Journal of the Southeastern Association for Research in Astronomy, 5, 25–28, 2012 February 1

ROTATION PERIODS OF 8 MAIN BELT ASTEROIDS OBSERVED IN 2003-2010

Dicy Ann Saylor[1]
Department of Physics and Astronomy, University of Georgia, Georgia, 30606
and
Martha A. Leake
Department of Physics, Astronomy, and Geosciences, Valdosta State University, Georgia, 31698

ABSTRACT

We report the rotation rates of the 8 main-belt asteroids 205 Martha, 252 Clementina, 506 Marion, 567 Eleutheria, 613 Ginevra, 869 Mellena, 996 Hilaritas, and 1490 Limpopo and discuss future work.

Subject headings: asteroids - rotation rates

1. INTRODUCTION

The study of main belt asteroids is an important topic because they can give us insight into planet formation and evolution. There are several ways to gather information on asteroids and the focus of this paper is to use photometry to learn rotation periods. Future work will focus on using this information to learn shape and pole orientation. Knowing the rotation rate, shape and orientation in addition to the mechanisms that change these characteristics can place constraints on the early solar system. This paper will focus on the light curves of one P and seven C-class asteroids located at heliocentric distances of 2.3 to 3.6 AU, placing them in the mid- to outer-asteroid belt. Seven of the light curves produced useful results: three of the periods are reported here for the first time, one expands on a previous publication, and the remaining three periods support previously published results.

2. OBSERVATIONS & REDUCTION

We selected objects to observe that are primitive mid- to outer-belt asteroids, a Tholen (Zellner et al. 1985) classification of P or C and its subclasses, for example, B,G,and F (de Pater & Lissauer 2001). We gave priority to targets that have previously unknown or ambiguous periods according to Brian Warner's CALL List `www.minorplanetobserver.com`. Observations were made using two telescopes, the SARA f/7.5 0.9-meter telescope at Kitt Peak National Observatory, Arizona (SARA North) and the SARA f/13.5 0.6-meter at Cerro Tololo Inter-American Observatory, Chile (SARA South). These telescopes both use Apogee Alta cameras; specific information about the cameras can be found in Table 1. Data were taken from 2003 November 5 to 2010 July 19 (see Table 2). The exposures range from 20-300 seconds. The images were processed and magnitudes extracted using MIRA Pro 6 and the synodic periods found using Brian Warner's MPO Canopus.

TABLE 1
Camera Information

Telescope	Type	Sensor Type	Gain	Read Noise (e^-)
SARA North	U55	1024×1024	3.0	15.9
SARA North	U42	2048×2048[a]	1.2	6.3
SARA South	U42	2048×2048	1.2	10.4

[a] These data were binned 2x2

3. RESULTS

Table 2 organizes the important information about the targets. Columns 1 and 2 are the number and name of the asteroid. Column 3 lists our calculated period and estimated error in hours, found using the MPO Canopus program. Column 4 lists the amplitude in magnitude and the error in column 5. These errors were found using a method suggested by Warner (2006). In column 6 are the dates observed and column 7 lists the corresponding solar phase angle, which is the angle between the sun and the earth as viewed from the asteroid. Phase angles were found using the website `ssd.jpl.nasa.gov/?horizons`. A range of phase angles is listed if the asteroid was observed on multiple nights. Column 8 is the exposure time in seconds and column 9 is the number of data points, N. Following the table we present a brief discussion of each asteroid followed by its light curve, which shows differential magnitude, Δm, versus phase, the fraction of the rotation period. The rotation period is included in the figure caption. A typical light curve for a non-tumbling, triaxial ellipsoid asteroid with a rotation axis perpendicular to the line of sight has two peaks corresponding to reflection from the broad sides of the asteroid. The light curve can be modified by variations in topography, albedo, orientation and phase angle, and each of those factors can complicate the determination of the rotation period.

3.1. *205 Martha*

Our period is inconsistent with the period of 9.637 h reported by Hawkins & Ditteon (2008). They do however report that a period of 11.90 h is also a possibility and we report here a period of 11.8 ± 0.1 h. Because we have more time on this target we have more confidence in our 11.8 h value. Note that this lightcurve does not have the typical bimodal shape (Figure 1).

3.2. *252 Clementina*

Warner (2008) reports a period of 10.862 h and we confirm his find with a period of 10.9 ± 0.1 h. We have

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Electronic address: dicy2007@uga.edu

[1] Southeastern Association for Research in Astronomy (SARA) NSF-REU 2010 Summer Intern

