

ASTEROID PHOTOMETRY: RESULTS FOR 15 MAIN-BELT ASTEROIDS AND AN APOLLO NEA

Milagros Colazo

Astronomical Observatory Institute, Faculty of Physics,
Adam Mickiewicz University,
ul. Słoneczna 36, 60-286 Poznań, POLAND
Grupo de Observadores de Rotaciones de Asteroides (GORA)
ARGENTINA

<https://aoacm.com.ar/gora/index.php>
milirita.colazovinovo@gmail.com

Gerard Tàrtalo

Dark Energy Observatory (DEO) -
Dark Energy Observatory 2 (DE2) -
Àger (Lleida - ESPAÑA)

Víctor Amelotti

Observatorio Astronómico Naos (GORA NAO) -
Observatorio Astronómico Naos 2 (GORA NA2) -
Observatorio Astronómico Naos 3 (GORA NA3) -
Alta Gracia (Córdoba - ARGENTINA)

Marcos Anzola

Observatorio Astronómico Vuelta por el Universo (GORA OMA)
Observatorio Astronómico Vuelta por el Universo 2 (GORA OM2)
Córdoba (Córdoba - ARGENTINA)
Estación Astrofísica Bosque Alegre (MPC 821) -
Departamento Punilla (Córdoba - ARGENTINA)

Raúl Melia

Observatorio de Raúl Melia Carlos Paz (GORA RMC) -
Carlos Paz (Córdoba - ARGENTINA)
Estación Astrofísica Bosque Alegre (MPC 821) -
Departamento Punilla (Córdoba - ARGENTINA)

Giuliat Navas

Observatorio Astronómico Nacional Llano del Hato (OAN) -
Observatorio Astronómico Nacional Llano del Hato (MPC 303) -
Centro de Investigaciones de Astronomía Francisco J. Duarte
(CIDA) - Apartaderos (Mérida - VENEZUELA)

Alejandro Moreschi

Observatorio Chopis (GORA OM3) -
Mercedes - (Buenos Aires - ARGENTINA)

Martín Leiva

Estación Astrofísica Bosque Alegre (MPC 821) -
Departamento Punilla (Córdoba - ARGENTINA)

Paolo Aldinucci

Osservatorio Astronomico Piero Angela (MPC D42) -
Scandicci (Firenze - ITALIA)

Zlatko Orbanic

Osservatorio Explorer (MPC M19) -
Pula (Istria - CROACIA)

José Álvarez

Observatorio Astronómico Corgas (MPC Z65) -
Corgas-Taboadela-Ourense (Galicia - ESPAÑA)

Carlos Colazo

Observatorio Astronómico El Gato Gris (MPC I19) -
Tanti (Córdoba - ARGENTINA)
Estación Astrofísica Bosque Alegre (MPC 821) -
Departamento Punilla (Córdoba - ARGENTINA)

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Synodic rotation periods and amplitudes are reported for: 703 Noemi, 1326 Losaka, 1714 Sy, 1858 Lobachevskij, 1892 Lucienne, 1908 Pobeda, 2359 Debehogne, 2552 Remek, 2949 Kaverznev, 3702 Trubetskaya, 4001 Ptolemaeus, 5676 Voltaire, 6422 Akagi, 6441 Milenajesenska, 6932 Tanigawadake, and (138205) 2000 EZ148.

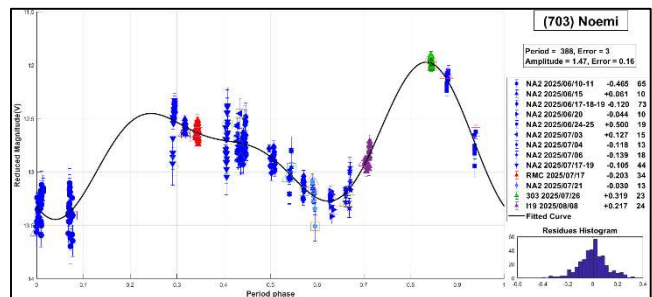
The periods and amplitudes of asteroid lightcurves presented in this paper are the product of collaborative work by the GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In all the studies, we have applied relative photometry assigning V magnitudes to the calibration stars.

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).

