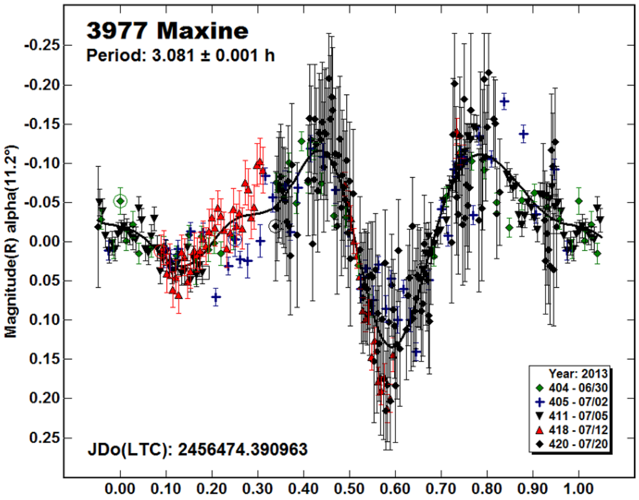

Figure 1. The lightcurve of 3977 Maxine with a period of 3.081 ± 0.001 h and amplitude of 0.25 ± 0.03 mag.

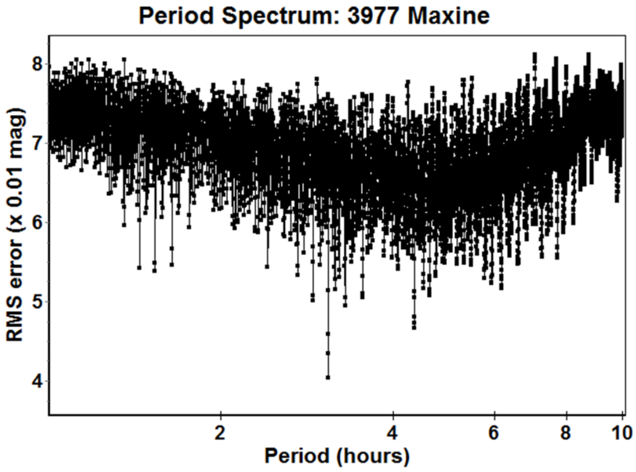

Figure 2. Period Spectrum shows an isolated solution.

# ASTEROID LIGHTCURVE ANALYSIS AT RIVERLAND DINGO OBSERVATORY (RDO): 2013 RESULTS

Kevin Hills
Riverland Dingo Observatory
Moorook, South Australia 5343
AUSTRALIA
kevinhills@me.com

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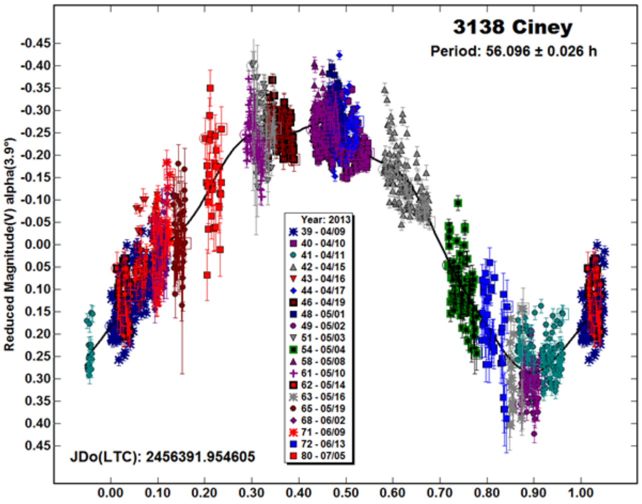
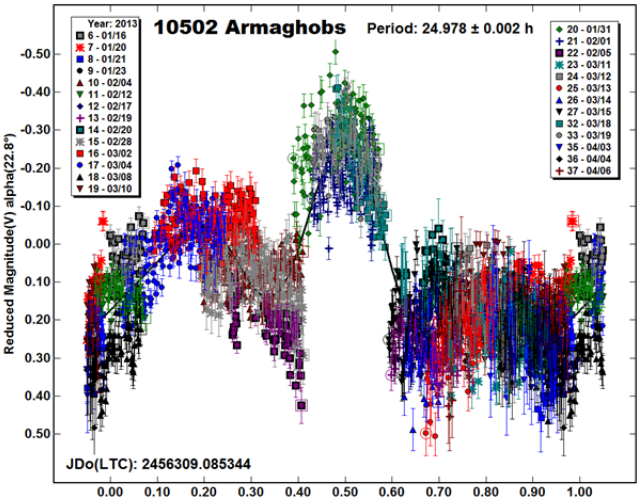
Lightcurves for three asteroids selected from the *Collaborative Asteroid Lightcurve Link* (CALL; Warner, 2011) were obtained at the Riverland Dingo Observatory (RDO) from 2013 January 16 – July 7: 3138 Ciney, 10502 Armagahobs, and 11441 Anadiego. In addition a lightcurve for (285263) 1998 QE2 was obtained following a request for data from Lance Benner posted on the Minor Planet Mailing List (MPML) Yahoo Group on the basis that it was a radar imaging target at Arecibo and Goldstone in late 2013 May and early June.

The observations reported here were all obtained using a 0.41-m *f*/9 Ritchey-Chrétien telescope and SBIG STL-1001E CCD camera with a clear filter. All images were bias, dark, and flat-field corrected and had an image scale of 1.35 arcsec per pixel. Differential photometry measurements were made in *MPO Canopus* (Warner, 2008). V magnitudes for comparison stars were extracted from the *AAVSO Photometric All-Sky Survey (APASS)* catalog. The Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) does not contain previously reported results for any of the asteroids reported here.

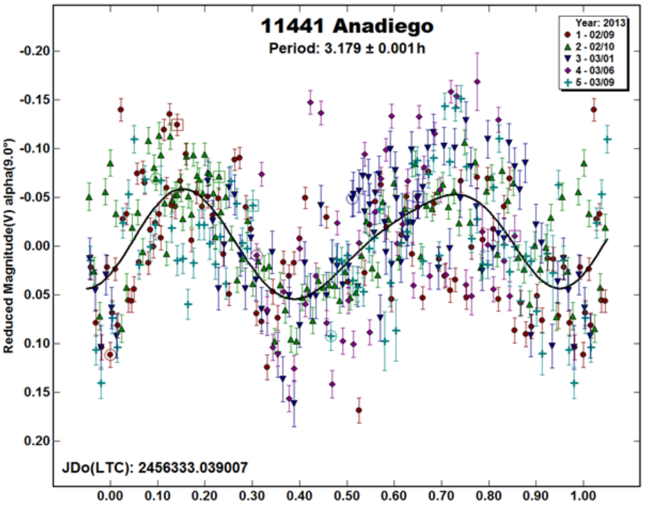
3138 Ciney is a main-belt asteroid discovered by H. Debehogne at La Silla in 1980. A total of 1548 data points were obtained over 20 nights during the period 2013 April 9 – July 5 as the solar phase angle increased from +3.9° to +29.0°. The average magnitude was 16.1 and average SNR was 88. The lightcurve shows a period of 56.096 ± 0.026 h and amplitude of 0.56 ± 0.02 mag, suggesting that the asteroid rotated 37 times during the period of observation.



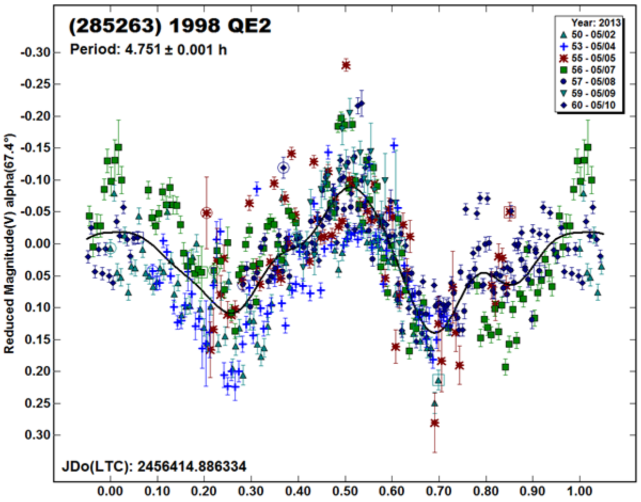
10502 Armagahobs is a Mars-crossing asteroid discovered by E.F. Helin at Palomar in 1987. A total of 2548 data points were obtained over 27 nights during the period 2013 January 16 – April 6 including solar phase angles between –22.8° to +24.3°. The average magnitude was 17.6 and average SNR was 31. The lightcurve shows a period of 24.978 ± 0.002 h and amplitude of 0.51 ± 0.09 mag suggesting that the asteroid rotated 76 times during the period of observation.



11441 Anadiego is a main-belt asteroid discovered by M.R. Cesco at El Leoncito in 1975. A total of 397 data points were obtained over five nights during the period 2013 February 9 – March 9 including solar phase angles between –9.0° to +13.4°. The average magnitude was 16.3 and average SNR was 91. The lightcurve shows a period of 3.179 ± 0.001 h and amplitude of 0.11 ± 0.01 mag suggesting that the asteroid rotated 211 times during the period of observation.



(285263) 1998 QE2 is a Potentially Hazardous Amor asteroid discovered by LINEAR at Socorro in 1998. A total of 515 data points were obtained over seven nights during the period 2013 May 2-10 including solar phase angles between +67.4° to +70.8°. The average magnitude was 16.1 and average SNR was 110. *MPO Canopus* suggests a number of possible lightcurve periods including 4.3, 4.7, 5.3 and 5.9 h. Subsequent analysis of radar data obtained at Goldstone and Arecibo shows that 1998 QE2 is a binary system. The primary has a rotation period of the order of 4.7 h and the satellite of the order of 32 h (*http://echo.jpl.nasa.gov/asteroids/1998QE2/1998QE2_planning.html*). The lightcurve presented in this paper shows a rotation period of 4.751 h ± 0.001 h, which is consistent with the radar data, and amplitude of 0.23 ± 0.01 mag suggesting that the asteroid rotated 40 times during the period of observation.



Acknowledgements

The measurements reported make use of the *AAVSO Photometric All-Sky Survey (APASS)* catalog, which is funded by the Robert Martin Ayers Sciences Fund.

Thank you to Darren Wallace of RDO and his collaborators at New Mexico Skies for maintaining the equipment in Australia.

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# LIGHTCURVE ANALYSIS FOR 3562 IGNATIUS

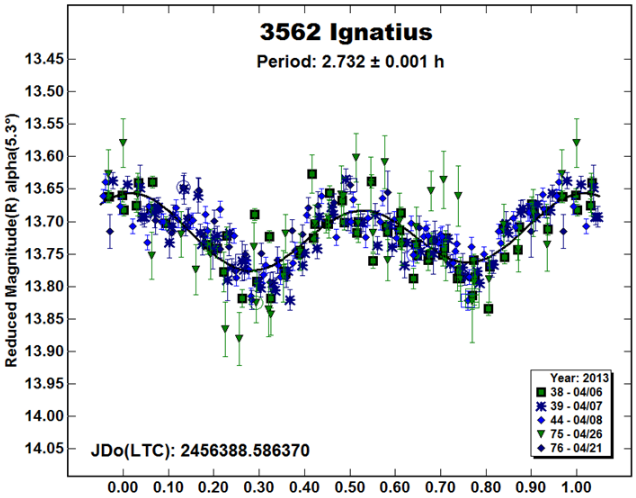
James Falese, Caroline Odden, and Pallavi Prakash
Phillips Academy Observatory (I12)
180 Main Street
Andover, MA 01810 USA
ceodden@andover.edu

(Received: 14 August)

A lightcurve for asteroid 3562 Ignatius was generated using images taken at the Phillips Academy Observatory in 2013 April. Results indicate a synodic rotation period of 2.732 ± 0.001 h and an amplitude of 0.12 mag.

Observations of the asteroid 3562 Ignatius were conducted at the Phillips Academy Observatory with a 0.4-m *f*/8 reflecting telescope by DFM Engineering using an SBIG 1301-E CCD camera, which has a 1280x1024 array of 16-micron pixels. The resulting image scale was 1.0 arcsecond per pixel. All images were guided, unfiltered, and unbinned. Exposures were 300 seconds, taken primarily at –35°C. Images were dark-field and flat-field corrected using *Maxim DL*. Processed images were measured with *MPO Canopus* (Warner, 2010) using a differential photometry technique. Comparison stars in the image field were chosen to have near-solar color with the program's "comp star selector" feature.

Period analysis was carried using *MPO Canopus* and its Fourier analysis feature of Harris (Harris *et al*., 1989). The resulting bimodal lightcurve contains 258 data points and indicates a period of $P = 2.732 \pm 0.001$ h and an amplitude of $A = 0.12$ mag.



Acknowledgements

Research at the Phillips Academy Observatory is supported by the Israel Family Foundation.

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# ASTEROIDS LIGHTCURVES AT OAVDA:
# 2012 JUNE – 2013 MARCH

Albino Carbognani
Astronomical Observatory of the Autonomous Region of the
Aosta Valley (OAVdA),
Lignan 39, 11020 Nus (Aosta), ITALY
albino.carbognani@gmail.com

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Ten asteroids, both near-Earth and in the main-belt, were observed at OAVdA from 2012 June through 2013 March: 1198 Atlantis, 1632 Siebohme, 2858 Carlosporter, 3948 Bohr, 5369 Virgiugum, (20899) 2000 XB3, (137199) 1999 KX4, (329338) 2001 JW2, (330825) 2008 XE3, and 2012 TC4.

This paper features the results of photometric observations on asteroids, both main-belt (MBA) and near-Earth (NEA), made at OAVdA Observatory (Carbognani and Calcidese, 2007), from 2012 June through to 2013 March, and as outlined in Carbognani (2011). The images were captured by means of a modified Ritchey-Chrétien 0.81-m *f*/7.9 telescope using an FLI PL 3041-1-BB in with an array of 2048×2048 pixels. The field-of-view was 16.5×16.5 arcmin and the plate scale was 0.97 arcsec per pixel in 2×2 binning mode.

We used *MPO Canopus* (Warner, 2009) version 10.4.1.0, for differential photometry and period analysis. All sessions were calibrated with the *MPO Canopus* "Comp Star Selector", which chooses comparison stars that are similar in color to the target (in general, solar-type stars), and the "DerivedMags" approach. The amplitude of the lightcurve was also obtained directly from *MPO Canopus* and not with a polynomial fit as in Carbognani (2011).

Known periods were drawn from the asteroid lightcurve database (LCDB; Warner *et al.*, 2009; 2013 March update).

1198 Atlantis is a Mars-crossing asteroid. A total of 200 images in R band and 54 in V band were taken on two nights, the first on 2012 July 15 (with bad seeing) and the second on 2012 August 8. The data of the first session, with phase angle 18°, show some variations in luminosity, whereas the data of the second session (phase angle 6°) show a monotonic decrease. It is not possible to determine a unique rotation period. A period value of about 5 h is the most probable for the first session, with an amplitude of 0.28 mag, while for the second session a value of about 20 h would appear more reasonable (if we assume a bimodal lightcurve). Considering the bad seeing conditions of the first session, the longer period appears more likely. No period was known for this object before.

1632 Siebohme is an MBA. A total of 690 images were taken over six nights in R band from 2012 August to September. Even with this data set, it was not possible to determine a definite rotation period. The most probable period was 56.81 ± 0.01 h, with a lower limit for amplitude of about 0.46 mag. The period values was in good agreement with the LCDB value: 56.65 h with U = 2 (Behrend, 2012). Note that the first session for this object (2012 August 11) shows a very fast luminosity increase (about 0.3 mag in 23 minutes only), followed by a linear decrease.

2858 Carlosporter is an MBA. A total of 354 images in R band and 98 in V band were taken over five nights, from 2012 July to October. The first session was discarded due to clouds. Between the second and the last three sessions, the lightcurve showed significant changes due to variation in lighting conditions. The period is 3.348 ± 0.008 h with amplitude of 0.16 mag for the second session, and 3.336 ± 0.001 h with amplitude of 0.47 mag for the last three. The results appear coherent and the last value is more reliable than the first. No period was known for this object before.

3948 Bohr is an MBA. A total of 101 images in R band and 102 in V band were taken but in only one session on 2012 July 11 and with bad seeing. The lightcurve of the 5-hour session shows a single maximum, which makes one suspect a period of about 20 h. This is compatible with the LCDB value of 24.884 h with U = 3 (Owings, 2013).

5369 Virgiugum is an MBA. A total of 451 images were taken on three nights in R band on 2012 August 9/10 and September 15. The lightcurve is well-covered with a period of 5.8422 ± 0.0002 h and an amplitude of 0.26 mag. This value is in excellent agreement with the LCDB: 5.8422 with U = 2+ (Owings, 2013).

(20899) 2000 XB3 is an MBA. A total of 242 images in R band and 60 in V band were taken over two nights, one month apart on July and August 2012. The lightcurves of the two sessions appear rather flat and similar. No period was derived, but it might be very long, the lower limit for the amplitude being about 0.1 mag. No period was known for this object before.

(137199) 1999 KX4 is an Amor object. A total of 941 images with a photometric C filter (to maximize the signal-to-noise ratio), were taken over five nights between February and March 2013 (the minimum distance from Earth of 0.211 UA was reached on January 28). The lightcurve of this object appears to change from session to session.

In the first session of 2013 February 15, the SNR is about 140 and the partial lightcurve appears quite regular with a period of 2.797 ± 0.01 h (Figure 9). The value is in good agreement with the one in the LCDB (2.767 h, U = 3). Unfortunately, the lightcurve of this session is only partial (despite the session duration of about 6 h), because of cloudy skies in the central part of the night.

In the sessions of 2013 March 1-2 (Figure 10-11), the SNR is around 70 and the data are noisier but the lightcurves appear completely different from the previous session, even if the phase angle has not changed dramatically. Furthermore, while the lightcurve on March 1 maintains a periodicity of 2.90 ± 0.02 h with an amplitude of 0.24 mag, the lightcurve of the session on March 2 shows a periodicity of about 5 h with an amplitude of about 0.34 mag. After a search of faint background stars that may have altered the lightcurve, we conclude that this behavior might be due to shadowing effects owing to the very high phase angle or to the presence of a companion, but the data recorded are not sufficient to derive the period of any satellite.

The subsequent sessions of 2013 March 10-13 (Figure 12), are not sufficient to solve the problem because the lightcurves appear to have qualitatively changed from the previous ones, with the secondary maximum lower than previously probably owing to change of lighting conditions. The problem is therefore still open.

(329338) 2001 JW2 is an Apollo object. A total of 440 images with clear filter were taken on a single session on 2012 November 14. The lightcurve is not completely covered, but the most probable period is between 10 and 15 h, with a lower limit for amplitude of 0.20 mag. No period was known before.

(330825) 2008 XE3 is an Amor object, discovered on 2008 December 12 by the LINEAR NEO survey. A total of 300 images in R band were taken on one single session (9 h length), on 2012 October 24. The lightcurve appears well-covered but it does not repeat exactly, i.e., there is some dispersion in the phased lightcurve, see 0.7 phase of Figure 14. For this reason we went looking for a second period due to a possible satellite as also suspected by Hicks *et al.* (2012), with observations spanning over three nights (2012 November 4-5-7) . The most likely solution is an asynchronous binary system with no mutual events (i.e. occultation or eclipses), but with the main body‘s lightcurve altered by the rotation of the secondary body around its axis. The bimodal rotation period of the suspected secondary is about 5.7 ± 0.1 h with an amplitude of 0.03 mag. Unfortunately, the data are a bit noisy and cannot be excluded that this is just only noise (Harris *et al.*, 2012), so further observations are needed. The rotation period of the primary one only is 4.41 ± 0.01 h with an amplitude of 0.17 mag. These values are in good agreement with Warner (2013) and Hicks *et al*. (2012).

2012 TC4 is an Apollo object. A total of 306 images with C filter were taken on two nights, before the Earth flyby on 2012 October 12 at a distance of 15.5 Earth-radii. The rotation period is very fast, 0.2067 ± 0.0001 h, with an amplitude of 0.76 mag, in good agreement with Polishook (2013) and Warner (2013). The value of the rotation period is under the “spin barrier” of about 2.2 h for a rubble pile asteroid (Pravec and Harris, 2000), so the structure of 2012 TC4 is “strength dominated”, but not necessarily monolithic.

## Acknowledgements

This research has made use of the NASA’s Astrophysics Data System and JPL Small-Body Database Browser.

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| Number | Dates yyyy mm dd | Phase [deg] | Period [h] | Amp [mag] |
|---|---|---|---|---|
| 1198 | 2012 07 15<br>2012 08 07 | 17.8-5.5 | ~ 20 (?) | ≥ 0.28 |
| 1632 | 2012 08 11/12<br>2012 09 05/06<br>2012 09 07/14 | 14.0-3.7 | 56.81 ± 0.01 | ≥ 0.46 |
| 2858 | 2012 07 10<br>2012 08 06<br>2012 09 10/27<br>2012 10 10 | 3.2-32.2 | 3.336 ± 0.001 | 0.47 |
| 3948 | 2012 07 11 | 8.3 | 15-20 | ≥ 0.26 |
| 5369 | 2012 08 09/10<br>2012 09 15 | 7.7-16.4 | 5.8422 ± 0.0002 | 0.26 |
| 20899 | 2012 07 14<br>2012 08 08 | 15.1-4.9 | (?) | ≥ 0.1 |
| 137199 | 2013 02 15<br>2013 03 01/02<br>2013 03 10/13 | 65.0-74.5 | 2.80 ± 0.01 (binary?) | ≥ 0.35 |
| 329338 | 2012 11 14 | 22.8 | 10-15 | ≥ 0.2 |
| 330825 | 2012 10 24 | 29.3 | 4.41 ± 0.01 (binary?) | 0.17 |
| 2012 TC4 | 2012 10 09/10 | 25.4 | 0.2067 ± 0.0001 | 0.76 |

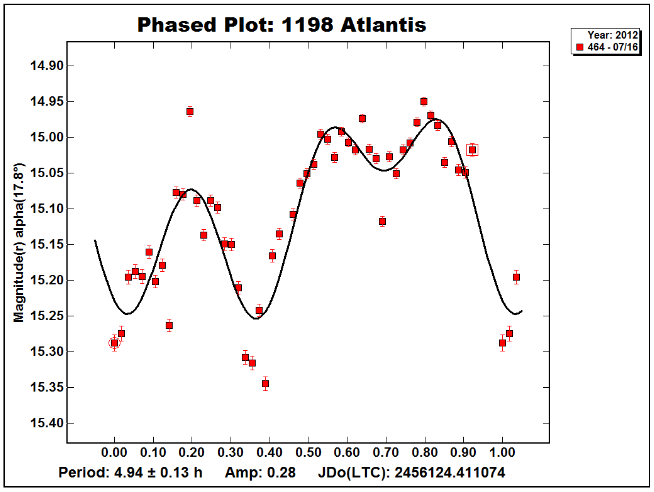

Figure 1. The lightcurve of the first session for 1198 Atlantis with a period of about 5 h.

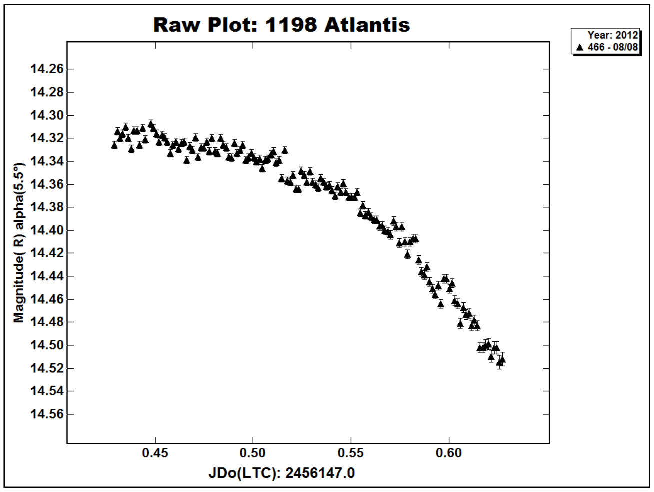

Figure 2. The raw lightcurve of the second session for 1198 Atlantis. Assuming a bimodal curve, a period of about 20 h appear more reasonable.

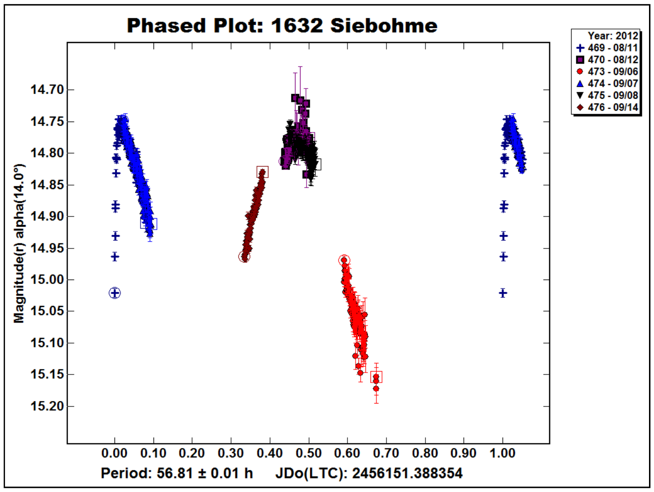

Figure 3. The partial lightcurve of 1632 Siebohme with the most probable period of about 56.81 h.

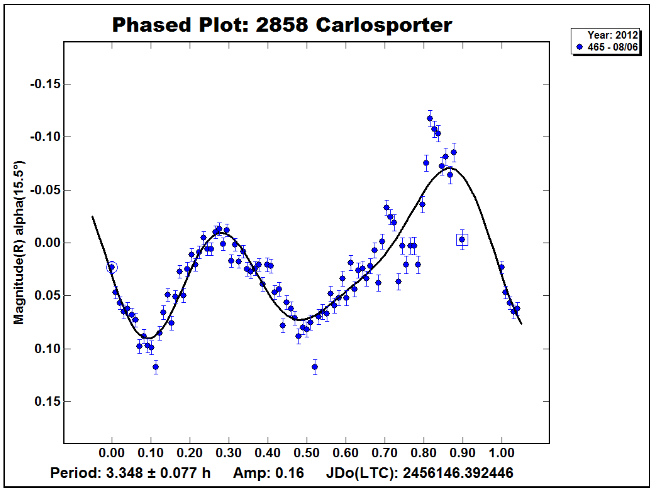

Figure 4. The full lightcurve of 2858 Carlosporter of 2012 August 06.

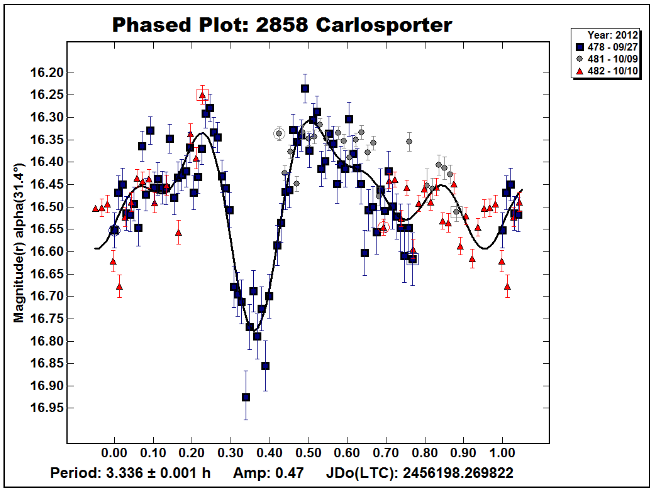

Figure 5. The full lightcurve of 2858 Carlosporter from 2012 September-October. The difference with the August lightcurve is obvious.

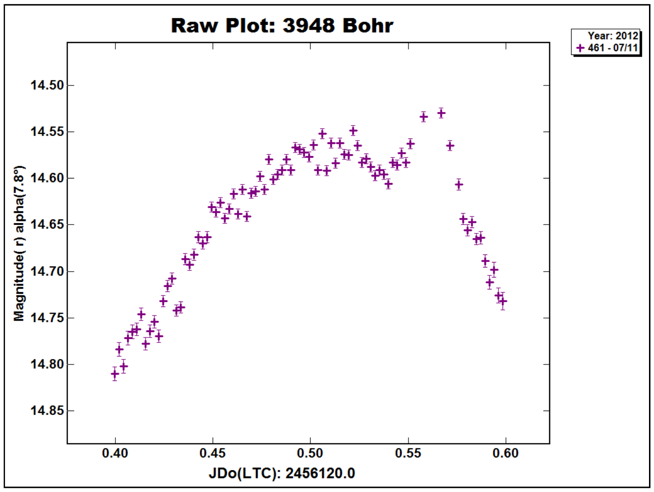

Figure 6. The partial raw lightcurve of 3948 Bohr.

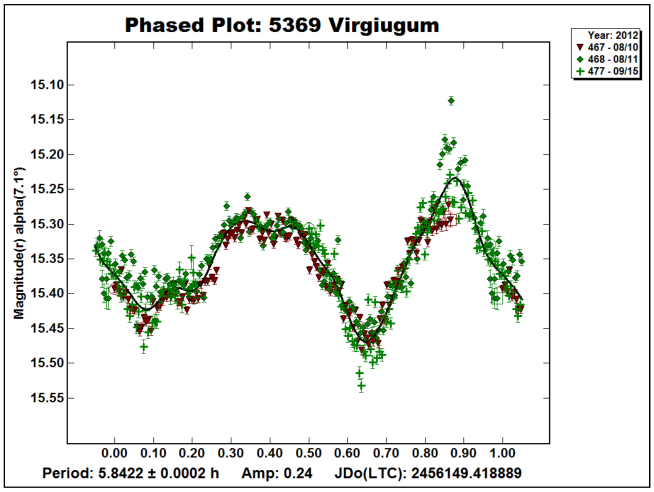

Figure 7. The full lightcurve of 5369 Virgiugum.

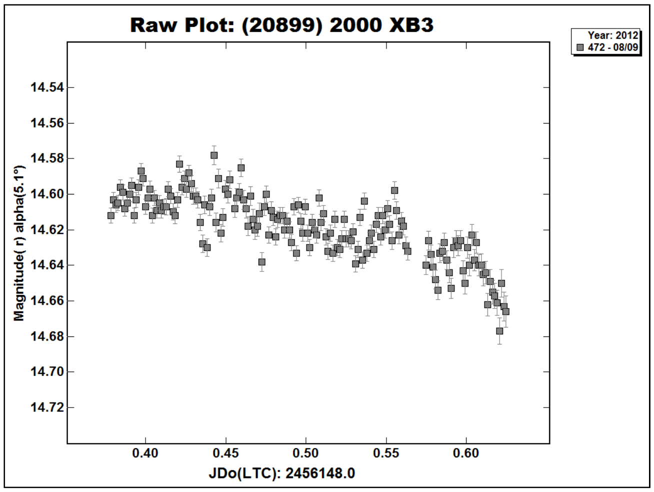

Figure 8. The featureless lightcurve of the second session of (20899) 2000 XB3.

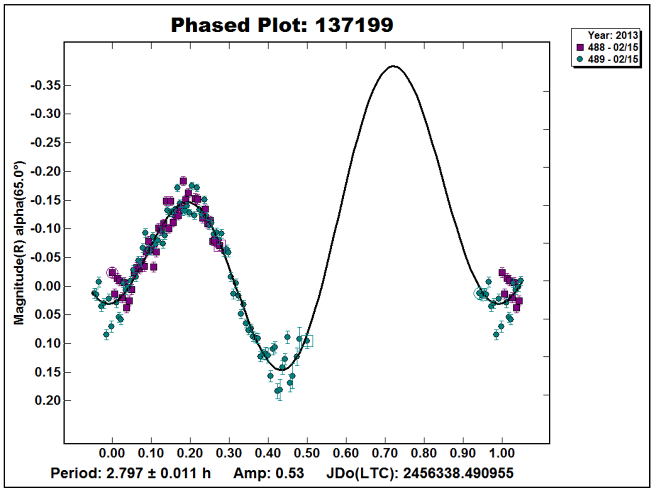

Figure 9. The partial lightcurve of (137199) 1999 KX4 in the February 15, 2013 session.

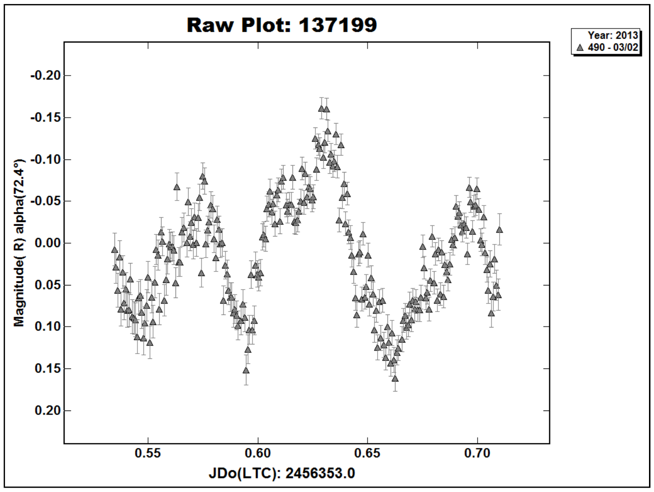

Figure 10. The raw lightcurve of (137199) 1999 KX4 in the 2013 March 02 session. The period is about 2.90 h.

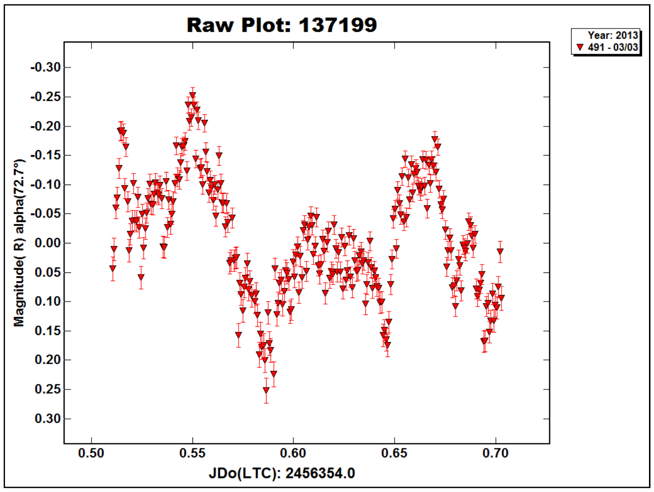

Figure 11. The raw lightcurve of (137199) 1999 KX4 in the 2013 March 03 session. The lightcurve have a periodicity of about 5 h, as discussed in the text.

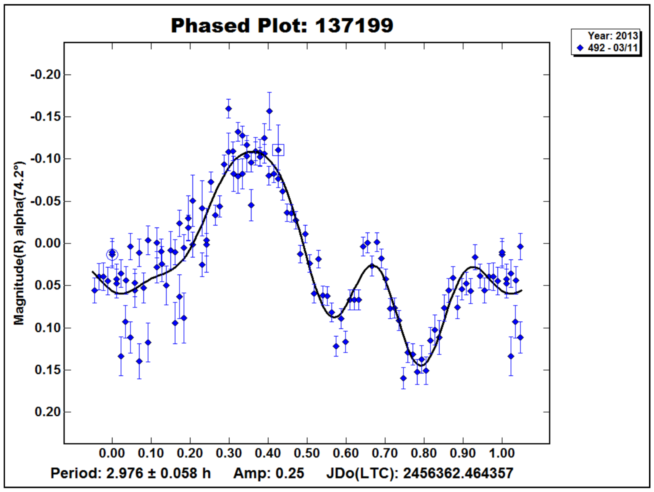

Figure 12. The raw lightcurve of (137199) 1999 KX4 in the 2013 March 11 session.

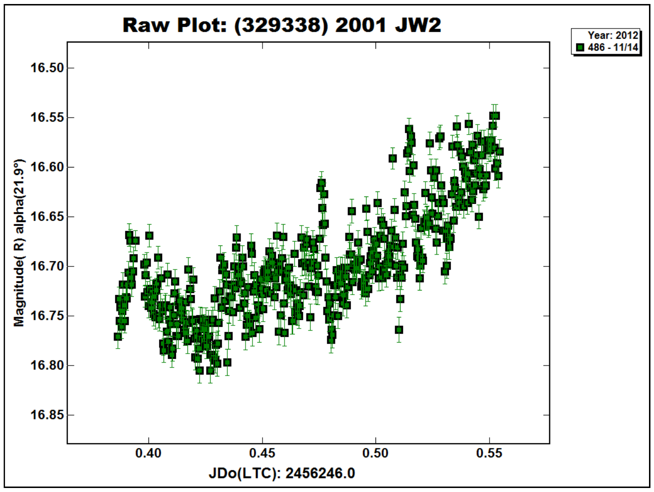

Figure 13. The partial lightcurve of (329338) 2001 JW2.

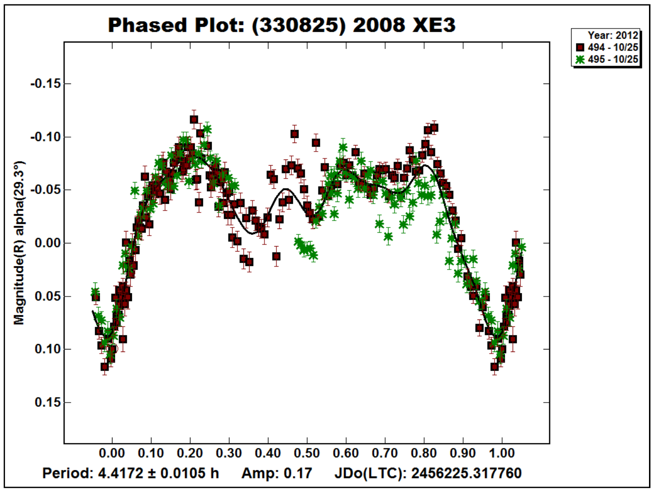

Figure 14. The full raw lightcurve of (330825) 2008 XE3. Some data are missing due to the asteroid being close to with a bright field star.

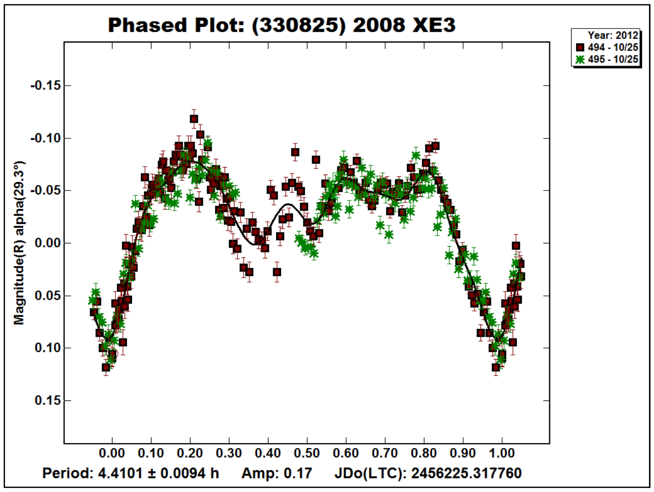

Figure 15. The full lightcurve, primary only, of (330825) 2008 XE3.

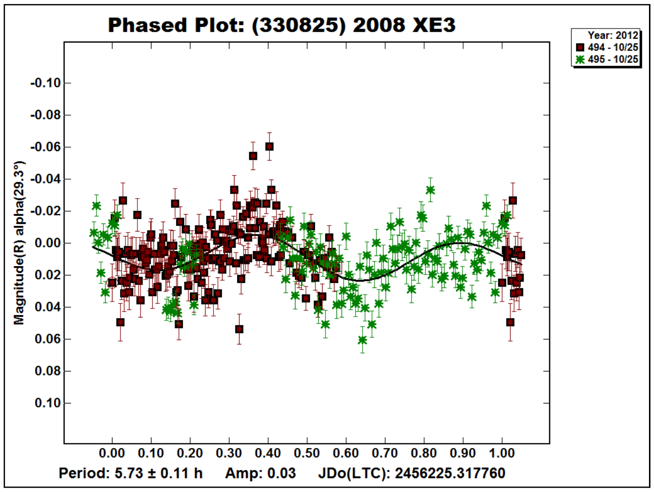

Figure 16. The full lightcurve, secondary only, of (330825) 2008 XE3.

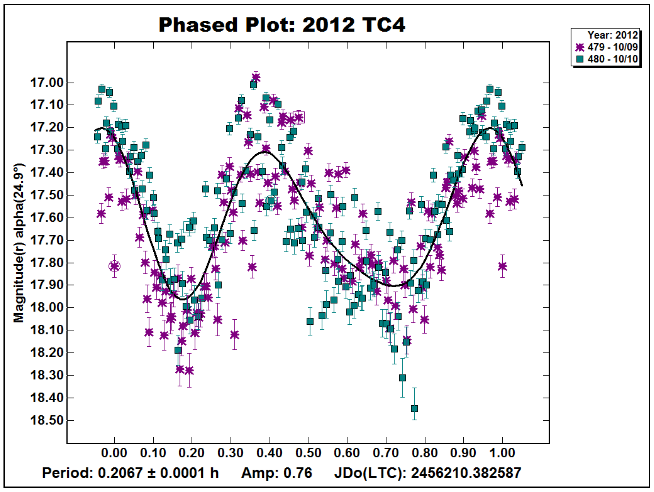

Figure 17. The full lightcurve of 2012 TC4.

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# COLLABORATIVE ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2013 APRIL-JUNE

Robert D. Stephens
Center for Solar System Studies / MoreData!
11355 Mount Johnson Court, Rancho Cucamonga, CA 91737
RStephens@foxandstephens.com

Daniel Coley
Center for Solar System Studies
Landers, CA USA

Brian D. Warner
Palmer Divide Observatory

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Lightcurves for 16 Hungaria asteroids were obtained at the Center for Solar System Studies (CS3) from 2013 April through June. Most of the efforts were follow-up to observations from previous apparitions to check for the possibility of previously undiscovered satellites and to provide additional data for spin axis and shape modeling.

CCD photometric observations of 16 Hungaria asteroids were made at the Center for Solar System Studies (CS3) located in Landers, CA. The primary purpose in many cases was to provide additional data for spin axis and shape modeling as part of a long-term study of these inner main-belt asteroids conducted by Warner (see Warner *et al*., 2009a).

We note that this is the first of what we anticipate to be an on-going series of papers that are the result of our collaboration. While each author has his own observatory (or observatories) at the CS3 site and engages in independent research, when science may be optimized, we do join forces to provide observations for one or more members of specific groups of asteroids, e.g., the Hungarias, Near-Earth asteroids (NEAs), and the Jupiter Trojans.

For all data reported on here, image processing and measurement as well as period analysis were done using *MPO Canopus* (Bdw Publishing). The period analysis is based on the FALC algorithm developed by Harris (Harris *et al.* 1989). Master flats and darks

| Number | Name | 2013 (mm/dd) | Obs | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | Sarmiento | 04/22-04/24 | DC | 287 | 17.5,17.9 | 191 | +23 | 4.038 | 0.003 | 0.29 | 0.03 |
| 2272 | Montezuma | 04/23-04/27 | RDS | 271 | 15.3,15.8 | 213 | +23 | 8.180 | 0.001 | 1.17 | 0.02 |
| 4764 | Joneberhart | 05/04-05/09 | RDS | 108 | 23.3,23.0 | 233 | +36 | 5.484 | 0.001 | 0.91 | 0.02 |
| 5427 | Jensmartin | 06/04-06/06 | RDS | 190 | 24.0,23.6 | 277 | +23 | 5.812 | 0.003 | 0.62 | 0.02 |
| 5577 | Priestley | 05/20-06/02 | RDS | 741 | 21.6,24.8 | 221 | +25 | 160. | 5. | 0.85 | 0.10 |
| 7660 | 1993 VM1 | 04/27-05/01 | DC | 368 | 15.7,17.2 | 199 | +19 | 5.924 | 0.002 | 0.36 | 0.03 |
| 9084 | Achristou | 04/29-05/03 | RDS | 215 | 12.8,15.5 | 204 | +9 | 8.84 | 0.02 | 0.09 | 0.01 |
| 10531 | 1991 GB1 | 04/29-05/09 | RDS | 380 | 12.1,18.0 | 202 | -2 | 55.1 | 0.2 | 0.21 | 0.02 |
| 24654 | Fossett | 05/11-05/26 | DC | 349 | 16.6,14.6,15.1 | 233 | +16 | 5.999 | 0.005 | 0.75 | 0.02 |
| 32814 | 1990 XZ | 04/21-04/22 | RDS | 143 | 16.7,17.0 | 190 | +20 | 2.84 | 0.01 | 0.09 | 0.02 |
| 35055 | 1984 RB | 05/10-05/12 | RDS | 160 | 21.5,22.0 | 204 | +28 | 3.656 | 0.005 | 0.49 | 0.02 |
| 35194 | 1994 ET3 | 05/02-05/07 | DC | 264 | 19.7,21.3 | 192 | +21 | 8.912 | 0.002 | 0.67 | 0.03 |
| 39665 | 1995 WU6 | 05/14-05/19 | RDS | 206 | 9.8,12.0 | 221 | +7 | 4.418 | 0.005 | 0.22 | 0.02 |
| 41660 | 2000 SV362 | 05/14-05/22 | DC | 605 | 11.2,13.2 | 226 | +13 | 77.2 | 0.5 | 0.65 | 0.05 |
| 53431 | 1999 UQ10 | 04/14-04/17 | RDS | 239 | 15.4,16.4 | 185 | +17 | 2.650 | 0.002 | 0.10 | 0.02 |
| 65637 | 1979 VS2 | 03/18-04/20 | RDS | 843 | 14.8,20.1 | 178 | +23 | 220. | 2. | 0.90 | 0.05 |

Table I. Observing circumstances. The Obs column gives the initials of the observer. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. $L_{PAB}$ and $B_{PAB}$ are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

were applied to the science frames prior to measurements. Stephens used either a 0.35-meter or 0.4-meter Schmidt-Cassegrain (SCT) and an SBIG STL-1001E CCD or FLI-1001E camera. Coley used a 0.35-meter SCT and SBIG ST-9XE. Images were unfiltered. Conversion to an internal standard system with approximately ±0.05 mag zero point precision was accomplished using the Comp Star Selector in *MPO Canopus* and the MPOSC3 catalog provided with that software. The magnitudes in the MPOSC3 are based on the 2MASS catalog converted to the BVRcIc system using formulae developed by Warner (2007c).

In the plots presented below for a single body or the primary of binary asteroids, the "Reduced Magnitude" is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. For plots showing the lightcurve due to the satellite, differential magnitudes are used, with the zero point being the average magnitude of the lightcurve for the primary. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotational phase, ranging from –0.05 to 1.05.

For the sake of brevity in the following discussions on specific asteroids, only some of the previously reported results may be referenced. For a more complete listing, the reader is referred to the asteroid lightcurve database (LCDB, Warner *et al.*, 2009b). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with bibcodes, is also available for download at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

1920 Sarmiento. Warner (2007a) reported a period of 4.050 h based on data obtained in late 2006. That data set was sparser than the one obtained in 2013, but it spanned about ten days, whereas the 2013 data set spanned only two days. This may explain the difference of 0.01 h in the results for the two years. For rotation rate studies, the periods are essentially identical. However, spin/shape axis modeling wants for at least one more data set that is both of somewhat higher quality than 2013 and spans a week or more, as in 2006.

2272 Montezuma. This Hungaria was observed by Warner (2012a), when a period of 8.183 h was found with an amplitude of 1.08 mag. The 2013 result confirms that period but with a slightly larger amplitude of 1.17 mag. The phase angle bisector longitude ($L_{PAB}$) difference between the two apparitions was about 110° while the phase angles were about the same. These circumstances would seem to indicate a low to modest obliquity for the spin axis since the amplitudes were similar despite significantly different viewing aspects.

4764 Joneberhart. This asteroid was observed at two previous apparitions by Warner (2007b, 2010b). The results from those earlier works and in 2013 agree to within 0.002 h. The amplitude in 2013 (0.91 mag) is about 0.05 mag smaller than the previous years, those having $L_{PAB}$ only 50° apart whereas the 2013 value was about 100° from the average of the two others. Here again, this seems to favor a low to modest obliquity for the spin axis.

5427 Jensmartin. Three previous results (Warner 2009, 2010b, 2012b) were within 0.003 h of one another. The amplitudes ranged from 0.44 mag (2008 apparition) to 0.64 mag (2011 apparition). The 2013 period agrees to the same precision and the amplitude was 0.62 mag. The combined data sets may finally provide sufficient for accurate spin axis modeling.

5577 Priestley. A period of 51.9 h was reported by Warner (2009) with an amplitude of 0.35 mag. No indications of non-principal axis rotation (NPAR, "tumbling") were reported. Pravec *et al.* (2005b), and references therein, provide an excellent background on tumbling asteroids. A closer review of the 2009 data set found only very slight indications of tumbling. On the other hand, the results from 2013 show clear indications of NPAR. The plot below shows a best fit of about 160 h, but some sessions obviously do not overlap others. Analysis by Petr Pravec (private communications) found periods of 162 h and 30 h, one being principal axis rotation and the other the precession period. However, these are not necessarily the true values since the data set does not allow a unique solution. Other solutions involving linear combinations of two rotation frequencies are possible.

(7660) 1993 VM1. Pravec *et al.* (2005a) reported a period of 5.916 h for this Hungaria member. The amplitude was 0.32 mag. Warner (2012a) found a period 5.92 h and amplitude of 0.86 mag from data obtained in late 2011. The 2013 results agree with the 5.92 period. The amplitude was 0.36 mag, in close agreement with

Pravec *et al*. This is not surprising since the $L_{PAB}$ for the two apparitions were within 20° of one another.

9084 Achristou. No previously-reported results could be found for this asteroid. The low amplitude (0.09 mag) makes this solution somewhat uncertain.

(10531) 1991 GB1. The 2013 results appear to be the first reported in the literature.

24654 Fossett. Pravec *et al*. (2005a) reported a period of 6.004 h with amplitude 0.8 mag based on data obtained in early 2005. Warner (2010a) found 6.003 h, amplitude 0.74. The average 2013 period and amplitude agree with the 2010 results. The $L_{PAB}$ difference between 2010 and 2013 was about 144°, so somewhat similar amplitudes were to be expected, especially if the spin axis obliquity is not too large. Three plots are presented. The first uses the combined data set spanning 17 days in 2013 May. The second and third plots use a subset covering, respectively, May 11-13 and May 23-26. Note the slight change in synodic period and shape of the curves, the late May one having uneven minimums.

(32814) 1990 XZ. Warner (2007a) found a period of 2.8509 h with an amplitude of 0.10 mag. These are traits common to the primaries of small binary asteroids, so the asteroid was observed in 2013 not only to obtain more data for modeling, but also to check for the presence of a satellite. Unfortunately, the asteroid was fainter than predicted and so the signal-to-noise (SNR) was too low to obtain the 0.02 mag or so precision usually required for binary detection.

(35055) 1984 RB. This asteroid was observed by Warner *et al.* (2010b) in 2010. There were some initial indications of a satellite at that time but those were eventually rejected. In 2011 Warner (2012a) observed the asteroid again with no indications of a satellite. The same held true in 2013. The derived period agrees closely with the earlier results and the amplitude was about 0.05 mag greater. The $L_{PAB}$ for 2010 and 2011 were about 180° apart, and so the similar amplitudes would be expected. The value for 2013 is about 60° from that line, and so, a different amplitude might be expected. Given that it was not dramatically different, this would be an indication, as in previous cases above, of a low to modest spin axis obliquity.

(35194) 1994 ET3. We could find no previously published results for this Hungaria. Assuming an equatorial view, the 0.67 mag amplitude implies an a/b ratio for an triaxial ellipsoidal body of ~1.8.

(39665) 1995 WU6. No previous results were found in a search of the literature. The shape of the lightcurve is somewhat unusual, having significantly different maximums.

(41660) 2000 SV362. The 2013 results appear to be the first reported. There does not appear to be obvious signs of tumbling in the lightcurve, although it would not be unexpected since the estimated damping time (Pravec *et al*. 2005b) is greater than the age of the Solar System.

(53431) 1999 UQ10. Warner (2010b) observed this Hungaria in early 2010 and found a period of 2.651 h and amplitude 0.15 mag. This made it another potential binary asteroid candidate. No indications of a satellite were seen over the four consecutive nights of observations in 2013 April, but that is not necessarily proof against a satellite. As a saying goes, "Absence of evidence is not evidence of absence." For example, 2131 Mayall was not found to have a satellite until the third time it was observed (Warner *et al.* 2010a).

(65637) 1979 VS2. We found no previously reported results in the literature. There are indications of low-level tumbling (small amplitude of one of the periods). Based on Pravec *et al*. (2005), the period for a damping time of 4.5 Ga is 66 hours, far less than the period of 220 hours indicated by the 2013 data.

