ASTEROID PHOTOMETRY AND LIGHTCURVE ANALYSIS AT GORA'S OBSERVATORIES

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Synodic rotation periods and amplitudes are reported for 179 Klytaemnestra, 372 Palma, 504 Cora, 739 Mandeville, 749 Malzovia, 925 Alphonsina, 1015 Christa, 1086 Nata, and 1794 Finsen.

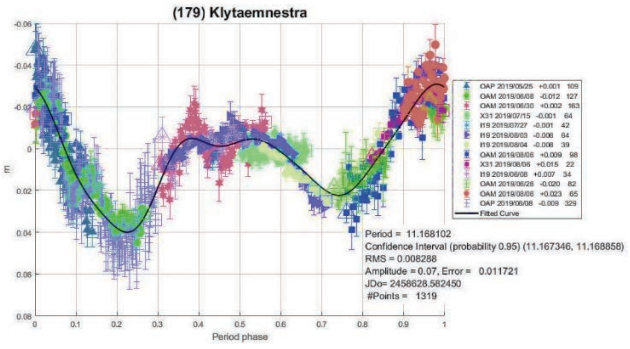
In this paper we present the collaborative work of amateur astronomers and undergraduate students belonging to the argentine group G.O.R.A (Grupo de Observadores de Rotaciones de Asteroides). GORA is a continuity of collaborative experience between argentine amateur observers initially joined under the name of "Asociación de Observatorios Argentinos de Cuerpos Menores" (AOACM), and dedicated to perform astrometry and photometry of minor bodies. Since 2019 March, an increasing number of members were incorporated to GORA to perform asteroid observations. To validate our working methodology, we first chose asteroids with known rotation periods. We will progressively select more complex challenges, as our learning consolidates. The observatories and equipment used are summarized in Table I. The results and observing circumstances are in Table II.

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 also were used. Differential 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: 1) the estimated period and amplitude, 2) a 95% confidence interval regarding the period estimate, 3) RMS of the fitting, 4) estimated amplitude and amplitude error, 5) Julian time corresponding to 0 rotation phase, and 6) the number of data points. In the reference boxes the columns represent, respectively, the marker, observatory MPC code, session date, session off-set, and number of data points. (Mazzone et al., 2014).

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 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.

179 Klytaemnestra. This asteroid belongs to the Telramund family and is classified as an S-type asteroid in the Tholem taxonomy. The last reported period was of 11.17342 ± 0.00005 h (Hanuš et al., 2016). We observed this asteroid from 2019 May 25 to August 8. The main difficulty that arose was the wealth of background stars that made us hesitate several times to continue observing this object. Despite this, we obtained a rotation period of 11.168 ± 0.008 h, quite similar to that of LCDB records. The last amplitude measurement in the databases corresponds to Ditteon and Hawkins (2007) and was of 0.55 ± 0.02 mag, whereas ours was of 0.07 ± 0.01 mag. The difference between these values may be an indicator of a noticeable change in the aspect angle of this asteroid.



372 Palma is a B-type asteroid. The last reported period was of 8.57964 ± 0.00005 h (Hanuš et al., 2016) and the last reported amplitude was of 0.10 ± 0.01 mag (Behrend, 2011). This asteroid was chosen because its brightness (V ~ 12.6) and declination (δ ~ –31 °) allowed it to be observed with culminations close to the local zenith of the observatories involved. Analysis of our data resulted in a period of 8.582 ± 0.009 h and amplitude of 0.07 ± 0.01 mag, which is in concordance with previously published data.

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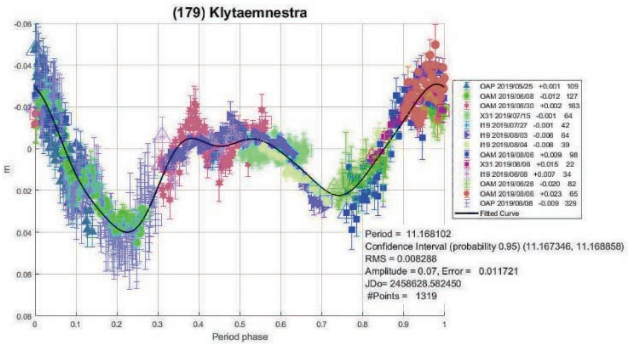

