PHOTOMETRIC ANALYSIS AND PHYSICAL PARAMETERS FOR SIX MARS-CROSSING AND TEN MAIN-BELT ASTEROIDS FROM APT OBSERVATORYGROUP: 2017 APRIL-SEPTEMBER

Amadeo Aznar Macías
Astronomía Para Todos Observatory Group
4650 Puzol, SPAIN
aptog@aptog.com

R. Cornea, O. Suciu
Romanian Society for Meteors and Astronomy (SARM)
CP 14 OP 1, 130170 Targoviste, ROMANIA

(Received: 2017 Oct 14)

Lightcurves of six Mars-crossing and eight main-belt asteroids were obtained at APT-Observatory Group from 2017 April to September. In addition, two more asteroids were captured in 2014 and 2015 during the EURONEAR project. Analysis of rotation period, lightcurve amplitude, and physical parameters (size and axis size relationship) are presented.

CCD photometric observations of six Mars-crossing and eight main-belt asteroids (MBA) were made by the APT Observatory Group from 2017 April to September along with two more MBAs observed serendipitously with the IAC80 telescope in 2014 and 2015. The planned asteroids were selected from those having a quality rating of U ≥ 2 in the asteroid lightcurve database (LCDB; Warner et al. 2009) or asteroids without any previously reported periods.

Even if an asteroid is rated U = 3, it can still be useful to make additional observations. One reason is to see how the lightcurve amplitude changes from one apparition to the next or how the amplitude changes in a single apparition as the viewing aspect changes, as measured by the phase angle bisector (PAB; Harris *et al.* 1984). Future analysis of changing lightcurve amplitudes from one or several additional apparitions can provide relevant information about the asteroid shape and spin axis orientation.

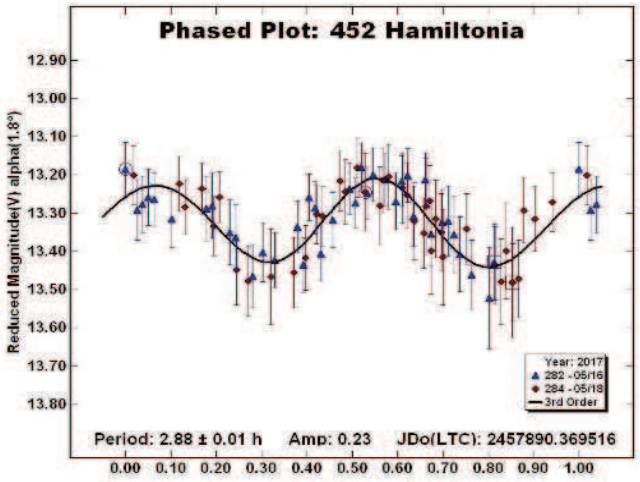
The APT Observatory Group is made up of two observatories. First is the Isaac Aznar Observatory located in Centro Astronómico del Alto Turia, Aras de los Olmos, Valencia, Spain, at an altitude of 1270 meters and under dark skies (21.7 mag/arcsec^2). The image scale is 1.44 arcsec/pixel. The second observatory is the POP-Punto de Observación de Puçol, Puçol, Spain. This is in an urban location and is equipped with a 0.25-m telescope, SBIG ST-9 CCD, and adaptive optics. The IAC80 is a medium size telescope located in Observatorio del Teide, in the Canary Islands. This telescope is equipped with a Tromseo CCD photometer with a plate scale of 0.3 arcsecond/pixel.

All images were obtained in 1x1 binning mode and were taken without any photometric filter. The SNR of the target assured a lightcurve of sufficient quality and low data dispersion. Dark and bias frames and twilight sky flat-fields were applied to each science image. Data reduction was done with *MPO Canopus*. This software implements the FALC period analysis algorithm developed by Harris (Harris et al., 1989). The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. The comp star magnitudes were taken from the APASS (Henden et al., 2009) and MPOSC3 catalogs (Warner, 2007), depending on availability of comparison stars. The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion reach 0.1 mag and more.

