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DIFFERENTIAL PHOTOMETRY AND LIGHTCURVE ANALYSIS FOR NUMBERED ASTEROIDS 229, 275, 426, 557, 613, 741, 788, 872, 907, AND 5010

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ABSTRACT

Partial lightcurves for asteroids 229 Adelinda, 275 Sapientia, 426 Hippo, 613 Ginevra, 741 Botolphia, 788 Hohensteina, 872 Holda, and 907 Rhoda are presented within this paper. Approximate rotation periods are suggested for 275 Sapientia, 613 Ginevra, and 872 Holda. Full lightcurves for asteroids 557 Violetta and 5010 Amenemhet, using previously published rotation periods, are presented within this paper. 557 Violetta was found to have a rotation period of 5.1 ± 0.1 hrs with an amplitude of 0.215 ± 0.044 magnitude (mag). No alternate rotation period or confirmation of the published period is suggested for 5010 Amenemhet.

Subject headings: Asteroids, Rotation Periods

1. INTRODUCTION

Ten asteroids were observed with the intention of creating partial lightcurves via differential photometry. Differential photometry is the measurement of the relative change in brightness of an object with respect to time. This change of brightness can then be plotted versus time in a lightcurve, and the displayed maxima and minima can be studied in order to determine the rotation period of the object. The rotation period, pole orientation, and especially the shape of many asteroids have yet to be fully determined. Observing these asteroids and creating partial lightcurves can help to improve published but uncertain rotation periods. The purpose of our observations is to provide partial lightcurves that can be combined with past and future observations in order to create complete lightcurves with well-defined rotation periods. Additionally, differential photometry of the same asteroid spanning several phase angles can help to determine the pole orientation and the shape of the asteroid (Magnusson et al. 1989). As the number of asteroids with well-defined rotation properties increases, the possibility of discovering relevant information pertaining to the asteroid belt, its collisional evolution, and the formation of the solar system also increases (Gil-Hutton 1998).

2. METHODS AND MATERIALS

The presented ten asteroids were chosen for observation based on several criteria, the most important of these being that the rotation period was not well established. Half of the given asteroids are either C class asteroids or subclasses thereof, located in the middle to the outer main belt, and have magnitudes of 14.5 or brighter, in accordance with an ongoing spectroscopic survey searching for water of hydration—evidence of silicates that have been altered by water (Leake et al. 2001). However, the other asteroids were chosen mainly based on their favorable observing positions, and were often found using a Minor Planet Observer lightcurve targets list (Collective Asteroid Lightcurve Link 2006). Lowell Observatory ASTFINDER finder charts (Asteroid Observer Service 2008) were used to locate each of the asteroids on all of the observation runs. Information regarding the given asteroids' specific classifications, along with other physical properties, can be found in Table 1.

The SARA 0.9 meter telescope at the Kitt Peak National Observatory (KPNO) was used for all observations. The data for June, 2008 were taken onsite, while the rest of the data were taken remotely. Information regarding the dates and times of observation for the asteroids can be found in Table 2. An Apogee Alta U-42 CCD camera with the Johnson-Cousins R filter was used for all observations. The Apogee Alta U-42 CCD camera has a gain of 1.2 electrons/ADU and a read noise of 10.4 electrons. The pixel size of the Apogee Alta U-42 is 13.5 x 13.5 microns, in a 2048 x 2048 array, which spans 12.6 x 12.6 arc minutes of sky with the SARA 0.9-m / f7.5 system. The images, camera statistics, and imaging conditions from each observing run were saved as FITS files by the software program MaxIm DL. All images were binned 2 x 2-and were therefore 1024 x 1024 pixels-and were converted to 32-bit real data files using the image processing software MIRA Pro 6.0. Exposure times ranged from 30 to 120 seconds and were chosen to produce good signal to noise without saturation.

