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CCD PHOTOMETRY OF ASTEROIDS 651 ANTIKLEIA, 738 ALAGASTA, AND 2151 HADWIGER USING A REMOTE COMMERCIAL TELESCOPE

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CCD photometry of asteroids 651 Antikleia, 738 Alagasta, and 2151 Hadwiger obtained remotely at Tenagra Observatories during March, April and May 2004 is reported. Our lightcurve period and amplitude results: 651 Antikleia, 20.287 ± 0.004 hr, 0.40 ± 0.05 mag; 738 Alagasta, 17.83 ± 0.04 hr, 0.20 ± 0.03 mag; 2151 Hadwiger, 5.872 ± 0.002 hr, 0.35 ± 0.02 mag. The three asteroids show nearly symmetrical lightcurves, although a complete lightcurve for Antikleia was not obtained. Three other asteroids (1926 Demiddelaer, 2375 Radek and 4293 Masumi) were also observed on seven nights, but no satisfactory lightcurves could be obtained.

The observations of 651 Antikleia, 738 Alagasta and 2151 Hadwiger reported here were made with the Tenagra II telescope at Tenagra Observatories (MPC 926). The instruments used to gather the data were a computerized 0.81m (32-inch) f/7 Ritchey-Chrétien telescope with a SITe-based 1024x1024x24 μm electronic imager yielding ~0.87 arc-seconds per pixel for a field of view of ~15'x15' (Schwartz, 2003). The chip temperature was set at –45º C and the images were 2x2 binned for file transfer economy. Tenagra Observatories offers commercial telescope time with two telescopes in southern Arizona. These are fully automated instruments. An observer only needs to send instructions on which objects to observe, and the imaging requests from several users are sorted and executed throughout the night. The data is stored for immediate FTP retrieval, including calibration frames. This convenient setup saves time, travel and lodging expenses and is ideal for individuals or universities with small research departments.

The targets were selected from a list of asteroid photometry opportunities published by Brian Warner on his Collaborative Asteroid Lightcurve Link (CALL) website (Warner, 2004). Selection criteria included: proximity of the asteroids to each other and to a nearby suitable star calibration field to save on telescope slewing time, asteroid declination and closeness of opposition date to dates of observation for maximum nightly coverage, appropriate asteroid magnitude to acquire enough counts for a S/N of at least 100 with 1-minute V-filtered exposures, and a high reported asteroid absolute magnitude (H-value) to target the smallest asteroid size possible.

Usable data were collected on 2004 March 16-17, 28-30 and April 14 & 16 for 651 Antikleia; and May 7 & 11-13 for 738 Alagasta and 2151 Hadwiger. All dates are UT. In total, 174 images were obtained and processed for Antikleia, 113 for Alagasta and 105 for Hadwiger, using a standard Johnson V photometric filter and 1-minute exposure times. Of these, 159 (91%) were used in the final analysis for Antikleia, 111 (98%) for Alagasta and 105 (100%) for Hadwiger. The rest were discarded because of asteroid proximity to stars. Standard bias, dark current and flat field corrections were applied. Five (in a few cases only three) stars were used in each image as magnitude comparisons for the asteroid. A nearby star field, identified from the 'LONEOS Photometric Calibration Star List' (Skiff, 2003), was observed each night for magnitude calibration. Stars with known magnitudes were used to determine the magnitudes of the asteroid comparison stars.

Times were corrected for light travel time from the asteroid to the Earth and were taken to be at the mid-times of the image exposures. Relative magnitudes from night to night were uncertain as different comparison star sets were used. This was dealt with by using additive constants to bring all the data into the best agreement possible. However, these arbitrary magnitude shifts were small (≤0.05 magnitudes). Additional magnitude shifts were also used to compensate for the intrinsic magnitude variation of the asteroids due to their change of distance with respect to the Earth, and to phase angle variations (5.3º-13.4º for 651 Antikleia, 7.9º-10.0º for 738 Alagasta, and 11.1º-13.3º for 2151 Hadwiger).

The best-fit rotational periods for the asteroids were obtained by computing the power spectrum of the time series of data (Scargle, 1982; Horne and Baliunas, 1986). The resulting synodic rotational period for 651 Antikleia from the data presented here is 20.287 ± 0.004 hours. The amplitude of the lightcurve is 0.40 ± 0.05 magnitudes (Figure 1). For 738 Alagasta the resulting synodic rotational period was 17.83 ± 0.04 hours with an amplitude of 0.20 ± 0.03 magnitudes (Figure 2). For 2151 Hadwiger the resulting synodic rotational period was 5.872 ± 0.002 hours with an amplitude of 0.35 ± 0.02 magnitudes (Figure 3). The asteroids exhibited two similar maxima and minima per rotation. The time scale is given in rotational phase with the zero corresponding to the epoch, in Julian Day, indicated in each figure. The magnitude scale is also referenced to this same epoch.