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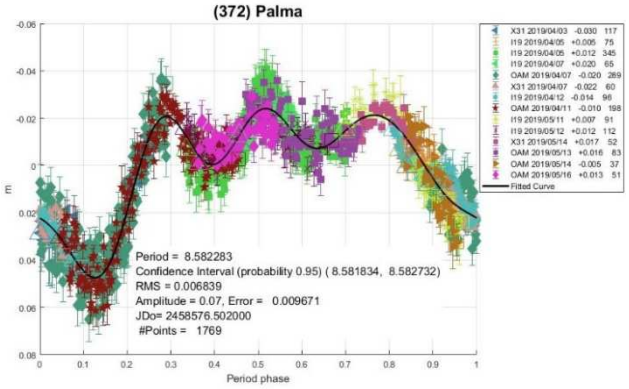
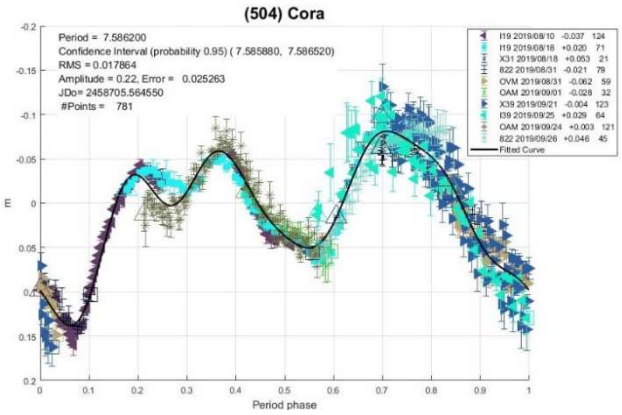
Observatory	Telescope	Camera
Estación Astrofísica Bosque Alegre	Newtonian telescope (D=1540mm; f=4.9)	CCD APOGEE Alta U9
Observatorio Astronómico Córdoba	Celestron SCT14 (D=355mm; f=11.0)	CCD SBIG ST7 + F.R.
Observatorio El Gato Gris	Celestron SCT14 (D=355mm; f=10.6)	CCD SBIG STF8300M
Observatorio Cruz del Sur	Newtonian telescope (D=200mm; f=4.0)	CCD Atik 414Ex
Observatorio Galileo Galilei (2019)	Celestron SCT14 (D=355mm; f=11.0)	CCD SBIG STF8300MT
Observatorio Galileo Galilei (2020)	RC ap (D=405mm; f=8.0)	CCD SBIG STF8300M
Observatorio Antares	Newtonian telescope (D=200mm; f=5.0)	CCD QHY9 Mono
Observatorio de Aldo Mottino	Newtonian telescope (D=250mm; f=4.7)	CCD SBIG STF8300M
Observatorio Punto Azul	Newtonian telescope (D=254mm; f=5.0)	CCD QHY6 Mono
Observatorio Astro Pulver	Celestron SCT8 (D=203mm; f=10.0)	CMOS QHY5 LII M + F.R.
Blue Mountains Observatory	SCT Edge (D=355m; f=7.0)	CCD SBIG STF8300M.

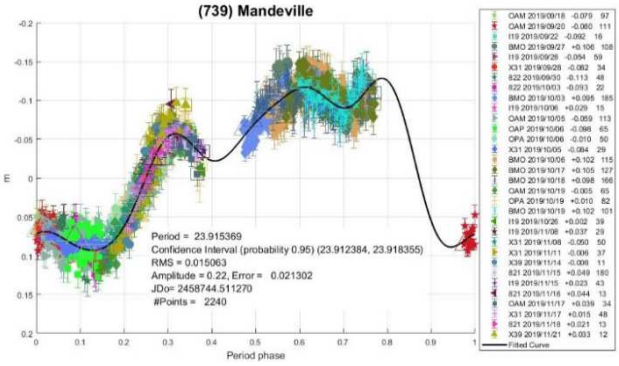
Table I. List of observatories and equipment.