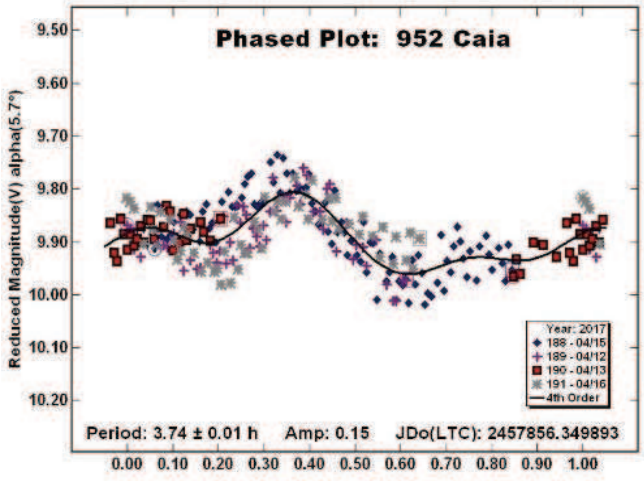
The StarBGone star subtraction algorithm in *MPO Canopus* was used when needed in order to remove the effect of stars located in the asteroid's path. This is most effective when the star's SNR is equal to or lower than asteroid's SNR (Aznar, 2013).

In Table I, the *a/b* and *b/c* columns give the axis ratios for an assumed triaxial ellipsoid that is viewed equatorially where $a > b$ and rotation is about the *c*-axis (Harris and Lupishko 1989). These were derived after reducing the lightcurve amplitude to zero phase angle (Zappala et al. 1980). Future analysis may determine the spin axis and shape model and so accurately define the two ratios.

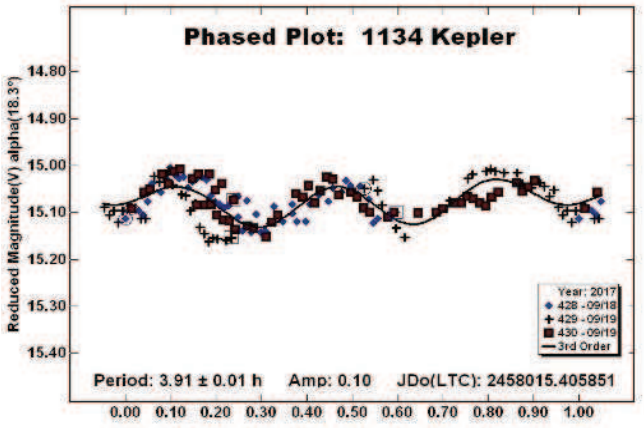
452 Hamiltonia. The period for this main-belt asteroid has been reported on three occasions in the LCDB (Warner et al., 2009. Two have a period of 2.8 hours while the third reports 3.8 hours. Period analysis based on a data set of 85 data points obtained during two sessions gave a period of 2.88 ± 0.01 h.



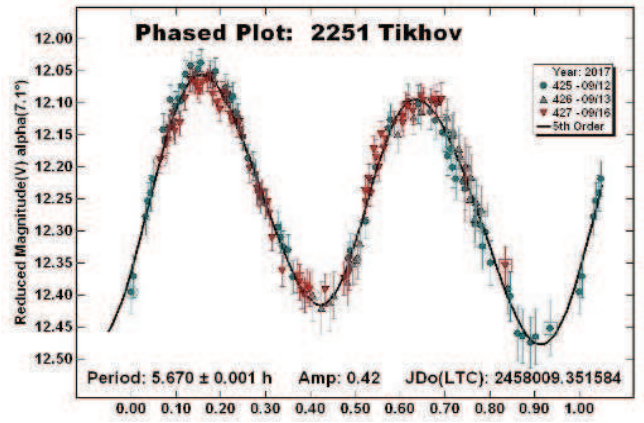
952 Caia. The period for Caia, a main-belt asteroid, has been reported on four occasions in the LCDB (Warner et al., 2009). Three report a period of 7.5 h while the fourth has 3.8 h, or about half the longer period. Analysis based on a data set obtained during four sessions gave a period of 3.74 ± 0.01 h.



