2008MPBu...35..175H

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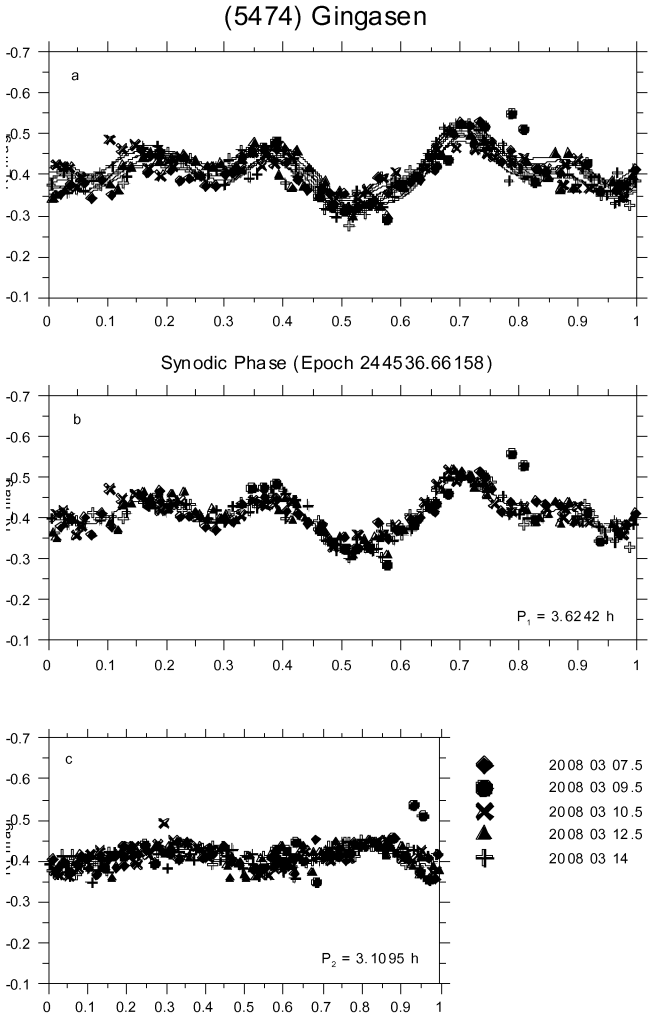
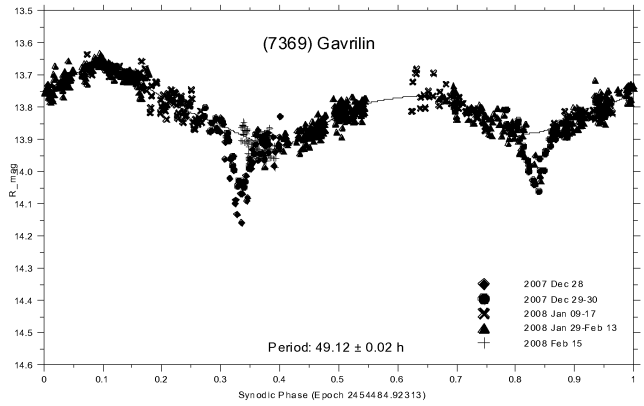


Fig 1: 5474 – Composite Lightcurve, Primary Component and Secondary Component



"DO WHAT YOU CAN PHOTOMETRY": UNFILTERED PHOTOMETRY OF NEOS 2005 PJ2, 2005 WC1, AND 2006 GY2

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(Received: 2008 July 1 Revised: 2008 July 7)

The authors made observations of three Near-Earth Objects (NEOs), 2005 PJ2, 2005 WC1 and 2006 GY2, using clear filter photometry and instrumental magnitude relationships to determine preliminary rotation periods. This study demonstrates the potential utility of what is referred to as "do what you can do" photometry.