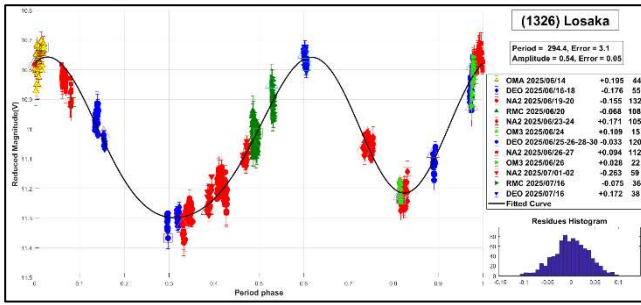
Below, we present the results for each asteroid studied. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - 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.

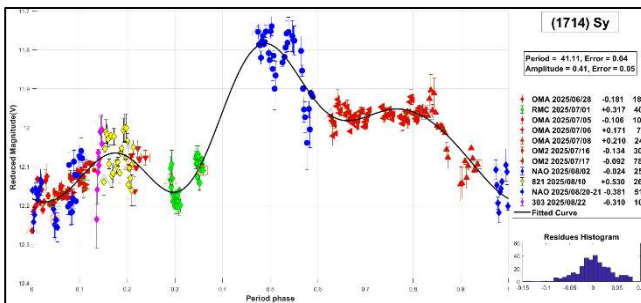
703 Noemi. Noemi is a main-belt asteroid discovered in 1910 by J. Palisa. It is a member of the Flora family (Nesvorný et al., 2015), with a diameter of 7.25 km. A previously reported rotational period for this asteroid is $P = 200$ h (Noschese et al., 2017). In this work, we propose a longer period of $P = 388 \pm 3$ h, with an amplitude of $\Delta m = 1.47 \pm 0.16$ mag.



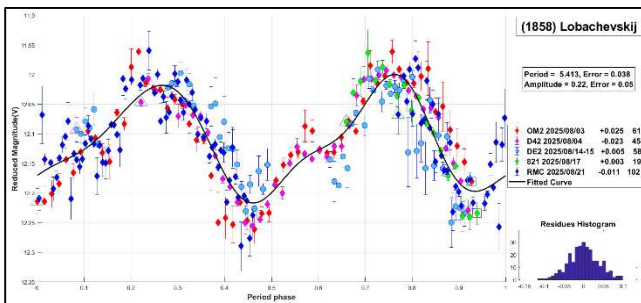
1326 Losaka. This main-belt asteroid was discovered in 1934 by C. Jackson. It is classified as a C-type asteroid according to the SDSS taxonomy (Hasselmann et al., 2012). The reported rotational period for this asteroid is 6.9 h (Warner, 2006). In this work, we propose a long period of $P = 294.4 \pm 3.1$ h with $\Delta m = 0.54 \pm 0.05$ mag.



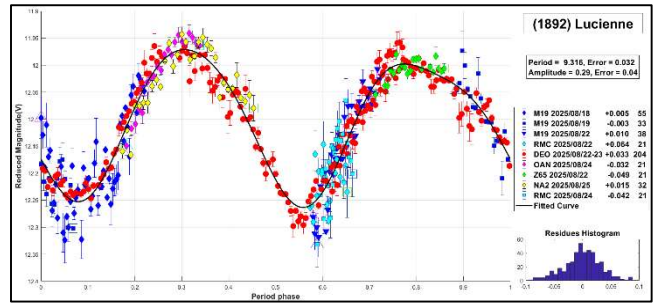
1714 Sy. This main-belt asteroid was discovered in 1951 by L. Boyer. It is classified as a L-type asteroid according to the SDSS-based Asteroid Taxonomy (Hasselmann et al., 2012), with a diameter of 13.998 km. For this asteroid, we could not find any published rotational periods in the literature. In this work, we propose a period of $P = 41.11 \pm 0.41$ h with $\Delta m = 0.41 \pm 0.05$ mag.



