PHOTOMETRY AND LIGHT CURVE ANALYSIS OF EIGHT ASTEROIDS BY GORA'S OBSERVATORIES.

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Synodic rotation periods and amplitudes are reported for 128 Nemesis, 236 Honoria, 329 Svea, 1021 Flammario, 1026 Ingrid, 1034 Mozartia, 1938 Lausanna, and (285571) 2000 PQ9.

The periods and amplitudes of asteroid lightcurves presented here are the product of collaborative work by 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.

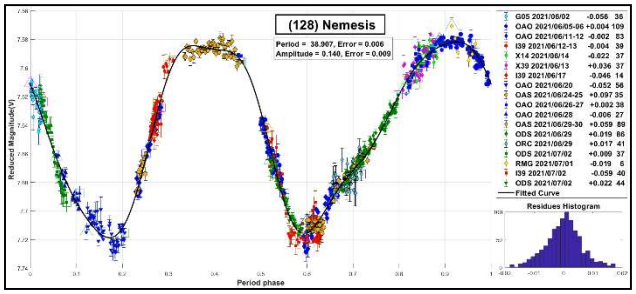
Image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected using dark frames and, in some cases, bias and flat-field were also used. Photometry measurements were performed using *FotoDif* software and, for the analysis, we employed *Periodos* software (Mazzone, 2012).

Below, we present the results for each asteroid under study. 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.

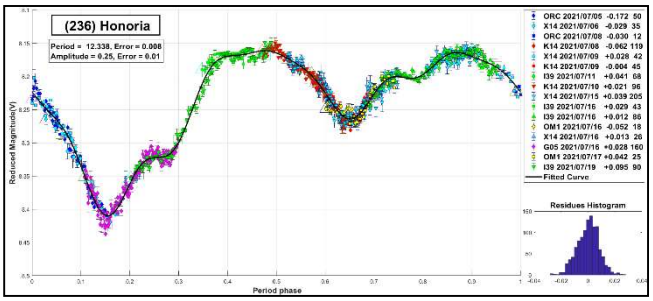
Targets were selected based on the following criteria: 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina or Spain, i.e., with negative or positive declinations δ, respectively, and 3) objects with few periods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

128 Nemesis is a C-type asteroid. It was discovered in 1872 by James Craig Watson. Our analysis yields a period P = 38.907 ± 0.006 h with Δm = 0.140 ± 0.009 mag. In previous observations, Scaltriti et al. (1979) reported a period P = 39 h and Pilcher (2015) a period P = 77.81 ± 0.01 h.

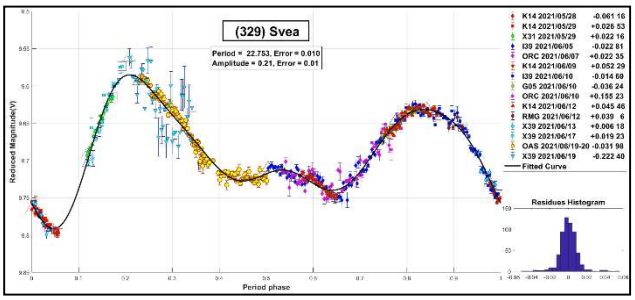
Note that our period is in good agreement with the one reported by Scaltriti et al. and is half the one measured by Pilcher. Irrespective of such dissimilarities, it is clear that this asteroid constitutes a long period example.



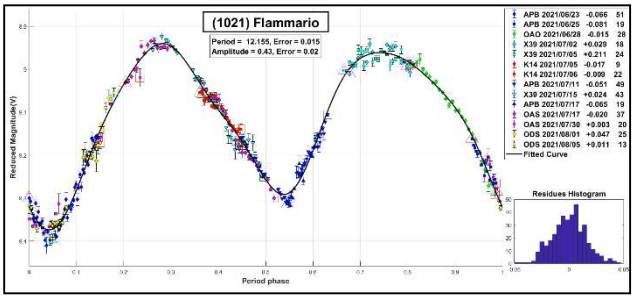
236 Honoria is an S-type asteroid. It was discovered in 1884 by Johann Palisa. We found in the literature two different periods calculated for this object: P = 12.338 ± 0.002 h with Δm = 0.27 ± 0.02 mag (Marciniak et al., 2014) and P = 16.8 ± 0.1 h with Δm = 0.05 ± 0.01 mag (Behrend, 2006web). The results we obtained are P = 12.338 ± 0.008 h and Δm = 0.25 ± 0.01 mag, with full coverage of the lightcurve. Our period agrees well with the one measured by Marciniak et al. (2014).