## Acknowledgements

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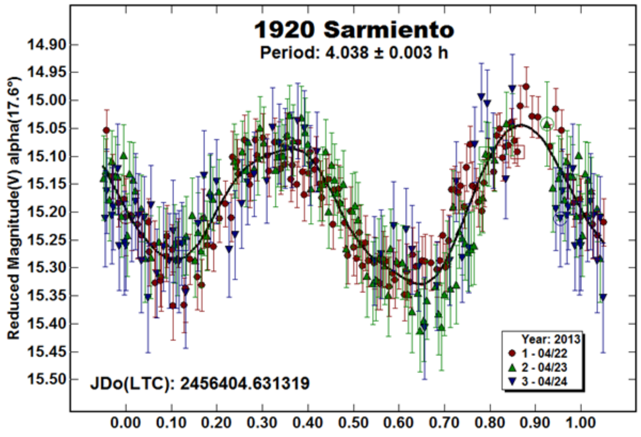

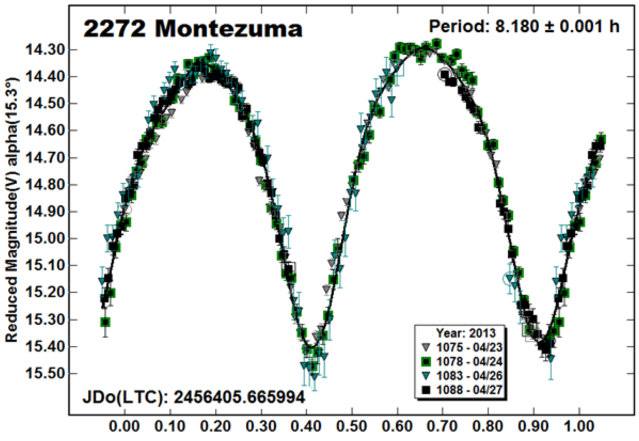

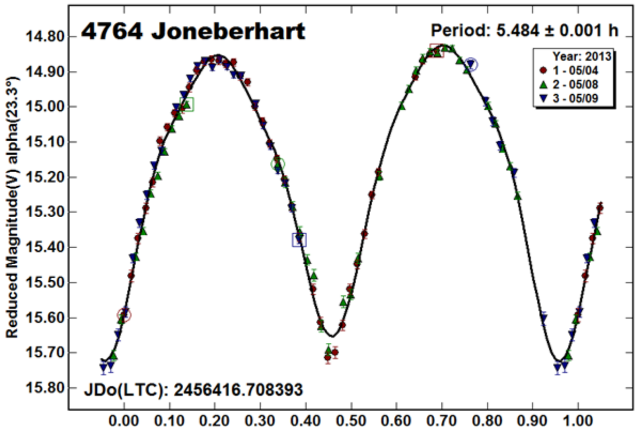

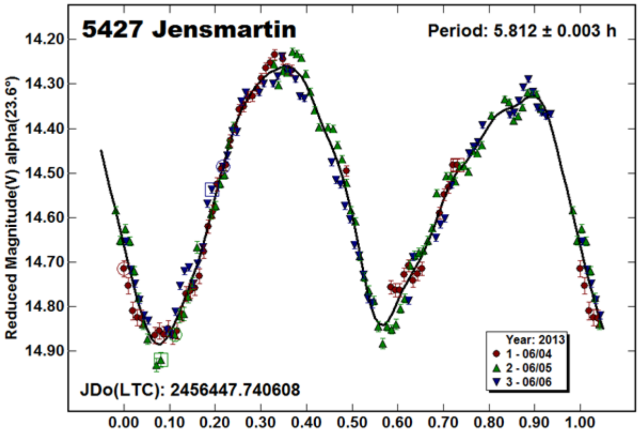

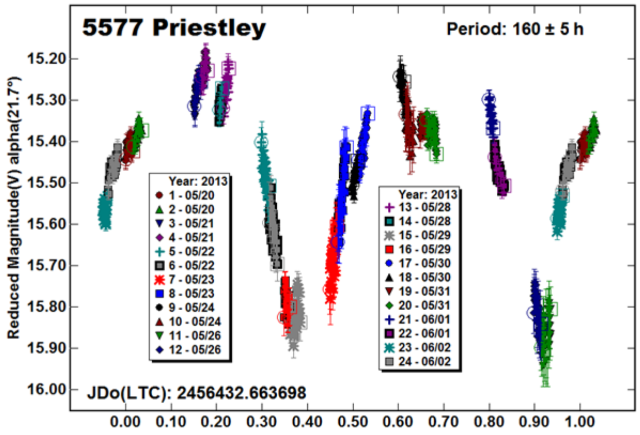

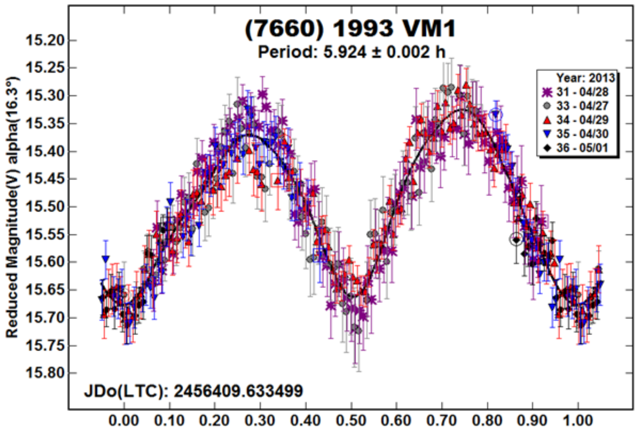

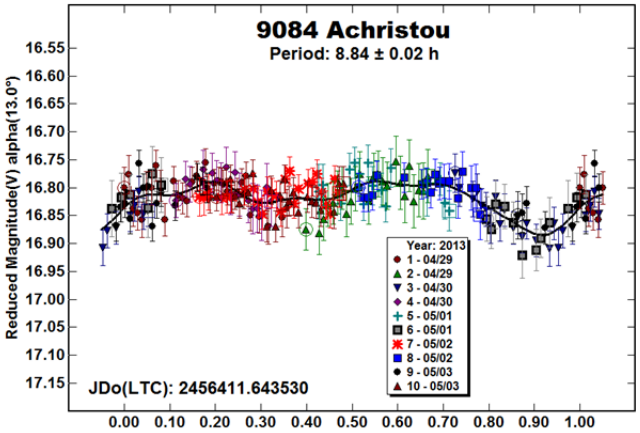
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16.75
16.80
16.85
16.90
16.95
17.00
17.05
17.10
17.15
Year: 2013
1 - 04/29
2 - 04/29
3 - 04/30
4 - 04/30
5 - 05/01
6 - 05/01
7 - 05/02
8 - 05/02
9 - 05/03
10 - 05/03
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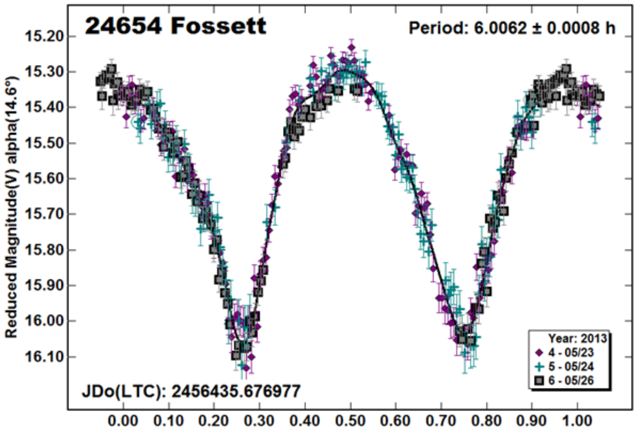
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16.00
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4 - 05/23
5 - 05/24
6 - 05/26
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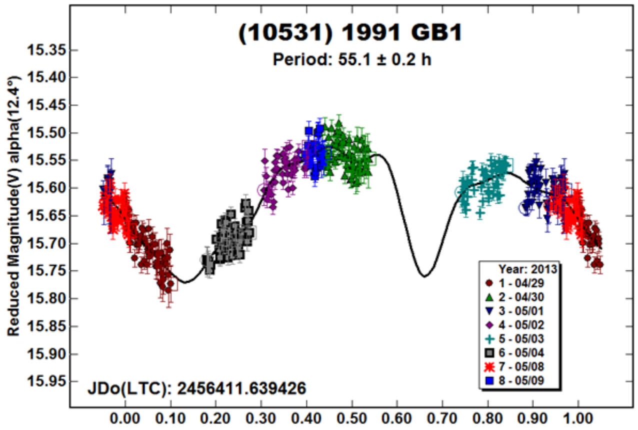
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15.90
15.95
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2 - 04/30
3 - 05/01
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5 - 05/03
6 - 05/04
7 - 05/08
8 - 05/09
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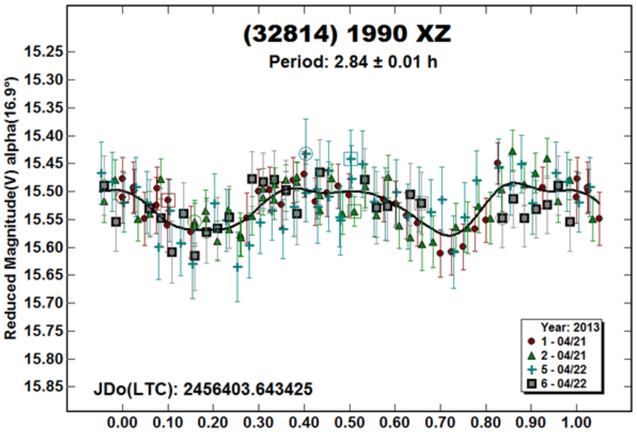
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Year: 2013
1 - 04/21
2 - 04/21
5 - 04/22
6 - 04/22
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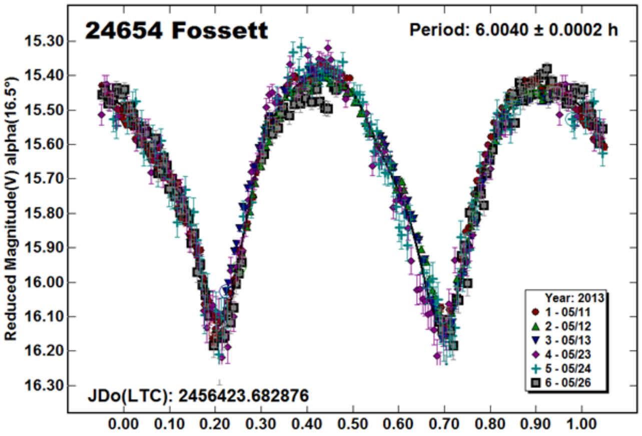
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16.20
16.30
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3 - 05/13
4 - 05/23
5 - 05/24
6 - 05/26
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0.90
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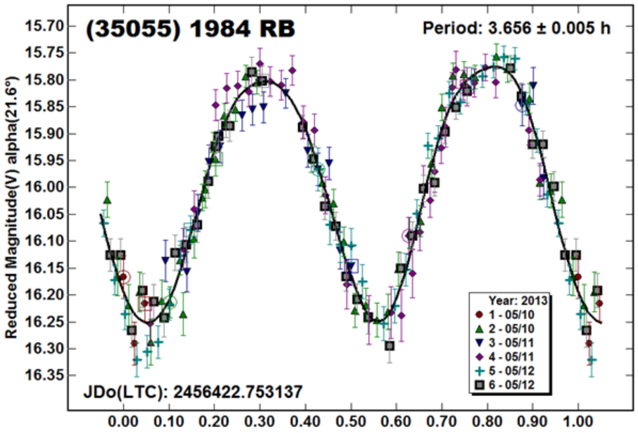
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6 - 05/12
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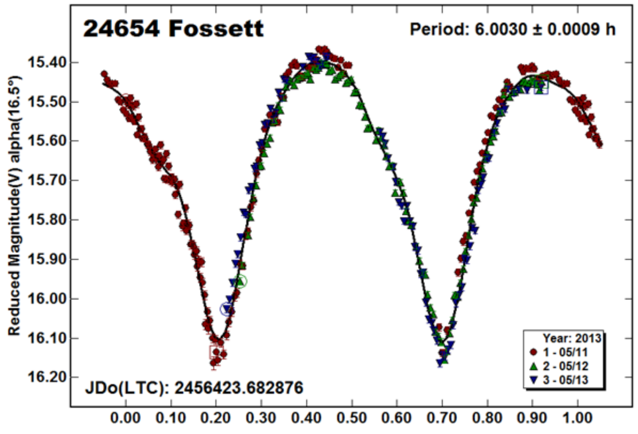
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16.20
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2 - 05/12
3 - 05/13
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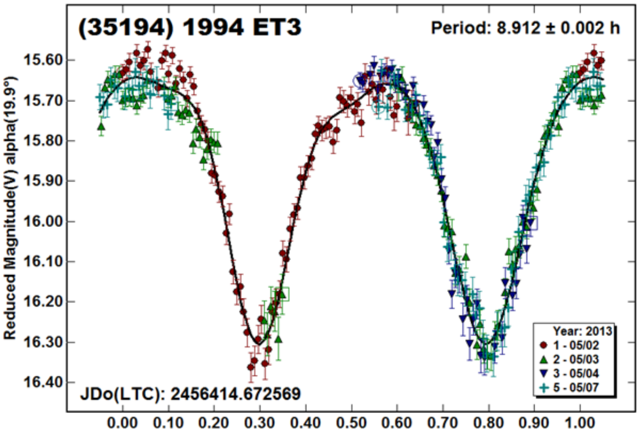
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15.80
15.90
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2 - 05/03
3 - 05/04
5 - 05/07
JDo(LTC): 2456414.672569
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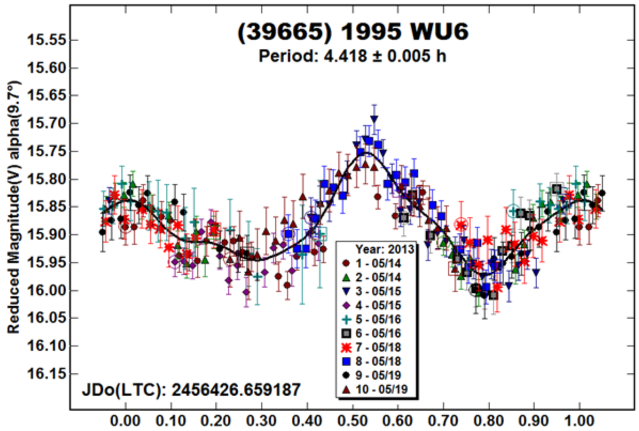
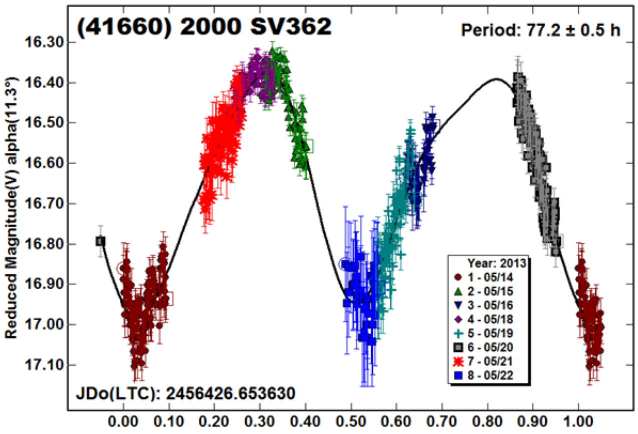
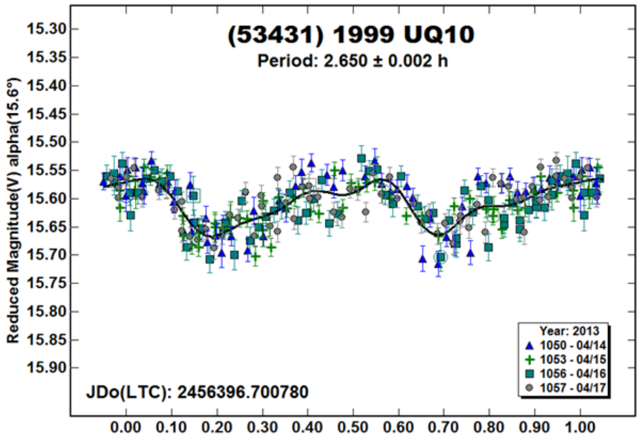
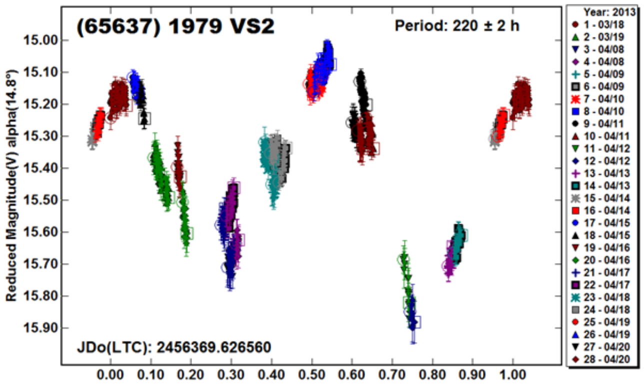
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00









# ASTEROIDS OBSERVED FROM CS3: 2013 JULY-SEPTEMBER

Robert D. Stephens
Center for Solar System Studies (CS3) / MoreData!
11355 Mount Johnson Ct., Rancho Cucamonga, CA 91737 USA
RStephens@foxandstephens.com

(Received: 25 September)

CCD photometric observations of eight asteroids were obtained at the Center for Solar System Studies from 2013 July to September.

The Center for Solar System Studies (CS3) started operations in late 2012. Its participants have a history of studying asteroid families such as Jovian Trojans, Hungarias, and near-Earth objects (NEOs). Brighter alternative targets are selected when program members of targeted families are not observable such as near the full moon.

All images were made with a 0.4-m or 0.35-m Schmidt-Cassegrain (SCT) with an FLI-1001E or a SBIG STL-1001E CCD camera. They were unbinned with no filter and had master flats and darks applied to the science frames prior to measurement. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins R magnitudes based on 2MASS J-K colors (Warner, 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

<u>1314 Paula</u>. This asteroid was observed by Laurent Bernasconi in 2008 September (Behrend, 2013) who determined the rotational period to be 5.9486 h. This result is in good agreement with that finding.

<u>2112 Ulyanov</u>. Ulyanov was observed in 2003 November (Maleszewki, 2004) at Bucknell University. A synodic rotation period of 3.000 ± 0.0001 h was determined, in good agreement with this result. The observed amplitude in 2003 was approximately 0.35 mag. The phase angle bisector longitude ($L_{PAB}$) was 58 degrees at the time.

<u>5431 Maxinehelin</u>. Maxinehelin was observed at Ondrejov, Czech Republic, by Peter Kusnirak and Jan Vrastil as part of the Binary Asteroid Photometric Survey Program. They reported a rotation period of 5.1951 ± 0.006 h, in good agreement with this result.

<u>(6495) 1992 UB1</u>. This asteroid was observed by Laurent Bernasconi in 2006 September (Behrend, 2013) who determined the rotation period to be 5.6974 h. This result is in good agreement with that work. It was also observed from Chiro Observatory (Clark, 2010) in 2009 June. The scatter of the observations was several tenths of a magnitude, but the resulting rotation period was reported to be 5.767 h, similar to this result.

<u>(16896) 1998 DS9</u>. No previous periods are reported in the Lightcurve Database (LCDB; Warner *et al.*, 2013). Zero-point adjustments applied to the observations were typically within the catalog errors. With a size of about 10 km, one might expect the tumbling damping time scale to be around 1 Ga (Pravec *et al.*,

| Number | Name | 2013 (mm/dd) | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1314 | Paula | 08/20-08/25 | 306 | 16.9,14.8 | 354 | +7 | 5.949 | 0.001 | 1.00 | 0.03 |
| 2112 | Ulyanov | 09/19-09/20 | 267 | 16.2,15.8 | 21 | +4 | 3.041 | 0.001 | 0.36 | 0.02 |
| 5431 | Maxinehelin | 07/25-07/29 | 194 | 26.6,21.8 | 333 | +20 | 5.195 | 0.001 | 0.20 | 0.02 |
| 6495 | 1992 UB1 | 08/24-08/25 | 397 | 22.3, 22.4 | 267 | -4 | 5.693 | 0.002 | 0.38 | 0.02 |
| 16896 | 1998 DS9 | 06/20-07/15 | 1450 | 25.0,17.9 | 301 | +26 | 708. | 3. | 0.43 | 0.10 |
| 20691 | 1999 VY72 | 07/13-07/24 | 216 | 17.8,21.5 | 259 | +12 | 2.70 | 0.01 | 0.18 | 0.02 |
| 25755 | 2000 BR14 | 08/06 | 39 | 14.8 | 350 | -4 | > 24 |  | > 0.35 |  |
| 277475 | 2005 WK4 | 08/07-08/08 | 168 | 97.9,87.1 | 3 | +55 | 2.595 | 0.002 | 0.36 | 0.03 |

2005). However, no trend was noticed that would suggest that the asteroid was tumbling.

(20691) 1999 VY72. Rene Roy (Behrend, 2013) observed this object on a single night in 2011 January reporting a period of 2.82 h. It was also observed by Jim Brinsfield at Via Capote Observatory as part of the Binary Asteroid Photometric Survey Program. They reported a rotation period of 2.6990 ± 0.0004 h. Both of these are in good agreement with this result.

(25755) 2000 BR14. This asteroid was in the field of view of another program asteroid and could be followed for only a single night. The period could not be determined, but it does appear to be greater than 24 h.

(277475) 2005 WK4. The radar team at Goldstone and Arcebio requested a lightcurve and rotation period in support of planned observations between 2013 August 3-10. Jose De Queiroz (Behrend, 2013) obtained observations of that covered half a bimodal lightcurve and reported a period of 2.73 h, in good agreement with this result. Radar observations obtained at Goldstone on 2013 August 8 showed the asteroid to be between 200 and 300 m in diameter with a rotation period of about 2.7 h.

## Acknowledgements

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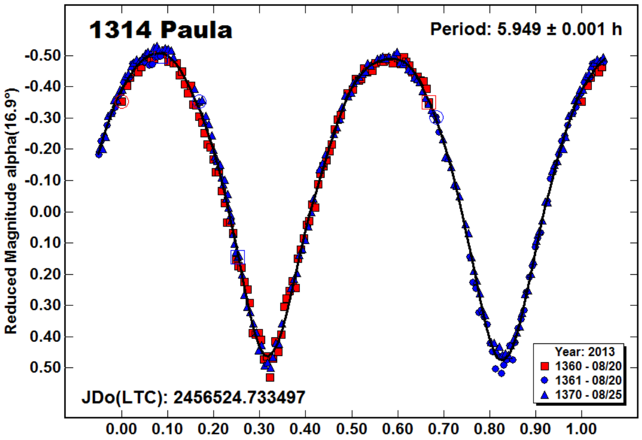

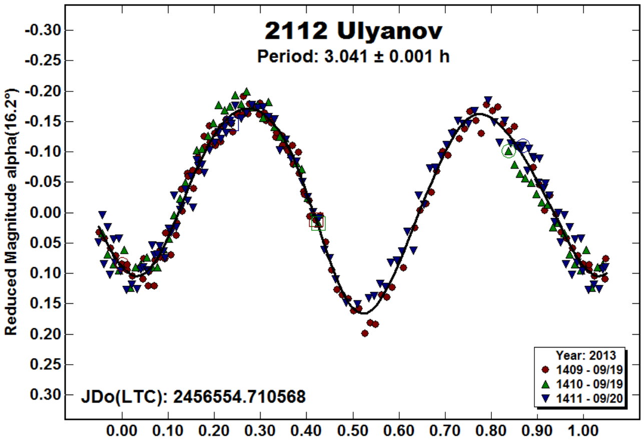

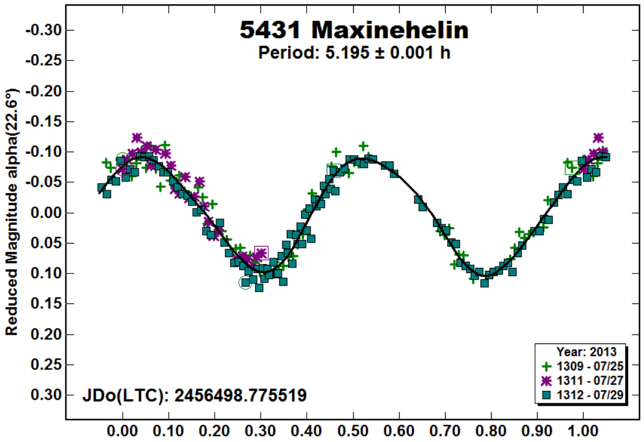

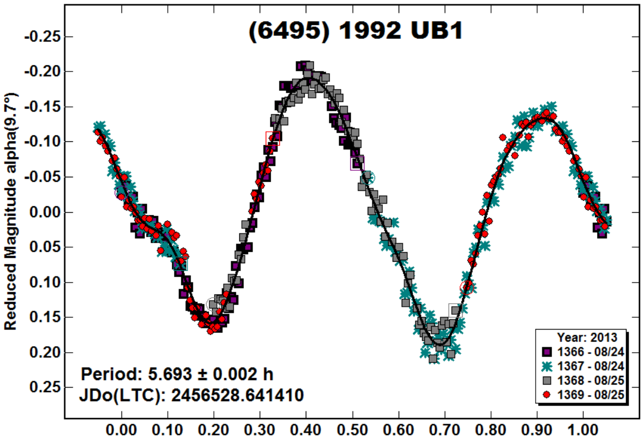

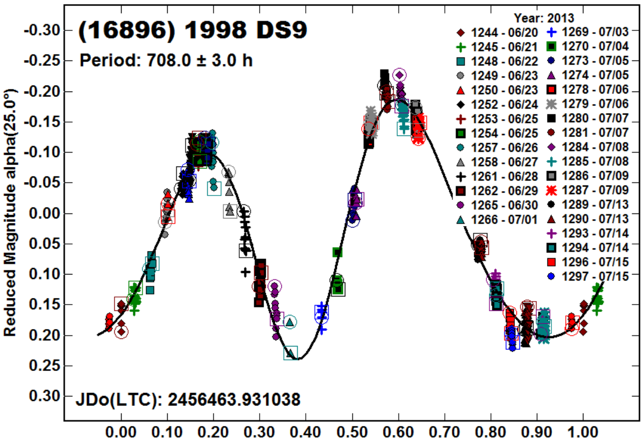

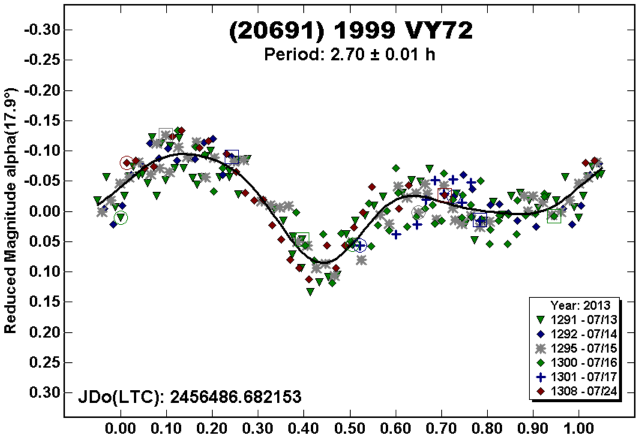

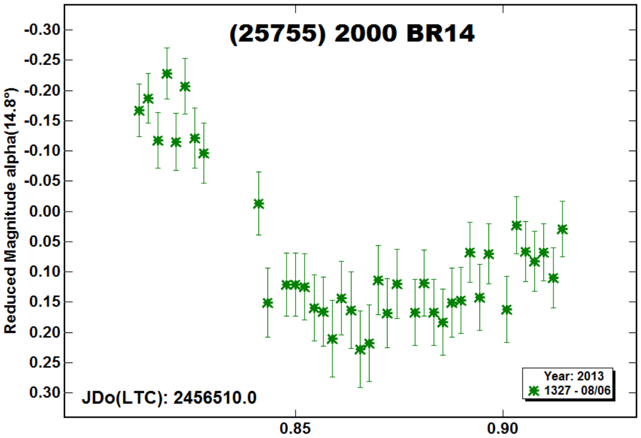

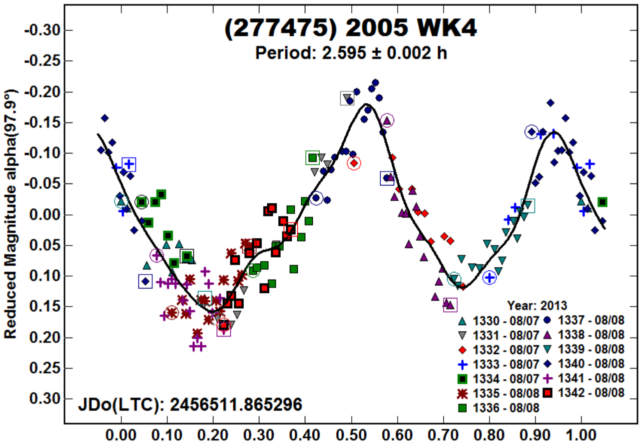

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# ASTEROID OBSERVATIONS AT ETSCORN: MID-2013

Daniel A. Klinglesmith III, Jesse Hanowell, Janek Turk,
Angelica Vargas, Curtis Alan Warren
Etscorn Campus Observatory, New Mexico Tech
101 East Road
Socorro, NM USA 87801
dklinglesmith@mro.nmt.edu

(Received: 11 September)

We present the lightcurves for three asteroids: 3657 Ermolova, 4404 Enirac, and 5095 Escalante. 3657 is a main-belt asteroid and a lightcurve inversion model candidate. 4404 and 5095 are main-belt asteroids without previous period determinations.

The Etscorn Campus Observatory (ECO, 2013) has three Celestron 0.35-meter *f*/11 Schmidt Cassegrain telescopes used for asteroid lightcurve research. Two of the telescopes are equipped with SBIG STL-1001E CCDs. The third telescope uses an SBIG ST-10 with an Optec 0.5x focal reducer. The STL-1001E CCDs have unbinned 1024x1024, 24-micron pixels providing 1.25 arcsec/pixel plate scale. Their field-of-view is approximately 22x22 arcmin. The ST-10 has 2x2 binned pixels which gives an effective 13.6 micron pixel. With the Optec 0.5x focal reducer, the plate scale is 1.28 arcsec/pixel. The combination gives a field of view of approximately 20x16 arcmin. Exposures were between 3 and 5 minutes depending on the brightness of the asteroid and taken with a clear filter. Depending on ambient temperature, the CCDs were cooled to between –10°C and –15°C using the theromoelectric coolers built into the SBIG cameras.

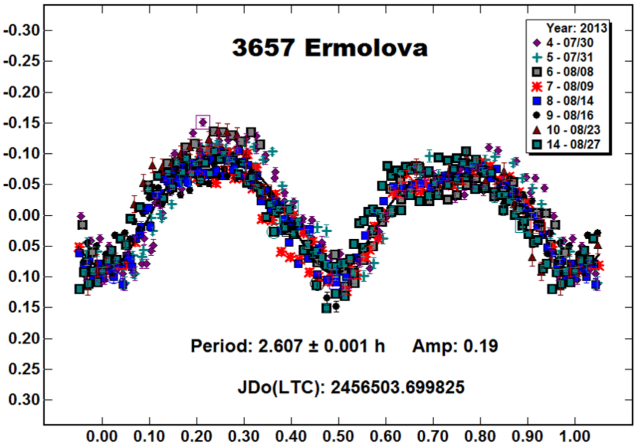
The telescopes were controlled and the images collected with Software Bisque's *TheSky* v6 and *CCDSoft* v5. On each night, a set of eleven flat field images were median combined and used as a master flat for flat-field correction, which was done using the batch processing option of *MPO Canopus* version 10.4.1.9 (Warner, 2012). Dark frames were automatically subtracted within CCDSoft while lightcurves were processed with *MPO Canopus* using the Fourier method developed by Harris *et. al.* (1989).

<u>3657 Ermolova</u> is a main-belt asteroid that was discovered by L. Zhuravleva at Nauchnyj on 1978 Sep 26 (JPL, 2013). It is also known as 1978 ST6, 1925 TE and 1984 GD1. It is an inversion model candidate suggested for observation during the 2013 opposition by Warner *et al.* (2013). It has known synodic period of

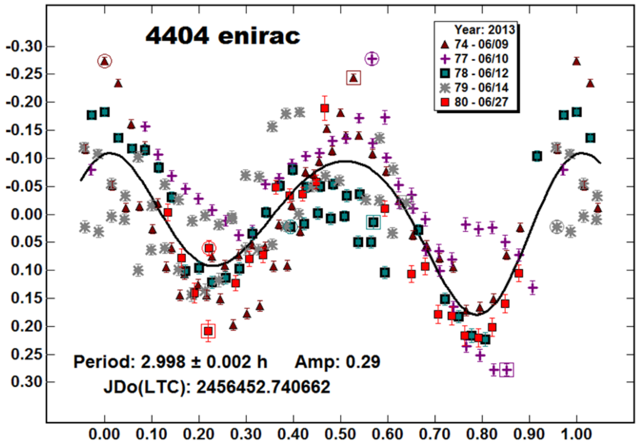
2.6064 h (LCDB, 2013) and has been observed at least three times in the past at different solar phase angle bisectors as shown in the table below.

| Date | PABL | PABB | Reference |
|---|---|---|---|
| 2006 Jul 24 | 340.7 | 7.8 | Pravec 2006 |
| 2006 Sep 07 | 345.5 | 8.2 | Behrend 2006 |
| 2010 Dec 10 | 074.1 | -2.4 | Pravec 2010 |

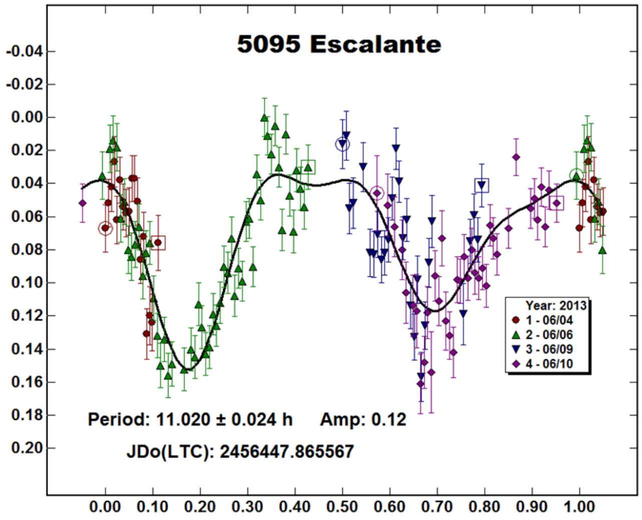
Our observations were obtained on eight nights between 2013 Jul 30 and Aug 27. During this period, the solar phase angle bisectors varied between 336.0 and 339.0 for longitude and 8.2 and 8.5 for latitude. We obtained a synodic period of 2.607 ± 0.001 h with an amplitude of 0.19 ± 0.02 mag.



4404 Enirac is a main-belt asteroid that was discovered by A. Maury at Palomar on 1987 Apr 02 (JPL, 2013). It is also known as 1987 GG and 1979 QG. We found no previous known synodic period for this asteroid. We observed it on five nights between 2013 Jun 09 and Jun 27. Our estimated synodic period is 2.998 ± 0.001 h with an amplitude of 0.29 ± 0.10 mag. The asteroid was moving through very crowded star fields on all nights with the result that there is a large scatter in the data.



5095 Escalante is a main-belt asteroid discovered by Edward Bowell on 1983 Jul 10 at Lowell Observatory (JPL, 2013). Observations occurred on four nights between 2013 Jun 04 to Jun 10. There is no reference to any known period in the lightcurve database (LCDB, 2013). The synodic period for 5095 Escalante was 11.020 ± 0.0020 h with an amplitude of 0.12 mag.



## Acknowledgments

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Technology (NMIMT). Student support at NMIMT is given by NASA EPSCoR grant NNX11AQ35A, the Department of Physics,and the Title IV of the Higher Education Act from the Department of Education

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# COLLABORATIVE ASTEROID PHOTOMETRY AND LIGHTCURVE ANALYSIS AT OBSERVATORIES OAEGG, OAC, EABA, AND OAS

Fernando Mazzone
Observatorio Astronómico Salvador (MPC I20), Achalay 1469
X5804HMI Río Cuarto, Córdoba, ARGENTINA
Departamento de Matemática
Universidad Nacional de Río Cuarto, Córdoba, ARGENTINA
fmazzone@exa.unrc.edu.ar

Carlos Colazo
Grupo de Astrometría y Fotometría
Observatorio Astronómico Córdoba
Universidad Nacional de Córdoba, (Córdoba) ARGENTINA
Observatorio Astronómico El Gato Gris (MPC I19)
Tanti (Córdoba), ARGENTINA

Federico Mina
Grupo de Astrometría y Fotometría, Observatorio Astronómico
Córdoba, Universidad Nacional de Córdoba
Córdoba, ARGENTINA

Raúl Melia
Grupo de Astrometría y Fotometría, Observatorio Astronómico
Córdoba, Universidad Nacional de Córdoba
Córdoba, ARGENTINA

Julio Spagnotto
Observatorio El Catalejo (MPC I48)
Santa Rosa (La Pampa), ARGENTINA

Alejandro Bernal
Grupo de Astrometría y Fotometría
Observatorio Astronómico Córdoba
Universidad Nacional de Córdoba
Córdoba, ARGENTINA

(Received: 18 September)

Synodic rotation periods and amplitudes are reported for: 1874 Kacivelia, 15.951 ± 0.001 h, 0.21 ± 0.02 mag; 2055 Dvorak, 4.4052 ± 0.0003 h, 0.17 ± 0.04 mag; 2185 Guangdong, 21.089 ± 0.002 h, 0.19 ± 0.02 mag; and 8059 Deliyannis, 6.0041 ± 0.0003 h, 0.39 ± 0.04 mag. The absolute magnitude ($H$) and/or slope parameter ($G$) for some of these asteroids are also reported.

This paper presents the collaborative work among a group of amateur astronomers and undergraduate students gathered in two Argentinian associations: Grupo de Astrometría y Fotometría (GAF) and Asociación de Observatorios Argentinos de Cuerpos Menores (AOACM). The observatories and equipment used were:

- Estación Astrofísica de Bosque Alegre (EABA, MPC 821): 1.54-m Newtonian (NT) and Apogee Alta U9 CCD.
- Observatorio Astronómico Córdoba (OAC, MPC 822): 0.35-m Schmidt-Cassegrain (SCT) and SBIG ST7 CCD.
- Observatorio Astronómico El Gato Gris (OAEGG, MPC I19): 0.35-m Schmidt-Cassegrain (SCT) and SBIG ST10 CCD.
- Observatorio Astronómico Salvador (OAS, MPC I20): 0.2-m Schmidt-Newtonian (SNT) and Starlight ST7-XME CCD.

All images were unfiltered, dark, bias and flat-field corrected, and then measured using Astrometrica software (Raab, 2013). We used *Periodos* software (Mazzone, 2012a) for the period analysis. We find that this software presents some novelties in the mathematical processing of the data. These are discussed in the appendix along with some details regarding our methods.

All targets were selected from the “Potential Lightcurve Targets” web site list on the Collaborative Asteroid Lightcurve Link site (CALL; Warner *et al*., 2011) as a favorable target for observation and with no previously reported period in the Lightcurve Database (LCDB, Warner *et al.*, 2009).

The lightcurve figures contain the following information: 1) the estimated period and amplitude, 2) a 95% confidence interval regarding the period estimate, 3) RMS of the fitting, 4) estimated amplitude and amplitude error, 5) the Julian time corresponding to 0 rotation phase, and 6) the number of data points. In the reference boxes the columns represent, respectively, the marker, observatory MPC code, session date, session off-set, and number of data points. See the appendix for a description of the off-sets and reduced magnitudes.

8059 Deliyannis. We collected 548 data points in five different sessions. The derived period and amplitude were 6.0041 ± 0.0003 h and 0.39 ± 0.04 mag. There is a lack of data between phase angles 0.63 and 0.7. We estimate the absolute magnitude $H$ to be 11.92 mag. Previously reported values were 11.8 mag (MPO 233564) and 12.0 (MPC 30957).

1874 Kacivelia. We observed this asteroid between phase angles 17° to 2°. We obtained a period of 15.951 ± 0.001 h and amplitude of 0.21 ± 0.02 mag. The MPCORB file gives $H$ = 11.2 (MPO 250216). We estimate a value of $H$ = 11.4. Given the wide range of phase angles covering our observations, we considered it appropriate to find the slope parameter, $G$ (see the appendix section for details). The MPCORB gives a default value of $G$ = 0.15. We found $G$ = 0.24 produces a better fit to our data.

2055 Dvorak. Analysis of our data found a period of 4.4052 ± 0.0003 h and amplitude and 0.17 ± 0.04 mag with a large dispersion among the offsets. The calculated absolute magnitude is 12.81. MPO 259350 reports $H$ = 12.6 and MPC 17264, $H$ = 13.5.

2185 Guangdong. This was a difficult target due to its relatively long rotation period. Unfortunately, the second half of the lightcurve has substantially fewer data than the first half. We derived a period of 21.089 ± 0.002 h and amplitude 0.19 ± 0.02 mag. We computed an absolute magnitude of $H$ = 11.57. The MPCORB file gives $H$ = 11.3 using $G$ = 0.15. We found that $G$ = 0.33 produces a smaller root-square norm for off-sets.

## Appendix: Data Analysis Strategy

In this section, we describe the method used for the data analysis, which has some differences with the usual methodology in similar work. We have successfully used these techniques before (Ambrosioni *et al*., 2011; Oey *et al*., 2012).

We programed a set of MATLAB® functions that implemented the calculations described below using functions from *Periodos* and *orbit_calc* (Mazzone, 2012a; Mazzone, 2012b).

Suppose that $m_i^j$, for $j = 1,\dots,N$ and $i = 1,\dots,M_j$, are the measured magnitudes for the asteroid corresponding to times $t_i^j$. Here $N$ is the number of different sessions and $M_j$, $j = 1,\dots,N$, is the number of data points in the session $j$. By session we mean the data collected by a unique observatory on a single night.

First we perform some corrections on the data. More specifically, times $t_i^j$ were light-time corrected and magnitudes were corrected to unity distance and normalized to the zero phase angle by applying standard formulas (Dymock, 2007). This reduction requires some orbital calculations, which are made by an adaptive collocation method that solves the n-body problem. Sun, planets and Moon were modeled as point masses.

Second we fit the model function

$$f(t_i^j) = \alpha^j + a_0 + \sum_{k=1}^{n} a_k \cos(\frac{2k\pi t_i^j}{T}) + b_k \sin(\frac{2k\pi t_i^j}{T})$$

to the observed data. More precisely, we look for parameters $\alpha^j, a_k, b_k$, and $T$ that minimize

$$\sum_{j=1}^{N} \sum_{i=1}^{M_j} | m_i^j - f(t_i^j) |^2$$

The fitted value of $T$ and $a_0$ can be interpreted as being the synodic rotation period of the asteroid and the absolute magnitude $H$, respectively. The parameters $\alpha^j$ depend on the sessions and represent the offsets among sessions. Usually one wants them to be zero. In order to obtain a well-posed problem, we need to introduce an extra condition. We adopted the restriction that the offsets $\alpha^j$ have a zero mean, i.e. $\sum \alpha^j = 0$. We think that this is a plausible assumption, if we consider offsets random normally distributed variables. However this affirmation is false in general. For example, an inaccurate determination of the slope parameter $G$ induces a pattern in the offsets. We think that the value of $G$ such that the offsets squares sum $(\alpha^1)^2 + \ldots + (\alpha^N)^2$ are minimized gives a good estimate for the $G$ parameter. In this way we obtained the value of $G$ reported for 1874 Kacivelia and 2185 Guangdong.

We note that our methods incorporate a Fourier algorithm (Harris *et al.,* 1989) and simultaneously adjust the offsets. This is a non-linear curve fitting problem and we use the native lsqcurvefit MATLAB® function for solving it.

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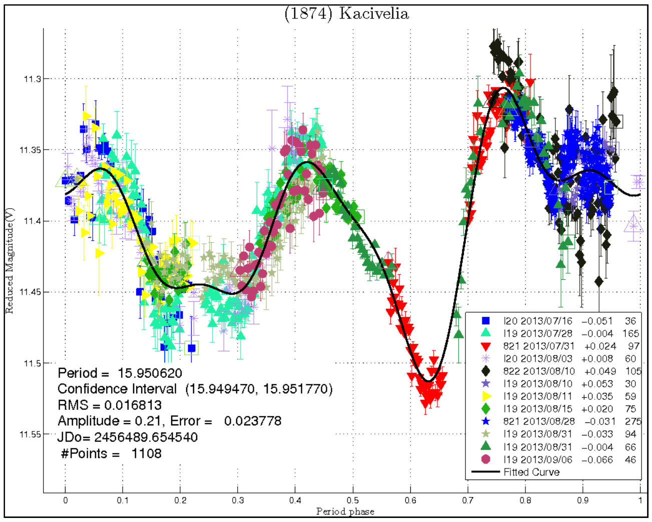

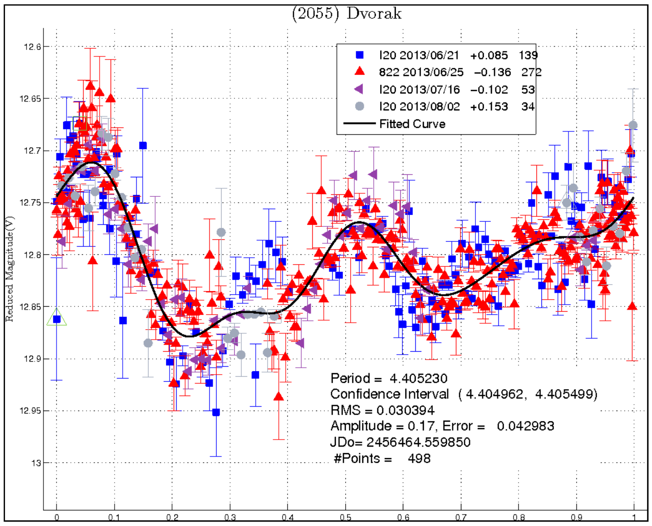

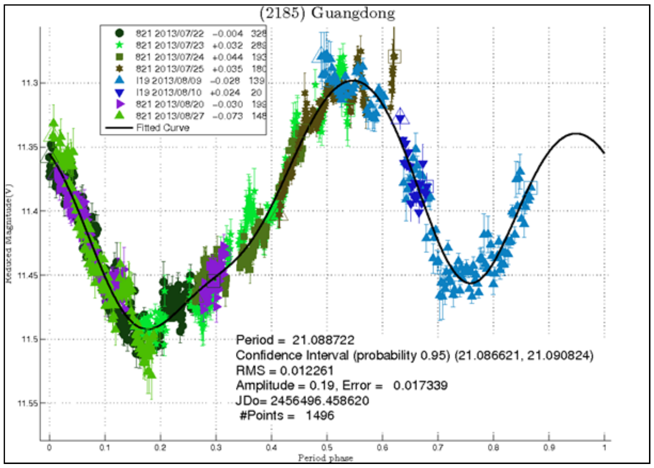

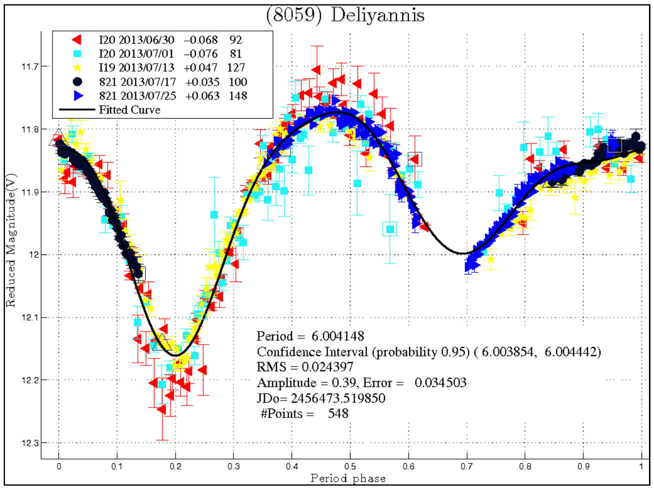

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# ROTATIONAL PERIOD AND H-G PARAMETERS FOR ASTEROID 2213 MEEUS

Angelo Tomassini, Maurizio Cervoni, Maurizio Scardella
Associazione Tuscolana di Astronomia (D06)
F. Fuligni Observatory
Via Lazio, 14 - località Pratoni del Vivaro – 00040
Rocca di Papa (RM) – ITALY

(Received: 3 October)

The main-belt asteroid 2213 Meeus was observed over several nights in 2013 August in order to determine its synodic rotation period, amplitude, absolute magnitude, and phase slope parameter. Lightcurve analysis shows a synodic period $P = 2.651 \pm 0.001$ h with an amplitude $A = 0.19 \pm 0.03$ mag. The H-G curve analysis shows an absolute magnitude $H = 13.118 \pm 0.083$ and a slope parameter $G = 0.139 \pm 0.122$.

The main-belt asteroid 2213 Meeus was selected from the "Low Phase Angle Opportunities" list for 2013 July-September that appeared in the *Minor Planet Bulletin* (Warner *et al.*, 2013). All the observations were carried out from F. Fuligni Observatory near Rome (Italy) using a 0.35-m *f*/10 Meade Advanced Coma Free telescope and SBIG ST8-XE CCD camera with Bessel R filter. All images were calibrated with dark frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012).

The derived synodic period was $P = 2.651 \pm 0.001$ h (Fig. 1) with an amplitude of $A = 0.19 \pm 0.03$ mag. The favorable initial phase angle at the beginning of the observations allowed extracting the absolute magnitude of $H = 13.118 \pm 0.083$ and slope parameter of $G = 0.139 \pm 0.122$ by means of the H-G Calculator utility of *MPO Canopus* (Fig. 2). These compare favorably with the values of $H = 13.3$ and $G = 0.15$ reported in the MPCORB file at the time (*http://www.minorplanetcenter.org/iau/MPCORB.html*).

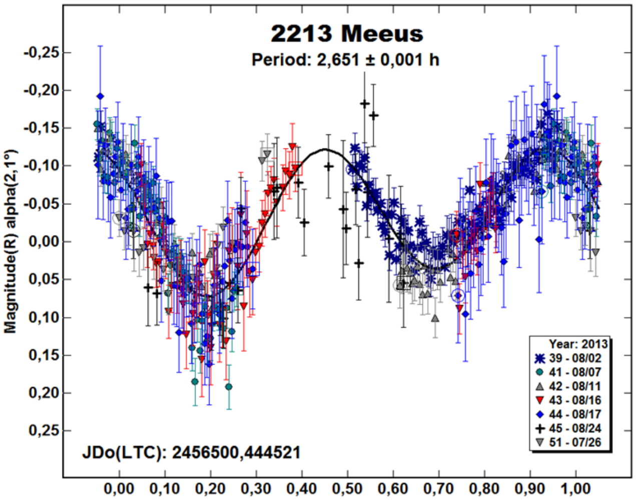

Figure 1. The lightcurve of 2213 Meeus with a period of 2.651 ± 0.001 h and an amplitude of 0.19 ± 0.03 mag.

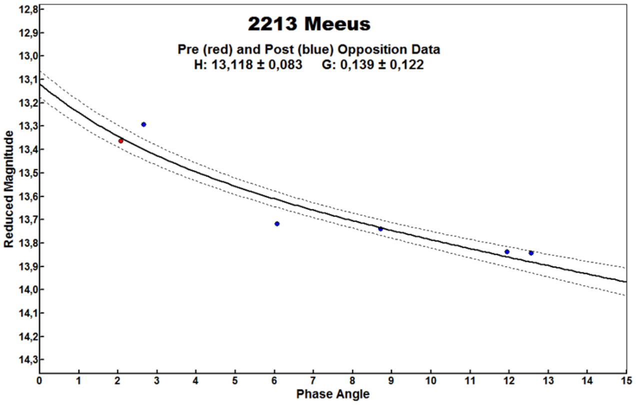

Figure 2. Reduced Magnitude of 2213 Meeus versus phase angle. The absolute magnitude and the slope parameter are, respectively, $H = 13.118 \pm 0.083$ and $G = 0.139 \pm 0.122$.

## Acknowledgements

We would like to thank Lorenzo Franco (A81 Balzaretto Observatory) who, with his invaluable guidance, provided theoretical and practical help to the ATA research team.

## References

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# MINOR PLANETS AT UNUSUALLY FAVORABLE ELONGATIONS IN 2014

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA
pilcher@ic.edu

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A list is presented of minor planets which are much brighter than usual at their 2014 apparitions.

The minor planets in the lists which follow will be much brighter at their 2014 apparitions than at their average distances at maximum elongation. Many years may pass before these objects will be again as bright as in 2014. Observers are encouraged to give special attention to those objects reaching peak brightness near the limit of their equipment.

These lists have been prepared by an examination of the maximum elongation circumstances of minor planets computed by the author for all years through 2060 with a full perturbation program written by Dr. John Reed, and to whom he expresses his thanks. Elements are from EMP 1992, except that for all objects for which new or improved elements have been published subsequently in the Minor Planet Ciculars or in electronic form, the newer elements have been used. Planetary positions are from the JPL DE-200 ephemeris, courtesy of Dr. E. Myles Standish.

Any minor planets whose brightest magnitudes near the time of maximum elongation vary by at least 2.0 in this interval and in 2014 will be within 0.3 of the brightest occurring, or vary by at least 3.0 and in 2014 will be within 0.5 of the brightest occurring; and which are visual magnitude 14.5 or brighter, are included. For those brighter than visual magnitude 13.5, which are within the range of a large number of observers, these standards have been relaxed somewhat to include a larger number of objects. Magnitudes have been computed from the updated magnitude parameters published in MPC28104-28116, on 1996 Nov. 25, or more recently in the Minor Planet Circulars.

Oppositions may be in right ascension or in celestial longitude. Here we use still a third representation, maximum elongation from the Sun, instead of opposition. Though unconventional, it has the advantage that many close approaches do not involve actual opposition to the Sun near the time of minimum distance and greatest brightness and are missed by an opposition-based program. Other data are also provided according to the following tabular listings: Minor planet number, date of maximum elongation from the Sun in format yyyy/mm/dd, maximum elongation in degrees, right ascension on date of maximum elongation, declination on date of maximum elongation, both in J2000 coordinates, date of brightest magnitude in format yyyy/mm/dd, brightest magnitude, date of minimum distance in format yyyy/mm/dd, and minimum distance in AU.

Four numbered minor planets are predicted to make close approaches to Earth at magnitudes brighter than 14.5. A special table of these is provided at the end of this paper.

Users should note that when the maximum elongation is about 177° or greater, the brightest magnitude is sharply peaked due to enhanced brightening near zero phase angle. Even as near as 10 days before or after minimum magnitude the magnitude is generally about 0.4 greater. This effect takes place in greater time interval for smaller maximum elongations. There is some interest in very small minimum phase angles. For maximum elongations E near 180° at Earth distance , an approximate formula for the minimum phase angle $\phi$ is $\phi=(180°-E)/(\Delta +1)$.