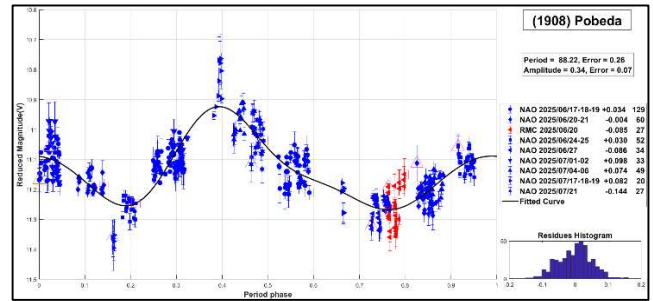
1858 Lobachevskij. This main-belt asteroid was discovered in 1927 by L. Zhuravleva. Based on the SMASSII taxonomy (Xu et al., 1995; Bus and Binzel, 2002), it is classified as an L-type, with a diameter of 10.769 km. The reported rotational period for this asteroid is $P = 5.413$ h (Durech et al., 2016). Our measurement of the period, $P = 5.413 \pm 0.038$ h, with $\Delta m = 0.22 \pm 0.05$, agrees well with the value reported by the authors.



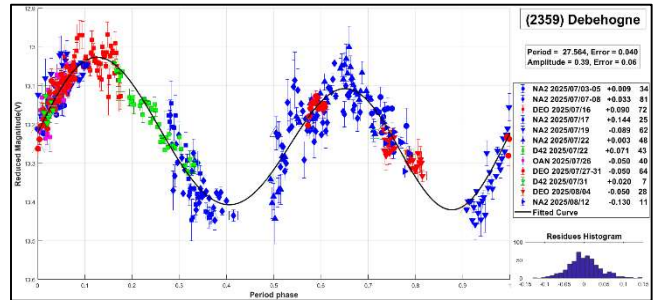
1892 Lucienne. This main-belt asteroid was discovered in 1971 by P. Wild. It is the parent body of the Lucienne family (Nesvorný et al., 2015). The diameter is 9.725 km. Martikainen et al. (2021) measured a rotational period of 9.31 h. Our measurement of the period, $P = 9.316 \pm 0.032$ h, with $\Delta m = 0.29 \pm 0.04$, agrees well with the value reported by the authors.



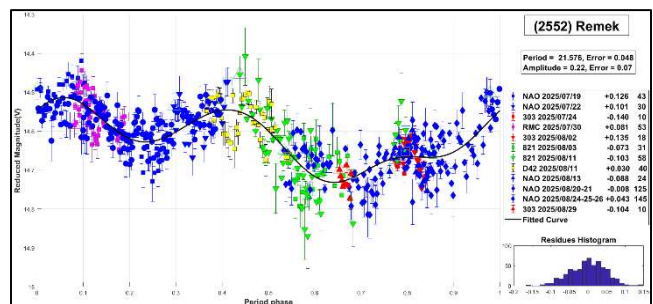
1908 Pobeda. This main-belt asteroid was discovered in 1972 by N. Chernykh, with a diameter of 18.384 km. The reported rotational period for this asteroid is $P = 149.95$ h (Durech et al., 2020). In this work, we propose a considerably shorter period of $P = 88.22 \pm 0.26$ h with $\Delta m = 0.34 \pm 0.07$ mag.



2359 Debehogne. This main-belt asteroid was discovered in 1931 by K. Reinmuth. For this asteroid, we could not find published periods in the literature either. In this work, we propose a period of $P = 27.564 \pm 0.040$ h with $\Delta m = 0.39 \pm 0.06$ mag.



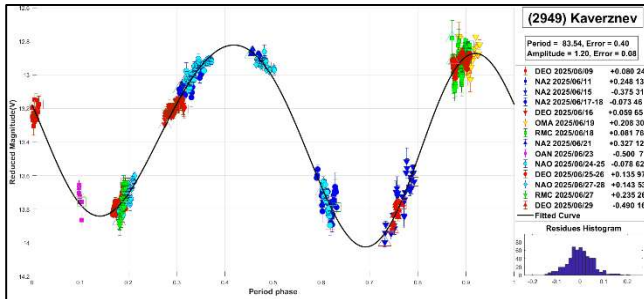
2552 Remek. This main-belt asteroid was discovered in 1978 by A. Mrkos. No published rotational periods for this asteroid were found in the literature. In this work, we propose a period of $P = 21.576 \pm 0.048$ h with $\Delta m = 0.22 \pm 0.07$ mag.



