ASTEROID PHOTOMETRY AND LIGHTCURVE ANALYSIS AT GORA'S OBSERVATORIES, PART IV.

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Comisión Nacional de Investigación y Desarrollo Aeroespacial del Perú - CONIDA

Observatorio Cruz del Sur (MPC I39) - San Justo (Buenos Aires-Argentina)

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

Observatorio Los Cabezones (MPC X12) - Santa Rosa (La Pampa-Argentina)

Observatorio Galileo Galilei (MPC X31) - Oro Verde (Entre Ríos-Argentina)

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

Observatorio Astronómico de Moquegua 1 (MPC W73) - Cambrune (Moquegua-Perú)

Observatorio AstroPilar (GORA APB) - Pilar (Buenos Aires-Argentina)

Observatorio Astronómico Calchaquí (GORA OAC) - El Bañado (Tucumán-Argentina)

Observatorio de Aldo Mottino (GORA OAM) - Rosario (Santa Fe-Argentina)

Observatorio Astro Pulver (GORA OAP) - Rosario (Santa Fe-Argentina)

Observatorio de Ariel Stechina 1 (GORA OAS) - Reconquista (Santa Fe-Argentina)

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

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

Observatorio de Raúl Melia (GORA RMG) - Gálvez (Santa Fe-Argentina)

Observatorio Astronómico Aficionado Omega (GORA OAO) - Córdoba (Córdoba-Argentina)

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Synodic rotation periods and amplitudes are reported for: 424 Gratia, 579 Sidonia, 589 Croatia, 693 Zerbinetta, 791 Ani, 824 Anastasia, 858 El Djezair, 1024 Hale, 1271 Isergina, 1663 van den Bos.

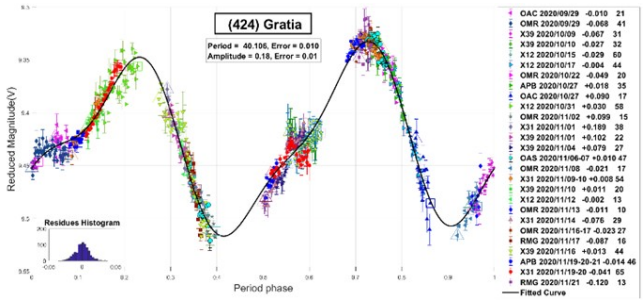
The periods and amplitudes of asteroid light curves currently presented are the product of a collaborative work by GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In all the studies we have applied relative photometry assigning V magnitudes to the calibration stars.

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 were also used. Photometry measurements were performed using *FotoDif* software and for the analysis we employed *Periodos* software (Mazzone, 2012).

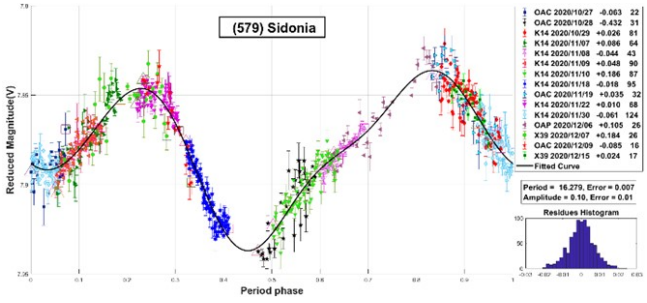
Below, we present the results for each asteroid under study. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes the columns represent, respectively, the marker, observatory MPC code or - failing that - the GORA internal code, session date, session off-set, and number of 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 i.e. with negative 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.

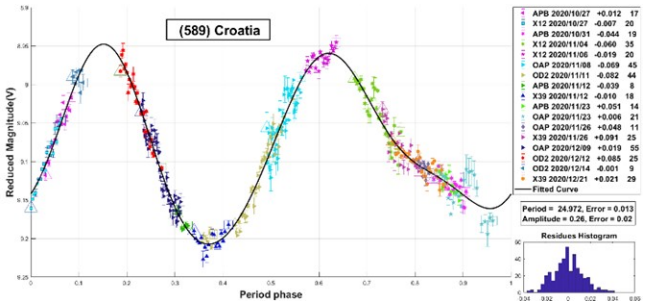
424 Gratia. This asteroid belongs to the main belt and was discovered in 1896 by Auguste Charlois. We found only one period in the literature, published by Florczak et al. (1997): P = 19.47 ± 0.01 h with Δm = 0.32 ± 0.02 mag. Our result of P = 40.106 ± 0.010 h clearly indicates a longer period, whereas our measured amplitude is significantly lower: Δm = 0.18 ± 0.01 mag. We consider this latter difference to be consequence of a change in the aspect angle.