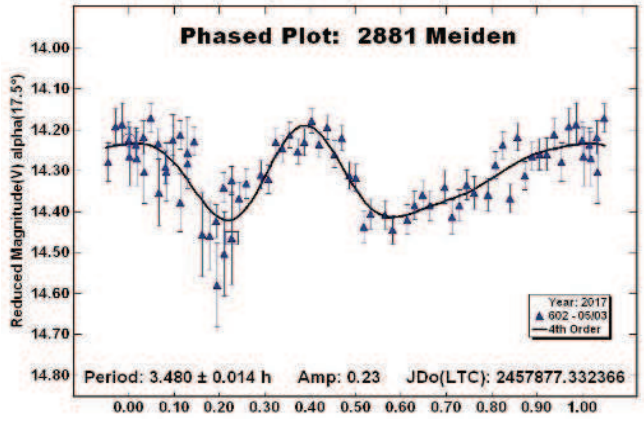
1134 Kepler. Kepler is a Mars-crossing asteroid with no reported period in the LCDB (Warner et al., 2009). Observations over two nights produced 240 data points. Analysis found a rotation period of 3.91 ± 0.01 h. The lightcurve shows a trimodal shape and amplitude of 0.10 mag at a phase angle of 19.0 degrees. This could mean that the asteroid is almost spherical (see Table I).



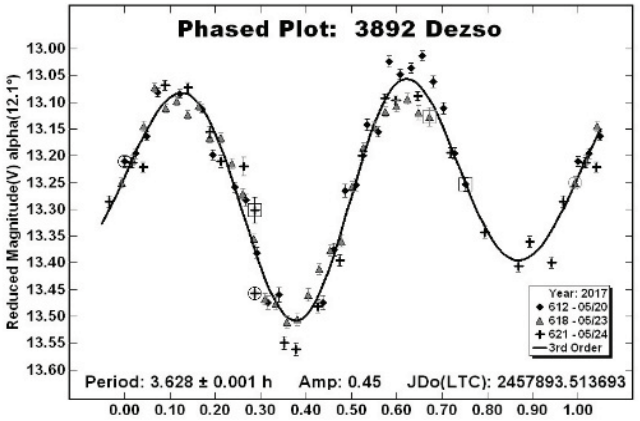
2251 Tikhow. The rotation period for this main-belt asteroid was last found in 2004. Analysis of the new data found a period of 5.67 ± 0.001 h and amplitude of 0.42 mag, indicating an elongated shape.



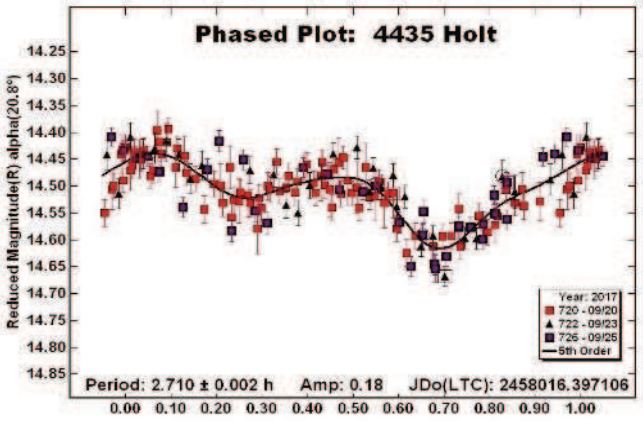
2881 Meiden. This main-belt asteroid has five entries in the LCDB. Three report a period of 3.48 h, one a period of 20.08 h, and the last a period of 6.06 h. Analysis of the new data found a period of 3.48 ± 0.014 h and amplitude of 0.23 mag.



