

LIGHTCURVES AND PERIODS FOR ASTEROIDS 1001 GAUSSIA, 1060 MAGNOLIA, 1750 ECKERT, 2888 HODGSON, AND 3534 SAX

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Five asteroids were observed and lightcurves measured
at OAVdA from 2009 September through November:
1001 Gaussia, 1060 Magnolia, 1750 Eckert,
2888 Hodgson, and 3534 Sax.

During the latter part of 2009, university student Dimitrij Bonzo and Dr. Albino Carbognani obtained lightcurves for five main-belt asteroids at OAVdA (Carbognani and Calciolone, 2007). The data were used for Dimitrij’s thesis but also to help increase of the number of asteroid rotation periods, which are still few to have a comprehensive statistical picture of the rotational evolution of these bodies (Carbognani, 2010).

The images were captured using a Ritchey-Chretien 0.4-m telescope operating at $f/7.7$. The CCD camera was an FLI PL-1001E with 1024×1024 pixels, a field of view of $26' \times 26'$, and an image scale of $1.6''/\text{pixel}$. Exposure times were 180 s with Clear filter, except for 2888 Hodgson for which we used 120-s exposures. We used Warner (2006) as a reference text for observational techniques and the asteroid lightcurve database (LCDB, Warner et al., 2009 April 21 release) to extract periods for those asteroids with previously reported lightcurve parameters.

Asteroids were chosen using the CALL homepage target list Warner (2009a). Due to the limited time available, we searched for asteroids with positive declination and short rotation period in order to catch the whole lightcurve in a small number of nights. A total of nine asteroids were observed in the period, but three of them were rejected because of a long rotation period: 711 Marmulla, 3345 Starkowsky and (88161) 2000 XK18. The remaining one, 433 Eros, was used to calibrate the optical system. We observed only asteroids that had no previously published results for rotational period, or at least an uncertain one. When possible, we tried to do our differential photometry using the same comparison stars for contiguous sessions in order to avoid the challenging problem of calibration among two or more sessions. For this last purpose, the CMC14 catalogue and method of Richard Miles and Roger Dymock (Miles and Dymock, 2009) was used. Comparison stars for differential photometry were chosen with $0.3 < J-K < 0.7$, i.e. stars of similar color to the Sun.

We used *MPO Canopus* (Warner, 2009b) for period analysis. For the reported lightcurve, we used a 4th order Fourier analysis, starting from a period of 2 h to 10 h, with steps of 0.001 h. Table I show the periods and the amplitudes results.

1001 Gaussia. A total of 115 images were taken in 4 nights. From the data we extracted a rotation period of 9.172 ± 0.002 h and an amplitude of 0.16 mag. Behrend (2009) previously reported a period of 4.08 h with quality $U = 1$. As seen in the lightcurve, the

last session had significantly larger photometric errors. These were due to clouds and poor seeing. We made a photometric calibration for the first and the second session, and another one for the remaining two. There were more than two weeks between the two pairs of sessions, which we couldn’t link to one another because of the opposition effect, which we did not try to correct.

1060 Magnolia. This is the noisiest lightcurve reported here. We observed this asteroid for two nights with bad atmospheric conditions. This fact caused a decrease of the signal-to-noise ratio and, consequently, an increase of the error bars. There was no need to calibrate sessions because of the short rotation period. Analysis of the data found a rotation period of 3.082 ± 0.003 h and an amplitude of 0.16 mag. Wisniewski et al. (1997) reported a period of 2.78 h while Behrend (2009) found a period of 2.9107 h.

1750 Eckert. A total of 120 images were taken in 2 nights. From the data we extracted a rotation period of 4.492 ± 0.001 h and an amplitude of 0.12 mag. This differs considerably with the period of 375 h found by Warner (2010), who reported an amplitude of 0.87 mag and that the asteroid was likely in non-principal axis rotation (“tumbling”).

2888 Hodgson. A total of 147 images were taken in 4 nights. From the data we extracted a rotation period of 4.842 ± 0.001 h and an amplitude of 0.12 mag. Brinsfield (2010) found a period of 6.905 h. As we did for 1001 Gaussia, we made a photometric calibration for the first and the second session, and separate one for the remaining two. We could not link all curves for the same reason already described for Gaussia.