Table I. Numerical Sequence of Favorable Elongations

| Planet | Max Elon D | Max E | RA | Dec | Br Mag D | Br Mag | Min Dist D | Min Dist |
|---|---|---|---|---|---|---|---|---|
| 2 | 2014/02/26 | 157.0° | 9h44m | -10° | 2014/02/25 | 7.0 | 2014/02/23 | 1.231 |
| 12 | 2014/09/09 | 163.5° | 22h40m | + 9° | 2014/09/06 | 9.0 | 2014/08/31 | 0.904 |
| 23 | 2014/12/03 | 178.7° | 4h34m | +23° | 2014/12/03 | 9.2 | 2014/12/10 | 1.205 |
| 24 | 2014/03/13 | 179.0° | 11h36m | + 3° | 2014/03/13 | 10.6 | 2014/03/12 | 1.789 |
| 33 | 2014/09/09 | 178.5° | 23h12m | - 6° | 2014/09/09 | 9.8 | 2014/09/08 | 0.895 |
| 37 | 2014/10/09 | 179.1° | 0h56m | + 6° | 2014/10/09 | 9.8 | 2014/10/13 | 1.327 |
| 54 | 2014/07/07 | 169.3° | 19h 6m | -33° | 2014/07/07 | 10.1 | 2014/07/09 | 1.177 |
| 55 | 2014/10/18 | 176.9° | 1h26m | +12° | 2014/10/18 | 10.5 | 2014/10/16 | 1.376 |
| 63 | 2014/08/24 | 178.7° | 22h15m | -12° | 2014/08/24 | 9.7 | 2014/08/19 | 1.189 |
| 66 | 2014/11/29 | 175.2° | 4h14m | +26° | 2014/11/28 | 11.8 | 2014/11/26 | 1.221 |
| 81 | 2014/12/18 | 166.6° | 5h44m | +36° | 2014/12/17 | 11.4 | 2014/12/14 | 1.361 |
| 84 | 2014/09/27 | 167.4° | 0h 0m | +13° | 2014/09/26 | 10.8 | 2014/09/21 | 0.836 |
| 104 | 2014/11/28 | 178.1° | 4h12m | +22° | 2014/11/28 | 11.6 | 2014/11/28 | 1.675 |
| 112 | 2014/08/11 | 179.4° | 21h23m | -15° | 2014/08/11 | 11.8 | 2014/08/12 | 1.124 |
| 114 | 2014/02/20 | 178.1° | 10h13m | + 8° | 2014/02/21 | 10.8 | 2014/02/22 | 1.326 |
| 144 | 2014/09/03 | 170.7° | 23h 4m | -15° | 2014/09/04 | 10.0 | 2014/09/07 | 1.077 |
| 146 | 2014/06/12 | 179.0° | 17h23m | -22° | 2014/06/12 | 11.3 | 2014/06/11 | 1.545 |
| 163 | 2014/02/23 | 179.0° | 10h26m | + 8° | 2014/02/23 | 11.3 | 2014/02/17 | 1.069 |
| 172 | 2014/07/28 | 171.0° | 20h34m | -27° | 2014/07/28 | 11.1 | 2014/07/30 | 1.121 |
| 190 | 2014/01/15 | 172.5° | 7h42m | +13° | 2014/01/15 | 12.4 | 2014/01/13 | 2.408 |
| 232 | 2014/05/09 | 168.8° | 15h19m | - 6° | 2014/05/09 | 12.6 | 2014/05/07 | 1.137 |
| 245 | 2014/11/03 | 177.0° | 2h37m | +12° | 2014/11/03 | 10.9 | 2014/11/01 | 1.514 |
| 253 | 2014/09/30 | 178.0° | 0h31m | + 1° | 2014/09/30 | 11.9 | 2014/09/23 | 0.994 |
| 258 | 2014/09/30 | 169.8° | 0h 5m | +11° | 2014/09/30 | 10.6 | 2014/09/28 | 1.087 |
| 259 | 2014/06/11 | 177.8° | 17h15m | -20° | 2014/06/11 | 11.3 | 2014/06/11 | 1.721 |
| 270 | 2014/09/14 | 174.9° | 23h20m | + 1° | 2014/09/14 | 10.1 | 2014/09/10 | 0.872 |
| 283 | 2014/09/23 | 169.2° | 23h42m | + 9° | 2014/09/23 | 12.2 | 2014/09/21 | 1.602 |
| 288 | 2014/04/06 | 172.3° | 13h12m | + 0° | 2014/04/06 | 12.3 | 2014/04/08 | 1.204 |
| 297 | 2014/08/05 | 175.9° | 21h 3m | -21° | 2014/08/05 | 13.0 | 2014/08/05 | 1.710 |
| 313 | 2014/03/13 | 178.4° | 11h31m | + 1° | 2014/03/13 | 10.6 | 2014/03/09 | 1.022 |
| 314 | 2014/09/19 | 177.9° | 23h48m | - 3° | 2014/09/19 | 12.7 | 2014/09/18 | 1.592 |
| 333 | 2014/11/06 | 175.4° | 2h38m | +20° | 2014/11/05 | 12.9 | 2014/11/02 | 1.685 |
| 373 | 2014/09/23 | 178.4° | 0h 3m | - 1° | 2014/09/23 | 12.5 | 2014/09/21 | 1.673 |
| 379 | 2014/09/24 | 179.6° | 0h 4m | + 0° | 2014/09/24 | 11.9 | 2014/09/22 | 1.554 |
| 385 | 2014/02/22 | 175.4° | 10h27m | +14° | 2014/02/22 | 10.6 | 2014/02/24 | 1.529 |
| 393 | 2014/09/26 | 165.2° | 23h38m | +13° | 2014/09/22 | 10.7 | 2014/09/12 | 1.091 |
| 458 | 2014/10/05 | 161.5° | 1h18m | -11° | 2014/10/07 | 12.8 | 2014/10/10 | 1.407 |
| 475 | 2014/10/23 | 175.2° | 1h49m | + 6° | 2014/10/22 | 12.8 | 2014/10/08 | 0.746 |
| 481 | 2014/12/01 | 179.1° | 4h31m | +22° | 2014/12/01 | 11.1 | 2014/11/29 | 1.338 |
| 485 | 2014/12/24 | 156.0° | 6h11m | - 0° | 2014/12/25 | 11.3 | 2014/12/26 | 1.294 |
| 486 | 2014/06/28 | 179.1° | 18h28m | -24° | 2014/06/28 | 12.6 | 2014/06/22 | 1.087 |
| 503 | 2014/11/21 | 178.5° | 3h49m | +18° | 2014/11/21 | 11.9 | 2014/11/26 | 1.390 |
| 506 | 2014/01/06 | 167.0° | 7h12m | +35° | 2014/01/06 | 12.4 | 2014/01/06 | 1.622 |
| 515 | 2014/11/20 | 177.0° | 3h43m | +16° | 2014/11/20 | 14.5 | 2014/11/19 | 1.607 |
| 549 | 2014/12/15 | 176.3° | 5h28m | +26° | 2014/12/15 | 12.8 | 2014/12/16 | 1.011 |
| 569 | 2014/12/10 | 178.4° | 5h 7m | +24° | 2014/12/10 | 12.3 | 2014/12/10 | 1.196 |
| 584 | 2014/08/18 | 164.2° | 21h34m | + 2° | 2014/08/20 | 10.4 | 2014/08/25 | 0.908 |
| 598 | 2014/12/14 | 176.3° | 5h26m | +19° | 2014/12/14 | 12.1 | 2014/12/06 | 1.307 |
| 606 | 2014/08/18 | 178.1° | 21h47m | -11° | 2014/08/18 | 12.5 | 2014/08/25 | 1.144 |
| 665 | 2014/07/02 | 172.4° | 18h47m | -30° | 2014/07/02 | 11.6 | 2014/06/30 | 1.625 |
| 672 | 2014/08/23 | 175.1° | 22h15m | -15° | 2014/08/23 | 13.6 | 2014/08/19 | 1.252 |
| 713 | 2014/11/03 | 179.1° | 2h35m | +14° | 2014/11/03 | 12.9 | 2014/10/29 | 1.965 |
| 725 | 2014/09/21 | 173.1° | 0h 5m | - 6° | 2014/09/22 | 13.9 | 2014/09/26 | 1.067 |
| 749 | 2014/05/28 | 171.9° | 16h25m | -13° | 2014/05/28 | 13.2 | 2014/05/28 | 0.850 |
| 769 | 2014/05/01 | 179.5° | 14h31m | -15° | 2014/05/01 | 12.6 | 2014/05/08 | 1.880 |
| 772 | 2014/05/05 | 162.4° | 14h59m | + 1° | 2014/05/05 | 12.2 | 2014/05/05 | 1.750 |
| 790 | 2014/05/22 | 173.8° | 15h48m | -26° | 2014/05/23 | 12.2 | 2014/05/27 | 2.031 |
| 794 | 2014/08/09 | 176.0° | 21h11m | -12° | 2014/08/09 | 13.5 | 2014/08/03 | 1.232 |
| 805 | 2014/08/03 | 164.4° | 20h29m | - 2° | 2014/08/02 | 13.4 | 2014/08/01 | 1.610 |
| 855 | 2014/04/08 | 179.5° | 13h 6m | - 7° | 2014/04/08 | 13.6 | 2014/04/15 | 1.056 |
| 881 | 2014/07/07 | 176.1° | 19h 5m | -18° | 2014/07/07 | 13.7 | 2014/07/12 | 1.112 |
| 883 | 2014/08/29 | 171.7° | 22h17m | - 1° | 2014/08/28 | 13.7 | 2014/08/26 | 0.789 |
| 901 | 2014/07/01 | 178.0° | 18h42m | -21° | 2014/07/02 | 12.5 | 2014/07/11 | 0.841 |
| 915 | 2014/09/17 | 177.1° | 23h42m | - 5° | 2014/09/17 | 13.5 | 2014/09/21 | 1.015 |
| 931 | 2014/11/08 | 162.7° | 3h11m | - 0° | 2014/11/09 | 12.7 | 2014/11/10 | 1.522 |
| 936 | 2014/07/20 | 176.8° | 20h 2m | -23° | 2014/07/20 | 13.2 | 2014/07/22 | 1.581 |
| 952 | 2014/09/30 | 176.3° | 0h30m | - 0° | 2014/09/30 | 11.7 | 2014/09/30 | 1.254 |
| 982 | 2014/07/15 | 176.9° | 19h36m | -24° | 2014/07/15 | 12.6 | 2014/07/14 | 1.334 |
| 1000 | 2014/08/12 | 177.6° | 21h31m | -17° | 2014/08/12 | 13.2 | 2014/08/03 | 1.752 |
| 1021 | 2014/01/05 | 174.6° | 7h 0m | +17° | 2014/01/05 | 11.4 | 2013/12/27 | 1.223 |
| 1041 | 2014/12/02 | 176.0° | 4h33m | +25° | 2014/12/02 | 13.4 | 2014/11/30 | 1.696 |
| 1057 | 2014/11/05 | 176.3° | 2h36m | +19° | 2014/11/05 | 13.4 | 2014/10/30 | 1.251 |
| 1067 | 2014/12/08 | 169.7° | 4h49m | +32° | 2014/12/07 | 13.7 | 2014/12/03 | 1.404 |
| 1080 | 2014/12/27 | 170.4° | 6h27m | +32° | 2014/12/26 | 13.7 | 2014/12/20 | 0.887 |
| 1093 | 2014/05/24 | 173.7° | 16h 3m | -27° | 2014/05/25 | 12.1 | 2014/06/02 | 1.559 |
| 1110 | 2014/09/26 | 168.5° | 23h50m | +11° | 2014/09/24 | 13.0 | 2014/09/15 | 0.766 |
| 1146 | 2014/04/18 | 177.1° | 13h39m | -13° | 2014/04/18 | 13.1 | 2014/04/28 | 1.605 |
| 1164 | 2014/02/28 | 177.2° | 10h49m | +10° | 2014/02/28 | 14.1 | 2014/02/26 | 0.885 |
| 1165 | 2014/09/05 | 165.9° | 22h30m | + 5° | 2014/09/03 | 13.8 | 2014/08/30 | 1.573 |
| 1196 | 2014/09/23 | 148.7° | 0h59m | -27° | 2014/09/23 | 13.2 | 2014/09/22 | 1.255 |
| 1197 | 2014/05/17 | 172.3° | 15h23m | -26° | 2014/05/16 | 13.1 | 2014/05/09 | 1.457 |
| 1304 | 2014/05/17 | 164.4° | 15h46m | - 3° | 2014/05/17 | 12.6 | 2014/05/18 | 1.838 |
| 1323 | 2014/04/28 | 175.9° | 14h25m | -10° | 2014/04/28 | 13.6 | 2014/04/26 | 1.814 |
| 1407 | 2014/10/31 | 171.0° | 2h 7m | +22° | 2014/10/30 | 12.6 | 2014/10/26 | 1.022 |
| 1463 | 2014/10/21 | 170.0° | 1h27m | +19° | 2014/10/21 | 14.0 | 2014/10/22 | 1.598 |

| Planet | Max Elon D | Max E | RA | Dec | Br Mag D | Br Mag | Min Dist D | Min Dist |
|---|---|---|---|---|---|---|---|---|
| 1525 | 2014/08/13 | 172.2° | 21h21m | - 7° | 2014/08/13 | 14.3 | 2014/08/17 | 1.003 |
| 1550 | 2014/10/09 | 164.3° | 1h16m | - 8° | 2014/10/09 | 13.0 | 2014/10/08 | 0.768 |
| 1578 | 2014/01/20 | 179.1° | 8h 9m | +20° | 2014/01/20 | 14.5 | 2014/01/15 | 2.174 |
| 1585 | 2014/02/06 | 169.2° | 9h 1m | + 5° | 2014/02/04 | 14.0 | 2014/01/27 | 1.527 |
| 1591 | 2014/06/23 | 179.0° | 18h 6m | -24° | 2014/06/23 | 13.2 | 2014/06/21 | 0.968 |
| 1656 | 2014/03/02 | 161.9° | 10h 6m | - 6° | 2014/03/01 | 13.6 | 2014/02/26 | 0.754 |
| 1662 | 2014/10/15 | 174.1° | 1h11m | +13° | 2014/10/15 | 13.9 | 2014/10/15 | 1.289 |
| 1667 | 2014/06/27 | 177.4° | 18h25m | -25° | 2014/06/27 | 13.2 | 2014/06/27 | 0.832 |
| 1705 | 2014/07/28 | 164.5° | 20h12m | - 4° | 2014/07/31 | 14.2 | 2014/08/06 | 0.812 |
| 1712 | 2014/05/07 | 173.8° | 14h47m | -22° | 2014/05/07 | 13.4 | 2014/05/11 | 1.727 |
| 1738 | 2014/10/11 | 175.3° | 1h13m | + 2° | 2014/10/11 | 13.6 | 2014/10/02 | 0.844 |
| 1747 | 2014/06/23 | 174.8° | 18h16m | -18° | 2014/06/23 | 13.2 | 2014/06/21 | 0.518 |
| 1756 | 2014/11/12 | 171.1° | 2h58m | +26° | 2014/11/12 | 14.1 | 2014/11/08 | 0.998 |
| 1803 | 2014/03/20 | 160.2° | 11h43m | -19° | 2014/03/23 | 13.9 | 2014/03/30 | 0.913 |
| 1842 | 2014/07/12 | 171.9° | 19h21m | -13° | 2014/07/12 | 13.8 | 2014/07/10 | 0.848 |
| 2014 | 2014/05/20 | 148.9° | 16h44m | + 7° | 2014/05/27 | 13.6 | 2014/06/02 | 0.858 |
| 2062 | 2014/01/03 | 155.9° | 5h54m | + 3° | 2014/01/05 | 14.3 | 2014/01/08 | 0.146 |
| 2078 | 2014/11/26 | 136.3° | 1h29m | +52° | 2014/11/12 | 13.3 | 2014/11/07 | 0.639 |
| 2290 | 2014/12/28 | 160.8° | 6h19m | + 4° | 2014/12/26 | 14.5 | 2014/12/23 | 1.076 |
| 2292 | 2014/09/04 | 174.4° | 22h41m | - 2° | 2014/09/03 | 13.8 | 2014/08/27 | 1.073 |
| 2324 | 2014/06/01 | 179.4° | 16h36m | -22° | 2014/06/01 | 14.3 | 2014/06/03 | 1.525 |
| 2340 | 2014/10/30 | 172.1° | 2h33m | + 6° | 2014/10/27 | 14.2 | 2014/10/21 | 0.048 |
| 2382 | 2014/07/30 | 123.2° | 20h20m | +38° | 2014/07/27 | 14.1 | 2014/07/27 | 1.086 |
| 2525 | 2014/09/18 | 175.5° | 23h51m | - 5° | 2014/09/18 | 13.8 | 2014/09/19 | 1.581 |
| 2571 | 2014/09/04 | 173.5° | 23h 2m | -13° | 2014/09/04 | 14.1 | 2014/09/05 | 0.793 |
| 2642 | 2014/10/10 | 177.5° | 0h55m | + 8° | 2014/10/10 | 14.3 | 2014/10/07 | 0.986 |
| 2648 | 2014/12/18 | 177.6° | 5h43m | +25° | 2014/12/18 | 14.3 | 2014/12/13 | 0.923 |
| 2693 | 2014/11/22 | 179.9° | 3h51m | +20° | 2014/11/22 | 14.3 | 2014/11/19 | 0.855 |
| 3037 | 2014/01/22 | 171.2° | 8h29m | +28° | 2014/01/21 | 14.3 | 2014/01/17 | 1.290 |
| 3089 | 2014/05/31 | 170.1° | 16h31m | -12° | 2014/05/31 | 14.0 | 2014/06/03 | 1.414 |
| 3165 | 2014/06/24 | 179.3° | 18h 9m | -23° | 2014/06/24 | 14.3 | 2014/07/01 | 0.949 |
| 3220 | 2014/10/29 | 177.7° | 2h11m | +15° | 2014/10/29 | 14.1 | 2014/10/30 | 0.858 |
| 3722 | 2014/11/22 | 178.3° | 3h52m | +18° | 2014/11/22 | 14.3 | 2014/11/14 | 0.914 |
| 3894 | 2014/08/24 | 174.6° | 22h 2m | - 6° | 2014/08/24 | 14.5 | 2014/08/26 | 1.183 |
| 3960 | 2014/12/07 | 174.4° | 4h52m | +17° | 2014/12/07 | 13.6 | 2014/12/11 | 0.956 |
| 4150 | 2014/08/20 | 177.1° | 22h 1m | -15° | 2014/08/20 | 14.1 | 2014/08/18 | 0.850 |
| 4349 | 2014/08/18 | 163.0° | 22h21m | -28° | 2014/08/21 | 14.1 | 2014/08/26 | 1.106 |
| 4378 | 2014/05/27 | 168.1° | 16h20m | - 9° | 2014/05/26 | 13.8 | 2014/05/24 | 1.039 |
| 4558 | 2014/07/12 | 130.1° | 20h45m | +24° | 2014/08/07 | 13.4 | 2014/08/16 | 0.606 |
| 4820 | 2014/10/29 | 157.2° | 1h44m | +35° | 2014/11/02 | 13.6 | 2014/11/06 | 0.972 |
| 4826 | 2014/07/16 | 159.8° | 20h25m | -39° | 2014/07/17 | 14.2 | 2014/07/19 | 0.953 |
| 4910 | 2014/09/18 | 179.0° | 23h41m | - 0° | 2014/09/18 | 14.5 | 2014/09/10 | 0.657 |
| 5142 | 2014/09/24 | 174.5° | 23h53m | + 5° | 2014/09/24 | 14.0 | 2014/10/01 | 0.923 |
| 5176 | 2014/11/07 | 168.2° | 3h 1m | + 4° | 2014/11/05 | 14.1 | 2014/10/27 | 0.977 |
| 5329 | 2014/09/27 | 161.2° | 0h54m | -14° | 2014/09/29 | 14.5 | 2014/10/03 | 0.997 |
| 5525 | 2014/09/03 | 179.5° | 22h50m | - 7° | 2014/09/03 | 14.2 | 2014/08/31 | 0.883 |
| 6361 | 2014/06/14 | 178.4° | 17h31m | -24° | 2014/06/14 | 14.1 | 2014/06/09 | 1.089 |
| 6364 | 2014/07/31 | 165.3° | 20h57m | -32° | 2014/08/01 | 14.5 | 2014/08/02 | 1.068 |
| 6425 | 2014/10/02 | 168.9° | 0h 9m | +13° | 2014/10/01 | 13.9 | 2014/09/27 | 1.054 |
| 6669 | 2014/07/19 | 166.2° | 20h 8m | -34° | 2014/07/19 | 13.9 | 2014/07/20 | 0.728 |
| 7369 | 2014/11/20 | 140.4° | 1h36m | +50° | 2014/11/15 | 14.4 | 2014/11/11 | 0.743 |
| 7393 | 2014/08/19 | 167.3° | 22h 8m | -24° | 2014/08/20 | 14.3 | 2014/08/23 | 0.830 |
| 7729 | 2014/06/14 | 176.8° | 17h29m | -20° | 2014/06/14 | 14.5 | 2014/06/20 | 0.881 |
| 7870 | 2014/12/09 | 177.5° | 5h 7m | +20° | 2014/12/09 | 14.0 | 2014/11/29 | 0.725 |
| 7898 | 2014/07/31 | 170.4° | 20h54m | -27° | 2014/08/01 | 14.2 | 2014/08/06 | 0.766 |
| 8355 | 2014/09/26 | 170.5° | 0h30m | - 6° | 2014/09/25 | 14.4 | 2014/09/20 | 0.673 |
| 10076 | 2014/08/21 | 179.6° | 21h59m | -12° | 2014/08/21 | 14.4 | 2014/08/22 | 0.771 |
| 10217 | 2014/09/11 | 175.4° | 23h22m | - 8° | 2014/09/11 | 14.1 | 2014/09/12 | 0.945 |
| 10565 | 2014/11/05 | 173.7° | 2h45m | + 9° | 2014/11/05 | 14.4 | 2014/11/01 | 1.084 |
| 11650 | 2014/08/03 | 176.7° | 20h52m | -14° | 2014/08/04 | 13.9 | 2014/08/11 | 0.884 |
| 13934 | 2014/06/04 | 177.2° | 16h49m | -19° | 2014/06/04 | 14.5 | 2014/06/17 | 0.864 |
| 14095 | 2014/08/18 | 177.7° | 21h57m | -14° | 2014/08/18 | 14.2 | 2014/08/18 | 0.801 |
| 14951 | 2014/08/02 | 178.7° | 20h52m | -18° | 2014/08/02 | 14.5 | 2014/08/08 | 0.822 |
| 15166 | 2014/09/03 | 175.6° | 22h40m | - 3° | 2014/09/03 | 14.4 | 2014/09/01 | 1.196 |
| 15673 | 2014/08/04 | 178.0° | 20h56m | -19° | 2014/08/04 | 14.2 | 2014/08/07 | 0.606 |
| 15779 | 2014/06/30 | 174.9° | 18h30m | -28° | 2014/06/30 | 14.3 | 2014/07/10 | 0.962 |
| 21374 | 2014/05/20 | 151.5° | 17h39m | -34° | 2014/05/20 | 14.1 | 2014/05/21 | 0.121 |
| 25916 | 2014/09/28 | 141.0° | 0h56m | -35° | 2014/07/20 | 14.1 | 2014/07/10 | 0.493 |
| 26822 | 2014/07/17 | 174.5° | 19h55m | -26° | 2014/07/18 | 14.5 | 2014/07/24 | 0.676 |
| 29769 | 2014/09/01 | 158.8° | 23h22m | -27° | 2014/08/31 | 14.5 | 2014/08/28 | 1.192 |
| 163132 | 2014/09/04 | 106.8° | 3h15m | -64° | 2014/08/30 | 13.9 | 2014/08/30 | 0.035 |

## Table II. Temporal Sequence of Favorable Elongations

| Planet | Max Elon D | Max E | RA | Dec | Br Mag D | Br Mag | Min Dist D | Min Dist |
|---|---|---|---|---|---|---|---|---|
| 2062 | 2014/01/03 | 155.9° | 5h54m | + 3° | 2014/01/05 | 14.3 | 2014/01/08 | 0.146 |
| 1021 | 2014/01/05 | 174.6° | 7h 0m | +17° | 2014/01/05 | 11.4 | 2013/12/27 | 1.223 |
| 506 | 2014/01/06 | 167.0° | 7h12m | +35° | 2014/01/06 | 12.4 | 2014/01/06 | 1.622 |
| 190 | 2014/01/15 | 172.5° | 7h42m | +13° | 2014/01/15 | 12.4 | 2014/01/13 | 2.408 |
| 1578 | 2014/01/20 | 179.1° | 8h 9m | +20° | 2014/01/20 | 14.5 | 2014/01/15 | 2.174 |
| 3037 | 2014/01/22 | 171.2° | 8h29m | +28° | 2014/01/21 | 14.3 | 2014/01/17 | 1.290 |
| 1585 | 2014/02/06 | 169.2° | 9h 1m | + 5° | 2014/02/04 | 14.0 | 2014/01/27 | 1.527 |
| 114 | 2014/02/20 | 178.1° | 10h13m | + 8° | 2014/02/21 | 10.8 | 2014/02/22 | 1.326 |
| 385 | 2014/02/22 | 175.4° | 10h27m | +14° | 2014/02/22 | 10.6 | 2014/02/24 | 1.529 |
| 163 | 2014/02/23 | 179.0° | 10h26m | + 8° | 2014/02/23 | 11.3 | 2014/02/17 | 1.069 |
| 2 | 2014/02/26 | 157.0° | 9h44m | -10° | 2014/02/25 | 7.0 | 2014/02/23 | 1.231 |
| 1164 | 2014/02/28 | 177.2° | 10h49m | +10° | 2014/02/28 | 14.1 | 2014/02/26 | 0.885 |
| 1656 | 2014/03/02 | 161.9° | 10h 6m | - 6° | 2014/03/01 | 13.6 | 2014/02/26 | 0.754 |
| 24 | 2014/03/13 | 179.0° | 11h36m | + 3° | 2014/03/13 | 10.6 | 2014/03/12 | 1.789 |
| 313 | 2014/03/13 | 178.4° | 11h31m | + 1° | 2014/03/13 | 10.6 | 2014/03/09 | 1.022 |
| 1803 | 2014/03/20 | 160.2° | 11h43m | -19° | 2014/03/23 | 13.9 | 2014/03/30 | 0.913 |
| 288 | 2014/04/06 | 172.3° | 13h12m | + 0° | 2014/04/06 | 12.3 | 2014/04/08 | 1.204 |
| 855 | 2014/04/08 | 179.5° | 13h 6m | - 7° | 2014/04/08 | 13.6 | 2014/04/15 | 1.056 |
| 1146 | 2014/04/18 | 177.1° | 13h39m | -13° | 2014/04/18 | 13.1 | 2014/04/28 | 1.605 |
| 1323 | 2014/04/28 | 175.9° | 14h25m | -10° | 2014/04/28 | 13.6 | 2014/04/26 | 1.814 |
| 769 | 2014/05/01 | 179.5° | 14h31m | -15° | 2014/05/01 | 12.6 | 2014/05/08 | 1.880 |
| 772 | 2014/05/05 | 162.4° | 14h59m | + 1° | 2014/05/05 | 12.2 | 2014/05/05 | 1.750 |
| 1712 | 2014/05/07 | 173.8° | 14h47m | -22° | 2014/05/07 | 13.4 | 2014/05/11 | 1.727 |
| 232 | 2014/05/09 | 168.8° | 15h19m | - 6° | 2014/05/09 | 12.6 | 2014/05/07 | 1.137 |
| 1197 | 2014/05/17 | 172.3° | 15h23m | -26° | 2014/05/16 | 13.1 | 2014/05/09 | 1.457 |
| 1304 | 2014/05/17 | 164.4° | 15h46m | - 3° | 2014/05/17 | 12.6 | 2014/05/18 | 1.838 |
| 2014 | 2014/05/20 | 148.9° | 16h44m | + 7° | 2014/05/27 | 13.6 | 2014/06/02 | 0.858 |
| 21374 | 2014/05/20 | 151.5° | 17h39m | -34° | 2014/05/20 | 14.1 | 2014/05/21 | 0.121 |
| 790 | 2014/05/22 | 173.8° | 15h48m | -26° | 2014/05/23 | 12.2 | 2014/05/27 | 2.031 |
| 1093 | 2014/05/24 | 173.7° | 16h 3m | -27° | 2014/05/25 | 12.1 | 2014/06/02 | 1.559 |
| 4378 | 2014/05/27 | 168.1° | 16h20m | - 9° | 2014/05/26 | 13.8 | 2014/05/24 | 1.039 |
| 749 | 2014/05/28 | 171.9° | 16h25m | -13° | 2014/05/28 | 13.2 | 2014/05/28 | 0.850 |
| 3089 | 2014/05/31 | 170.1° | 16h31m | -12° | 2014/05/31 | 14.0 | 2014/06/03 | 1.414 |
| 2324 | 2014/06/01 | 179.4° | 16h36m | -22° | 2014/06/01 | 14.3 | 2014/06/03 | 1.525 |
| 13934 | 2014/06/04 | 177.2° | 16h49m | -19° | 2014/06/04 | 14.5 | 2014/06/17 | 0.864 |
| 259 | 2014/06/11 | 177.8° | 17h15m | -20° | 2014/06/11 | 11.3 | 2014/06/11 | 1.721 |
| 146 | 2014/06/12 | 179.0° | 17h23m | -22° | 2014/06/12 | 11.3 | 2014/06/11 | 1.545 |
| 6361 | 2014/06/14 | 178.4° | 17h31m | -24° | 2014/06/14 | 14.1 | 2014/06/09 | 1.089 |
| 7729 | 2014/06/14 | 176.8° | 17h29m | -20° | 2014/06/14 | 14.5 | 2014/06/20 | 0.881 |
| 1591 | 2014/06/23 | 179.0° | 18h 6m | -24° | 2014/06/23 | 13.2 | 2014/06/21 | 0.968 |
| 1747 | 2014/06/23 | 174.8° | 18h16m | -18° | 2014/06/23 | 13.2 | 2014/06/21 | 0.518 |
| 3165 | 2014/06/24 | 179.3° | 18h 9m | -23° | 2014/06/24 | 14.3 | 2014/07/01 | 0.949 |
| 1667 | 2014/06/27 | 177.4° | 18h25m | -25° | 2014/06/27 | 13.2 | 2014/06/27 | 0.832 |
| 486 | 2014/06/28 | 179.1° | 18h28m | -24° | 2014/06/28 | 12.6 | 2014/06/22 | 1.087 |
| 15779 | 2014/06/30 | 174.9° | 18h30m | -28° | 2014/06/30 | 14.3 | 2014/07/10 | 0.962 |
| 901 | 2014/07/01 | 178.0° | 18h42m | -21° | 2014/07/02 | 12.5 | 2014/07/11 | 0.841 |
| 665 | 2014/07/02 | 172.4° | 18h47m | -30° | 2014/07/02 | 11.6 | 2014/06/30 | 1.625 |
| 54 | 2014/07/07 | 169.3° | 19h 6m | -33° | 2014/07/07 | 10.1 | 2014/07/09 | 1.177 |
| 881 | 2014/07/07 | 176.1° | 19h 5m | -18° | 2014/07/07 | 13.7 | 2014/07/12 | 1.112 |
| 1842 | 2014/07/12 | 171.9° | 19h21m | -13° | 2014/07/12 | 13.8 | 2014/07/10 | 0.848 |
| 4558 | 2014/07/12 | 130.1° | 20h45m | +24° | 2014/08/07 | 13.4 | 2014/08/16 | 0.606 |
| 982 | 2014/07/15 | 176.9° | 19h36m | -24° | 2014/07/15 | 12.6 | 2014/07/14 | 1.334 |
| 4826 | 2014/07/16 | 159.8° | 20h25m | -39° | 2014/07/17 | 14.2 | 2014/07/19 | 0.953 |
| 26822 | 2014/07/17 | 174.5° | 19h55m | -26° | 2014/07/18 | 14.5 | 2014/07/24 | 0.676 |
| 6669 | 2014/07/19 | 166.2° | 20h 8m | -34° | 2014/07/19 | 13.9 | 2014/07/20 | 0.728 |
| 936 | 2014/07/20 | 176.8° | 20h 2m | -23° | 2014/07/20 | 13.2 | 2014/07/22 | 1.581 |
| 172 | 2014/07/28 | 171.0° | 20h34m | -27° | 2014/07/28 | 11.1 | 2014/07/30 | 1.121 |
| 1705 | 2014/07/28 | 164.5° | 20h12m | - 4° | 2014/07/31 | 14.2 | 2014/08/06 | 0.812 |
| 2382 | 2014/07/30 | 123.2° | 20h20m | +38° | 2014/07/27 | 14.1 | 2014/07/27 | 1.086 |
| 6364 | 2014/07/31 | 165.3° | 20h57m | -32° | 2014/08/01 | 14.5 | 2014/08/02 | 1.068 |
| 7898 | 2014/07/31 | 170.4° | 20h54m | -27° | 2014/08/01 | 14.2 | 2014/08/06 | 0.766 |
| 14951 | 2014/08/02 | 178.7° | 20h52m | -18° | 2014/08/02 | 14.5 | 2014/08/08 | 0.822 |
| 805 | 2014/08/03 | 164.4° | 20h29m | - 2° | 2014/08/02 | 13.4 | 2014/08/01 | 1.610 |
| 11650 | 2014/08/03 | 176.7° | 20h52m | -14° | 2014/08/04 | 13.9 | 2014/08/11 | 0.884 |
| 15673 | 2014/08/04 | 178.0° | 20h56m | -19° | 2014/08/04 | 14.2 | 2014/08/07 | 0.606 |
| 297 | 2014/08/05 | 175.9° | 21h 3m | -21° | 2014/08/05 | 13.0 | 2014/08/05 | 1.710 |
| 794 | 2014/08/09 | 176.0° | 21h11m | -12° | 2014/08/09 | 13.5 | 2014/08/03 | 1.232 |
| 112 | 2014/08/11 | 179.4° | 21h23m | -15° | 2014/08/11 | 11.8 | 2014/08/12 | 1.124 |
| 1000 | 2014/08/12 | 177.6° | 21h31m | -17° | 2014/08/12 | 13.2 | 2014/08/03 | 1.752 |
| 1525 | 2014/08/13 | 172.2° | 21h21m | - 7° | 2014/08/13 | 14.3 | 2014/08/17 | 1.003 |
| 584 | 2014/08/18 | 164.2° | 21h34m | + 2° | 2014/08/20 | 10.4 | 2014/08/25 | 0.908 |
| 606 | 2014/08/18 | 178.1° | 21h47m | -11° | 2014/08/18 | 12.5 | 2014/08/25 | 1.144 |
| 4349 | 2014/08/18 | 163.0° | 22h21m | -28° | 2014/08/21 | 14.1 | 2014/08/26 | 1.106 |
| 14095 | 2014/08/18 | 177.7° | 21h57m | -14° | 2014/08/18 | 14.2 | 2014/08/18 | 0.801 |
| 7393 | 2014/08/19 | 167.3° | 22h 8m | -24° | 2014/08/20 | 14.3 | 2014/08/23 | 0.830 |
| 4150 | 2014/08/20 | 177.1° | 22h 1m | -15° | 2014/08/20 | 14.1 | 2014/08/18 | 0.850 |
| 10076 | 2014/08/21 | 179.6° | 21h59m | -12° | 2014/08/21 | 14.4 | 2014/08/22 | 0.771 |
| 672 | 2014/08/23 | 175.1° | 22h15m | -15° | 2014/08/23 | 13.6 | 2014/08/19 | 1.252 |
| 63 | 2014/08/24 | 178.7° | 22h15m | -12° | 2014/08/24 | 9.7 | 2014/08/19 | 1.189 |
| 3894 | 2014/08/24 | 174.6° | 22h 2m | - 6° | 2014/08/24 | 14.5 | 2014/08/26 | 1.183 |
| 883 | 2014/08/29 | 171.7° | 22h17m | - 1° | 2014/08/28 | 13.7 | 2014/08/26 | 0.789 |
| 29769 | 2014/09/01 | 158.8° | 23h22m | -27° | 2014/08/31 | 14.5 | 2014/08/28 | 1.192 |
| 144 | 2014/09/03 | 170.7° | 23h 4m | -15° | 2014/09/04 | 10.0 | 2014/09/07 | 1.077 |
| 5525 | 2014/09/03 | 179.5° | 22h50m | - 7° | 2014/09/03 | 14.2 | 2014/08/31 | 0.883 |
| 15166 | 2014/09/03 | 175.6° | 22h40m | - 3° | 2014/09/03 | 14.4 | 2014/09/01 | 1.196 |
| 2292 | 2014/09/04 | 174.4° | 22h41m | - 2° | 2014/09/03 | 13.8 | 2014/08/27 | 1.073 |
| 2571 | 2014/09/04 | 173.5° | 23h 2m | -13° | 2014/09/04 | 14.1 | 2014/09/05 | 0.793 |
| 163132 | 2014/09/04 | 106.8° | 3h15m | -64° | 2014/08/30 | 13.9 | 2014/08/30 | 0.035 |
| 1165 | 2014/09/05 | 165.9° | 22h30m | + 5° | 2014/09/03 | 13.8 | 2014/08/30 | 1.573 |
| 12 | 2014/09/09 | 163.5° | 22h40m | + 9° | 2014/09/06 | 9.0 | 2014/08/31 | 0.904 |
| 33 | 2014/09/09 | 178.5° | 23h12m | - 6° | 2014/09/09 | 9.8 | 2014/09/08 | 0.895 |
| 10217 | 2014/09/11 | 175.4° | 23h22m | - 8° | 2014/09/11 | 14.1 | 2014/09/12 | 0.945 |
| 270 | 2014/09/14 | 174.9° | 23h20m | + 1° | 2014/09/14 | 10.1 | 2014/09/10 | 0.872 |
| 915 | 2014/09/17 | 177.1° | 23h42m | - 5° | 2014/09/17 | 13.5 | 2014/09/21 | 1.015 |
| 2525 | 2014/09/18 | 175.5° | 23h51m | - 5° | 2014/09/18 | 13.8 | 2014/09/19 | 1.581 |
| 4910 | 2014/09/18 | 179.0° | 23h41m | - 0° | 2014/09/18 | 14.5 | 2014/09/10 | 0.657 |
| 314 | 2014/09/19 | 177.9° | 23h48m | - 3° | 2014/09/19 | 12.7 | 2014/09/18 | 1.592 |
| 725 | 2014/09/21 | 173.1° | 0h 5m | - 6° | 2014/09/22 | 13.9 | 2014/09/26 | 1.067 |
| 283 | 2014/09/23 | 169.2° | 23h42m | + 9° | 2014/09/23 | 12.2 | 2014/09/21 | 1.602 |
| 373 | 2014/09/23 | 178.4° | 0h 3m | - 1° | 2014/09/23 | 12.5 | 2014/09/21 | 1.673 |
| 1196 | 2014/09/23 | 148.7° | 0h59m | -27° | 2014/09/23 | 13.2 | 2014/09/22 | 1.255 |
| 379 | 2014/09/24 | 179.6° | 0h 4m | + 0° | 2014/09/24 | 11.9 | 2014/09/22 | 1.554 |
| 5142 | 2014/09/24 | 174.5° | 23h53m | + 5° | 2014/09/24 | 14.0 | 2014/10/01 | 0.923 |
| 393 | 2014/09/26 | 165.2° | 23h38m | +13° | 2014/09/22 | 10.7 | 2014/09/12 | 1.091 |
| 1110 | 2014/09/26 | 168.5° | 23h50m | +11° | 2014/09/24 | 13.0 | 2014/09/15 | 0.766 |
| 8355 | 2014/09/26 | 170.5° | 0h30m | - 6° | 2014/09/25 | 14.4 | 2014/09/20 | 0.673 |
| 84 | 2014/09/27 | 167.4° | 0h 0m | +13° | 2014/09/26 | 10.8 | 2014/09/21 | 0.836 |
| 5329 | 2014/09/27 | 161.2° | 0h54m | -14° | 2014/09/29 | 14.5 | 2014/10/03 | 0.997 |
| 25916 | 2014/09/28 | 141.0° | 0h56m | -35° | 2014/07/20 | 14.1 | 2014/07/10 | 0.493 |
| 253 | 2014/09/30 | 178.0° | 0h31m | + 1° | 2014/09/30 | 11.9 | 2014/09/23 | 0.994 |
| 258 | 2014/09/30 | 169.8° | 0h 5m | +11° | 2014/09/30 | 10.6 | 2014/09/28 | 1.087 |
| 952 | 2014/09/30 | 176.3° | 0h30m | - 0° | 2014/09/30 | 11.7 | 2014/09/30 | 1.254 |
| 6425 | 2014/10/02 | 168.9° | 0h 9m | +13° | 2014/10/01 | 13.9 | 2014/09/27 | 1.054 |
| 458 | 2014/10/05 | 161.5° | 1h18m | -11° | 2014/10/07 | 12.8 | 2014/10/10 | 1.407 |
| 37 | 2014/10/09 | 179.1° | 0h56m | + 6° | 2014/10/09 | 9.8 | 2014/10/13 | 1.327 |

| Planet | Max Elon D | Max E | RA | Dec | Br Mag D | Br Mag | Min Dist D | Min Dist |
|---|---|---|---|---|---|---|---|---|
| 1550 | 2014/10/09 | 164.3° | 1h16m | - 8° | 2014/10/09 | 13.0 | 2014/10/08 | 0.768 |
| 2642 | 2014/10/10 | 177.5° | 0h55m | + 8° | 2014/10/10 | 14.3 | 2014/10/07 | 0.986 |
| 1738 | 2014/10/11 | 175.3° | 1h13m | + 2° | 2014/10/11 | 13.6 | 2014/10/02 | 0.844 |
| 1662 | 2014/10/15 | 174.1° | 1h11m | +13° | 2014/10/15 | 13.9 | 2014/10/15 | 1.289 |
| 55 | 2014/10/18 | 176.9° | 1h26m | +12° | 2014/10/18 | 10.5 | 2014/10/16 | 1.376 |
| 1463 | 2014/10/21 | 170.0° | 1h27m | +19° | 2014/10/21 | 14.0 | 2014/10/22 | 1.598 |
| 475 | 2014/10/23 | 175.2° | 1h49m | + 6° | 2014/10/22 | 12.8 | 2014/10/08 | 0.746 |
| 3220 | 2014/10/29 | 177.7° | 2h11m | +15° | 2014/10/29 | 14.1 | 2014/10/30 | 0.858 |
| 4820 | 2014/10/29 | 157.2° | 1h44m | +35° | 2014/11/02 | 13.6 | 2014/11/06 | 0.972 |
| 2340 | 2014/10/30 | 172.1° | 2h33m | + 6° | 2014/10/27 | 14.2 | 2014/10/21 | 0.048 |
| 1407 | 2014/10/31 | 171.0° | 2h 7m | +22° | 2014/10/30 | 12.6 | 2014/10/26 | 1.022 |
| 245 | 2014/11/03 | 177.0° | 2h37m | +12° | 2014/11/03 | 10.9 | 2014/11/01 | 1.514 |
| 713 | 2014/11/03 | 179.1° | 2h35m | +14° | 2014/11/03 | 12.9 | 2014/10/29 | 1.965 |
| 1057 | 2014/11/05 | 176.3° | 2h36m | +19° | 2014/11/05 | 13.4 | 2014/10/30 | 1.251 |
| 10565 | 2014/11/05 | 173.7° | 2h45m | + 9° | 2014/11/05 | 14.4 | 2014/11/01 | 1.084 |
| 333 | 2014/11/06 | 175.4° | 2h38m | +20° | 2014/11/05 | 12.9 | 2014/11/02 | 1.685 |
| 5176 | 2014/11/07 | 168.2° | 3h 1m | + 4° | 2014/11/05 | 14.1 | 2014/10/27 | 0.977 |
| 931 | 2014/11/08 | 162.7° | 3h11m | - 0° | 2014/11/09 | 12.7 | 2014/11/10 | 1.522 |
| 1756 | 2014/11/12 | 171.1° | 2h58m | +26° | 2014/11/12 | 14.1 | 2014/11/08 | 0.998 |
| 515 | 2014/11/20 | 177.0° | 3h43m | +16° | 2014/11/20 | 14.5 | 2014/11/19 | 1.607 |
| 7369 | 2014/11/20 | 140.4° | 1h36m | +50° | 2014/11/15 | 14.4 | 2014/11/11 | 0.743 |
| 503 | 2014/11/21 | 178.5° | 3h49m | +18° | 2014/11/21 | 11.9 | 2014/11/26 | 1.390 |
| 2693 | 2014/11/22 | 179.9° | 3h51m | +20° | 2014/11/22 | 14.3 | 2014/11/19 | 0.855 |
| 3722 | 2014/11/22 | 178.3° | 3h52m | +18° | 2014/11/22 | 14.3 | 2014/11/14 | 0.914 |
| 2078 | 2014/11/26 | 136.3° | 1h29m | +52° | 2014/11/12 | 13.3 | 2014/11/07 | 0.639 |
| 104 | 2014/11/28 | 178.1° | 4h12m | +22° | 2014/11/28 | 11.6 | 2014/11/28 | 1.675 |
| 66 | 2014/11/29 | 175.2° | 4h14m | +26° | 2014/11/28 | 11.8 | 2014/11/26 | 1.221 |
| 481 | 2014/12/01 | 179.1° | 4h31m | +22° | 2014/12/01 | 11.1 | 2014/11/29 | 1.338 |
| 1041 | 2014/12/02 | 176.0° | 4h33m | +25° | 2014/12/02 | 13.4 | 2014/11/30 | 1.696 |
| 23 | 2014/12/03 | 178.7° | 4h34m | +23° | 2014/12/03 | 9.2 | 2014/12/10 | 1.205 |
| 3960 | 2014/12/07 | 174.4° | 4h52m | +17° | 2014/12/07 | 13.6 | 2014/12/11 | 0.956 |
| 1067 | 2014/12/08 | 169.7° | 4h49m | +32° | 2014/12/07 | 13.7 | 2014/12/03 | 1.404 |
| 7870 | 2014/12/09 | 177.5° | 5h 7m | +20° | 2014/12/09 | 14.0 | 2014/11/29 | 0.725 |
| 569 | 2014/12/10 | 178.4° | 5h 7m | +24° | 2014/12/10 | 12.3 | 2014/12/10 | 1.196 |
| 598 | 2014/12/14 | 176.3° | 5h26m | +19° | 2014/12/14 | 12.1 | 2014/12/06 | 1.307 |
| 549 | 2014/12/15 | 176.3° | 5h28m | +26° | 2014/12/15 | 12.8 | 2014/12/16 | 1.011 |
| 81 | 2014/12/18 | 166.6° | 5h44m | +36° | 2014/12/17 | 11.4 | 2014/12/14 | 1.361 |
| 2648 | 2014/12/18 | 177.6° | 5h43m | +25° | 2014/12/18 | 14.3 | 2014/12/13 | 0.923 |
| 485 | 2014/12/24 | 156.0° | 6h11m | - 0° | 2014/12/25 | 11.3 | 2014/12/26 | 1.294 |
| 1080 | 2014/12/27 | 170.4° | 6h27m | +32° | 2014/12/26 | 13.7 | 2014/12/20 | 0.887 |
| 2290 | 2014/12/28 | 160.8° | 6h19m | + 4° | 2014/12/26 | 14.5 | 2014/12/23 | 1.076 |

Table III. Numerical Sequence of Close Approaches

| Planet | Max Elon D | Max E | RA | Dec | Br Mag D | Br Mag | Min Dist D | Min Dist |
|---|---|---|---|---|---|---|---|---|
| 2062 | 2014/01/03 | 155.9° | 5h54m | + 3° | 2014/01/05 | 14.3 | 2014/01/08 | 0.146 |
| 2340 | 2014/10/30 | 172.1° | 2h33m | + 6° | 2014/10/27 | 14.2 | 2014/10/21 | 0.048 |
| 21374 | 2014/05/20 | 151.5° | 17h39m | -34° | 2014/05/20 | 14.1 | 2014/05/21 | 0.121 |
| 163132 | 2014/09/04 | 106.8° | 3h15m | -64° | 2014/08/30 | 13.9 | 2014/08/30 | 0.035 |

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# A PHOTOMETRIC STUDY OF 582 OLYMPIA

Frederick Pilcher
Organ Mesa Observatory
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA

Andrea Ferrero
Bigmuskie Observatory (B88)
Via Italo Aresca 12, 14047 Mombercelli-Asti ITALY

Lorenzo Franco
A81 Balzaretto Observatory, Rome ITALY

Julian Oey
Leura Observatory
94 Rawson Pde. Leura, NSW, AUSTRALIA

Brian D. Warner
Center for Solar System Studies
446 Sycamore Ave.
Eaton, CO 80615 USA

(Received: 29 September)

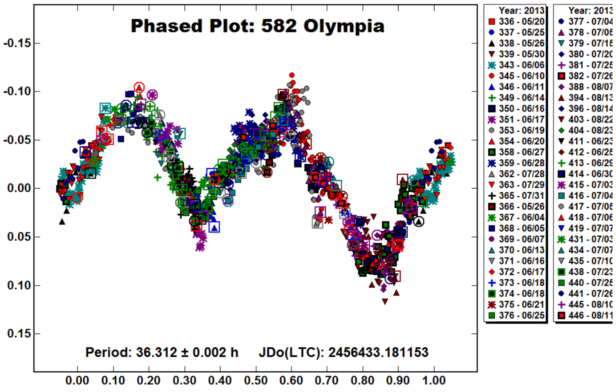
The lightcurve period for asteroid 582 Olympia has been ambiguous due to its having a rotation period commensurate with the Earth's. A consortium of observers from Australia, Europe, and North America have obtained full phase coverage and find a rotation period of 36.312 ± 0.002 hours, amplitude 0.14 ± 0.02 mag. *H* and *G* parameters were computed from sparse data only and yield $H = 9.19 \pm 0.06$, $G = 0.23 \pm 0.06$.

Previous studies of the rotation period of 582 Olympia obtained the following results: Behrend (2005), 10.68 hours; Higgins *et al.* (2004), 72.0 hours; Menke (2011), 72 hours, whose observations are also included in Higgins *et al.* (2004); Schober *et al.* (1993), 36.0 hours. With a strong suggestion of an Earth-day commensurate period observers Pilcher, Ferrero, and Oey agreed to collaborate so that their wide distribution of longitudes would most likely enable full lightcurve coverage. Warner independently obtained several sessions. When they learned of each other's observations, they agreed to collaborate and combine their data. Table I lists the equipment used by each observer.

| Obs | Telescope | CCD |
|---|---|---|
| AF | 0.3-m f/8 R-C | ST-9 |
| JO | 0.35-m f/5.9 SCT<br>0.25-m f/11 SCT | ST-8XME |
| FP | 0.35-m SCT | STL-1001E |
| BW | 0.35-m f/9.1 SCT | FLI-1001E |

Table I. List of equipment used by each observer.

A total of 56 sessions obtained between 2013 May 26 and Aug 23 are included in this analysis. Sixteen other sessions were not used; generally these were of lower signal-to-noise, short duration, or not diagnostic for discriminating between alternate period solutions. Pilcher, Ferrero, and Oey measured calibration magnitudes in the R band while Warner used the V band. This caused the V band magnitudes to be about 0.5 fainter than the R band magnitudes. Furthermore, within the R band measurements, misfits of up to 0.2 magnitudes were encountered, due primarily to errors in the calibration star magnitudes. Therefore, the instrumental magnitude of each session was adjusted separately to best fit. This best fit corresponded to a bimodal lightcurve with period of 36.312 ± 0.002 hours, amplitude 0.14 ± 0.02 magnitudes. The half-period can be immediately ruled out by the asymmetry of the bimodal lightcurve. A trial plot to the double-period showed the two halves indistinguishable within the errors of measurement. Therefore, we also reject the double-period as extremely unlikely and consider the 36.312 hour period as the only one that can be supported by our observations. Trial lightcurves were also drawn for several subsets of data covering intervals of 30 to 45 days throughout the full



observation interval. The overall form of the lightcurve did not change perceptibly with phase angle or viewing aspect.

Further evidence against the double period near 72.6 hours is provided by Schober *et al.* (1993). They draw a composite bimodal lightcurve phased to 36.0 hours based on data from 6 consecutive nights with about 60% phase coverage. Overlapping sessions on this lightcurve centered near 1989 Nov 30.3 and Dec 3.3 each show a small rise followed by a fall greater than 0.4 magnitudes in about 6 hours. This sets a lower limit in their data for the amplitude. An amplitude as large as 0.4 magnitudes is possible only for a bimodal lightcurve.

Independently, Franco drew an *H-G* plot based only on sparse data from the U.S. Naval Observatory (USNO), i.e., not including any of the new photometry. These data contain no correction for rotational variation and in include the inherent scatter in the USNO data itself. The large quantity of data points partially compensates for the somewhat large scatter in the data set and establish moderately precise and reliable values of $H = 9.19 \pm 0.06$ mag, $G = 0.23 \pm 0.06$, which agrees with the JPL Small-Body Database Browser (JPL, 2013) value of $H = 9.11$.

The observing cadence by FP at Organ Mesa Observatory is such that a much larger number of data points were acquired than at any of the other observatories. To make the large number of data points in the segments of the lightcurve included by Organ Mesa observations more legible, those data have been binned in sets of five points with a maximum of ten minutes between points.

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# PERIOD DETERMINATION FOR 330 ADALBERTA: A LOW NUMBERED ASTEROID WITH A PREVIOUSLY UNKNOWN PERIOD

Eduardo Manuel Álvarez
OLASU (I38)
Costanera Sur 559, Salto 50.000, URUGUAY
olasu@adinet.com.uy

Frederick Pilcher
Organ Mesa Observatory (G50)
Las Cruces, NM 88011, USA

(Received: 29 September Revised: 12 November)

Lightcurve analysis for 330 Adalberta was performed using observations obtained from two observatories during its 2013 opposition. The synodic rotation period was found to be 3.5553 ± 0.0001 h and the lightcurve amplitude was 0.44 ± 0.04 mag.

330 Adalberta is a small main-belt asteroid with an interesting story. Originally, the name was assigned to a supposed asteroid discovered by Max Wolf on 1892 March 18 (provisional designation 1892 X) but it was lost and never recovered. Ninety years later, in 1982, it was determined that the observations leading to the designation of 1892 X were actually stars: the asteroid never existed. The number and name 330 Adalberta were then reassigned to another asteroid, also discovered by Max Wolf on 1910 February 2 (provisional designation A910 CB), which – in turn – had earlier been incorrectly identified with 783 Nora. Also worth mentioning is that, at the time of our study (2013 August), 330 Adalberta was the second lowest numbered asteroid that appeared to have no previously reported rotation period. This made it particularly appealing to us when reviewing the CALL web site list of asteroids reaching a favorable apparition in 2013.

Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC code I38) and at the Organ Mesa Observatory, New Mexico, USA (MPC code G50). Table I gives the equipment used and Table II the imaging parameters for each observatory.

| Observatory Equipment | | |
|---|---|---|
| Obs | Telescope | CCD camera |
| I38 | 0.30-m f/6.9 Meade LX200 ACF | QSI 516wsg NABG |
| G50 | 0.35-m f/10 Meade LX200 GPS | SBIG STL-1001E |

Table I. Telescope and CCD cameras.

| Imaging parameters | | | | | |
|---|---|---|---|---|---|
| Obs | Exp | Temp | Guiding | Image scale | Field-of-view |
| I38 | 90 s | -10°C | yes | 1.77 arcs/px | 23 x 16 arcmin |
| G50 | 60 s | -12°C | no | 1.40 arcs/px | 24 x 24 arcmin |

Table II. Imaging parameters.

| Session Data | | | | |
|---|---|---|---|---|
| Session | Observer | 2013 Sept | UT | Data Pts |
| 1 | EMA | 2-3 | 22:22 - 02:43 | 101 |
| 2 | EMA | 3-4 | 22:30 - 04:00 | 202 |
| 3 | EMA | 4-5 | 22:43 - 02:48 | 139 |
| 4 | EMA | 8-9 | 23:20 - 04:02 | 177 |
| 5 | EMA | 9-10 | 22:32 - 04:02 | 207 |
| 6 | EMA | 10-11 | 22:54 - 03:12 | 162 |
| 7 | FP | 22 | 02:15 - 08:19 | 290 |

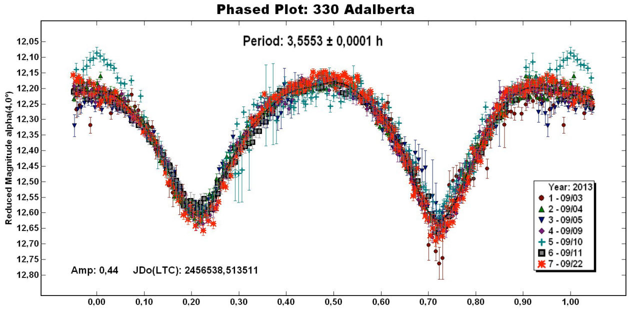
Table III. Observing Circumstances. In the Observer column, EMA is Alvarez at OLASU and FP is Pilcher at Organ Mesa.

A total of seven sessions were devoted exclusively to observing the main-belt asteroid from 2013 September 2-22. Table III summarizes the session data.

All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.0.20 with a differential photometry technique. The data were light-time corrected. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors according to recommendations by Warner (2007) and Stephens (2008). Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

More than 34 hours of observations and about 1,300 data points were obtained to solve the lightcurve. Over the span of observations, the phase angle varied from 3.5º to 14.3º, the phase angle bisector ecliptic longitude ranged from 335.2º to 336.8º, and the phase angle bisector ecliptic latitude from –3.3º to –4.4º. The rotation period for 330 Adalberta was determined to be 3.5553 ± 0.0001 h along with a peak-to-peak amplitude of 0.44 ± 0.04 mag. Despite its short 'potentially convenient' period, no clear evidence of a binary companion was seen in the lightcurve.

Our study now leaves only four asteroids numbered below 500 for which no rotation parameters are currently found in the literature. They are 299 Thora, 398 Admete, 457 Alleghenia, and 473 Nolli. Among the asteroids numbered from 501 to 1000, only 27 have no period that we could find. This is a dramatic reduction from two years ago (Alvarez, 2012), thus leaving only 31 asteroids among the first 1000 numbered asteroids with no previously reported rotation period. Even in cases where low numbered asteroids do have reported lightcurve parameters, not all of these period determinations are secure (Q=3) and ongoing investigations to verify, refine, or revise their values remains an important endeavor.



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# PERIOD DETERMINATION OF FOUR MAIN-BELT ASTEROIDS IN MID-2013

Andrea Ferrero
Bigmuskie Observatory
via Italo Aresca 12
14047 Mombercelli, Asti, ITALY

(Received: 10 October Revised: 7 November)

Observations of four main-belt asteroids (MBA) produced lightcurve parameters of: 1030 Vitja, *P* = 6.332 ± 0.001 h, *A* = 0.21 mag; 1058 Grubba, *P* = 46.30 ± 0.01 h, *A* = 0.24 mag; 1486 Marilyn, *P* = 4.568 ± 0.001 h, *A* = 0.42 mag.; and 3255 Tholen, *P* = 2.947 ± 0.001 h, *A* = 0.11 mag.

Because of prolonged periods of bad weather, only four asteroids observed during the first half of 2013 at the Bigmuskie Observatory. All of the four are main-belt members: 1030 Vitja, 1058 Grubba, 1486 Marilyn, and 3255 Tholen.