TABLE 2
ASTEROID INFORMATION

#	Name	Per (h)	Amp (mag)	Err (mag)	UT Dates	Phase Angle	Exp (s)	N
205	Martha	11.8 ± 0.1	0.309	0.012	2010 Jan 5,16	13.22,16.24	30	671
252	Clementina	10.9 ± 0.1	0.320	0.040	2003 Nov 5;2009 Dec 16	2.48, 6.49	60	378
506	Marion	13.6 ± 0.1	0.173	0.037	2009 Jan 11,Feb 19	11.88,5.31	20	871
567	Eleutheria	10.8 ± 0.1	0.342	0.023	2010 May 18,20	12.98,19.82	60	376
613	Ginevra	16.9 ± 0.1	0.222	0.014	2006 Nov 18,19,Dec 16;2010 Jul 19	4.40,4.67,13.70,7.62	45	348
869	Mellena	11.8 ± 0.1	0.201	0.032	2010 Jun 14-17,Jul 19	7.53,8.26,12.04	30,45	503
996	Hilaritas	8.5 ± 0.1	0.523	0.035	2009 Dec 16;2010 Mar 12	21.57,1.65	240,300	189
1490	Limpopo	12.3 ± 0.1	0.263	0.049	2005 Sep 30,Nov 6	11.88,5.31	45,300	89

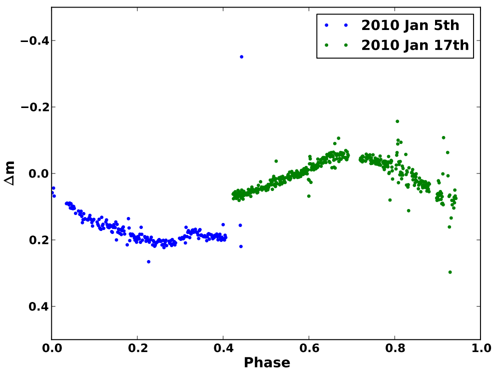

FIG. 1.— 205 Martha, $P = 11.8$ h.

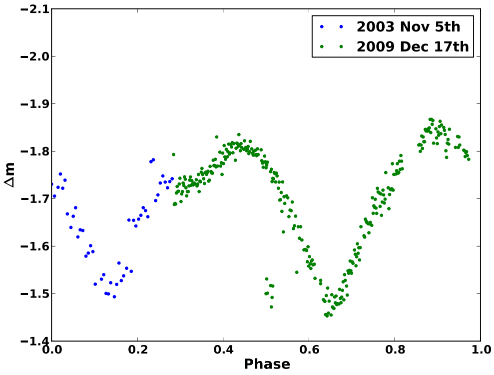

FIG. 2.— 252 Clementina, $P = 10.9$ h.

presented data on this target previously (Jutzeler et al. 2007; Jeffery & Leake 2002) that will be combined with these results in the future (Figure 2).

3.3. *506 Marion*

Warner (2009) reports a period of 13.53 h and we confirm it here with a period of 13.6 ± 0.1 h. It is also a good candidate for our future work. The apparent 40-min "eclipse" near rotational phase 0.8 is likely an artifact of the processing (Figure 3).

3.4. *567 Eleutheria*

We report here a new observation for this target. We observed Eleutheria for over 4 hours on two different nights and found the period to be 10.8 ± 0.1 h with an amplitude of 0.342 ± 0.023 mag. 567 Eleutheria shows

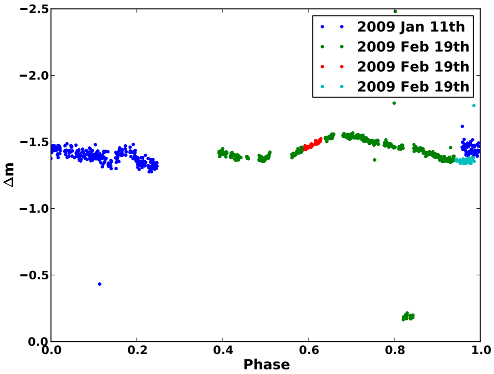

FIG. 3.— 506 Marion, $P = 13.6$ h.

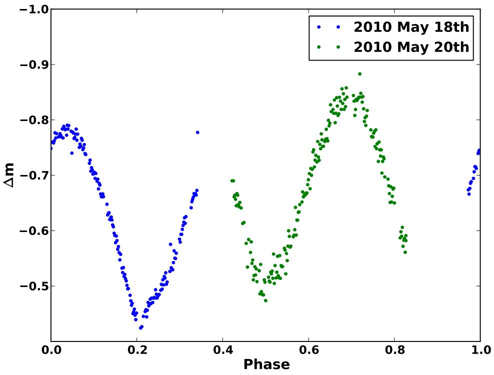

FIG. 4.— 567 Eleutheria, $P = 10.8$ h.

a typical bimodal period and a large amplitude. It is a priority in our future work (Figure 4).

3.5. *613 Ginevra*

This target has been reported before in our projects (Piltz et al. 2009) to have a period of 16.45 ± 0.01 h but with current data and Brian Warner's Canopus program, we are now able to more confidently report a period of 16.9 ± 0.1 h and an amplitude of 0.222 ± 0.014 mag. Our period is consistent with the work of Gil-Hutton (1998), however our amplitude is not (he reports 0.63 ± 0.02 mag). This may be due to the difference in phase angles between the two data sets, or a consequence of the complex lightcurve. We would like to note here that there could be period aliasing with this target: using only the 2006 data sets we found 9.05 h to be a plausible

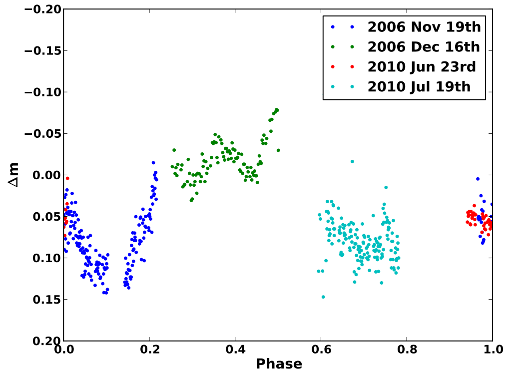

FIG. 5.— 613 Ginevra, $P = 16.9$ h.

