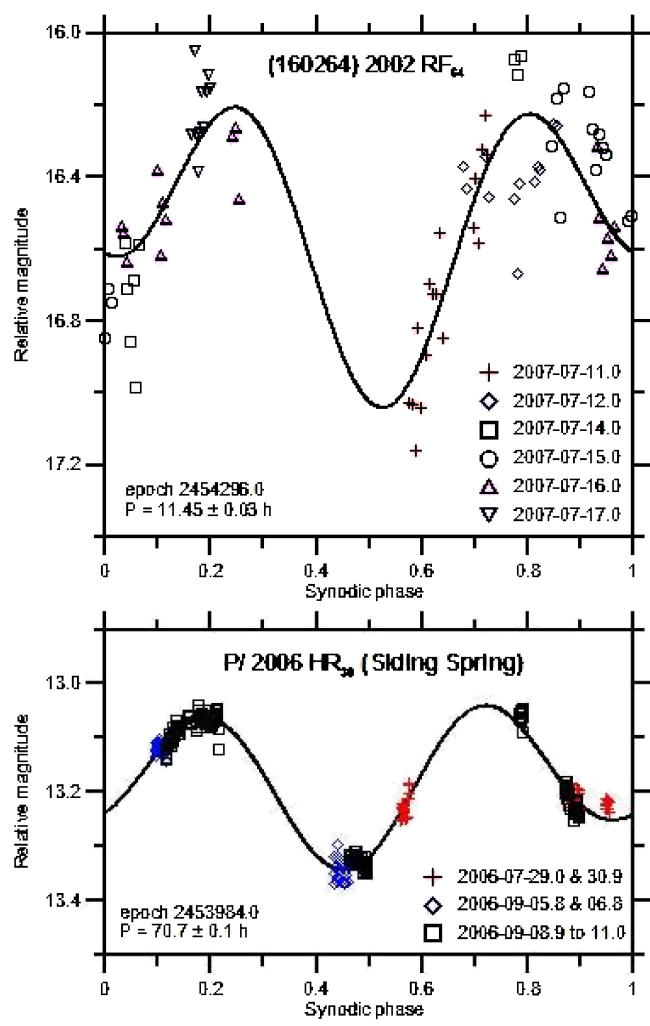




LONG PERIOD ASTEROIDS OBSERVED FROM GMARS AND SANTANA OBSERVATORIES

Robert D. Stephens
Goat Mountain Astronomical Research Station (GMARS)
11355 Mount Johnson Court, Rancho Cucamonga, CA 91737
RStephens@foxandstephens.com

(Received: 1 October)

Lightcurve period and amplitude results for 181 Eucharis and 408 Fama were obtained at Santana and GMARS Observatories June through September 2007.

The author operates telescopes at two observatories. Santana Observatory (MPC Code 646) is located in Rancho Cucamonga, California and GMARS (Goat Mountain Astronomical Research Station, MPC G79) located at the Riverside Astronomical Society's observing site. Details appear in Stephens (2006).

The targets were chosen from the list of asteroid photometry opportunities published by Brian Warner and Alan Harris on the Collaborative Asteroid Lightcurve Link (CALL) website (Harris 2007). The author measured the images using MPO Canopus, which employs differential aperture photometry to produce the

raw data. Period analysis was done using Canopus, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989). Both targets had reported ambiguous long periods based upon previous observations. For that reason, a new method developed by Warner (2007) included in the latest release of Canopus was used to calibrate each session to an internal standard. Since long period asteroids often have large amplitudes, it can be critical to tie the resulting observations together using a standard or internal system. It can be even more critical if a long period asteroid has a very small amplitude such as when it is being observing pole on.

The new calibration method converts instrumental magnitudes to B, V or R using a modification of a method described by Binzel (2005). Since one can seldom use the same comparison stars for more than a couple of consecutive nights, the magnitudes of up to five comparison stars are compared to their computed standard magnitudes. These observations are either taken through photometric filters or shot unfiltered and compared to the magnitude band that most closely matches the telescope/camera system.

Since there are few, if any well-calibrated stars in any random field, the JHK magnitudes of selected stars in the 2MASS catalog have been calibrated against Landolt field stars existing in the same catalog. In order to reduce internal errors in the catalog, stars with flags indicating problems with the J or K magnitudes, stars with close companions, and stars with J-K values outside a range of -0.1 to 1.0 have been rejected. The result is a table of 2MASS stars and set of conversion formulae applied to the UCAC2 J-K magnitudes within Canopus. One or the other catalog typically contains several comparison stars available for use in each field.

In order to provide for additional consistency, when possible, the same comparison stars were used two nights in a row and, in a few cases, three nights in a row. New comparison stars favored the west side of the field – the direction of motion of the asteroid. In addition, comparison stars were usually limited to a color range $0.3 < V-R < 0.7$ to match the color range of most asteroids. Experience shows that with this methodology and telescope/camera system, errors in matching to an internally calibrated system average 0.02 to 0.03 when using a photometric filter and 0.03 to 0.05 when shooting unfiltered. When measurements outside of those errors occurred, it was often found that removing a single comparison star would produce a better fit to the Fourier curve. On rare instances, the images were remeasured using an entirely different set of comparison stars to see if that would improve the fit. The plots in this article contain only adjustments calculated using this calibration method and those to correct for changing phase angle and distance, i.e., there were no arbitrary changes made to force a better fit.

