

ANALYSIS OF THE LIGHTCURVE OF (217807) 2000 XK44: A TUMBLING NEA

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We report on our CCD photometric observations on the near-Earth asteroid (NEA), (217807) 2000 XK44. Our analysis shows that the asteroid is in non-principle axis rotation (NPAR) with the strongest harmonics in the frequency analysis corresponding to periods of 51.9 and 66.8 h.

Observations of the near-Earth asteroid (NEA), (17807) 2000 XK44 were made in 2009 November by Warner, Stephens, and Pray in support of planned radar observations. The equipment and basic image acquisition methods used by the authors have been previously described (see Stephens, 2006; Warner, 2009b). We linked our observations from night-to-night using the 2MASS (Skrutskie et al., 2006) to BVRI conversions developed by Warner (2007) and applied as described by Stephens (2008).

It became apparent after the first few observing runs that the lightcurve showed signs that the asteroid was in non-principal axis rotation (NPAR) and so the observers sought help from Petr Pravec who has developed software that can analyze multiple periods that are not additive. His analysis shows that the strongest harmonics correspond to periods of 51.9 and 66.8 h and $PAR = -2$ to -3 . See Pravec et al, 2005, for a discussion of period analysis for tumbling asteroids and the PAR rating system.

These may be the actual periods of rotation and wobble (free precession), or they may be linear combinations of the true frequencies, e.g. $2*f_1 \pm 2*f_2$ (see Pravec et al. 2005 for further discussion of lightcurve analysis of NPA rotators). Unfortunately all of the observations were taken at close to the same longitude, so it was not possible to remove the commensurability of the observations with a 24-hour cadence. Observations from other longitudes might have allowed finding the true frequencies (periods) of the NPA rotation.

The results were communicated to observers at Arecibo and Goldstone. Results from their observations are pending. It may be that the combined data sets allow for a more definitive solution to the nature of the asteroid's rotational characteristics.

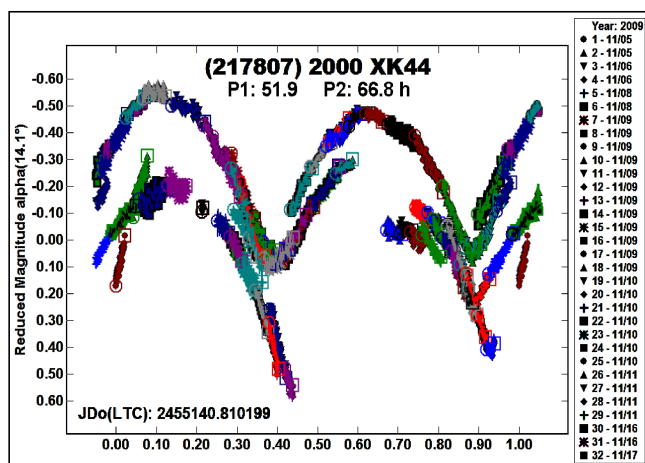
Some initial results from thermal observations obtained in coordination with the radar observations show the asteroid to be a type S (Howell, private communication). Assuming an albedo of 0.2 and the MPC value of $H = 18.2$, this yields a diameter of ~ 0.7 km. There are approximately 20 asteroids in the asteroid lightcurve database (LCDB, Warner et al, 2009a) that can be considered very likely to certain "tumblers." The sizes range from a few hundred meters to 52 km. What distinguishes this particular asteroid is the amount and quality of data that allowed establishing the two periods reported here.

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References

- Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., and 15 colleagues. (2005). "Tumbling Asteroids." *Icarus* **173**, 108-131.
- Skrutskie, M.F., Cutri, R.M., Stiening, R., et al. (2006). "The Two Micron All Sky Survey (2MASS)." *Astron. Jour.* **131**, 1163-1183.
- Stephens, R.D. (2008). "Long Period Asteroids Observed from GMARS and Santana Observatories." *Minor Planet Bul.* **35**, 21-22.
- Warner, B.D. (2007b). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul.* **34**, 113-119.
- Warner, B.D., Harris, A.W., and Pravec, P. (2009a) "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146.
- Warner, B.D. (2009b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2008 December – 2009 March." *Minor Planet Bul.* **36**, 109-116.



LIGHTCURVE ANALYSIS OF ASTEROIDS 3567 ALVEMA AND 5421 ULANOVA

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Two main-belt asteroids without previously reported lightcurves were observed between 2009 September and December. Lightcurve parameters were found for 3567 Alvema ($P = 11.542 \pm 0.003$ h, $A = 0.17$ mag) and 5421 Ulanova ($P = 9.77 \pm 0.01$ h, $A = 0.60$ mag).

Main-belt asteroids 3567 Alvema and 5421 Ulanova were studied using two observatories. The majority of the observations were made at Gothers Observatory in the UK (MPC J03). A smaller but significant number were made using the robotic telescope facility provided by the Tzec Maun Foundation in New Mexico, USA (MPC H10). Gothers Observatory measurements were made using a 0.25-m Schmidt-Cassegrain with an f/3.3 focal reducer. The detector was a QHY6 Pro CCD featuring a 752 X 585 array of 8.6x8.3 micron pixels binned at 1x1. The resulting optical train produced an image scale of 1.69x1.63 arcsec/pixel. The camera was used with set point cooling of -10°C . All images were dark and flat field corrected. These observations were made unguided and unfiltered with exposures of 210 s. Automated computer control of the mount and CCD camera allowed unsupervised imaging for extended durations in excess of 8 hours. Typical FWHM of point sources was 4 arcsec for the reduced data sets. Further details can be seen at www.gothersobservatory.org.uk.