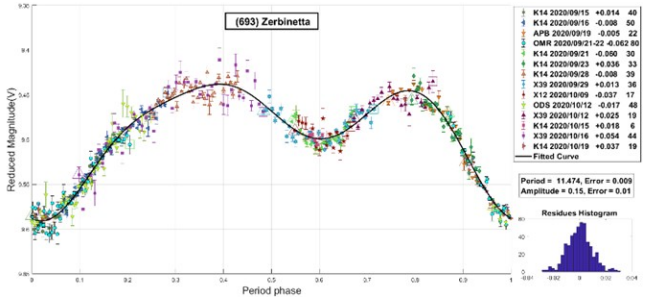
579 Sidonia. Sidonia is a bright S-type asteroid discovered in 1905 by August Kopff. The periods published for this asteroid are: P = 13.00 h (Tedesco, 1979), P = 18.72 h (Behrend, 2005web) and P = 16.286 ± 0.001 h (Stephens, 2010a). We have determined a period of P = 16.279 ± 0.007 h with an amplitude of Δm = 0.10 ± 0.01 mag. Our result on the period agrees with that published by Stephens, which is the most recent we found in the literature.



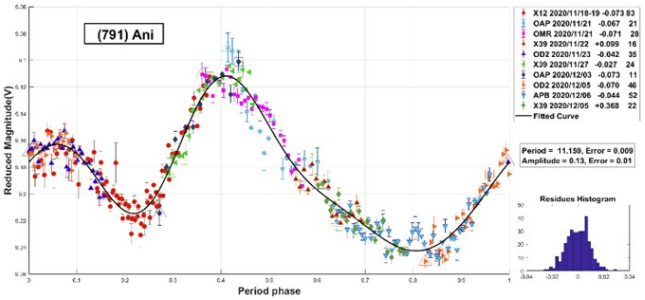
589 Croatia. This asteroid was discovered in 1906 by August Kopff. Three different periods were found in the literature: P = 11.7 ± 0.1 h with Δm = 0.16 ± 0.02 mag (Warner, 2008), P = 24.821 ± 0.002 h with Δm = 0.25 ± 0.03 mag (Behrend, 2013web) and P = 16.3854 ± 0.0931 h with Δm = 0.32 mag (Waszczak et al., 2015). We have calculated a period of P = 24.972 ± 0.013 h with an amplitude of Δm = 0.26 ± 0.02, well in agreement with the period published by Behrend (2013web).



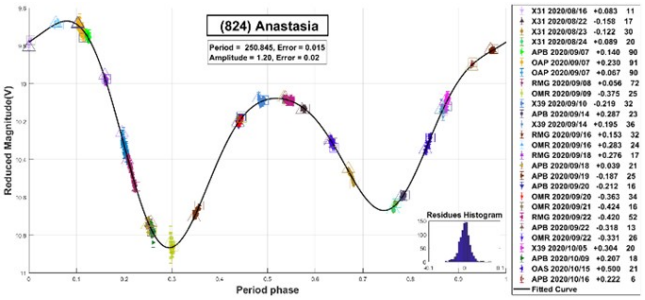
693 Zerbinetta was discovered on September 21, 1909, by August Kopff. Several measurements of the period were reported in the literature for this particular object, such as: P = 11.32 ± 0.05 h with Δm = 0.18 ± 0.01 mag (Behrend, 2005web), P = 11.475 ± 0.001 h with Δm = 0.29 ± 0.2 mag (Chiorny et al., 2007), P = 11.32 ± 0.01 h with Δm = 0.14 ± 0.01 mag (Behrend, 2010web), and P = 11.3 ± 0.5 h with Δm = 0.16 ± 0.01 mag (Behrend, 2011web). We found a period of P = 11.474 ± 0.009 h, in accordance with that obtained by Chiorny et al. (2007), with an amplitude of Δm = 0.15 ± 0.01 mag.



