

A LIGHTCURVE ANALYSIS FOR NINE MAIN-BELT AND ONE MARS-CROSSING ASTEROIDS

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Synodic rotation periods and amplitudes are reported for:
153 Hilda, 975 Perseverantia, 1203 Nanna, 1366 Piccolo,
1397 Umtata, 1763 Williams, 2168 Swope, 3768
Monroe, 6164 Gerhardmuller, 6601 Schmeer, 7000 Curie

The periods and amplitudes of asteroid lightcurves presented in this paper are the product of collaborative work by the 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.

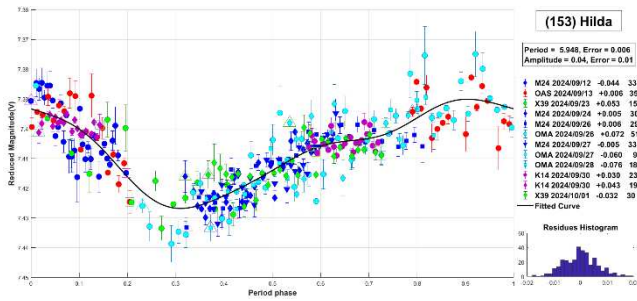
The image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected using dark frames and, in some cases, bias and flat-field corrections were also used. Photometry measurements were performed using *FotoDif* software and for the analysis, we employed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

Below, we present the results for each asteroid studied. 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.

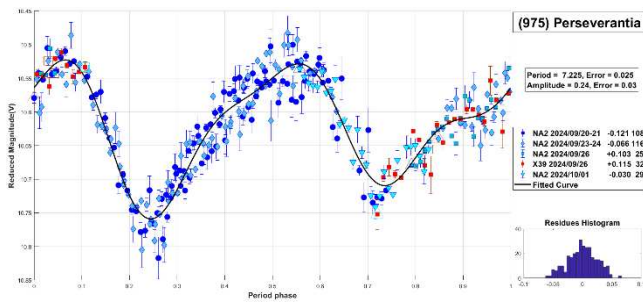
Targets were selected based on the following criteria: 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina or Spain or Italy, i.e. with negative or positive declinations δ , respectively, and 3) objects with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

In this work, we present measurements of periods corresponding to asteroids previously analyzed by our team. These lightcurves display improved results and are part of a new long-term project that we are initiating.

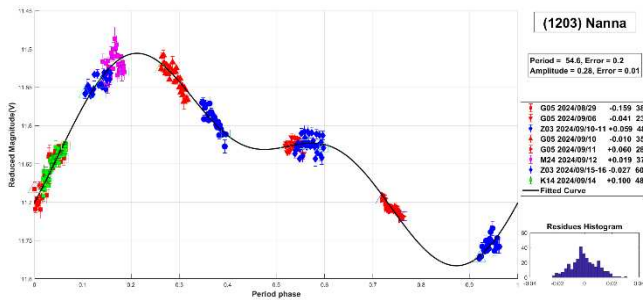
153 Hilda. Hilda is an outer main-belt asteroid, discovered in 1875 by J. Palisa. Classified as a P-type asteroid according to the Tholen taxonomy, it is the parent body of the Hilda family (Nesvorný et al., 2015). The diameter, derived from IRAS observations, is 170.63 km. Shevchenko et al. (2009) measured a rotation period of 5.9587 ± 0.0005 h. Our measurement of the period, $P = 5.948 \pm 0.006$ h, with $\Delta m = 0.04 \pm 0.01$ mag, agrees well with the value reported by the previous authors.



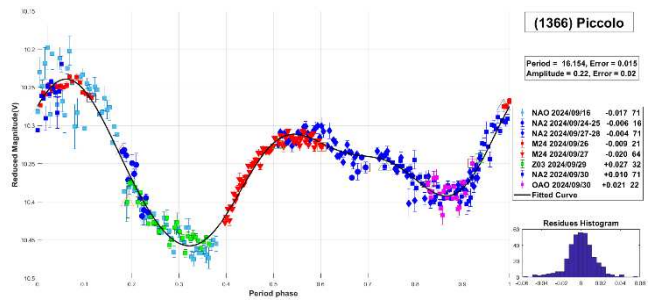
975 Perseverantia. This main-belt asteroid was discovered in 1922 by J. Palisa. Classified as an S-type asteroid according to the Tholen taxonomy, it is a member of the Koronis family (Nesvorný et al., 2015). The diameter is 22.169 km. The reported rotation period for this asteroid is 7.267 h (Behrend, 2003web). Our measurement of the period, $P = 7.225 \pm 0.025$ h, with $\Delta m = 0.24 \pm 0.03$ mag, agrees well with the value reported by the previous author.