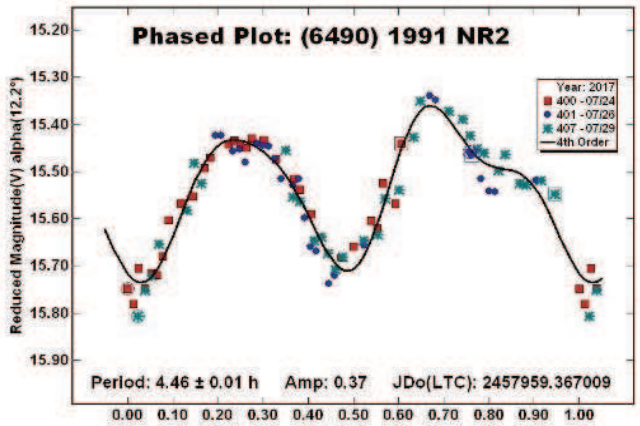
3892 Dezso. There are four entries in the LCDB (Warner et al., 2009) for this main-belt asteroid. All have a period of 3.620 ± 0.001 h. The new data set of 153 points led to a bimodal lightcurve with a maximum amplitude of 0.45 mag and period of 3.628 h.



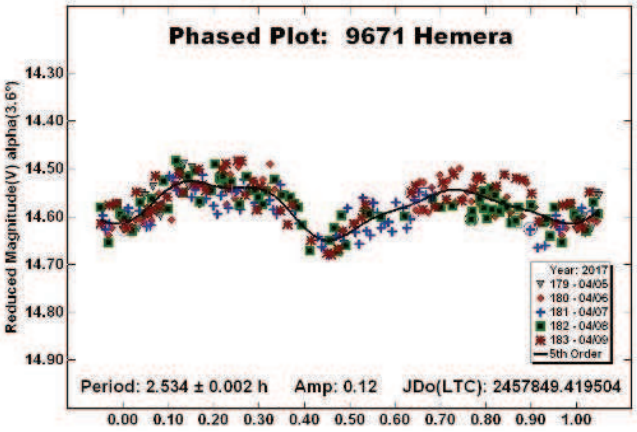
4435 Holt. No reported periods were found for this Mars-crossing asteroid. Analysis of the new data found a period of 2.710 ± 0.002 h and amplitude 0.18 mag.



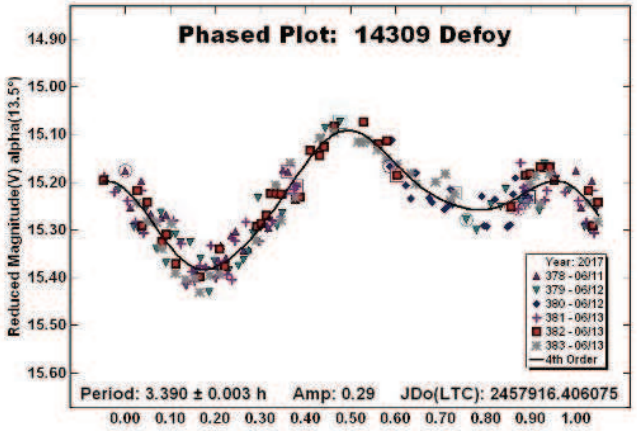
(6490) 1991 RN2. Analysis of the new data found a period of 4.46 ± 0.01 h and peak-to-peak amplitude of 0.37 mag,



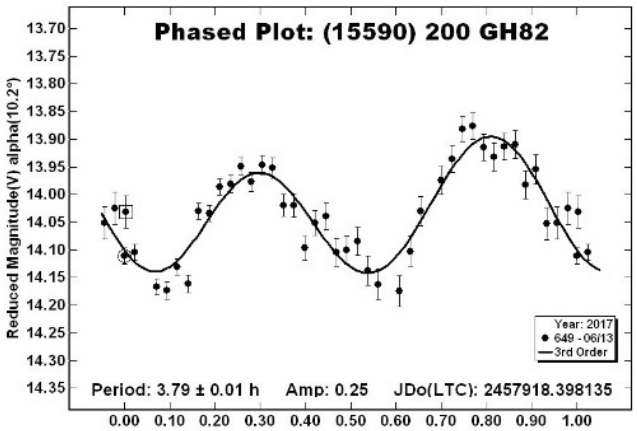
9671 Hemera. There were four LCDB (Warner et al., 2009) entries for this Mars-crosser, all of which gave a period of 2.534 h. The period reported here is the same. The peak-to-peak amplitude of the lightcurve is 0.12 mag.



