ASTEROID PHOTOMETRY AND LIGHTCURVES OF NINE ASTEROIDS

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)
AREGENTINA *https://aoacm.com.ar/gora/index.php*
milirita.colazovinovo@gmail.com

Francisco Santos
Observatorio Astronómico Giordano Bruno (MPC G05)
Piconcillo (Córdoba-España)

Bruno Monteleone
Osservatorio Astronomico
La Macchina del Tempo (MPC M24)
Ardore Marina (Reggio Calabria-Italia)

Paolo Aldinucci
Osservatorio Astronomico di Orciatico (OAL)
Lajatico (Pisa-Italia)

Giuseppe Ciancia
CapoSudObservatory (GORA CS1)
Palizi Marina (Reggio Calabria-Italia)

CapoSudObservatory (GORA CS2)
Palizzi Marina (Reggio Calabria-Italia)

Damián Scotta
Observatorio de Damián Scotta 2 (GORA OD2)
San Carlos Centro (Santa Fe-Argentina)

Néstor Suárez
Observatorio Antares (MPC X39)
Pilar (Buenos Aires-Argentina)

Alberto García
Observatorio Río Cofio (MPC Z03)
Robledo de Chavela (Madrid-España)

Raúl Melia
Observatorio de Raúl Melia Carlos Paz (GORA RMC)
Carlos Paz (Córdoba-Argentina)

Mario Morales
Observatorio de Sencelles (MPC K14)
Sencelles (Mallorca-Islas Baleares-España)

Nicola Montecchiari
Elijah Observatory (MPC M27)
Lajatico (Pisa-Italia)

Tiago Speranza
Observatorio Astronómico Municipal Reconquista (GORA OMR)
Reconquista (Santa Fe-Argentina)

Carlos Colazo
Observatorio Astronómico El Gato Gris (MPC I19)
Tanti (Córdoba-Argentina)

(Received: 2024 Feb 12 Revised: 2024 May 14)

Synodic rotation periods and amplitudes are reported for: 526 Jena; 667 Denise; 717 Wisibada; 892 Seeligeria; 1429 Pemba; 1504 Lappeenranta; 2052 Tamriko; 2967 Vladisvyat; and 3819 Robinson.

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 (Castellano, 2023) and for the analysis, we employed *Periodos* software (Mazzone, 2012).

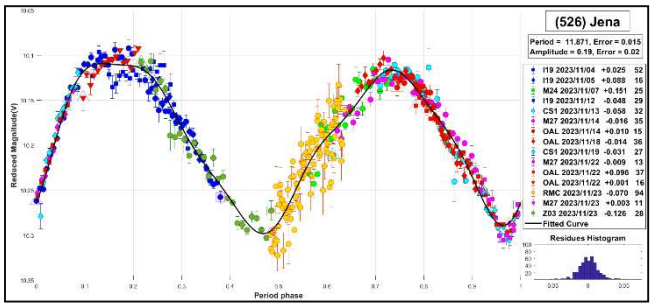
Below, we present the results for each asteroid studied. The lightcurve figures contain the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - failing that - the GORA internal code, session date, session offset, and several data points.

Targets were selected based on 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina or Spain or Italy, i.e. with negative or positive declinations δ, respectively, and 3) objects with few periods reported in the literature and/or LCDB (Warner et al., 2009) with quality codes (U) of less than 3.

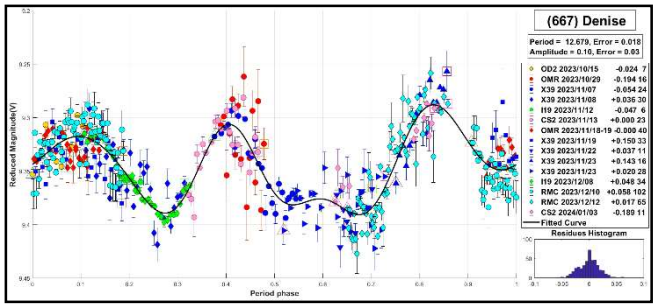
In this work, we present measurements of periods corresponding to asteroids previously analyzed by our team. These lightcurves display improved results and are part of a new long-term project that we are initiating.

For 717 Wisibada and 1429 Pemba, we applied the formula: $DP = 0.027778 * P^2 / T$, where P is the period and T is the total span of the observations, to estimate the period error (Warner, private communication).