The data for all observations included in this paper were reduced using MIRA Pro 6.0. The data reduc-

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tion process included subtracting the master bias and the master dark frames, and dividing by the master sky-flat frame (Axiom Research 2000). Hot and cold pixel removal was accomplished using the MIRA Pro 6.0 pixel mask command, and was performed on all data sets except the three 613 Ginevra data sets. There were also a few minor issues while reducing the June, 2008 data. The June 2^{nd} images all displayed very bright areas along the left and top edges that were not corrected during the reduction process. However, these areas did not interfere with the differential photometry measurements, which were made using stars not close to the perimeter. The darks that were taken on June 3^{rd} appeared as "light-frames" instead of "dark-frames" in the fits header display, and were therefore not used in the reduction process. We instead subtracted the June 2^{nd} master dark from the June 3^{rd} data the CCD camera was the same temperature on June 2^{nd} and June 3^{rd}. The June 3^{rd} images therefore had dark areas along the left and top edges. These areas also did not interfere with the differential photometry measurements.

Differential photometry for all data sets was accomplished using the MIRA Pro 6.0 aperture photometry measurements toolbar. The magnitudes of the asteroids were measured using three or four reference stars that were selected from the field of view that the asteroid traveled through during one observation run. The selected reference stars were not standards, but were stars with good signal to noise—on average 200, but always more than 100—and magnitude similar to that of the asteroid. The reference stars for each asteroid were selected using Lowell Observatory ASTPLOT finder charts (Asteroid Observing Service 2008). After the reference stars were selected, the REFNET service provided by the Lowell Observatory Asteroid Observing Service (2008) was used to determine the red magnitudes of the reference stars via the USNO-A2.0 catalog. The red magnitudes of the reference stars were entered into MIRA Pro 6.0 and were used to calculate the magnitudes of the asteroids. In order to ensure that the selected reference stars did not cause unnecessary noise within the differential magnitude of the asteroid, a graph of the averaged reference stars vs. time was plotted, using Microsoft Excel, for each data set. These graphs were more or less straight, flat lines, with any magnitude variance being on the order of $\pm$ 0.00033 or $\pm$ 0.00025 mag.

Microsoft Excel was used to calculate the differential magnitudes of the asteroids after Mira Pro 6.0 had measured the magnitudes of the reference stars and the asteroids. It is important to note that the differential magnitude for each asteroid was calculated by subtracting the magnitude of the asteroid from the magnitude of the averaged reference stars. In this manner, an increase in the differential magnitude of an asteroid represents an increase in the apparent brightness of the asteroid, and vice versa. All of the full and partial lightcurves presented within this paper are plotted using differential magnitude, and can be read as such.

Rotation periods and amplitudes are suggested for some of the asteroids within this paper. The lightcurves that were created in Microsoft Excel were used to determine approximate rotation periods for several of the asteroids; the authors hope to determine better rotation periods using the Minor Planet Observer's Canopus program in the future. The suggested rotation periods are further explained in the results section. The amplitudes of the asteroids were calculated using the process explained by Warner (2006) in his discussion of how to calculate the amplitude of a lightcurve using a spreadsheet.

The MIRA Pro 6.0 image processing software includes theoretical and empirical error within its aperture photometry program. The empirical error, "an estimate of the 1-sigma error based on the noise measured in the background annulus plus the gain, aperture size, and signal level" (Axiom Research 2000), was used to create the error bars within the full and partial lightcurves presented in this paper. The noise apparent in these lightcurves is often greater than the error bars and is probably due to the seeing conditions during the observations.