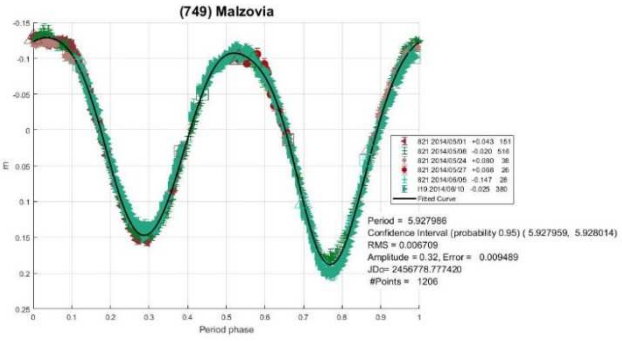
504 Cora. On the Tholen taxonomic scheme, as well as by the NEOWISE mission of NASA's Wide-field Infrared Survey Explorer (WISE), Cora is classified as a metallic M-type asteroid (Mainzer et al., 2011). The last periods registered in the literature were of 7.5915 ± 0.0043 h and 7.5882 ± 0.0023 h, with amplitudes of 0.15 mag and 0.17 mag, respectively (Waszczak et al., 2015). Seven GORA members observed this asteroid between 2019 August 10 and September 26. Despite some stretches with large dispersions and some discordant junctions, our data derived a period of rotation of 7.59 ± 0.02 h and amplitude of 0.22 ± 0.03 mag, quite similar to those found in the literature. The small difference in amplitude may be due to the aspect angle of the asteroid being progressively changing.



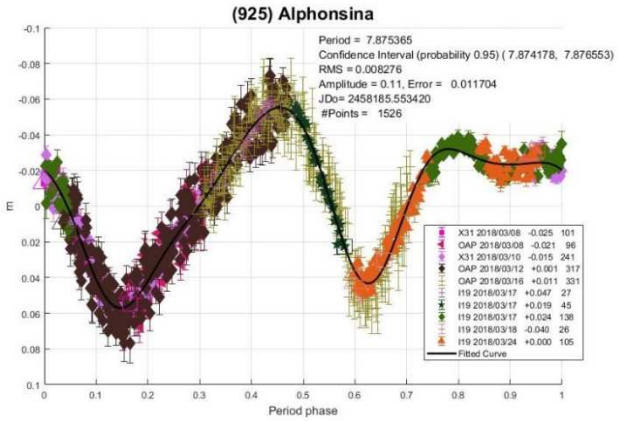
739 Mandeville is classified as type X in the Tholen taxonomy. There are three periods reported in the literature with marked differences: 15.9 h (Zappalá, 1983), 11.931 ± 0.010 h (Harris and Zappalá, 1989) and 24 ± 1 h (Behrend, 2005). The last amplitude reported is 0.14 ± 0.03 mag (Melton et al., 2012). This asteroid was the one in which we invested the largest number of observations because we had to deal with candidate periods that were multiple or divisors of 24 h. We observed it from 2019 September 18 to November 21. We requested and received the generous and valuable collaboration of Julian Oey, who contributed observations from Australia. As a final result, we found a period of 23.92 ± 0.02 h and amplitude of 0.22 ± 0.02 mag.



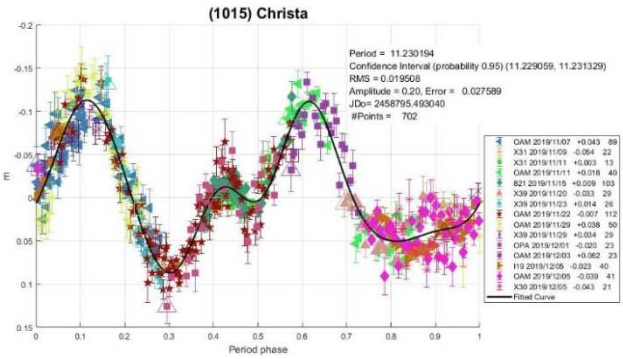
749 Malzovia. This S-type asteroid has a reported period of 5.9275 ± 0.0002 h with amplitude of 0.30 ± 0.03 mag (Oey, 2016). It was observed between 2014 May 1 and June 8. As with 1794 Finsen, the studies were performed before GORA's consolidation, so we decided to include it in this paper. We obtained a period of 5.928 ± 0.008 h and amplitude of 0.32 ± 0.01 mag, similar to the data found in literature.



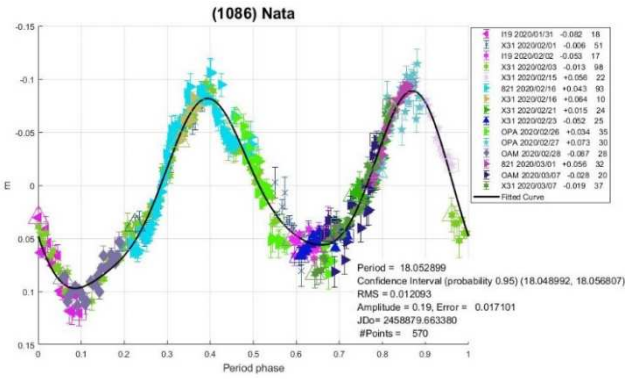
925 Alphonsina is a Hansian asteroid from the central region of the asteroid belt. The last reported period in the literature of this S-type asteroid was 7.87754 ± 0.00005 h (Durech et al., 2011; Hanuš et al., 2011). The last reported amplitude was of 0.30 ± 0.01 mag (Hamanowa and Hamanowa, 2011). We studied this asteroid between 2018 March 8-24, with the novelty of participation of three amateur observatories in association. Analysis of our data resulted in a period of 7.88 ± 0.01 h, which is in concordance with previously published data. Our calculated amplitude, however, was 0.11 ± 0.02 mag, which clearly differs from that published by Hamanowa and Hamanowa (2011).