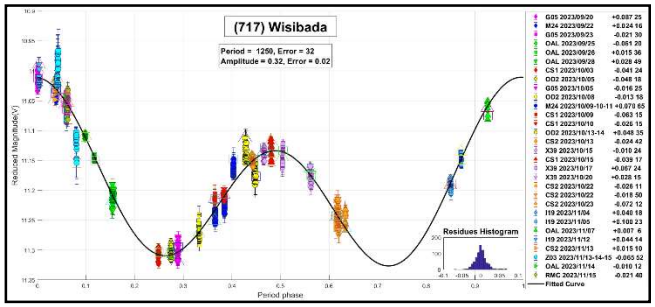
526 Jena is a B-type asteroid discovered in 1904 by M. Wolf. The most recent period from the literature is $P = 11.87651 \pm 0.00006$ h (Martiknainen et al., 2021). We determined a period of 11.871 ± 0.015 h with $\Delta m = 0.19 \pm 0.02$ mag, which is consistent with the one proposed by Martikainen et al.



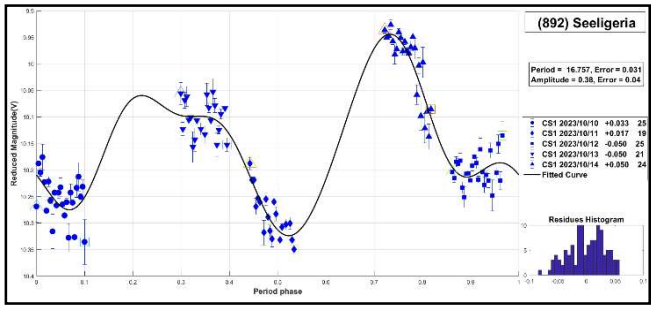
667 Denise was discovered in 1908 by A. Kopff. The most recent period from in the literature is $P = 12.684$ h (Wilawer et al., 2022). Our period of $P = 12.679 \pm 0.018$ h with $\Delta m = 0.10 \pm 0.03$ mag agrees with the one measured by Wilawer.



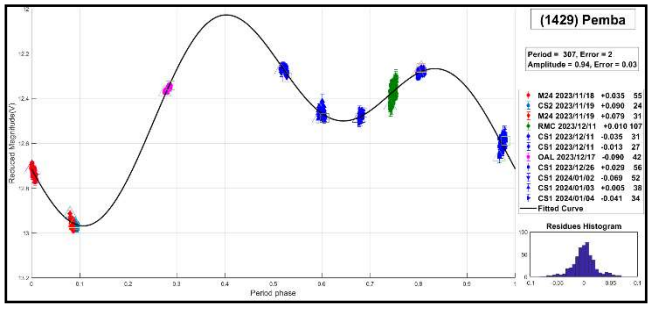
717 Wisibada is a DX-type asteroid discovered in 1911 by F. Kaiser. We couldn't find a reported period for this object. We propose a long-term period of P = 1250 ± 35 h with Δm = 0.32 ± 0.02 mag.



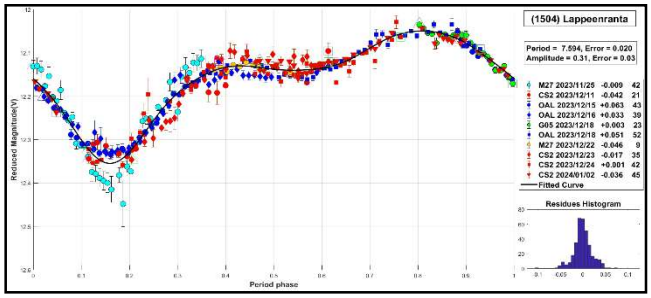
892 Seeligeria was discovered in 1918 by M. Wolf. We previously measured the period of this asteroid, obtaining a result of P = 16.693 ± 0.008 h with Δm = 0.11 ± 0.01 mag (Colazo et al., 2023). In this work, we report P = 16.757 ± 0.031 h with Δm = 0.38 ± 0.04 mag obtained at a different solar phase angle and phase angle bisector.