3. RESULTS

Previously published rotation periods and amplitudes, along with other physical properties, are presented in Table 1. The semi-major axes (a), diameters (D), absolute magnitudes (H), and geometric albedos (Ag) of the asteroids are approximate values. The spectral types of the asteroids are listed, when known, in both the Tholen (T) and the SMASSII (S) categories. The rotation periods (P) and the amplitudes (Δm) of the asteroids appear as published, except for 557 Violetta, which has a period of 5.0887 $\pm$ 0.0001 hrs and an amplitude of 0.25 $\pm$ 0.03 mag (Pilcher 2008), and 741 Botolphia, which has a period of 23.93 $\pm$ 0.02 hrs and an amplitude of $\approx$0.15 mag (Bucheim 2007). The reliability code (R) of the rotation periods and amplitudes is presented in the last column of Table 1. As explained in Minor Planet Center (2006) and Collective Asteroid Lightcure Link (2008), a "3" indicates a full, reliable lightcurve with no known pole orientation; a "2" indicates that the rotation period and amplitude are based on partial lightcurve(s) and may be wrong by about 30%, or that the number of extrema in the lightcurve is not reliable and the period may be off by an integer multiple; and a "1" indicates that the rotation period and amplitude are based on small lightcurve fragment(s) and may be wrong entirely. A reliability code of "1+" indicates that the rotation period and amplitude are slightly more reliable than a "1", but not as reliable as a "2" (Minor Planet Center 2006).

The dates and times of observation are listed in Table 2; the authors did not correct for light-time. (All dates and times presented hereafter will appear in UT.) The right ascension (R.A., J2000), declination (Dec., J2000), phase angle (α, Sun-asteroid-Earth), and magnitude (mag) listed in Table 2 were determined based on the start time of each observation. The listed rotation periods (hrs) and amplitudes (mag) are not precise measurements and do not always agree with the published values. In many cases there was insufficient data to determine a rotation period or amplitude for the observed asteroid; these instances are listed as "?" in Table 2. The rotation periods and amplitudes determined for each of the ten asteroids will be further discussed in the ensuing sections.

3.1. *229 Adelinda*

TABLE 1
Published Data

Asteroid #	a (AU) [4]	D (km) [4]	H (mag) [4]	A_g [4]	Type (T/S) [4]	P (hrs) [5]	Δm (mag) [5]	R [5]
229	3.4221	93.20	9.13	0.0453	BCU / -	6.60	0.04-0.30	3
275	2.7724	103	8.85	0.036	X / C	>20	>0.05	1
426	2.8871	127.10	8.42	0.0469	F / -	34.3	0.22	2
557	2.4421		11.8			5.0887 [6]	0.25 [6]	
613	2.9191	80.04	9.67	0.0374	P / -	16.45	0.63	1
741	2.7202	29.64	10.40	0.1391	X / X	23.93 [2]	0.15 [2]	
788	3.1329	103.68	8.30	0.0787		18.43 [3]	0.15 [3]	1+ [3]
872	2.7333	30.04	9.91	0.2127	M / X	7.20	0.34	2
907	2.7989	62.73	9.76	0.0560	C / Xk	22.44	0.16	2
5010	2.7172	13.8 [1]	12.2		- / S	3.2	0.14-0.30	1

References. — (1) Angeli et al. 2001; (2) Bucheim 2007; (3) Collective Asteroid Lightcurve Link 2006-2008; (4) JPL Small-Body Database Browser; (5) Minor Planet Lightcurve Parameters 2006; (6) Pilcher 2008.

TABLE 2
Observed Data

Asteroid #	UT Date	UT Time	R.A. *	Dec. *	mag *	α **	P	Δm
229	2008 06 03	09:39-10:49	21 46	-16 07	14.5	18.5	?	≥0.134
229	2008 06 04	08:51-11:04	21 46	-16 06	14.4	18.4	?	≥0.134
275	2008 04 26	03:31-10:21	12 35	+03 54	12.2	12.4	9-10	≥0.066
426	2008 01 20	11:44-13:11	11 04	-04 50	12.7	16.9	?	?
557	2008 01 20	05:50-11:24	08 33	+18 00	14.2	3.0	5.1	0.215
613	2006 11 18	04:43-09:56	02 50	+26 41	13.5	4.5	16.45	≥0.221
613	2006 11 19	03:06-09:24	02 49	+26 38	13.5	4.7	16.45	≥0.221
613	2006 12 16	01:40-05:51	02 31	+25 07	14.1	13.7	16.45	≥0.076
741	2007 03 31	02:45-05:35	08 06	+27 02	15.1	21.9	?	?
788	2008 06 03	04:05-05:47	14 30	+02 09	12.7	14.1	?	≥0.036
788	2008 06 04	03:30-04:31	14 30	+02 10	12.7	14.3	?	≥0.036
872	2007 03 31	06:00-11:07	12 54	-06 14	13.1	1.9	≈6	≥0.173
907	2008 01 20	01:55-05:16	02 42	+26 58	14.4	21.9	?	?
5010	2008 06 02	04:16-07:58	14 38	+06 39	15.4	18.0	?	0.217

References. — (*) Lowell Observatory Astfinder from Asteroid Observing Services 2008; (**) Minor Planet & Comet Ephemeris Service.