3534 Sax. A total of 224 images were taken in 5 nights. From the data we extracted a rotation period of 6.221 ± 0.001 h and an amplitude of 0.30 mag. No period had been previously reported. This is the best result for our photometry; there was no need to calibrate sessions because of the short rotation period and high precision data points.

Number	Dates 2009 mm/dd	Phase [deg]	Period [h]	Amp [mag]
1001	11/10-24	9.4-13.7	9.172 ± 0.002	0.16
1060	11/10-21	5.9-11.5	3.082 ± 0.003	0.16
1750	11/10-20	21.8-22.4	4.492 ± 0.001	0.12
2888	09/28-10/25	2.0-14.7	4.842 ± 0.001	0.12
3534	10/26-11/11	9.7-2.1	6.221 ± 0.001	0.30

Table I. Asteroids with observation dates, minimum and maximum solar phase angles, derived synodic rotation periods with uncertainties, and lightcurve amplitudes.

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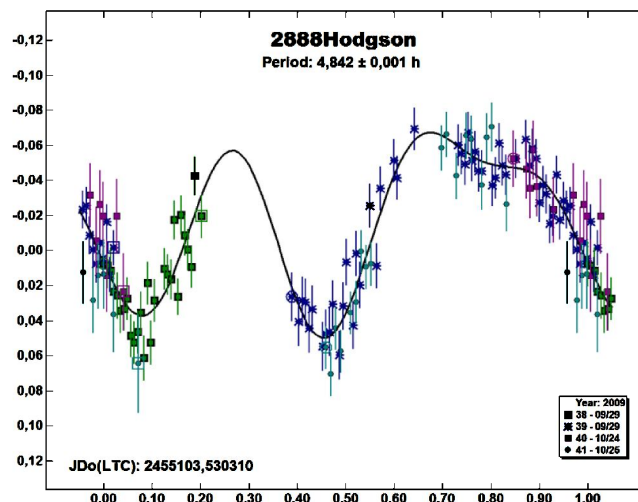
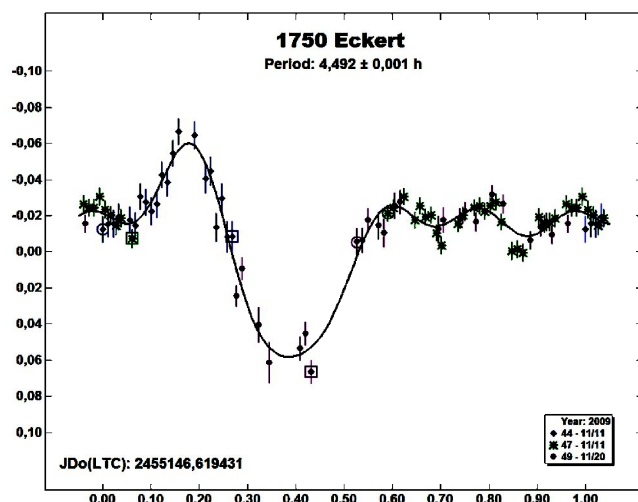
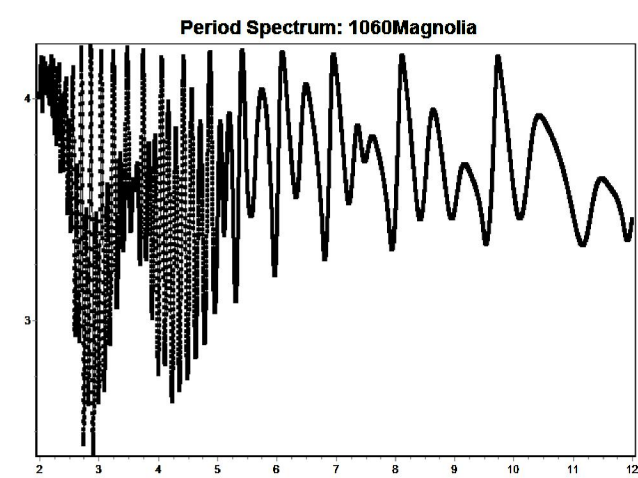
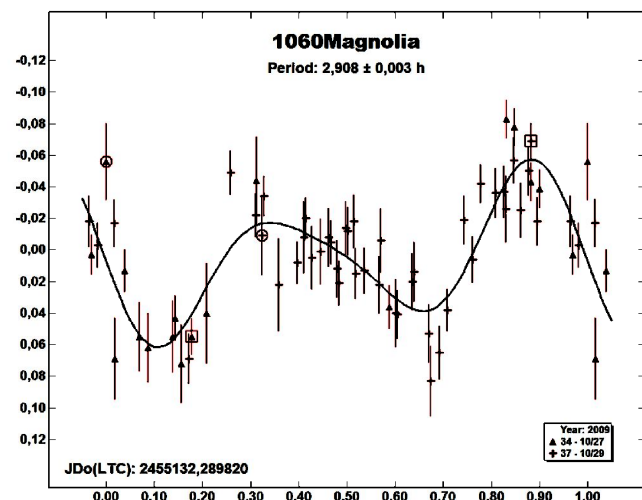
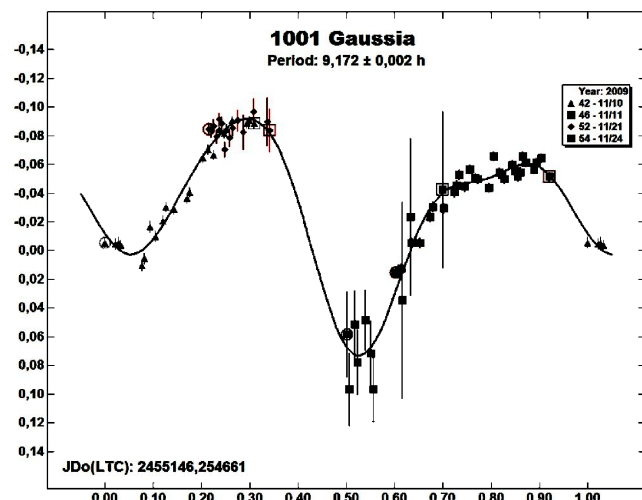
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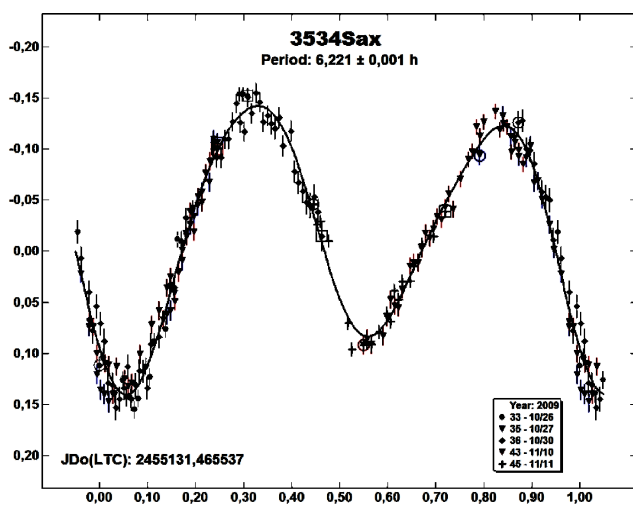
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PHOTOMETRIC OBSERVATIONS OF THE NEAR-EARTH ASTEROIDS 1999 AP10, 2000 TO64, 2000 UJ1, 2000 XK44, 2001 MZ7, 2003 QO104, 2005 RQ6, 2005 WJ56 AND 2009 UN3

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The near-Earth asteroids 1999 AP10, 2000 TO64, 2000 UJ1, 2000 XK44, 2001 MZ7, 2003 QO104, 2005 RQ6, 2005 WJ56 and 2009 UN3 were observed by the authors between 2008 January and 2010 February at Salvador (Bahia, Brazil), Mayhill (New Mexico, USA) and Moorook (South Australia, Australia) to determine their Johnson-Cousins BVRI colors and from those, provide an estimate of the Tholen taxonomic classification. From our colors, we found that 1999 AP10, 2000 TO64, 2000 UJ1, 2000 XK44 and 2003 QO104 are probably S-complex members. We reanalysed our previous observations of 2005 WJ56 and confirmed a classification as an X type. The latter results agree with the classifications made by other research groups. We propose that 2001 MZ7 is a G type from its presented colors and G parameter. 2005 RQ6 and 2009 UN3 have colors more similar to O-types.