All observations were made with a Marcon 0.30-meter *f*/8 Ritchey-Chretién and SBIG ST-9 CCD camera with a pixel array of 512x512x20 microns. The combination produced a field-of-view of 15x15 arcmin and scale of 1.72 arcsec/pixel. Exposures were unguided and taken using an Astrodon R filter. *MPO Canopus* v10.4.1.9 (Warner, 2012) was used for image calibration and photometrical measurements. Night-to-night zero-point calibration was done using the Comparison Star Selector utility in *MPO Canopus* and from three to five solar-colored comparison stars from the MPOSC3 catalog supplied with *MPO Canopus*.

<u>1030 Vitja.</u> Behrend (2007) reported a period of 5.7014 h and an amplitude of 0.18 mag. After five sessions, two periods appeared reliable, but none of them is fully satisfactory. From the period spectrum, the higher probability is at *P* = 6.332 ± 0.001 h and amplitude 0.21 mag. However, scattering of the data is evident between phase 0.40-0.70. The second solution, very close to the one found by Behrend, is at *P* = 5.590 ± 0.001 h, but with a worse fit of the data and much less probability than the first one. An even worse solution is present around *P* = 7.29 h. Other solutions present in the period spectrum are only the semi-periods of the three principal periods.

<u>1058 Grubba.</u> This target shows a classical bimodal curve even if, at first, a monomodal curve seemed to be preferred. Adding further sessions showed a difference between the first and second halves of the curve. Final analysis found a lightcurve with a period *P* = 46.30 ± 0.01 h and amplitude *A* = 0.24 mag. Vesely (1985) found a period of *P* > 18 h and Behrend (2003) one of *P* > 12 h.

<u>1486 Marilyn.</u> The short period for this asteroid allowed covering more than one rotation during a single night. With two sessions spaced by two days, the resulting period is 4.568 ± 0.001 h with an amplitude of 0.42 mag. Given this amplitude and low phase angle, a bimodal solution is almost certain. The period is about double that reported by Behrend (2012).

<u>3255 Tholen.</u> This appears to be a fast rotator with small amplitude. The minimum at phase 0.90 of the curve helped to calibrate each session with the others by acting as a "stationary landmark" during the period search. The final period is 2.947 ± 0.001 h with an amplitude of 0.11 mag. This is in agreement with the results of 3 h reported by Wisniewski (1997).

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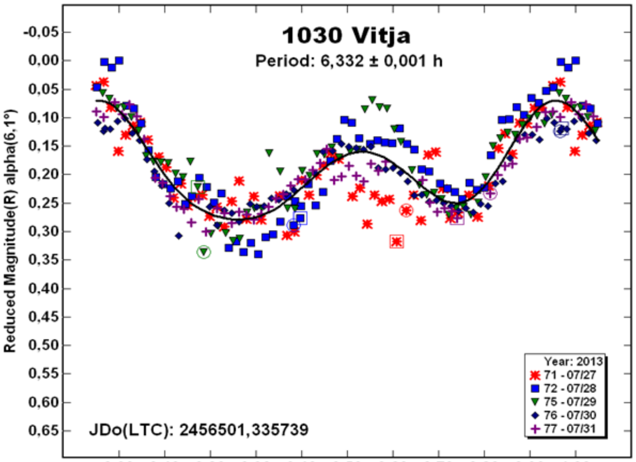

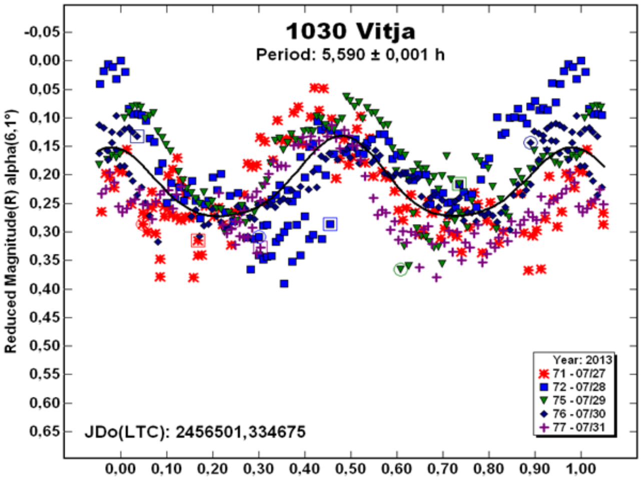

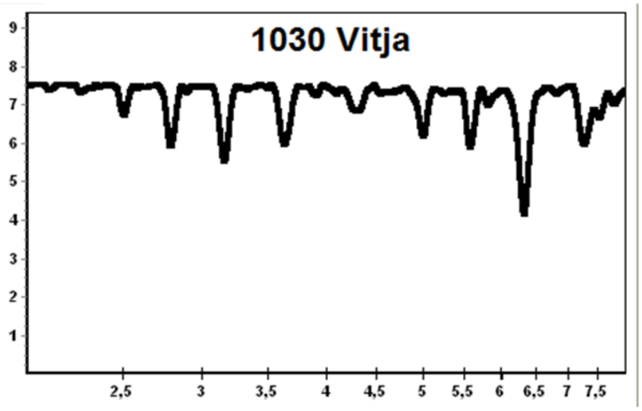

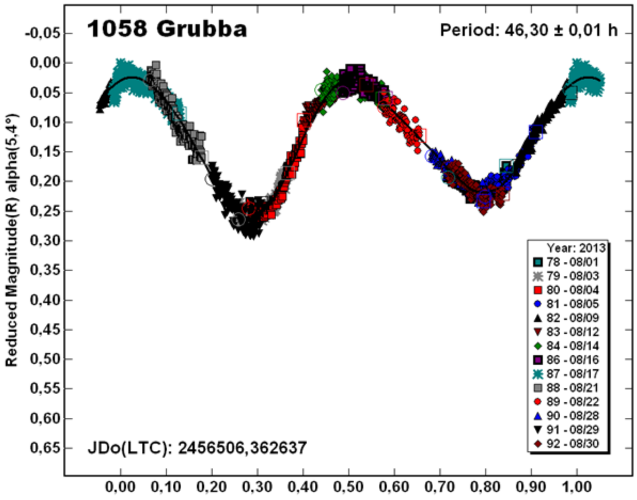

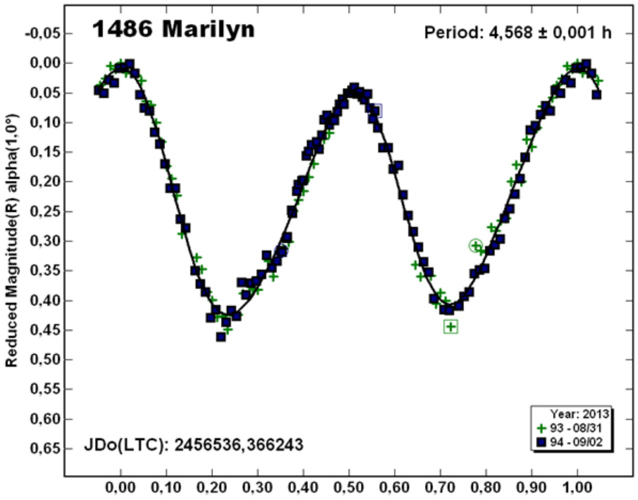

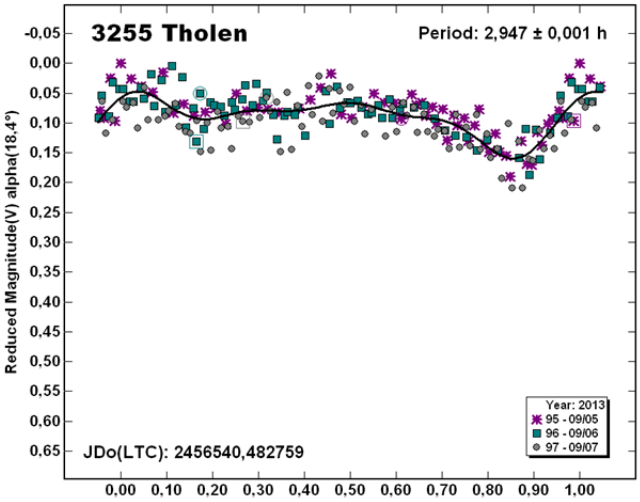

## ASTEROID-DEEPSKY APPULSES IN 2014

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

(Received: 6 October)

The list presented here represents only some highlights from a search for asteroid-deepsky appulses for calendar year 2014. The selections are based on close approaches of brighter asteroids to brighter DSOs. The complete set of predictions is available at

*http://www.minorplanet.info/ObsGuides/Appulses/DSOAppulses.htm*

For any event not covered, the Minor Planet Center's web site at *http://www.minorplanetcenter.net/cgi-bin/checkmp.cgi* allows you to enter the location of a suspected asteroid or supernova and check if there are any known targets in the area.

For this listing of 2014 events, the Table columns are explained below. Table entries in **bold** may be of particular interest to astrophotographers.

| | |
|---|---|
| Date/Time | Universal Date (MM DD) and Time of closest approach |
| #/Asteroid | The number and name of the asteroid |
| RA/Dec | The J2000 position of the asteroid |
| AM | The approximate visual magnitude of the asteroid |
| Sep/PA | The separation in arcseconds and the position angle from the DSO to the asteroid |
| DSO | The DSO name or catalog designation |
| DM | The approximate total magnitude of the DSO |
| DT | The type of DSO: OC = Open Cluster; GC = Globular Cluster; G = Galaxy |
| SE/ME | The elongation in degrees from the sun and moon respectively |
| MP | The phase of the moon: 0 = New, 1.0 = Full. Positive = waxing; Negative = waning |

| Date | UT | # | Name | RA | Dec | AM | Sep | PA | DSO | DM | DT | SE | ME | MP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 04 | 07:36 | 626 | Notburga | 08:01.78 | +56 35.0 | 12.4 | 58 | 350 | NGC 2488 | 12.4 | G | 144 | 129 | 0.12 |
| 01 04 | 16:19 | 751 | Faina | 09:43.18 | +31 52.9 | 12.8 | 243 | 62 | NGC 2964 | 11.3 | G | 143 | 155 | 0.15 |
| 01 04 | 21:12 | 751 | Faina | 09:43.08 | +31 55.1 | 12.8 | 103 | 240 | NGC 2968 | 11.7 | G | 143 | 154 | 0.17 |
| 02 03 | 23:12 | 345 | Tercidina | 07:34.15 | +04 30.4 | 11.7 | 102 | 204 | UGC 3912 | 12.8 | G | 154 | 104 | 0.22 |
| 02 05 | 18:04 | 59 | Elpis | 08:45.45 | +09 41.6 | 11.8 | 108 | 27 | NGC 2657 | 13.0 | G | 170 | 97 | 0.40 |
| 02 23 | 07:12 | 287 | Nephthys | 09:18.29 | +16 14.7 | 11.4 | 126 | 36 | NGC 2819 | 12.8 | G | 163 | 115 | -0.43 |
| **03 03** | **05:32** | **410** | **Chloris** | **12:35.31** | **+14 27.0** | **12.2** | **244** | **223** | **M91** | **10.1** | **G** | **154** | **161** | **0.05** |
| 03 28 | 02:36 | 100 | Hekate | 14:00.57 | -02 51.8 | 12.5 | 57 | 210 | NGC 5400 | 12.9 | G | 156 | 121 | -0.10 |
| 03 30 | 03:18 | 487 | Venetia | 11:20.08 | +18 20.2 | 12.4 | 52 | 199 | NGC 3626 | 11.0 | G | 152 | 157 | -0.01 |
| 03 31 | 00:35 | 631 | Philippina | 11:53.76 | -19 37.1 | 12.4 | 277 | 228 | NGC 3957 | 11.8 | G | 161 | 162 | 0.00 |
| 04 01 | 06:17 | 19 | Fortuna | 07:09.41 | +20 41.8 | 11.9 | 166 | 4 | NGC 2342 | 12.6 | G | 95 | 76 | 0.03 |
| 04 03 | 08:18 | 478 | Tergeste | 13:12.79 | -19 33.2 | 12.3 | 158 | 215 | NGC 5018 | 10.8 | G | 165 | 144 | 0.15 |
| 04 25 | 13:39 | 187 | Lamberta | 20:31.60 | -30 52.8 | 12.6 | 109 | 182 | NGC 6923 | 11.9 | G | 93 | 48 | -0.16 |
| 04 29 | 05:32 | 772 | Tanete | 15:06.46 | +01 38.1 | 12.2 | 133 | 346 | NGC 5846 | 10.0 | G | 161 | 162 | 0.00 |
| 04 29 | 13:16 | 772 | Tanete | 15:06.12 | +01 36.8 | 12.2 | 74 | 165 | NGC 5845 | 12.5 | G | 161 | 163 | 0.00 |
| 04 30 | 01:41 | 772 | Tanete | 15:05.56 | +01 34.6 | 12.2 | 209 | 166 | NGC 5839 | 12.7 | G | 161 | 163 | 0.01 |
| 04 30 | 13:11 | 349 | Dembowska | 10:25.17 | +17 10.4 | 11.2 | 63 | 67 | NGC 3239 | 11.3 | G | 112 | 96 | 0.02 |
| 05 02 | 07:03 | 153 | Hilda | 12:52.98 | -10 32.3 | 13.0 | 177 | 218 | NGC 4760 | 11.4 | G | 154 | 118 | 0.10 |
| **05 06** | **21:16** | **402** | **Chloe** | **15:18.55** | **+02 01.3** | **12.4** | **226** | **193** | **M5** | **5.8** | **GC** | **160** | **95** | **0.48** |
| 05 26 | 03:05 | 380 | Fiducia | 17:21.21 | -19 37.9 | 13.0 | 173 | 176 | NGC 6342 | 9.9 | GC | 163 | 132 | -0.07 |
| 05 27 | 02:07 | 488 | Kreusa | 15:00.81 | -07 28.9 | 12.2 | 57 | 173 | NGC 5812 | 11.2 | G | 158 | 172 | -0.03 |
| 05 27 | 04:29 | 65 | Cybele | 15:21.57 | -13 06.5 | 11.1 | 95 | 194 | NGC 5915 | 12.3 | G | 165 | 174 | -0.03 |
| 06 01 | 07:47 | 39 | Laetitia | 18:54.63 | -08 47.9 | 10.3 | 127 | 11 | IC 1295 | 12.7 | PN | 144 | 169 | 0.12 |
| 06 04 | 07:55 | 39 | Laetitia | 18:53.08 | -08 44.5 | 10.2 | 154 | 187 | NGC 6712 | 8.2 | GC | 147 | 136 | 0.36 |
| 06 20 | 22:53 | 270 | Anahita | 23:11.74 | -02 08.2 | 12.2 | 122 | 332 | NGC 7506 | 12.9 | G | 101 | 27 | -0.37 |
| 06 25 | 03:14 | 393 | Lampetia | 23:25.00 | +15 13.8 | 12.0 | 160 | 147 | NGC 7653 | 12.7 | G | 95 | 72 | -0.05 |
| 06 25 | 22:03 | 198 | Ampella | 17:18.09 | -23 42.8 | 11.3 | 208 | 21 | NGC 6325 | 10.7 | GC | 166 | 175 | -0.02 |
| 06 28 | 06:03 | 259 | Aletheia | 17:01.57 | -21 48.8 | 11.7 | 76 | 344 | IC 4634 | 12.0 | PN | 160 | 150 | 0.01 |
| 07 04 | 16:00 | 4 | Vesta | 13:30.12 | -01 42.5 | 7.1 | 114 | 219 | NGC 5184 | 12.6 | G | 99 | 21 | 0.42 |
| 07 04 | 17:04 | 4 | Vesta | 13:30.16 | -01 42.9 | 7.1 | 82 | 39 | NGC 5183 | 12.7 | G | 99 | 20 | 0.42 |
| **07 20** | **07:13** | **212** | **Medea** | **20:06.11** | **-21 55.8** | **12.7** | **51** | **173** | **M75** | **8.6** | **GC** | **178** | **103** | **-0.37** |
| 07 22 | 22:06 | 80 | Sappho | 20:47.39 | +00 15.9 | 10.1 | 187 | 182 | NGC 6964 | 13.0 | G | 157 | 121 | -0.14 |
| 07 22 | 22:11 | 80 | Sappho | 20:47.39 | +00 15.9 | 10.1 | 247 | 182 | NGC 6962 | 12.1 | G | 157 | 121 | -0.14 |
| 07 24 | 11:45 | 29 | Amphitrite | 17:44.48 | -32 18.2 | 10.0 | 180 | 20 | NGC 6416 | 5.7 | OC | 144 | 164 | -0.06 |
| 07 25 | 22:33 | 433 | Eros | 17:50.41 | -30 17.0 | 12.6 | 332 | 224 | NGC 6451 | 8.2 | OC | 145 | 153 | -0.01 |
| 07 31 | 03:18 | 433 | Eros | 17:46.57 | -29 16.6 | 12.8 | 158 | 57 | Cr 347 | 8.8 | OC | 139 | 93 | 0.15 |
| 08 02 | 16:58 | 70 | Panopaea | 00:46.97 | -11 57.5 | 11.8 | 292 | 202 | NGC 246 | 8.5 | PN | 123 | 156 | 0.37 |
| **09 22** | **11:41** | **165** | **Loreley** | **18:24.37** | **-24 46.7** | **13.0** | **334** | **342** | **M28** | **6.9** | **GC** | **96** | **116** | **-0.03** |
| 09 22 | 17:50 | 148 | Gallia | 05:05.31 | -09 08.9 | 11.9 | 9 | 37 | NGC 1779 | 12.1 | G | 103 | 87 | -0.02 |
| **09 25** | **14:16** | **139** | **Juewa** | **05:35.96** | **+34 11.7** | **13.0** | **248** | **334** | **M36** | **6.0** | **OC** | **97** | **112** | **0.02** |
| 10 01 | 09:41 | 55 | Pandora | 01:41.99 | +12 41.8 | 10.9 | 348 | 358 | NGC 658 | 12.5 | G | 160 | 115 | 0.46 |
| 10 20 | 03:22 | 250 | Bettina | 01:49.10 | +13 01.8 | 11.6 | 12 | 178 | NGC 677 | 12.2 | G | 176 | 134 | -0.13 |
| 10 22 | 04:45 | 173 | Ino | 06:23.08 | +05 09.6 | 12.1 | 224 | 45 | Cr 92 | 8.5 | OC | 111 | 93 | -0.03 |
| 10 22 | 04:48 | 475 | Ocllo | 01:51.90 | +06 19.3 | 12.8 | 164 | 33 | NGC 706 | 12.5 | G | 175 | 160 | -0.03 |
| 10 23 | 23:53 | 258 | Tyche | 23:55.29 | +05 54.4 | 11.1 | 104 | 283 | NGC 7785 | 11.6 | G | 150 | 149 | 0.00 |
| 10 29 | 17:17 | 170 | Maria | 00:38.45 | +29 27.1 | 13.0 | 210 | 145 | NGC 183 | 12.7 | G | 153 | 91 | 0.35 |
| 11 15 | 14:49 | 28 | Bellona | 02:11.16 | -01 27.5 | 11.1 | 153 | 347 | NGC 850 | 12.9 | G | 154 | 122 | -0.41 |
| 11 18 | 21:11 | 144 | Vibilia | 22:59.87 | -12 45.3 | 11.6 | 344 | 325 | NGC 7444 | 12.8 | G | 105 | 148 | -0.14 |
| 11 18 | 22:52 | 144 | Vibilia | 22:59.94 | -12 44.6 | 11.6 | 246 | 325 | NGC 7443 | 12.6 | G | 105 | 147 | -0.13 |
| 11 19 | 08:01 | 148 | Gallia | 05:07.91 | -18 11.2 | 11.2 | 14 | 162 | NGC 1794 | 12.7 | G | 136 | 116 | -0.10 |
| 11 25 | 00:06 | 714 | Ulula | 06:13.72 | +12 49.4 | 12.5 | 107 | 321 | NGC 2194 | 8.5 | OC | 147 | 174 | 0.08 |

# ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2013 JUNE-SEPTEMBER

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

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Lightcurves for 22 main-belt asteroids were obtained at the Center for Solar System Studies–Palmer Divide Station (CS3-PDS) from 2013 June through September. The majority of the objects were members of the Hungaria group/family for which many of the observations were follow-up to previous apparitions to check for the possibility of undiscovered satellites or to provide additional data for spin axis and shape modeling.

CCD photometric observations of 22 asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 June through September. Table I gives a listing of the telescope/CCD camera combinations used for the observations. 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 |
|---|---|---|
| PDS-1-12N | 0.30-m f/6.3 Schmidt-Cass | ST-9XE |
| PDS-1-14S | 0.35-m f/9.1 Schmidt-Cass | FLI-1001E |
| PDS-2-14N | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-2-14S | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-20 | 0.50-m f/8.1 Ritchey-Chretien | FLI-1001E |

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

All lightcurve observations were made with no filter (a clear filter can result in a 0.1-0.3 magnitude loss). The exposures were guided. The duration varied depending on the asteroid's brightness and sky motion. In most cases, however, it was 240 seconds.

Measurements were done using *MPO Canopus* and its Comp Star Selector utility that finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes were usually taken from the MPOSC3 catalog, which is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007b). When possible, magnitudes are taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ±0.05 magnitude or better, but on occasion are as large as 0.1 mag. This reasonably good consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis was also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.*, 1989).

In the plots below, the "Reduced Magnitude" is Johnson V (or Cousins R) as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009c). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with bibcodes, is also available for download at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

1799 Koussevitzky. This Eos member was observed by Ivarsen *et al.* (2004), who reported a period of 6.325 h. The PDS period from 2013 observations of $P = 6.318$ h is in good agreement.

2495 Noviomagum. This appears to be the first reported period for this Hungaria member.

2911 Miahelena. Previous results for this outer main-belt asteroid include Brinsfield (2008, 4.19 h) and Klinglesmith *et al.* (2013, 4.202 h). The PDS observations were about a month later than those by Klinglesmith *et al.* and showed a slightly larger amplitude. This was to be expected since the phase angle had increased from about 10 to 18 degrees over that period.

3225 Hoag. The 2013 apparition was the fourth one at which the author had observed this Hungaria member. The results were consistent with those reported in previous years (Warner 2007, 2009b, and 2010).

4952 Kibeshigemaro. This is an outer main-belt member with an estimated diameter of 25 km (Masiero *et al.* 2012). No previously reported periods were found.

6249 Jennifer. Warner *et al.* (2006a) reported a period of 4.9535 h from observations in 2005. Other results include Behrend (2005, 4.9557 h) and Warner (2010, 4.961 h). The results from the 2013 PDS observations were $P = 4.956$ h. The data from the 2005 observations were reviewed to try to find a less ambiguous solution. This lead to a revised period with greater confidence of $P = 4.9566$ h.

6401 Roentgen. Behrend (2013) reported a period of 15.98 h for this Eunomia member. The PDS results are in good agreement.

6602 Gilclark. This was the third apparition that the author observed this Hungaria member. Previous results were 4.574 h (Warner, 2009a) and 4.573 h (Warner, 2012b).

(6618) 1936 SO. The results from the 2013 observations of $P = 4.139$ h for this Hungaria member were both secure and contradicted previous findings by the author that indicated a period of 8.3 h (Warner, 2009a; 2012b). This prompted a review of the data from those previous efforts with the result of adopting the shorter period of about 4.14 h as being more likely correct. Plots showing the 2008 and 2012 data forced to near 4.14 h are included below.

| Number | Name | 2013 (mm/dd) | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1799 | Koussevitzky | 06/21-06/24 | 161 | 15.5 14.7 | 308 | +8 | 6.318 | 0.005 | 0.40 | 0.02 |
| ***2495*** | ***Noviamagum*** | ***07/04-07/07*** | ***211*** | ***32.1 31.6*** | ***325*** | ***+28*** | ***6.645*** | ***0.003*** | ***1.06*** | ***0.03*** |
| 2911 | Miahelena | 06/24-06/26 | 126 | 17.5 18.0 | 234 | +12 | 4.201 | 0.005 | 0.66 | 0.02 |
| ***3225*** | ***Hoag*** | ***08/18-08/21*** | ***200*** | ***25.0 23.7*** | ***358*** | ***+15*** | ***2.3737*** | ***0.0004*** | ***0.14*** | ***0.01*** |
| 4952 | Kibeshigemaro | 06/24-06/29 | 239 | 15.1 16.1 | 237 | +17 | 9.166 | 0.002 | 0.47 | 0.02 |
| ***6249*** | ***Jennifer*** | ***08/20-08/24*** | ***253*** | ***34.7 34.0*** | ***11*** | ***+30*** | ***4.956*** | ***0.003*** | ***0.13*** | ***0.02*** |
| | ***""*** | ***07/12-09/18 2005*** | ***407*** | ***35.4 25.9*** | ***353*** | ***+33*** | ***4.9566*** | ***0.0002*** | ***0.10*** | ***0.01*** |
| ***6401*** | ***Roentgen*** | ***06/15-06/23*** | ***257*** | ***14.5 16.8*** | ***241*** | ***+16*** | ***15.96*** | ***0.01*** | ***0.67*** | ***0.02*** |
| ***6602*** | ***Gilclark*** | ***09/18-09/23*** | ***609*** | ***14.6 13.3*** | ***9*** | ***+15*** | ***4.5686*** | ***0.0005*** | ***0.26*** | ***0.02*** |
| ***6618*** | ***1936 SO*** | ***08/18-08/22*** | ***198*** | ***23.2 21.7*** | ***0*** | ***+9*** | ***4.139*** | ***0.005*** | ***0.20*** | ***0.02*** |
| | ***""*** | ***09/16-09/18 2008*** | ***150*** | ***27.0 26.5*** | ***30*** | ***+24*** | ***4.142*** | ***0.003*** | ***0.19*** | ***0.02*** |
| | ***""*** | ***02/16-02/24 2012*** | ***150*** | ***3.9 3.7*** | ***150*** | ***+3*** | ***4.141*** | ***0.005*** | ***0.16*** | ***0.02*** |
| ***6635*** | ***Zuber*** | ***09/25-09/28*** | ***345*** | ***5.1 3.0*** | ***8*** | ***+2*** | ***5.5355*** | ***0.0004*** | ***0.75*** | ***0.02*** |
| ***6911*** | ***Nancygreen*** | ***06/27-07/05*** | ***259*** | ***23.6 22.8*** | ***294*** | ***+33*** | ***59.1*** | ***0.5*** | ***0.35*** | ***0.05*** |
| ***7959*** | ***Alysecherri*** | ***06/30-07/06*** | ***175*** | ***29.5 28.5*** | ***318*** | ***+26*** | ***3.161*** | ***0.005*** | ***0.13*** | ***0.02*** |
| ***15692*** | ***1984 RA*** | ***07/08-08/01*** | ***273*** | ***17.4 23.1*** | ***271*** | ***+22*** | ***37.44*** | ***0.05*** | ***0.66*** | ***0.03*** |
| ***16421*** | ***Roadrunner*** | ***08/02-08/14*** | ***729*** | ***8.9 4.9*** | ***322*** | ***+6*** | ***174.*** | ***3.*** | ***1.00*** | ***0.05*** |
| ***20231*** | ***1997 YK*** | ***07/06-07/29*** | ***413*** | ***32.7 29.2*** | ***338*** | ***+21*** | ***178.*** | ***3.*** | ***0.70*** | ***0.05*** |
| ***30958*** | ***1994 TV3*** | ***08/02-08/04*** | ***179*** | ***21.7 21.5*** | ***315*** | ***+30*** | ***5.811*** | ***0.005*** | ***0.85*** | ***0.03*** |
| ***41503*** | ***2000 QG148*** | ***07/08-08/01*** | ***430*** | ***27.4 31.2*** | ***277*** | ***+35*** | ***42.81*** | ***0.05*** | ***1.00*** | ***0.05*** |
| ***45898*** | ***2000 XQ49*** | ***08/15-08/17*** | ***193*** | ***16.2 15.2*** | ***349*** | ***+2*** | ***5.416*** | ***0.002*** | ***1.01*** | ***0.02*** |
| ***48336*** | ***2002 PS6*** | ***08/02-08/04*** | ***253*** | ***18.3 18.2*** | ***316*** | ***+23*** | ***7.031*** | ***0.002*** | ***1.18*** | ***0.02*** |
| 51926 | 2001 QE98 | 09/06-09/12 | 202 | 11.3 9.4 | 12 | +6 | 5.610 | 0.005 | 0.19 | 0.02 |
| 56777 | 2000 OC39 | 06/24-07/01 | 122 | 19.3 21.5 | 240 | +17 | 6.692 | 0.005 | 0.28 | 0.03 |
| *216910* | *Vnukov* | *06/15-06/18* | *47* | *17.1 18.1* | *242* | *+16* | *9.0* | *1.0* | *0.80* | *0.05* |

Table II. Observing circumstances. Rows in bold italics text indicate members of the Hungaria group/family. The phase angle ($\alpha$) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. $L_{PAB}$ and $B_{PAB}$ are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

6635 Zuber. Analysis of the 2013 data found $P$ = 5.5355 h. This is in very good agreement with the results from two previous apparitions (Warner 2010, 2012b).

6911 Nancygreen. This Hungaria member has been a difficult one when it comes to finding a period. Previous results from the author include Warner (2006b, 5.3 h; 2009a, 4.33 h; and 2010, 17.14 h). The 2013 observations provided yet a fourth option: $P$ = 59.1 h, $A$ = 0.35 mag along with the possibility that that object is tumbling, i.e., in non-principal axis rotation. The data from 2013 could not be fit to the earlier results. On the other hand, the data from 2010, assuming some large zero point shifts, can be made to fit a monomodal solution of 59.8 h, $A$ = 0.22 mag, also with some indications of tumbling. However, this is a marginal data set with very short sessions and somewhat large scatter within each data run.

7959 Alysecherri. This appears to be the first reported period for this Hungaria member.

(15692) 1984 RA. The results of analysis for this Hungaria member indicate a period of 37.44 h. As noted by Warner *et al.* (2009e), such a long period is not uncommon among the Hungarias, where about 30% of those with well-determined lightcurves have periods of $P > 24$ h.

(16421) Roadrunner. This is another long period Hungaria. Observations in 2012 (Warner, 2012b) lead to a result only 1 hour shorter than found in 2013. Because of the long period and small diameter, $D \sim 3.4$ km, signs of tumbling are expected. However, none were found at either apparition. See Pravec *et al.* (2005) for a discussion regarding tumbling asteroids and tumbling damping time.

(20231) 1997 YK. Previous observations of this Hungaria (Warner, 2006c; Warner *et al.,* 2009f) were not successful at finding a definitive period or determining if the asteroid is tumbling or not. The 2006 result (data from late 2005) was 48.2 h. However, the data from 2013 cannot possibly fit that period. The 2005 data, however, can be somewhat fit to a period near 178 h and show some very strong indications of tumbling. That data set is too sparse to allow even a reasonably secure result.

(30958) 1994 TV3. The WISE survey (Mainzer *et al.,* 2011) reported an unusually large albedo of $p_V$ = 0.8269 for this Hungaria member. As discussed in Warner (2012a), this was likely due to using a value for $H$ that was too bright due to assuming $G$ = 0.15 for high phase angle observations. The data set from 2013 covered too small a range to establish a new value for $G$. However, when using a default value for type E (high albedo) objects of $G$ = 0.43 (see Warner *et al.,* 2009c), a new value of $H$ = 15.4 ± 0.2 was found. Using the approach outlined in Warner (2012a) to use this new value for $H$ with the WISE results, this lead to $p_V = 0.3797 \pm 0.1055$ and a new diameter of 1.79 km (instead of 1.93 km found by WISE). The new value for $p_V$ is within one-sigma of the average albedo for type E objects found by Warner *et al.* (2009b) using LCDB data.

(41503) 2000 QG148. This turned out to be another long period Hungaria asteroid. Using the rule of thumb for tumbling damping times (Pravec *et al.,* 2005), the odds favor the asteroid to be tumbling. However, there were no signs of this, at least within the observational and calibration errors.

(45898) 2000 XQ49. The 2013 observations were follow-up to those made at two previous apparitions (Warner, 2009c; 2012b). The results from all three years are in good agreement.

(48336) 2002 PS6. The 2013 results appear to be the first to be reported in the literature.

(51926) 2001 QE98. The lightcurve for this outer main-belt asteroid is a bit more complex than usual, having what appears to be three maximums/minimums per rotation. Attempts were made to find a bimodal solution, but the results were rejected.

(56777) 2000 OC39. This outer main-belt asteroid, like the other non-Hungaria objects in this work, was a *target of opportunity* (TOO) in that it happened to be in the same field as a planned target for one or more nights. Many times, the TOO is followed after it's out of the field of the original target for as long as needed to determine a reliable period. This helps avoid observational biases by "tossing back" the difficult and incomplete lightcurves.

216910 Vnukov. Because of numerous other targets on the observing list, this Eunomia member, another target of opportunity, could be observed for only two nights. The individual nights seem to indicate a high amplitude lightcurve with a period of $P < 12$ h. The solution presented in the table and plot should not be considered very reliable let alone definitive.

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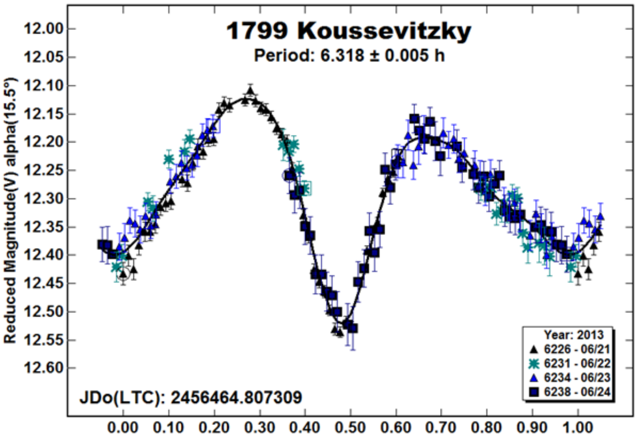
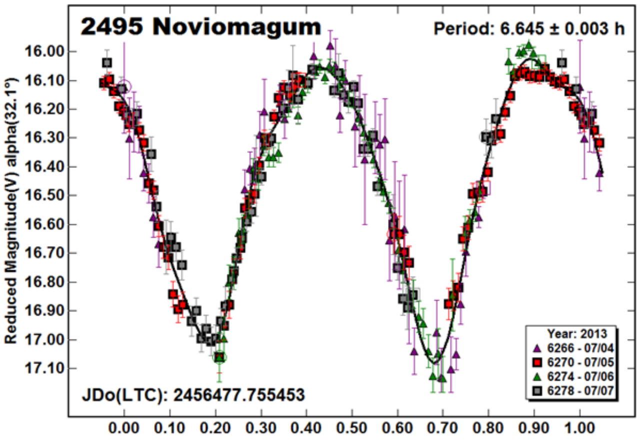
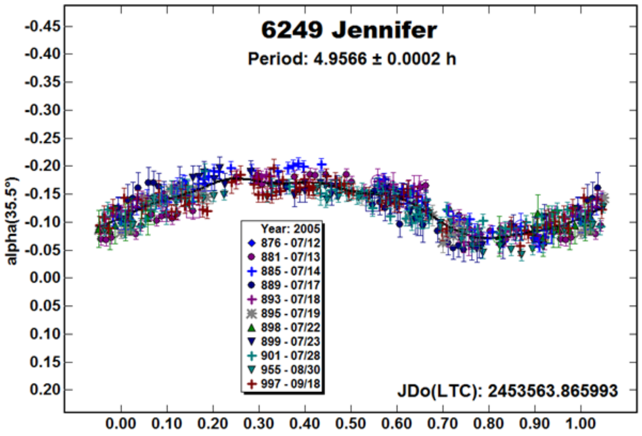



2495 Noviomagum
Period: 6.645 ± 0.003 h
Reduced Magnitude(V) alpha(32.1°)
16.00
16.10
16.20
16.30
16.40
16.50
16.60
16.70
16.80
16.90
17.00
17.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456477.755453
Year: 2013
6266 - 07/04
6270 - 07/05
6274 - 07/06
6278 - 07/07


6249 Jennifer
Period: 4.9566 ± 0.0002 h
alpha(35.5°)
-0.45
-0.40
-0.35
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2453563.865993
Year: 2005
876 - 07/12
881 - 07/13
885 - 07/14
889 - 07/17
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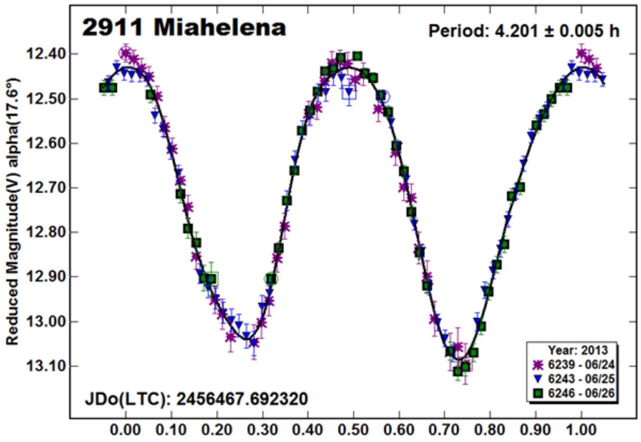
895 - 07/19
898 - 07/22
899 - 07/23
901 - 07/28
955 - 08/30
997 - 09/18


2911 Miahelena
Period: 4.201 ± 0.005 h
Reduced Magnitude(V) alpha(17.6°)
12.40
12.50
12.60
12.70
12.80
12.90
13.00
13.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
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Year: 2013
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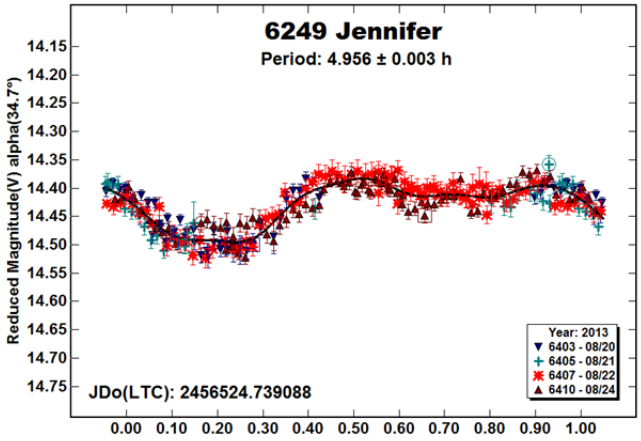
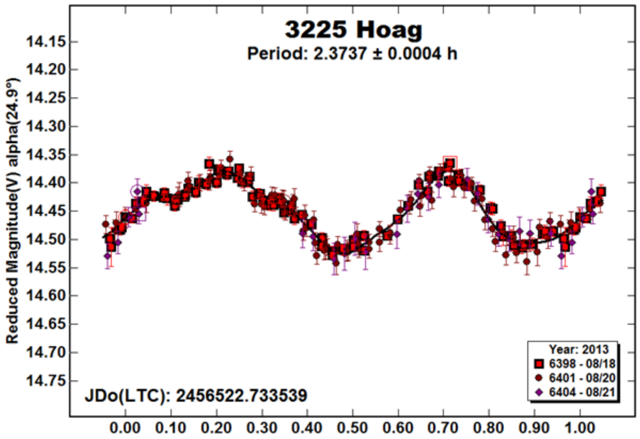
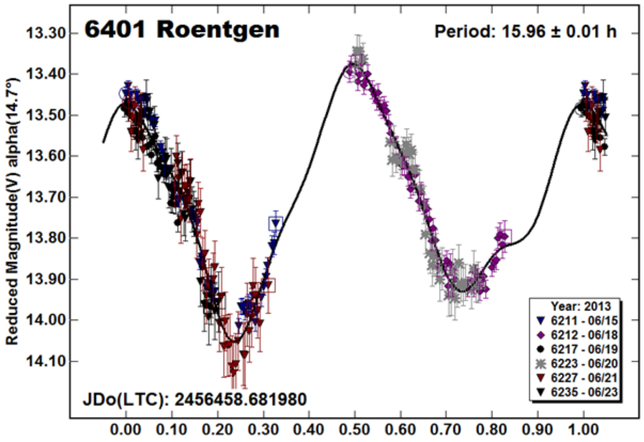
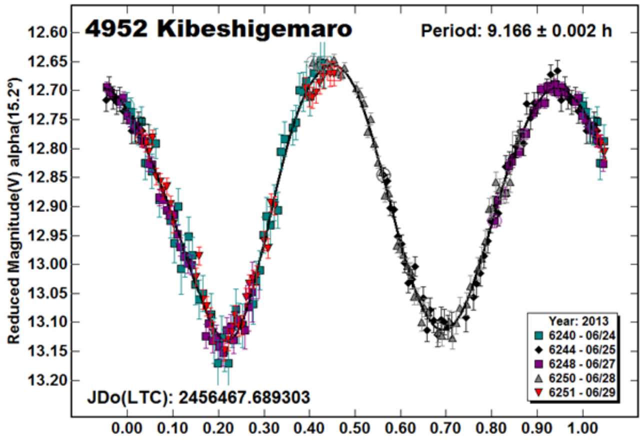
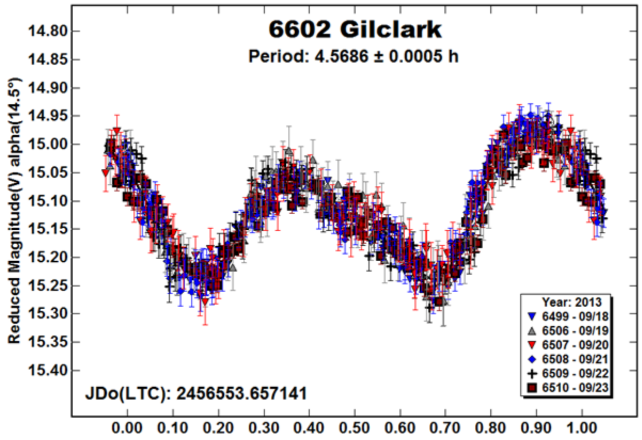
6246 - 06/26

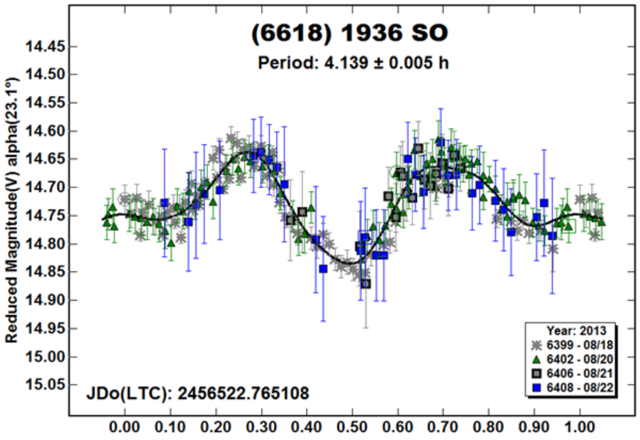

6249 Jennifer
Period: 4.956 ± 0.003 h
Reduced Magnitude(V) alpha(34.7°)
14.15
14.20
14.25
14.30
14.35
14.40
14.45
14.50
14.55
14.60
14.65
14.70
14.75
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456524.739088
Year: 2013
6403 - 08/20
6405 - 08/21
6407 - 08/22
6410 - 08/24

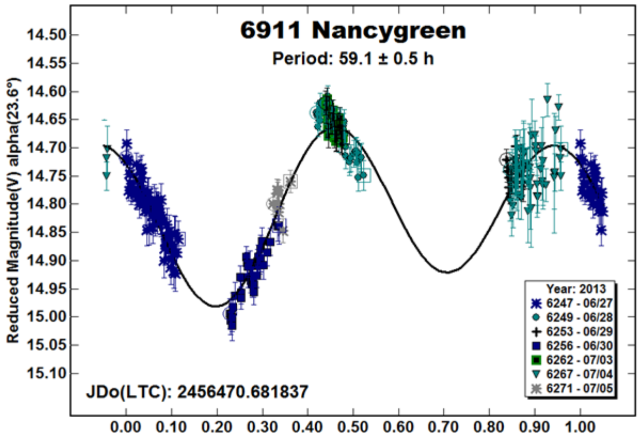

3225 Hoag
Period: 2.3737 ± 0.0004 h
Reduced Magnitude(V) alpha(24.9°)
14.15
14.20
14.25
14.30
14.35
14.40
14.45
14.50
14.55
14.60
14.65
14.70
14.75
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456522.733539
Year: 2013
6398 - 08/18
6401 - 08/20
6404 - 08/21

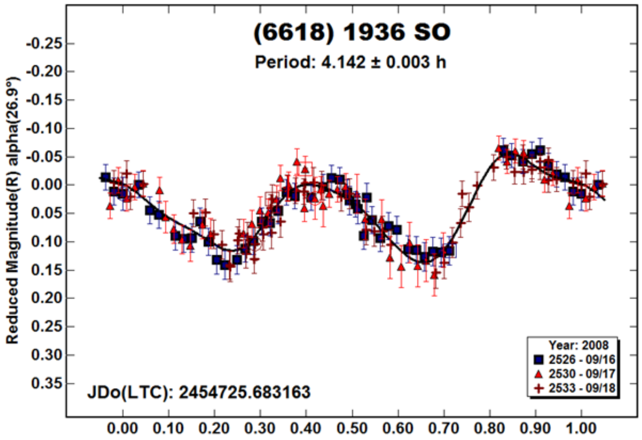

6401 Roentgen
Period: 15.96 ± 0.01 h
Reduced Magnitude(V) alpha(14.7°)
13.30
13.40
13.50
13.60
13.70
13.80
13.90
14.00
14.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456458.681980
Year: 2013
6211 - 06/15
6212 - 06/18
6217 - 06/19
6223 - 06/20
6227 - 06/21
6235 - 06/23

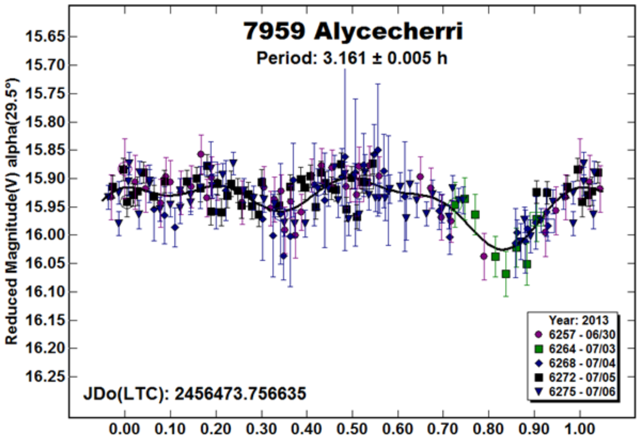

4952 Kibeshigemaro
Period: 9.166 ± 0.002 h
Reduced Magnitude(V) alpha(15.2°)
12.60
12.65
12.70
12.75
12.80
12.85
12.90
12.95
13.00
13.05
13.10
13.15
13.20
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456467.689303
Year: 2013
6240 - 06/24
6244 - 06/25
6248 - 06/27
6250 - 06/28
6251 - 06/29

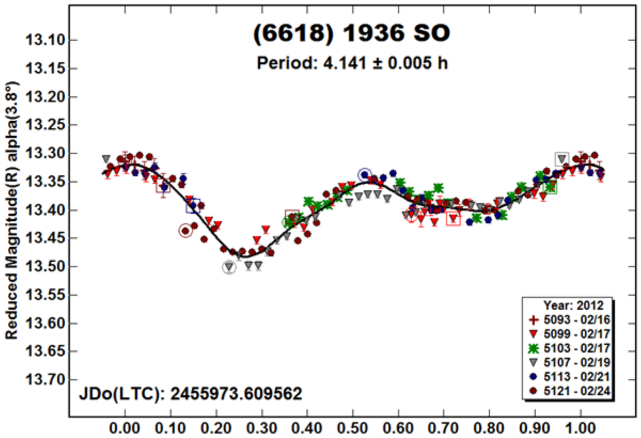

6602 Gilclark
Period: 4.5686 ± 0.0005 h
Reduced Magnitude(V) alpha(14.5°)
14.80
14.85
14.90
14.95
15.00
15.05
15.10
15.15
15.20
15.25
15.30
15.35
15.40
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
JDo(LTC): 2456553.657141
Year: 2013
6499 - 09/18
6506 - 09/19
6507 - 09/20
6508 - 09/21
6509 - 09/22
6510 - 09/23

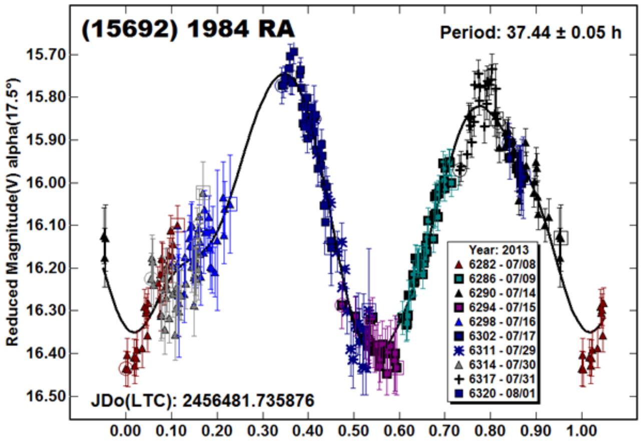

(6618) 1936 SO
Period: 4.139 ± 0.005 h
Reduced Magnitude(V) alpha(23.1°)
14.45
14.50
14.55
14.60
14.65
14.70
14.75
14.80
14.85
14.90
14.95
15.00
15.05
Year: 2013
6399 - 08/18
6402 - 08/20
6406 - 08/21
6408 - 08/22
JDo(LTC): 2456522.765108
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

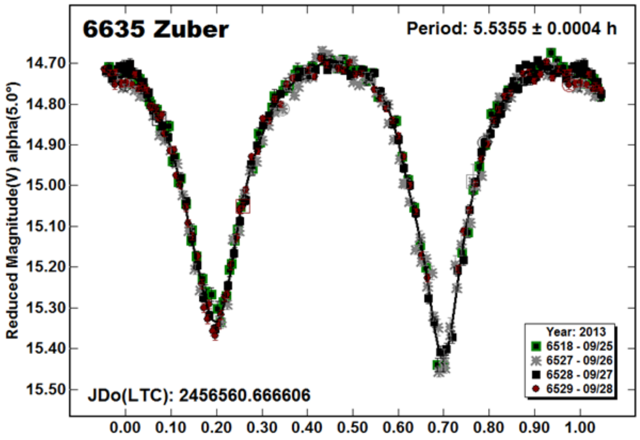

6911 Nancygreen
Period: 59.1 ± 0.5 h
Reduced Magnitude(V) alpha(23.6°)
14.50
14.55
14.60
14.65
14.70
14.75
14.80
14.85
14.90
14.95
15.00
15.05
15.10
Year: 2013
6247 - 06/27
6249 - 06/28
6253 - 06/29
6256 - 06/30
6262 - 07/03
6267 - 07/04
6271 - 07/05
JDo(LTC): 2456470.681837
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

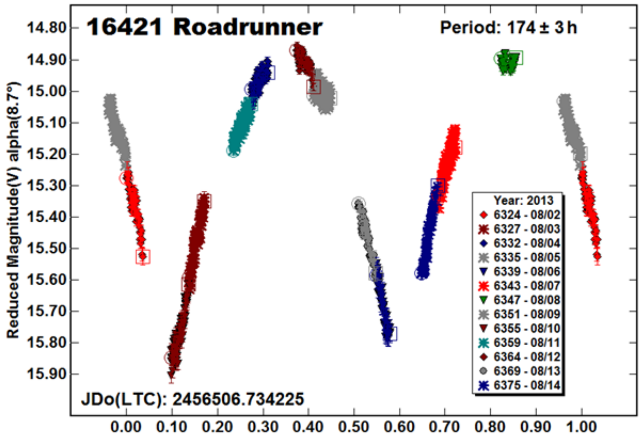

(6618) 1936 SO
Period: 4.142 ± 0.003 h
Reduced Magnitude(R) alpha(26.9°)
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Year: 2008
2526 - 09/16
2530 - 09/17
2533 - 09/18
JDo(LTC): 2454725.683163
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

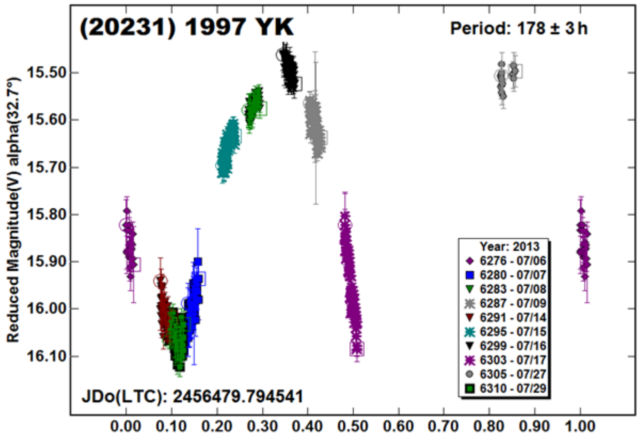

7959 Alycecherri
Period: 3.161 ± 0.005 h
Reduced Magnitude(V) alpha(29.5°)
15.65
15.70
15.75
15.80
15.85
15.90
15.95
16.00
16.05
16.10
16.15
16.20
16.25
Year: 2013
6257 - 06/30
6264 - 07/03
6268 - 07/04
6272 - 07/05
6275 - 07/06
JDo(LTC): 2456473.756635
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

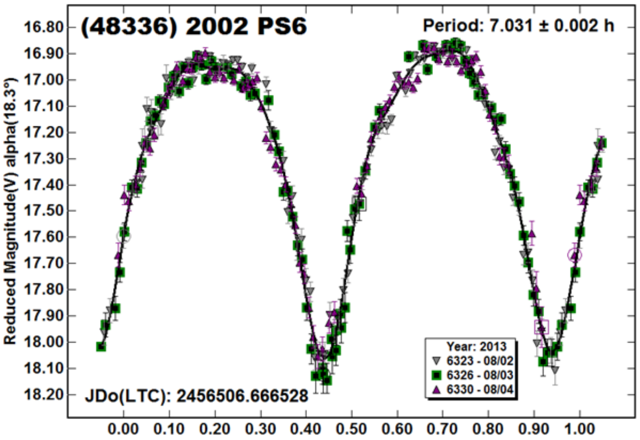

(6618) 1936 SO
Period: 4.141 ± 0.005 h
Reduced Magnitude(R) alpha(3.8°)
13.10
13.15
13.20
13.25
13.30
13.35
13.40
13.45
13.50
13.55
13.60
13.65
13.70
Year: 2012
5093 - 02/16
5099 - 02/17
5103 - 02/17
5107 - 02/19
5113 - 02/21
5121 - 02/24
JDo(LTC): 2455973.609562
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

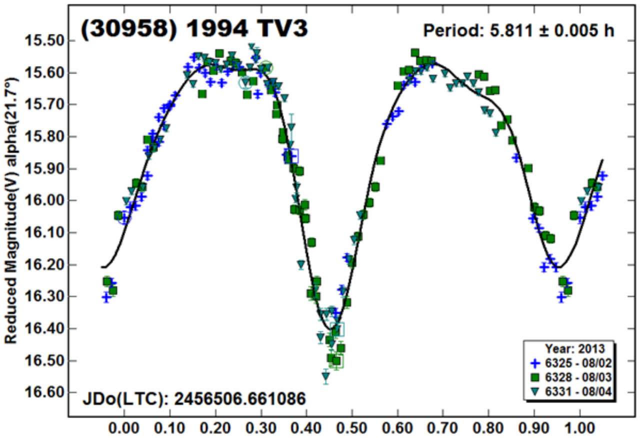

(15692) 1984 RA
Period: 37.44 ± 0.05 h
Reduced Magnitude(V) alpha(17.5°)
15.70
15.80
15.90
16.00
16.10
16.20
16.30
16.40
16.50
Year: 2013
6282 - 07/08
6286 - 07/09
6290 - 07/14
6294 - 07/15
6298 - 07/16
6302 - 07/17
6311 - 07/29
6314 - 07/30
6317 - 07/31
6320 - 08/01
JDo(LTC): 2456481.735876
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