229 Adelinda was observed on two nights in June, 2008. All exposure times were 120 seconds. Figure 1 displays differential magnitude vs. time for the 229 Adelinda 2008 June 03 data, and Figure 2 displays differential magnitude vs. time for the 229 Adelinda 2008 June 04 data. The scale of differential magnitude varies from one graph to the other because different reference stars were used on the two nights. However, the scale ranges 0.30 mag for each graph, making the brightness variation of the asteroid easy to compare between nights.

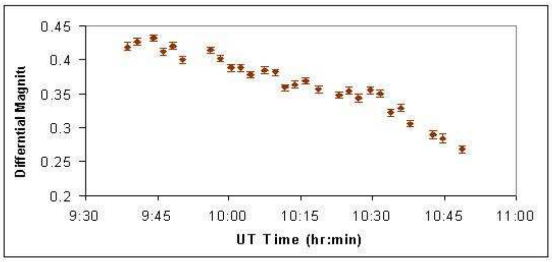

Fig. 1.— 229 Adelinda observed 2008 June 03.

Figure 3 displays an incomplete, composite lightcurve comprising both nights of the 229 Adelinda data. The rotational phase displayed in Figure 3 is based on the published rotation period of 6.6 hours (Lagerkvist et al.

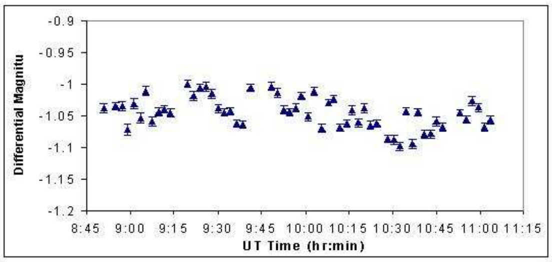

Fig. 2.— 229 Adelinda observed 2008 June 04

2001). The two nights of data were combined using two major steps. The first step was to fit the data together according to the correct rotational phase. The second step was to adjust for the brightness variation of the two nights.

Combining the data according to the correct rotational phase was a multi-step process. The first image on the first night of observation, June 3^{rd}, was used as the first data point for the combined graph and assigned a time value of 00:00:00. All of the times for June 3^{rd} were changed to correspond with the new start time. The time that elapsed from the start of the observation run on June $3^r d$ to the start of the observation run on night two, June 4^{th}, was then calculated, and changed into the number of rotation periods that occurred from one night to the other. Approximately 3.5156 rotation periods of

6.6 hours elapsed between the first image taken on June 3^{rd} and the first image taken on June 4^{th}. Therefore, the first image taken on June 4^{th} occurs three full rotation periods and approximately 3.4037 hrs after the first image taken on June 3^{rd}. Since the first image on June 3^{rd} was assigned a time value of 00:00:00, the first image on June 4^{th} was assigned a time value of 03:24:19. All of the times for the June 4^{th} data were changed to correspond with the new start time. Lastly, the assigned times for the two nights of data were changed into decimal numbers that correspond with one rotation period of the asteroid, where 00:00:00 equals 0.00 and 6:36:00 equals 1.00, in accordance with the typical display of lightcurves.

In order to account for the brightness variation caused by the different reference stars and seeing conditions on the two nights, the reference stars for each night were used to measure an "object"—a star that was not used as a reference star on either night —that was in the field of view for both night one and night two. The differential magnitude was then calculated for this object using the reference stars from each night. The calculated differential magnitudes were then compared in order to determine if the asteroid was brighter on night one or night two. The differential magnitude was approximately 1.4432 mag brighter on June 3^{rd} than it was on June 4^{th}. A magnitude offset of 1.4432 mag was therefore added to the June 4^{th} differential magnitude values that are displayed in Figure 3.