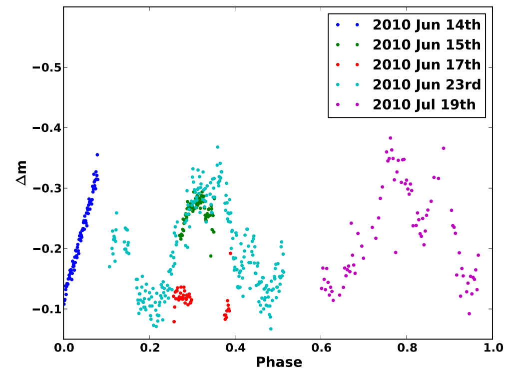

FIG. 6.— 869 Mellena, $P = 11.8$ h.

period (Figure 5).

3.6. *869 Mellena*

We observed Mellena on five different nights in June and July 2010 gathering over 11 hours of data. Our period of 11.8 ± 0.1 h is the first published rotation period of this asteroid. We found an amplitude of 0.201 ± 0.032 mag. Three of our data sets may have been too brief, and we found that if we focused on the 23 June and 19 July data sets that a period of 7.5 ± 0.1 h is plausible. This seems to indicate that there could be period aliasing with this target. More data or a collaboration will yield an improved period. It is worth noting that on our two nights of full coverage 869 Mellena showed some fine structure at its maximum that will be interesting to investigate further (Figure 6).

3.7. *996 Hilaritas*

We gathered over 7 hours of data on Hilaritas between one night in December 2009 and a second night in March 2010. Angeli et al. (2001) report a period of 7.2 h. We report here a period of 8.5 ± 0.1 h (Figure 7).

3.8. *1490 Limpopo*

Our light curve of 1490 Limpopo is noisy and the period is not well determined. We need more time on this target to determine if the period is 12.3 or 6.15 ± 0.1 h (Figure 8).

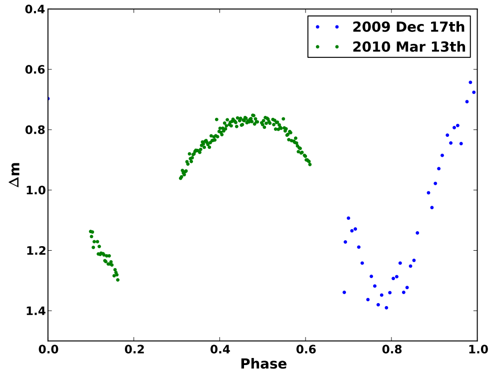

FIG. 7.— 996 Hilaritas, $P = 8.5$ h.

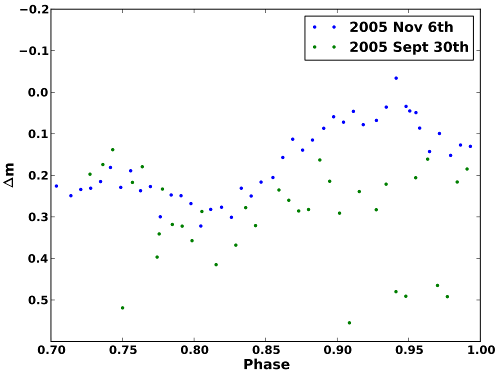

FIG. 8.— 1490 Limpopo, $P = 12.3$ h.

4. CONCLUSION & FUTURE WORK

Finding rotation periods of asteroids from their light curves is an exciting field because it is easily accessible to both the professional and amateur astronomer. It is important to gather as much data on these objects as we can to establish their rotation rates and amplitudes so that we can take this information a step further. By inverting a well established light curve using programs like M. Kaasalainen's DAMIT or Brian Warner's LCInvert it is possible to find the shape and pole position of the asteroid. In our immediate future work we plan to combine the above targets that make good candidates with the work of others and gather more of our own data so that we may establish their shapes and pole positions. The importance of learning the dynamics and shape of an asteroid is that it can be combined with theoretical work to produce a better understanding of our early solar system and we could apply these findings to extra solar planet systems. A interesting project will be to gather spectra on these to see how the reflectance spectrum might change as it rotates.

This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872. Special thanks to Liza Piltz (SARA REU 2008) for reducing the 2006 data for 613 Ginevra and to Eric Hausel and Elise Jutzeler (SARA REU 2006) for reducing the 2003 data for 252 Clementina. Also thank you to Dr. Stuart Lynn for helping us with Python coding. Both authors would like to thank Gary Henson and Matt Wood for useful suggestions.

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