ASTEROID PHOTOMETRY AND LIGHTCURVE ANALYSIS AT GORA'S OBSERVATORIES – PART II.

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(Received: 2020 May 22)

Synodic rotation periods and amplitudes are reported for 414 Liriope, 949 Hel, 952 Caia, and 1145 Robelmonte.

In this work, we present periods and amplitudes of lightcurves for 414 Liriope, 949 Hel, 952 Caia, and 1145 Robelmonte. These results are the product of a collaborative work by GORA (Grupo de Observadores de Rotaciones de Asteroides). In a recent publication (Colazo et al., 2020), we limited our observations to asteroids with well-defined periods, as part of a preliminary learning. Now, we have focused the study on more complex objectives, which allowed us to provide novel data of scientific relevance. The observatories and equipment used are listed in Table 1.

Observatory	Telescope	Camera
Estación Astrofísica Bosque Alegre	Newtonian telescope (D=1540mm; f=4.9)	CCD APOGEE Alta U9
Observatorio Astronómico Córdoba	Celestron SCT (D=355mm; f=11.0)	CCD SBIG ST7 + F.R.
Observatorio El Gato Gris	Celestron SCT (D=355mm; f=10.6)	CCD SBIG STF8300M
Observatorio Galileo Galilei	Third Planet Optics RC (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 de Ariel Stechina	Newtonian telescope (D=254mm; f=4.7)	CCD SBIG STF402
Observatorio de Damián Scotta	Newtonian telescope (D=300mm; f=4.0)	CCD Atik314l
Observatorio Punto Azul	Newtonian telescope (D=254mm; f=5.0)	CCD QHY6 Mono
Observatorio de Raúl Melia	Celestron-Byers SCT (D=200mm; f=10.0)	CCD Meade DSI Pro II

Table I. List of observatories and equipment.

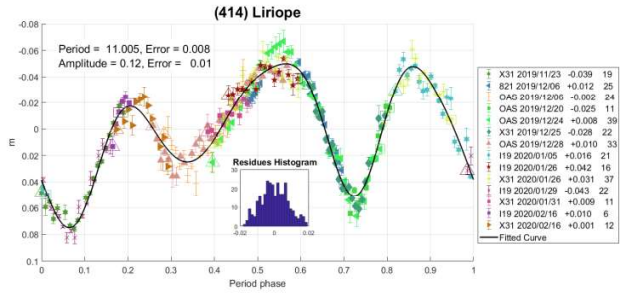
Image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected with dark frames and, in some cases, bias and flat-field frames were also used. Differential photometry measurements were performed using *FotoDif* software and for the analysis we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

Below, we present the results for each asteroid under study. The lightcurve figures contain the estimated period and amplitude, a 95% confidence interval regarding the period estimate, RMS of the fitting, estimated amplitude and amplitude error, Julian date corresponding to 0° rotation phase, and the number of data points. 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 (Mazzone et al., 2014).

Targets were selected based on three criteria: those asteroids with magnitudes accessible to the equipment of all participants; those with favorable observation conditions from Argentina i.e. with negative declinations δ; and 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.

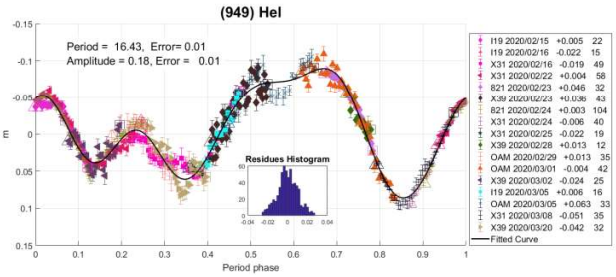
414 Liriope. This asteroid is classified as a C-type asteroid in Tholen taxonomy and has an estimated diameter of 88.760 ± 2.169 km (Mainzer et al., 2016). It was discovered on 1896 January 16 by Charlois. The last period and amplitude reported in the literature were from Waszczak et al. (2015). Those were 7.3397 ± 0.0056 h and 0.11 mag.

Our observations were made between 2019 November 22 and 2020 February 15. After several observations were completed, we realized that there were no good fits to the published periods. We decided to continue accumulating observations until a more confident period solution became evident. We found a period 11.005 ± 0.008 h and lightcurve amplitude of 0.12 ± 0.01 mag.