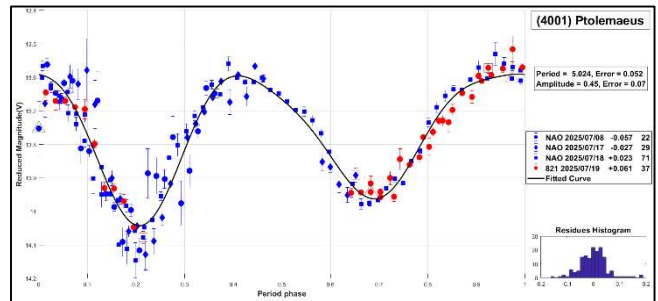
Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
703	Noemi	25/06/10-25/08/09	*10.5, 19.6	278	3	288	3	1.47	0.16	Flora
1326	Losaka	25/06/14-25/07/16	3.4, 13.7	260	6	294.4	3.1	0.54	0.05	MB-M
1714	Sy	25/06/28-25/08/22	*5.0, 20.5	285	-2	41.11	0.04	0.41	0.05	MB-I
1858	Lobachevskij	25/08/03-25/08/21	*2.5, 06.1	315	2	5.413	0.038	0.22	0.05	MB-O
1892	Lucienne	25/08/18-25/08/25	10.9, 08.2	344	8	9.316	0.032	0.29	0.04	Lucie
1908	Pobeda	25/06/17-25/07/22	*5.9, 09.2	278	-6	88.2	0.26	0.34	0.07	MB-O
2359	Debehogne	25/07/03-25/08/12	*10.9, 11.6	299	6	27.564	0.040	0.39	0.06	MB-I
2552	Remek	25/07/19-25/08/29	*6.8, 19.2	307	-1	21.576	0.048	0.22	0.07	MB-I
2949	Kaverznev	25/06/09-25/06/29	*8.8, 07.4	269	7	83.54	0.40	1.20	0.08	MB-I
3702	Trubetskaya	25/06/21-25/07/07	*6.8, 03.8	281	7	8.295	0.059	0.27	0.08	MB-M
4001	Ptolemaeus	25/07/08-25/07/19	12.5, 06.3	305	2	5.024	0.052	0.45	0.07	Dup
5676	Voltaire	25/07/19-25/08/28	*12.4, 18.4	306	19	8.202	0.034	0.16	0.05	MB-I
6422	Akagi	25/07/08-25/07/18	9.4, 04.3	302	3	7.748	0.041	0.90	0.06	Euno
6441	Milenajesenska	25/07/03-25/07/07	9.3, 07.0	294	3	2.820	0.038	0.40	0.05	Her
6932	Tanigawadake	25/08/22-25/08/22	2.7, 05.3	329	-4	3.794	0.031	0.41	0.04	MB-I
138205	2000 EZ148	25/06/08-25/06/25	46.0, 67.0	263	-39	4.980	0.037	0.26	0.05	NEA

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). Flora: 8 Flora; MB-M: main-belt middle, MB-I: main-belt inner, MB-O: main-belt outer, Lucie: 1892 Lucienne; Dup: 1338 Duponta, Euno: 15 Eunomia, Her: 135 Hertha, NEA: NEA.

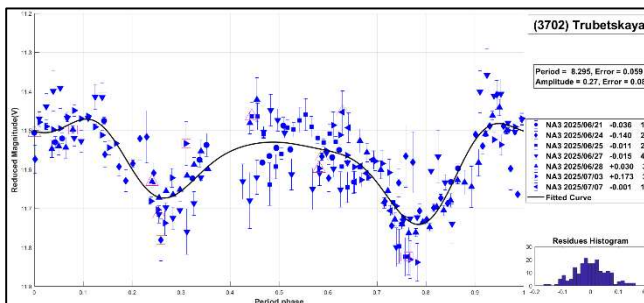
2949 Kaverznev. This main-belt asteroid with a diameter of 6.959 km was discovered in 1970 by the Crimean Astrophysical Observatory. It is classified as an S-type asteroid according to the SMASSII spectral type scheme (Xu et al., 1995; Bus and Binzel, 2002). For this asteroid, we couldn't find published periods in the literature either. Based on our observations and thorough analysis, we propose a long period of $P = 83.54 \pm 0.40$ h and $\Delta m = 1.20 \pm 0.08$ mag.