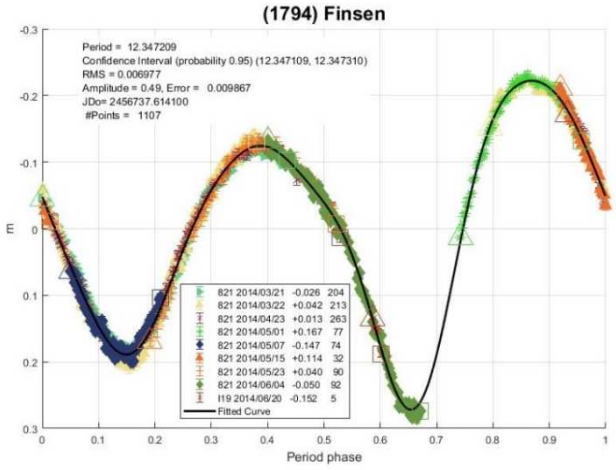
1015 Christa. Christa is a non-family asteroid from the main-belt background population. In the Tholen classification, Christa is a common C-type asteroid. Two different periods were reported in the literature: 12.189 ± 0.001 h (Behrend, 2005) and 11.230 ± 0.004 h (Warner, 2009). The respective reported amplitudes were 0.20 ± 0.01 mag and 0.12 ± 0.01 mag. Observations made by GORA from 2019 November 7 to December 5 provided a rotation period of 11.23 ± 0.03 h and an amplitude of 0.20 ± 0.04 mag, in good agreement with the period reported by Warner (2009).



1086 Nata is a member of the Veritas family and has an estimated diameter of 72 ± 11 km. The only reported period we found in the literature is 18.074 ± 0.002 h with an amplitude 0.17 ± 0.03 mag (Sheridan, 2002). We started observing Nata on 2020 January 30 and concluded on March 6, obtaining a period of 18.05 ± 0.02 h and amplitude of 0.18 ± 0.02 mag.



1794 Finsen. This C-type asteroid has a reported period of 12.3495 ± 0.0055 h and amplitude of 0.38 mag (Waszczak et al, 2015). It was observed from 2014 March 21 to June 20. However, the corresponding report was never published by the AOACM, so that we decided to include it here. Our data resulted in a period of rotation of 12.347 ± 0.009 h and amplitude of 0.49 ± 0.01 mag, quite similar to those found in the literature.



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We want to thank Julio Castellano as we use his *FotoDif* program for preliminary analyses and to Fernando Mazzone for his *Periods* program, used in final analyses. 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.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
179	Klytaemnestra	2019/05/25-08/08	*7.9,17.2	264	2	11.1682	0.008	0.07	0.01
372	Palma	2019/04/03-05/16	7.8,12.9	197	-23	8.582	0.009	0.07	0.01
504	Cora	2019/08/10-09/26	*12.4,13.0	335	-15	7.59	0.02	0.22	0.03
739	Mandeville	2019/09/18-11/21	5.8,17.7	348	-15	23.92	0.02	0.22	0.02
749	Malzovia	2014/05/01-06/08	*16.9,7.7	246	6	5.928	0.008	0.32	0.01
925	Alphonsina	2018/03/08-03/24	9.6,13.2	162	-20	7.88	0.01	0.11	0.02
1015	Christa	2019/11/07-12/05	13.1,18.2	10	-11	11.23	0.03	0.20	0.04
1086	Nata	2020/01/30-03/06	*7.5,6.4	149	-3	18.05	0.02	0.18	0.02
1794	Finsen	2014/03/21-06/20	*8.1,21.9	197	-5	12.347	0.009	0.49	0.01

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range. If there is an asterisk before the first phase value, the phase angle reached a maximum or minimum during the period. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude (see Harris et al.,1984).

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"May–July" 23.
"August–October" 38.
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