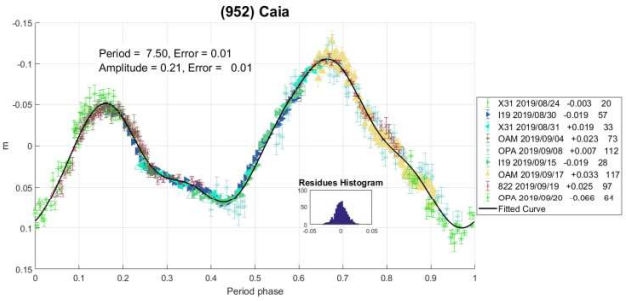
949 Hel. This asteroid was discovered in 1921 by Maximilian Franz Wolf from the Heidelberg-Königstuhl Observatory, Germany. It has an estimated diameter of 63.494 ± 0.743 km (Mainzer et al., 2016). The periods previously reported were 10.862 ± 0.007 h and 10.85 ± 0.05 h (Behrend 2001; 2004) with amplitudes of 0.12 ± 0.01 and 0.14 ± 0.02 mag, respectively.

Our calculated period was 16.43 ± 0.01 h with a lightcurve amplitude of 0.18 ± 0.01 mag. It is interesting to note that Brines et al. (2017) reported a period of 8.215 ± 0.01 h, about half the period that we have reported in this paper.



952 Caia. This asteroid was discovered on 1916 October 27 by Neujmin. Mainzer et al. (2016) found an estimated diameter of 88.692 ± 0.422 km. We observed this asteroid from 2019 August 24 to September 20, inspired by the discrepancy in the information found in the literature.

While a short period of around 3.7 h was reported by Behrend (2004; 2009) and Aznar Macias et al. (2018), periods of around 7.5 h were reported by Harris (1978; 7.50 ± 0.01 h) and Stanzel and Schober (1980; 7.51 h). For the Behrend and Aznar Macias et al. results, the U values were below 3. Our observations resulted in a period of 7.50 ± 0.01 h with amplitude of 0.21 ± 0.01 mag. These better agree with the longer periods reported by Harris (1978) and by Stanzel and Schober (1980).

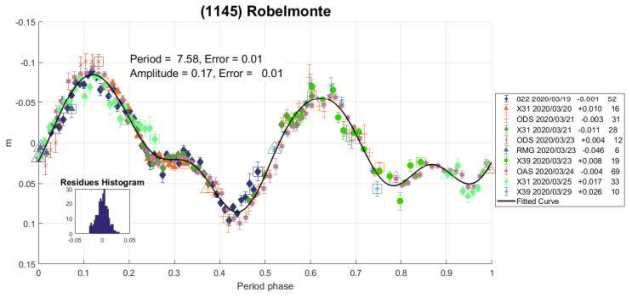


Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
414	Liriope	19/11/22-20/02/15	4.0,17.0	75	-5	11.005	0.008	0.12	0.01	MB-O
949	Hel	20/02/15-03/20	17.9,7.1	189	-9	16.43	0.01	0.18	0.01	MB-O
952	Caia	19/06/24-09/20	*22.0,11.4	331	-10	7.50	0.01	0.21	0.01	MB-O
1145	Robelmonte	20/03/19-03/29	10.8,6.2	198	-4	7.58	0.01	0.17	0.01	V

Table II. 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 extrema 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: outer main-belt. V: Vestoid.

1145 Robelmonte. This asteroid belongs to the Vesta family and has an estimated diameter of 22.822 ± 0.348 km (Mainzer et al., 2016). It was discovered on 1929 February 3 by Delporte.

The last reported period was of 7.5822 ± 0.0027 h with a lightcurve amplitude of 0.13 mag (Waszcazk et al., 2015). Gatrelle (2012) reported a period of 9.01 ± 0.01 h while Mansego et al., (2016) found a period of 8.002 ± 0.002 h. Our observations resulted in a period of 7.58 ± 0.01 h with amplitude of 0.17 ± 0.01 mag, which is in concordance with the results obtained by Waszckak et al. (2015).



Acknowledgements

We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analysis and to Fernando Mazzone for his *Periodos* program that was 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.

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