

ASTEROID PHOTOMETRY FOR NINE MAIN-BELT AND TWO MARS-CROSSING ASTEROIDS

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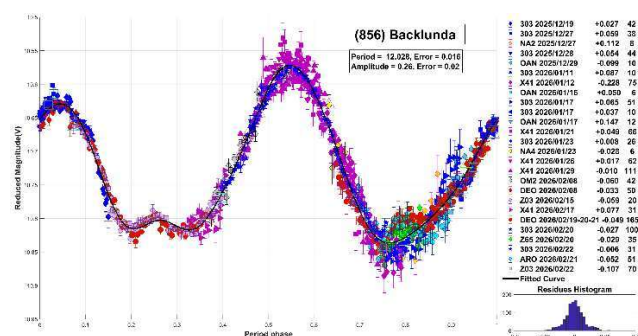
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Synodic rotation periods and amplitudes are reported for: 856 Backlunda, 1390 Abastumani, 1952 Hesburgh, 2810 Lev Tolstoj, 3940 Larion, 5514 Karelraska, 7631 Vokrouhlicky, 10416 Kottler, 16958 Klaasen, 21831 1999 TX93, 70171 1999 OL2.

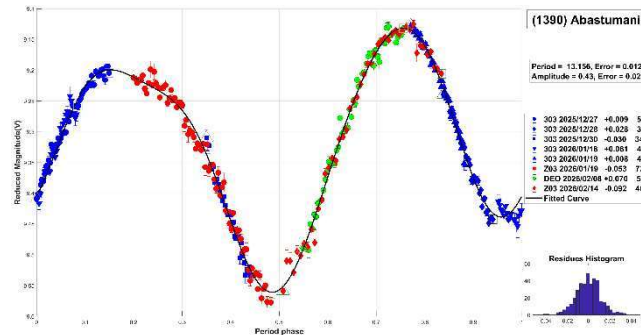
The periods and amplitudes of asteroid lightcurves presented in this paper are the product of collaborative work by the GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In all the studies, we have applied relative photometry assigning V magnitudes to the calibration stars. The image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected using dark frames and, in some cases, bias and flat-field corrections were also used. Photometry measurements were performed using *FotoDif* software and for the analysis, we employed *Periodos* software (Mazzone, 2012).

Below, we present the results for each asteroid studied. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - failing that - the GORA internal code, session date, session offset, and several data points. Targets were selected based on the following criteria: 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina, Venezuela, Spain, Italy, or Croatia, i.e. with negative or positive declinations δ , and 3) objects with few periods reported in the literature and/or with Lightcurve Database (LCDB) (Warner et al., 2009) quality codes (U) of less than 3.

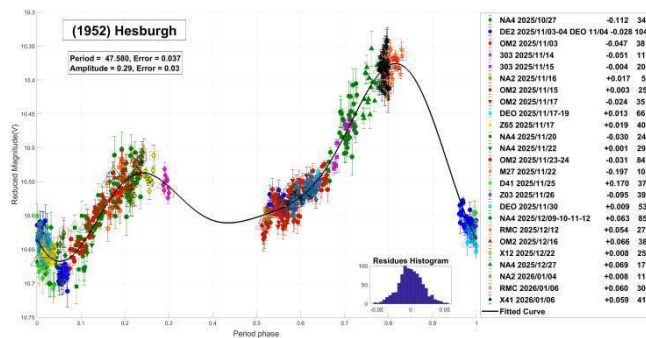
(856) Backlunda: Backlunda is a main-belt asteroid discovered in 1916 by S. Belyavskij. Based on the SMASSII taxonomy (Xu et al., 1995; Bus and Binzel, 2002), it is classified as a C-type, with a diameter of 45.449 km. The reported rotation period for this asteroid is $P = 12.08$ h (Polakis, 2019). Our measurement of the period, $P = 12.028 \pm 0.016$ h, agrees well with the value reported by the author.



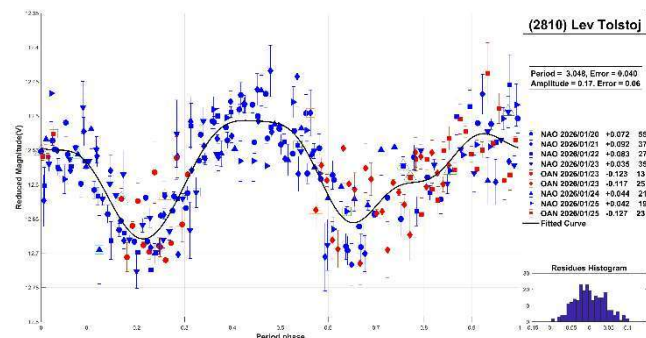
(1390) Abastumani: This outer main-belt asteroid was discovered in 1935 by P. Shajn, with a diameter of 95.849 km. The reported rotation period for this asteroid is $P = 26.49$ h (Polakis, 2021). In this work, we propose a considerably shorter period of $P = 13.156 \pm 0.012$ h, based on a well-covered lightcurve.



