ASTEROID PHOTOMETRY AND LIGHTCURVE ANALYSIS AT GORA OBSERVATORIES

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

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

Observatorio Orbis Tertius (MPC X14)
Córdoba (Córdoba- ARGENTINA)

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

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

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

Observatorio AstroPilar (GORA APB)
Pilar (Buenos Aires- 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 Ariel Stechina 2 (GORA OA2)
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Observatorio Astronómico de Moquegua 1 (GORA OMP)
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Observatorio Municipal de Reconquista (GORA OMR)
Reconquista (Santa Fe- ARGENTINA)

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

Observatorio Uraniborg (MPC Z55)
Écija (Sevilla- ESPAÑA)

Observatorio Mazariegos (MPC Z50)
Mazariegos (Palencia- ESPAÑA)

Observatorio Nuevos Horizontes (MPC Z73)
Camas (Sevilla- ESPAÑA)

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Synodic rotation periods and amplitudes are reported for 57 Mnemosyne, 188 Menippe, 191 Kolga, 236 Honoria, 261 Prymno, 270 Anahita, 469 Argentina, 530 Turandot, 584 Semiramis, 921 Jovita, 936 Kunigunde, 994 Otthild, 1157 Arabia, 1180 Rita, 1269 Rollandia, 1594 Danjon, 3519 Ambiorix, and (52768) 1998 OR2.

In this work, we present periods and amplitudes of lightcurves for 57 Mnemosyne, 188 Menippe, 191 Kolga, 236 Honoria, 261 Prymno, 270 Anahita, 469 Argentina, 530 Turandot, 584 Semiramis, 921 Jovita, 936 Kunigunde, 994 Otthild, 1157 Arabia, 1180 Rita, 1269 Rollandia, 1594 Danjon, 3519 Ambiorix, and (52768) 1998 OR2.

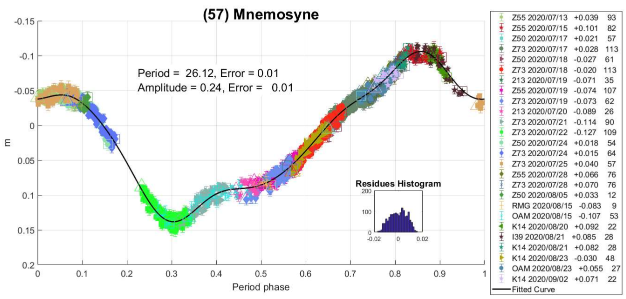
These results are the product of a collaborative work by GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In previous publications (Colazo et. al 2020a; Colazo et al. 2020b) we limited ourselves to the use of differential photometry for the analysis of our observations. However, on this occasion, we applied relative photometry assigning V magnitudes to the calibration stars, especially when observing more challenging asteroids.

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

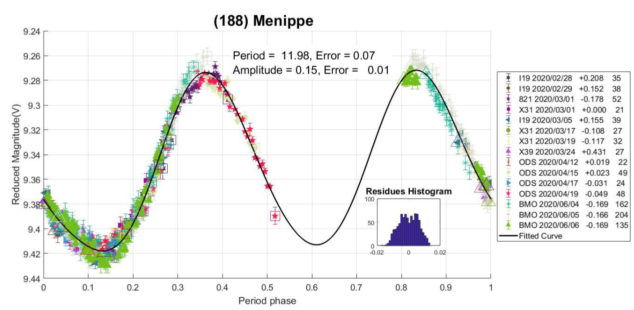
Below, we present the results for each asteroid. The lightcurve figures contain the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code or - failing that - the GORA internal code, session date, session off-set, and number of 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 i.e. with negative declinations, and 3) objects with few periods reported in the literature and/or with a quality code U < 3 in the Asteroid Lightcurve Database (LCDB; Warner et al., 2009).