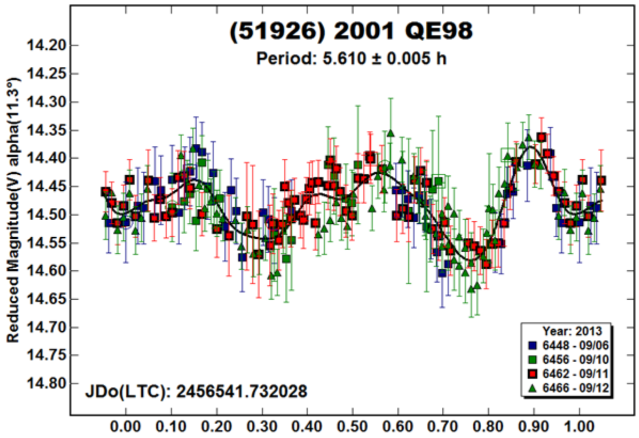

6635 Zuber
Period: 5.5355 ± 0.0004 h
Reduced Magnitude(V) alpha(5.0°)
14.70
14.80
14.90
15.00
15.10
15.20
15.30
15.40
15.50
Year: 2013
6518 - 09/25
6527 - 09/26
6528 - 09/27
6529 - 09/28
JDo(LTC): 2456560.666606
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

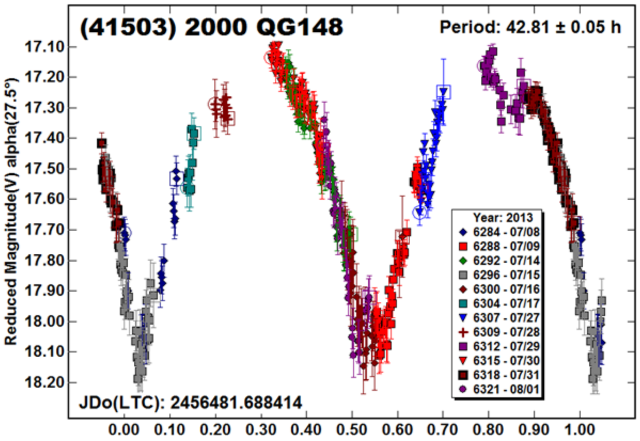

16421 Roadrunner
Period: 174 ± 3 h
Reduced Magnitude(V) alpha(8.7°)
14.80
14.90
15.00
15.10
15.20
15.30
15.40
15.50
15.60
15.70
15.80
15.90
Year: 2013
6324 - 08/02
6327 - 08/03
6332 - 08/04
6335 - 08/05
6339 - 08/06
6343 - 08/07
6347 - 08/08
6351 - 08/09
6355 - 08/10
6359 - 08/11
6364 - 08/12
6369 - 08/13
6375 - 08/14
JDo(LTC): 2456506.734225
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

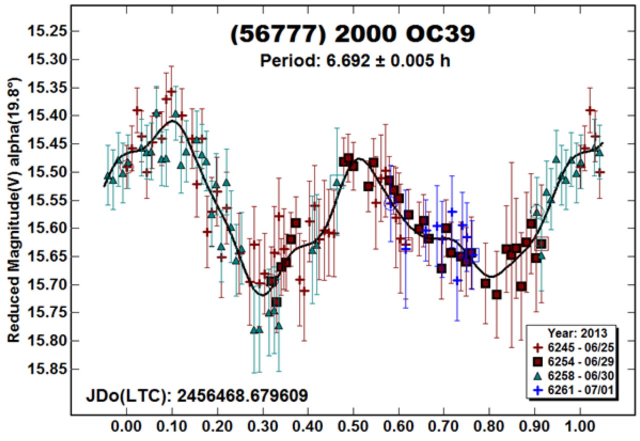

(20231) 1997 YK
Period: 178 ± 3 h
Reduced Magnitude(V) alpha(32.7°)
Year: 2013
6276 - 07/06
6280 - 07/07
6283 - 07/08
6287 - 07/09
6291 - 07/14
6295 - 07/15
6299 - 07/16
6303 - 07/17
6305 - 07/27
6310 - 07/29
JDo(LTC): 2456479.794541

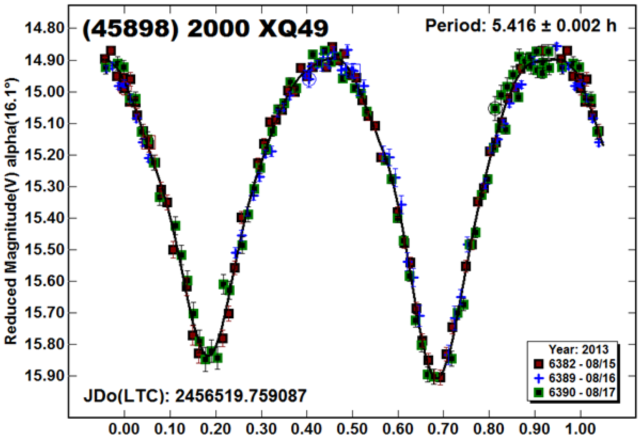

(48336) 2002 PS6
Period: 7.031 ± 0.002 h
Reduced Magnitude(V) alpha(18.3°)
Year: 2013
6323 - 08/02
6326 - 08/03
6330 - 08/04
JDo(LTC): 2456506.666528

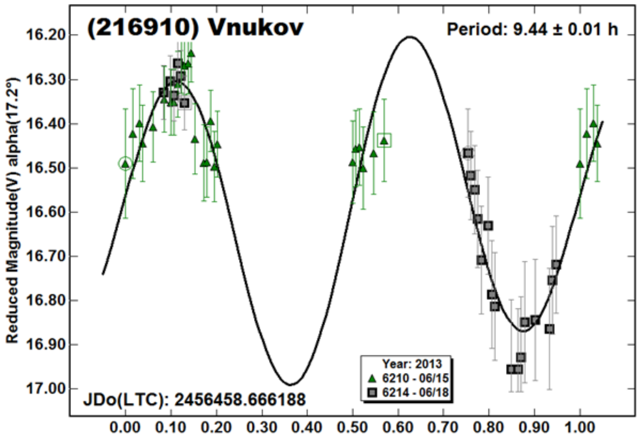

(30958) 1994 TV3
Period: 5.811 ± 0.005 h
Reduced Magnitude(V) alpha(21.7°)
Year: 2013
6325 - 08/02
6328 - 08/03
6331 - 08/04
JDo(LTC): 2456506.661086


(51926) 2001 QE98
Period: 5.610 ± 0.005 h
Reduced Magnitude(V) alpha(11.3°)
Year: 2013
6448 - 09/06
6456 - 09/10
6462 - 09/11
6466 - 09/12
JDo(LTC): 2456541.732028


(41503) 2000 QG148
Period: 42.81 ± 0.05 h
Reduced Magnitude(V) alpha(27.5°)
Year: 2013
6284 - 07/08
6288 - 07/09
6292 - 07/14
6296 - 07/15
6300 - 07/16
6304 - 07/17
6307 - 07/27
6309 - 07/28
6312 - 07/29
6315 - 07/30
6318 - 07/31
6321 - 08/01
JDo(LTC): 2456481.688414


(56777) 2000 OC39
Period: 6.692 ± 0.005 h
Reduced Magnitude(V) alpha(19.8°)
Year: 2013
6245 - 06/25
6254 - 06/29
6258 - 06/30
6261 - 07/01
JDo(LTC): 2456468.679609


(45898) 2000 XQ49
Period: 5.416 ± 0.002 h
Reduced Magnitude(V) alpha(16.1°)
Year: 2013
6382 - 08/15
6389 - 08/16
6390 - 08/17
JDo(LTC): 2456519.759087


(216910) Vnukov
Period: 9.44 ± 0.01 h
Reduced Magnitude(V) alpha(17.2°)
Year: 2013
6210 - 06/15
6214 - 06/18
JDo(LTC): 2456458.666188

# THE ROTATION PERIOD OF 1137 RAISSA

Andrea Ferrero
Bigmuskie Observatory
via Italo Aresca 12
14047 Mombercelli, Asti, ITALY
bigmuskie@alice.it

Daniel A. Klinglesmith III
New Mexico Institute of Mining and Technology
Etscorn Campus Observatory
Socorro, NM 87801 USA

Frederick Pilcher
Organ Mesa Observatory
Las Cruces, NM 88011 USA

(Received: 10 October)

Analysis of observations of the main-belt asteroid 1137 Raissa over the last four months of 2012 lead to a rotation period of 142.79 ± 0.1 h and an amplitude of 0.56 mag.

In 2012 September, Bigmuskie Observatory started to observe the main-belt asteroid 1137 Raissa. The 23.7 km asteroid was reported to have a period of about 37 h (Binzel, 1987). The asteroid lightcurve database (LCDB; Warner *et al.*, 2009) rated this solution as U = 1, which means it could be completely wrong. Initial observations made it evident that this was a long period rotator. Further observations lead to a preliminary period close to six Earth days (144 h). In this case, it is very difficult for only one observer to cover the entire curve. A request for help was sent to Frederick Pilcher of Organ Mesa Observatory and to Dan Klinglesmith of Etscorn Campus Observatory, both in New Mexico, USA, and well-spaced in longitude from Bigmuskie Observatory, Italy, so that they could cover missing parts of the curve.

Ferrero used a 0.30-meter *f*/8 Ritchey-Chrétien coupled to an SBIG ST-9 CCD camera with a photometric Astrodon R filter. Exposures were 240 sec and unguided. Pilcher worked with a Meade 0.35-m LX200 GPS and an SBIG STL-1001E CCD camera. Exposures used a clear filter and were 60 sec. Klinglesmith worked with a Celestron 0.35-m and SBIG ST-10 CCD camera. The 180 sec exposure used a clear filter. The Comparison Star Selector (CSS) utility in *MPO Canopus* was used by all observers to perform the photometric reductions.

Sessions 5 to 26 and 33 were measured by Ferrero. Pilcher worked sessions 27-28-30, and Klinglesmith worked sessions 29-35. The CSS utility produced good preliminary linkages between all the sessions despite the different instruments and observing conditions. Fine adjustments to the zero point for each session made by Pilcher produced a clear bimodal curve without evidence of tumbling and the definitive period of 142.79 ± 0.01 h with an amplitude of 0.59 mag.

## References

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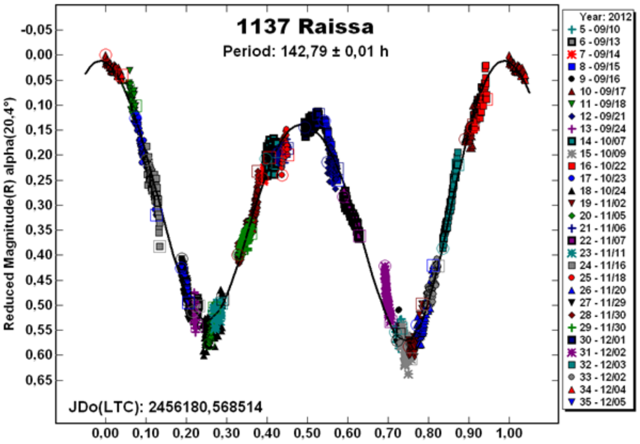

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# LIGHTCURVE ANALYSIS OF NEAR-EARTH ASTEROID 2010 TN54

Brian D. Warner
Center for Solar System Studies – Palmer Divide Station
446 Sycamore Ave, Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA

Andrea Ferrero
Bigmuskie Observatory (B88)
Via Italo Aresca 12, 14047 Mombercelli-Asti ITALY

(Received: 11 October)

CCD photometry observations of the near-Earth asteroid (NEA) 2010 TN 54 indicates a period of either 6.14 h or 12.12 h, depending on whether a monomodal or bimodal lightcurve is adopted. The amplitude was only 0.07 ± 0.01 mag, which – along with the period being nearly commensurate with an Earth day – made finding a definitive solution difficult, despite being observed from locations in North America and Europe.

CCD photometric observations of the near-Earth asteroid were made by the authors from 2013 August 12-31. Table I lists the observers and equipment used while Table II lists the dates of observation and the observer.

| OBS | Telescope | | Camera |
|---|---|---|---|
| Warner | 0.35-m f/9.1 | Schmidt-Cass | STL-1001E |
| Benishek | 0.35-m f/10 | Schmidt-Cass | ST-8XME |
| Ferrero | 0.30-m f/8 | Ritchey-Chretien | ST-9 |

Table I. List of observers and equipment.

| Obs | Dates (2013 August) | Sessions |
|---|---|---|
| Warner | 08-12, 16-18 | 1 2 3 4 7 10 11 |
| Benishek | 15-17, 31 | 6 8 9 12 |
| Ferrero | 15 | 5 |

Table II. Dates of observation for each observer. The Sessions column gives the session numbers shown in the lightcurve legend.

The phase angle throughout the range of observations was 21 ± 1°. The phase angle bisector longitude/latitude (see the appendix in

Harris *et al.,* 1984) ranged from 327°/11.6° (Aug 12) to 342°/13.8° (Aug 31) while the asteroid remained near V = 17.

Initial measurements by all three authors were made using *MPO Canopus* (Bdw Publishing) using the Comp Star Selector utility in that program to select up to five comparison stars of near solar color. The MPOSC3 catalog provided with *MPO Canopus* was used to provide the comparison star magnitudes. The magnitudes in the catalog are based on the 2MASS catalog converted to the BVRcIc system using formulae developed by Warner (2007). Ferrero and Benishek sent their data files to Warner, who then merged those data with his to create the combined data set for period analysis. This was also done in MPO Canopus, which implements the Fourier analysis FALC algorithm developed by Harris (Harris *et al.,* 1989).

In the plots presented below for the presumed primary of the binary system, the "Reduced Magnitude" is Johnson V corrected to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. In addition, the magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using *G* = 0.15.

The initial observations by Warner indicated a period nearly commensurate with an Earth day, meaning that observations from one night to the next covered the same part of the lightcurve. Analysis was further complicated by the very low amplitude, only 0.07 mag. The night-to-night zero point calibrations of ±0.05 mag indicated no long term period, apparently confirming that the period analysis was not just locking onto noise in the data.

In such cases, observations at different locations in longitude can often resolve the ambiguities of a nearly-commensurate period. It's better if the difference in longitude between two observers doesn't nearly match the period of the lightcurve or is also Earth-day commensurate. For example, if two observers are almost exactly 6 hours apart (90°) and the period is also about 6 hours, the western observer sees almost the exactly same part of the lightcurve but on the following rotation. Warner contacted Ferrero and Benishek, both of whom had collaborated before in similar situations and the collaboration was begun.

The combined data set included 862 observations used in the period analysis. The period spectrum favors a period of 12.12 ± 0.01 h, which produces a bimodal lightcurve. The half-period of 6.14 ± 0.01 h cannot be formally excluded and results in a monomodal lightcurve. The latter might be expected if the viewing aspect during the apparition was nearly pole-on or, in either case, if the asteroid was nearly spheroidal, i.e., with very little elongation. Observations at a future apparition may be able to resolve the ambiguity.

## Acknowledgements

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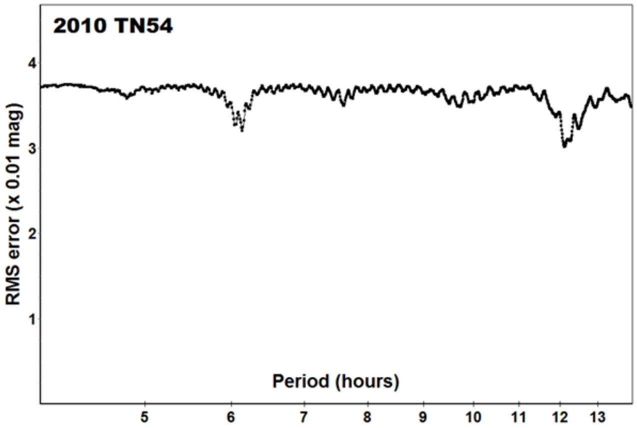

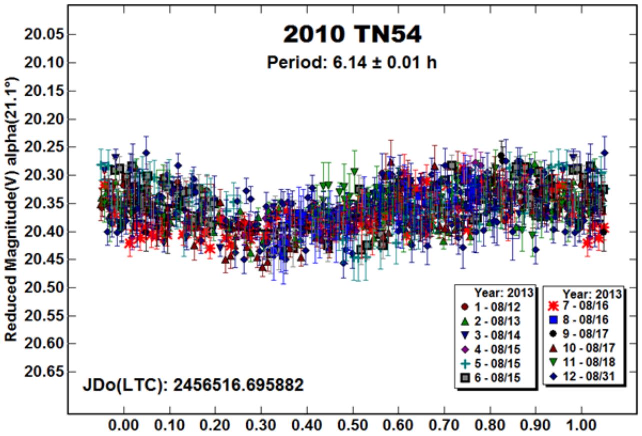

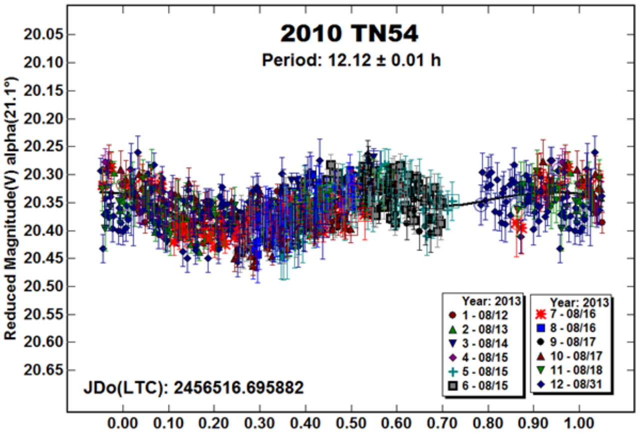

# ROTATION PERIOD AND H-G PARAMETERS OF 682 HAGAR

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, New Mexico 88011 USA
fpilcher35@gmail.com

Lorenzo Franco
Balzaretto Observatory (A81)
Rome, ITALY

(Received: 7 October)

Analysis of photometric observations for 682 Hagar reveal a synodic rotation period of $P$ = 4.8503 ± 0.0001 h and amplitude $A$ = 0.52 ± 0.03 mag. The absolute magnitude and the phase slope parameter were found to be $H$ = 12.27 ± 0.07, $G$ = 0.05 ± 0.05. The V-R color index is 0.40 ± 0.04. Both the color index and $G$ value are compatible with a low albedo asteroid. The diameter is estimated to be $D$ = 19 ± 4 km when using an albedo of $p_V$ = 0.06 ± 0.02.

Observations of 682 Hagar were made by Pilcher at the Organ Mesa Observatory with a 0.35-m Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001-E CCD. Exposures were 60 seconds, unguided, and unfiltered. The observations by Franco were with a 0.20-m Meade LX200 SCT and SBIG ST-7XME CCD camera. Exposures were 300 seconds when using a clear filter. Exposures in the V and R bands were 600 seconds. Photometric measurement, data sharing, and lightcurve construction were done using *MPO Canopus* software (Warner, 2013). To reduce the number of points on the lightcurve and make it easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes between consecutive points within a given bin.

For each session the comparison stars were selected with near-solar color indexes and were calibrated using the method described by Dymock and Miles (2009) and CMC-14 catalogue by using Vizier Service (2013). Photometric data from nine nights from 2013 July 17 to October 2 provided a good fit to a bimodal lightcurve with a period $P$ = 4.8503 ± 0.0001 h and amplitude $A$ = 0.52 ± 0.03 mag (Figure 1). Warner *et al.* (2013) report no previous observations of the asteroid.

The asteroid was observed in V and R band at Balzaretto Observatory on August 16. This allowed us to find a color index V-R = 0.40 ± 0.04 (Figure 2). The absolute magnitude ($H$) and phase slope parameter ($G$) were found using the H-G calculator function of *MPO Canopus*. For each lightcurve, the R mag was measured as half peak-to-peak amplitude. The results were $H_R$ = 11.87 ± 0.06 mag and $G$ = 0.05 ± 0.05 (Figure 3). The absolute magnitude was converted to $H_V$ = 12.27 ± 0.07 mag using our color index V-R = 0.40 ± 0.04.

Both the color index (V-R) and $G$ value are compatible with a low albedo asteroid (Shevchenko and Lupishko, 1998). For a C-type asteroid, the geometric albedo is $p_V$ = 0.06 ± 0.02 (Shevchenko and Lupishko, 1998). With these values we estimated the diameter as $D$ = 19 ± 4 km, using the formula by Pravec and Harris (2007):

$$D_{(km)} = \frac{1329}{\sqrt{p_v}} 10^{-0.2 H v} \qquad (1)$$

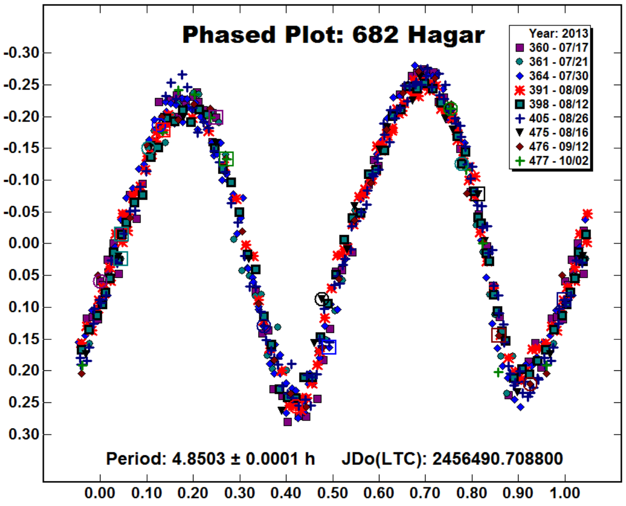

Figure 1. Composite lightcurve of 682 Hagar.

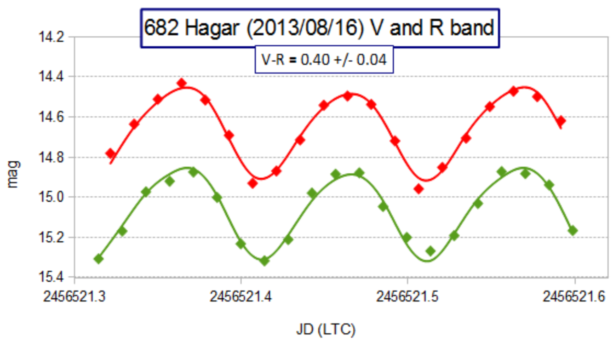

Figure 2. V and R lightcurves of 682 Hagar on 2013 Aug. 16.

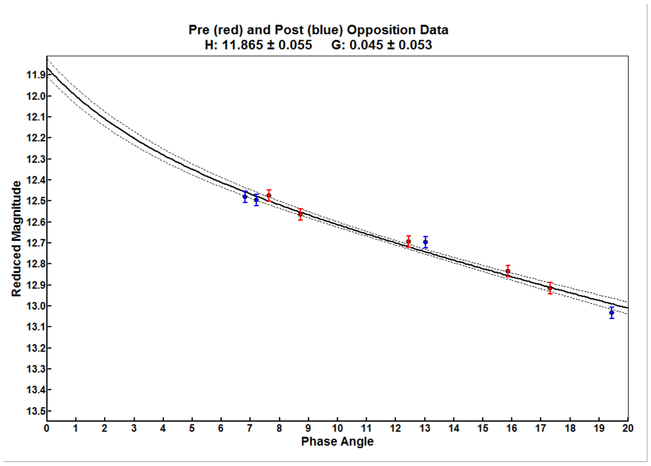

Figure 3. H-G plot in R magnitude band for 682 Hagar.

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# ROTATION PERIOD DETERMINATION FOR 682 HAGAR

Alexander Kurtenkov
Department of Astronomy, University of Sofia
5 James Bourchier Blvd.
Sofia 1164, BULGARIA
kurtenkov@phys.uni-sofia.bg

Deana Teneva
Yuri Gagarin Public Astronomical Observatory
Stara Zagora, BULGARIA

Lachezar Todorov
University of Durham
Durham, UNITED KINGDOM

Stanislav Stoyanov
University of Konstanz
Konstanz, GERMANY

(Received: 13 October)

CCD photometric observations of the main-belt asteroid 682 Hagar were obtained in 2013 August. A synodic rotation period of 4.854 ± 0.011 h with an amplitude of 0.49 ± 0.03 mag was found.

Minor planet 682 Hagar was discovered in 1909 by August Kopff at Heidelberg. It is a main-belt asteroid with an orbital period of 4.32 years (MPC, 2013). As of 2013 October there was no lightcurve or rotation period information for this object in the Asteroid Lightcurve Database (LCDB; Warner *et al.,* 2009).

Photometric observations of 682 Hagar were carried out on four consecutive nights (2013 Aug 05-08) during the 2013 Summer School of Astronomy and Astrophysics “Beli Brezi” (41°34′N 25°10′E). The images were obtained with a 0.25-m *f*/4.8 Skywatcher Newtonian on an EQ6 mount and an SBIG ST-1603ME CCD camera. The exposures were 300 sec each and unfiltered. Data reduction and aperture photometry were done using *IRAF (Image Reduction and Analysis Facility)*. Differential magnitudes were calculated on the basis of two reference stars per night with a standard error of 4 mmag. The results were corrected to unity distance by applying –5*log(rΔ) to the calculated differential magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances taken from Minor Planet Center’s Minor Planet and Comet Ephemeris Service.

The amplitude and rotation period were derived using the Phase Dispersion Minimization (PDM) technique (Stellingwerf, 1978). The *IRAF pdm* procedure was run within a trial period range from 0.15 to 1.0 d as the lightcurve shows no more than two minima in a single night.

Acknowledgements

All observations were made within the 2013 Summer School of Astronomy and Astrophysics “Beli Brezi” co-organized by the Kardzhali Astronomical Observatory and the University of Sofia.

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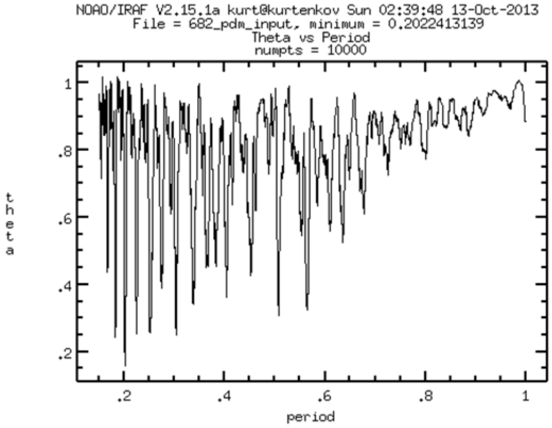
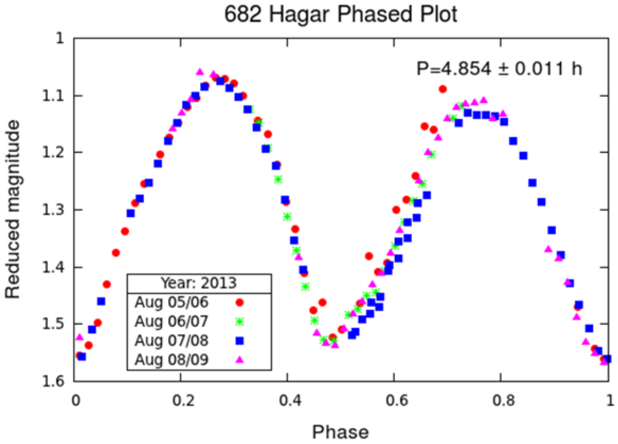


The Θ statistic (Stellingwerf 1978) was plotted as a function of period (shown in days on the diagram). A best fit ($\Theta_{min}$) was obtained at 4.854 ± 0.011 h with an amplitude of 0.49 ± 0.03 mag.



# *TARGET ASTEROIDS!* OBSERVING TARGETS FOR 2014 JANUARY THROUGH MARCH

Carl Hergenrother and Dolores Hill
Lunar & Planetary Laboratory
University of Arizona
1629 E. University Blvd.
Tucson, AZ 85721 USA

(Received: 14 October)

Asteroids to be observed for the *Target Asteroids!* program during the period of 2014 January to March are presented. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and easier to observe for small telescope users and 2) analogous to (101955) Bennu, the target asteroid of the OSIRIS-REx sample return mission.

## Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for unmanned sample return. The program also focuses on the study of asteroids that are analogous to 101955 Bennu (provisional designation 1999 RQ36), the target asteroid of the NASA OSIRIS-REx sample return mission. An introduction to the *Target Asteroids!* program can be found at Hergenrother and Hill (2013).

Even though many of the observable objects for this program are faint, acquiring a large number of low S/N observations allows many important parameters of the asteroid to be determined. For example, an asteroid's phase function can be constrained by obtaining photometry taken over a wide range of phase angles. There is a direct correlation between the phase function and albedo. The absolute magnitude can be estimated by extrapolating the phase function to a phase angle of 0°. By combining the albedo and absolute magnitude, the size of the object can be estimated.

## Quarterly Targets

There are many list asteroids that are observable in very large telescopes. For this observing plan, only objects that become brighter than V = 20.0 are presented in detail. A short summary of our knowledge about each asteroid and 10-day (shorter intervals for objects that warrant it) ephemerides are presented. The ephemerides include rough RA and Dec positions, distance from the Sun in AU (r), distance from Earth in AU (Δ), V magnitude, phase angle in degrees (PH) and elongation from the Sun in degrees (Elong).

Observers with access to large telescopes may also be interested in observing targets that are between V magnitude ~20.0 and ~22.0 during the quarter (contained in the table below).

| Asteroid Number | Name | Peak V Mag | Time of Peak Brightness |
|---|---|---|---|
| (137799) | 1999 YB | 21.0 | late Mar |
| (173664) | 2001 JU2 | 20.5 | late Mar |
| (292220) | 2006 SU49 | 21.1 | early Jan |
| (307564) | 2003 FQ6 | 20.9 | early Jan |
| (311925) | 2007 BF72 | 20.7 | late Mar |
| | 1994 CJ1 | 20.2 | mid Feb |
| | 1997 WB21 | 20.3 | late Jan |
| | 2003 CC | 20.2 | late Jan |
| | 2003 GY | 21.4 | early Jan |
| | 2006 YF | 19.6 | early Jan |
| | 2008 SO | 20.8 | late Jan/early Feb |
| | 2009 DN1 | 21.9 | early Jan |

The V < 20 selected targets are split up into four sections: 1) Carbonaceous *Target Asteroids!* List targets, 2) *Target Asteroids!* List targets of unknown type, 3) Non-carbonaceous *Target Asteroids!* List targets, and 4) Other asteroids analogous to the OSIRIS-REx target Bennu or provide an opportunity to fill some of the gaps in our knowledge of Bennu (examples include very low and high phase angle observations, phase functions in different filters and any color changes with phase angle).

The ephemerides listed below are just for planning purposes. In order to produce ephemerides for your observing location, date and time, please use the Minor Planet Center's Minor Planet and Comet Ephemeris Service:

*http://www.minorplanetcenter.net/iau/MPEph/MPEph.html*

or the *Target Asteroids!* specific site created by Tomas Vorobjov and Sergio Foglia of the International Astronomical Search Collaboration (IASC) at

*http://iasc.scibuff.com/osiris-rex.php.*

## Carbonaceous *Target Asteroids!* List Objects

None this quarter.

## *Target Asteroids!* List Objects of Unknown Type

**(187040) 2005 JS108 (*a* = 1.36 AU, *e* = 0.32, *i* = 6.0°, H = 19.2)**
There is little known about the physical properties of this low delta-V potential spacecraft target. Though it only brightens to V = 19.5 observations near its minimum phase angle of 3.6° are requested.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 10 00.2 | +14 08 | 0.62 | 1.48 | 20.3 | 29 | 133 |
| 01/11 | 09 48.7 | +16 37 | 0.60 | 1.52 | 20.0 | 21 | 147 |
| 01/21 | 09 31.6 | +19 27 | 0.59 | 1.56 | 19.7 | 12 | 161 |
| 01/31 | 09 11.1 | +22 10 | 0.61 | 1.59 | 19.5 | 4 | 174 |
| 02/10 | 08 51.2 | +24 20 | 0.65 | 1.63 | 19.9 | 8 | 166 |
| 02/20 | 08 35.2 | +25 45 | 0.71 | 1.66 | 20.4 | 16 | 153 |
| 03/02 | 08 24.9 | +26 29 | 0.79 | 1.68 | 20.9 | 22 | 141 |
| 03/12 | 08 20.7 | +26 40 | 0.89 | 1.71 | 21.3 | 27 | 130 |
| 03/22 | 08 21.8 | +26 28 | 1.00 | 1.73 | 21.7 | 30 | 120 |
| 04/01 | 08 27.3 | +25 58 | 1.11 | 1.75 | 22.0 | 32 | 112 |

## Non-carbonaceous *Target Asteroids!* List Objects

### 2001 QC34 (*a* = 1.13 AU, *e* = 0.19, *i* = 6.2°, H = 20.0)

2001 QC34 is a Q- or O-type asteroid. Phase function and lightcurve photometry will shed more light on this potential spacecraft target, which was once considered a target for the JAXA Hayabusa 2 mission.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 23 42.1 | +00 53 | 0.25 | 0.95 | 20.0 | 89 | 76 |
| 01/11 | 00 10.8 | -01 20 | 0.23 | 0.94 | 20.1 | 95 | 72 |
| 01/21 | 00 40.8 | -04 31 | 0.21 | 0.92 | 20.1 | 101 | 67 |
| 01/31 | 01 11.8 | -09 01 | 0.18 | 0.92 | 20.1 | 106 | 63 |
| 02/10 | 01 43.8 | -15 11 | 0.16 | 0.92 | 20.1 | 111 | 60 |
| 02/20 | 02 17.1 | -23 12 | 0.14 | 0.92 | 20.0 | 113 | 59 |
| 03/02 | 02 53.2 | -32 49 | 0.13 | 0.94 | 19.7 | 112 | 62 |
| 03/12 | 03 36.3 | -43 20 | 0.12 | 0.96 | 19.2 | 106 | 68 |
| 03/22 | 04 34.6 | -53 31 | 0.11 | 0.98 | 18.6 | 96 | 77 |
| 04/01 | 06 04.7 | -61 20 | 0.11 | 1.00 | 18.1 | 84 | 90 |

## Other Asteroids Analogous to the OSIRIS-REx Target Bennu

### 142 Polana (*a* = 2.42 AU, *e* = 0.13, *i* = 2.2°, H = 10.3)

Near-Earth asteroids such as the OSIRIS-REx target Bennu originated in the Main Belt. Work by Bottke *et al.* (2002) found that asteroids with low delta-V relative to Earth are from the innermost part of the Main Belt. This region of the Belt (semi-major axes between 2.1 and 2.5 AU) contains a few carbonaceous asteroid families. It is possible that Bennu was formed during an ancient collision that formed one of these families.

Asteroid 142 Polana is the largest member of a recently recognized family called the 'New Polana' family, which formed over 2 billion years ago (Walsh *et al*., 2013). Much is already known about Polana such as its rotation period (9.77 h with ~0.1 magnitude amplitude), taxonomy (F- or B-type), albedo (0.045), and diameter (50-55 km). Its taxonomy and albedo are very similar to those values found for Bennu. Polana's phase angle ranges from a minimum of 0.17° on January 4 UT to ~24° in late March. It reaches a peak brightness of V = 13.3 on January 4 UT.

Our plan is to determine if Polana's phase function is dependent on color and whether its color changes with phase angle and rotational phase. Due to its brightness, we also ask capable observers to obtain spectra at different phase angles and rotational phases. Additional details on observing Polana will be sent to Target Asteroids! participants.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 07 06.4 | +23 04 | 1.56 | 2.55 | 13.5 | 2 | 175 |
| 01/11 | 06 55.1 | +23 11 | 1.55 | 2.53 | 13.6 | 3 | 172 |
| 01/21 | 06 44.6 | +23 14 | 1.57 | 2.52 | 13.8 | 8 | 160 |
| 01/31 | 06 35.9 | +23 13 | 1.62 | 2.51 | 14.0 | 12 | 147 |
| 02/10 | 06 30.1 | +23 09 | 1.69 | 2.49 | 14.3 | 16 | 136 |
| 02/20 | 06 27.6 | +23 03 | 1.77 | 2.48 | 14.4 | 19 | 125 |
| 03/02 | 06 28.4 | +22 56 | 1.87 | 2.46 | 14.6 | 21 | 115 |
| 03/12 | 06 32.3 | +22 47 | 1.98 | 2.45 | 14.8 | 23 | 106 |
| 03/22 | 06 39.0 | +22 36 | 2.09 | 2.43 | 14.9 | 24 | 98 |
| 04/01 | 06 48.0 | +22 22 | 2.20 | 2.42 | 15.0 | 24 | 90 |

### 163 Erigone (*a* = 2.37 AU, *e* = 0.19, *i* = 4.8°, H = 9.5)

Erigone is the parent body of the 'Erigone' asteroid family. Similar to the 'New Polana' family, the 'Erigone' family is carbonaceous, located in the inner Main Belt, and a possible source of carbonaceous spacecraft targets such as Bennu and 1999 JU3. Vokrouhlicky *et al.* (2006) found an age of 280 million years for this family, which is significantly younger than the aforementioned 'New Polana' family and the 'Eulalia' family (see next object).

Erigone is a Ch-type meaning it shows evidence of hydrated minerals in its spectra. It is ~72 km in diameter with an albedo of 0.055, a rotation period of 16.14 h, and lightcurve amplitude of ~0.4 magnitudes. During the January to March period its phase angle will span from 26° in early January to a minimum of 0.40° on February 23 UT. It also reaches a peak brightness of V = 11.3 on February 23 UT. Our plan is to obtain the same sort of photometric and spectroscopic data summarized in the Polana section. Additional details on observing Erigone will be sent to Target Asteroids! participants.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 10 45.4 | +04 34 | 1.30 | 1.98 | 13.0 | 26 | 119 |
| 01/11 | 10 48.5 | +04 31 | 1.22 | 1.99 | 12.8 | 23 | 129 |
| 01/21 | 10 48.1 | +04 55 | 1.16 | 2.01 | 12.5 | 19 | 139 |
| 01/31 | 10 44.4 | +05 44 | 1.11 | 2.02 | 12.2 | 14 | 150 |
| 02/10 | 10 37.8 | +06 55 | 1.08 | 2.04 | 11.9 | 8 | 163 |
| 02/20 | 10 29.4 | +08 20 | 1.07 | 2.06 | 11.5 | 2 | 175 |
| 03/02 | 10 20.6 | +09 47 | 1.09 | 2.07 | 11.7 | 4 | 172 |
| 03/12 | 10 13.0 | +11 06 | 1.13 | 2.09 | 12.1 | 9 | 160 |
| 03/22 | 10 07.6 | +12 07 | 1.20 | 2.11 | 12.5 | 14 | 149 |
| 04/01 | 10 05.2 | +12 47 | 1.28 | 2.13 | 12.9 | 18 | 139 |

### 495 Eulalia (*a* = 2.49 AU, *e* = 0.13, *i* = 2.3°, H = 10.8)

Before Polana was recognized as the parent of the 'New Polana' family, it was thought to be the parent of a different family, once called the original 'Polana' family. The same work by Walsh *et al.* (2013) that found that Polana is actually the parent of the 'New Polana' family also found that asteroid Eulalia is the true parent of the old 'Polana' family, now renamed the 'Eulalia' family. The 'Eulalia' family is estimated to be between 0.9 and 1.5 billion years old.

As with most large Main Belt asteroids, much is known about Eulalia such as its taxonomy (C-type), albedo (0.057), and diameter (~39 km). It has a long rotation period that is estimated to be around 29 h. Eulalia can be observed from phase angles of 21° in early January to an extreme minimum of 0.10° on April 1 UT. A peak brightness of V = 14.3 is also reached on April 1 UT. Our plan is to obtain the same sort of photometric and spectroscopic data summarized in the Polana section. Additional details on observing Eulalia will be sent to Target Asteroids! participants.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 12 50.6 | -06 02 | 2.59 | 2.71 | 16.1 | 21 | 86 |
| 01/11 | 12 58.1 | -06 45 | 2.46 | 2.72 | 15.9 | 21 | 95 |
| 01/21 | 13 03.8 | -07 16 | 2.33 | 2.73 | 15.8 | 21 | 103 |
| 01/31 | 13 07.4 | -07 33 | 2.21 | 2.74 | 15.7 | 19 | 112 |
| 02/10 | 13 08.7 | -07 36 | 2.09 | 2.75 | 15.5 | 18 | 122 |
| 02/20 | 13 07.6 | -07 23 | 1.99 | 2.75 | 15.3 | 15 | 133 |
| 03/02 | 13 03.9 | -06 53 | 1.90 | 2.76 | 15.1 | 12 | 144 |
| 03/12 | 12 57.9 | -06 09 | 1.83 | 2.77 | 14.9 | 9 | 155 |
| 03/22 | 12 50.3 | -05 12 | 1.79 | 2.77 | 14.7 | 5 | 168 |
| 04/01 | 12 41.6 | -04 10 | 1.78 | 2.78 | 14.3 | 0 | 180 |

### (52760) 1998 ML14 (*a* = 2.41 AU, *e* = 0.62, *i* = 2.4°, H = 17.5)

Much is already known about 1998 ML14. Radar observations made in 1998 found a diameter of 1 km, albedo of 0.27, and a nearly spherical shape. Additional spectroscopic and photometric observations identified it as either an S, Sq, or V type and having a rotation period of 14.98 h. The near-spherical shape results in a small lightcurve amplitude allowing a phase function to be measured with little interference from rotational variations. 1998 ML14 reached a minimum phase angle in late December. Since it will have already been observed over a wide range of phase angles over the last four months of 2013, observations are only requested for the month of January.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 06 17.3 | +28 40 | 0.66 | 1.64 | 18.1 | 5 | 172 |
| 01/11 | 06 04.3 | +28 01 | 0.77 | 1.72 | 18.8 | 11 | 160 |
| 01/21 | 05 57.3 | +27 21 | 0.90 | 1.81 | 19.4 | 17 | 149 |
| 01/31 | 05 55.4 | +26 47 | 1.04 | 1.89 | 20.0 | 20 | 138 |

**(243566) 1995 SA (*a* = 2.46 AU, *e* =0.64, *i* = 19.9°, H = 17.4)**
The WISE infrared space observatory observed 1995 SA and found a low albedo of ~0.09, suggesting a possible carbonaceous nature. A minimum phase angle of 22° is reached in late January and a maximum phase angle of 111° in mid-April.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 08 59.1 | -14 27 | 0.95 | 1.75 | 19.7 | 25 | 130 |
| 01/11 | 08 56.2 | -16 07 | 0.81 | 1.66 | 19.2 | 24 | 136 |
| 01/21 | 08 49.2 | -17 14 | 0.68 | 1.57 | 18.6 | 23 | 142 |
| 01/31 | 08 37.5 | -17 23 | 0.56 | 1.48 | 18.1 | 23 | 145 |
| 02/10 | 08 21.2 | -16 00 | 0.46 | 1.39 | 17.6 | 24 | 145 |
| 02/20 | 08 00.9 | -12 22 | 0.38 | 1.30 | 17.1 | 29 | 140 |
| 03/02 | 07 37.9 | -05 32 | 0.30 | 1.21 | 16.8 | 39 | 130 |
| 03/12 | 07 12.7 | +05 37 | 0.25 | 1.13 | 16.5 | 52 | 117 |
| 03/22 | 06 42.5 | +22 11 | 0.21 | 1.05 | 16.5 | 70 | 99 |
| 04/01 | 05 54.7 | +43 24 | 0.19 | 0.98 | 16.9 | 90 | 79 |

**(251346) 2007 SJ (*a* = 2.01 AU, *e* = 0.53, *i* = 8.2°, H = 16.8)**
Little is known about this upcoming radar target. In early January it reaches a peak V magnitude of 15.3. After a short span when it will be too close to the Sun for observation in mid-January, 2007 SJ again becomes visible towards the end of January as a far southern object around magnitude 15.5. Astrometry, phase function, color filter, and lightcurve photometry are requested. We ask that phase function photometry be attempted at large phase angles.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 22 52.4 | +35 15 | 0.12 | 0.98 | 15.3 | 90 | 83 |
| 01/11 | 21 54.2 | +26 38 | 0.08 | 0.95 | 15.6 | 116 | 60 |
| 01/21 | 19 43.2 | -04 08 | 0.05 | 0.94 | 21.7 | 162 | 17 |
| 01/31 | 17 04.6 | -36 59 | 0.07 | 0.95 | 16.0 | 123 | 54 |
| 02/10 | 15 42.3 | -45 18 | 0.11 | 0.97 | 15.4 | 95 | 78 |
| 02/20 | 15 02.9 | -47 42 | 0.16 | 1.01 | 15.5 | 78 | 93 |
| 03/02 | 14 36.2 | -48 27 | 0.20 | 1.06 | 15.7 | 64 | 106 |
| 03/12 | 14 11.8 | -47 58 | 0.24 | 1.12 | 15.9 | 52 | 117 |
| 03/22 | 13 48.1 | -46 13 | 0.28 | 1.19 | 16.0 | 41 | 129 |
| 04/01 | 13 26.8 | -43 17 | 0.32 | 1.26 | 16.2 | 31 | 140 |

**(275677) 2000 RS11 (*a* = 1.28 AU, *e* = 0.32, *i* = 17.1°, H = 19.1)**
2000 RS11 peaks in brightness at V = 15.0 on March 15. Its 2014 close approach of Earth allows observations to be obtained between phase angles of 128° on March 3 and 40° in late May. RS11 approaches Earth from the southern sky and will be invisible to most Northern Hemisphere observers until March 10 or so. Observations by Spitzer show it to be a highly reflective body with an albedo of 0.35. Its Sa taxonomic type confirms this. 2000 RS11 is also a radar target. Lightcurve and color photometry is requested. We are especially interested in phase function photometry (with color or luminance filters) made at high phase angles.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 00 01.8 | -43 53 | 0.42 | 0.90 | 20.1 | 88 | 67 |
| 01/11 | 00 23.2 | -45 07 | 0.37 | 0.88 | 20.1 | 95 | 63 |
| 01/21 | 00 41.3 | -46 37 | 0.32 | 0.87 | 20.0 | 101 | 60 |
| 01/31 | 00 53.6 | -48 30 | 0.26 | 0.87 | 19.9 | 108 | 57 |
| 02/10 | 00 55.5 | -50 54 | 0.20 | 0.89 | 19.8 | 115 | 54 |
| 02/20 | 00 34.2 | -53 58 | 0.13 | 0.91 | 19.5 | 122 | 51 |
| 03/02 | 22 56.9 | -56 16 | 0.07 | 0.95 | 18.7 | 127 | 49 |
| 03/08 | 20 10.9 | -44 59 | 0.04 | 0.97 | 17.1 | 122 | 56 |
| 03/12 | 18 10.5 | -15 31 | 0.04 | 0.99 | 15.4 | 99 | 79 |
| 03/16 | 16 54.5 | +13 06 | 0.05 | 1.01 | 15.1 | 75 | 102 |
| 03/20 | 16 10.5 | +27 21 | 0.07 | 1.02 | 15.5 | 63 | 114 |
| 03/24 | 15 42.7 | +34 14 | 0.09 | 1.04 | 16.0 | 57 | 119 |
| 03/28 | 15 23.2 | +37 56 | 0.11 | 1.06 | 16.4 | 53 | 122 |

**(277570) 2005 YP180 (*a* = 1.37 AU, *e* = 0.62, *i* = 4.1°, H = 19.3)**
Little is known of this near-Earth asteroid other than its albedo, which was measured by WISE at 0.18 suggesting a non-carbonaceous object. Phase function photometry between 10° and ~130° is possible. Due to its brightness, we request color and lightcurve photometry as well.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/11 | 17 09.1 | -25 51 | 0.12 | 0.88 | 21.8 | 144 | 32 |
| 01/13 | 16 38.2 | -26 51 | 0.11 | 0.91 | 20.4 | 135 | 41 |
| 01/15 | 15 58.3 | -27 37 | 0.10 | 0.93 | 19.2 | 124 | 52 |
| 01/17 | 15 07.9 | -27 34 | 0.09 | 0.95 | 18.0 | 111 | 65 |
| 01/19 | 14 08.9 | -26 03 | 0.08 | 0.97 | 17.2 | 96 | 80 |
| 01/21 | 13 07.0 | -22 47 | 0.08 | 1.00 | 16.5 | 79 | 96 |
| 01/23 | 12 10.3 | -22 47 | 0.08 | 1.02 | 16.2 | 64 | 112 |
| 01/25 | 11 23.4 | -13 28 | 0.09 | 1.04 | 16.0 | 50 | 126 |
| 01/27 | 10 46.7 | -09 10 | 0.10 | 1.06 | 16.0 | 39 | 138 |
| 01/29 | 10 18.6 | -05 36 | 0.12 | 1.08 | 16.1 | 30 | 147 |
| 02/10 | 08 59.8 | +05 12 | 0.23 | 1.21 | 17.1 | 10 | 168 |
| 02/20 | 08 39.1 | +08 34 | 0.34 | 1.31 | 18.4 | 17 | 157 |
| 03/02 | 08 32.2 | +10 18 | 0.46 | 1.40 | 19.5 | 24 | 146 |
| 03/12 | 08 32.6 | +11 14 | 0.60 | 1.48 | 20.3 | 28 | 136 |

**(348306) 2005 AY28 (*a* = 0.87 AU, *e* = 0.57, *i* = 5.9°, H = 21.5)**
Little is known about the physical properties of this asteroid. We plan to help change that during its January/February flyby of Earth. With a peak V magnitude of 16.5 and observable phase angles between 24° and ~130°, our observations will augment those scheduled with the Goldstone radar telescope.

| DATE | RA | DEC | Δ | r | V | PH | Elong |
|---|---|---|---|---|---|---|---|
| 01/01 | 10 29.3 | +08 42 | 0.40 | 1.25 | 21.6 | 40 | 125 |
| 01/11 | 10 36.5 | +10 04 | 0.28 | 1.20 | 20.6 | 37 | 134 |
| 01/21 | 10 40.7 | +14 12 | 0.18 | 1.13 | 19.4 | 31 | 144 |
| 01/31 | 10 37.8 | +29 44 | 0.08 | 1.06 | 17.4 | 25 | 153 |
| 02/02 | 10 33.9 | +38 04 | 0.07 | 1.04 | 16.9 | 28 | 151 |
| 02/04 | 10 24.7 | +51 29 | 0.05 | 1.03 | 16.6 | 36 | 142 |
| 02/06 | 09 45.4 | +72 39 | 0.04 | 1.01 | 16.6 | 55 | 123 |
| 02/08 | 00 23.5 | +77 39 | 0.04 | 0.99 | 17.3 | 82 | 96 |
| 02/10 | 23 17.7 | +54 16 | 0.05 | 0.97 | 18.7 | 105 | 72 |
| 02/12 | 23 05.9 | +38 43 | 0.06 | 0.96 | 20.2 | 121 | 56 |
| 02/14 | 23 00.8 | +29 04 | 0.08 | 0.94 | 21.6 | 131 | 46 |
| 02/16 | 22 57.9 | +22 47 | 0.09 | 0.92 | 22.8 | 138 | 38 |

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Bottke, W., Durda, D., Nesvorny, D., Jedicke, R., Morbidelli, A., Vokrouhlicky, D., and Levison, H. (2002). “Debiased Orbital and Absolute Magnitude Distribution of Near-Earth Objects.” *Icarus* **179**, 63-94.

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# ASTEROID LIGHTCURVE ANALYSIS AT ELEPHANT HEAD OBSERVATORY: 2013 AUGUST–OCTOBER

Michael S. Alkema
Elephant Head Observatory (G35)
Sahuarita, AZ 85629
msalkema@gmail.com

(Received: 13 October)

Photometric observations of two main-belt asteroids, 541 Deborah and 1468 Zomba, were made from Elephant Head Observatory during 2013 August to October. The period and amplitude results are, respectively, P = 29.368 ± 0.005 h, A = 0.10 ± 0.01 mag; P = 2.773 ± 0.001 h, A = 0.34 ± 0.02 mag.

CCD photometric observations were made of the main-belt asteroids 541 Deborah and 1468 Zomba in 2013 August to October for the purpose of determining the lightcurve parameters of synodic rotation period and amplitude. Observations were conducted with a 0.36-m Schmidt-Cassegrain telescope (SCT) on a German Equatorial mount (GEM) using an SBIG STT-8300M CCD camera with 5.4-micron pixels binned at 4x4. The combination produced an image scale of 1.56 arcsec/pixel. A clear filter was used for all exposures. All images were dark and flat-field corrected. The lightcurve data have been submitted to the ALCDEF database via the Minor Planet Center's web site (*http://www.minorplanetcenter.net/light_curve*).

The images for this study were obtained using an automated routine in *CCDAutopilot* v5. Imaging and plate solving were done with *Maxim DL* v5 and *TheSkyX* v10. Data were reduced in *MPO Canopus* v10 using differential photometry. Comparison stars were chosen for near-solar color index with the "comp star selector" of *MPO Canopus*. Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Both asteroids were reported as lightcurve opportunities in the *Minor Planet Bulletin*.

541 Deborah. A search for previous period determinations of 541 Deborah found Benishek (2009, 13.91 h). New observations were obtained over nine nights in 2013 Sep and Oct. Analysis of the data found a period of 29.368 ± 0.005 h, amplitude 0.10 ± 0.01 mag. The newly determined period differs from that of Benishek, whose period appears to be aliased around the phase 0.15 to 0.70.

1468 Zomba. A search for previous period determinations of 1468 Zomba found one by Wisniewski and McMillan (1987, 2.77 h). New observations were obtained over four nights in 2013 Aug and Sep. Analysis of the data found a period of 2.773 ± 0.001 h, amplitude 0.34 ± 0.02 mag. The newly determined period is within experimental uncertainty of that found by Wisniewski and McMillan.

References

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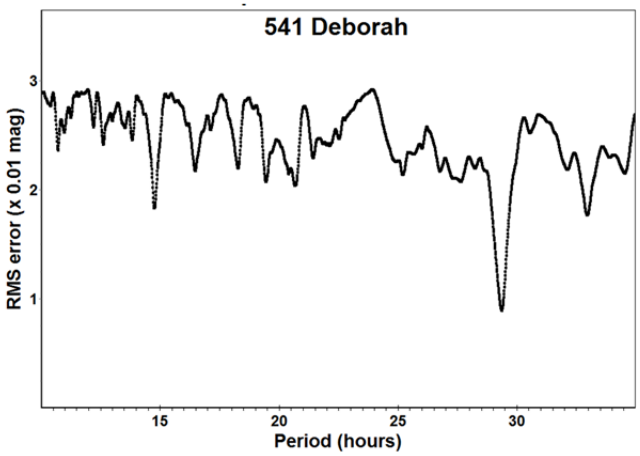
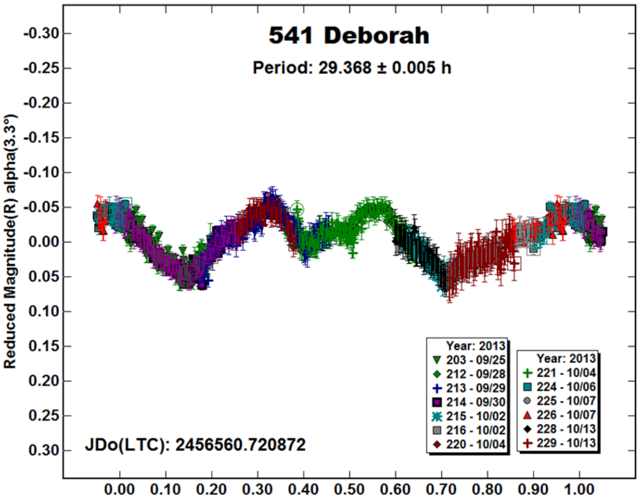
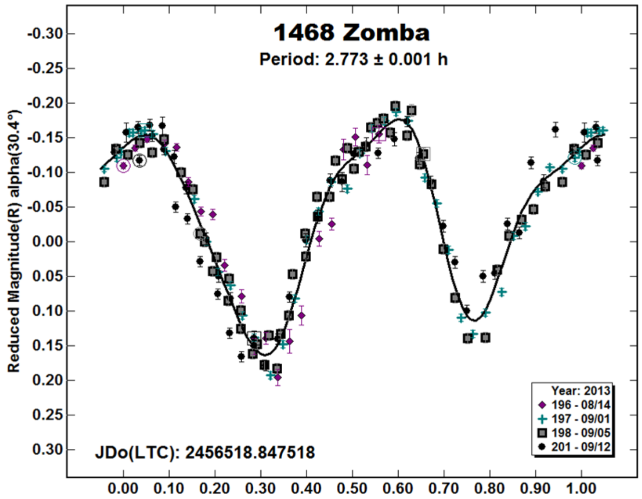
Wisniewski, W.Z. and McMillan, R.S. (1987). "Differential CCD photometry of faint asteroids in crowded star fields and nonphotometric sky conditions." *Astron. J.* **93**, 1264-1267.







# NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2013 JUNE-SEPTEMBER

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

(Received: 7 October)

Lightcurves for 12 near-Earth asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2013 June through September.

CCD photometric observations of 12 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 June through September. Table I gives a listing of the telescope/CCD camera combinations used for the observations. 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 |
|---|---|---|
| PDS-1-12N | 0.30-m f/6.3 Schmidt-Cass | ST-9XE |
| PDS-1-14S | 0.35-m f/9.1 Schmidt-Cass | FLI-1001E |
| PDS-2-14N | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-2-14S | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-20 | 0.50-m f/8.1 Ritchey-Chretien | FLI-1001E |

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

All lightcurve observations were made with no filter (a clear filter can result in a 0.1-0.3 magnitude transmission loss) and were guided on a field star, resulting in some cases in a trailed image for the asteroid. The duration varies depending on the asteroid's brightness and sky motion.

Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture set with the long axis corresponding to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes are usually taken from the MPOSC3 catalog, which is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). When possible, magnitudes are taken from the APASS catalog (Henden *et al.* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ±0.05 magnitude or better, but on occasion are as large as 0.1 mag. This reasonably good consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.* 1989).

In the plots below, the "Reduced Magnitude" is Johnson V (or Cousins R) as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB, Warner *et al.* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html)* allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcodes, is also available for download. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

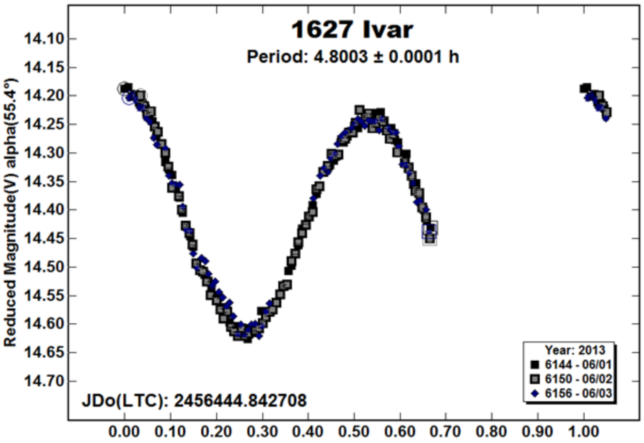
<u>1627 Ivar</u>. The period for this 9-km NEA has been determined numerous times in the past (see the LCDB entries). It was observed at CS3 in support of radar and spectroscopic work by Ellen Howell. Ivar is a very difficult asteroid to work from a single station since the period is almost exactly 1/5 of an Earth day. It takes many days for the slight difference in rotational phase to show up. Unless each session can cover a full rotation, the lightcurve is never quite complete, as is shown in some of the lightcurve plots below.

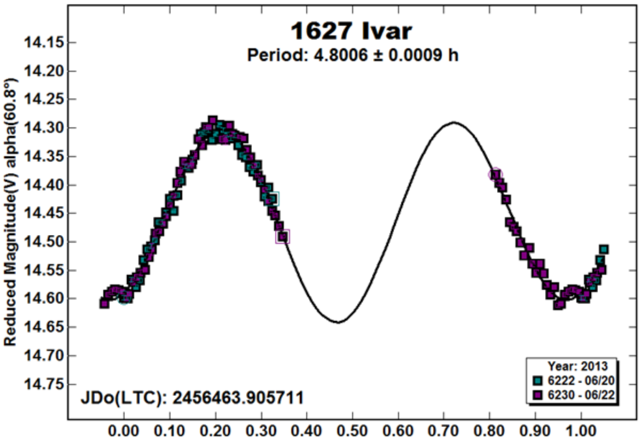
Data for Ivar were obtained in four sets of runs: three nights in

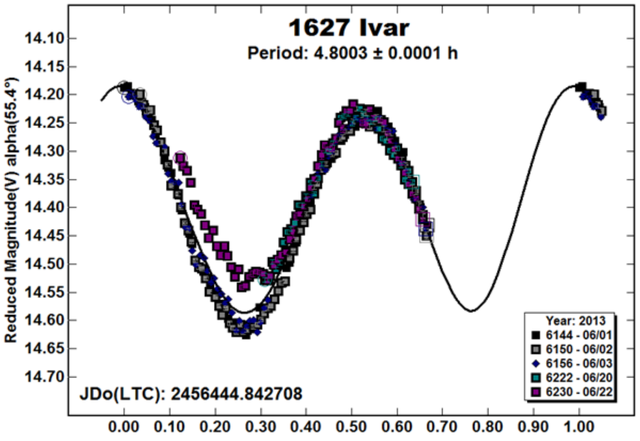
| Number | Name | 2013 (mm/dd) | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1627 | Ivar | 06/01-06/03 | 222 | 55.2 55.8 | 295 | 14 | 4.8003 | 0.0001 | 0.42 | 0.02 |
| ″″ | ″″ | 06/20-06/22 | 105 | 60.7 61.1 | 316 | 10 | 4.8006 | 0.0009 | 0.30 | 0.02 |
| ″″ | ″″ | 08/14-08/16 | 408 | 52.1 51.1 | 3 | -8 | 4.7961 | 0.0005 | 0.72 | 0.02 |
| ″″ | ″″ | 10/15 | 520 | 18.3 | 19 | -16 | 4.789 | 0.004 | 0.74 | 0.02 |
| 9950 | ESA | 08/05-08/11 | 330 | 55.1 57.0 | 355 | 31 | 6.712 | 0.005 | 0.56 | 0.03 |
| 11405 | 1999 CV3 | 08/14-08/18 | 208 | 67.0 62.3 | 279 | 14 | 6.501 | 0.005 | 0.89 | 0.03 |
| 24445 | 2000 PM8 | 08/05-08/11 | 289 | 44.8 46.4 | 11 | 23 | 6.811 | 0.005 | 0.25 | 0.02 |
| 152664 | 1998 FW4 | 09/12-09/23 | 772 | 20.5 59.1 | 3 38 | -2 4 | 17.38 | 0.01 | 0.34 | 0.03 |
| 168378 | 1997 ET30 | 09/04-09/12 | 229 | 24.6 17.6 | 5 | -6 | 5.721 | 0.002 | 0.13 | 0.01 |
| 329437 | 2002 OA22 | 08/24-09/02 | 260 | 47.0 42.0 | 4 | 6 | 2.6214 | 0.0005 | 0.20 | 0.02 |
| ″″ | ″″ | 09/13-09/17 | 389 | 36.0 33.6 | 12 | -1 | 2.6209 | 0.0003 | 0.19 | 0.02 |
| 350988 | 2003 GW | 09/04-09/11 | 215 | 40.8 30.7 | 16 | 9 | 9.58 | 0.02 | 0.18 | 0.02 |
| 361071 | 2006 AO4 | 08/12-08/14 | 361 | 46.7 48.2 | 353 | 15 | 4.093 | 0.001 | 0.32 | 0.02 |
| 368664 | 2005 JA22 | 09/12-09/18 | 366 | 16.0 15.4 | 1 | -6 | 31.7 | 0.2 | 0.92 | 0.05 |
|  | 2006 EE1 | 08/28-08/29 | 180 | 3.8 6.7 | 331 | -1 | 4.62 | 0.02 | 0.10 | 0.02 |
|  | 2013 OM9 | 08/25-09/02 | 209 | 15.4 22.6 | 331 | 17 | 12.60 | 0.02 | 0.17 | 0.03 |
|  | 2013 QJ10 | 09/02-09/11 | 324 | 48.3 38.0 | 2 356 | 23 26 | 29.0* | 0.1 | 0.10 | 0.02 |

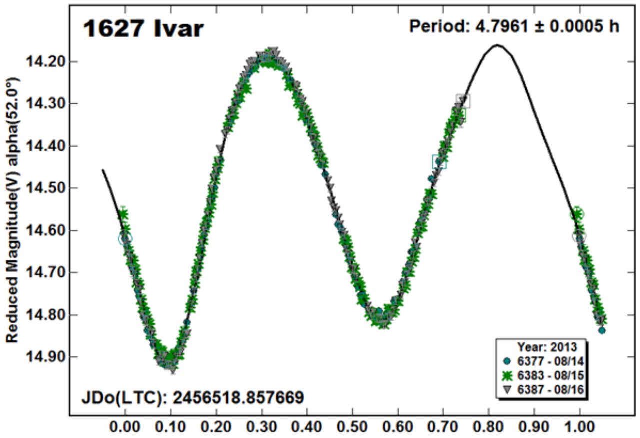
Table II. Observing circumstances. * Solution is for a bimodal lightcurve (see text). The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. $L_{PAB}$ and $B_{PAB}$ are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

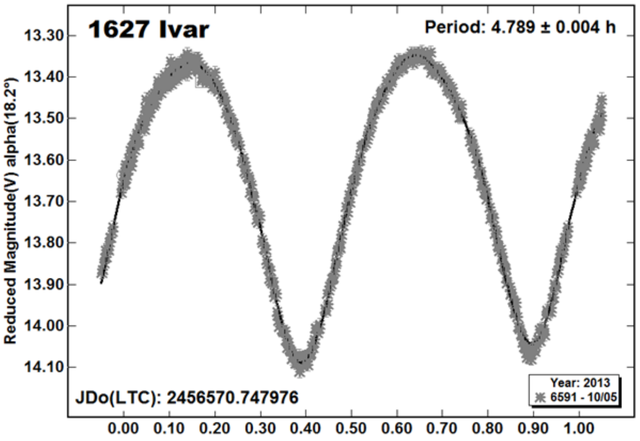
early 2013 June, two nights in mid-June, three nights in mid-August, and one night in early October. The first two plots below show the lightcurves from the two sets in June. The synodic period and amplitude changed slightly in the two-week interval between the two sets. The third plot combines the two to show the evolution of the curve more clearly. The plot from mid-August reveals a significantly larger amplitude and that the sidereal period had shortened slightly. The final lightcurve, from 2013 October 5, covers almost the entire period and shows that the minimums are closer to equal depth than in some of the earlier plots.









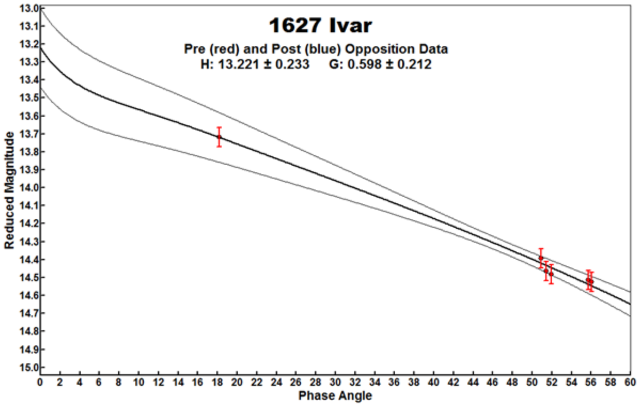


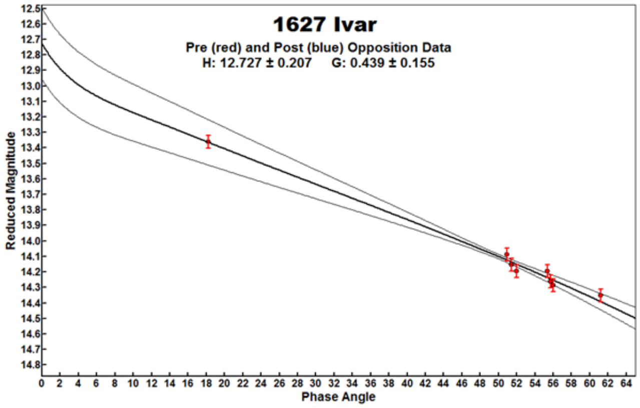
There is a seeming contradiction regarding the *H*-*G* and albedo values for Ivar. The MPCORB file gives $G = 0.6$, which would be expected for a very high albedo object, $p_V > 0.4$ (see Warner *et al.*, 2009). On the other hand, numerous works, e.g., Mainzer *et al.* (2011), found $p_V \sim 0.15$, which would be more consistent with $G \sim 0.20$ (Warner *et al.* 2009).

This difference may be mostly due to the unreliability of finding *G* using data from only high phase angles, when the amplitude of an object, especially one as elongated as Ivar, can change dramatically. This makes it difficult to determine the true average magnitude of the lightcurve, which is the traditional value used for finding *H* and *G*. In other words, a value for *G* found using only high phase angle data can have little or no physical foundation.

For a very non-spherical body, the phase curve corresponding to *maximum* light comes closest to approximating the curve for a spherical body of the same surface properties. This can be explained by considering the "mean slope" of the projected area of a prolate ellipsoid. When viewed end-on, i.e., minimum light, one sees a steeply sloping surface along both projected axes (polar and short-equatorial). At maximum light, there is a less-than sphere slope profile along the equatorial direction and a more-than-sphere slope profile along the shorter polar direction. The mean slope, therefore, is a closer average of an equivalent sphere (Alan Harris, private communications).

Obtaining data points at smaller phase angles, preferably $\alpha < 10°$, can make a considerable difference, although the caveats above remain. The fourth lightcurve in the series provided a point at $\alpha = 18.1°$, only 3° from the minimum during the 2013 apparition. The first H-G plot below used the average magnitude of the lightcurves in the combined data set. This gave values almost identical to those in the MPCORB file. The second H-G plot used the maximum light of the lightcurves, producing a lower value for *G* and brighter value for *H*. Even so, the value for *G* is still more consistent with a body of higher albedo.



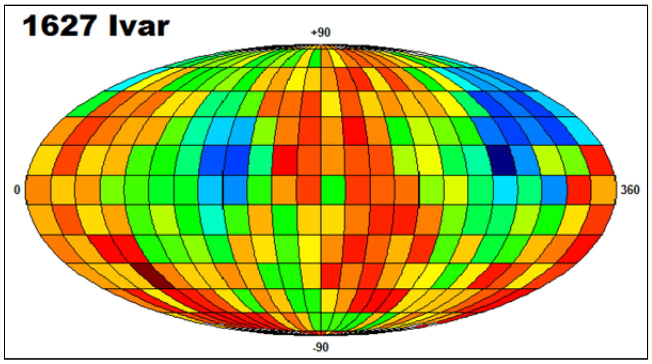


The lesson here is that, while it's important to have data points covering a wide range of phase angles, especially those at $\alpha < 10°$ to cover the so-called *opposition effect*, it's best to avoid data from phase angles greater than about 30-40°. This also is a cautionary tale against making assumptions about albedo and, therefore, taxonomic class, based only the value of *G*.

In most cases, it is not possible to get a reasonable solution for a pole using lightcurve inversion using data from one apparition, e.g., the total time span of the data is too short and/or the range of phase angles is too small. It may be possible, however, to get an initial start if, as in the case of the 2013 observations, the total span covers several hundred rotations (about 600 in this case), covers a good range of phase angles, the synodic period is well-established, and the data are of high-quality. It is particularly helpful if the viewing aspect as measured by the phase angle bisector (see appendix in Harris *et al.*, 1984) goes through a relatively large range as well. This is far more likely with an NEA than an inner main-belt object and completely ruled out by the time one reaches the middle to outer main-belt and beyond.

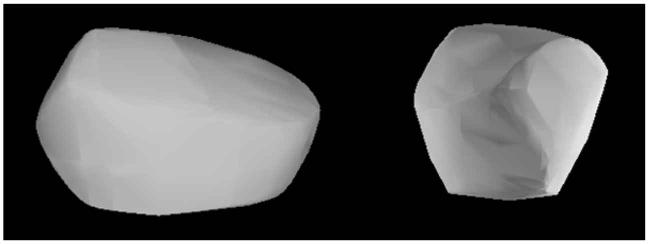
Kaasalainen *et al*. (2004) generated a model for Ivar using new data from 2000 and archived dense data from the Uppsala Catalog. The total span of their data was about 16 years and included 56 dense lightcurves. They found *Psidereal* = 4.79517 h and a pole of ecliptic longitude-latitude of (333°, +43°). It was decided to try using only the data from the 2013 apparition to test if it was possible to find a preliminary solution from a single apparition, keeping in mind that the results would likely not be very reliable. The Kaasalainen *et al.* results were used for comparison to determine the success of the effort. It's important to mention again that this is *not* recommended for almost all single-apparition data sets, especially those involving anything from the inner main-belt and beyond, and that the solution, if any, almost certainly cannot be considered definitive.

The process started by finding the sidereal period of the asteroid. A search in *MPO LCInvert* was confined to 4.793 to 4.805 h on the assumption that the period of 4.795170 h found by Kaasalainen *et al.* (2004) was correct. Given the quality of their solution, this seemed a reasonable assumption. The period search found *Psidereal* = 4.79612 h with a Chi-square value about 1/4 of that for the next best period. The best period from the search was used in a pole search that involved finding the Chi-square fit for each of 312 discrete ecliptic longitude-latitude pairs. While the pole direction was fixed for each test, the period was allowed to float in order to get the best model fit.



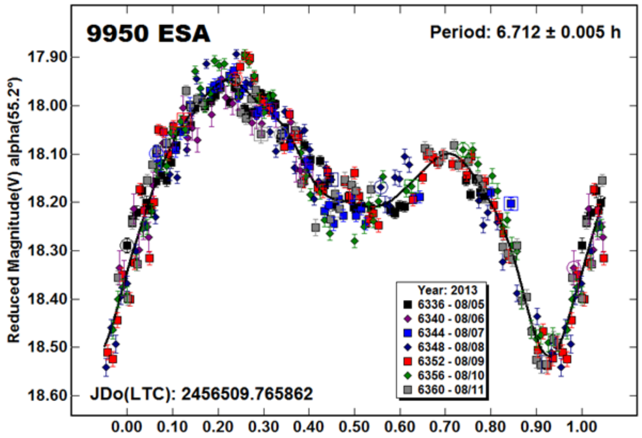
The plot above shows the results of the pole search as a map of the ecliptic sky. The deep blue region represents the discrete pole with the lowest Chi-square value. The Chi-square value increases as the color goes to light blue to green to yellow to orange and finally to deep red (maroon). Ideally, one hopes to find one small "island" of deep blue surrounded by shades of green to red. Since the lightcurve inversion process often produces two solutions, differing by 180° longitude, the next best solution is two islands separated by 180° or one with four where the latitudes are mirrored as well.

The initial pole search found the lowest Chi-square at (285°, +15°, 4.79607 h). The third best fit was at (330°, +45°, 4.79564 h). A refined search centered on (300°, +30°) – the approximate average of the solutions with the three lowest Chi-square values – that spanned ±30° in longitude and latitude found a final solution of (299°, +27°, 4.79604 h). The model is shown below as equatorial views separated by 90° rotation about the Z-axis.

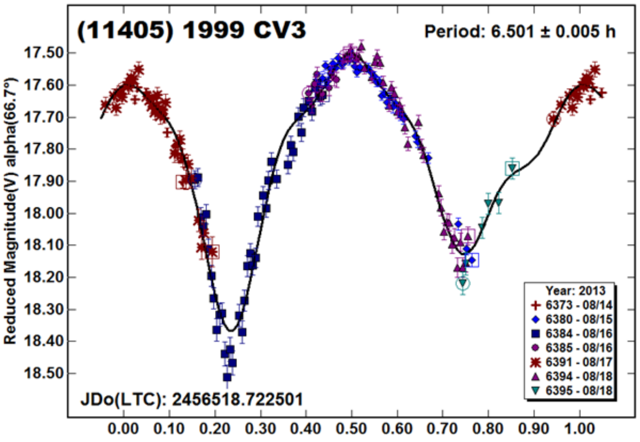


The overall results are similar to Kassalainen *et al.* but there are differences. One test of the model is to compare the model lightcurve against the actual lightcurves. The latter from early June and October match the model well. The mid-August lightcurves have a noticeably larger amplitude than the model. Modeling that includes archived dense and sparse data is planned for the future.

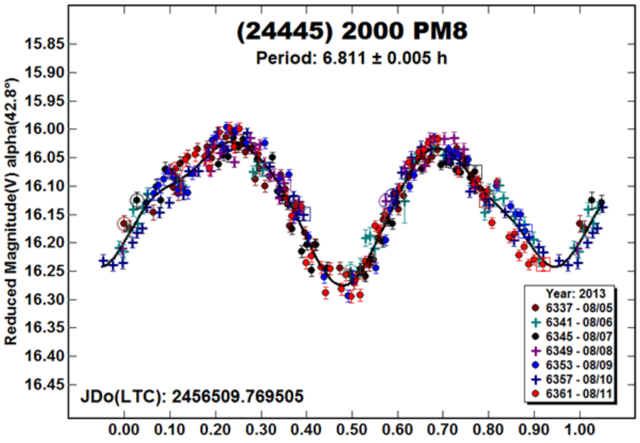
9950 ESA. The estimated diameter of ESA is 2 km, assuming $H$ = 15.9 and $p_V$ = 0.20.



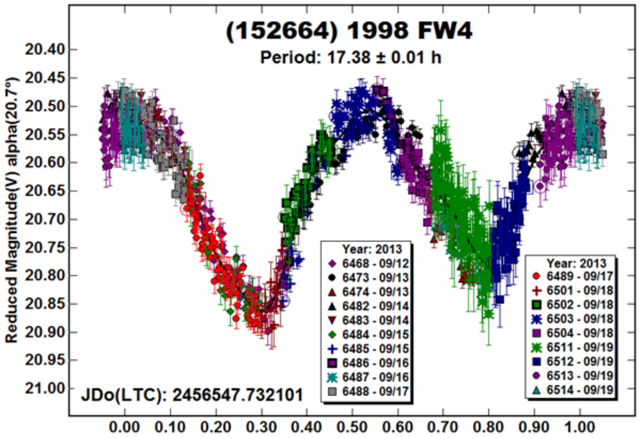
(11405) 1999 CV3. Pravec *et al.* (1999) reported a period of about 6.510 h for this 2.7 km asteroid ($H$ = 15.2, $p_V$ = 0.20) while Warner (2013) found a period of 6.504 h. Analysis of new data from 2013 August found almost the same period but a larger amplitude. The shape of the lightcurve had evolved as well, from one of nearly equal minimums to the one in August with a much shallower second maximum.



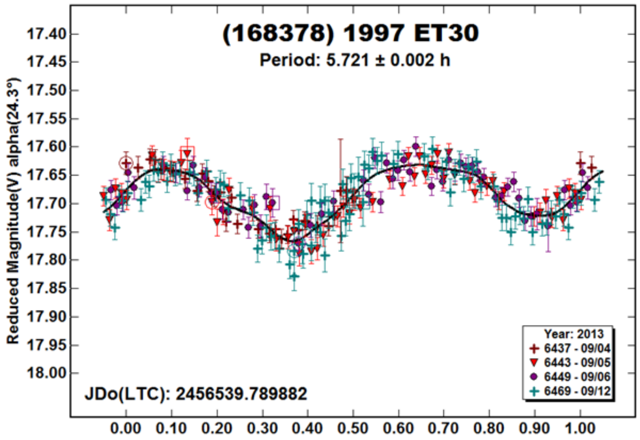
(24445) 2000 PM8. Using the MPCORB $H$ = 15.2 and assumed $p_V$ = 0.20, typical for S-type asteroids which dominate the NEA population, the estimated diameter of 2000 PM8 is 3.6 km. This appears to be the first published period for the asteroid.



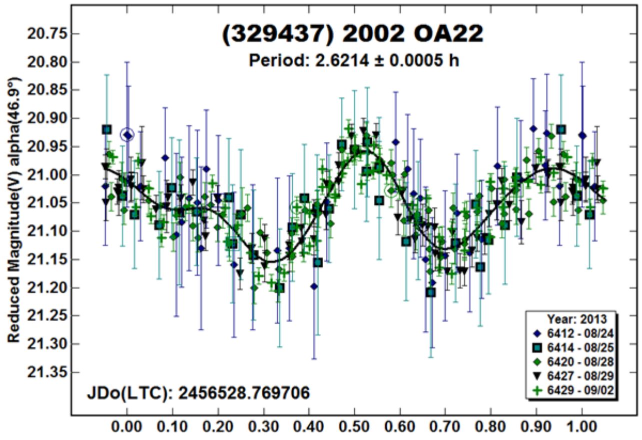
(152664) 1998 FW4. Using $H$ = 19.6 and $p_V$ = 0.20, the estimated diameter for 1998 FW4 is about 400 meters. The small size and period favor this asteroid to be in non-principal axis rotation, i.e., tumbling (see Pravec *et al.* 2005). However, there were no signs of this, at least within the observational and calibration errors.



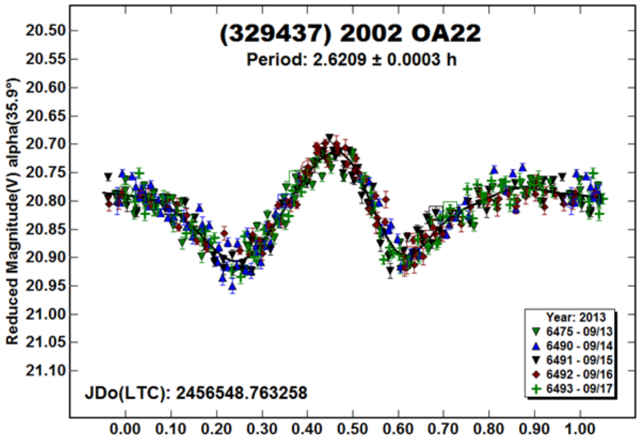
(168378) 1997 ET30. The estimated diameter of 1997 ET30 is 1.2 km ($H$ = 16.9 and $p_V$ = 0.20). No previously reported periods were found in the literature.



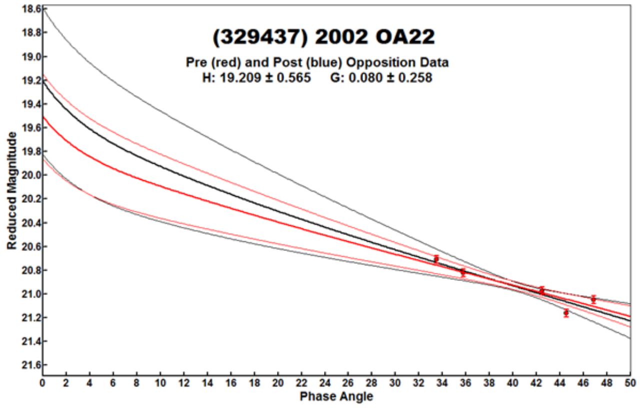
(329437) 2002 OA22. 2002 OA22 has an estimated diameter of $D$ = 0.4 km ($H$ = 19.4, $p_V$ = 0.20). It was first observed in 2013 August, when it was relatively faint and so the noise was somewhat high. However, it was still possible to obtain a good period solution of 2.6214 h.



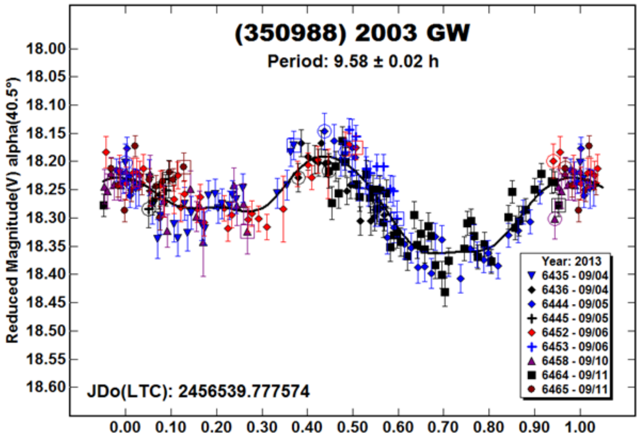
The asteroid was observed again in September when it was brighter and so the noise considerably lower. The second set of observations was made to support radar observations being made around that time.



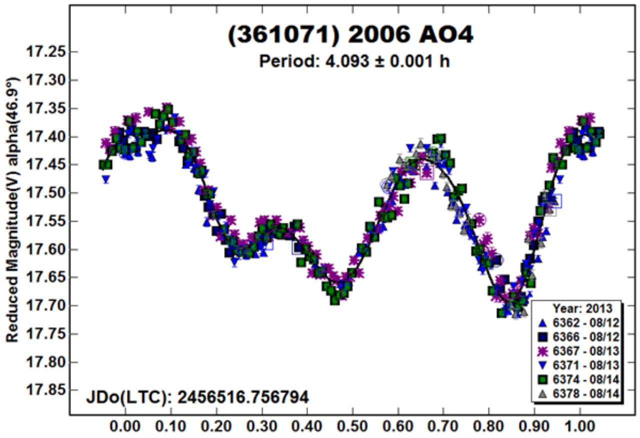
The observations covered a range of phase angles of 33° to 47°. Keeping in mind the issues discussed under 1627 Ivar above, the data were used to find $H$ and $G$. When the solution was allowed to “float”, this gave $G = 0.08 \pm 0.26$ (black lines in H-G plot below). When $G$ was forced to 0.20, the resulting value for $H$ decreased by about 0.3 mag (red lines).



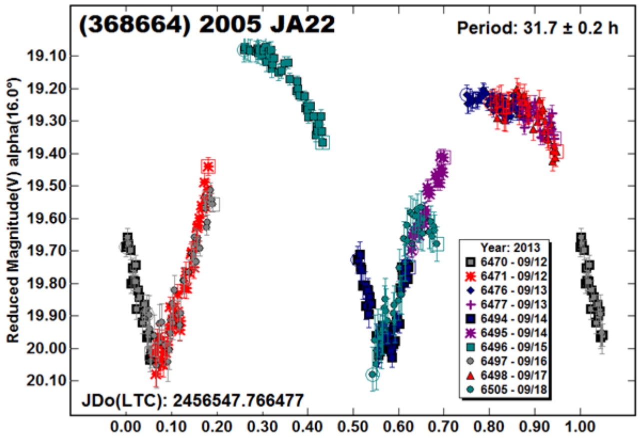
(350988) 2003 GW. The estimated diameter is 1.3 km ($H = 16.8$, $p_V = 0.20$). The certainty of the solution is diminished by the noise in the data and the somewhat unusual lightcurve shape.

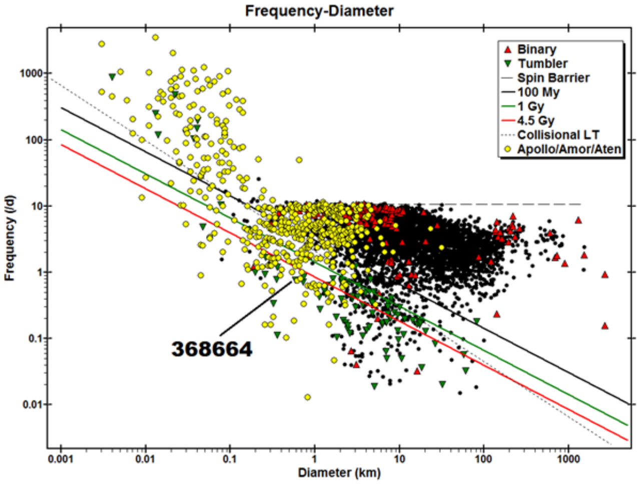


(361071) 2006 AO4. 2006 AO4 ($H = 15.5$, $p_V = 0.2$, $D = 2.4$ km) does not have a typical bimodal lightcurve. Given the uneven extremes, the half or double-period were ruled out. No previously reported periods could be found in the literature.



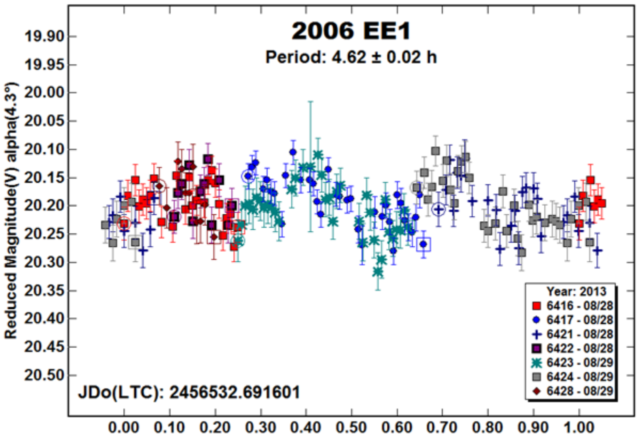
(368664) 2005 JA22. This 600 meter NEA ($H = 18.6$, $p_V = 0.20$) shows some signs of being in non-principal axis rotation (NPAR, see Pravec *et al.* 2005) in the form that at least one overlapping session cannot be fit to the general lightcurve and the maximum near 0.3 rotation phase is noticeably asymmetric in comparison to the general curve.

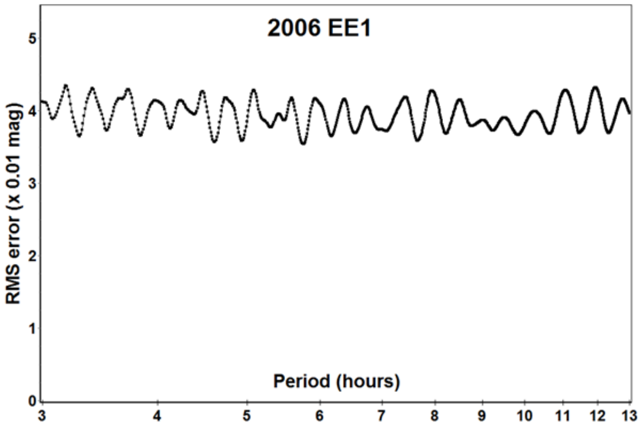




NPAR in this case is not unexpected since the simple rule of thumb for the damping time to go from tumbling to single axis rotation for the given period is well in excess of the age of the Solar System. More so, the collisional lifetime based on the size of this object makes that a considerable overestimate. The long period for such a small object puts the asteroid in the prime region for tumblers in the frequency-diameter plot generated from the LCDB (Warner *et al.* 2009) in which tumblers are seen as down-pointing green triangles.

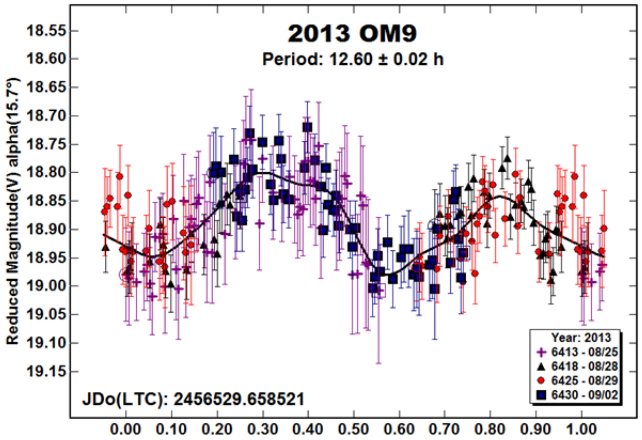
2006 EE1. The 325 meter ($H = 19.8$, $p_V = 0.20$) 2006 EE1 proved to be a difficult target. After two nights, there was no indication of a long period (overall slow rise or decline) within the calibration errors and the lightcurve was irregular with no clear indications of a unique period solution, as shown the period spectrum below.

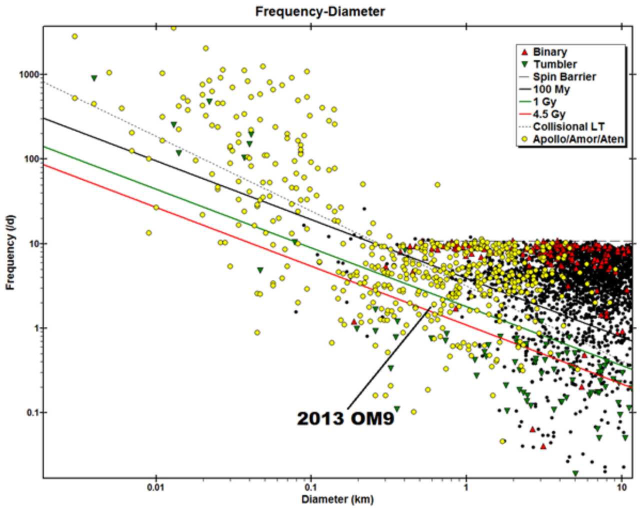




The lightcurve shows the data forced to one of the many possible periods using a fourth-order Fourier fit and should not be considered trustworthy, especially since using a second-order fit gives considerably different results. The asteroid moved too far south to follow it a third night and beyond.

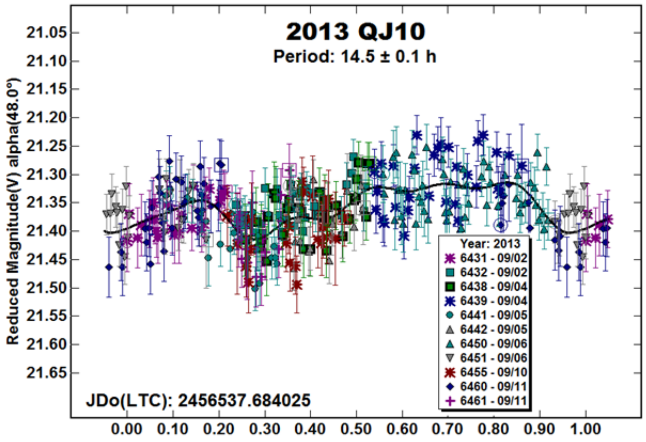
2013 OM9. At only 620 meters ($H = 18.4$, $p_V = 0.20$), 2013 OM9 lies below the collisional life-time line in the LCDB frequency-diameter plot, although the rule of thumb tumbling damping time lies between 1 and 4.5 Ga.

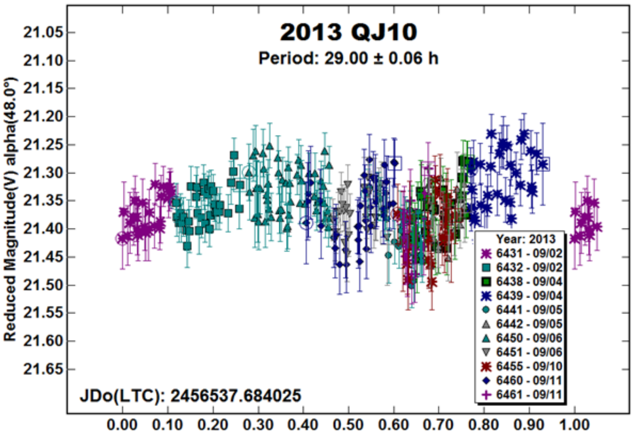


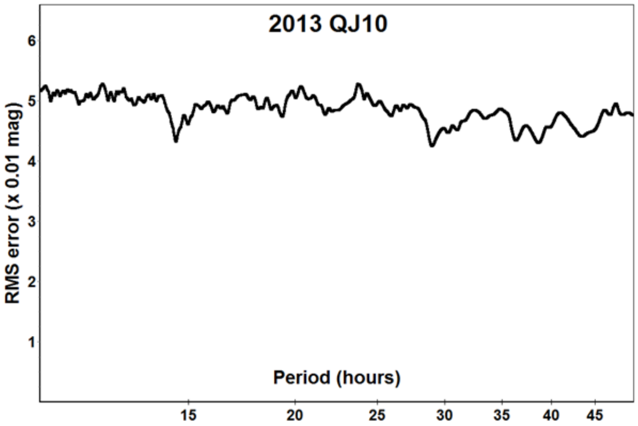


As such, it wouldn't be surprising to find signs of tumbling. However, the high noise in comparison to the lightcurve amplitude masked any obvious indications. Regardless, the period solution is reasonably sound if assuming single-axis rotation.

2013 QJ10. No definitive period could be found for this NEA of 375 meter effective diameter ($H = 19.5$, $p_V = 0.20$). The period spectrum shows a few possibilities favored over the general noise, and the two plots below are forced to two of those, but neither should be considered reliable.







## Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation Grant AST-1210099. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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# ROTATION PERIOD DETERMINATIONS FOR 205 MARTHA AND 482 PETRINA

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA
pilcher@ic.edu

(Received: 3 October)

The synodic rotation periods and amplitudes for two asteroids are reported: 205 Martha, 14.905 ± 0.001 h, amplitude ranging from 0.21 to 0.14 magnitudes; and 482 Petrina, 11.7922 ± 0.0001 h, *A* = 0.53 ± 0.05 mag. The changes in the lightcurve of 205 Martha in the interval 2013 Aug. 2 - Oct. 2 are documented.

Observations to determine the lightcurve parameters for 205 Martha and 482 Petrina were made at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001-E CCD. Photometric measurement and lightcurve construction are with *MPO Canopus* software. All exposures were 60 seconds, unguided, and used a clear filter. To reduce the number of points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes between consecutive points in each bin.

205 Martha. Previous efforts to find the period for this asteroid have yielded many different values, all of them being close to commensurate with an Earth day. This is especially likely to yield a convincing but incorrect alias period. These periods, and their approximate fractions of the Earth's period, are: Behrend (2003), 11.899 hours, 1/2; Behrend (2004), 11.92 hours, 1/2; Behrend (2007), 11.92 hours, 1/2; Chiorny *et al.* (2007), 9.78 hours, 2/5; Hawkins and Ditteon (2008), 9.74 hours, 2/5; Warner (2010), 39.8 hours, 5/3; Saylor and Leake (2012), 11.8 hours, 1/2; and Stephens and Warner (2012), 14.912 hours, 3/5, who also found the data

published in Warner (2010) compatible with a period of 14.93 hours.

New observations were made on 13 nights from 2013 Aug. 2 to Oct 2. During this interval, the lightcurve changed appreciably. A subset of five sessions from Aug. 2-6 near phase angle 19 degrees provides a good fit to a lightcurve phased to 14.891 ± 0.005 h with an amplitude 0.21 ± 0.02 mag. Another subset of five sessions from Sept. 24 - Oct. 2 near phase angle 3 degrees provides a good fit to a lightcurve phased to 14.911 ± 0.002 h with an amplitude of 0.14 ± 0.01 mag.

Each of these subsets was phased to its respective double period and each provides a lightcurve for which the two halves are the same within reasonable errors of observation. A shape model highly symmetric over a 180 degree rotation is required to provide these symmetric lightcurves. That the two halves furthermore change by the same amount requires even higher symmetry. The probability that a real asteroid could have a shape as symmetric as this assumption requires is extremely small and may be safely rejected. A period spectrum was drawn between 5 and 45 hours to include all previously suggested periods. The two minima near 14.9 and 29.8 hours, respectively, were much lower than any other minima. Trial lightcurves phased to all other minima were drawn and all showed large misfits. Therefore, it seems a period near 14.9 hours is secure.

A lightcurve drawn for all 13 sessions from 2013 Aug. 2 - Oct. 2 provides the best fit to a period 14.905 ± 0.001 h. The changes in the lightcurve shape are clearly shown. Those individual sessions following Aug. 6 and preceding Sept. 24 have lightcurves whose amplitudes are intermediate between those of Aug. 2-6 and Sept. 24 - Oct. 2 as described above.

482 Petrina. Previous rotation period and amplitude determinations for 482 Petrina all obtained different results and, as for 205 Martha, were close to being commensurate with an Earth day. The periods, approximate fraction of Earth's period, amplitude, and approximate ecliptic longitudes at which they were found are: Behrend (2002), a very uncertain 18 hours, 3/4, with a single four-hour lightcurve showing an amplitude >0.13 magnitude, 310 degrees; Buchheim (2007), 15.73 hours, 2/3, 0.48 magnitude, 184 degrees; Stephens (2009), 9.434 hours, 2/5, 0.06 magnitude, 295 degrees; and Pilcher *et al.* (2012), 11.794 hours, 1/2, 268 degrees, 0.10 magnitude, who also claimed that the lightcurves by Buchheim (2007) and Stephens (2009) were compatible with their 11.794 hour period.

Pilcher *et al.* (2012) used the amplitude-aspect relationship to suggest that the rotational pole was fairly close to the orbital plane and with a longitude of about 280 degrees, or between longitudes of the Stephens (2009) and Pilcher *et al.* (2012) small amplitude observations. This model predicts that the viewing aspect, near ecliptic longitude 9 degrees at the 2013 apparition, would be close to equatorial. If the prediction were correct, the amplitude would be nearly the maximum possible. In addition, the period would be 11.794 ± 0.01 h and the amplitude within a few hundredths magnitude of the 0.48 magnitudes reported by Buchheim (2007), whose observations were at 184 degrees. Only the JD of lightcurve minimum was completely unknown.

Analysis of observations on eight nights between 2013 Aug. 7 and Oct. 3 are fully compatible with this prediction and allow confidence in the spin model. They provide a good fit to a lightcurve with period 11.7922 ± 0.0001 h, amplitude 0.53 ± 0.05 mag. All other suggested periods are now definitively ruled out.

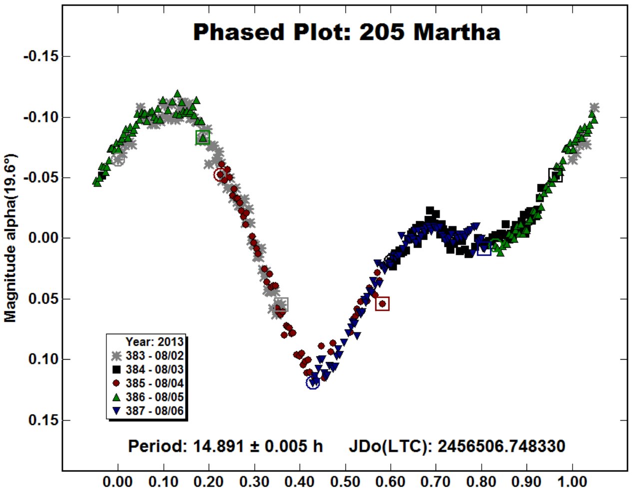

Figure 1. Lightcurve of 205 Martha for the interval 2013 Aug. 2-6.

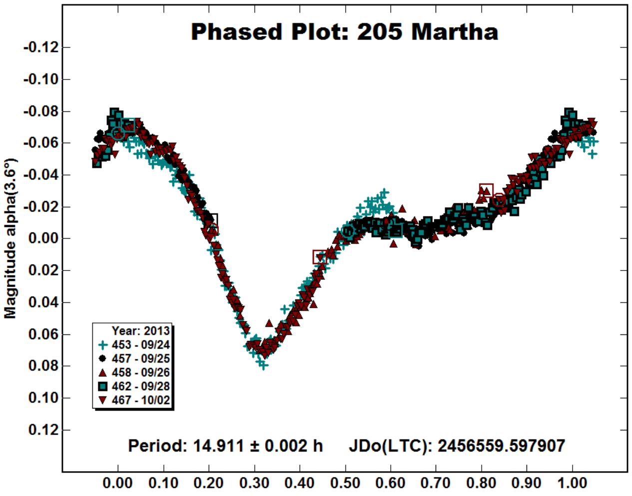

Figure 2. Lightcurve of 205 Martha for the interval 2013 Sept. 24 - Oct. 2.

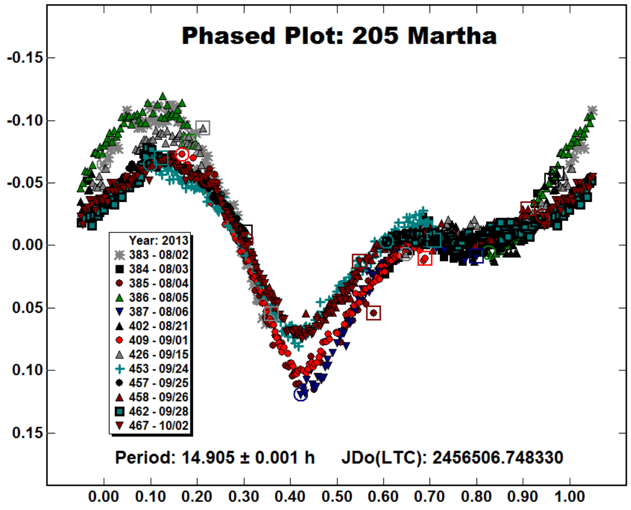

Figure 3. Lightcurve of 205 Martha for the interval 2013 Aug. 2 - Oct. 2.

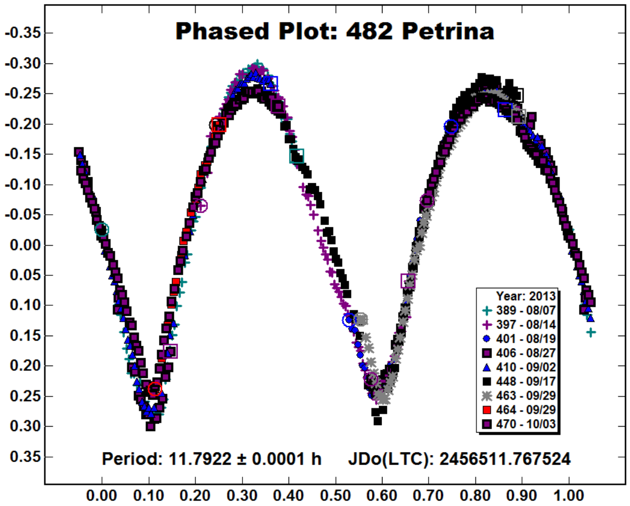

Figure 4. Lightcurve of 482 Petrina.

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# SPINS, LIGHTCURVES, AND BINARITY OF EIGHT ASTEROID PAIRS: 4905, 7745, 8306, 16815, 17288, 26416, 42946, AND 74096

David Polishook
Department of Earth, Atmospheric, and Planetary Science
Massachusetts Institute of Technology, Cambridge MA 02139
davidpol@mit.edu

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*Asteroid pairs* are two asteroids found to share almost identical orbital elements. Studies have shown that each pair had a single progenitor that split in the last couple of million years due to rotational-fission of a 'rubble-pile' structured body. Here we report the lightcurves and spins of eight primary members of asteroid pairs observed at the Wise Observatory in Israel. The lightcurves of two of the observed asteroids present light attenuation in addition to the standard periodicity; these are most probably the results of satellites causing mutual events of eclipse and occultation.

Pairs of asteroids move about the Sun on very similar orbits (Vokrouhlický and Nesvorný, 2008), but are gravitationally unbound to each other as opposed to a related class of binary asteroids. Using backward integration it was shown that members of each pair were in the same location in space at a certain time within the past couple of million years (Pravec *et al.*, 2010). This suggests a common origin for the components of each pair. Indeed, spectroscopic observations and broadband photometry studies have shown that members of observed pairs have similar spectra or colors (Moskovitz, 2012).

Photometric measurements (Pravec *et al.*, 2010) showed that rotation periods of the larger members of asteroid pairs are correlated with the mass ratio in a way that matches the rotational-fission mechanism (Fig. 1): (i) if the secondary (the smaller member) is massive enough, it carries a significant amount of angular momentum and the rotation rate of the primary (the larger member) will decelerate; (ii) if the secondary is not massive, the primary will continue to rotate fast. Therefore, it is accepted that each pair was formed by a fast rotating asteroid that split into two objects.

## Method

The observations took place on 17 nights between 2011 and 2013. Observations were performed using the 0.46-m Centurion telescope (Brosch *et al.*, 2008) of the Wise Observatory (MPC 097). The telescope was used with an SBIG STL-6303E CCD. This CCD has an array of 3072x2048 pixels and covers a wide field-of-view of 75x50 arcmin with a scale of 1.47 arcsec/pixel, unbinned. On 2011 April 1 and 2, and on 2013 October 28, Wise Observatory's 1-m telescope was used with a PI CCD. This CCD with its array of 1340x1300 pixels covers a field-of-view of 13x13 arcmin; the plate scale is 0.58 arcsec/pixel, unbinned. Observations were performed in "white light" with no filters (Clear). The asteroids were observed while crossing a single field, thus the same comparison stars were used to calibrate the images. See observational circumstances in Table I.