Given the incomplete coverage of the data taken for 229 Adelinda, a reliable rotation period will not be suggested in this paper. However, Figure 3 yielded an amplitude of $\geq$0.134 $\pm$0.024 mag. This is within the range of published amplitudes for 229 Adelinda (see Table 1).

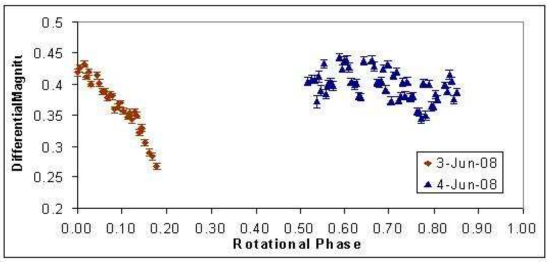

Fig. 3.— 229 Adelinda folded on a period of 6.6 hours.

3.2. *275 Sapientia*

275 Sapientia was observed for one night in April, 2008. All exposure times were 30 seconds. Figure 4 displays a plot of differential magnitude vs. a period of nine to ten hours. The graph was aligned so that the first image corresponds with time 00:00:00, as explained in the discussion for 229 Adelinda. With two obvious minima and two apparent maxima, the period was estimated based on the slope of the portion of the curve that would have to connect the first minimum with the second maximum, but was kept vague due to the asymmetry of the curve. The presented rotation period assumes that the lightcurve contains only two minima and two maxima. The partial lightcurve presented in Figure 4 yielded an amplitude of $\geq$0.066 $\pm$ 0.016 mag.

There have been a few different rotation periods published for 275 Sapientia. Denchev (2000) reported a rotation period of greater than 20 hrs based on two lightcurve fragments. Warner (2007) reported a rotation period of 14.766 $\pm$ 0.006 hrs, but suggested the possibility that the observation yielding this period may have been a pole-on observation, and therefore presented a possible period of twice the first one, 29.53 $\pm$ 0.03 hrs. There is also a period for 275 Sapientia published on the Genve observatory website of 24.0696 $\pm$ 0.0009 hrs (Antonini 2007). The partial lightcurve presented on the Genve observatory website shows an overall amplitude of about 0.08 mag, but contains some variations resembling maxima and minima within the curve that also have substantial amplitude.

The different publications for 275 Sapientia do not have similar lightcurves and do not have rotation periods that are easily or clearly related. The slight upward trend apparent in Figure 4 might be similar to what appears in the lightcurve published on the Genve observatory website, but the length of the upward slope should be no more than 6.0174 hours if the rotation period for 275 Sapientia is 24.0696 hrs, and the upward slope apparent in Figure 4 seems to last for the full 6 hrs and 50 minutes of the observation run.

Further observations of 275 Sapientia should help to establish the rotation period. Perhaps 275 Sapientia has a satellite, a highly erratic rotation with a wobble, considerable topographic structure, or albedo variations. A possible international observational campaign might be necessary in order to help determine the cause of the apparent variability of the asteroid.

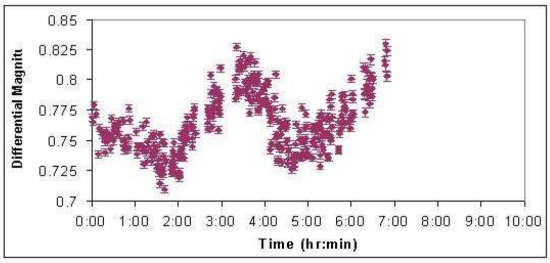

Fig. 4.— 2275 Sapientia displays a period of 9-10 hours.

3.3. *426 Hippo*

426 Hippo was observed for one night in January, 2008. All exposure times were 60 seconds. Figure 5 displays a plot of differential magnitude vs. time. A downward slope is visible in Figure 5, but there are no apparent minima or maxima. With the amount of data collected, it is impossible to suggest a rotation period or an amplitude for 426 Hippo. Being that the published rotation period for 426 Hippo is 34.3 hrs (see Table 1), the lack of shape seen in Figure 5 is not unexpected.