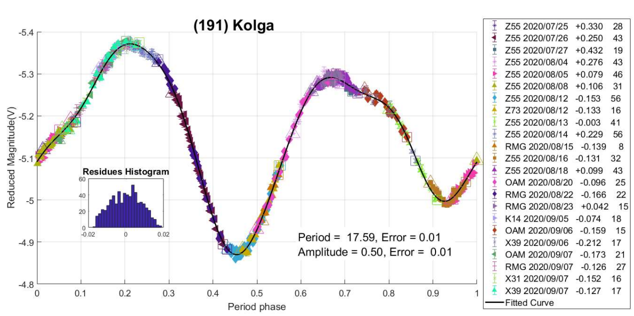
57 Mnemosyne. We found two reports of periods in the literature for this asteroid: P = 12.463 ± 0.007 h with an amplitude of 0.12 mag (Harris et al., 1992) and P = 12.66 ± 0.03 h with A = 0.14 ± 0.01 mag (Ditteon and Hawkins, 2007). In this paper we propose a new period corresponding to P = 26.12 ± 0.01 h and lightcurve amplitude of A = 0.24±0.01 mag.



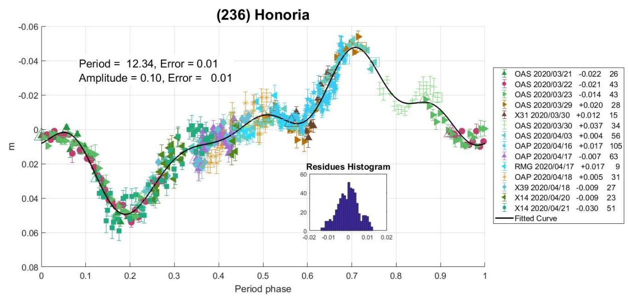
188 Mennipe. This main-belt asteroid was discovered in 1878 by Christian Heinrich Friedrich (C.H.F.) Peters, is of taxonomic type S, and has an estimated diameter of 35.75 km. The last reported periods are 11.98 ± 0.02 h (Warner and Higgins, 2010) and 11.9765 ± 0.0005 h, A = 0.28 ± 0.02 mag (Hanuš et al., 2011). This object was one of those we analyzed using relative photometry. At the beginning, we got two candidate periods, ~12 and ~24 hours. Although the RMS value is lower for the ~24-hour period, we consider that the adjustment with the lower period is closer to the shape of the lightcurve that we expect given the current 3D model of this asteroid. The results of this analysis are a period of P = 11.98 ± 0.07 h and amplitude A = 0.15±0.01 mag.



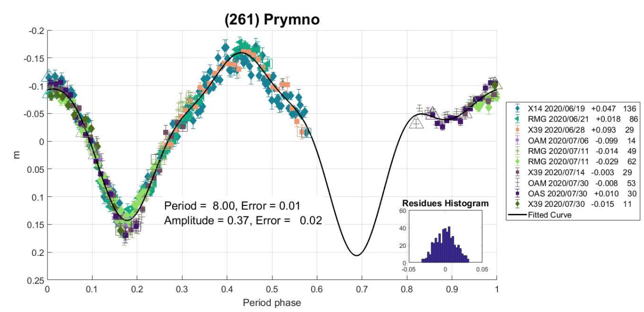
191 Kolga. We found two references to possible periods for this object: P = 13.7 ± 0.7 h, A = 0.21 ± 0.01 mag (Behrend, 2009) and P = 17.604 ± 0.001 h, A = 0.30 ± 0.02 mag (Pilcher, 2013). In our case, the analysis of the observations suggests agreement with the period published by Pilcher since the results are P = 17.59 ± 0.01 h and A = 0.50 ± 0.01 mag.