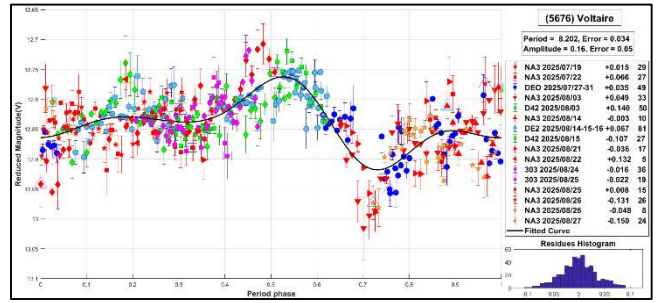
4001 Ptolemaeus. This main-belt asteroid was discovered in 1949 by K. Reinmuth. It is listed as a member of the Flora family (Nesvorný et al., 2015), although its possible association with the Baptistina family has also been noted. Its estimated diameter is 4.641 km. It is an S-type asteroid in the SMASSII spectral type scheme (Xu et al., 1995; Bus and Binzel, 2002). Interestingly, we could not find a reported rotational period for this object in the literature. Based on our observations and thorough analysis, we propose a period of $P = 5.024 \pm 0.052$ h and $\Delta m = 0.45 \pm 0.07$ mag.



3702 Trubetskaya. This main-belt asteroid was discovered in 1970 by L. Chernykh, with a diameter of 18.158 km. It is classified as a C-type asteroid according to the SDSS taxonomy (Hasselmann et al., 2012). The reported rotational period for this asteroid is $P = 8.2905$ h (Durech et al., 2020). In this work, we measure a period of $P = 8.295 \pm 0.059$ h with $\Delta m = 0.27 \pm 0.08$.



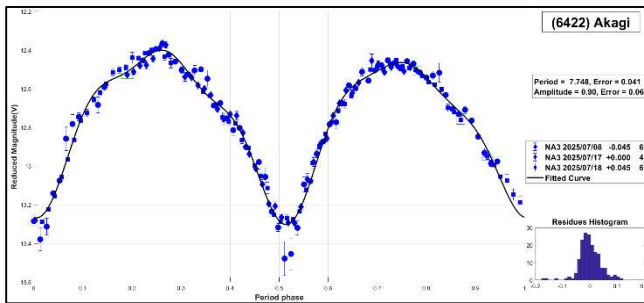
5676 Voltaire. This outer main-belt asteroid, with a diameter of 10.433 km, was discovered in 1986 by L.G. Karachkina. The reported rotational period for this asteroid is $P = 5.039$ h (Pravec et al., 2010web). Our observations suggest a longer period, yielding a value of $P = 8.202 \pm 0.034$ h with $\Delta m = 0.26 \pm 0.05$.



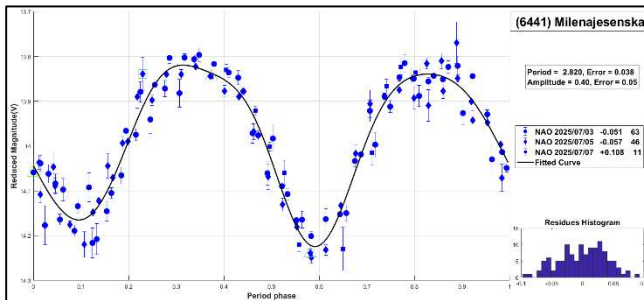
Observatory	Telescope	Camera
303 Obs.Astr.Nacional Llano del Hato	Newtonian (D=1000mm; f=5.5)	CCD FLI PL4240
821 Est.Astrof.Bosque Alegre	Newtonian (D=1540mm; f=4.9)	CCD APOGEE Alta U9
D42 Osservatorio Astronomico Piero Angela	SCT (D=300mm; f=6.2)	CMOS Touptek 2600 KMA
M19 Osservatorio Explorer	RCT (D=304 mm; f=6,5)	CCD Moravian G2 4000
I19 Obs.Astr.El Gato Gris	SCT (D=355mm; f=10.6)	CCD SBIG STF-8300M
Z65 Obs.Astr.Corgas	Newtonian (D=310mm; f=4.8)	CMOS ZWO ASI 294 MM
DE0 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
OAN Obs.Astr.Nacional Llano del Hato	Cámara Schmidt (D=1000mm; f=3.0)	CMOS Fujifilm GFX 50R
OMA Obs.Astr.Vuelta por el Universo	Newtonian (D=150mm; f=5.0)	CMOS POA Neptune-M
OM2 Obs.Astr.Vuelta por el Universo 2	Newtonian (D=200mm; f=5.0)	CMOS POA Neptune-M
OM3 Obs.Astr.Chopis-Mercedes	Newtonian (D=200mm; f=4.5)	CMOS ZWO ASI 294 MM-PRO
RMC Obs.Astr.de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