3.4. *557 Violetta*

557 Violetta was observed for one night in January, 2008. All exposure times were 60 seconds. Figure 6 displays our complete lightcurve with phase based on the published rotation period of 5.0887 $\pm$ 0.0001 hrs (Pilcher 2008). The rotational phase plot displayed in Figure 6

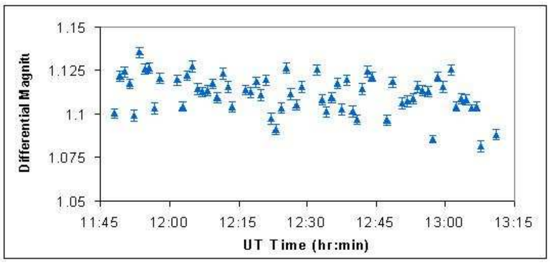

FIG. 5.— 426 Hippo observed 2008 January 20.

was created using the same process that was outlined in the discussion for 229 Adelinda, except that only one night of data was obtained. The rotation period for 557 Violetta was determined based on how well the repeating maximum fit together with the first maximum when phased for one full rotation period. The data displayed in Figure 6 first yielded a rotation period of 5.1 ± 0.1 hrs, which fits the published 5.0887 ± 0.0001 hrs very well. The amplitude of the data displayed in Figure 6 is 0.215 ± 0.044 mag.

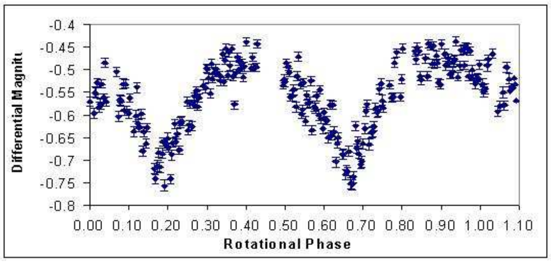

FIG. 6.— 557 Violetta folded on a period of 5.0887 hours.

3.5. *613 Ginevra*

613 Ginevra was observed for two nights in November, 2006, and one night in December, 2006. The November images were all 30 second exposures, and the December images were all 120 second exposures. Figure 7 displays a plot of differential magnitude vs. rotational phase for both of the November, 2006 nights. The rotational phase was based on a rotation period of 16.45 hrs, in accordance with previous publications (see Table 1). The two nights of data were combined into a partial, composite lightcurve using the same steps that were outlined in the discussion for 229 Adelinda. Figure 7 displays a false maximum at around 0.41 of its rotational phase. This peak corresponds with a star that the asteroid passed in front of; the general shape of the lightcurve was not impaired due to this interruption. The light from this star was not able to be subtracted using MIRA Pro 6.0.

Figure 8 displays a composite lightcurve of all three observations in 2006 for 613 Ginevra. The observations from November to December were only about one month apart, but have phase angles that vary by about 9 degrees, which could explain the large difference in amplitude from one month to the next. There was no way to compare the brightness variation of the December data to the November data using differential photometry, so an arbitrary magnitude offset was subtracted from the December data in order to better align it with the November data.

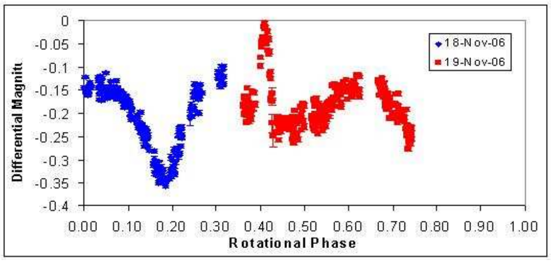

FIG. 7.— 613 Ginevra folded on a period of 16.45 hours.

