CCD PHOTOMETRY LIGHTCURVES OF THREE MAIN BELT ASTEROIDS

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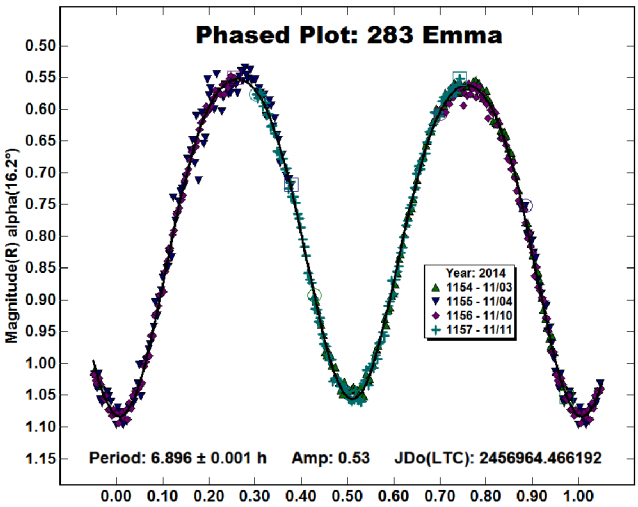
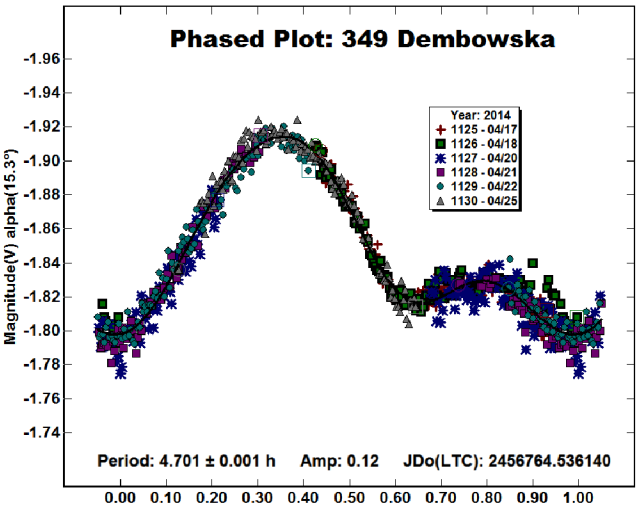
Fourier analyses of new CCD-derived lightcurves produced synodic period solutions for 283 Emma (6.896 ± 0 .001 h), 349 Dembowska (4.701 ± 0.001 h), and 409 Aspasia (9.023 ± 0.001 h).

The photometric instrument used at UnderOak Observatory (UO) for these studies was a 0.28-m SCT equipped with an SBIG ST-8XME thermoelectrically-cooled CCD. This combination produced a 10.4×15.6 arcmin field-of-view (FOV). Image calibration and registration procedures typically used at UO have been published elsewhere (Alton, 2013). Data reduction with *MPO Canopus* (Warner, 2013) used at least three non-varying comparison stars in the same FOV to generate lightcurves by differential aperture photometry. Data were light-time corrected but not reduced to standard magnitudes. Fourier analysis (Harris *et al.*, 1989) yielded a period solution from each folded dataset and then independently verified with *Peranso* (Vannmunster, 2006) using ANOVA (Schwarzenberg-Czerny, 1996). Phased lightcurve data are available upon written request. Relevant aspect parameters for each of these main belt asteroids taken at the mid-point from each observing session are shown in Table I.

283 Emma. Discovered in 1889 by Auguste Charlois, this fairly dark (p_V = 0.0262) main belt asteroid (D = 148.1 ± 4.6 km) was found by Merline *et al.* (2003) to have a satellite (9 ± 5 km) which orbits every 3.364 d at a distance of 370 km. The first photometric study that determined the primary's synodic period was published by Stanzel (1978; 6.89 h). Additional photometric (Strabla, 2011) and shape modeling studies (Michalowski *et al.*, 2006; Marchis *et al.*, 2008) point to an asteroid with a nearly perfect ellipsoid shape. At UO, a total of 524 images (R_c bandpass for 90 s) were taken over four nights (2014 Nov 3-11). Fourier analysis of the lightcurves produced the best fit at 6.896 h, identical to the value presently posted at the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). The sinusoidal nature of the lightcurve and peak-to-peak amplitude (0.53 mag) observed during this most recent apparition were consistent with the shape and range (0.14-0.57 mag) published for this object by Stanzel (1978), Michalowki *et al.* (2006), and Strabla (2011).