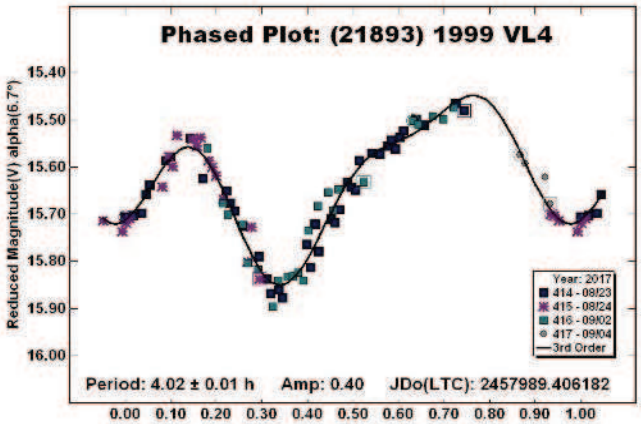
14309 Defoy. This is a Mars-crossing asteroid with only one entry in the LCDB (Warner et al., 2009), which gives a period of 3.391 h. The period found here is nearly the same: 3.390 ± 0.003 h. The lightcurve amplitude is 0.29 mag.



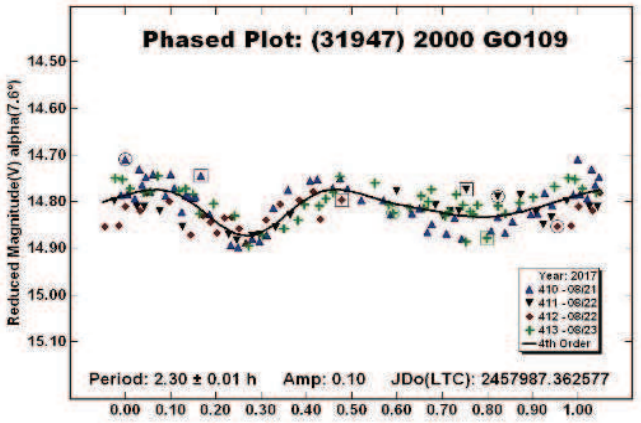
(15590) 200 GH82. The LCDB (Warner et al., 2009) listed no periods for this Mars-crosser. Analysis of the new data found 3.79 ± 0.01 h and amplitude of 0.25 mag. Future observations are encouraged to improve the period solution.



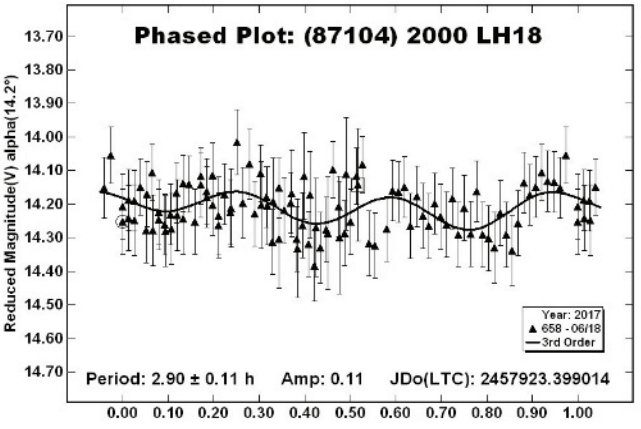
(21883) 1999 VL4. This Mars-crossing asteroid had no period listed in the LCDB (Warner et al., 2009). The latest data set of 92 observations led to a period of 4.02 ± 0.01 h with a lightcurve amplitude of 0.40 mag. The lightcurve is not complete and so the period is not secure. Future observations are needed.



(31947) 2000 JO109. This main-belt asteroid had only one entry in the LCDB (Warner et al., 2009), which reported a period 2.31 h based on observations in 2012. This is similar to the period of 2.30 ± 0.1 h reported here. The lightcurve has a typical bimodal shape with an amplitude of 0.10 mag.