613 Ginevra has a published rotation period of 16.45 ± 0.01 hrs with an amplitude of 0.63 ± 0.02 mag (Gil-Hutton 1998). The lightcurve by Gil-Hutton has only two maxima and two minima, while Figure 8 suggests four maxima and minima: The rotation period does seem to be around 16.45 hrs, though, as made clear by how well the two nights in November, 2006, fit together when plotted against the rotational phase of a 16.45 hr period. However, the misalignment of the maximum between the November and December data indicates that the rotation period may be off by a fraction of an hour. The amplitude yielded from the data presented in Figure 8 is ≥ 0.076 ± 0.017 and ≥ 0.221 ± 0.017 mag. The difference in the number of extrema and the difference in amplitude from the published lightcurve and the lightcurve presented in this paper may be due to a difference in phase angle or a difference in the orientation of the asteroid.

Further observations of 613 Ginevra on successive nights will help refine the rotation period. Multiple observations spanning several months may help to determine what appears to be an interesting shape and pole-orientation.

3.6. *741 Botolphia*

741 Botolphia was observed for one night in March, 2007. All exposure times were 120 seconds. Figure 8 displays a plot of differential magnitude vs. time. A possible partial maximum is displayed in Figure 9, but there is not sufficient data to suggest a rotation period or an amplitude for 741 Botolphia. Based on the published rotation period of 23.93 ± 0.02 hrs (see Table 1), the lack of shape in Figure 9 is not unexpected.

3.7. *788 Hohensteina*

788 Hohensteina was observed for two nights in June, 2008. All exposure times were 90 seconds. Figure 10 displays a composite, partial lightcurve that was created using the same steps that are outlined in the discussion for 229 Adelinda. Sufficient data was not acquired for

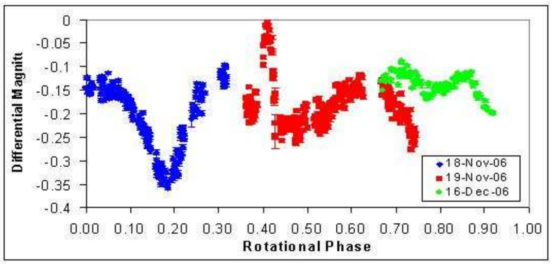

FIG. 8.— 613 Ginevra folded on a period of 16.45 hours, this time including data from 2006 Dec 16.

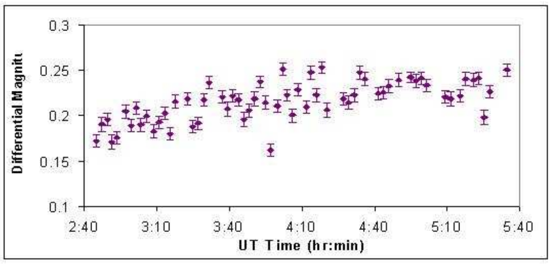

FIG. 9.— 741 Botolphia observed 2007 March 31.

788 Hohensteina in order to suggest a rotation period, but an amplitude of $\geq 0.036 \pm 0.015$ mag is apparent in Figure 10. Given the published rotation period for 788 Hohensteina of 18.43 hrs, the lack of definitive shape displayed in Figure 10 is not unexpected.

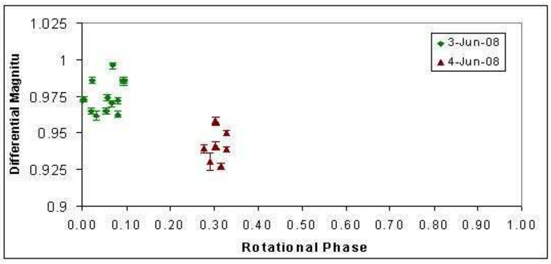

FIG. 10.— 788 Hohenstina folded on a period of 18.43 hours.

3.8. *872 Holda*

872 Holda was observed for one night in March, 2007. All exposure times were 120 seconds. Figure 11 displays a plot of differential magnitude vs. a period of approximately six hrs. The graph was aligned so that the first image corresponds with time 00:00:00, as explained in the discussion for 229 Adelinda. Based on the nearly complete lightcurve displayed in Figure 11, a rotation period of ∼6 hrs and an amplitude of $\geq 0.173 \pm 0.016$ mag is suggested for 872 Holda. The rotation period was determined by finding the length of time spanned between the clearly displayed maximum and minimum, and multiplying that number by four. The published rotation period for 872 Holda is 7.20 hrs (Lagerkvist et al. 1998). Lagerkvist et al. (1998) also suggested a rotation period of 6.78 hrs.