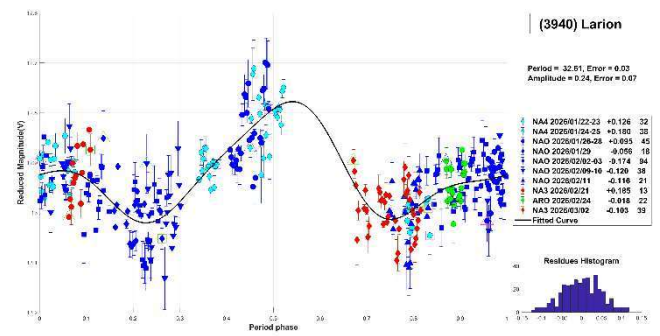
(1952) Hesburgh: It is a main-belt asteroid with a diameter of 37.501 km, discovered in 1951 at the Goethe Link Observatory. The reported rotation period for this asteroid is 47.52 h (Behrend, 2019web). We also measured a period of $P = 47.580 \pm 0.037$ h.



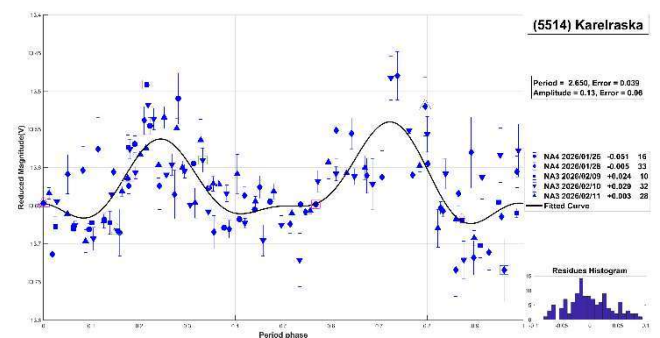
(2810) Lev Tolstoj: It is a main-belt asteroid with an estimated diameter of 7.91 km. It was discovered in 1978 by N. Chernykh. It belongs to the Eunomia family (Nesvorný et al., 2015). We couldn't find a reported period for this object in the literature. We propose a short period of $P = 3.048 \pm 0.040$ h with $\Delta m = 0.17 \pm 0.06$ mag.



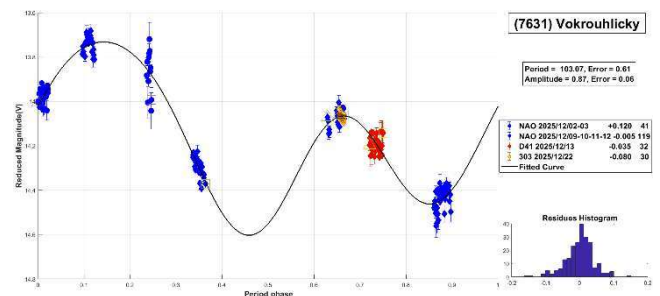
(3940) Laron: It is an inner main-belt asteroid discovered in 1973 by Zhuravleva. It is classified as a C-type asteroid according to the SDSS-based Asteroid Taxonomy (Hassellmann et al., 2012), with a diameter of 5.079 km. The reported rotation period for this asteroid is $P = 84$ h (Warner, 2007). In this work, we propose a shorter period of $P = 32.61 \pm 0.03$ h.



(5514) Karelraska: It is a main-belt asteroid, discovered in 1989 by Z. Vavrova, with an estimated diameter of 5.229 km. It is classified as an S-type asteroid according to the SDSS-based Asteroid Taxonomy (Hassellmann et al., 2012). For this asteroid, we could not find published periods in the literature, either. In this work, we propose a short period of $P = 2.650 \pm 0.039$ h with $\Delta m = 0.13 \pm 0.06$ mag.



(7631) Vokrouhlicky: It is a main-belt asteroid, discovered in 1981 by E. Bowell. For this asteroid, we could not find published periods in the literature, either. In this work, we propose a long period of $P = 103.07 \pm 0.61$ h with $\Delta m = 0.87 \pm 0.06$ mag.