The observation of asteroids that come close to the Earth, i.e., Near-Earth Objects (NEOs), by instruments of moderate aperture is often problematic due to the small size and rapid apparent movement of these objects in the sky. To obtain data with a reasonable signal-to-noise ratio (SNR) requires either a long exposure time or unfiltered photometry. These solutions come with their own problems of potential streaking of the image and contamination from fringing (Newton's rings). Even if these issues can be mitigated, comparison star photometric methods are very difficult due to the rapidly changing field of the asteroid over the course of an observation run. In such cases where this is the only way important data can be obtained, observers with moderate instruments are challenged to "do what you can do".

In this study, three NEOs were observed and preliminary lightcurves calculated using instrumental magnitudes and the magnitude/intensity relationship (M/IR) derived from catalog stars. This method is described by Gary (2005) and achieves accuracy of ~0.10 magnitudes by using the UCAC2 catalog and eliminating reference stars with magnitudes >10.5. The *Canopus* software used for the calculations determines the M/IR from these known "reference" stars in the UCAC2 Catalog (Warner 2004).

The clear filter at Badlands Observatory had no IR blocking properties at the time of these observations. This meant that the images were prone to fringing. This non-uniform contribution to the background noise could potentially have made accurate photometry difficult. Still, using a V or R filter would reduce the signal-to-noise ratio (SNR) of the asteroid to unacceptable levels. Therefore it was decided to go with the clear filter and experiment with exposure time.

2005 PJ2 2005 PJ2 is an Apollo asteroid that was discovered by NEAT on 2005 August 4. Although not a radar target, it was categorized as a Potentially Hazardous Asteroid (PHA) and observations were required to accurately determine its orbit for future oppositions and close approaches. With an estimated diameter of 370-840 meters, it was also a rather large PHA. Still, at a closest approach of 0.102 AU, it would be only 16th magnitude and moving about seven arc seconds per second, thus

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making clear-filter photometry a necessity. However, since the goal was primarily astrometry, this was not a factor at the time. Approximately six hours of data were collected over three nights, 2005 August 28, 29, and September 2. Exposure times were 45 s through a clear filter. Astrometric data were sent to the Minor Planet Center, much improving the orbit of 2005 PJ2 (Dyvig et.al., 2005). In fact, this project and Badlands Observatory were the last observations taken of 2005 PJ2 during the opposition.

The astrometric goal having been accomplished, the data were set aside. The asteroid was moving through a very crowded star field and a lightcurve was impossible to achieve via comparison star methods. However, with the success of the observations of 2005 WC1 (see next section) the data for 2005 PJ2 were reanalyzed. Each image was re-examined and many were eliminated where there was interference from background stars. The results are shown in Figures 1 and 2. Though the data set was sparse because of the large number of rejected images, a possible sinusoidal pattern could be discerned.

Two maxima (marked M1 and M2 in Figures 1 and 2) were identified. For August 27, the difference between the maxima was M2-M1 = 0.8219 h while for August 28 it was M1-M2 = 0.5883 h, which in theory yields a period of 1.4102 h. This figure was used as a starting point to calculate the number of rotations between the maxima and $M2_{28Aug} - M2_{27Aug}$ = 22.8294 h which = 16.189 * 1.4102 h while $M1_{28Aug} - M1_{27Aug}$ = 24.2508 h which is 17.197 * 1.4102 h. If one then iterates this process using 16 and 17 rotations, a good agreement with a period of 1.4268 h is achieved, which gives some confidence to a final period of 1.42 ± 0.03 h.

There are, however, problems with this assessment. The observing run on August 28 is long enough to have shown M2 twice and does not. However, the data are sparse and it is not surprising that double-coverage is lacking. The minima associated with M2, marked as m2 in Figure 2, does show up twice with a period of 1.433 h. Given the rapid oscillations, the shape of the lightcurve is also suspect since it is difficult to reconcile the oscillations with a reasonable asteroid shape. The M1 and M2 points may be anomalous and would be extremely difficult to relate to a realistic change in shape of the asteroid. Part of this is possibly due to the known error (±0.10 magnitudes) of the method used to determine the M/IR. This in itself could introduce a wider than actual variation in the lightcurve. It should also be noted that in a single 24-hour period between observing runs, the amplitude of the lightcurve doubled indicating a rapid change in aspect and orientation.