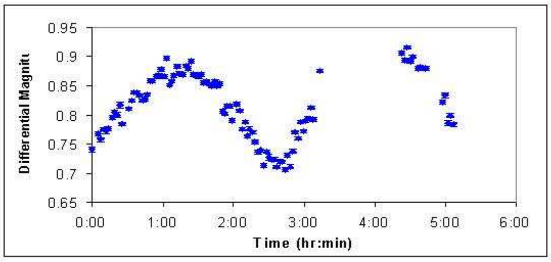

FIG. 11.— 872 Holda displays a period of roughly 6 hours.

3.9. *907 Rhoda*

907 Rhoda was observed for one night in January, 2008. All exposure times were either 60 or 120 seconds. Figure 12 displays a plot of differential magnitude vs. time. Approximately 45 minutes of marginal data is visible in Figure 12, starting around 2:15, possibly due to cirrus clouds. Figure 12 displays a slight downward trend, but does not have sufficient data to suggest a rotation period or an amplitude. Given the published rotation period for 907 Rhoda of 22.44 hrs and the low amplitude (see Table 1), the lack of shape displayed in Figure 12 is not unexpected.

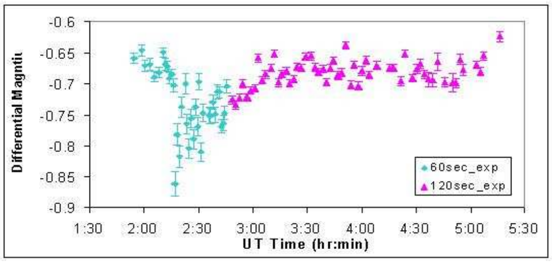

FIG. 12.— 907 Rhoda observed 2008 Jan 20.

3.10. *5010 Amenemhet*

5010 Amenemhet was observed for one night in June, 2008. All exposure times were 120 seconds. Figure 13 displays a plot of differential magnitude vs. a rotational phase based on the previously published rotation period of 3.2 hrs (Angeli et al. 2001). Figure 13 was created using the same process that was outlined in the discussion for 229 Adelinda, except that only one night of data was obtained. The lack of any distinctive shape displayed in Figure 13 is probably due to the phase angle (see Table 2) or orientation of 5010 Amenemhet during the observation. However, due to this indistinctive shape, a rotation period will not be suggested for 5010 Amenemhet in this paper. An amplitude of 0.217 ± 0.048 mag is apparent in Figure 13.

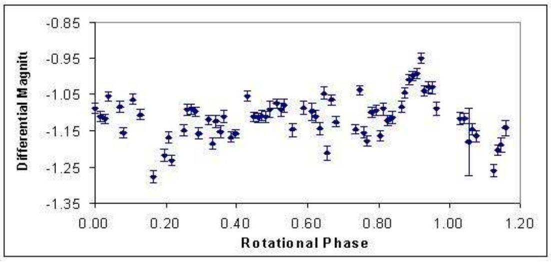

FIG. 13.— 5010 Amenemhet with a period of 3.2 hours.

4. DISCUSSION

Presented within this paper are partial lightcurves for numbered asteroids 229, 426, 741, 788, and 907 that did not contain enough data to indicate any rotation periods; partial lightcurves for numbered asteroids 275, 613, and 872 that did contain enough data to suggest rotation periods and associated amplitudes; and complete lightcurves for numbered asteroids 557 and 5010, with a suggested rotation period and associated amplitude for 557 and a suggested amplitude for 5010. These full and partial lightcurves can be combined with past and future lightcurves in order to help refine previously published rotation periods, and eventually to help determine pole orientations and possible shapes for the presented ten asteroids.

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