(87104) 2000 LH18. The LCDB had no entries for this main-belt asteroid. Analysis of the latest data set found a period of 2.90 ± 0.11 h and lightcurve amplitude of 0.11 mag. The lightcurve shows a trimodal shape with a peak-to-peak of 0.11 magnitudes. Such shapes are possible when the amplitude and phase angle are low (Harris et al., 2014).

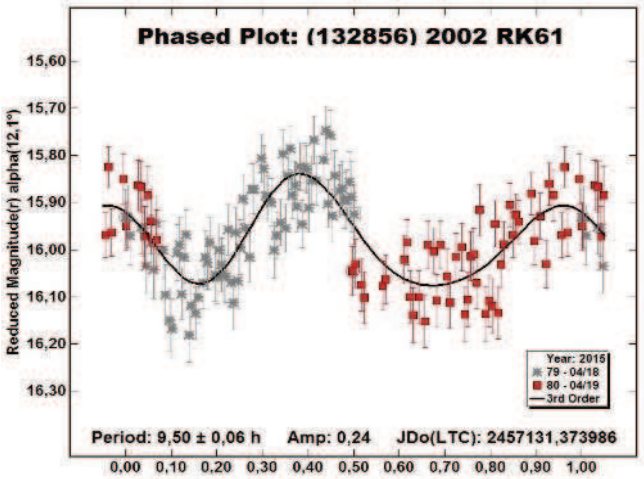


(132856) 2002 RK61. No reported periods were found for this main-belt asteroid. It was identified in images of an NEA taken during the EURONEAR (*www.euronear.org*) project in 2015.

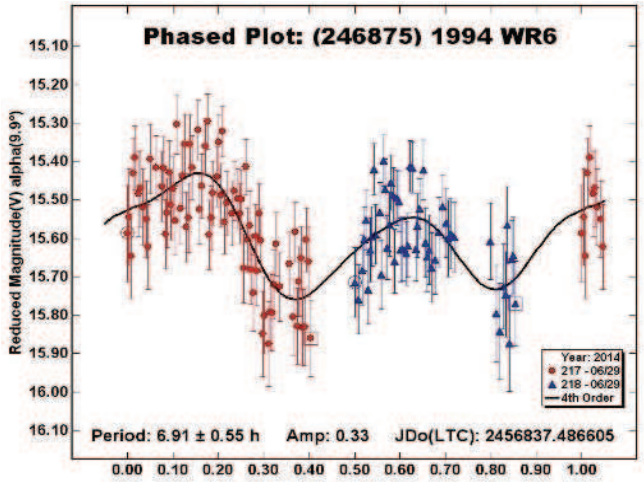
Number	Name	20xx/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	a/b	b/c
452	Hamiltonia	17/05/16-05/18	85	1.7,2.4	232	3	2.88	0.01	0.23	0.05	1.22	0.98
952	Caia	17/04/12-04/16	213	4.8,5.9	186	2	3.74	0.01	0.15	0.04	1.14	1.03
1134	Kepler	17/09/18-09/19	240	19.0,18.3	14	0	3.91	0.01	0.10	0.05	1.07	1.01
2251	Tikhov	17/09/12-09/16	180	7.5,5.6	3	2	5.670	0.001	0.42	0.04	1.42	1.06
2881	Meiden	17/05/03	160	17.0	195	3	3.480	0.014	0.23	0.03	1.15	1.02
3891	Dezso	17/05/20-05/24	153	6.4,5.6	81	0	3.628	0.001	0.45	0.02	1.36	0.91
4435	Holt	17/09/20-09/25	243	26.2,25.9	71	6	2.710	0.002	0.18	0.03	1.11	1.02
6490	1991 RN2	17/07/24-07/29	100	12.3,12.0	310	11	4.46	0.01	0.37	0.05	1.28	0.97
9671	Hemera	17/04/05-04/09	271	3.6,2.1	198	-2	2.534	0.002	0.12	0.04	1.13	1.01
14309	Defoy	17/06/11-06/13	193	13.5,14.6	247	11	3.390	0.003	0.29	0.05	1.21	1.00
15590	2000 GH82	17/06/13	46	10.1	252	15	3.79	0.01	0.25	0.04	1.21	1.02
21893	1999 VL4	17/08/23-09/04	92	6.6,13.1	327	-5	4.02	0.01	0.40	0.06	1.34	1.00
31947	2000 GO109	17/08/21-08/23	220	7.1,8.1	321	5	2.30	0.01	0.10	0.05	1.08	1.01
87104	2000 LH18	17/06/18	176	13.9	239	16	2.90	0.11	0.11	0.08	1.08	1.01
132856	2022 RK61	15/04/18-04/19	173	11.8,12.1	178	4	9.50	0.06	0.20	0.07	1.19	1.02
246875	1994 WR6	14/06/29	163	9.9	212	2	6.91	0.55	0.33	0.07	1.28	1.01

Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The phase angle values are for the first and last date, L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude. Period is in hours. Amp is peak-to-peak amplitude in magnitudes. AE is the amplitude error in magnitudes. The last two columns give the a/b and b/c ratios for an assumed triaxial ellipsoid viewed equatorially based on the amplitude.

Data analysis from only one night found a period of 9.50 ± 0.24 h and amplitude of 0.24 mag. Future observations are encouraged.



(246785) 1994 WR6. This main-belt asteroid was observed in 2014 during the EURONEAR project as a stray target in the field of an NEA. Data from one night produced a period of 6.91 ± 0.55 h and amplitude of 0.33 mag. Future observations may find a more secure period.



Acknowledgements

I would like to express my gratitude to Brian Warner for supporting LCDB as a primary database for the study of asteroids. Also thanks to Ovidiu Vaduvescu and Radu Cornea for letting me include the photometry of 132856 and 246785.

References

Aznar. A. (2013). "Lightcurve of 3422 Reid Using Star Subtraction Techniques." *Minor Planet Bull*. **40**, 214-215.

Aznar, A. (2016). "Parameters of Rotation Shapes of Main-belt Asteroids from APT Observatory Group: Second Quarter 2016." *Minor Planet Bull.* **43**, 350-353.

Harris, A.W., Lupishko, D.F. (1989). "Photometric lightcurve observations and reduction techniques." in Asteroids II (R.P. Binzel, T. Gehrels, M.S. Matthews eds.) pp. 39-53. University of Arizona Press. Tucson, AZ.

Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H.J., Debehogne, H., Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Harris, A.W., Pravec, P., Galad, A., Skiff, B.A., Warner, B.D., Vilagi, J., Gajdos, S., Carbognani, A., Hornoch, K., Kusnirak, P., Cooney, W.R., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2017 Sep. *http://www.MinorPlanet.info/lightcurvedatabase.html*

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

LIGHTCURVE OF NEA 1993 RA

Ovidiu Vaduvescu
ING, IAC/ULL & EURONEAR
Apartado de correos 321 E-38700 Santa Cruz de La Palma,
Canary Islands, Spain
ovidiu.vaduvescu@gmail.com

Amadeo Aznar Macías
Astronomía Para Todos Observatory Group
EURONEAR
4650 Puzol, Spain

(Received: 2017 Oct 15)

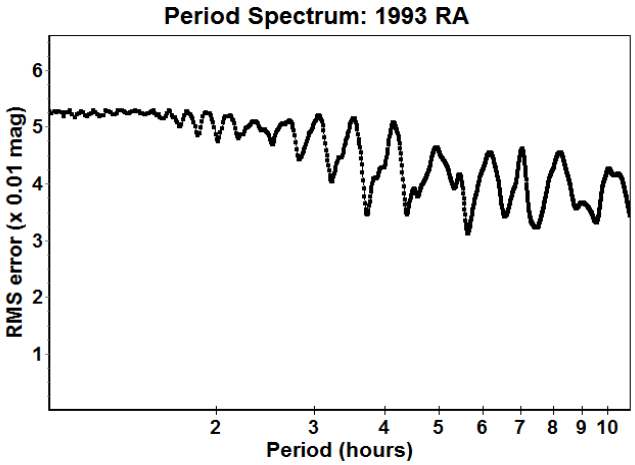
The near-Earth asteroid (NEA) 1993 RA was observed with the 2.5-m Isaac Newton Telescope (INT) in full Moon conditions for 8h total during three successive nights (2017 Oct 3-6). The composite lightcurve could be fit by a 3-order period P = 5.64 ± 0.01 h with amplitude of 0.13 mag; other solutions are possible.