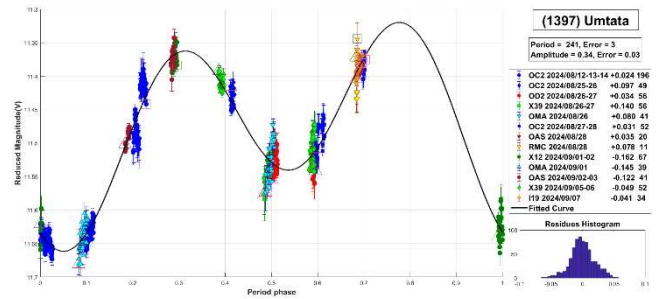
1203 Nanna. This main-belt asteroid was discovered in 1931 by M. Wolf, with a diameter of 35.18 km. The reported rotation period for 1203 Nanna is $P = 18.54 \pm 0.01$ h (Warner, 2011). However, the same author previously measured a longer period: $P = 25.80 \pm 0.05$ h (Warner, 2010). In this work, we propose an even longer period of $P = 54.6 \pm 0.2$ h with $\Delta m = 0.28 \pm 0.01$ mag.



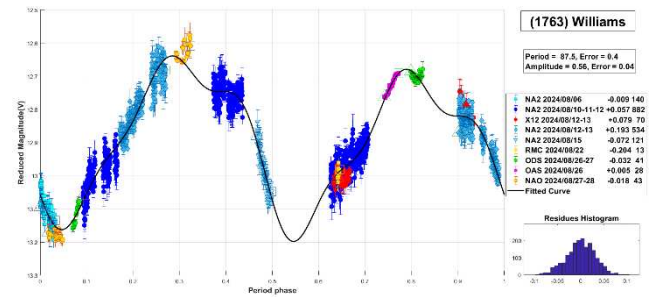
1366 Piccolo. This main-belt asteroid was discovered in 1932 by E. Delporte. It is classified as an X-type asteroid according to the Tholen taxonomy. The diameter is 27.55 km. The reported rotation period for this asteroid is 16.57 h (Binzel, 1987). We measured a period of $P = 16.154 \pm 0.015$ h, with $\Delta m = 0.22 \pm 0.02$ mag.



1397 Umtata. This main-belt asteroid was discovered in 1936 by C. Jackson, with a diameter of 20.798 km. An initial estimate of rotation period was reported as $P = 30$ h (Binzel, 1987). In this work, we propose a considerably longer period of $P = 241 \pm 3$ h with $\Delta m = 0.34 \pm 0.03$ mag.



1763 Williams. Williams is a main-belt asteroid with a diameter of 6.982 km, discovered in 1953 by the Goethe Link Observatory. A previously reported rotation period for this asteroid is $P = 88.62$ h (Durech et al., 2018). Our observations also support the long-period conclusion, yielding a similar value of $P = 87.5 \pm 0.4$ h with $\Delta m = 0.56 \pm 0.04$ mag.



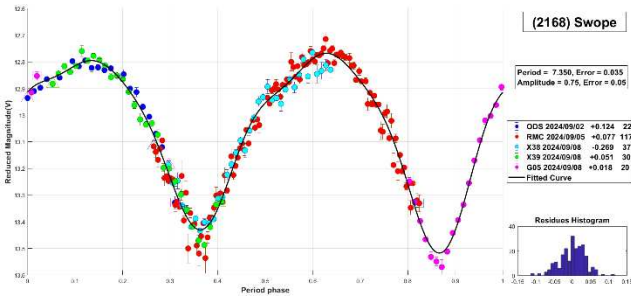
2168 Swope. This main-belt asteroid was discovered in 1955 at the Goethe Link Observatory. It is classified as a V-type asteroid according to the Tholen taxonomy, with a diameter of 8.205 km. Interestingly, we could not find a reported rotation period for this object in the literature. Based on our observations and thorough analysis, we propose a period of $P = 7.350 \pm 0.035$ h and $\Delta m = 0.75 \pm 0.05$ mag.

Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
153	Hilda	24/09/12-24/10/02	3.8,8.5	340	8	5.948	0.006	0.04	0.01	HIL
975	Perseverantia	24/09/20-24/10/01	3.5,7.7	349	-2	7.225	0.025	0.24	0.03	KOR
1203	Nanna	24/08/29-24/09/16	11.9,04.5	358	6	54.6	0.2	0.28	0.01	MB-O
1366	Piccolo	24/09/16-24/09/30	6.9,01.7	7	-4	16.154	0.015	0.22	0.02	MB-O
1397	Umtata	24/08/12-24/09/08	*3.6,12.4	324	-5	241	3	0.34	0.03	MB-M
1763	Williams	24/08/06-24/08/29	1.0,15.2	315	2	87.5	0.4	0.56	0.04	MB-I
2168	Swope	24/09/02-24/09/08	4.4,02.4	346	4	7.350	0.035	0.75	0.05	MB-I
3768	Monroe	24/08/28-24/09/14	*4.7,04.9	343	-5	56.7	0.2	0.38	0.03	MB-O
6164	Gerhardmuller	24/07/18-24/09/06	*13.7,17.4	316	-5	361	3	0.36	0.04	FLO
6601	Schmeer	24/08/25-24/08/30	9.0,11.9	320	-3	2.667	0.026	0.14	0.04	MB-I
7000	Curie	24/08/27-24/10/04	*16.9,13.5	355	-14	805	20	0.29	0.03	MB-I

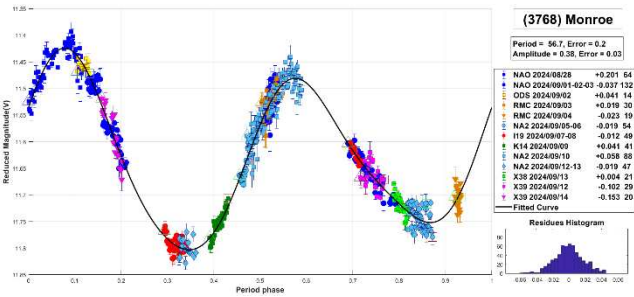
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extremum during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). MB-I: main-belt inner; MB-M: main-belt middle; MB-O: main-belt outer; FLO: 8 Flora; KOR: 158 Koronis; HIL: 153 Hilda.

Observatory	Telescope	Camera
G05 Obs.Astr.Giordano Bruno	SCT (D=203mm; f=6.3)	CCD Atik 420 m
I19 Obs.Astr.El Gato Gris	SCT (D=355mm; f=10.6)	CCD SBIG STF-8300M
K14 Obs.Astr.de Sencelles	Newtonian (D=250mm; f=4.0)	CCD SBIG ST-7XME
M24 Oss.Astr.La Macchina del Tempo	RCT (D250mm; f=8.0)	CMOS ZWO ASI 1600MM
X12 Obs.Astr.Los Cabezones	Newtonian (D=200mm; f=5.0)	CMOS QHY 174M
X38 Observatorio Pueyrredón	Newtonian (D=300mm; f=4.5)	CCD Apogee U8300
X39 Obs.Astr.Antares	Newtonian (D=250mm; f=4.72)	CCD QHY9 Mono
Z03 Obs.Astr.Río Cofio	SCT (D=254mm; f=6.3)	CCD SBIG ST-8XME
NAO Obs.Astr.Naos	Newtonian (D=250mm; f=4.0)	CMOS QHY 163M
NA2 Obs.Astr.Naos 2	Newtonian (D=200mm; f=5.0)	CMOS ZWO ASI 174
OA0 Obs.Astr.Aficionado Omega	Newtonian (D=150mm; f=5.0)	CMOS QHY 174M
OAS Obs.Astr.de Ariel Stechina 1	Newtonian (D=254mm; f=4.7)	CCD SBIG STF-402
OA2 Obs.Astr.de Ariel Stechina 2	Newtonian (D=305mm; f=5.0)	CMOS QHY 174M
ODS Obs.Astr.de Damián Scotta 1	Newtonian (D=300mm; f=4.0)	CMOS QHY 174M
OD2 Obs.Astr.de Damián Scotta 2	Newtonian (D=250mm; f=4.0)	CCD SBIG STF-8300M
OC2 Obs.Astr.de Carlos Ambrosioni	SCT (D=279mm; f=6.7)	CCD SBIG ST8XME
OMA Obs.Astr.Vuelta por el Universo	Newtonian (D=150mm; f=5.0)	CMOS POA Neptune-M
RMC Obs.Astr.de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