Therefore, while 2005 PJ2 may indeed be a rapid rotator, the value derived here of its rotation period should not be used without further confirmation.

2005 WC1 2005 WC1 was discovered by LINEAR on 2005 November 21. It was predicted to approach within 0.02 AU (7.7 lunar distances) of Earth on 2005 December 14. Its physical properties were unknown, but assuming an albedo between 0.04 and 0.20, its absolute magnitude of 20.5 suggested a diameter (within a factor of two) of ~250 m. Due to the proximity of its approach and its size, 2005 WC1 was a strong radar target. Goldstone observations were scheduled on December 15 in one very short track, and Arecibo observations were scheduled on December 14. There was an urgent request for astrometric and photometric support of the radar observations.

Due to its proximity to Earth, 2005 WC1 was moving at an apparent rate of approximately one arc second per second. This rate again made differential photometry very difficult since it would be in a new field every fifteen minutes. At its rate of motion, the images showed streaking in ~ 4s exposures; increasing the exposures beyond even ~10 s did not enhance the SNR.

This was "do what you can do" photometry at its most basic. Approximately four-and-a-half hours of data were collected on 2005 December 13 using ten-second exposures and a clear filter when the asteroid was approximately 16th magnitude. The results were more than satisfactory. As shown in Figure 3, the period appeared to be about 2_ hours with an amplitude of almost two magnitudes. This was confirmed by time-sequenced radar images that showed about 40% of a rotation occurring in the one hour observed. The asteroid had a very "blocky: shape (see Figure 4 [Benner, 2005]) that may account for the large amplitude with a single maximum.

2006 GY2 2006 GY2 is an Apollo asteroid discovered by LINEAR on 2006 April 9. It was to make a very close approach to within 0.017 AU (only 6.6 lunar distances) of Earth on May 16. Its physical properties were unknown, but its absolute magnitude of 18.6 suggested a diameter within a factor of two of 600 meters. This NEO was also classified as a PHA by the MPC. Goldstone radar observations were scheduled on May 13 and 16, and Arecibo observations were scheduled on May 15 and 16. Astrometry and photometry support was requested.

This was a very challenging target and early observations were taken on April 23. These were also unfiltered but with a long exposure of 120 s. Identical observations were taken on May 3 while the May 4 observations used 90-second exposures. Observations were not taken during the close approach since the moon was full and would have interfered too much. Though the field was not crowded, the long exposure through a clear filter no doubt increased the noise due to fringing. A period could not be accurately determined before the encounter, though the results and some preliminary periods were sent to the radar investigators. After 2006 GY2 was observed in radar, preliminary images indicated a period less than three hours and that the asteroid had a satellite (see Figure 5 [Benner, 2006]). This was enough of a starting point to enable a better period to be found using the comparison star method. Though the amplitude was quite low (~0.10), a period of two hours 16 minutes was the best fit as shown in Figure 5.

Conclusions

After working these three NEOs, we have preliminarily concluded that under most circumstance, fringing is not a major problem at short to moderate exposures (< 60 s) with magnitudes brighter than ~17 and that the MIR method is "good enough" for photometry of large amplitude objects. We believe this method particularly appropriate for fast-moving NEOs and more work should be done to repeat results.

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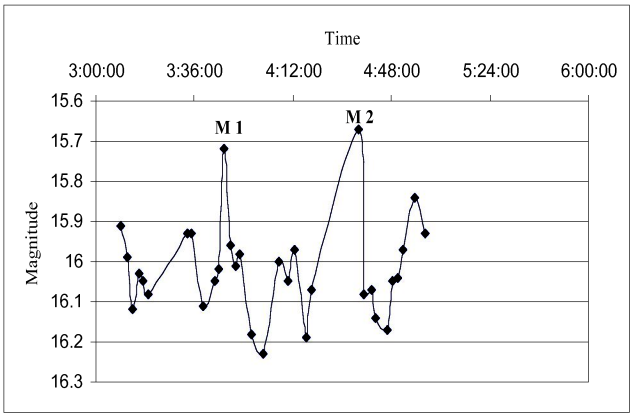

Figure 1. 2005 PJ2 lightcurve 2005 August 27.