329 Svea is classified as type C in the Tholen taxonomy. It was discovered by Max Wolf in 1892. Two different periods were reported in the literature. Marciniak et al. (2017) found a period of 22.778 ± 0.006 h, whereas Pray (2006) measured a period of P = 15.201 ± 0.005 h. We have determined a period of 22.753 ± 0.010 h, which is consistent with the one proposed by Marciniak.

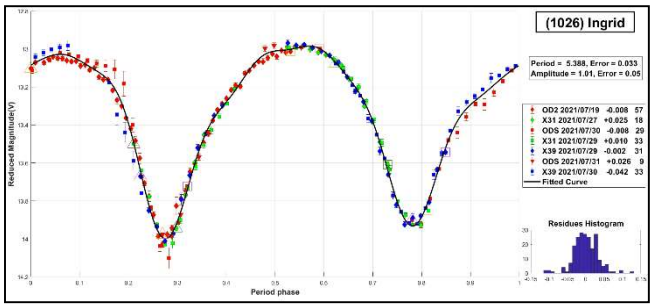


1021 Flammario is an F-type asteroid, discovered in 1924 by Max Wolf. The period more recently reported in the literature is P = 12.15186 ± 0.00005 h (Hanuš et al., 2016).

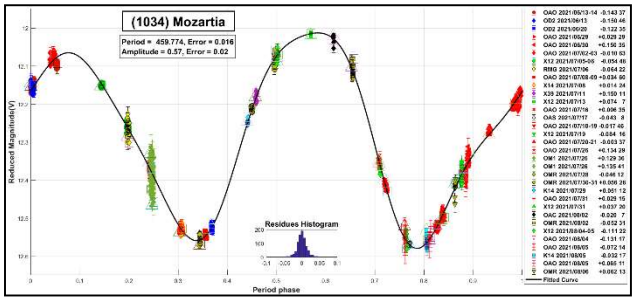


The results we obtained are P = 12.155 ± 0.015 h and Δm = 0.43 ± 0.02 mag. Our period agrees well with the one measured by Hanuš et al. (2016).

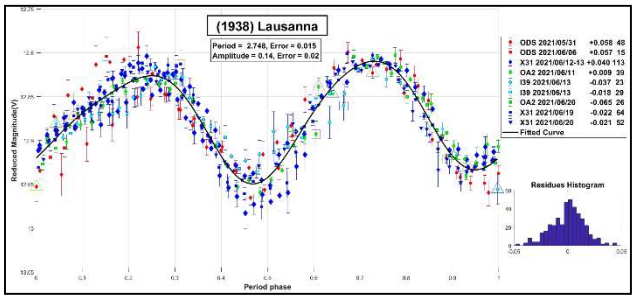
1026 Ingrid was discovered in 1923 by Karl Wilhelm Reinmuth. We measured a period of 5.388 ± 0.033 h with Δm = 1.01 ± 0.05 mag. A similar period was previously reported by Székely et al. (2005), consisting of P = 5 h. A large amplitude was also reported by these authors, resulting in Δm > 0.5 mag.



1034 Mozartia is an S-type asteroid in the Bus-taxonomy, discovered in 1924 by Vladímir Albitski. Interestingly, we couldn't find a reported period for this object in the literature. According to our observations and after a thorough analysis, we propose a long-term period of P = 459.774 ± 0.016 h and Δm = 0.57 ± 0.02 mag. As can be seen, we have performed numerous observations on this object, with permanent generation of ephemeris to fill the gaps, which successfully allowed us to complete the curve. More important, we have observations on consecutive days, using same calibration stars, so that they were taken as a single observation. That way we were able to solve the puzzle related to this slow rotator.



1938 Lausanna is an S-type asteroid. It was discovered in 1974 by Paul Wild. The period reported in the literature is P = 2.748 ± 0.001 h with Δm = 0.12 ± 0.02 mag (Warell and Pappini, 2015). Our observations resulted in P = 2.748 ± 0.015 h with Δm = 0.14 ± 0.02 mag, consistent with a short-period asteroid, and in good agreement with the results from Warell & Pappini.