This is probably the first reported rotational period for 651 Antikleia and 738 Alagasta since they are not listed in A. Harris and B. Warner's 'Minor Planet Lightcurve Parameters' list (Harris and Warner, 2005). For Antikleia the rotation period and coverage were such that we were unable to obtain a complete lightcurve, although we are confident about the result since we had a one-month baseline of observations. The uncertainty in the derived period for Alagasta is comparatively larger since we had little overlap in the lightcurve with only four nights of observations spread over a week.

Alvarez-Candal et al. (2004) report a rotation period for 2151 Hadwiger of 2.29 ± 0.01 hours and an amplitude of 0.38 magnitudes from a single night of observations in April 2000. Although our amplitudes are consistent for this asteroid, we cannot explain the discrepancy in the derived rotational periods. More specifically, we do not see the bimodal nature of the lightcurve Alvarez-Candal et al. show in their 2.17 hours of coverage. Also, phasing our data with their period did not yield a reasonable lightcurve. However, we are confident about our result since we observed the asteroid for over 18 hours on 4 nights (covering 3 full rotations) and used five comparison stars to obtain asteroid magnitudes.

Other Asteroids Observed

As part of the same program we observed three other asteroids over seven nights (nearly coincident with the observations of 651 Antikleia) during March and April of 2004. These asteroids were 1926 Demiddelaer, 2375 Radek, and 4293 Masumi. These asteroids exhibited small brightness variations (<0.10 magnitudes) during each observing session, and we were unable to derive an unambiguous rotation period through their power spectrum. We then attempted to obtain a reasonable lightcurve by sequentially adopting rotation periods using time increments of 0.001 hours and phasing the data. These were visually inspected in order to find the best fit possible. Small nightly magnitude shifts (≤0.05 mag.) to the data were also attempted. No clear and satisfactory solutions were apparent. Our inability to find rotation periods for these asteroids may be related to the fact that they may possess low brightness amplitudes, long rotation periods, complex lightcurve shapes, or a combination of these. It was also apparent that longer exposure times (greater S/N) would have been helpful in clearly delineating the observed low amplitude brightness variations.

Acknowledgments

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References

Alvarez-Candal, A., Duffard, R., Angeli, C. A., Lazzaro, D. and Fernández, S. (2004). "Rotational Lightcurves of Asteroids belonging to Families". Icarus **172** pp. 388-401.

Harris, A. W. and Warner, B. D. (2005). "Minor Planet Lightcurve Parameters". Posted on the WWW: http://cfa-www.harvard.edu/iau/lists/LightcurveDat.html (2005 February 5 update).

Horne, J. H. and Baliunas, S. L. (1986). "A Prescription for Period Analysis of Unevenly Sampled Times Series". Astrophysical Journal **302** pp. 757-763.

Scargle, J. D. (1982). "Studies in Astronomical Time Series Analysis. II - Statistical Aspects of Spectral Analysis of Unevenly Spaced Data". Astrophysical Journal **263** pp. 835-853.

Schwartz, M. (2003). "Tenagra Observatories, Ltd." Posted on the WWW: http://www.tenagraobservatories.com/

Skiff, B. (2003). "LONEOS Photometric Calibration Star List". Posted on the WWW: ftp://ftp.lowell.edu/pub/bas/starcats/loneos.phot (2003 July 15 update).

Warner, B. D. (2004). "Potential Lightcurve Targets 2004: January 1 – March 31" and "Potential Lightcurve Targets 2004: April 1 – June 30". Posted on the WWW: http://www.minorplanet observer.com/astlc/default.htm

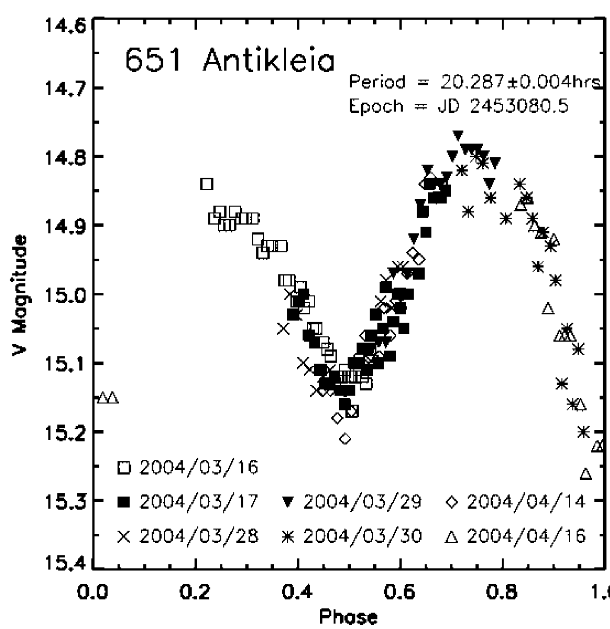

Figure 1: Composite lightcurve of asteroid 651 Antikleia derived from 159 observations and a 20.287-hour rotation period.

