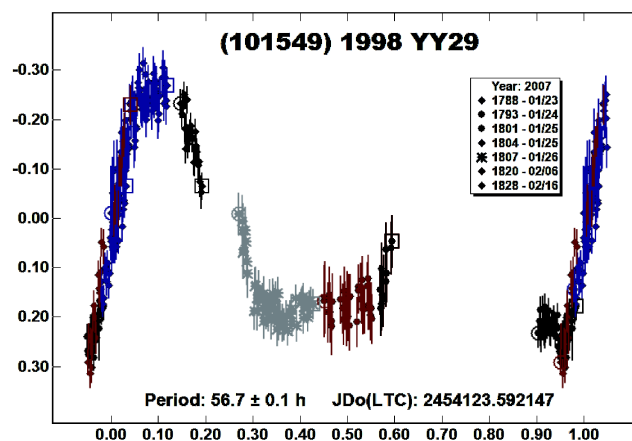
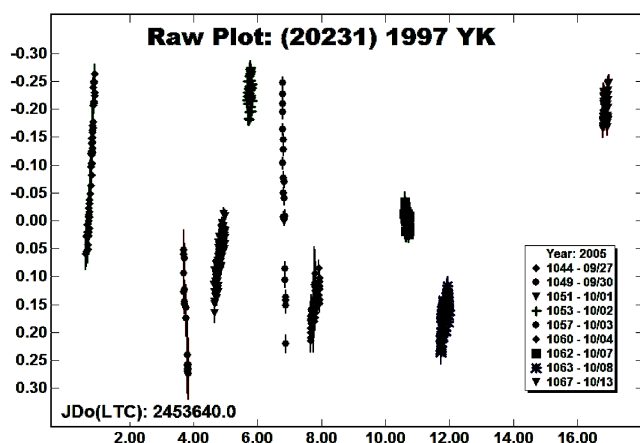




ANALYSIS OF THE SLOW ROTATOR (143651) 2003 QO104

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We report on our collaboration to obtain photometric data on the near-Earth asteroid (143651) 2003 QO104 in support of radar observations. Our initial data indicated a slowly rotating asteroid, which allowed radar observers to change their observing schedule accordingly. After obtaining data from 2009 March through April, we were able to determine a synodic period of 115 ± 1 h and amplitude of 1.60 ± 0.05 mag. There are indications that the asteroid may be in non-principal axis rotation, i.e., tumbling.

Observations of the near-Earth asteroid (143651) 2003 QO104 were started by Warner and Carbognani in 2009 mid-March. Stephens contributed data during the campaign to help avoid gaps due to weather and other circumstances. Warner and Stephens linked their observations from night-to-night using the 2MASS (Neugebauer and Leighton, 1969) to BVRI conversions developed by Warner (2007) and applied as described by Stephens (2008).

Initial indications were for a long period, probably > 24 h and amplitude of at least 0.5 mag. As more data became available, it was increasingly obvious that the asteroid had a much longer period and larger amplitude. This proved important to radar observers (Benner, private communications) since the slow rotation would mean higher signal-to-noise values. Accordingly, observing schedules at both Arecibo and Goldstone were changed to obtain additional data. The final data set of photometric observations spanned from 2009 March 17 to April 19. During

that time, all but one session – April 15 – “fell into line.” Disregarding this anomaly, we derived a synodic period of 114.42 ± 0.02 h and amplitude of 1.60 ± 0.05 mag for the ~ 1.9 km diameter asteroid

Tumbling Considerations

Figure 1 shows the entire lightcurve data set phased to the adopted period of 114.42 h. Note how the April 15 session appears to cover a minimum but is displaced both in time and zero point from the rest of the curve. Figure 2 is a close-up of the plot in Figure 1, showing in more detail the “break-away” April 15 session. If one assumes a minimum was captured, then the vertical displacement (change in zero point) is ~ 0.75 mag and the period that would match it to the minimum covered on March 17 would be 115.5 h. This period would, however, seriously spoil the match-up of other parts of the composite. Such mis-fits in both time and magnitude level are common signs of tumbling. If we adopt that explanation, then the period is not a constant single value; we thus adopt a period of 115 ± 1 h. Exploring the alternate assumption of observational error on April 15, if one removes the first ten or so data points from the session, removing the apparent minimum, then a shift of ~ 0.35 mag brings the session into line with the rest of the curve with the period of 114.42 h. This offset in the zero point is considerably larger than the average error of the calibration method used ($\sim \pm 0.05$ mag), though offsets that large have been seen under rare circumstances. As a check, the images were measured a second time using a different set of comparison stars. The result was the same apparent capture of a minimum and the large magnitude displacement.