The near-Earth asteroids 1999 AP10, 2000 TO64, 2000 UJ1, 2000 XK44, 2001 MZ7, 2003 QO104, 2005 RQ6, 2005 WJ56 and 2009 UN3 were observed between 2008 January and 2010 February at

Salvador (Bahia, Brazil), Mayhill (New Mexico, USA) and Moorook (South Australia, Australia). The characteristics of the telescopes used and observation sites are shown in Table I. Our goal was to estimate, if possible, the B-V, V-R and R-I colour indexes, H and G parameters and from the asteroid's colors doing an estimative of the Tholen taxonomic classification.

All science images obtained in Salvador, Mayhill and Moorook were corrected with bias, dark, and dome or sky flat-field frames. Photometric calibration was done using 2MASS stars in the asteroid's field. The 2MASS J-K field star color index were converted to the equivalent V magnitude and B-V, V-R and R-I index of the Johnson-Cousins system using the transformation equations from Warner (2007) and Gary (2008). The color transformation coefficient between the instrumental and Johnson-Cousins photometric system were calculated using definitions by Gary (2006) in every observation session using no less than 10 stars in the asteroid's field. Only stars with near-solar colors were used to calculate the asteroid color index or obtain their apparent magnitudes. To improve the SNR of the asteroids and comparison stars, we summed images using the IRIS V. 5.52 program.

The taxonomic classification method used in this work is based in the use of two-color diagrams involve the color indices of Tholen classes and the object as used by Dandy et al (2003). Our color index estimates and Tholen taxonomic classifications are summarized in Table II. For an ambiguity in the classification, we list first the type with better color compatibility with the mean Tholen class. This color compatibility was determined using the L1 norm, which was used due to its robustness.

1999 AP10. 1999 AP10 was classified as an S-complex member (L) in the SMASS II taxonomic system using visible long-slit spectra (Hicks and Lawrence 2009). We observed this object in Mayhill in 2009 September 27.23 UT ($\alpha=26.2^{\circ}$), obtained 16 images of 60s of exposure in B, V, R and I filters. We found $B-V=0.859\pm0.002$, $V-R=0.459\pm0.001$ and $R-I=0.395\pm0.002$, matching the S-type.

2000 TO64. 2000 TO64 was classified as S-complex member (Sq) in the SMASS II taxonomic system using visible long-slit spectra (Hicks and Lawrence 2009). We observed this object at Mayhill in 2009 November 07.11 UT ($\alpha=56.4^{\circ}$). We obtained 12 images of 60s of exposure in V, R and I filters. We found $V-R=0.485\pm0.003$ and $R-I=0.379\pm0.03$. Our colors match the S-type.

2000 UJ1. 2000 UJ1 was classified as S-complex member (S) in the SMASS II taxonomic system using visible long-slit spectra (Hicks and Lawrence 2009). We observed this object in Mayhill in 2009 November 06.12 UT ($\alpha=56.4^0$), obtained 12 images of 60s of exposure in V, R and I filters. We found $V-R=0.474\pm0.002$ and $R-I=0.381\pm0.005$. Our colors match the S-type.

2000 XK44. 2000 XK44 was classified as an S-complex member (S) in the SMASS II taxonomic system using visible long-slit spectra (Hicks and Lawrence 2009) and by BVRI colors (Hicks et al. 2010). We observed this object at Mayhill in 2009 November 05.29 UT ($\alpha=15.7^0$). We obtained 16 images of 60s of exposure in B, V, R and I filters. We found $B-V=0.87\pm0.03$, $V-R=0.481\pm0.006$ and $R-I=0.27\pm0.01$. Our colors matched an RS-type (Fig.1).

2001 MZ7. 2000 MZ7 was classified as X-complex member in the SMASS II taxonomic system using near-infrared spectra (Lazzarin et al., 2005). We observed this object at Mayhill and Moorook (G6) in 2010 January 12.33; 16.33; 21.64 and 24.62