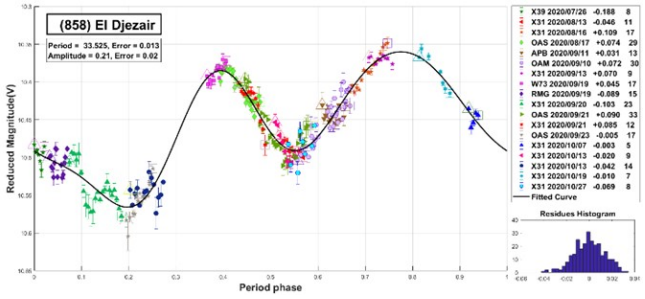
791 Ani is a dark carbonaceous C-type asteroid discovered in 1914 by Grigory Neujmin. In the literature, three different measurements have been published for the period of this object. On the one hand, the Behrend measurement (2011web) suggests a period of P = 12.0 ± 0.5 h with Δm = 0.38 ± 0.02 mag. A slightly longer period was published by Sauppe et al. (2007), P = 16.72 ± 0.03 h with Δm = 0.32 ± 0.05 mag and by Warner (2011web), P = 16.8 ± 0.1 h with Δm = 0.35 ± 0.05. Finally, the longest period estimations correspond to: P = 22.850 ± 0.003 h with Δm = 0.17 ± 0.01 mag and P = 22.85 ± 0.05 h with Δm = 0.38 ± 0.02 mag (Behrend, 2005web, 2007web). Our analysis yields a period of P = 11.159 ± 0.009 h with Δm = 0.13 ± 0.01 mag, consistent with the shortest period reported previously.



824 Anastasia. Anastasia was discovered on March 25, 1916, by Grigory Neujmin. Our preliminary analysis indicated that we were dealing with a very long-period object and that the study would be harder than expected. Our final results are: P = 250.845 ± 0.015 h with Δm = 1.20 ± 0.02 mag. Previous results in the literature support these data, as is the case of Stephens (2010b), who measured a period of 250 ± 1 h with an amplitude of Δm = 1.20 ± 0.05 mag.



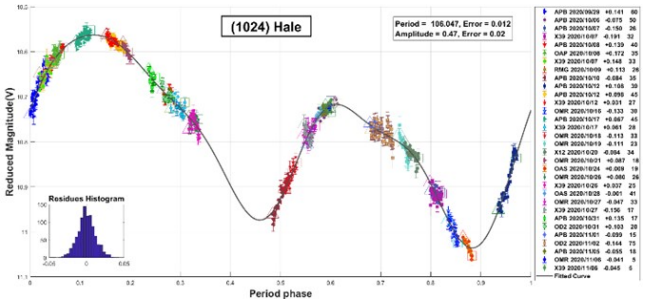
858 El Djezair is a bright S-type asteroid discovered in 1916 by Frédéric Sy. We found in the literature two different periods calculated for this object: P = 22.31 ± 0.02 h with Δm = 0.10 ± 0.02 mag (Warner, 2005) and P = 19 ± 1 h with Δm = 0.06 ± 0.02 mag (Behrend, 2007web). In this work we proposed a different period for this asteroid, which is P = 33.525 ± 0.013 h, with Δm = 0.21 ± 0.02 mag.



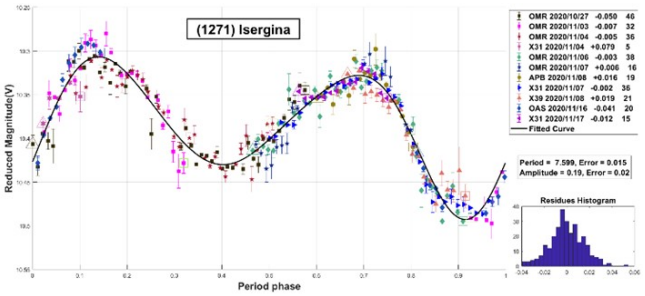
1024 Hale is a carbonaceous C-type asteroid discovered in 1923 by George Van Biesbroeck. We found only one period published in the literature for this asteroid: P = 16.0 ± 0.1 h, with Δm = 0.10 ± 0.02 mag (Alkema, 2013). According to our analysis, this object constitutes another case of long-period asteroid. The results we obtained are P = 106.047 ± 0.012 h and Δm = 0.47 ± 0.02 mag.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
424	Gratia	2020 09/29-11/21	*07.7,16.7	19	-10.4	40.106	0.010	0.18	0.01	MB-O
579	Sidonia	2020 10/27-12/15	*09.4,09.2	58	-5.7	16.279	0.007	0.10	0.01	MB-O
589	Croatia	2020 10/27-12/21	*07.4,13.7	50	-10.9	24.972	0.013	0.26	0.02	MB-O
693	Zerbinetta	2020 09/15-10/19	*03.5,10.0	0	3.2	11.474	0.009	0.15	0.01	MB-O
791	Ani	2020 11/18-12/06	*07.6,09.3	57	-19.2	11.159	0.009	0.13	0.01	MB-O
824	Anastasia	2020 08/16-10/16	*05.5,18.3	335	-3.4	250.845	0.015	1.20	0.02	MB-O
858	El Djezair	2020 07/26-10/27	04.6,21.4	304	-9.7	33.525	0.013	0.21	0.02	MB-O
1024	Hale	2020 09/29-11/06	*10.0,17.1	10	-15.5	106.047	0.012	0.47	0.02	MB-O
1271	Isergina	2020 10/27-11/17	*05.4,06.1	43	-8.5	7.599	0.015	0.19	0.02	MB-O
1663	van den Bos	2020 09/19-11/20	*06.8,27.5	3	-7.7	767.148	0.020	0.94	0.03	MB-O