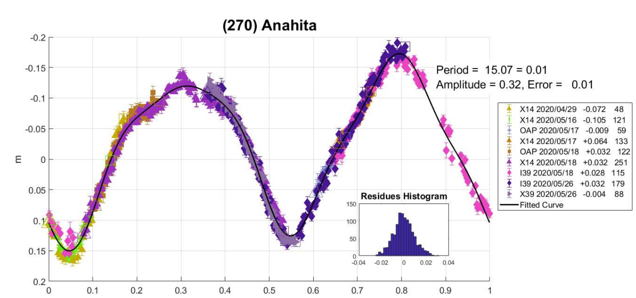
236 Honoria. This is an S-type asteroid with an estimated diameter of 77 km. There are two published periods from Behrend (2006, P = 16.8 ± 0.1 h; 2007, P = 17 h). On the other hand, Marciniak et al. (2014) found P =12.338 ± 0.002 h and (Pilcher, 2014a) reported P = 12.336 ± 0.001 h. The analysis of the GORA team data gives P = 12.34 ± 0.01 h and A = 0.10 ± 0.01 mag, making our period in agreement with those form Marciniak et al. and Pilcher.



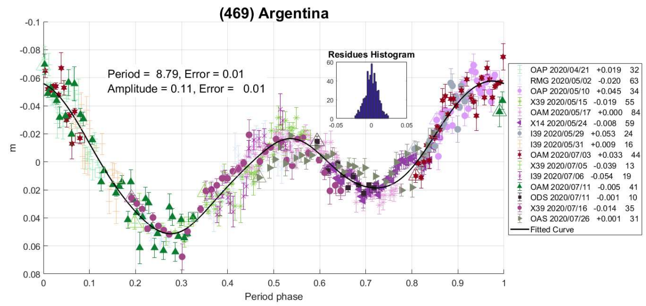
261 Prymno. This asteroid belongs to the main belt, is classified as type B within the Tholen (1984) taxonomy, and has an estimated diameter of 50 km. The last two reported periods from the literature are P = 3.9990 ± 0.0002 h with A = 0.14±0.01 mag (Behrend, 2009) and P = 8.007 ± 0.002 h with A = 0.13 ± 0.01 mag (Warner, 2009). Our data yielded P = 8.00 ± 0.01 h and A = 0.37 ± 0.02 mag, which is in accordance with that published by Warner. The difference in amplitude may be due to a change in the aspect angle.



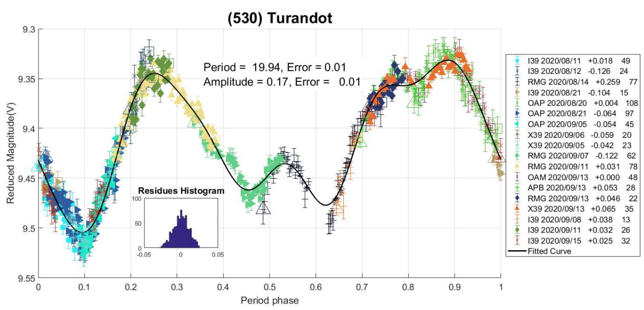
270 Anahita. This is an S-type asteroid discovered in 1887 by C.H.F Peters. The last reported periods (both sidereal) are P = 15.05906 ± 0.00005 h (Hanuš et al., 2016) and P = 15.05950 ± 0.00001 h (Ďurech et al., 2016). The analysis of our data results in a period of P = 15.07 ± 0.01 h and A = 0.32 ± 0.01 mag.



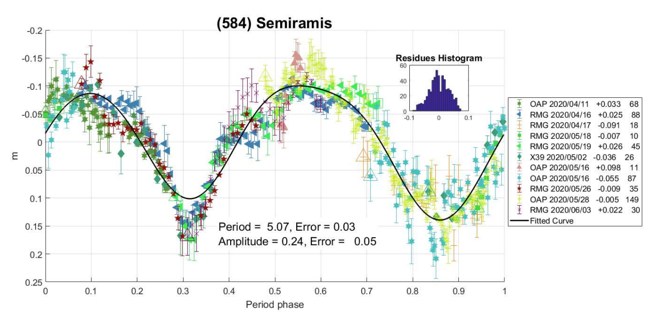
<u>469 Argentina</u>. This type X asteroid has three different periods published in the literature: P = 12.3 h, A = 0.12 mag (Székely et al., 2005); P = 13.122 h, A = 0.1 mag Wang et al. (2005); and P = 17.573 ± 0.003 h, A = 0.12 mag (Warner, 2007). The fitting of our lightcurves gives P = 8.79 ± 0.01 h and A = 0.11 ± 0.01 mag. In this way, we propose a new candidate period to those already published by other authors.