181 Eucharis. Eucharis was reported to have a period exceeding 24 hours (Harris 2007). Schober (1994) observed it over seven nights in 1983 but did not report a period. The resultant lightcurves showed a gradually increasing trend or a flat curve for the night. Riccioli (2001) and di Martino (1984) also did not report a period. Since this was a favorable opposition for Eucharis, it was relatively bright and all observations were shot through a Johnson-Cousins R filter. This turned out to be advantageous when observing the asteroid close to the Moon and because it reduced the scatter when fitting the observations together.

Eucharis was observed during short summer nights when the typical run was only five to six hours long. All observations were

obtained with the Santana 0.30m SCT using a SBIG ST1001e CCD Camera. The resulting lightcurve shows each observational run covered less than 10 percent of the period with each session showing a slight rise or decline.

Eucharis was found to have a period of 52.23 ± 0.05 hours with an amplitude of 0.05 ± 0.02 magnitudes. Twenty-one sessions were used between June 27 and July 20, 2007. The phase angle changed from 5.7 to 9.3 degrees. The Phase Angle Bisector (PAB) longitude and latitude changed from 269.7 to 269.1 and from 17.9 to 16.9 respectively.

408 Fama. Fama was reported in 2002 to have a 64.8 hour period from observations made by Behrend et al (2007). Observations obtained on August 11, 12, 13 and 19, 2007, were with the GMARS 0.35m SCT/RXC using a SBIG ST9e CCD camera which fit the resulting Fourier curve reasonably well. All other observations were obtained with the Santana 0.30m SCT using a SBIG ST1001e CCD Camera.

Fama was found to have a period of 202.100 ± 0.011 hours with an amplitude of 0.61 ± 0.03 magnitudes. Twenty one sessions were used between August 7 and September 11, 2007. Two sessions were not plotted since the error in their fit to the Fourier curve exceeded 0.05 magnitudes. The phase angle changed from 5.8 down to 2.4 and up to 7.6 degrees. The Phase Angle Bisector (PAB) longitude and latitude changed from 129.3 to 130.3 and from 329.6 to 329.5 respectively. There are indications of non-principal axis rotation, but no secondary period could be found. The lightcurve plot is presented with five observations binned (average) as one in order to reduce the number of data points in the long period lightcurve.

Conclusions

Transforming instrumental magnitudes to the standard system or even an internal system can be critical in deriving a rotational period. It likely would not have been possible to arrive at a period for either 181 Eucharis or 408 Fama unless the magnitudes of each night's observations were tied together on the same scale. This method takes little additional reduction time and should be routine for all asteroids reduced using Canopus.

Acknowledgements

Thanks are given to Dr. Alan Harris of the Space Science Institute, Boulder, CO, and Dr. Petr Pravec of the Astronomical Institute, Czech Republic, for their ongoing support of all amateur asteroid. Also, thanks to Brian Warner for his continuing work and enhancements to the software program "Canopus" which makes it possible for amateur astronomers to analyze and collaborate on asteroid rotational period projects and for maintaining the CALL Web site which helps coordinate collaborative projects between amateur astronomers.

References

- Behrend, R. (2007) Observatoire de Geneve web site, http://obswww.unige.ch/~behrend/page_cou.html
- Binzel, R. P. (2005). "A Simplified Method for Standard Star Calibration." *Minor Planet Bulletin*, **32** 93-95.
- di Martino, M.; and Cacciatori, S. "Photoelectric Photometry of 14 Asteroids." *Icarus* **60**, 75-82.
- Harris, A. W., Young, J. W., Bowell, E., Martin, L. J., Millis, R. L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H. J., Debehogne, H., and Zeigler, K. W., (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.
- Riccioli, D., Blanco, C., and Cigna, M. (2001). "Rotational periods of asteroids II." *Planetary and Space Science* **49**, 657-671.
- Schober, H. J., Erikson, A., Hahn, G., Lagerkvist, C.-I., Albrecht, R., Ornig, W., Schroll, A., and Stadler, M. (1994) "Physical studies of asteroids. XXVIII. Lightcurves and photoelectric photometry of asteroids 2, 14, 51, 105, 181, 238, 258, 369, 377, 416, 487, 626, 679, 1048 and 2183." *Astron. Astrophys. Suppl.* **105**, 281-300.
- Stephens, R. D. (2006). "Asteroid Lightcurve Photometry From Santana and GMARS Observatories – September to December 2006". *Minor Planet Bulletin* **34**, 31-32.
- Warner, B. D. (2007). "Initial Results From a Dedicated H-G Project". *Minor Planet Bulletin* **34** 113-119.