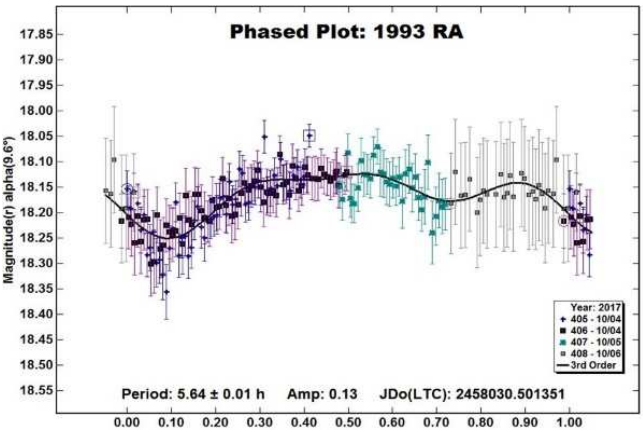
In 2014, the European Near-Earth Asteroids Research (EURONEAR; *www.euronear.org*) started its NEA Lightcurve Survey. Our first set of results for about 150 NEAs were published by Aznar Macias et al. (2017), Vaduvescu et al. (2017), and in a paper in progress. Following this work in 2017, we resumed observations during "free time" on the telescopes available to the EURONEAR network. This included the nights of 2017 Oct 3-5 that were used for student training at the Isaac Newton Telescope (INT). Using the EURONEAR long planning tool, we searched for NEAs brighter than V = 18, having no lightcurve data, and targeted 1993 RA, which had no previously reported periods.

1993 RA was discovered by Spacewatch at Kitt Peak on 1993 Sep 9 (MPC 22555). It was recovered in 2001 and the followed for another four other oppositions through 2017. During this time, it remained fainter than V = 18. It has an Amor-type orbit with a = 1.91 A.U., e = 0.42, and i = 5.6°. Its absolute magnitude is H = 19.2 and diameter of 500 meters if the albedo is 0.15. We used the Wide Field Camera (WFC) which can be windowed to 10′x10′ and read in fast mode (10s). Exposures were 1 min and tracked at half the asteroid sky motion. We used a Sloan *r* filter to minimize scattered light from a very close full Moon. The seeing was around 1.2″ during all three nights.

Bias and flat-fields were applied using IRAF. We used *MPO Canopus* for photometric measurement, choosing up to five reference stars with magnitudes taken from the SDSS12 catalog. This assured precise (~0.01 mag) night-to-night linkage. The RMS errors of the measurements were 0.02 mag during the first night, 0.03-0.04 mag during the second, and 0.07 mag during the third night when the Moon was only 6° away.

As show in the period spectrum, a 3-order Fourier fit results in P = 5.64 ± 0.01 h with other solutions between 4–8 h. Unfortunately, none of these could be covered completely during the available time any night since our longest run was 4 hours.





Acknowledgements

Based on discretionary-time observations made with the Isaac Newton Telescope operated on the island of La Palma by the Isaac Newton Group of Telescopes in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias. The following ING staff and students attended the observations: Marie Karjalainen, Rosa Clavero, Lucia Suarez, Tarik Zegmott, Thomas Wilson, Rachel Cochrane, Lara Monteagudo and Alex Brown.

References

Aznar Macias, A., Predatu, M., Vaduvescu, O., Oey, J. (2017). "EURONEAR – First Lighcurves and Physical Properties of Near

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
	1993 RA	10/03-10/06	384	9.6,8.8	17	-5	5.64	0.01	0.13	0.04

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).