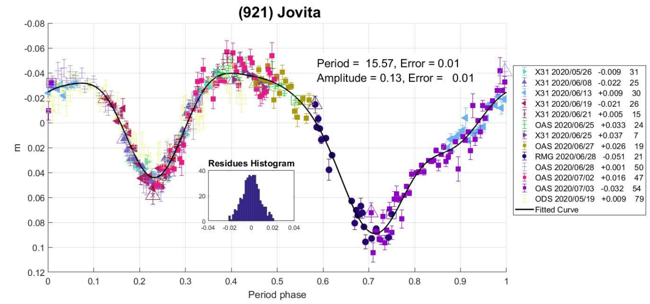
<u>530 Turandot</u>. The last reported period that we have found in the literature for this F-type asteroid corresponds to 19.960 ± 0.001 h with A = 0.13±0.01 mag (Pilcher, 2014b). Our period is in fairly good agreement with Pilcher and presents a small variation in the amplitude of the lightcurve, probably due to a change in the aspect angle. Our result is P = 19.94 ± 0.01 h and A = 0.17 ± 0.01 mag.



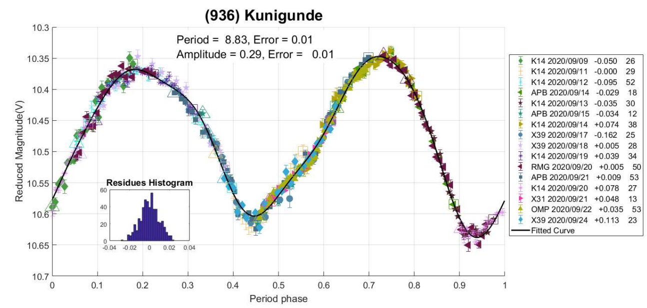
<u>584 Semiramis</u>. Most of the reported periods for this S-type asteroid point to 5.06 hours, for example, the last one is P = 5.0689 ± 0.0001 h with an amplitude of 0.24 ± 0.02 mag (Connour et al., 2015). Our observational data are also consistent with this value, yielding P = 5.07 ± 0.03 h and A = 0.24 ± 0.05 mag.



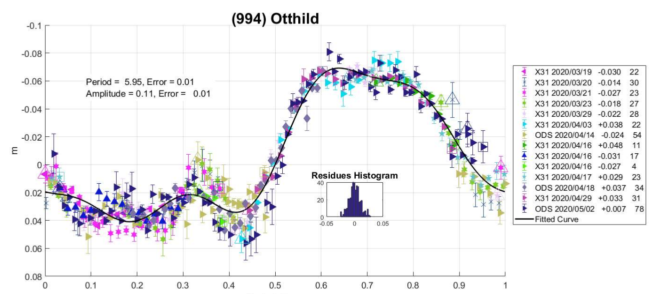
<u>921 Jovita</u>. This asteroid was discovered on 1919 September 4 by K. Reinmuth in Heidelberg. It has an estimated diameter of 58 km. We found two different periods in the literature: P = 23.00 ± 0.07 h with A = 0.07 ± 0.01 mag (Behrend, 2004) and P = 15.64 ± 0.02 h with A = 0.12 ± 0.02 mag (Warner, 2005). Our observations and the corresponding analysis agree with those published by Warner: P = 15.57 ± 0.01 h and A = 0.13 ± 0.01 mag.