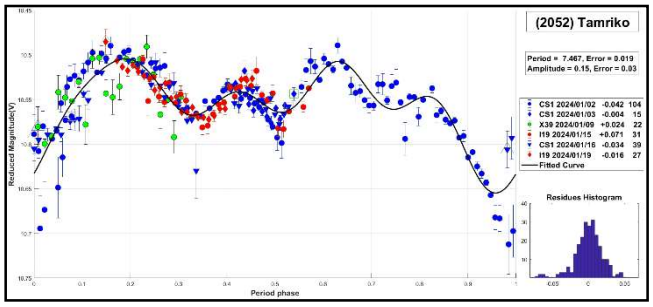
1429 Pemba was discovered in 1918 by C. Harris Jackson. Harris et al. (1999) estimated that the period of this object should be longer than 20 hours. We couldn't find any other period reported in the literature, apart from this estimate. In this work, we propose a long-term period of P = 307 ± 3 h with Δm = 0.94 ± 0.03 mag.



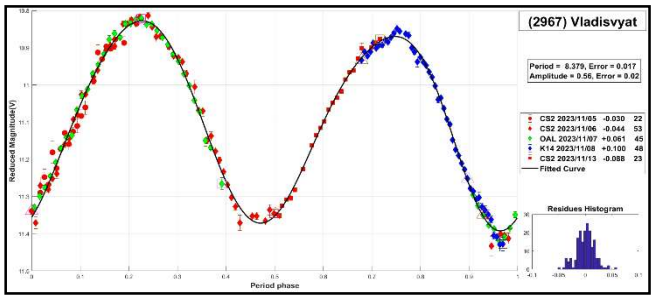
1504 Lappeenranta is an S-type asteroid, discovered in 1939 by L. Oterma. The most recent period in the literature corresponds to P = 15.187 ± 0.002 h (Dose, 2021). In this work, we provide a different result of P = 7.594 ± 0.020 h and Δm = 0.31 ± 0.03 mag.



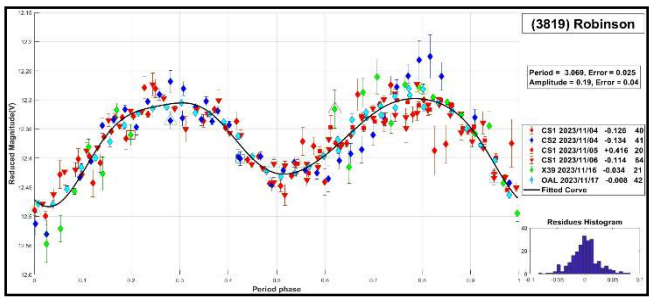
2052 Tamriko is an S-type asteroid discovered in 1976 by R.M. West. The most recent period in the literature corresponds to P = 7.462 h (Pál et al., 2020). We measured a period of P = 7.467 ± 0.019 h with Δm = 0.11 ± 0.04 mag.



2967 Vladisvyat was discovered in 1977 by N. Chernykh. We couldn't find previous published periods in the literature. Based on a well-sampled bimodal curve, we propose a period of P = 8.379 ± 0.017 h with Δm = 0.56 ± 0.02 mag.



3819 Robinson was discovered in 1983 by B.A. Skiff. The period most recently reported is P = 3.070 ± 0.002 h (Ferrero and Bonamico, 2020). The results we obtained are P = 3.069 ± 0.025 h and Δm = 0.19 ± 0.04 mag. Our period agrees well with the one measured by Ferrero.



Acknowledgements

We would like to express our gratitude to Brian Warner for his invaluable suggestions and explanations, which have significantly contributed to the enhancement of our results.

We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analyses, Fernando Mazzone for his *Periods* 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. This research has made use of the Small Bodies Data Ferret (*http://sbn.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.

References

Castellano, J. (2023). *FotoDif* software. *http://www.astrosurf.com/orodeno/fotodif/*

Colazo, M.; Scotta, D.; Melia, R.; Ciancia, G.; Fornari, C.; Morales, M.; Monteleone, B.; Wilberger, A.; Santos, F.; García, A.; Suárez, N.; Bellocchio, E.; Chapman, A.; Nolte, R.; Martini, M.; Mottino, A.; Colazo, C. (2023). "Asteroid Photometry and Lightcurve." *Minor Planet Bulletin* **50**, 51-53.

Dose, E.V. (2021). "Lightcurves of Twelve Asteroids." *Minor Planet Bulletin* **48**, 375-380.

Ferrero, A.; Bonamico, R. (2020). "Lightcurves of Seven Main-Belt Asteroids." *Minor Planet Bulletin* **47**, 147-148.

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.; Tholen, D.J. (1999). "Asteroid lightcurve observations from 1981 to 1983." *Icarus* **142**, 173-201.

Martikainen, J.; Muinonen, K.; Penttilä, A.; Cellino, A.; Wang, X.B. (2021). "Asteroid absolute magnitudes and phase curve parameters from Gaia photometry." *Astron. Astrophys.* **649**, A98.