The images were reduced in a standard way. IRAF's *phot* function was used for the photometric measurements. After measuring, the photometric values were calibrated to a differential magnitude

| Asteroid | Date | Time span [hours] | N | r [AU] | Δ [AU] | α [Deg] | $L_{PAB}$ [Deg] | $B_{PAB}$ [Deg] | Mean M [Mag] |
|---|---|---|---|---|---|---|---|---|---|
| (4905) Hiromi | Oct 28, 2013 | 8.47 | 253 | 2.17 | 1.19 | 5.89 | 26.7 | -2.8 | 14.6 |
| *(7745) 1987 DB$_6$* | Oct 1, 2013 | 3.02 | 46 | 2.56 | 1.57 | 4.54 | 1.4 | -5.2 | 16.7 |
| | Oct 4, 2013 | 6.60 | 96 | 2.55 | 1.57 | 5.78 | 1.6 | -5.3 | 16.7 |
| *(8306) Shoko* | Sep 11, 2013 | 2.02 | 39 | 1.75 | 0.75 | 7.90 | 356.5 | 3.8 | 16.1 |
| | Sep 26, 2013 | 3.09 | 61 | 1.75 | 0.74 | 4.26 | 0.4 | 3.1 | 15.8 |
| | Sep 27, 2013 | 3.04 | 44 | 1.75 | 0.76 | 4.72 | 0.7 | 3.0 | 15.9 |
| | Sep 28, 2013 | 4.94 | 88 | 1.75 | 0.76 | 5.27 | 1.0 | 3.0 | 15.9 |
| | Oct 1, 2013 | 1.32 | 25 | 1.75 | 0.76 | 6.89 | 1.7 | 2.8 | 16.0 |
| (16815) 1997 UA$_9$ | Oct 30, 2013 | 6.85 | 91 | 2.61 | 1.68 | 9.53 | 19.0 | -8.1 | 16.4 |
| *(17288) 2000 NZ$_{10}$* | Dec 19, 2011 | 2.62 | 27 | 2.26 | 1.28 | 2.76 | 85.5 | 4.2 | 16.7 |
| | Dec 20, 2011 | 0.88 | 12 | 2.26 | 1.28 | 3.01 | 85.6 | 4.2 | 16.7 |
| *(26416) 1999 XM$_{84}$* | Mar 8, 2011 | 6.69 | 77 | 2.25 | 1.37 | 15.06 | 141.5 | -5.1 | 17.6 |
| | Mar 23, 2011 | 2.28 | 21 | 2.25 | 1.49 | 20.38 | 143.5 | -5.1 | 17.9 |
| | Apr 1, 2011 | 4.31 | 55 | 2.24 | 1.57 | 22.75 | 144.9 | -5.1 | 18.1 |
| | Apr 2, 2011 | 2.78 | 15 | 2.24 | 1.58 | 22.98 | 145.1 | -5.1 | 18.1 |
| *(42946) 1999 TU$_{95}$* | Jan 18, 2013 | 3.37 | 38 | 2.60 | 1.81 | 15.49 | 83.2 | -3.9 | 17.8 |
| | Jan 19, 2013 | 4.83 | 66 | 2.60 | 1.82 | 15.77 | 83.3 | -3.8 | 17.8 |
| (74096) 1998 QD$_{15}$ | Oct 25, 2013 | 0.54 | 7 | 2.29 | 1.29 | 2.04 | 29.0 | -0.2 | 18.0 |
| | Oct 28, 2013 | 7.84 | 99 | 2.29 | 1.31 | 3.67 | 29.3 | -0.3 | 18.2 |

Table I. Observational circumstances. Legend: asteroid name, observation date, nightly time span of the specific observation, the number of images obtained (N), the object's heliocentric (r) and geocentric distances (Δ), the phase angle (α), the Phase Angle Bisector (PAB) ecliptic coordinates ($L_{PAB}$, $B_{PAB}$), and the magnitude as posted by the MPC.

| Name | a [AU] | H [MPC] | Tax | D [km] | 1/2 | partner | dH [MPC] | Spin [hours] | Amp [mag] | U |
|---|---|---|---|---|---|---|---|---|---|---|
| 4905 | 2.60 | 12.1 | S | 10.8 ± 0.3 | 1 | 7813 | 1 | 6.05 ± 0.04 | 0.41 ± 0.01 | 3 |
| 7745 | 2.79 | 13.3 | C | 12.1 ± 0.6 | 1 | 37319 | 0.6 | 7.04 ± 0.01 | 0.89 ± 0.03 | 3 |
| 8306 | 2.24 | 14.9 | S | 3.0 ± 0.1 | 1 | 2011 SR158 | 3.2 | 3.604 ± 0.002 | 0.10 ± 0.01 | 2 |
| 16815 | 2.56 | 12.6 | C/X | 14 ± 4 | 1 | 2011 GD83 | 4.7 | 2.9 ± 0.1 | 0.20 ± 0.02 | 3 |
| 17288 | 2.29 | 14.1 | S | 4.3 ± 0.1 | 1 | 203489 | 2.3 | 4.3 ± 0.1 | 0.15 ± 0.05 | 2- |
| 26416 | 2.34 | 14.3 | - | 5.5 ± 2.5 | 1 | 214954 | 2.5 | 2.907 ± 0.001 | 0.2 ± 0.03 | 2 |
| 42946 | 2.57 | 13.6 | S | 5.4 ± 0.1 | 1 | 165548 | 2.1 | 3.42 ± 0.03 | 0.30 ± 0.05 | 3 |
| 74096 | 2.38 | 15.5 | S | 2.3 ± 0.1 | 1 | 224857 | 1.5 | 5.99 ± 0.07 | 0.27 ± 0.03 | 3 |

Table II. Results and physical data of the observed asteroids: asteroid name, semi-major axis, absolute magnitude, taxonomy, diameter, membership role in the pair, name of the partner in the pair, absolute magnitude difference between the pairs, rotation period, lightcurve amplitude, quality code.

level using ~1000 local comparison stars (~30 stars when using the PI CCD). The brightness of these stars remained constant to ± 0.02 mag. Analysis for the lightcurve period and amplitude was done by Fourier series analysis (Harris and Lupishko, 1989). See Polishook and Brosch (2009) for complete description about reduction, measurements, calibration, and analysis.

## Results

Here we report about photometric observations of eight primary members of asteroid pairs: (4905) Hiromi, (7745) 1987 DB6, (8306) Shoko, (16815) 1997 UA9, (17288) 2000 NZ10, (26416) 1999 XM84, (42946) 1999 TU95 and (74096) 1998 QD15 (Fig. 2-11). 17288, 26416, and 42946 were reported by Pravec and Vokrouhlicky (2009); 4905, 7745, 8306, 16815, and 74096 were reported by Pravec (personal communication). The orbital and physical parameters of the observed pairs, including their period and lightcurve amplitude, appear in Table II. Semi-major axis, absolute magnitude *H*, and the difference between the absolute magnitudes of the primary and the secondary *dH*, are from the MPC website. Taxonomy is from Polishook *et al.* (2013), and the diameter was calculated using the absolute magnitude and an albedo value, assumed by the taxonomy (0.22 ± 0.01 for S-complex, 0.06 ± 0.01 for C-complex, and 0.05 to 0.4 for unknown taxonomy; Mainzer *et al.*, 2011). All of the secondary members, but one (37319, the secondary of 7745), are significantly smaller (diameter ratio $D_2/D_1$, range between 0.1 and 0.6) and lighter (mass ratio $M_2/M_1$, range between 0.1% and 25%) compared to the observed primary members, assuming similar albedo and density values. Plotting the rotational periods as a function of the size ratio (Fig. 1), it is interesting to note that the correlation noted by Pravec *et al.* (2010) is kept for seven of the pairs observed here.

Therefore, these seven pairs were probably formed by the rotational-fission mechanism. See below about 7745, the exception to this rule.

(4905) Hiromi. We drive a rotation period of 6.05 ± 0.04 hours and amplitude of 0.41 ± 0.01 magnitudes (Fig. 2).

(7745) 1987 DB6. We drive a rotation period of 7.04 ± 0.01 hours and amplitude of 0.89 ± 0.03 magnitudes (Fig. 3). 7745 is almost similar in size to its secondary 37319 ($D_2/D_1 = 0.8 \pm 0.1$, $M_2/M_1 = 0.4 \pm 0.2$). This mass ratio is larger than the maximal limit as predicted by theoretical models of the rotational-fission mechanism (e.g., Scheeres, 2007). Since 7745 and 37319 are part of the dynamical family of the asteroid (668) Dora (AstDys website: *http://hamilton.dm.unipi.it/astdys/*), their formation might involve a catastrophic collision rather than the classical rotational-fission mechanism (Pravec *et al*., 2010). An alternative scenario points to a mistake in the absolute magnitude values of one or both pair members as given by the Minor Planet Center. Such a mistake can happen if the asteroid was observed during a minima or maxima of its lightcurve. Since the amplitude of 7745 is quite large, the possibility of a mistake in the reported absolute magnitude for 7745 is likely. Decreasing the absolute magnitude of 7745 by 0.7 mag puts it in the “safe zone” for rotational-fission as predicted by the models. Therefore, measuring the absolute magnitude of 7745 is important to understand its origin and evolution.

(8306) Shoko. We derive a rotation period of 3.604 ± 0.002 hours and amplitude of 0.10 ± 0.01 magnitudes (Fig. 4). In the lightcurves of 2013 September 26 and 28, it is possible to note attenuation of the light on top the lightcurve periodicity (Fig. 5). This is due, most probably, to the existence of a satellite that creates eclipse and occultation events. These parts of the lightcurve were omitted when doing period analysis. We did not observe 8306 long enough in order to derive the orbital parameters of its satellite. Mutual events were observed on two additional asteroid pairs, (3749) Balam, which was first defined as a binary asteroid (Merline *et al.*, 2004) and only later as an asteroid pair (Vokrouhlický, 2009), and (25884) 2000 SQ4 (Warner et al., 2012). Since binary asteroids and asteroid pairs can be formed by the same rotational-fission mechanism (Jacobson and Scheeres, 2011), it is not surprising that some asteroids present both characteristics. The ratio of binaries that are also pairs among the population of binary asteroids can shed light on the way asteroids shed mass and disintegrate due to fast rotation and on the way they maintain or lose their satellites.

(16815) 1997 UA9. We derive a rotation period of 2.9 ± 0.1 hours and amplitude of 0.20 ± 0.02 magnitudes (Fig. 6). Such a fast rotation is characterized for asteroids that ejected small secondaries; indeed, the diameter of 16815 is ten times larger than the diameter of its secondary.

(17288) 2000 NZ10. We derive a rotation period of 4.3 ± 0.1 hours and amplitude of 0.15 ± 0.05 magnitudes (Fig. 7).

(26416) 1999 XM84. We derive a rotation period of 2.907 ± 0.002 hours and amplitude of 0.2 ± 0.03 magnitudes (Fig. 8). As in the case of 8306, 26416’s lightcurve also shows light attenuations probably caused by the existence of a satellite (Fig. 9). These parts of the lightcurve were omitted during period analysis. We did not observe 26416 long enough in order to derive the orbital parameters of its satellite.

(42946) 1999 TU95. We derive a rotation period of 3.42 ± 0.03 hours and amplitude of 0.30 ± 0.05 magnitudes (Fig. 10).

(74096) 1998 QD15. We derive a rotation period of 4.3 ± 0.1 hours and amplitude of 0.15 ± 0.05 magnitudes (Fig. 11).

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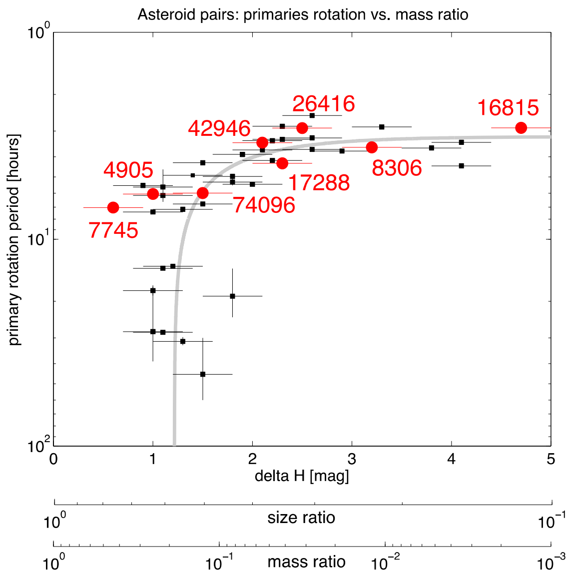

Fig. 1: Correlation between the rotation period of the primary to the size/mass ratio between the two components of each pair. The data (black squares) and the model (gray line) were published by Pravec et al. (2010). The eight asteroids observed here are marked in red. In most cases, the error on the Y-axis is negligible.

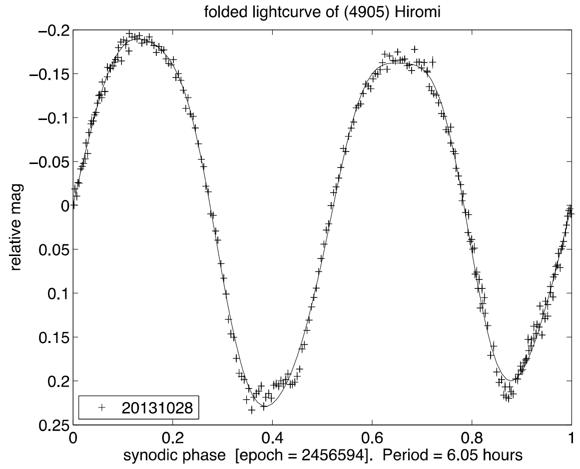

Fig. 2: The lightcurve of (4905) Hiromi folded by a period of 6.05 hours.

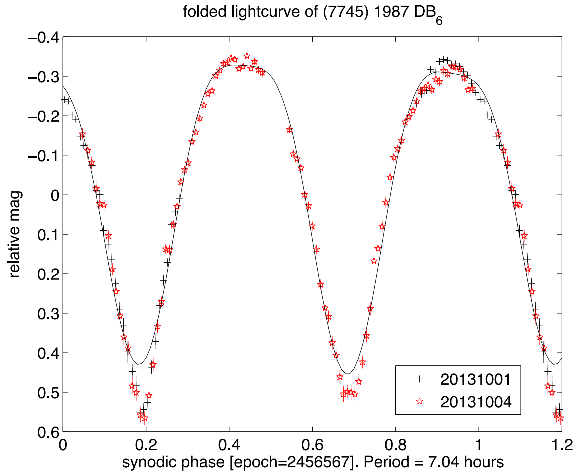

Fig. 3: The lightcurve of (7745) 1987 DB6 folded by a period of 7.04 hours.

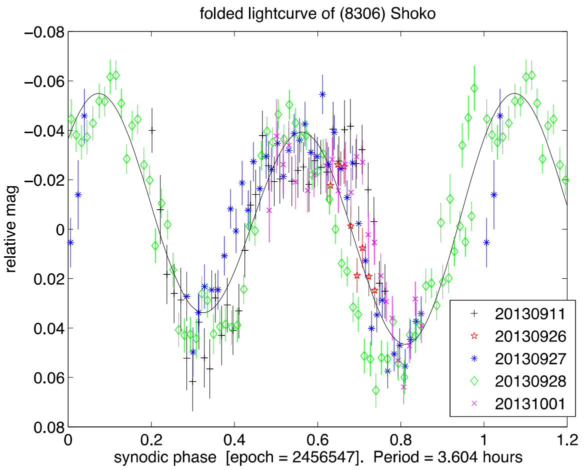

Fig. 4: The lightcurve of (8306) Shoko folded by a period of 3.604 hours.

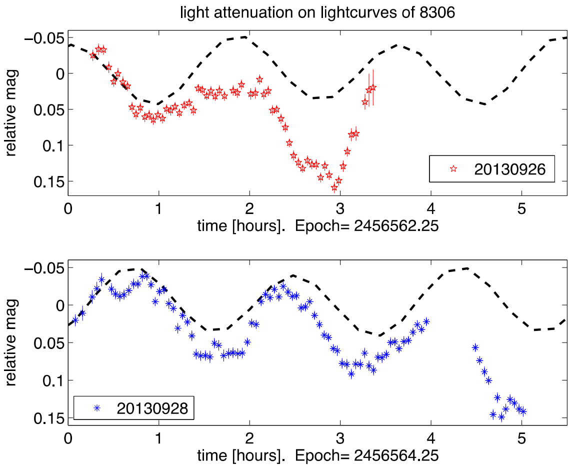

Fig. 5: Light attenuation from the periodicity model of 8306 (dashed-line) was seen on two nights. This is probably caused by the existence of a satellite causing mutual events.

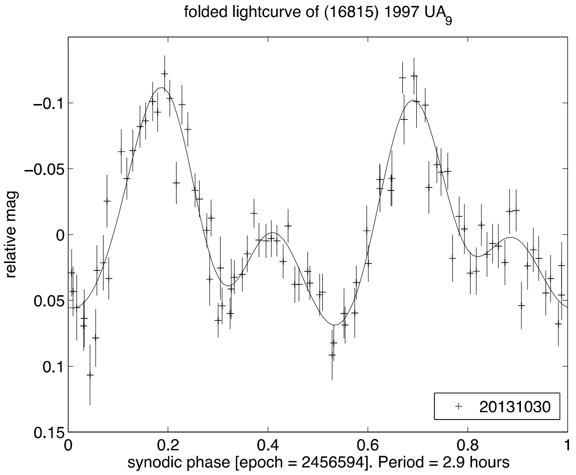

Fig. 6: The lightcurve of (16815) 1997 UA9 folded by a period of 2.9 hours.

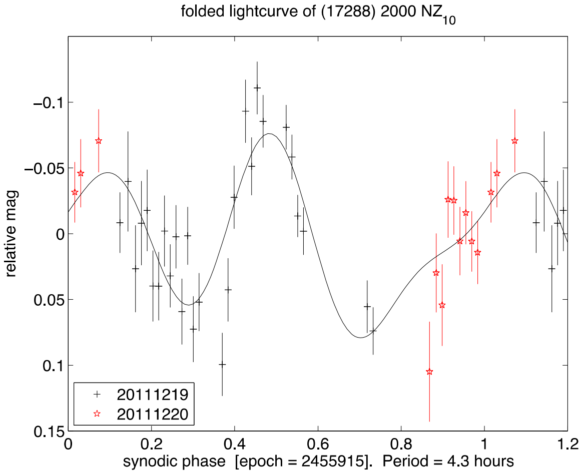

Fig. 7: The lightcurve of (17288) 2000 NZ10 folded by a period of 4.3 hours.

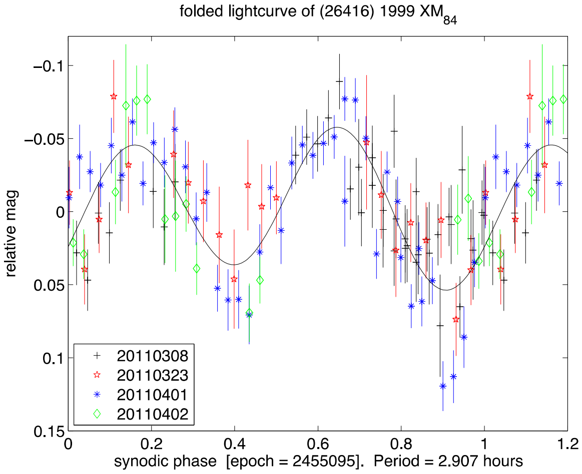

Fig. 8: The lightcurve of (26416) 1999 XM84 folded by a period of 2.907 hours.

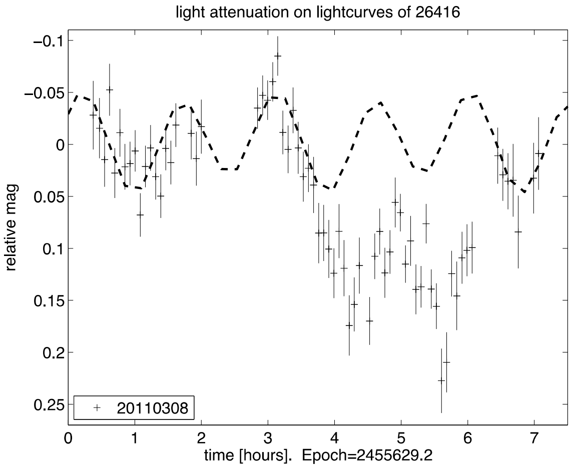

Fig. 9: Light attenuation from the periodicity model of 26416 (dashed-line) was seen on one night. This is probably caused by the existence of a satellite causing mutual events.

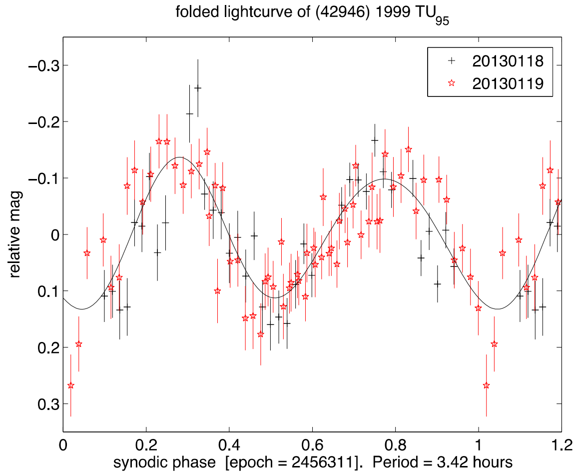

Fig. 10: The lightcurve of (42946) 1999 TU95 folded by a period of 3.42 hours.

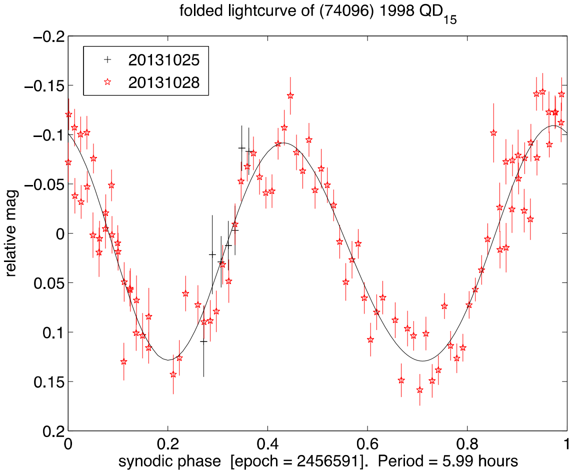

Fig. 11: The lightcurve of (74096) 1998 QD15 folded by a period of 5.99 hours.

# BINARY ASTEROID LIGHTCURVE ANALYSIS AT THE CS3-PALMER DIVIDE STATION: 2013 JUNE-SEPTEMBER

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

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Lightcurves from CCD photometry observations for four suspected or confirmed binary asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2013 June through September. All four objects are members of the Hungaria family/group. 5968 Trauger showed signs of a satellite based on a single possible event. (11217) 1999 JC4 is a more likely candidate based on a strong secondary period; no mutual events were observed, however. (15822) 1999 TV15 is the most likely new binary discovery by the author, showing mutual events in its lightcurve, albeit they were close to the limit of detection. (76818) 2000 RG79 was a known binary asteroid (Warner *et al.*, 2005). The 2013 observations provided additional data for modeling the system.

CCD photometric observations of four Hungaria asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 June through September. Table I gives a listing of the telescope/CCD camera combinations used for observations at the facility. 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 |
|---|---|---|
| PDS-1-12N | 0.30-m f/6.3 Schmidt-Cass | ST-9XE |
| PDS-1-14S | 0.35-m f/9.1 Schmidt-Cass | FLI-1001E |
| PDS-2-14N | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-2-14S | 0.35-m f/9.1 Schmidt-Cass | STL-1001E |
| PDS-20 | 0.50-m f/8.1 Ritchey-Chretien | FLI-1001E |

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

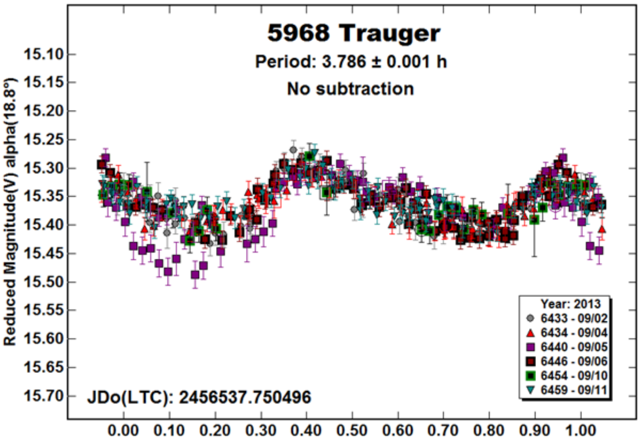
All lightcurve observations are made with no filter (a clear filter can result in a 0.1-0.3 magnitude loss) with comparison stars for differential photometry limited to near solar-color in order to minimize errors due to color differences. The exposures are guided. The duration varies depending on the asteroid's brightness and sky motion. In most cases, however, it is 240 seconds.

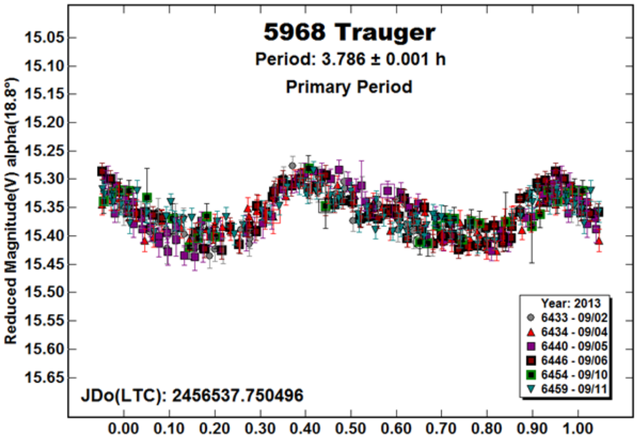
Measurements are done using *MPO Canopus* and its Comp Star Selector utility that finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes are usually taken from the MPOSC3 catalog, which is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007b). When possible, magnitudes are taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ±0.05 magnitude or better, but on occasion are as large as 0.1 mag. This reasonably good consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis is also done using MPO Canopus, which implements the FALC algorithm developed by Harris (Harris *et al.*, 1989).

In the primary lightcurves below, the magnitudes in the Y-axis are sky magnitudes in Johnson V (or Cousins R). If the Y-axis title includes "Reduced Magnitudes", the values have been converted to unity distance by applying –5*log (rΔ) to the measured magnitude with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using *G* = 0.15, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0. For the secondary lightcurves, the magnitudes are in reference to the average value of the data after subtracting the primary lightcurve.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is referred to the asteroid lightcurve database (LCDB, Warner *et al.,* 2009a). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with bibcodes, is also available for download at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

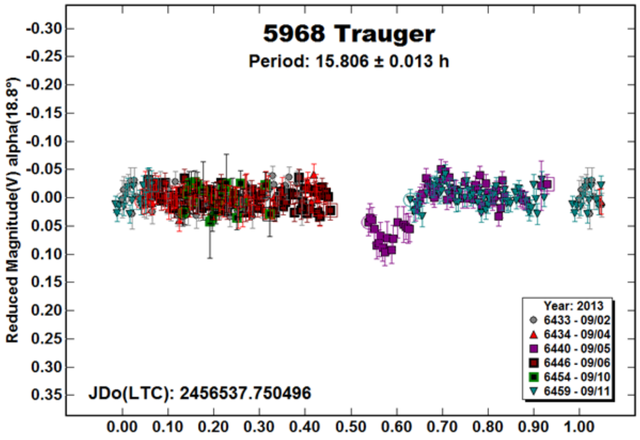
5968 Trauger. This was the fourth apparition at which the asteroid had been observed by the author (Warner, 2006; 2011a; 2012). Careful re-examination of the data sets prior to 2013 did not find any traces of a satellite, be it a second period or apparent *mutual events* due to occultations and/or eclipses involving a satellite.

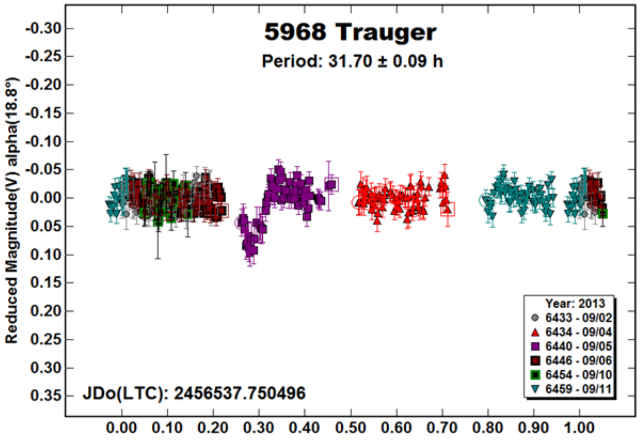




| Number | Name | 2013 (mm/dd) | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 5968 | Trauger | 09/02-09/11 | 349 | 18.9 14.1 | 9 | 5 | 3.786 | 0.001 | 0.11 | 0.01 |
| 11217 | 1999 JC4 | 07/07-08/01 | 420 | 28.3 23.1 | 323 | 28 | 4.8219 | 0.0004 | 0.11 | 0.01 |
| 15822 | 1994 TV15 | 08/15-08/25 | 549 | 23.1 18.5 | 350 | 17 | 2.95998 | 0.00006 | 0.27 | 0.01 |
| 76818 | 2000 RG79 | 08/03-08/13 | 774 | 13.7 11.2 | 326 | 14 | 3.1669 | 0.0002 | 0.15 | 0.02 |

Table II. Observing circumstances. Rows in bold italics text indicate members of the Hungaria group/family. Period is that of the primary in a suspected or known binary system. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. $L_{PAB}$ and $B_{PAB}$ are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

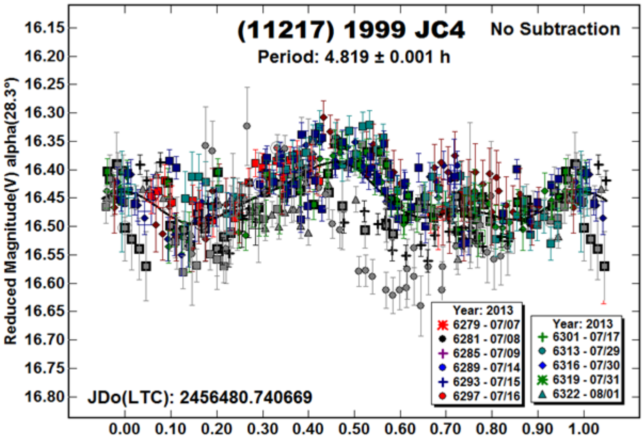


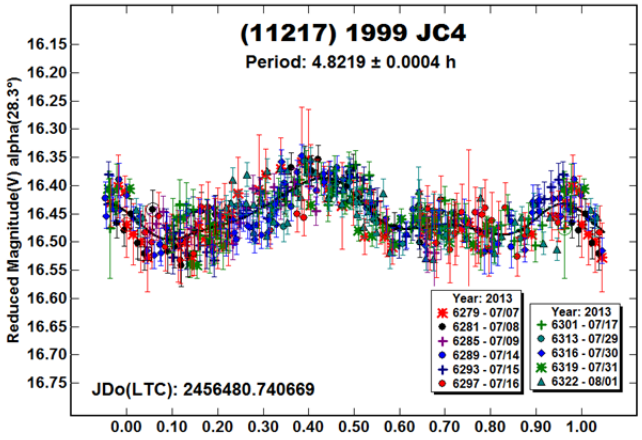


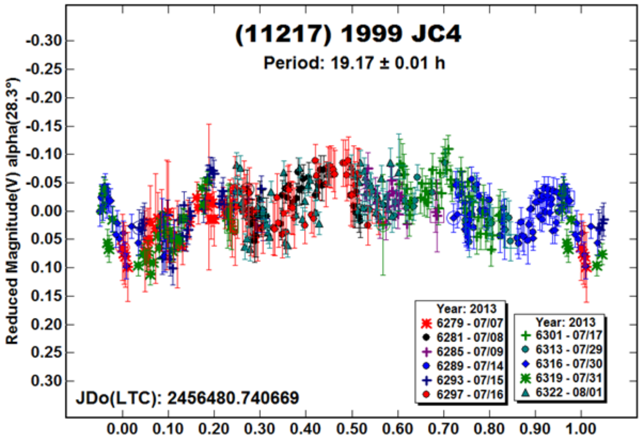
In 2013, one such event appears to have been observed on Sep 5 but, unfortunately, there were no confirming detections on any other night. The supposed event, seen as a deviation between 0.0 and 0.3 rotation phase in the "No Subtraction" plot seemed to have the correct shape and duration as judged from the lightcurves of known binary asteroids. When the primary rotation ("Primary Period" plot) of 3.786 ± 0.001 h is removed, the alleged event is very apparent. The two plots showing the lightcurve after removing the rotation of the primary are phased to two possible solutions. Without a second event, however, these are only first-order estimates.

If nothing else, the 2013 observations helped confirmed the rotation period of about 3.78 h. Given the lack of evidence from past apparitions (not always the best test) and only the one night showing a deviation, the most that can be said is that this is an asteroid of interest and observations are encouraged when the asteroid is again near the same phase angle bisector longitude or its 180° opposite, i.e., 10° or 190°.

(11217) 1999 JC4. No previously published period could be found for 1999 JC4.





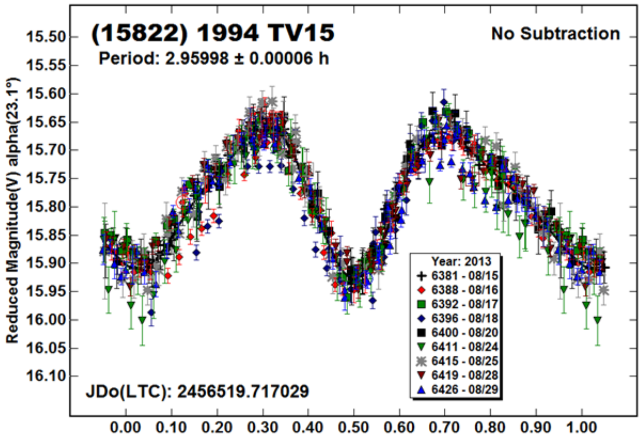


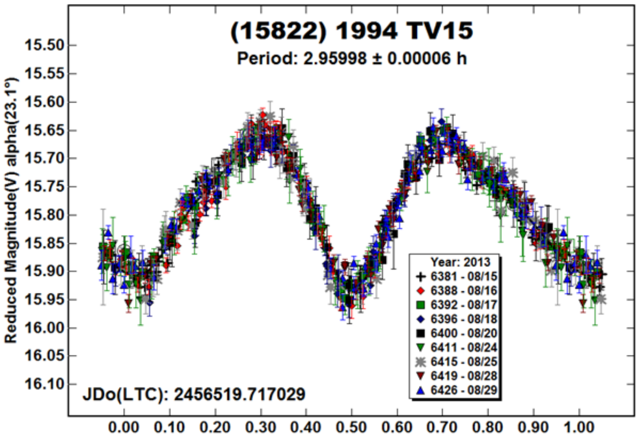
The single period analysis lightcurve ("No Subtraction") appears to have large amounts of scatter. The dual period search feature of *MPO Canopus* improved things considerably by finding a primary lightcurve with a period of $P = 4.8219 \pm 0.0004$ h and amplitude of $A = 0.11 \pm 0.01$ mag along with a secondary period of 19.17 ± 0.01 h. The secondary lightcurve shows a trait common to binary asteroids, i.e., an upward bowing. This is thought to be the result of the rotation of an elongated satellite that is tidally locked to its orbital period. There are *very* faint hints of mutual events at about 0.3 and 0.8 rotation phase in the secondary curve, but they are barely above the noise level, if at all.

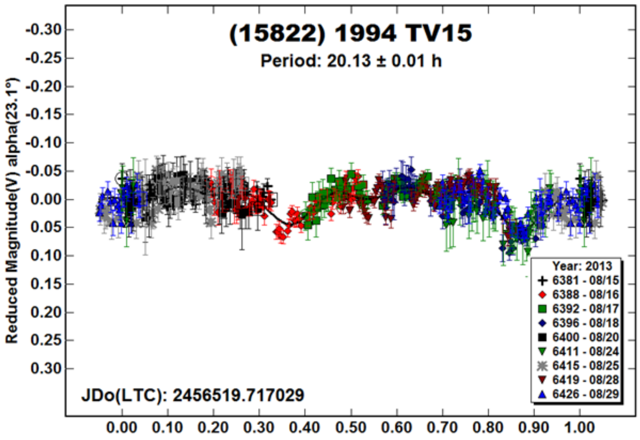
Generally speaking, when using only photometry, an asteroid is not considered to be a confirmed binary unless mutual events are seen, even though there is strong evidence for a second period and the shape of the secondary lightcurve is similar to the one for 1999 JC4. Therefore, this must be considered only a probable, possibly likely, binary until additional supporting evidence is produced.

(15822) 1994 TV15. The evidence for a satellite in an unsubtracted lightcurve is not always obvious, especially when the amplitude of the lightcurve is on the order of 0.3 mag and the deviations due to mutual events are only 0.05 mag. Such was the case for 1994 TV15. However, the unsubtracted lightcurve showed deviations from about 0.7 to 1.0 rotation phase on several nights and so the dual period search feature in *MPO Canopus* was applied.

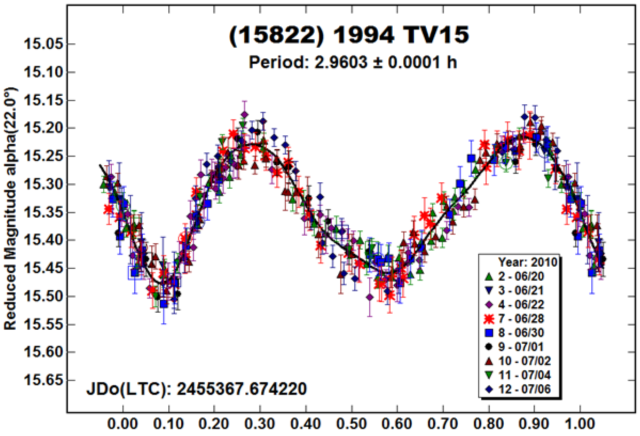
This resulted in finding a primary period identical to the unsubtracted period of $P = 2.95998 \pm 0.00006$ h and a significantly lower RMS value for the fit to the Fourier curve. The purported events are seen after subtracting the primary period from the data and appear at about 0.4 and 0.9 rotation phase. The depth of the shallower event can be used to estimate the effective size ratio of the secondary to the primary. In this case, the drop was 0.05 mag, which gives Ds/Dp = 0.19 ± 0.02. Since the deeper event does not appear to be total, i.e., it is not flat, this ratio is a minimum, meaning that the purported satellite could be larger.

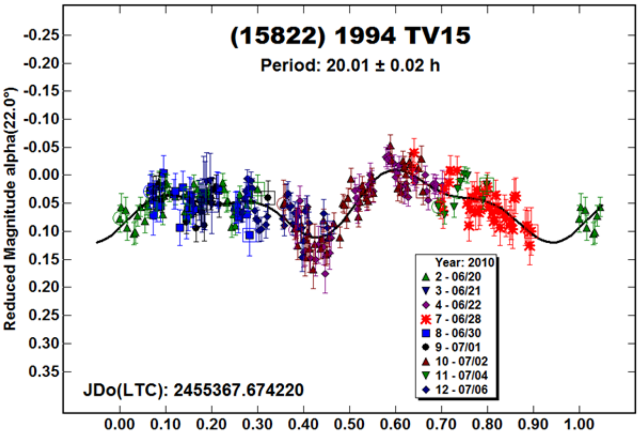






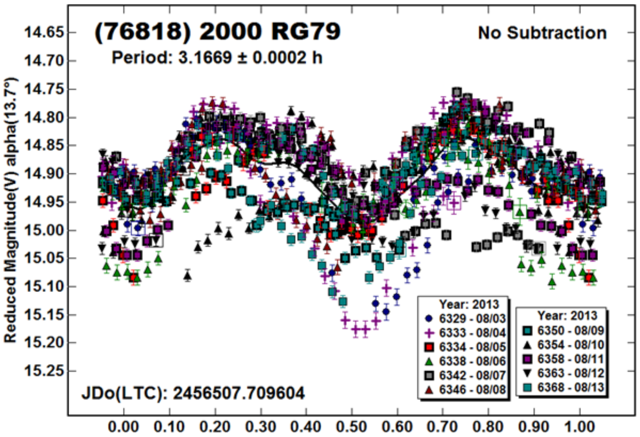
This Hungaria had been observed at two previous apparitions (Warner, 2007a; Warner and Pray, 2011b). There were no indications of a satellite in 2007. However, the observations from 2010 reported by Warner and Pray did suggest the existence of a satellite with an orbital period of about 37 hours. Suspected events were seen on three nights in mid-June but none in late June or early July. Assuming there is a satellite, those observations may have been out of "eclipse season" due to changing geometry.

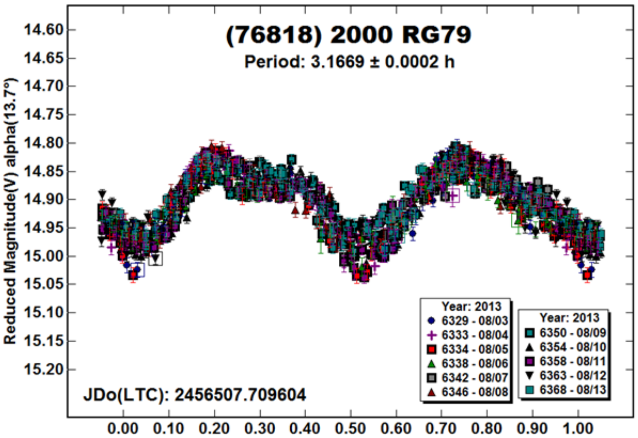


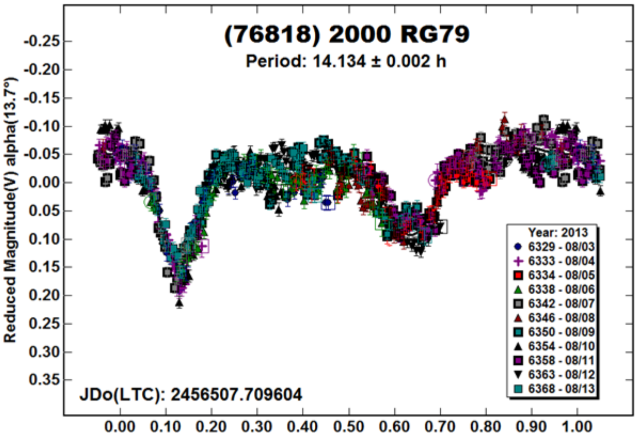


The 2010 data set was re-visited to see if it could be fit to the 2013 results. Two observing sessions used in the initial analysis were discarded for being too sparse and/or noisy. The revised analysis found good evidence for mutual events with an orbital period very similar to the one based on the 2013 data set. The size ratio estimate from this data set is also about Ds/Dp = 0.19. This asteroid should be considered a likely binary, if not confirmed, although future observations are strongly encouraged to refine and confirm the results reported here.

(76818) 2000 RG79. Since this was a known binary (Warner *et al.*, 2005), the 2013 observations were intended to provide additional data for modeling the system. The unsubtracted lightcurve left no doubt for there being evidence of a satellite, if one could safely assume no random or systematic errors in the data. The primary period of 3.1669 ± 0.0002 h agrees well with previous results (Warner *et al.*, 2005, 2009b; Pravec *et al.*, 2012), as does the orbital period of 14.134 ± 0.002 h. The mutual events seemed to have evolved a little over the 10-day span of the observations, most notably in the secondary (shallower) event. Assuming a depth of 0.12 mag, this gives an estimated size ratio of Ds/Dp = 0.32 ± 0.02. This is a minimum since the events do not appear to be total. Pravec *et al*. (2012) gave Ds/Dp ≥ 0.35.







## Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation Grant AST-1210099. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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# LIGHTCURVE RESULTS FOR 899 JOKASTE AND 3782 CELLE FROM WALLACE ASTROPHYSICAL OBSERVATORY

Rachel Bowens-Rubin
Phoebe Henderson
Dept. of Earth, Atmospheric and Planetary Sciences, 54-425
Massachusetts Institute of Technology
77 Massachusetts Avenue Cambridge, MA 02139-4307
rbowru@mit.edu, phoebeh@mit.edu

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Photometric observations of the asteroids 899 Jokaste and 3782 Celle were measured at Wallace Astrophysical Observatory (WAO) during 2012 July. The rotational period and amplitude obtained during the analysis of these data were: 899 Jokaste, $P$ = 6.247 ± 0.003 h, $A$ = 0.18 ± 0.01 mag; 3782 Celle, $P$ = 3.8389 –0.0007/+0.0006 h or $P$ = 3.9419 –0.0007/+0.0005 h, $A$ = 0.11 ± 0.01 mag.

Observations of 899 Jokaste and 3782 Celle were carried out at George R. Wallace Jr. Astrophysical Observatory (WAO) using the observatory's 0.6-meter Research Cassegrain Cloudé reflector and 0.35-meter Celestron Schmidt-Cassegrain telescopes. These telescopes were equipped with SBIG STL-1001E CCD cameras. Image reduction was completed using *IRAF*.

The resulting lightcurves were fit to determine the primary rotational period and amplitude of each asteroid's rotation. These fits utilized a Marquardt Gradient-Expansion algorithm to fit a fourth-degree Fourier series (with a delta-function offset between each data session). The amplitude reported for each asteroid is the maximum amplitude associated with the first-order terms in the Fourier series. The data were light-time corrected using information from the JPL Small-Body Database.

899 Jokaste. Observations of 899 Jokaste were made between 2012 July 11-13 using WAO's 0.35-meter and 0.60-meter telescopes. The sessions from July 11-13 were obtained using one of WAO's 0.35-meter telescopes and one session, on July 13, was obtained using the 0.60-meter telescope. The observations on July 11 and 12 (UT) were made using a clear filter, while observations on July 13 were made using a red filter. Figure 1 shows a lightcurve for the 899 Jokaste data.

Fitting was performed using all four data sessions as well as excluding July 11, which had the lowest signal to noise of the sessions. The fit that excluded July 11 was more stable and produced lower chi-square values. Thus, the solutions reported for the period and amplitude for 899 Jokaste do not include the data from July 11.

The best-fit period was determined to be $P$ = 6.247 ± 0.003 h with an amplitude of $A$ = 0.18 ± 0.01 mag. This solution for the rotation period is within one-sigma of those found in Stephens (2004, 6.245 ± 0.005 h), Clark (2006, 6.2475 ± 0.0001 h), and Hanus (2011, 6.24812 h). The solution is also within two-sigma of the result reported by Stephens (2004, 6.245 ± 0.005 h). Figure 2 shows chi-square distribution, which includes a comparison of the best-fit result to the previous period measurements.

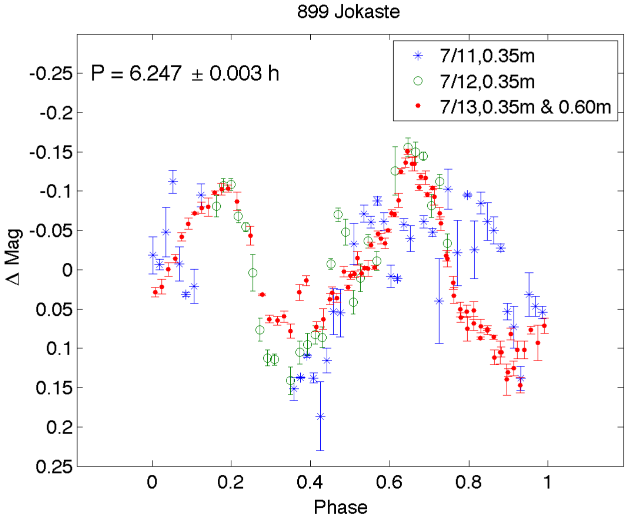

Figure 1: Wallace Observatory lightcurve for asteroid 899 Jokaste. The rotational period of 899 Jokaste was best fit to a period of $P$ = 6.247 ± 0.003 h with an amplitude of $A$ = 0.18 ± 0.01 mag. This fit was made using the data from July 12 and 13 (and excluded July 11). The data from the three nights of observation are displayed in bins of 6-minutes.

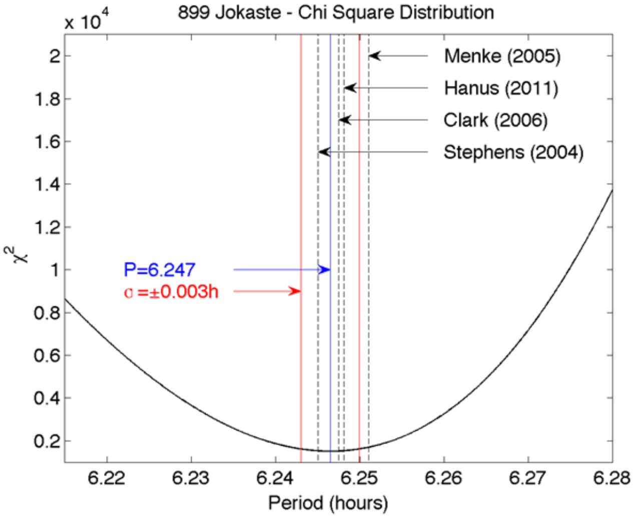

Figure 2: 899 Jokaste: Chi-Square Distribution by Period. The smallest chi-square value occurred at a period of $P$ = 6.247 h (represented in blue). The one-sigma error margin (represented in red) intersects the chi-square distribution at a values ±0.003 h from the period of best fit. The previously measured results from Stephens (2004), Clark (2006), and Hanus (2011) occur within one-sigma error of the solution.

3782 Celle. Observations of 3782 Celle were made on 2012 July 13, 25, and 31 using WAO's 0.35-meter and 0.60-meter telescopes. Two sessions, July 13 and 25, were obtained using a 0.35-meter telescope and two sessions, July 25 and 31, were obtained using the 0.60-meter telescope. All observations were made using a clear filter. Lightcurves for the 3782 Celle data are shown in Figure 3 and Figure 4.

3782 Celle is a known binary system (Ryan, 2004). The data from July 13 show signs of a mutual event, so the dataset was excluded from the fit for the primary rotation period and amplitude.

The one-sigma solution for the rotation period revealed two possible values: $P$ = 3.8389 –0.0007/+0.0006 h and $P$ = 3.9419 –0.0007/+0.0005 h, with an amplitude of $A$ = 0.11 ± 0.01 mag. The lower period solution was within one-sigma of the result presented in Ryan (2004, 3.839 ± 0.002 h). Figure 5 shows the 3782 Celle chi-square distribution, which includes a comparison of the solutions to the previously measured period.

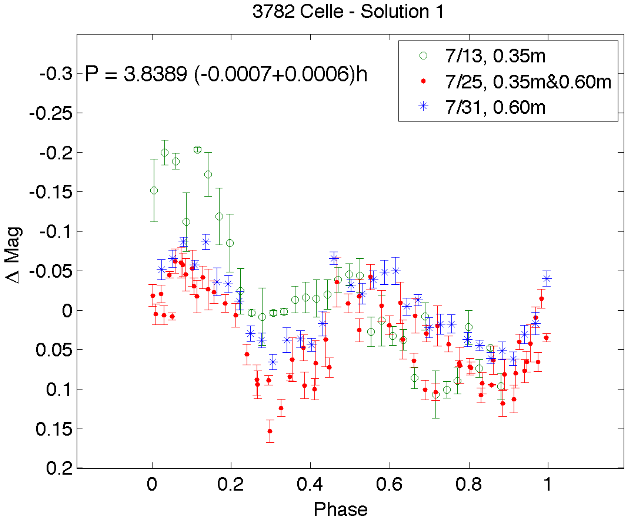

Figure 3: Wallace Observatory lightcurve for asteroid 3782 Celle; Period Solution $P$ = 3.8389 –0.0007, +0.0006 h. The fit for the rotational period of the 3782 Celle was made using data from July 25 and 31 (excluding July 13) and produced two possible results. These data are displayed in bins of 6-minutes and phased to the lower period solution ($P$ = 3.8389h).

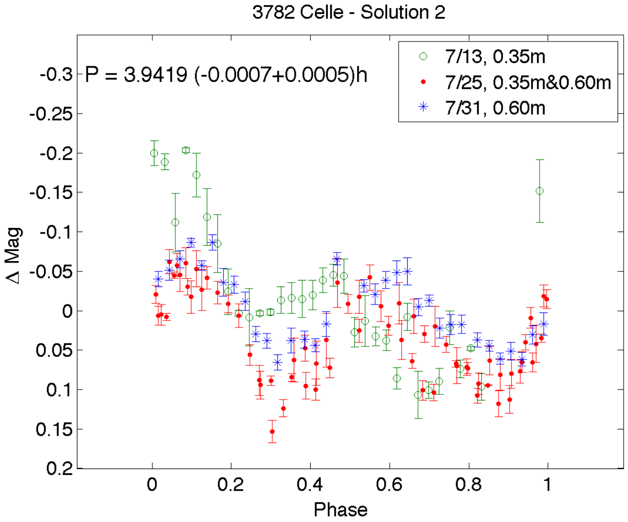

Figure 4: Wallace Observatory lightcurve for asteroid 3782 Celle; Period Solution $P$ = 3.9419 –0.0007, + 0.0005h. The fit for the rotational period of the 3782 Celle was made using data from July 25 and 31 (excluding July 13) and produced two possible results. These data are displayed in bins of 6-minutes and phased to the higher period solution ($P$ = 3.8389h).

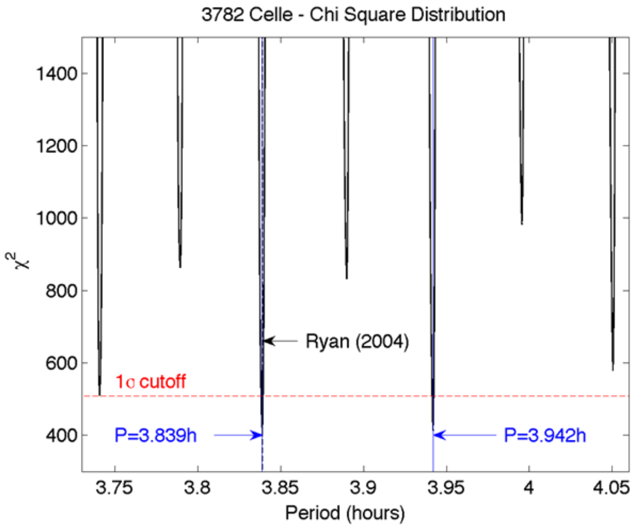

Figure 5: 3782 Celle: Chi-Square Value by Period. Two solutions for the rotational period of 3782 Celle (represented in blue) had chi-square values below the one-sigma cutoff (represented in red) for the fit to the WAO data: $P$ = 3.8389 +0.0007/–0.0006 and $P$ = 3.9419 +0.0007/–0.0005. The previously measured result from Ryan (2004) is within one-sigma of the lower period solution.

## Acknowledgements

We would like to thank our advisor, Michael Person, and David Polishook for overseeing the observations and data reduction. We would also like to thank Amanda Zangari for offering her advice on the analysis, and Tim Brothers for his assistance at WAO.

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# PHOTOMETRIC OBSERVATIONS OF ASTEROID 570 KYTHERA USING THE VIRTUAL TELESCOPE PROJECT

Cristian F. Chavez
Department of Mechanical Engineering
Pontificia Universidad Católica de Chile
cchavez@ing.puc.cl

(Received: 15 October)

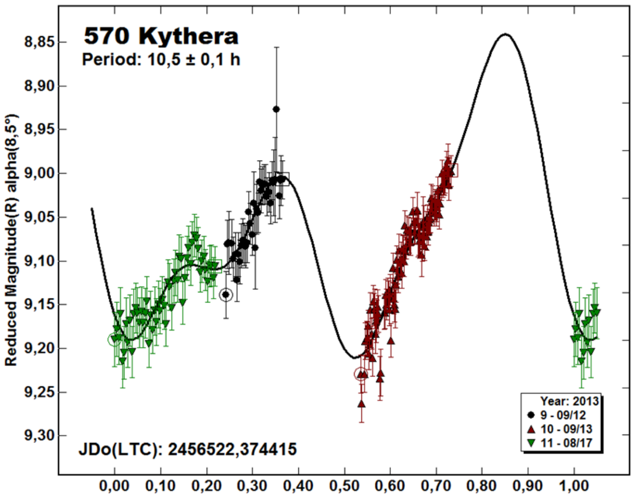
Asteroid 570 Kythera was remotely tracked and observed using the Virtual Telescope Project 2.0 instruments during three sessions performed in 2013 August and September. An inconclusive period of 10.5 hours was derived, which needs to be verified or corrected in future research.

Asteroid 570 Kythera, discovered in 1905 by German astronomer Max Wolf, is an interesting target to study: it shows clear, uncommon features in its spectra according to Lebofsky *et al.* (1990) and Vilas and McFadden (1992). Furthermore, in the Small Bodies Database (*http://ssd.jpl.nasa.gov/*) it is listed as a main-belt asteroid with a period of 8.12 hours, but with a level of uncertainty up to 30% of this value. In fact, former studies gave it a smaller period of 6.919 ± 0.006 h (Gil-Hutton and Canada, 2003). It seemed this asteroid needed more study to solve some of its mysteries. This motivating background guided the decision to choose it from the list of lightcurve photometry opportunities 2013 July-September (Warner *et al.*, 2013).

In order to perform the observations of Kythera with some hope of success, it was decided to make use of on-line telescopes that were better suited for the work rather than personal equipment. Among the options available at the time, Virtual Telescope Project 2.0 (VTP) services were chosen because of the good balance between price and instrument quality. As with some other on-line telescopes, VTP offers the option of "real time" observations (the customer uses the telescope remotely in real time), or "service mode", which is operated by the observatory's astronomers (VTP, 2013). Due to time zone differences between the location of the author (Chile) and telescopes (Italy), and the chance of continuing observation on another day if the weather was bad, the "service mode" was chosen for this research.

Unfiltered CCD images of Kythera were taken at Virtual Telescope locations in Ceccano, Italy, (MPC code 470) through a Celestron 0.35-m *f*/8.4 Schmidt-Cassegrain with StarBright XLT coatings mounted on a Paramount ME robotic mount. The camera was an SBIG ST-8 CCD. A total of three sessions on three different nights were performed. The first one was on August 17, the second on September 12, and the last one on September 13. The exposure time of all images was set to 60 seconds. The camera worked between –5°C (first session) and –15°C (second and third session). Weather conditions and observatory schedule were the main constraints and did not allow for having more nights of observations.