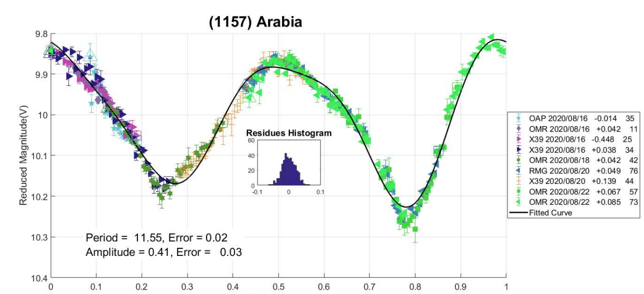
<u>936 Kunigunde</u>. The last two periods reported in the literature are P = 8.80 h with A = 0.25 mag (Angeli et al., 2001) and P = 8.82653 ± 0.00005 h (Hanuš et al., 2013). We obtained a result that agrees with the previous measurements: P = 8.83 ± 0.01 h, A = 0.29 ± 0.01 mag.



<u>994 Othild</u>. The last reported periods of this asteroid are 5.944 ± 0.002 h with an amplitude of 0.09 ± 0.01 mag (Behrend, 2001) and 5.9473 ± 0.0001 h with A = 0.15±0.01 mag (Behrend, 2005). The results obtained by our group are P = 5.95 ± 0.01 h with A = 0.11 ± 0.01 mag. These results are consistent with those previously published, the small difference in the amplitude of the lightcurve may be due to a change in the aspect angle.



<u>1157 Arabia</u>. We found only one reported period in the literature, that is P = 15.225 ± 0.005 h with A = 0.37 ± 0.03 mag (Caspari, 2008). The analysis of our observations suggests a shorter period of P = 11.55 ± 0.01 h with A = 0.41 ± 0.03 mag.



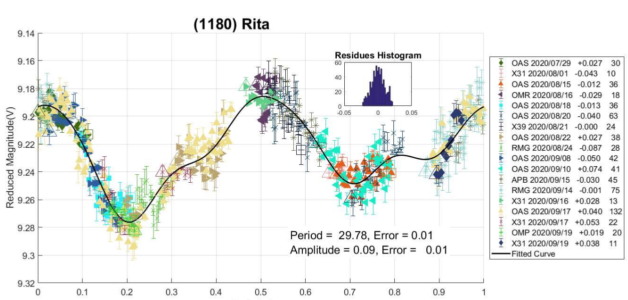
Observatory	Telescope	Camera	
Estación Astrofísica Bosque Alegre	Newtonian (1540 mm; f/4.9)	CCD	APOGEE Alta U9
Observatorio El Gato Gris	SCT (355 mm; f/10.6)	CCD	SBIG STF-8300M
Observatorio Cruz del Sur	Newtonian (200 mm; f/4.0)	CMOS	QHY-174
Observatorio Orbis Tertius	Newtonian (200 mm; f/5.0)	CCD	QHY6 Mono
Observatorio de Sencelles	SCT (254 mm; f/4.3)	CCD	SBIG ST-7XME
Observatorio Galileo Galilei	RCT ap (405 mm; f/8.0)	CCD	SBIG STF-8300M
Observatorio Antares	Newtonian (250 mm; f/5.0)	CCD	QHY9 Mono
Observatorio AstroPilar	ODK (250 mm; f/6.8)	CCD	FLI-8300M
Observatorio de Aldo Mottino	Newtonian (250 mm; f/4.7)	CCD	SBIG STF-8300M
Observatorio Astro Pulver	SCT (203 mm; f/10.3)	CMOS	QHY5 LII M
Observatorio de Ariel Stechina 1	Newtonian (254 mm; f/4.7)	CCD	SBIG STF-402
Observatorio de Ariel Stechina 2	Newtonian (305 mm; f/5.0)	CMOS	QHY 174M
Observatorio de Damián Scotta	Newtonian (300 mm; f/4.0)	CCD	SBIG ST-402 XME
Observatorio Astronómico de Moquegua	RCT APM (1000 mm; f/8)	CCD	FLI ProLine 16803
Observatorio Municipal Reconquista	Newtonian (254 mm; f/4)	CMOS	QHY 174M
Observatorio de Raúl Melia	SCT (200 mm; f/10.0)	CCD	Meade DSI Pro II
Observatorio Uraniborg	SCT (280 mm; f/6.3)	CCD	ATIK 414ex
Observatorio Mazariegos	SCT (200 mm; f/7.6)	CCD	ATIK 314L
Observatorio Nuevos Horizontes	SCT (235 mm; f/6.3)	CCD	Atik 3.14 L Plus
Observatorio Montcabrer	SCT (300 mm; f/9.2)	CCD	Moravian G4-9000
Blue Mountains Observatory	SCT Edge (355 m; f/7.0)	CCD	SBIG STF-8300M