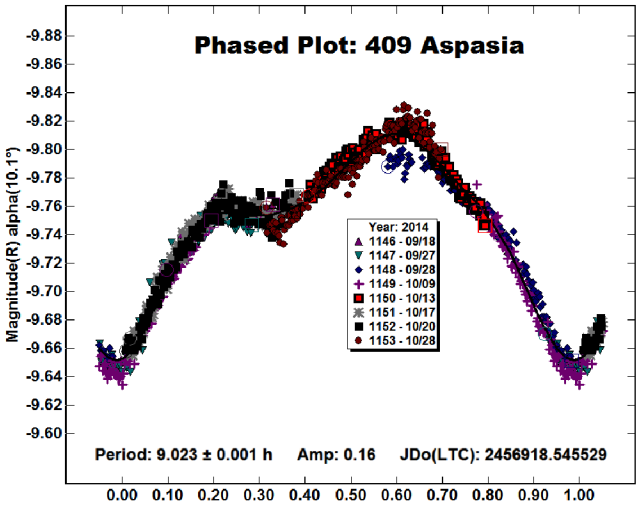
349 Dembowska. This main belt asteroid (D ≈ 140 km) was discovered by Auguste Charlois in 1892. Chang and Chang (1963) published the earliest lightcurve followed by similar studies from other investigators (Zappalà *et al.*, 1979; Di Martino *et al.*, 1987; Weidenschilling *et al.*, 1987; Lagerkvist *et al.*, 1988; and Majaess *et al.*, 2008). The most remarkable features of this object are its very high albedo (p_V = 0.384) and unique composition; it is the first of only a few asteroids thus far classified as R-type (Abell and Gaffey, 2000; Bus and Binzel, 2002). Shape and spin-axis modeling for this object has been reported by Torppa *et al.* (2003) and Majaess *et al.* (2008). A total of 785 images (clear filter for 60 s) were acquired at UO on six nights between 2014 Apr 17-25. The synodic period (4.701 h) estimated from the resulting lightcurve is identical to the value presently reported by the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). The folded lightcurve exhibited a peak-to-peak amplitude (0.12 mag) which was within the published range (0.08-0.47 mag) for this object.



Object	Range Over Observation Period			
	UT Date mm/dd	Phase	L_{PAB}	B_{PAB}
283 Emma	2014 11/03-11/11	16.2,18.1	2,3	+9,+9
349 Dembowska	2014 04/17-04/25	15.3,16.6	159,160	+7,+6
409 Aspasia	2014 09/18-10/28	10.1,19.7	338,341	+14,+12

Table I. Observing circumstances. Phase is the solar phase angle. PAB is the phase angle bisector.

409 Aspasia. This large CX-type asteroid ($D \approx 162$ km) was also discovered by Auguste Charlois, in 1895. A partial lightcurve was first reported by Lagerkvist (1981). Complete lightcurves were subsequently published by Di Martino and Cacciatori (1984), Hainaut-Rouelle *et al*. (1995), Piironen *et al*. (1998), and López-González and Rodríguez (2005). Shape and spin-axis models for this minor planet have been developed by Warner *et al*. (2008) and Ďurech *et al*. (2011). During the photometric study at UO, 1129 images (R_c bandpass for 75 s) were acquired on eight nights between 2014 Sep 18 and Oct 28. The synodic period solution (9.023 h) was very similar to the value (9.022 h) presently reported on the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). This lightcurve exhibited a peak-to-peak amplitude (0.16 mag), which was within the range (0.09-0.16 mag) estimated from all the lightcurves referenced herein.



Acknowledgements

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THE ROTATION PERIOD OF 4528 BERG

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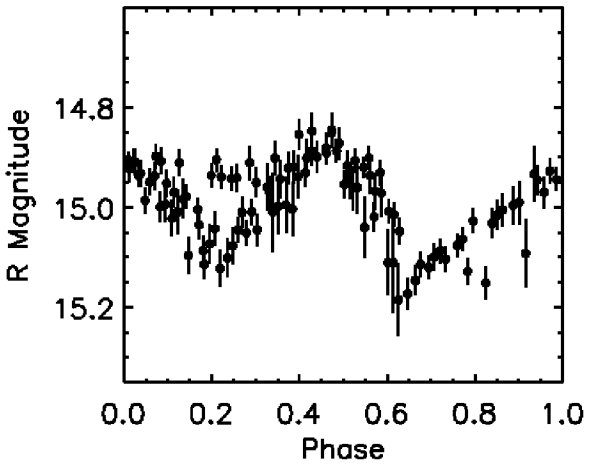
We observed 4528 Berg for 5.6 hours on 2014 March 30 and obtained R and V standard magnitudes. The period was determined to be 3.47 ± 0.44 h, which is consistent with the period of 3.5163 ± 0.0004 h previously reported by Behrend (2006).

On 2014 March 30 we made photometric measurements of 4528 Berg in the R and V bands using the 0.35-m Schmidt-Cassegrain (SCT) at Hobbs Observatory near Fall Creek, Wisconsin (MPC code 750). Sixty-second exposures were taken using an SBIG STL-1001E camera. The images were dark-subtracted and flat-fielded before measuring and analysis. Photometric transforms were found using standard stars from the LONEOS catalog and first order extinction coefficients were determined using the modified Hardie method as described in Warner (2006). The image analysis was carried out with *MPO Canopus* version 10.4.3.7 (Warner, 2013). A Lomb periodogram (Press *et al.*, 1992) was performed on the lightcurve data to find the most likely rotation period of the asteroid. Our data have been submitted to the Minor Planet Center's Light Curve Database.

The R and V data were analyzed independently of each other and the period for both lightcurves was found to be 3.47 ± 0.44 h, where the uncertainly was determined from the full-width at half-maximum of the periodogram's power spectrum. This period is consistent with the value of 3.5163 ± 0.0004 h reported by Behrend (2006). R magnitudes varied from about 14.85 to 15.2. The range for V magnitudes was about to 15.25 to 15.7. A phased plot of the R data is shown here; the V data show a similar shape.



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