Observations at Tzec Maun were made using two different telescopes. The first was a 0.35-m Maksutov-Newtonian f/3.8 reflector. It was equipped with a SBIG ST-10XME giving an image scale of 1.05 arcsec/pixel. The second instrument was a 0.4-m RCOS Ritchey-Chretien telescope equipped with an SBIG STL-6303. This combination provided an image scale of 1 arcsec/pixel (binned 2x2). Both telescopes were operated remotely over the Internet from the UK. All images were made using a Johnson V filter and were dark corrected. The larger aperture of the remote telescopes was useful since they allowed photometry to be performed during the following lunation, when the objects had become too faint for the smaller instrument. These later data allowed significant reduction of the errors in the period of the lightcurve.

The asteroids were selected from the CALL lightcurve targets page (Warner, 2009). The targets were selected as those being of $V < 16$ and without a previously reported lightcurve. Preference was also given to targets with high declination and low angular motion, the second criteria allowing long integration times necessary to minimise noise with the relatively small aperture. Image calibration and differential photometry were undertaken using *Astrometrica* (Raab, 2009) and Carlsberg Meridian Catalogue 14 (Evans et al., 2002). Period determination was performed using *Peranso* lightcurve analysis software (Vanmunster, 2009) and Microsoft *Excel*. The selected targets and the parameters at the first observation of their respective campaigns are shown in Table I. Composite lightcurves collected for the objects are shown in Figures 1 and 2.

3567 Alvema. This object was imaged 211 times over 7 nights (2009 October 13, 20, 22; December 5, 12, 16, 17). The rotational period solution was initially difficult to determine until the obvious deep minimum was observed several times, thus allowing a greater degree of certainty in registering the data sets. The lightcurve has a synodic period of $P = 11.542 \pm 0.003$ h and amplitude $A = 0.17 \pm 0.05$ mag.

5421 Ulanova This object was imaged 204 times over 5 nights (2009 November 8, 10, 11; December 5, 12). The lightcurve exhibits a bimodal curve. Despite the relatively faint nature of the target, the scatter on the data points was limited to ± 0.07 mag. The synodic period is $P = 9.77 \pm 0.01$ h and $A = 0.60 \pm 0.05$ mag.

Object	Date/Time (UT)	Dec	("'/min)	V
3567	2009-10-13.80551	+24°	0.43	14.5
5421	2009-11-8.75956	+13°	0.35	15.6

Table I. Selected asteroid targets and their initial campaign parameters.

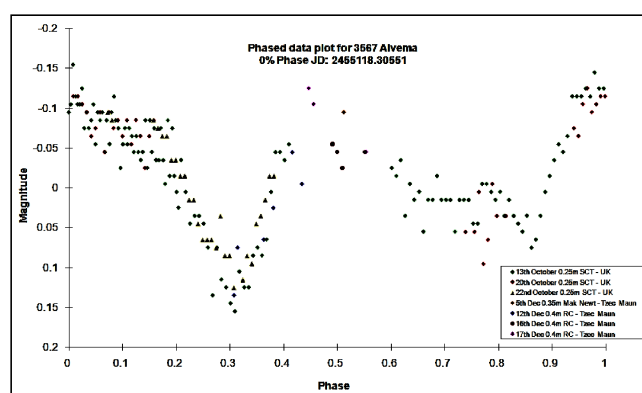


Figure 1. Lightcurve for 3567 Alvema.

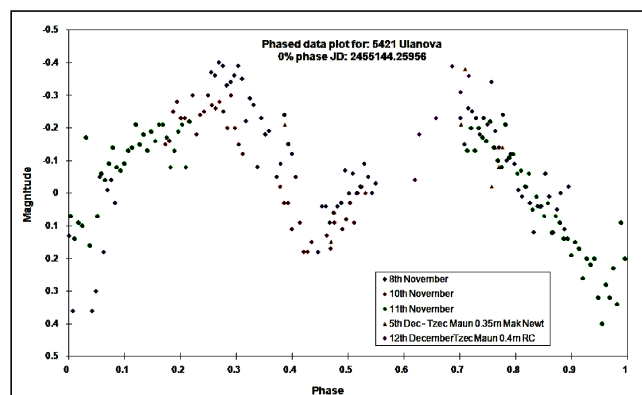


Figure 2. Lightcurve for 5421 Ulanova.

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References

- Evans, D.W., Irwin, M.J., and Helmer, L. (2002). "The Carlsberg Meridian Telescope CCD drift scan survey." *A&A* **395**, 347-356. <http://www.ast.cam.ac.uk/~dwe/SRF/cmc14.html>
- Raab, H. (2009). *Astrometrica* software. <http://www.astrometrica.at/>