Table II. List of observatories and equipment.

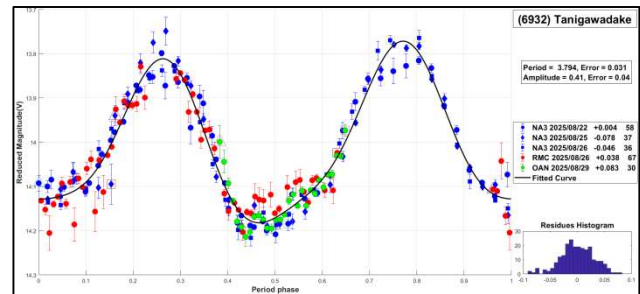
6422 Akagi. This main-belt asteroid was discovered in 1994 by T. Kobayashi. Classified as an L-type asteroid according to the SDSS taxonomy (Hasselmann et al., 2012), it is a member of the Eunomia family (Nesvorný et al., 2015). The diameter is 9.084 km. The reported rotational period for this asteroid is 7.74 h (Pál et al., 2020). Our measurement of the period, $P = 7.748 \pm 0.041$ h, with $\Delta m = 0.40 \pm 0.05$, agrees well with the value reported by the author.



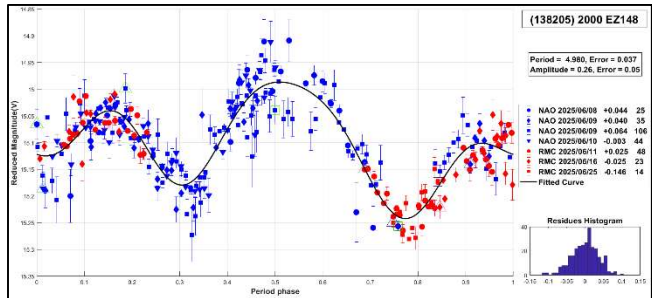
6441 Milenajesenska. This main-belt asteroid with a diameter of 4.829 km, was discovered in 1988 by A. Mrkos. It belongs to the Nysa-Polana family (Nesvorný et al., 2015). No published rotational period has been found in the literature for this asteroid. In this work, we propose a short period of $P = 2.820 \pm 0.038$ h with $\Delta m = 0.40 \pm 0.05$ mag, consistent with its small diameter.



6932 Tanigawadake. This main-belt asteroid with a diameter of 5.211 km, was discovered in 1994 by T. Kobayashi. It is classified as an L-type asteroid according to the SDSS-based Asteroid Taxonomy (Hasselmann et al., 2012). The reported rotational period for this asteroid is 3.79 h (Waszczak et al., 2015). Our measurement of the period, $P = 3.794 \pm 0.031$ h, with $\Delta m = 0.41 \pm 0.04$, agrees well with the value reported by the authors.



(138205) 2000 EZ148. This Apollo near-Earth asteroid was discovered in 2000 by the Catalina Sky Survey. It is classified as an S-type asteroid according to the SMASSII spectral type scheme (Xu et al., 1995; Bus and Binzel, 2002). No published rotational periods for this asteroid were found in the literature. In this work, we propose a period of $P = 4.980 \pm 0.037$ h with $\Delta m = 0.26 \pm 0.05$ 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, and Matías Martini for his *CalculadorMDE_v0.2* used for generating ephemerides used in the planning stage of the observations. 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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