Martini, M. Calculador de magnitud diferencial estandarizada. *https://www.observatorioomega.com.ar/2020/11/calculador-de-magnitud-diferencial.html*

Mazzone, F.D. (2012). *Periodos* sotware, version 1.0. *http://www.astrosurf.com/salvador/Programas.htm*

Pál, A.; Szakáts, R.; Kiss, C.; Bódi, A.; Bognár, Z.; Kalup, C.; Kiss, L.L.; Marton, G.; Molnár, L.; Plachy, E.; Sárneczky, K.; Szabó, G.M.; Szabó, R. (2020). "Solar System Objects Observed with TESS - First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey." *Ap. J. Suppl Ser*. **247**, id. 26.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The asteroid lightcurve database." *Icarus*, **202**, 134-146.

Wilawer, E.; Oszkiewicz, D.; Kryszczyńska, A.; Marciniak, A.; Shevchenko, V.; Belskaya, I.; Kwiatkowski, T.; Kankiewicz, P.; Horbowicz, J.; Kudak, V.; Kulczak, P.; Perig, V.; Sobkowiak, K. (2022). "Asteroid phase curves using sparse Gaia DR2 data and differential dense light curves." *Monthly Notices of the Royal Astronomical Society* **513**, 3242-3251.

Number	Name	20 yy/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
526	Jena	23/11/04-23/11/23	*3.8,03.9	50	-3	11.871	0.015	0.19	0.02	THM
667	Denise	23/10/15-24/01/03	9.1,20.5	19	-24	12.679	0.018	0.10	0.03	MB-O
717	Wisibada	23/09/20-23/11/16	*14.2,12.6	26	2	1250	35	0.32	0.02	MB-O
892	Seeligeria	23/10/10-23/10/14	14.8,14.4	268	20	16.757	0.031	0.38	0.04	MB-O
1429	Pemba	23/11/18-24/01/04	4.8,23.1	50	2	307	3	0.94	0.03	MB-I
1504	Lappeenranta	23/11/25-24/01/02	*14.6,06.1	90	-2	7.594	0.020	0.31	0.03	MB-I
2052	Tamriko	24/01/02-24/01/19	11.6,06.5	129	-12	7.467	0.019	0.15	0.03	EOS
2967	Vladisvyat	23/11/05-23/11/14	*3.6,03.1	48	6	8.379	0.017	0.56	0.02	URS
3819	Robinson	23/11/04-23/11/17	0.9,06.9	40	-1	3.069	0.025	0.19	0.04	MB-O

Table I. Observing circumstances and results. The phase angle is given for the first and last date, with an asterisk used if the phase angle reached an extremum. 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 family/group (Warner et al., 2009). THM: 24 Themis; MB-O: main-belt outer; MB-I: main-belt inner; EOS: EOS; URS: Ursula.

Observatory		Telescope	Camera
G05	Obs. Astr. Giordano Bruno	SCT (D=203mm; f=6.3)	CCD Atik 420 m
I19	Obs. Astr. El Gato Gris	SCT (D=355mm; f=10.6)	CCD SBIG STF-8300M
K14	Obs. Astr. de Sencelles	Newtonian (D=250mm; f=4.0)	CCD SBIG ST-7XME
24	Oss. Astr. La Macchina del Tempo	RCT (D250mm; f=8.0)	CMOS ZWO ASI 1600MM
M27	Elijah Observatory	RCT (D250mm; f=6.0)	CCD QSI 683
X39	Obs. Astr. Antares	Newtonian (D=250mm; f=4.72)	CCD QHY9 Mono
Z03	Obs. Astr. Río Cofio	SCT (D=254mm; f=6.3)	CCD SBIG ST-8XME
CS1	CapoSudObservatory	RCT (D=400mm; f=5.7)	CCD Atik 383L+Mono
CS2	CapoSudObservatory	Newtonian (D=254mm; f=4.7)	CCD Atik 420 Mono
OAL	Osservatorio Astronomico di Orciatico	SCT (D=355mm; f=7.4)	CCD SBIG ST10XME
OD2	Obs. Astr. de Damián Scotta 2	Newtonian (D=250mm; f=4.0)	CCD SBIG STF-8300M
OMR	Obs. Astr. Municipal Reconquista	Newtonian (D=254mm; f=4.0)	Player One Ceres-M
RMC	Obs. Astr. de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

Table II. List of observatories and equipment.