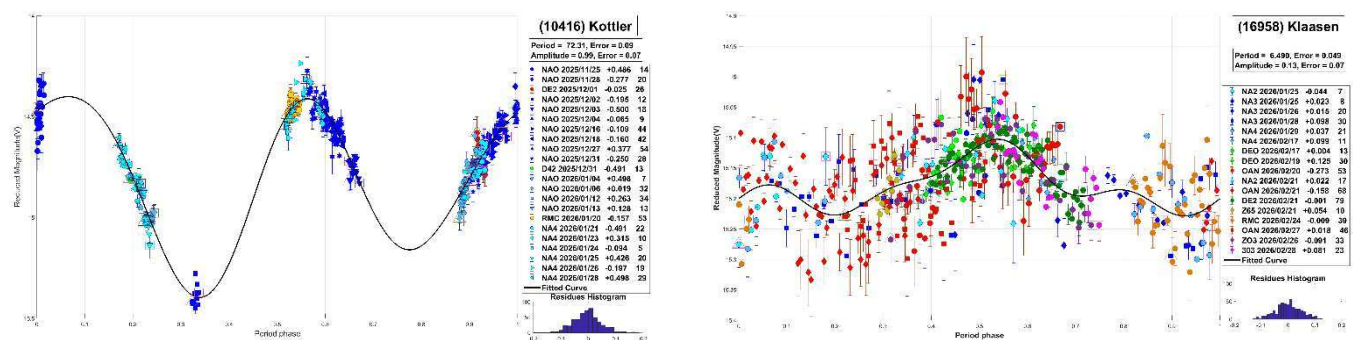
(10416) Kottler: It is a Mars-crossing asteroid with a diameter of 3.157 km, discovered in 1998 by the Lincoln Laboratory Near-Earth Asteroid Research Team. For this asteroid, we could not find any published rotation periods in the literature. In this work, we propose a period of $P = 72.31 \pm 0.09$ h with $\Delta m = 0.99 \pm 0.07$ mag.

Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	Amp.E.	Grp
856	Backlunda	25/12/19-26/02/22	*23.0,05.6	146	5	12.028	0.016	0.26	0.02	MB-I
1390	Abastumani	25/12/27-26/02/14	09.3,16.5	72	18	13.156	0.012	0.43	0.02	MB-O
1952	Hesburgh	25/10/27-26/01/06	*08.3,19.0	50	-7	47.580	0.037	0.29	0.03	MB-O
2810	Lev Tolstoj	26/01/20-26/01/25	11.1,09.6	134	-15	3.048	0.040	0.17	0.06	Euno
3940	Larion	26/01/22-26/03/02	*20.8,23.6	131	-30	32.61	0.03	0.24	0.07	Hung
5514	Karelska	26/01/26-26/02/11	*07.9,01.3	140	-2	2.650	0.039	0.13	0.06	MB-I
7631	Vokrouhlicky	25/12/02-25/12/22	14.8,03.6	90	-5	103.07	0.61	0.87	0.06	MB-I
10416	Kottler	25/11/25-26/01/29	*27.2,31.8	107	-16	72.31	0.09	0.99	0.07	M-cros
16958	Klaasen	26/01/25-26/02/28	*22.6,11.6	148	-11	6.490	0.049	0.13	0.07	M-cros
21831	1999 TX93	26/01/28-26/02/13	15.3,07.6	155	-6	4.094	0.031	0.13	0.04	MB-I
70171	1999 OL2	26/01/28-26/02/22	*14.1,07.8	148	-7	3.437	0.052	0.15	0.07	Pho

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extremum during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). MB-I: main-belt inner; MB-O: main-belt outer; Euno: 15 Eunomia; Hung: Hungaria; M-cros: Mars-crosser; Pho: 25 Phocaea.