The conclusion from all this is that the April 15 session may be an indication of tumbling since it, being from a second cycle, did not match the curve based on the first cycle. In support of this contention, the maxima and minima are not quite equal, which is another potential sign of tumbling. The lack of overlapping coverage prevents a more certain determination. Had we obtained more data from a second cycle and they also did not match with those from the first, then that would have been almost conclusive evidence of tumbling. Finally, in support of tumbling, the approximate tumbling damping time for the given period and diameter of the asteroid is on the order of 85 Gyr. This is the time that it would take the asteroid to stabilize into single (principal) axis rotation. That is many times longer than the age of the Universe, let alone the Solar System. See Pravec et al. (2005) for a thorough discussion of tumbling asteroids.

We note that this campaign provides yet another example of the importance of collaboration among optical observers, coordination with observers in other disciplines, and of putting optical data onto at least an internal system in order to analyze data correctly.

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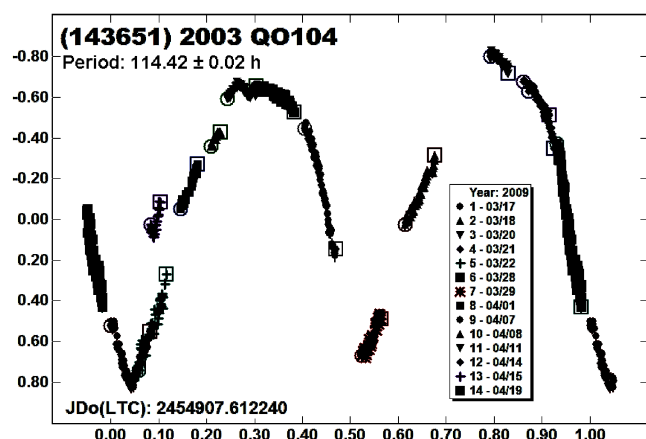


Figure 1. Lightcurve of (143651) 2003 QO104.

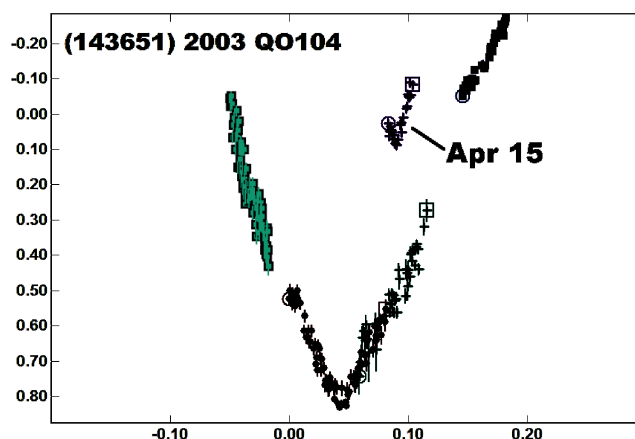


Figure 2. Close-up of Figure 1 showing details of the April 15 data.

PHOTOMETRIC OBSERVATIONS AND LIGHTCURVE ANALYSIS OF NEAR-EARTH ASTEROIDS (136849) 1998 CS1, 2006 SZ217, AND 2008 UE7

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Near-Earth Asteroids (NEAs) (136849) 1998 CS1, 2006 SZ217, and 2008 UE7 were observed photometrically in the course of Lulin Sky Survey (LUSS) in 2008 December and 2009 January. The rotation periods and lightcurve amplitudes for these three asteroids have been determined as: (136849) 1998 CS1, 4.150 ± 0.001 h and 0.11 mag; 2006 SZ217, 3.2474 ± 0.0001 h and 0.10 mag; 2008 UE7, 3.25146 ± 0.00001 h and 0.13 mag.

Photometric studies of three near-Earth asteroids (NEAs) were carried out in 2008 December and 2009 January in the course of Lulin Sky Survey (LUSS). LUSS was equipped with a 0.41-m Ritchey-Chretien telescope operating at f/6.25 and a back-illuminated Apogee U42 CCD. The program's main goal is obtaining astrometric observations of asteroids and comets, but photometric studies are performed occasionally, usually targeting unusual asteroids such as NEAs or those with a large orbital