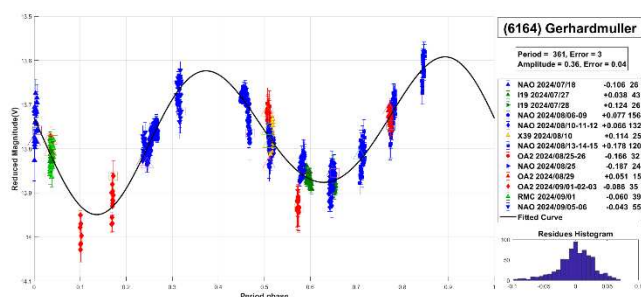
Table II. List of observatories and equipment.



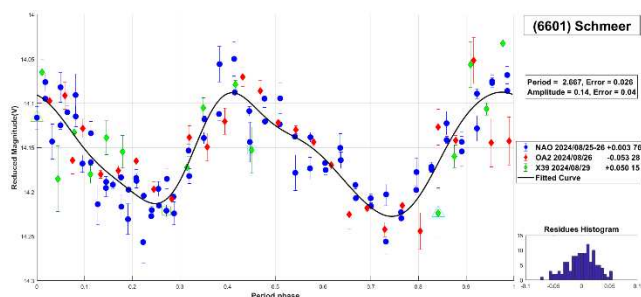
3768 Monroe. This main-belt asteroid was discovered in 1937 by C. Jackson. It is classified as a C-type asteroid according to the Tholen taxonomy, with a diameter of 26.601 km. For this asteroid, we could not find any published rotation periods in the literature. In this work, we propose a period of $P = 56.7 \pm 0.2$ h with $\Delta m = 0.38 \pm 0.03$ mag.



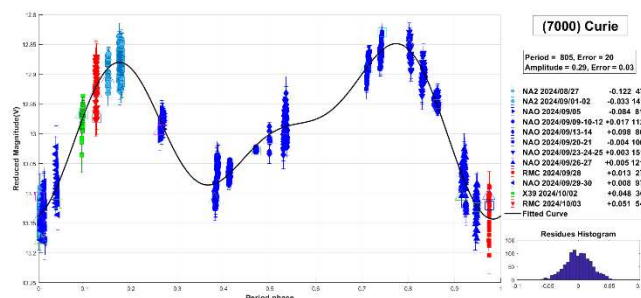
6164 Gerhardmuller. This main-belt asteroid was discovered in 1977 by N.S. Chernykh. It is a member of the Flora family (Nesvorný et al., 2015), with a diameter of 4.912 km. A review of the literature revealed no published rotation periods for this asteroid. In this work, we propose a long period of $P = 361 \pm 3$ h with $\Delta m = 0.36 \pm 0.04$ mag.



6601 Schmeer. Schmeer is a main-belt asteroid with a diameter of 6.946 km, discovered in 1988 by S. Ueda and H. Kaneda. No published rotation periods for this asteroid were found in the literature. In this work, we propose a short period of $P = 2.667 \pm 0.026$ h with $\Delta m = 0.14 \pm 0.04$ mag.



7000 Curie. Curie is a main-belt asteroid with a diameter of 6.497 km, discovered in 1939 by F. Rigaux. For this asteroid, we couldn't find published periods in the literature either. In this work, we propose a long period of $P = 805 \pm 20$ h with $\Delta m = 0.29 \pm 0.03$ mag.



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