Once the FITS files were created by Virtual Telescope staff, they were downloaded by the author from the Virtual Telescope website and processed with the software package *MPO Canopus* version 10.4.1.15 (Warner, 2013) using a differential photometry technique to determine a lightcurve for the asteroid. The three sessions gave a total of 192 data points, which are presented in the lightcurve.



Furthermore, thanks to the Fourier analysis algorithm incorporated in the *MPO Canopus*, developed by Harris (Harris *et al.*, 1989), the software is able to estimate a rotation period for the asteroid. Data analysis found a synodic period of $P$ = 10.5 ± 0.1 h, which is within the 30% of uncertainty depicted in JPL website. However, the large gaps in coverage of the lightcurve demand more sessions and analysis to find a more reliable period. No doubt this interesting asteroid is worth the effort.

## Acknowledgments

I would like to thank Brian Warner for his support in the use of *MPO Canopus* software and wise advice regarding my research, and to Gialuca Massi, Virtual Telescope Project 2.0 astronomer, for his dedicated work in taking the images of the asteroid.

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VTP, Virtual Telescope Project 2.0
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# CALL FOR OBSERVATIONS: UNUSUAL OPPORTUNITY FOR 185 EUNIKE

Brian D. Warner
Alan W. Harris
MoreData!, Inc.
brian@MinorPlanetObserver.com

(Received: 15 October)

The main-belt asteroid 185 Eunike will reach an unusually favorable opposition in 2014 February and March. This will provide an unusual opportunity for observers to resolve its rotation period ambiguity.

Despite being a bright, low-numbered main-belt asteroid, there is some doubt about the rotation period for 185 Eunike. Some observers have reported a period of about 14.5 hours while others have found 21.8 hours. We have examined several data sets from past apparitions and can get some of them to fit both periods, although with some difficulty and not the most convincing of fits. Others work only with one period or the other. An extended campaign, especially one involving observers at different longitudes and, equally important, putting all data onto a common photometry system, would very likely remove the ambiguous solutions. That common system can be internal or referenced to a standard system, e.g., Johnson-Cousins BVRI. Simple differential values with no ties to a calibrated zero-point will not suffice.

The second goal is to determine the phase angle relationship of the asteroid, i.e., find the value for *G*. The asteroid reaches a minimum phase angle of 1.7 degrees on 2014 March 2. Finding a reliable value for *G* requires observing the asteroid over as wide a range of phase angles as possible, not just near opposition. This means out to at least 10-15 degrees, more if possible. It is also good to get both “before” and “after” opposition measures in order to separate phase angle change in brightness from changes due to aspect.

Eunike will be $V < 13$ from the beginning of January through most of May, and ranges from +3° to +18° Declination. This makes it an easy target for even modest backyard telescopes. The phase angle will be about 18 degrees at the beginning and end of this interval and go down to 1.7 degrees on March 2. Only modest stretches of coverage at large phase angle are needed to define the phase curve. Near opposition, extensive coverage all night each night for preferably a week to ten days will be needed to unambiguously define the lightcurve, and hopefully, the period.

The CALL web site (*http://www.MinorPlanet.info/call.html*) has an observing notifications page where observers can post their intention to observe the asteroid, which can then lead to a coordinated campaign to observe the asteroid.

It is rare for asteroids numbered below 1000, even 500, not to have a reliable period determination. We encourage observers to take advantage of this unusual opportunity to remove any doubt about the rotation period of 185 Eunike.

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# LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2014 JANUARY-MARCH

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

Alan W. Harris
MoreData!
La Cañada, CA 91011-3364 USA

Petr Pravec
Astronomical Institute
CZ-25165 Ondřejov, CZECH REPUBLIC

Josef Ďurech
Astronomical Institute
Charles University in Prague
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance.benner@jpl.nasa.gov

We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling via lightcurve inversion. We also include lists of objects that will be the target of radar observations. Lightcurves for these objects can help constrain pole solutions and/or remove rotation period ambiguities that might not come from using radar data alone.

## At a Cross-Roads

The core purpose of this paper has been unchanged for many decades: to provide a list of asteroids for which lightcurves and, therefore, rotation periods could be obtained. In the last decade or so, the list has expanded considerably as the definition of “backyard telescope” changed to involve much larger apertures, sometimes one meter or more, and the number of people using the list has grown, now including a number of professional individuals and groups.

The asteroid lightcurve database (LCDB, Warner *et al.*, 2009) now includes statistically valid rotation periods for more than 4500 asteroids. There are still some gaps to cover, namely among small asteroids in order to confirm such things as the percentage of tumbling asteroids, binary or multiple systems, and an excess of slow rotators. All of these may be related to one degree or another to thermal effects such as YORP. Objects on the outer reaches of the main-belt out to the KBOs can also use some concentrated work. Randomly picked targets, except for the sake of learning photometry and checking reduction methods by comparing to know results, are not as useful as concentrating on particular groups or families of asteroids to look for similar traits.

It’s not just rotation periods that are needed or wanted any more but data sets that extend the number of years an asteroid has been observed so that, by using lightcurve inversion techniques, the shape and spin axis of an asteroid can be determined. Even a few years ago, there was only a small number of objects with shapes and/or well-known spin axes. Now the DAMIT site (see below) list hundreds of objects. Many were solved using so-called *sparse* data sets, and so still need detailed (*dense*) lightcurves, but there's no longer the requirement to follow a given asteroid for decades.

Given the number of potential targets each quarter, it's no longer practical for the authors simply to put together lists to determine which ones are the "best" targets. It's both too time-consuming and too much a broad sweep of the brush when fine touch ups are required. This is even after we've done filtering to eliminate objects with presumably well-known periods from the opportunities list and applied other restrictions.

We believe it's time to make some changes to this regular feature. We have our own ideas but they may not fit with the corps of observers standing by to take part in asteroid photometry. We'd like your feedback on what targets you'd like to see included or filters that we would apply to the growing list of objects within reach of today's equipment and methods. Which lists, if any, would you eliminate? Expand? Change? How? Why?

We will say that the list in support of radar observations is "safe" in that it will not go away. However, maybe the ephemerides are no longer needed given on-line resources and the often rapidly changing viewing circumstances for NEAs. The original intent for the ephemerides was to indicate the approximate best dates for observing. Your definition of "best" may be different from ours.

To paraphrase, "So many asteroids, so little time." If possible we'd like to hear how we can help you make the most that "little time." This includes even if to say that you think things are good as they are. Please send your comments, thoughts, and/or suggestions to Brian Warner at brian@MinorPlanetObserver.com.

## Lightcurve Opportunities

We present lists of "targets of opportunity" for the period 2014 January-March. For background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188. In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

*http://www.minorplanet.info/lightcurvedatabase.html*

Objects with U = 1 should be given higher priority over those rated U = 2 or 2+ but not necessarily over those with no period. On the other hand, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

The first list is an *abbreviated list* of those asteroids reaching V < 15.0 at brightest during the period and have either no or poorly-constrained lightcurve parameters.

The goal for these asteroids is to find a well-determined rotation rate. The target list generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.0 during any month in the current year, e.g., limiting the results by magnitude and declination.

*http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*

In a general note, small objects with periods up to 4 hours or even longer are possible binaries. For longer periods (4-6 hours or so), the odds of a binary may be less, but the bonus is that the size of the secondary, if it exists, is likely larger (see Pravec *et al.* (2010), *Nature* **466**, 1085-1088), thus eclipses, if they occur, will be deeper and easier to detect.

The Low Phase Angle list includes asteroids that reach very low phase angles. The "α" column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the "opposition effect." You will have the best chance of success working objects with low amplitude and periods that allow covering, e.g., a maximum, every night. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data have to be reduced to the average magnitude of the asteroid for each night. Without knowing the period and/or the amplitude at the time, that reduction becomes highly uncertain. As an aside, some use the maximum light to find the phase slope parameter (*G*). However, this can produce a significantly different value for both *H* and *G* versus using average light, which is the method used for values listed by the Minor Planet Center.

The third list is of those asteroids needing only a small number of lightcurves to allow spin axis and/or shape modeling. Those doing work for modeling should contact Josef Ďurech at the email address above and/or visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site for existing data and models:

*http://astro.troja.mff.cuni.cz/projects/asteroids3D*

The fourth list gives a brief ephemeris for planned radar targets. Supporting optical observations to determine the lightcurve period, amplitude, and shape are needed to supplement the radar data. *High-precision work, 0.01-0.02 mag, is preferred, especially if the object is a known or potential binary*. Those obtaining lightcurves in support of radar observations should contact Dr. Benner directly at the email given above.

Future radar targets:
*http://echo.jpl.nasa.gov/~lance/future.radar.nea.periods.html*

Past radar targets:
*http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html*

Arecibo targets:
*http://www.naic.edu/~pradar/sched.shtml*
*http://www.naic.edu/~pradar*

Goldstone targets:
*http://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html*

As always, we encourage observations of asteroids even if they have well-established lightcurve parameters and especially if they are lacking good spin axis and/or shape model solutions. Every lightcurve of sufficient quality supports efforts to resolve a number of questions about the evolution of individual asteroids and the general population. For example, pole directions are known for only about 30 NEAs out of a population of 8000. This is hardly sufficient to make even the most general of statements about NEA pole alignments, including whether or not the thermal YORP effect is forcing pole orientations into a limited number of preferred directions (see La Spina *et al.*, 2004, *Nature* **428**, 400-401). Data from many apparitions can help determine if an asteroid's rotation rate is being affected by YORP, which can also cause the rotation rate of a smaller, irregularly-shaped asteroid to increase or decrease. See Lowry *et al.* (2007) *Science* **316**, 272-274 and Kaasalainen *et al.* (2007) *Nature* **446**, 420-422.

The ephemeris listings for the optical-radar listings include lunar elongation and phase. Phase values range from 0.0 (new) to 1.0 (full). If the value is positive, the moon is waxing – between new and full. If the value is negative, the moon is waning – between full and new. The listing also includes the galactic latitude. When this value is near 0°, the asteroid is likely in rich star fields and so may be difficult to work. It is important to emphasize that the ephemerides that we provide are only guides for when you might observe a given asteroid. Obviously, you should use your discretion and experience to make your observing program as effective as possible.

Once you've analyzed your data, it's important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It's also important to make the data available at least on a personal website or upon request.

## Lightcurve Opportunities

An asterisk (*) follows the name if the asteroid is reaching a particularly favorable apparition.

| | | Brightest | | | LCDB Data | | |
|---|---|---|---|---|---|---|---|
| # | Name | Date | Mag | Dec | Period | Amp | U |
| 520 | Franziska | 01 01.5 | 14.5 | +38 | 14. | 0.51 | 2 |
| 1793 | Zoya | 01 01.8 | 14.5 | +21 | 5.753 | 0.40 | 2+ |
| 1628 | Strobel | 01 02.2 | 14.3 | -6 | 9.52 | 0.20-0.22 | 2 |
| 863 | Benkoela | 01 03.5 | 13.7 | +13 | 7.03 | 0.05 | 2+ |
| 2062 | Aten | 01 05.3 | 13.9 | +6 | 40.77 | 0.26 | 2 |
| 1178 | Irmela | 01 06.1 | 14.9 | +12 | 11.989 | 0.34-0.40 | 2 |
| 949 | Hel | 01 06.8 | 14.0 | +32 | 10.862 | 0.12-0.14 | 2 |
| 973 | Aralia | 01 06.9 | 14.3 | +43 | 7.29 | 0.20-0.25 | 2+ |
| 673 | Edda | 01 07.3 | 13.9 | +19 | 14.92 | 0.12 | 2 |
| 1604 | Tombaugh | 01 07.5 | 14.8 | +28 | 7.047 | 0.16-0.35 | 2+ |
| 1006 | Lagrangea | 01 07.6 | 14.8 | +25 | 32.79 | 0.17 | 1 |
| 625 | Xenia | 01 08.1 | 14.2 | +16 | 21.101 | 0.37-0.50 | 2 |
| 903 | Nealley | 01 12.9 | 14.6 | +9 | 21.6 | 0.13-0.15 | 2 |
| 1086 | Nata* | 01 17.0 | 13.7 | +24 | 18.074 | 0.17 | 2 |
| 2381 | Landi* | 01 17.6 | 14.4 | +8 | 3.91 | 0.75 | 2 |
| 422 | Berolina | 01 19.7 | 14.1 | +28 | 12.79 | 0.06-0.11 | 2 |
| 1578 | Kirkwood | 01 20.2 | 14.5 | +21 | 12.518 | 0.05-0.22 | 2 |
| 236 | Honoria | 01 21.3 | 12.5 | +10 | 12.333 | 0.05-0.18 | 2+ |
| 1390 | Abastumani | 01 22.5 | 14.7 | +46 | 17.1 | 0.15 | 2 |
| 227 | Philosophia | 01 23.0 | 13.7 | +25 | 18.048 | 0.06-0.20 | 2 |
| 850 | Altona | 01 24.0 | 14.0 | +20 | 11.197 | 0.12-0.16 | 2+ |
| 597 | Bandusia | 01 24.9 | 13.4 | +37 | 11.5 | 0.05 | 2 |
| 807 | Ceraskia* | 01 28.1 | 14.2 | +17 | 7.4 | 0.25 | 2 |
| 748 | Simeisa | 01 30.7 | 13.7 | +15 | 11.919 | 0.22-0.36 | 2 |
| 868 | Lova | 01 31.0 | 13.5 | +20 | 41.3 | 0.40 | 2 |
| 1007 | Pawlowia | 02 01.1 | 14.7 | +17 | 8.23 | 0.02 | 1 |
| 1181 | Lilith | 02 01.6 | 14.3 | +10 | | 0.13 | |
| 3431 | Nakano | 02 01.6 | 14.8 | +17 | 9.2 | 0.24 | 2 |
| 1854 | Skvortsov* | 02 01.8 | 15.0 | +10 | 78.5 | 0.56 | 2 |
| 460 | Scania | 02 04.6 | 14.5 | +10 | 9.56 | 0.05 | 2 |
| 1585 | Union | 02 04.8 | 14.0 | +5 | 9.38 | 0.22 | 2 |
| 1970 | Sumeria* | 02 05.1 | 14.9 | +15 | | | |
| 1064 | Aethusa | 02 10.9 | 14.6 | +5 | 8.621 | 0.12-0.18 | 2 |
| 1483 | Hakoila* | 02 11.2 | 14.4 | +21 | > 12. | 0.05 | 1 |
| 1166 | Sakuntala | 02 11.6 | 14.7 | +30 | 6.3 | 0.40 | 2 |
| 396 | Aeolia | 02 12.1 | 14.1 | +10 | 22.2 | 0.30 | 2- |
| 897 | Lysistrata | 02 12.7 | 14.3 | -5 | 11.26 | 0.11 | 2 |
| 1796 | Riga | 02 12.9 | 14.8 | -7 | 10.608 | 0.10-0.14 | 2 |
| 671 | Carnegia | 02 13.3 | 14.3 | +20 | | | |
| 464 | Megaira | 02 13.9 | 14.1 | +22 | 12.726 | 0.08 | 2 |
| 3614 | Tumilty | 02 15.6 | 14.8 | -2 | 26.8 | 0.10 | 2- |
| 783 | Nora | 02 16.0 | 14.6 | +14 | 34.4 | 0.08-0.2 | 2 |
| 1266 | Tone | 02 17.3 | 14.1 | +9 | 7.4 | 0.06-0.12 | 2 |
| 684 | Hildburg | 02 19.2 | 13.7 | +12 | 11.92 | 0.23 | 2 |
| 858 | El Djezair | 02 19.9 | 14.2 | +24 | 22.31 | 0.06-0.1 | 2 |
| 3181 | Ahnert | 02 20.5 | 14.5 | +4 | | 0.08 | |
| 738 | Alagasta* | 02 21.2 | 13.9 | +12 | 17.83 | 0.20 | 2 |
| 1587 | Kahrstedt | 02 21.2 | 13.7 | +16 | 7.93 | 0.12 | 2+ |
| 2995 | Taratuta* | 02 21.8 | 14.6 | +3 | 6.6 | 0.06 | 1 |
| 29146 | McHone* | 02 22.0 | 14.9 | +11 | | | |
| 7203 | Sigeki* | 02 23.2 | 14.9 | +9 | | | |
| 1135 | Colchis | 02 24.3 | 14.3 | +11 | 23.47 | 0.45 | 2 |
| 1137 | Raissa | 02 24.8 | 14.1 | +16 | 37. | 0.11-0.34 | 1 |
| 1244 | Deira | 02 24.8 | 13.9 | -4 | 210.6 | 0.50 | 2 |
| 3385 | Bronnina | 02 25.4 | 14.8 | +2 | 2.996 | 0.25 | 2+ |
| 845 | Naema | 02 26.2 | 14.8 | +24 | 20.892 | 0.16 | 2 |
| 2367 | Praha* | 02 26.3 | 14.7 | +7 | | | |
| 896 | Sphinx | 02 27.5 | 14.5 | -4 | 26.27 | 0.08 | 1 |
| 992 | Swasey | 03 02.3 | 14.5 | -5 | 13.308 | 0.17 | 2 |
| 1025 | Riema* | 03 03.3 | 13.7 | +6 | 3.581 | 0.10-0.25 | 2+ |
| 1908 | Pobeda | 03 03.3 | 14.8 | +11 | | | |
| 1455 | Mitchella | 03 03.9 | 14.9 | +15 | 118.7 | 0.60 | 2+ |
| 2770 | Tsvet | 03 04.7 | 14.6 | +11 | | | |
| 1004 | Belopolskya | 03 07.0 | 15.0 | +6 | 9.44 | 0.14 | 2 |
| 6139 | Naomi | 03 08.1 | 15.0 | -14 | 21.35 | 0.20 | 2+ |
| 487 | Venetia | 03 08.3 | 12.1 | +16 | 13.28 | 0.03-0.30 | 2 |
| 2052 | Tamriko | 03 08.4 | 14.8 | -5 | 7.462 | 0.11-0.15 | 2 |
| 2812 | Scaltriti* | 03 09.6 | 15.0 | +17 | | | |
| 891 | Gunhild | 03 09.9 | 14.2 | +21 | 7.93 | 0.18 | 2 |
| 4628 | Laplace | 03 09.9 | 14.1 | -14 | 11.105 | 0.32-0.48 | 2 |
| 2832 | Lada* | 03 10.4 | 14.6 | +5 | 8.357 | 0.47 | 2+ |
| 2422 | Perovskaya* | 03 11.0 | 14.6 | +6 | > 40. | 0.17 | 2 |
| 1143 | Odysseus | 03 11.4 | 14.6 | +1 | 10.111 | 0.11-0.22 | 2+ |
| 1517 | Beograd | 03 11.7 | 14.9 | +11 | 6.943 | 0.18 | 2 |
| 1105 | Fragaria | 03 13.0 | 14.9 | +15 | 10.88 | 0.12 | 1 |
| 932 | Hooveria | 03 13.1 | 13.1 | +8 | 39.1 | 0.20-0.22 | 2+ |
| 1780 | Kippes | 03 15.1 | 15.0 | -9 | 18. | 0.23 | 2 |
| 308 | Polyxo | 03 17.2 | 11.8 | +1 | 12.032 | 0.08-0.15 | 2+ |
| 1938 | Lausanna | 03 19.4 | 14.2 | +1 | | | |
| 1805 | Dirikis* | 03 21.1 | 15.0 | +3 | 23. | 0.45 | 2 |
| 392 | Wilhelmina | 03 21.4 | 14.3 | -10 | 17.96 | 0.04-0.70 | 2 |
| 1803 | Zwicky* | 03 23.7 | 13.9 | -20 | 27.1 | 0.08 | 1 |
| 529 | Preziosa | 03 24.0 | 14.8 | +12 | 27. | 0.20-0.56 | 2 |
| 4528 | Berg | 03 27.6 | 14.8 | +3 | 3.5163 | 0.16 | 2 |
| 1532 | Inari | 03 28.1 | 14.9 | -10 | 25. | 0.09 | 1+ |
| 819 | Barnardiana | 03 28.6 | 14.2 | -8 | 66.7 | 0.82 | 2+ |
| 5069 | Tokeidai | 03 29.8 | 14.9 | -2 | | | |
| 1232 | Cortusa | 03 30.0 | 14.4 | -17 | 25.16 | 0.10 | 2 |
| 1039 | Sonneberga* | 03 30.1 | 14.5 | -7 | 34.2 | 0.41 | 2 |
| 1281 | Jeanne | 03 30.9 | 14.6 | -8 | 15.2 | 0.45 | 2 |
| 1968 | Mehltretter | 03 31.1 | 14.8 | +2 | | | |
| 521 | Brixia | 03 31.7 | 13.2 | +9 | 9.78 | 0.05-0.11 | 2- |

## Low Phase Angle Opportunities

| # | Name | Date | α | V | Dec | Period | Amp | U |
|---|---|---|---|---|---|---|---|---|
| 1302 | Werra | 01 01.2 | 0.31 | 14.0 | +24 | | 0.1 | |
| 142 | Polana | 01 04.9 | 0.18 | 13.3 | +23 | 9.764 | 0.11 | 3 |
| 241 | Germania | 01 07.0 | 0.68 | 11.9 | +20 | 15.51 | 0.10-0.17 | 3 |
| 11 | Parthenope | 01 11.1 | 0.70 | 9.9 | +20 | 13.7204 | 0.05-0.12 | 3 |
| 414 | Liriope | 01 16.9 | 0.42 | 14.0 | +22 | 7.353 | 0.13 | 3- |
| 740 | Cantabia | 01 18.8 | 0.25 | 12.7 | +21 | 64.453 | 0.16 | 3 |
| 462 | Eriphyla | 01 19.6 | 0.39 | 13.2 | +21 | 8.64 | 0.11-0.39 | 3 |
| 1245 | Calvinia | 01 20.9 | 0.73 | 13.9 | +18 | 4.84 | 0.37-0.7 | 3 |
| 317 | Roxane | 01 21.6 | 0.61 | 12.9 | +18 | 8.169 | 0.61-0.75 | 3 |
| 850 | Altona | 01 23.9 | 0.31 | 14.0 | +20 | 11.197 | 0.12 | 2 |
| 90 | Antiope | 01 25.6 | 0.67 | 13.3 | +21 | 16.509 | 0.08-0.90 | 3 |
| 748 | Simeisa | 01 30.8 | 0.66 | 13.7 | +15 | 11.919 | 0.22-0.36 | 2 |
| 868 | Lova | 01 31.1 | 0.92 | 13.5 | +20 | 41.3 | 0.40 | 2 |
| 558 | Carmen | 02 04.1 | 0.70 | 12.8 | +14 | 11.387 | 0.2 -0.31 | 3 |
| 129 | Antigone | 02 05.6 | 0.16 | 10.9 | +16 | 4.9572 | 0.21-0.49 | 3 |
| 184 | Dejopeja | 02 08.0 | 0.12 | 12.3 | +16 | 6.455 | 0.25-0.3 | 3 |
| 287 | Nephthys | 02 09.6 | 0.29 | 11.0 | +14 | 7.605 | 0.15-0.37 | 3 |
| 822 | Lalage | 02 10.4 | 0.68 | 13.8 | +13 | 3.345 | 0.47-0.58 | 3 |
| 208 | Lacrimosa | 02 11.9 | 0.61 | 12.7 | +16 | 14.085 | 0.15-0.33 | 3 |
| 1098 | Hakone | 02 16.5 | 0.26 | 13.7 | +13 | 7.142 | 0.35-0.40 | 3 |
| 306 | Unitas | 02 18.0 | 0.53 | 12.4 | +13 | 8.736 | 0.23-0.34 | 3 |
| 684 | Hildburg | 02 19.2 | 0.41 | 13.7 | +12 | 11.92 | 0.23 | 2 |
| 114 | Kassandra | 02 21.0 | 0.78 | 10.8 | +09 | 10.7431 | 0.12-0.25 | 3 |
| 738 | Alagasta | 02 21.2 | 0.64 | 13.9 | +12 | 17.83 | 0.20 | 2 |
| 167 | Urda | 02 21.3 | 0.28 | 13.0 | +10 | 13.07 | 0.24-0.39 | 3 |
| 122 | Gerda | 02 21.4 | 0.34 | 12.1 | +10 | 10.685 | 0.10-0.26 | 3 |
| 73 | Klytia | 02 21.7 | 0.79 | 12.3 | +12 | 8.297 | 0.26-0.35 | 3 |
| 163 | Erigone | 02 23.9 | 0.40 | 11.3 | +09 | 16.136 | 0.37 | 3 |
| 273 | Atropos | 02 25.1 | 0.67 | 13.4 | +08 | 23.924 | 0.52-0.65 | 3 |
| 526 | Jena | 02 25.7 | 0.41 | 13.6 | +10 | 9.474 | 0.27-0.35 | 3 |
| 304 | Olga | 02 26.6 | 0.24 | 13.6 | +08 | 18.36 | 0.14-0.20 | 3 |
| 1025 | Riema | 03 03.3 | 0.64 | 13.7 | +06 | 3.581 | 0.10-0.25 | 2+ |
| 135 | Hertha | 03 03.9 | 0.08 | 12.0 | +07 | 8.403 | 0.12-0.30 | 3 |
| 107 | Camilla | 03 08.7 | 0.37 | 11.6 | +04 | 4.844 | 0.32-0.53 | 3 |
| 670 | Ottegebe | 03 10.0 | 0.31 | 13.9 | +03 | 10.045 | 0.34-0.35 | 3 |
| 388 | Charybdis | 03 11.0 | 0.21 | 12.8 | +05 | 9.516 | 0.14-0.25 | 3 |
| 313 | Chaldaea | 03 13.9 | 0.76 | 10.6 | +01 | 8.392 | 0.08-0.24 | 3 |
| 24 | Themis | 03 14.0 | 0.28 | 10.6 | +03 | 8.374 | 0.09-0.14 | 3 |
| 308 | Polyxo | 03 17.2 | 0.24 | 11.8 | +01 | 12.032 | 0.08-0.15 | 2+ |
| 48 | Doris | 03 20.5 | 0.24 | 11.1 | +00 | 11.89 | 0.17-0.36 | 3 |
| 91 | Aegina | 03 25.3 | 0.19 | 12.0 | -01 | 6.025 | 0.12-0.27 | 3 |

## Shape/Spin Modeling Opportunities

There are two lists here. The first is for objects for which good occultation profiles are available. These are used to constrain the models obtained from lightcurve inversion, eliminating ambiguous solutions and fixing the size of asteroid. Lightcurves are needed for modeling and/or to establish the rotation phase angle at the time the profile was obtained. The second list is of those objects for which another set of lightcurves from one more apparitions will allow either an initial or a refined solution. These objects might also be good targets for occultation profiles, in which case, absolute calibration of size would be possible when combining the inversion model and occultation data.

Some good links for asteroid occultations are:

*http://www.asteroidoccultation.com/*
*http://www.poyntsource.com/New/Global.htm*

The latter includes links to show the occultation path in detail using GoogleMap or Google Earth.

### Occultation Profiles Available

| | | Brightest | | | LCDB DATA | | |
|---|---|---|---|---|---|---|---|
| # | Name | Date | Mag | De | Period | Amp | U |
| 51 | Nemausa | 01 03.4 | 10.4 | +06 | 7.783 | 0.10-0.25 | 3 |
| 345 | Tercidina | 01 18.5 | 11.5 | +03 | 12.371 | 0.11-0.23 | 3 |
| 141 | Lumen | 01 26.0 | 12.0 | +23 | 19.87 | 0.12-0.2 | 3 |
| 234 | Barbara | 01 26.5 | 12.9 | +11 | 26.468 | 0.19-0.20 | 3- |
| 18 | Melpomene | 01 27.7 | 9.3 | +12 | 11.570 | 0.10-0.34 | 3 |
| 914 | Palisana | 02 04.1 | 13.4 | -15 | 15.922 | 0.04-0.18 | 3 |
| 704 | Interamnia | 02 06.7 | 10.8 | +00 | 8.727 | 0.04-0.11 | 3 |
| 154 | Bertha | 03 11.1 | 12.0 | +26 | 25.224 | 0.04-0.20 | 3 |
| 308 | Polyxo | 03 17.2 | 11.8 | +01 | 12.032 | 0.08-0.15 | 2+ |
| 102 | Miriam | 03 24.6 | 13.9 | -05 | 23.613 | 0.04-0.14 | 3 |

### Inversion Modeling Candidates

| | | Brightest | | | LCDB Data | | |
|---|---|---|---|---|---|---|---|
| # | Name | Date | Mag | Dec | Period | Amp | U |
| 1339 | Desagneauxa | 01 03.9 | 14.4 | +25 | 9.380 | 0.45-0.48 | 3 |
| 1021 | Flammario | 01 05.0 | 11.4 | +17 | 12.160 | 0.14-0.40 | 3- |
| 1219 | Britta | 01 05.8 | 13.7 | +30 | 5.575 | 0.48-0.75 | 3 |
| 239 | Adrastea | 01 09.3 | 13.9 | +13 | 18.4707 | 0.34-0.51 | 3 |
| 3573 | Holmberg | 01 11.9 | 14.9 | +20 | 6.5431 | 1.03 | 3 |
| 271 | Penthesilea | 01 13.5 | 13.7 | +25 | 18.787 | 0.33 | 3 |
| 620 | Drakonia | 01 15.5 | 14.9 | +32 | 5.487 | 0.52-0.62 | 3 |
| 1044 | Teutonia | 01 17.3 | 14.7 | +26 | 3.153 | 0.20-0.28 | 3 |
| 2381 | Landi | 01 17.6 | 14.4 | +08 | 3.91 | 0.75 | 2 |
| 345 | Tercidina | 01 18.5 | 11.5 | +03 | 12.371 | 0.11-0.23 | 3 |
| 317 | Roxane | 01 21.5 | 12.9 | +18 | 8.169 | 0.61-0.75 | 3 |
| 2791 | Paradise | 01 26.9 | 14.2 | +56 | 9.81 | 0.25-0.34 | 3 |
| 868 | Lova | 01 31.0 | 13.5 | +20 | 41.3 | 0.40 | 2 |
| 1251 | Hedera | 02 08.6 | 14.5 | +15 | 19.9000 | 0.41-0.61 | 3- |
| 1299 | Mertona | 02 09.9 | 14.7 | +09 | 4.977 | 0.46-0.55 | 3 |
| 822 | Lalage | 02 10.4 | 13.8 | +13 | 3.345 | 0.47-0.58 | 3 |
| 208 | Lacrimosa | 02 11.9 | 12.7 | +16 | 14.085 | 0.15-0.33 | 3 |
| 643 | Scheherezade | 02 11.9 | 14.4 | -04 | 14.161 | 0.23-0.36 | 3 |
| 1294 | Antwerpia | 02 13.5 | 14.5 | +24 | 6.63 | 0.3 -0.40 | 3 |
| 2144 | Marietta | 02 13.9 | 14.7 | +14 | 5.489 | 0.40-0.44 | 3- |
| 616 | Elly | 02 22.2 | 13.8 | +20 | 5.297 | 0.34-0.44 | 3 |
| 155 | Scylla | 02 24.2 | 14.4 | +25 | 7.9597 | 0.11-0.46 | 3 |
| 1135 | Colchis | 02 24.3 | 14.3 | +11 | 23.47 | 0.45 | 2 |
| 1244 | Deira | 02 24.8 | 13.9 | -04 | 210.6 | 0.50 | 2 |
| 244 | Sita | 02 28.6 | 14.8 | +05 | 129.51 | 0.80-0.82 | 3- |
| 986 | Amelia | 03 09.1 | 14.9 | +22 | 9.52 | 0.25-0.43 | 3 |
| 670 | Ottegebe | 03 10.0 | 13.9 | +03 | 10.045 | 0.34-0.35 | 3 |
| 1321 | Majuba | 03 12.2 | 14.8 | -03 | 5.207 | 0.24-0.43 | 3 |
| 2209 | Tianjin | 03 18.4 | 14.8 | +03 | 9.47 | 0.41-0.42 | 3 |
| 564 | Dudu | 03 19.7 | 14.7 | +27 | 8.882 | 0.43-0.55 | 3 |
| 1805 | Dirikis | 03 21.1 | 15.0 | +03 | 23.0 | 0.45 | 2 |
| 191 | Kolga | 03 25.1 | 13.5 | +05 | 17.604 | 0.21-0.40 | 3 |
| 1309 | Hyperborea | 03 25.7 | 14.7 | -07 | 13.88 | 0.34-0.41 | 3 |
| 1175 | Margo | 03 25.9 | 14.9 | -18 | 6.01 | 0.22-0.40 | 3- |
| 199 | Byblis | 03 29.8 | 13.0 | +19 | 5.2201 | 0.05-0.15 | 3 |
| 1232 | Cortusa | 03 30.0 | 14.4 | -17 | 25.16 | 0.10 | 2 |
| 1281 | Jeanne | 03 30.9 | 14.6 | -08 | 15.2 | 0.45 | 2 |

## Radar-Optical Opportunities

Use the ephemerides below as a guide to your best chances for observing, but remember that photometry may be possible before and/or after the ephemerides given below. Some of the targets may be too faint to do accurate photometry with backyard telescopes. However, accurate astrometry using techniques such as “stack and track” is still possible and can be helpful for those asteroids where the position uncertainties are significant. Note that the intervals in the ephemerides are not always the same and that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

MPC: *http://www.minorplanetcenter.net/iau/MPEph/MPEph.html*
JPL: *http://ssd.jpl.nasa.gov/?horizons*

In the ephemerides below, ED and SD are, respectively, the Earth and Sun distances (AU), V is the estimated Johnson V magnitude, and $\alpha$ is the phase angle. SE and ME are the great circles distances (in degrees) of the Sun and Moon from the asteroid. MP is the lunar phase and GB is the galactic latitude. “PHA” in the header indicates that the object is a “potentially hazardous asteroid”, meaning that at some (long distant) time, its orbit might take it very close to Earth.

The first two objects are repeats from the previous issue since they are still observable at the start of 2014.

### 2006 CT (Dec-Jan, H = 22.3)

Because of the wide range of phase angles, there is an excellent chance to get a series of lightcurves that show amplitude and/or shape evolution from late December into 2014 January. The estimated size is 100 meters and the LCDB has no period.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/25 | 09 56.3 | +19 07 | 0.07 | 1.03 | 18.5 | 48.5 | 128 | 33 | -0.56 | +49 |
| 12/30 | 09 15.3 | +18 52 | 0.08 | 1.05 | 18.4 | 34.6 | 143 | 108 | -0.09 | +40 |
| 01/04 | 08 41.3 | +18 23 | 0.09 | 1.07 | 18.4 | 22.4 | 155 | 167 | +0.10 | +32 |
| 01/09 | 08 13.9 | +17 50 | 0.11 | 1.09 | 18.4 | 12.1 | 167 | 93 | +0.59 | +26 |
| 01/14 | 07 52.6 | +17 20 | 0.12 | 1.11 | 18.4 | 4.3 | 175 | 27 | +0.96 | +21 |
| 01/19 | 07 36.5 | +16 55 | 0.14 | 1.13 | 18.8 | 6.3 | 173 | 36 | -0.93 | +17 |
| 01/24 | 07 24.7 | +16 37 | 0.16 | 1.14 | 19.4 | 12.3 | 166 | 101 | -0.52 | +15 |
| 01/29 | 07 16.5 | +16 24 | 0.19 | 1.16 | 19.9 | 17.8 | 159 | 173 | -0.06 | +13 |

### 2009 WZ104 (Jan, H = 20.0)

Karashevich *et al.* (2012; *Solar System Research* **46**, 143-148) reported a period of 19.304 hours, but could not formally exclude the half-period of 9.652 hours. Be prepared for either possibility.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 01/01 | 11 15.2 | -27 18 | 0.15 | 1.01 | 18.4 | 74.2 | 98 | 94 | +0.00 | +31 |
| 01/04 | 11 18.9 | -32 23 | 0.14 | 1.01 | 18.4 | 75.1 | 97 | 129 | +0.10 | +27 |
| 01/07 | 11 22.9 | -37 39 | 0.14 | 1.01 | 18.4 | 76.3 | 96 | 145 | +0.38 | +22 |
| 01/10 | 11 27.4 | -43 04 | 0.14 | 1.00 | 18.4 | 77.9 | 94 | 131 | +0.69 | +17 |
| 01/13 | 11 32.6 | -48 34 | 0.14 | 1.00 | 18.5 | 79.7 | 92 | 108 | +0.91 | +12 |
| 01/16 | 11 38.9 | -54 04 | 0.14 | 0.99 | 18.5 | 81.7 | 90 | 87 | +1.00 | +7 |
| 01/19 | 11 46.8 | -59 30 | 0.14 | 0.99 | 18.6 | 84.0 | 88 | 70 | -0.93 | +2 |
| 01/22 | 11 57.5 | -64 48 | 0.14 | 0.98 | 18.7 | 86.5 | 85 | 61 | -0.72 | -3 |

### 2011 BT15 (Jan-Feb, H = 21.7, PHA)

No previously reported period was found in the literature for 2011 BT15. The estimated effective diameter is only 140 meters. As such, there is a good chance that it will be super-fast rotator, i.e., $P < 2$ h. In such cases, it’s best to start with exposures as short as possible so that the lightcurve is not “smeared” and the rotation information is lost (see Pravec *et al.*, 2000; *Icarus* **147**, 477-486). In short, if the exposure exceeds ~0.185 x rotation period, the second order harmonic, which dominates the lightcurve of an elongated object, are lost and so an accurate period may be difficult, if not impossible to obtain.

*The radar team is requesting astrometry in late 2013 December and early 2014 January to reduce the sky pointing errors so that radar observations can be made.*

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 01/01 | 13 09.3 | -10 26 | 0.03 | 0.98 | 17.8 | 97.6 | 80 | 74 | +0.00 | +52 |
| 01/06 | 11 55.5 | +02 01 | 0.04 | 1.00 | 17.3 | 70.4 | 107 | 169 | +0.28 | +62 |
| 01/11 | 11 09.4 | +09 39 | 0.06 | 1.02 | 17.4 | 51.6 | 126 | 111 | +0.77 | +60 |
| 01/16 | 10 38.7 | +14 16 | 0.07 | 1.04 | 17.5 | 38.0 | 139 | 43 | +1.00 | +57 |
| 01/21 | 10 16.5 | +17 12 | 0.09 | 1.06 | 17.7 | 27.4 | 150 | 25 | -0.80 | +53 |
| 01/26 | 09 59.4 | +19 10 | 0.10 | 1.08 | 17.9 | 18.6 | 159 | 93 | -0.31 | +50 |
| 01/31 | 09 45.8 | +20 30 | 0.12 | 1.11 | 18.1 | 11.4 | 167 | 165 | +0.00 | +47 |
| 02/05 | 09 35.1 | +21 22 | 0.14 | 1.13 | 18.3 | 6.4 | 173 | 114 | +0.32 | +45 |

**(252346) 2007 SJ (Jan, March, H = 16.8, PHA)**

Observers in both hemispheres get their own shot at this 1.3 km near-Earth asteroid. In the opening days of 2014, the asteroid is fairly bright and well north of the celestial equator. However, it is not very far from the sun in the sky and the phase angles are very large. Southern observers have things a little better in March, when the asteroid is well south of the celestial equator and further away from the sun. Their disadvantage is that the nearly full moon will interfere around the middle of March No period could be found in the literature.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 01/01 | 22 52.2 | +35 15 | 0.12 | 0.98 | 15.3 | 90.4 | 83 | 85 | +0.00 | -22 |
| 01/02 | 22 48.2 | +34 46 | 0.11 | 0.97 | 15.3 | 92.4 | 81 | 72 | +0.01 | -22 |
| 01/03 | 22 44.0 | +34 14 | 0.11 | 0.97 | 15.3 | 94.5 | 79 | 59 | +0.04 | -22 |
| 01/04 | 22 39.4 | +33 38 | 0.11 | 0.97 | 15.3 | 96.7 | 77 | 48 | +0.10 | -22 |
| 01/05 | 22 34.4 | +32 58 | 0.10 | 0.96 | 15.3 | 99.0 | 75 | 39 | +0.18 | -22 |
| 01/06 | 22 29.0 | +32 13 | 0.10 | 0.96 | 15.3 | 101.4 | 73 | 35 | +0.28 | -22 |
| 01/07 | 22 23.2 | +31 22 | 0.09 | 0.96 | 15.4 | 104.0 | 71 | 37 | +0.38 | -22 |
| 01/08 | 22 16.8 | +30 25 | 0.09 | 0.95 | 15.4 | 106.7 | 68 | 43 | +0.49 | -22 |
| | | | | | | | | | | |
| 03/01 | 14 38.8 | -48 26 | 0.20 | 1.06 | 15.7 | 65.4 | 104 | 103 | +0.00 | +11 |
| 03/06 | 14 26.5 | -48 25 | 0.22 | 1.09 | 15.8 | 59.0 | 110 | 146 | +0.26 | +12 |
| 03/11 | 14 14.3 | -48 05 | 0.24 | 1.12 | 15.8 | 53.0 | 116 | 113 | +0.73 | +13 |
| 03/16 | 14 02.3 | -47 26 | 0.26 | 1.15 | 15.9 | 47.2 | 122 | 62 | +0.99 | +14 |
| 03/21 | 13 50.5 | -46 27 | 0.28 | 1.18 | 16.0 | 41.7 | 128 | 35 | -0.81 | +15 |
| 03/26 | 13 39.3 | -45 11 | 0.30 | 1.22 | 16.1 | 36.5 | 133 | 84 | -0.28 | +17 |
| 03/31 | 13 28.8 | -43 38 | 0.32 | 1.26 | 16.2 | 31.6 | 139 | 142 | +0.00 | +19 |
| 04/05 | 13 19.6 | -41 53 | 0.34 | 1.29 | 16.3 | 27.3 | 144 | 126 | +0.28 | +21 |

**2006 DP14 (Feb, H = 18.8, PHA)**

The estimated diameter for 2006 DP14 is 500 meters; the period is not known.

*The radar team is requesting accurate astrometry just before closest approach, i.e., sometime in early February.*

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 02/10 | 22 39.5 | -51 48 | 0.02 | 0.97 | 17.1 | 139.6 | 40 | 115 | +0.79 | -55 |
| 02/11 | 04 35.8 | -55 37 | 0.02 | 0.99 | 13.1 | 92.6 | 86 | 78 | +0.86 | -41 |
| 02/12 | 06 54.0 | -26 24 | 0.02 | 1.00 | 12.8 | 55.9 | 123 | 44 | +0.92 | -11 |
| 02/13 | 07 26.6 | -12 54 | 0.04 | 1.02 | 13.4 | 41.8 | 137 | 30 | +0.96 | +2 |
| 02/14 | 07 40.3 | -06 32 | 0.05 | 1.03 | 13.9 | 35.8 | 142 | 27 | +0.99 | +8 |
| 02/15 | 07 47.9 | -02 56 | 0.07 | 1.04 | 14.4 | 32.7 | 145 | 32 | +1.00 | +11 |
| 02/16 | 07 52.8 | -00 39 | 0.08 | 1.06 | 14.9 | 31.0 | 147 | 41 | -0.99 | +13 |
| 02/17 | 07 56.2 | +00 56 | 0.10 | 1.07 | 15.2 | 30.0 | 147 | 51 | -0.96 | +15 |

**(348306) 2005 AY28 (Feb, H = 21.5, PHA)**

With an estimated diameter of 140 meters, this is another asteroid with a good potential for being a super-fast rotator. There is no known period. Normally, because of the moon being nearly full throughout the ephemeris period, this object would not have been included. However, since it brightens above 13th magnitude, the exposures can be kept short for reasons beyond the potential for being a super-fast rotator.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 02/10 | 22 39.5 | -51 48 | 0.02 | 0.97 | 17.1 | 139.6 | 40 | 115 | +0.79 | -55 |
| 02/11 | 04 35.8 | -55 37 | 0.02 | 0.99 | 13.1 | 92.6 | 86 | 78 | +0.86 | -41 |
| 02/12 | 06 54.0 | -26 24 | 0.02 | 1.00 | 12.8 | 55.9 | 123 | 44 | +0.92 | -11 |
| 02/13 | 07 26.6 | -12 54 | 0.04 | 1.02 | 13.4 | 41.8 | 137 | 30 | +0.96 | +2 |
| 02/14 | 07 40.3 | -06 32 | 0.05 | 1.03 | 13.9 | 35.8 | 142 | 27 | +0.99 | +8 |
| 02/15 | 07 47.9 | -02 56 | 0.07 | 1.04 | 14.4 | 32.7 | 145 | 32 | +1.00 | +11 |
| 02/16 | 07 52.8 | -00 39 | 0.08 | 1.06 | 14.9 | 31.0 | 147 | 41 | -0.99 | +13 |
| 02/17 | 07 56.2 | +00 56 | 0.10 | 1.07 | 15.2 | 30.0 | 147 | 51 | -0.96 | +15 |

**(275677) 2000 RS11 (Mar, H = 19.1, PHA)**

The estimated diameter is 450 meters; no reported period could be found. Judging from the ephemeris below, the final days of March may provide the best opportunity in terms of the phase and sky distance from the asteroid of the moon and the asteroid's magnitude. The asteroid is still within reach during at least part of April, which allows extending an observing campaign if needed.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 03/10 | 19 06.3 | -32 22 | 0.04 | 0.98 | 16.2 | 112.6 | 65 | 163 | +0.64 | -17 |
| 03/13 | 17 47.6 | -07 01 | 0.04 | 0.99 | 15.2 | 92.3 | 86 | 135 | +0.87 | +11 |
| 03/16 | 16 54.7 | +13 07 | 0.05 | 1.01 | 15.1 | 75.4 | 102 | 86 | +0.99 | +32 |
| 03/19 | 16 19.7 | +24 45 | 0.06 | 1.02 | 15.4 | 65.4 | 111 | 54 | -0.95 | +43 |
| 03/22 | 15 55.4 | +31 23 | 0.08 | 1.03 | 15.8 | 59.3 | 117 | 50 | -0.72 | +50 |
| 03/25 | 15 37.3 | +35 23 | 0.10 | 1.05 | 16.1 | 55.4 | 120 | 73 | -0.39 | +54 |
| 03/28 | 15 23.3 | +37 57 | 0.11 | 1.06 | 16.4 | 52.6 | 122 | 102 | -0.10 | +57 |
| 03/31 | 15 11.8 | +39 37 | 0.13 | 1.08 | 16.7 | 50.4 | 124 | 123 | +0.00 | +58 |

**(363599) 2004 FG11 (Mar-Apr, H = 21.0, PHA)**

Previous radar observations show this to be a synchronous binary with a rotation period of about 20.4 ± 0.4 hours (Taylor *et al.*, 2012, *CBET* **3091**). This calls out for an observing campaign involving observers at several locations around the world. The estimated diameter is about 200 meters.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 03/30 | 14 45.8 | +03 13 | 0.19 | 1.16 | 19.0 | 28.6 | 146 | 136 | -0.01 | +54 |
| 04/01 | 14 54.4 | +05 18 | 0.16 | 1.14 | 18.6 | 30.1 | 145 | 156 | +0.02 | +53 |
| 04/03 | 15 06.2 | +08 11 | 0.13 | 1.11 | 18.3 | 32.8 | 143 | 155 | +0.12 | +53 |
| 04/05 | 15 23.8 | +12 26 | 0.11 | 1.08 | 17.9 | 37.4 | 139 | 139 | +0.28 | +51 |
| 04/07 | 15 52.6 | +18 59 | 0.08 | 1.06 | 17.5 | 45.7 | 131 | 122 | +0.47 | +48 |
| 04/09 | 16 46.7 | +29 15 | 0.06 | 1.03 | 17.3 | 60.5 | 116 | 111 | +0.66 | +39 |
| 04/11 | 18 38.5 | +41 55 | 0.05 | 1.00 | 17.6 | 85.3 | 92 | 112 | +0.82 | +20 |
| 04/13 | 21 25.8 | +45 00 | 0.06 | 0.98 | 19.2 | 114.6 | 63 | 127 | +0.94 | -4 |

## IN THIS ISSUE

This list gives those asteroids in this issue for which physical observations (excluding astrometric only) were made. This includes lightcurves, color index, and H-G determinations, etc. In some cases, no specific results are reported due to a lack of or poor quality data. The page number is for the first page of the paper mentioning the asteroid. EP is the "go to page" value in the electronic version.

| Number | Name | EP | Page |
|---|---|---|---|
| 205 | Martha | 47 | 47 |
| 330 | Adalberta | 23 | 23 |
| 482 | Petrina | 47 | 47 |
| 541 | Deborah | 40 | 40 |
| 570 | Kythera | 60 | 60 |
| 582 | Olympia | 22 | 22 |
| 682 | Hagar | 35 | 35 |
| 682 | Hagar | 36 | 36 |
| 899 | Jokaste | 58 | 58 |
| 1030 | Vitja | 24 | 24 |
| 1058 | Grubba | 24 | 24 |
| 1137 | Raissa | 33 | 33 |
| 1198 | Atlantis | 4 | 4 |
| 1314 | Paula | 13 | 13 |
| 1468 | Zomba | 40 | 40 |
| 1486 | Marilyn | 24 | 24 |
| 1627 | Ivar | 41 | 41 |
| 1632 | Siebohme | 4 | 4 |
| 1799 | Koussevitzky | 27 | 27 |
| 1874 | Kacivelia | 17 | 17 |
| 1920 | Sarmiento | 8 | 8 |
| 2055 | Dvorak | 17 | 17 |
| 2112 | Ulyanov | 13 | 13 |
| 2185 | Guangdong | 17 | 17 |
| 2213 | Meeus | 19 | 19 |
| 2272 | Montezuma | 8 | 8 |
| 2495 | Noviomagnum | 27 | 27 |
| 2858 | Carlosporter | 4 | 4 |
| 2911 | Miahelena | 27 | 27 |
| 3138 | Ciney | 2 | 2 |
| 3225 | Hoag | 27 | 27 |
| 3255 | Tholen | 24 | 24 |
| 3562 | Ignatius | 3 | 3 |
| 3657 | Ermolova | 15 | 15 |
| 3782 | Celle | 58 | 58 |
| 3948 | Bohr | 4 | 4 |
| 3977 | Maxine | 1 | 1 |
| 4404 | Enirac | 15 | 15 |
| 4764 | Joneberhart | 8 | 8 |
| 4905 | Hiromi | 49 | 49 |
| 4952 | Kibeshigemaro | 27 | 27 |
| 5095 | Escalante | 15 | 15 |
| 5369 | Virgiugum | 4 | 4 |
| 5427 | Jensmartin | 8 | 8 |
| 5431 | Maxinehelin | 13 | 13 |
| 5577 | Priestley | 8 | 8 |
| 5968 | Trauger | 54 | 54 |
| 6249 | Jennifer | 27 | 27 |
| 6401 | Roentgen | 27 | 27 |
| 6495 | 1992 UB1 | 13 | 13 |
| 6602 | Gilclark | 27 | 27 |
| 6618 | 1936 SO | 27 | 27 |
| 6635 | Zuber | 27 | 27 |
| 6911 | Nancygreen | 27 | 27 |
| 7660 | 1993 VM1 | 8 | 8 |
| 7745 | 1987 DB6 | 49 | 49 |
| 7959 | Alysecherri | 27 | 27 |
| 8059 | Deliyannis | 17 | 17 |
| 8306 | Shoko | 49 | 49 |
| 9084 | Achristou | 8 | 8 |
| 9950 | ESA | 41 | 41 |
| 10502 | Armaghobs | 2 | 2 |
| 10531 | 1991 GB1 | 8 | 8 |
| 11217 | 1999 JC4 | 54 | 54 |
| 11405 | 1999 CV3 | 41 | 41 |
| 11441 | Anadiego | 2 | 2 |
| 15692 | 1984 RA | 27 | 27 |
| 15822 | 1994 TV15 | 54 | 54 |
| 16421 | Roadrunner | 27 | 27 |
| 16815 | 1997 UA9 | 49 | 49 |
| 16896 | 1998 DS9 | 13 | 13 |
| 17288 | 2000 NZ10 | 49 | 49 |
| 20231 | 1997 YK | 27 | 27 |
| 20691 | 1999 VY72 | 13 | 13 |
| 20899 | 2000 XB3 | 4 | 4 |
| 24445 | 2000 PM8 | 41 | 41 |
| 24654 | Fossett | 8 | 8 |
| 25755 | 2000 BR14 | 13 | 13 |
| 26416 | 1999 XM84 | 49 | 49 |
| 30958 | 1994 TV3 | 27 | 27 |
| 32814 | 1990 XZ | 8 | 8 |
| 35055 | 1984 RB | 8 | 8 |
| 35194 | 1994 ET3 | 8 | 8 |
| 39665 | 1995 WU6 | 8 | 8 |
| 41503 | 2000 QG148 | 27 | 27 |
| 41660 | 2000 SV362 | 8 | 8 |
| 42946 | 1999 TU95 | 49 | 49 |
| 45898 | 2000 XQ49 | 27 | 27 |
| 48336 | 2002 PS6 | 27 | 27 |
| 51926 | 2001 QE98 | 27 | 27 |
| 53431 | 1999 UQ10 | 8 | 8 |
| 56777 | 2000 OC39 | 27 | 27 |
| 65637 | 1979 VS2 | 8 | 8 |
| 74096 | 1998 QD15 | 49 | 49 |
| 76818 | 2000 RG79 | 54 | 54 |
| 137199 | 1999 KX4 | 4 | 4 |
| 152664 | 1998 FW4 | 41 | 41 |
| 168378 | 1997 ET30 | 41 | 41 |
| 216910 | Vnukov | 27 | 27 |
| 277475 | 2005 WK4 | 13 | 13 |
| 285263 | 1998 QE2 | 2 | 2 |
| 329338 | 2001 JW2 | 4 | 4 |
| 329437 | 2002 OA22 | 41 | 41 |
| 330825 | 2008 XE3 | 4 | 4 |
| 350988 | 2003 GW | 41 | 41 |
| 361071 | 2006 AO4 | 41 | 41 |
| 368644 | 2005 JA22 | 41 | 41 |
|  | 2006 EE1 | 41 | 41 |
|  | 2010 TN54 | 33 | 33 |
|  | 2012 TC4 | 4 | 4 |
|  | 2013 OM9 | 41 | 41 |
|  | 2013 QJ10 | 41 | 41 |

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Nonmembers are invited to join ALPO by communicating with: Matthew L. Will, A.L.P.O. Membership Secretary, P.O. Box 13456, Springfield, IL 62791-3456 (will008@attglobal.net). The Minor Planets Section is directed by its Coordinator, Prof. Frederick Pilcher, 4438 Organ Mesa Loop, Las Cruces, NM 88011 USA (pilcher@ic.edu), assisted by Lawrence Garrett, 206 River Rd., Fairfax, VT 05454 USA (LSGasteroid@msn.com). Dr. Alan W. Harris (Space Science Institute; awharris@spacescience.org), and Dr. Petr Pravec (Ondrejov Observatory; ppravec@asu.cas.cz) serve as Scientific Advisors. The Asteroid Photometry Coordinator is Brian D. Warner, Palmer Divide Observatory, 17995 Bakers Farm Rd., Colorado Springs, CO 80908 USA (brian@MinorPlanetObserver.com).

*The Minor Planet Bulletin* is edited by Professor Richard P. Binzel, MIT 54-410, Cambridge, MA 02139 USA (rpb@mit.edu). Brian D. Warner (address above) is Assistant Editor. The *MPB* is produced by Dr. Robert A. Werner, 3937 Blanche St., Pasadena, CA 91107 USA (bwernerca1@att.net) and distributed by Derald D. Nye. Direct all subscriptions, contributions, address changes, etc. to:

Mr. Derald D. Nye - Minor Planet Bulletin
10385 East Observatory Drive
Corona de Tucson, AZ 85641-2309 USA
(nye@kw-obsv.org) (Telephone: 520-762-5504)

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* * * * *

The deadline for the next issue (41-2) is January 15, 2014. The deadline for issue 41-3 is April 15, 2014.