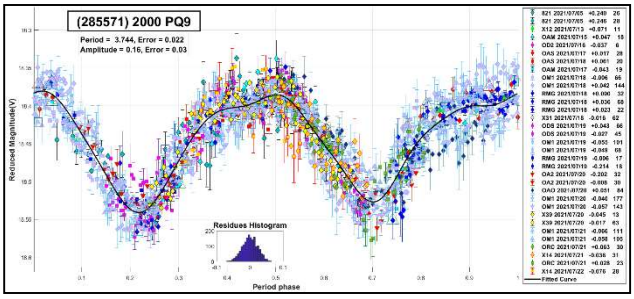
(285571) 2000 PQ9 was discovered in 2000 by LINEAR. It is a poorly studied object. Here we propose a candidate period of P = 3.744 ± 0.022 h and Δm = 0.16 ± 0.03 mag. This fast rotator hypothesis is consistent with its small estimated diameter of ~1 km. Also, it is important to note that we have performed several observations on this object leading to a very good coverage of the lightcurve.

Number	Name	yy/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
128	Nemesis	21/06/02-21/07/02	2.6,13.2	245	1	38.907	0.006	0.14	0.01	MB-O
236	Honoria	21/07/05-21/07/19	9.9,5.4	301	10	12.338	0.008	0.25	0.01	MB-O
329	Svea	21/05/28-21/06/20	10.3,16.0	241	19	22.753	0.010	0.21	0.01	MB-I
1021	Flammario	21/06/23-21/08/05	*5.5,11.9	283	4	12.155	0.015	0.43	0.02	MB-O
1026	Ingrid	21/07/19-21/07/30	3.0,9.8	293	-2	5.388	0.033	1.01	0.05	FLOR
1034	Mozartia	21/06/13-21/08/06	*20.4,12.0	294	-2	459.774	0.016	0.57	0.02	MB-I
1938	Lausanna	21/05/31-21/06/20	*5.0,9.9	255	5	2.748	0.015	0.14	0.02	FLOR
285571	2000 PQ9	21/07/05-21/07/22	*35.3,6.7	287	-11	3.744	0.022	0.16	0.03	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). MB-I/O: main-belt inner/outer.

Observatory	Telescope	Camera
821 Est.Astrof.Bosque Alegre	Telesc. Newtoniano (D=1540mm; f=4.9)	CCD APOGEE Alta U9
G05 Obs.Astr.Giordano Bruno	Telesc. SCT (D=203mm; f=6.0)	CCD Atik 420 m
I39 Obs.Astr.Cruz del Sur	Telesc. Newtoniano (D=254mm; f=4.7)	CMOS QHY174
K14 Obs.Astr.de Sencelles	Telesc. Newtoniano (D=250mm; f=4.0)	CCD SBIG ST-7XME
X12 Obs.Astr.Los Cabezones	Telesc. Newtoniano (D=200mm; f=5.0)	CMOS QHY174MGPS
X14 Obs.Astr.Orbis Tertius	Telesc. Newtoniano (D=200mm; f=5.0)	CCD QHY6 Mono
X31 Obs.Astr.Galileo Galilei	Telesc. RCT ap (D=405mm; f=8.0)	CCD SBIG STF8300M
X39 Obs.Astr.Antares	Telesc. Newtoniano (D=250mm; f=4.7)	CCD QHY9 Mono
APB Obs.Astr.AstroPilar	Telesc. Refractor (D=150mm; f=7.0)	CCD ZWO-ASI183
OAC Obs.Astr.Calchaquí	Telesc. GSO RC (D=203mm; f=8.0)	CCD QHY9S
OAM Obs.Astr.de Aldo Mottino	Telesc. Newtoniano (D=250mm; f=4.7)	CCD SBIG STF8300M
OAO Obs.Astr.Aficionado Omega	Telesc. Newtoniano (D=150mm; f=5.0)	CMOS ZWO ASI178mm
OAS Obs.Astr.de Ariel Stechina 1	Telesc. Newtoniano (D=254mm; f=4.7)	CCD SBIG STF402
OA2 Obs.Astr.de Ariel Stechina 2	Telesc. Newtoniano (D=305mm; f=5.0)	CMOS QHY 174M
ODS Obs.Astr.de Damián Scotta 1	Telesc. Newtoniano (D=300mm; f=4.0)	CCD SBIG St-402 XME
OD2 Obs.Astr.de Damián Scotta 2	Telesc. Newtoniano (D=250mm; f=4.0)	CCD Atik 314L+
OM1 Obs.Astr.Chopis	Telesc. Newtoniano (D=200mm; f=4.5)	CMOS Nikon D5200
OMR Obs.Astr.Municipal Reconquista	Telesc. Newtoniano (D=254mm; f=4.0)	CMOS QHY5 Mono
ORC Obs.Astr.Río Cofio	Telesc. SCT (D=254mm; f=6.3)	CCD SBIG ST8-XME
RMG Obs.Astr.de Raúl Melia	Telesc. Newtoniano (D=254mm; f=4.7)	CCD Meade DSI Pro II