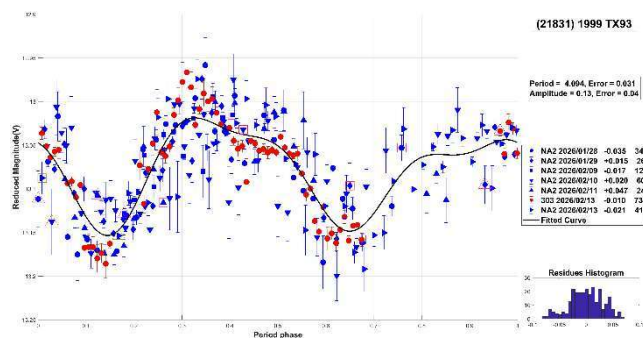
Observatory	Telescope	Camera
303 Obs.Astr.Nacional Llano del Hato	Newtonian (D=1000mm; f=5.5)	CCD FLI PL4240
D41 OsservatorioAstronomico di Orciatice	SCT (D=355mm; f=7.4)	CCD SBIG ST10XME
D42 OsservatorioAstronomico Piero Angela	SCT (D=300mm; f=6.2)	CMOS Touptek 2600 KMA
M27 Elijah Observatory	RCT (D=250mm; f=8.0)	CCD QSI 683
X12 Obs.Astr.Los Cabezones	Newtonian (D=200mm; f=5.0)	CMOS QHY 174M
X41 Observatorio Protón-Protón	Newtonian (D=250mm; f=5.0)	CMOS ZWO ASI120MINI MM
Z03 Obs.Astr.Río Cofio	SCT (D=254mm; f=6.3)	CCD SBIG ST-8XME
Z65 Obs.Astr.Corgas	Newtonian (D=310mm; f=4.8)	CMOS ZWO ASI 294 MM
ARO Obs.Astr. de Albatàrrec	Refractor (D=160mm; f=5.6)	CMOS Player O-P M Pro
DEO Dark Energy Observatory	Refractor (D=115mm; f=7.0)	CMOS QHY 294M pro
DE2 Dark Energy Observatory 2	RCT (D=200mm; f=5.4)	CMOS Player One Ares-M
NAO Obs.Astr.Naos	Newtonian (D=250mm; f=4.0)	CMOS ZWO 183
NA2 Obs.Astr.Naos 2	Newtonian (D=200mm; f=5.0)	CMOS ZWO ASI 174
NA3 Obs.Astr.Naos 3	SCT (D=279; f=10)	CMOS QHY 163M
NA4 Obs.Astr.Naos 4	Newtonian (D=200mm; f=5.0)	CMOS ZWO ASI 174
OAN Obs.Astr.Nacional Llano del Hato	Cámara Schmidt (D=1000mm; f=3.0)	CMOS Fujifilm GFX 50R
OM2 Obs.Astr.Vuelta por el Universo 2	Newtonian (D=200mm; f=5.0)	CMOS POA Neptune-M
RM Obs.Astr.de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

Table II. List of observatories and equipment.

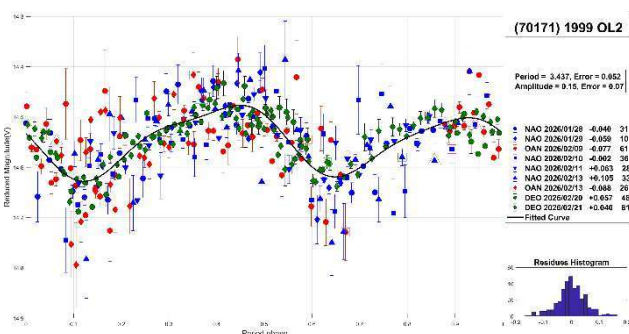


(16958) **Klaasen**: It is a Mars-crossing asteroid discovered in 1998 by the Lowell Observatory Near-Earth Object Search. For this asteroid, we could not find any published rotational periods in the literature. In this work, we propose a period of $P = 6.490 \pm 0.049$ h with $\Delta m = 0.13 \pm 0.07$ mag.

(21831) **1999 TX93**: It is a main-belt asteroid discovered in 1999 by LINEAR, with a diameter of 13.826 km. It is classified as a C-type asteroid according to the SDSS taxonomy (Hasselmann et al., 2012). The reported rotation period for this asteroid is $P = 4.084$ h (Benishek, 2022). In this work, we measure a period of $P = 4.094 \pm 0.031$ h.



(70171) 1999 OL2: It is a main-belt asteroid discovered in 1999 by LINEAR with an estimated diameter of 3.980 km. It is a member of the Phocaea family (Nesvorný et al., 2015). For this asteroid, we could not find any published rotation periods in the literature. In this work, we propose a short period of $P = 3.437 \pm 0.052$ h with $\Delta m = 0.15 \pm 0.07$ mag.



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We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analyses, Fernando Mazzone for his *Periodos* program, which was used in final analyses. We also used *Seqplot* (<https://www.aavso.org/seqplot>), which proved very effective for checking the magnitudes of the calibration stars. This research has made use of the Small Bodies Data Ferret (<https://sbnapps.psi.edu/ferret/>), supported by the NASA Planetary System. This research has made use of data and/or services provided by the International Astronomical Union's Minor Planet Center.

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