Table I. List of observatories and equipment.

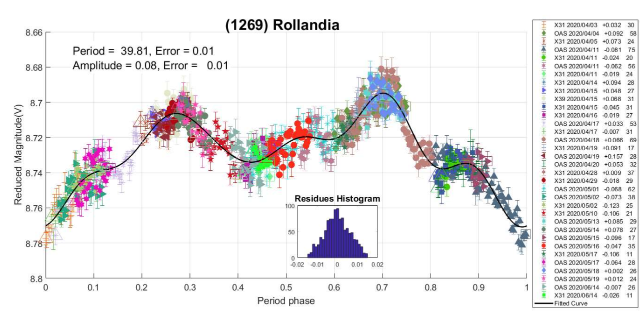
Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp.	A.E.	Grp
57	Mnemosyne	07/13-09/02	11.7,17.2	258	16	26.12	0.01	0.24	0.01	MB-O
188	Menippe	02/28-06/06	*17.0,17.9	209	-8	11.98	0.07	0.15	0.01	MB-O
191	Kolga	07/25-09/08	13.7,19.9	270	11	17.59	0.01	0.50	0.01	MB-O
236	Honoria	03/21-04/21	*9.8,1.6	209	3	12.34	0.01	0.10	0.01	MB-O
261	Prymno	06/19-07/30	18.9,25.6	235	2	8.00	0.01	0.37	0.02	FLOR
270	Anahita	04/29-05/26	*9.4,6.0	236	-1	15.07	0.01	0.32	0.01	FLOR
469	Argentina	04/21-07/26	*8.7,20.4	227	-14	8.79	0.01	0.11	0.01	MB-O
530	Turandot	08/11-09/15	6.5,18.5	307	-1	19.94	0.01	0.17	0.01	MB-O
584	Semiramis	04/11-06/03	11.3,20.1	177	-12	5.07	0.03	0.24	0.05	MB-I
921	Jovita	05/19-07/03	6.2,19.7	229	11	15.57	0.01	0.13	0.01	MB-O
936	Kunigunde	09/09-09/24	*4.1,2.7	389	-3	8.83	0.01	0.29	0.01	THM
994	Otthild	03/19-05/02	*15.8,5.8	219	-11	5.95	0.01	0.11	0.01	MB-I
1157	Arabia	08/15-08/23	1.9,4.8	320	-3	11.55	0.02	0.41	0.03	MB-O
1180	Rita	07/29-09/20	2.1,14.7	304	-6	29.78	0.01	0.09	0.01	HIL
1269	Rollandia	04/03-06/14	*2.1,15.1	199	3	39.81	0.01	0.08	0.01	HIL
1594	Danjon	05/03-07/26	*10.9,30.3	242	0	116.02	0.01	0.72	0.01	MB-I
3519	Ambiorix	07/11-09/21	*9.0,27.9	305	-1	5.78	0.03	0.29	0.05	MB-I
52768	1998 OR2	05/08-05/17	36.9,33.3	236	-20	4.01	0.02	0.19	0.03	NEA

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 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). FLOR: Flora; HIL: Hilda; MB-I/O: main-belt inner/outer; NEA: Near-Earth Asteroid; THM: Themis