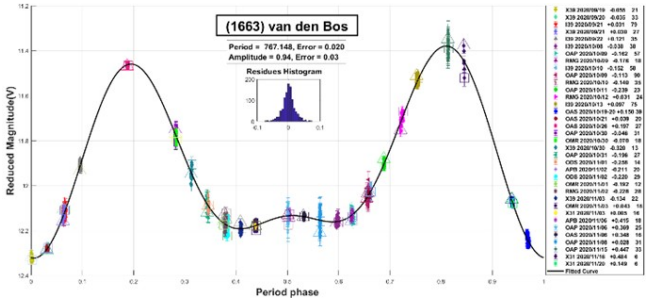
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extremum during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al.,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



1271 Isergina is a carbonaceous asteroid discovered on October 10, 1931, by Grigory Neujmin. The periods published for this asteroid are: P = 7.59932 ± 0.00009 h with maximum amplitude of 0.24 mag (Benishek, 2016), P = 7.829 ± 0.002 h with maximum amplitude of 0.27 mag (Aznar Macias et al., 2016) and P = 9.864 ± 0.004 h (Behrend, 2017web). Our results show a better concordance with those of Benishek (2016) since we found a period P = 7.599 ± 0.015 h, with Δm = 0.19 ± 0.02 mag. The difference in amplitude may be due to the change in aspect angle.



1663 van den Bos is an S-type asteroid discovered in 1926, by Harry Edwin Wood. The periods reported in the literature suggest that it is a case of a slow rotator: P = 155 ± 5 h with Δm = 0.5 ± 0.1 mag (Ruthroff, 2011) and P = 740 ± 10 h with Δm = 0.80 ± 0.05 mag (Stephens and Higgins, 2011). The results we obtained, P = 767.148 ± 0.020 h with Δm = 0.94 ± 0.03 mag, are similar to those obtained by Stephens and Higgins (2011), thus supporting the hypothesis that it is indeed a slow rotator.



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Observatory	Telescope	Camera
I39 Obs.Astr.Cruz del Sur	Telesc. Newtoniano (D=200mm; f=4.0)	CMOS QHY174
K14 Obs.Astr.de Sencelles	Telesc. SCT (D=254mm; f=4.3)	CCD SBIG ST-7XME
X12 Obs.Astr.Los Cabezones	Telesc. Newtoniano (D=200mm; f=5.0)	CMOS QHY174MGPS
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=5.0)	CCD QHY9 Mono
W73 Obs.Astr.de Moquegua	Telesc. RCT APM (D=1000mm; f=8.0)	CCD FLI ProLine 16803
APB Obs.Astr.AstroPilar	Telesc. ODK (D=250mm; f=6.8)	CCD FLI8300M
OAC Obs.Astr.Calchaquí	Telesc. Refractor (D=100mm; F=9.0)	CCD QHY9S
OAM Obs.Astr.de Aldo Mottino	Telesc. Newtoniano (D=250mm; f=4.7)	CCD SBIG STF8300M
OAP Obs.Astr.Astro Pulver	Telesc. SCT (D=203mm; f=7.0)	CMOS QHY5 LII M
OAS Obs.Astr.de Ariel Stechina 1	Telesc. Newtoniano (D=254mm; f=4.7)	CCD SBIG STF402
OD2 Obs.Astr.de Damián Scotta 2	Telesc. Newtoniano (D=200mm; f=5.0)	CCD Atik 314L+
OMR Obs.Astr.Municipal Reconquista	Telesc. Newtoniano (D=254mm; f=4.0)	CMOS QHY 174M
RMG Obs.Astr.de Raúl Melia	Telesc. SCT (D=200mm; f=10.0)	CCD Meade DSI Pro II

Table II. List of observatories and equipment.

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