Table II. List of observatories and equipment.



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References

Behrend, R. (2006web). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Hanuš, J.; Ďurech, J.; Oszkiewicz, D.A.; Behrend, R.; Carry, B.; and 164 colleagues (2016). "New and updated convex shape models of asteroids based on optical data from a large collaboration network." *Astronomy & Astrophysics* **586**, A108.

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.

Marciniak, A.; Pilcher, F.; Santana-Ros, T.; Oszkiewicz, D.; Kankiewicz, P. (2014). *ACM 2014*, Poster 57.

Marciniak, A.; Pilcher, F.; Oszkiewicz, D.; Santana-Ros, T.; Urakawa, S.; and 19 colleagues (2017). "Against the biases in spins and shapes of asteroids." *Planetary and Space Science* **118**, 256-266.

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

Pilcher, F. (2015). "New Photometric Observations of 128 Nemisis, 249 Ilse, and 279 Thule." *Minor Planet Bulletin* **42**, 190-192.

Pray, D.P. (2006). "Lightcurve analysis of asteroids 326, 329, 426, 619, 1829, 1967, 2453, 10518 and 42267." *Minor Planet Bulletin* **33**, 4-5.

Scaltriti, F.; Zappalà, V.; Schober, H.J. (1979). "The rotations of 128 Nemesis and 393 Lampetia: The longest known periods to date." *Icarus* **37**, 133-141.

Székely, P.; Kiss, L.L.; Szabó, Gy.M.; Sárneczky, K.; Csák, B.; Váradi, M.; Mészáros, Sz. (2005). "CCD photometry of 23 minor planets." *Planetary and Space Science* **53**, 925-936.

Warell, J.; Pappini, R. (2015). "Rotational Period of 1938 Lausanna." *Minor Planet Bulletin* **42**, 20-21.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2021 Oct. *http://www.minorplanet.info/lightcurvedatabase.html*

LIGHTCURVE ANALYSIS OF L4 TROJAN ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2021 JULY TO SEPTEMBER

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Lightcurves for 11 Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2021 July to September.

For several years, the Center for Solar System Studies (CS3, MPC U81) has been conducting a study of Jovian Trojan asteroids. This paper reports CCD photometric observations of nine Trojan asteroids from the L_4 (Greek) Lagrange point and two from the L_5 (Trojan) Lagrange point from 2021 July to September.

All observations were made using a 0.4-m f/10 Schmidt-Cassegrain telescope and an FLI Proline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. The exposures were 180 seconds.

Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs and are the "native" magnitudes of the catalog.

The Y-axis of lightcurves gives ATLAS SR "sky" (catalog) magnitudes. During period analysis, the magnitudes were normalized to the phase angle and value for *G* given in the parentheses. The X-axis rotational phase ranges from –0.05 to 1.05.

The amplitude indicated in the plots (e.g., Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

624 Hektor. The LCDB shows that many synodic periods for Hektor were found in the past, all about 6.92 h. Hektor has also been previously found to be a binary asteroid (Marchis et al., 2006) with a primary that might have a bilobated shape approximately 350×210 km and a secondary estimated to be 15 km in size. Marchis et al. found a pole position with ecliptic coordinates of $\lambda_1 = 332°$ and $\beta_1 = –32°$. Pole positions have also been independently found a number of times over the years, the latest by Hanuš et al. (2015), which is similar to the Marchis et al solution. Most of the pole solutions reported a sidereal period of 6.92051 h.