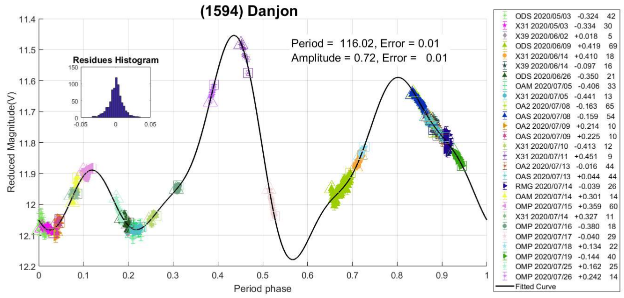
1180 Rita. This P-type asteroid is a very interesting case since it has several reported periods that differ from each other: P = 9.605 ± 0.006 h, A = 0.15 ± 0.03 mag (Polishook, 2012); P = 14.902 h with A = 0.29 mag (Dahlgren et al., 1998); and P = 20.496 ± 0.005 h with A = 0.05 mag (Slyusarev et al., 2012). Our observations suggest that the period of this object is even longer: P = 29.78 ± 0.01 h with an amplitude of 0.09 ± 0.01 mag.



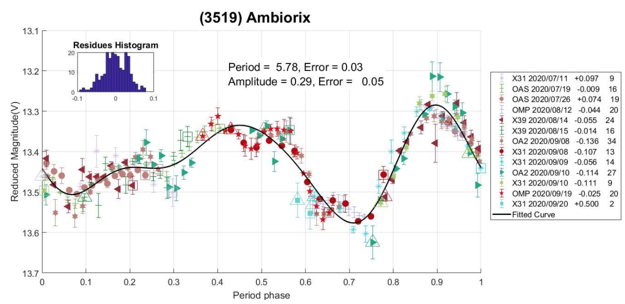
1269 Rollandia. This is a D-type asteroid with an estimated diameter of 104 km. As in the case of 188 Menippe, the analysis of the observations was made with relative photometry. Some of the previously reported periods are P = 30.98 ± 0.93 h, A = 0.02 mag (Slyusarev et al., 2012) and P = 15.32 ± 0.03 h with A = 0.13 ± 0.02 mag (Fauvaud and Fauvaud, 2013). In our case, we obtained a period similar to that found by Slyusarev: P = 39.81 ± 0.01 h with A = 0.08 ± 0.01 mag.



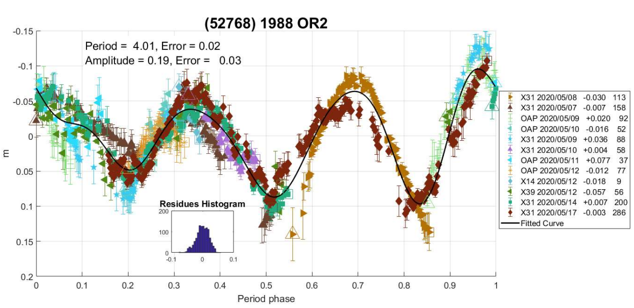
1594 Danjon. This is another object analyzed by relative photometry. Behrend (2006) reported a 12 h period for this asteroid, with an amplitude of 0.03 mag. In our case, we propose a much longer period: P = 116.02 ± 0.01 h with A = 0.72 ± 0.01 mag.



3519 Ambiorix. We found no previous reports for this object. After analyzing our observations, we propose a rotation period of P = 5.78 ± 0.03 h with an amplitude of A = 0.29 ± 0.05 mag.



(52768) 1998 OR2. We found two different periods reported in the literature: P = 3.198 ± 0.006 h with A = 0.29 ± 0.02 mag (Betzler and Novaes, 2009) and P = 4.112 ± 0.002 h with A = 0.16 ± 0.02 mag (Koehn et al., 2014). Our results suggest a period of 4.01 ± 0.02 h with amplitude A = 0.19 ± 0.03 mag.



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