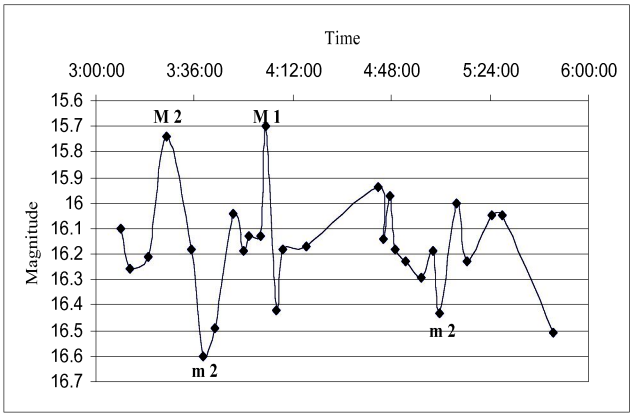

Figure 2. 2005 PJ2 lightcurve 2005 August 28.

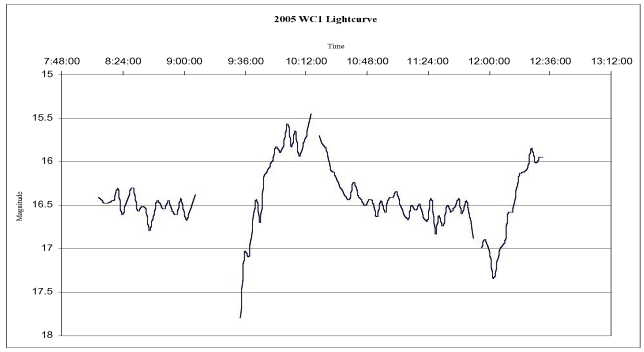

Figure 3. Lightcurve of 2005 WC1.

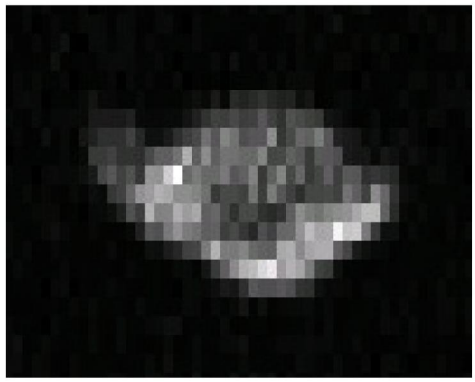

Figure 4. Radar Image of 2005 WC1.

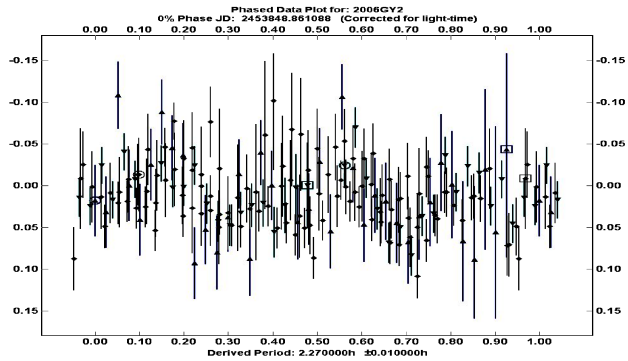

Figure 5. Lightcurve of 2006 GY2.

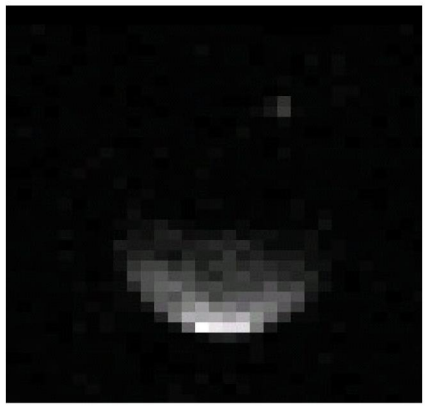

Figure 6. Radar image of 2006 GY2 and its satellite.

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