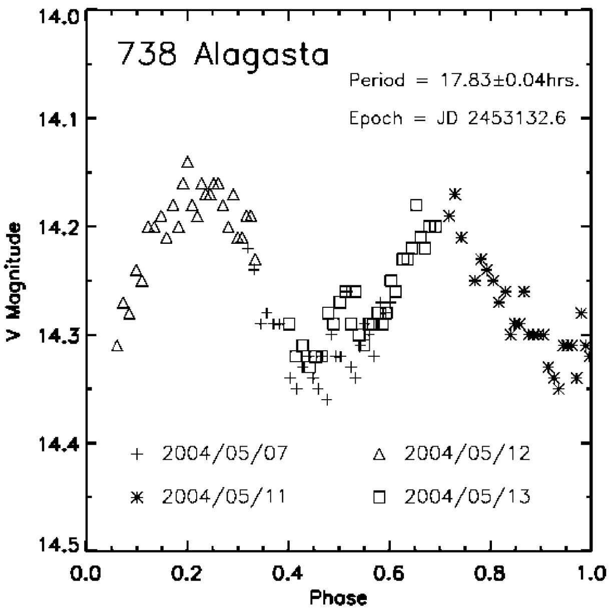

Figure 2: Composite lightcurve of asteroid 738 Alagasta derived from 111 observations and a 17.83-hour rotation period.

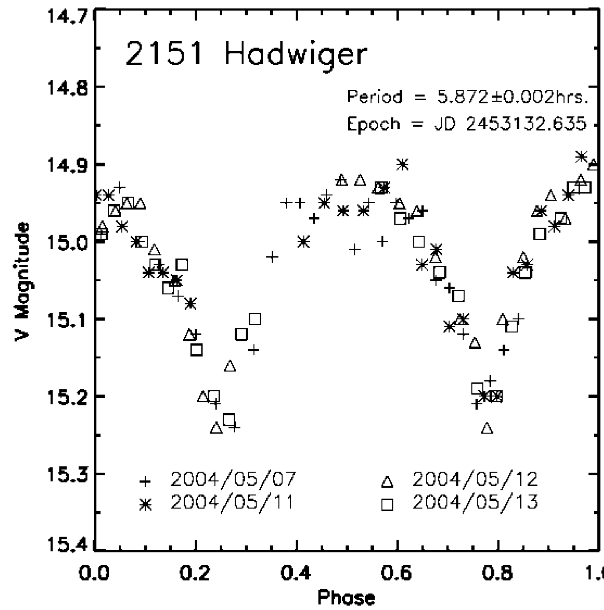

Figure 3: Composite lightcurve of asteroid 2151 Hadwiger derived from 105 observations and a 5.872-hour rotation period.

LIGHTCURVES AND PERIODS FOR ASTEROIDS 2103 LAVERNA AND 3445 PINSON

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Two asteroids were selected from the CALL list for asteroids with unknown periods. Data were obtained on 8 nights between March 30 and April 8, 2005. The period and amplitude results are: 2103 Laverna 9.249 ± 0.003 hr, 0.27 mag; 3445 Pinson 7.801 ± 0.002 hr, 0.37 mag. Laverna shows a bump on the second rising branch of its bimodal light curve while Pinson exhibits a more or less symmetrical bimodal lightcurve.

Here we report lightcurve observations of asteroids 2103 Laverna and 3445 Pinson made at the Frank T. Etscorn Campus observatory of New Mexico Tech using a Celestron C-14 and SBIG ST-8e CCD camera system mounted on a Bisque Paramount ME. We obtained all of our images through a Bessel-R filter. All of the exposures for 2103 Laverna were 120 seconds long. For 3445 Pinson we used 120 seconds for all but the last night when we switched to 180 seconds for a better signal-to-noise ratio. The telescope was controlled by Software Bisque's "*TheSky*" version 5 and the CCD was controlled by their "*CcdSoft*" version 5. The CCD was cooled to -15°C and automatic dark subtraction was used. On each night, a series of 11 dome flats was obtained using a tungsten-halogen lamp pointed at the opposite wall. These 11 images were median combined using IDL procedures as described in Jamieson and Klinglesmith (2004). These nightly master flats were combined at the end of the 10 night run to create a master flat that was used to flat field correct all the images for the final data analysis.

Both of these asteroids were moving slowly enough that a whole night's data (up to 6 hours) could be reduced in one session using the same comparison stars. Two methods were used to independently analyze the differential lightcurves. The first method used aperture photometry on the asteroid and all stars brighter than the asteroid. These stars' instrumental magnitudes were median combined and subtracted from the asteroid's instrumental magnitude to produce the differential lightcurve. The second method used MPO *Canopus* published by BDW Publishing, and used up to 5 comparison stars per night (session). The final periods were determined using the Fourier method from MPO Canopus. Standard light-time corrections were applied to the UT dates and times of the observations.

Our observing run lasted from UT March 30, 2005 through April 8, 2005. We were clouded out one night and winds were too high on another. The table below shows the UT dates of our observations, the number of images obtained for each asteroid for each night and the time interval (hr) of the observations. Assuming that our periods are correct, 2103 Laverna was observed for ~ 19 cycles and 3445 Pinson was observed for ~28 cycles.