

LIGHTCURVE PHOTOMETRY OF ASTEROID 490 VERITAS

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Overcoming the 24 hour commensurability of the Earth's rotation for mid-latitude observatories requires multiple sites widely separated in longitude. An ongoing collaborative lightcurve investigation between Thornton Observatory in the United States and Flarestar Observatory in Malta (separated in longitude by 119 degrees) reveals asteroid 490 Veritas to have a nearly commensurate period of 7.930 ± 0.005 hours. The lightcurve amplitude is 0.50 magnitude ± 0.03 magnitude

Thornton Observatory is located in Thornton, Colorado, at an elevation of 5530'. Since 1997, the observatory, operating as Minor Planet Center observatory code 713, has been performing asteroid astrometry and photometry. Flarestar Observatory is located in San Gwann, Malta at an altitude of 300 feet. In 1999, Flarestar started operation as Minor Planet Center observatory code 171 and has been performing asteroid astrometry and photometry. Details of both observatories' equipment may be found in Koff and Brincat (2000).

The target was selected based on its magnitude and position in the sky, to maximize the length of time it would be observable, particularly under the restricted sky visibility of Thornton Observatory. Veritas is a main belt asteroid, discovered in 1902 by M. Wolf. It is approximately 120 km in diameter. Initially, no light curve data were found for this object (Harris, 1997). However, an update of the available data by Dr. Harris revealed that the object had been studied, but the results were considered uncertain. In fact, this study revealed a different period than the published value.

Observation of this object began at Thornton Observatory on February 13, 2001 and continued until March 19, 2001. It became clear early on that the most likely period was close to 8 hours. In fact, the period turned out to be 7.93 hours, which complicated the analysis. Further complicating the analysis was the symmetry of the curve, which allowed for multiple solutions. Observations were requested from Flarestar Observatory in Malta, a frequent collaborator with Thornton. Flarestar was able to contribute two nights of data, but the data were found to overlap that from Thornton. Bad weather hampered both observatories throughout the project. Finally, the stubborn gap in the lightcurve was closed by observations at Thornton on March 16 and 19th, 2001. The final segments matched up at both ends of the gap, enhancing the confidence in the period solution. This is a graphic example of the problem of commensurability.

Observations from Thornton were made on 10 nights during the period from February 13 to March 19, 2001. Exposure times at Thornton these investigations were two minutes each. Images were taken at 3-minute intervals in unfiltered light. Dark frames

and flat fields were used to calibrate each image. Observations from Flarestar were made on two nights, February 24 and March 14. Images were of 3 minutes duration at an average interval of 7 minutes in unfiltered light. Dark frames and flat fields were used for calibration. The differential photometry was measured using the program "Canopus" by Brian Warner, which uses aperture photometry. Magnitudes were calculated using reference stars from the USNO-A 2.0 and GSC catalogs. Comparison stars differed from night-to-night due to movement of the asteroid. Lightcurves were prepared using "Canopus", based on the method developed by Dr. Alan Harris (Harris et al, 1989). This program allows compensation for night-to-night comparison star variation by manually shifting individual night's magnitude scales to obtain a best fit. A total of 788 images were used in the solution.

Figure 1 shows the composite lightcurve for Veritas. The zero point of the curve is J.D. 2451953.7025. The period is 7.930 hours ± 0.005 hours. The amplitude is 0.50 magnitude ± 0.03 . The mean measured magnitude is 12.85, which should be considered an instrumental magnitude.

Acknowledgments

Thanks go to Brian Warner for his continuing work on the program "Canopus", which has made it possible for amateurs to analyze and share lightcurve data.

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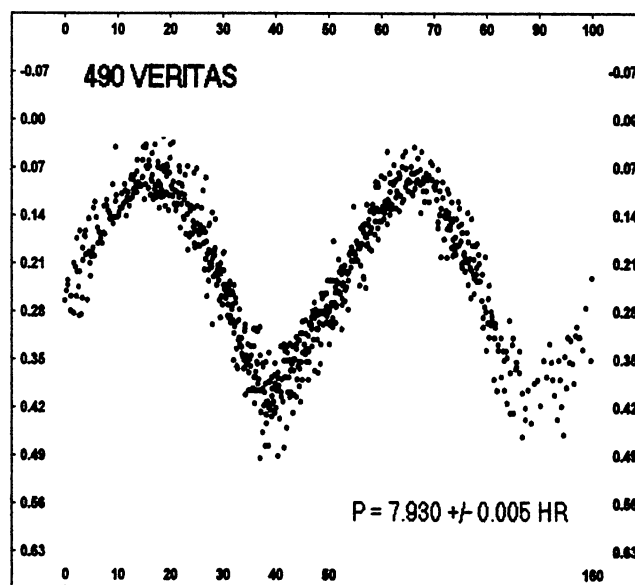


Figure 1. Lightcurve of 490 Veritas, based on a rotational period of 7.930 hours. Ordinate is relative magnitude.

LIGHTCURVES AND PERIOD DETERMINATION FOR 640 BRAMBILLA

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Minor planet 640 Brambilla was observed over a period of 16 days (46 rotations) during March and April, 2001. Lightcurves obtained on 6 nights with an unfiltered CCD have yielded a rotational (synodic) period of 7.768 ± 0.006 hrs. The complete lightcurve is doubly periodic, with a total amplitude range of 0.25 ± 0.02 .

Introduction

Asteroid 640 Brambilla is one of the many discovered by A. Kopff from Heidelberg. Originally designated 1907 ZW, it was found on Aug. 29, 1907. This main-belt asteroid was subsequently named after the 1821 novel Prinzessin Brambilla by the German writer and composer E. Hoffmann. The tabulated data in *Asteroids II* (Binzel et al. 1989a) list a B-V of 0.75 and a low albedo of 0.063, with a diameter of 84.8 ± 2.3 km. The Tholen class is G, indicating spectral characteristics similar to C types, but with strong UV absorption. The tabulations of Harris (1999) were also examined. However, no lightcurve data are listed in either of these sources.

Observations and Results

Brambilla was chosen from the CALL list of Warner (2001). At this opposition it was at Declination -17° , making it suitable for southern hemisphere observers. Observations were made from Mt Tarana Observatory near Bathurst, NSW. The site is at 880m and the Lat. is S 33.4348, Long. E 149.7576. The equipment and methodology have been described by Bembrick (2001). The observational circumstances summary (Table I), also shows the percent of the rotational lightcurve covered on each night.

Data from each night were plotted as differential instrumental magnitude vs U.T. No light-time corrections were applied. Data from the better nights show two maxima and two minima, with the least noisy light curve on 26 March. Thus the epoch of zero phase was chosen as the prominent maximum of Mar 26 at 13.09 UT (JDGeo 2451995.04792). In all, 18 extrema were identified from the lightcurves and the time differences between these were used to estimate the rotational period. This led to an estimate of 7.768 ± 0.006 hours. On this basis the observations cover 46 rotational cycles. Using the above epoch and period, the data were phase folded to produce the results shown in Figure 1. This figure displays data from -0.2 to $+1.0$ phase so as to show fully the most prominent maximum. Magnitudes of the primary maxima from other nights were adjusted to the magnitude of the zero phase maximum on the night of epoch. From Figure 1, the average amplitudes of the extrema were estimated. The zero phase maximum is approximately 0.23, whereas the following maximum (at 0.55 phase) is approximately 0.25 magnitudes. From the comparison and check star differences for each night an estimate of the sky stability was made. These differences were ± 0.02 , giving an indication of the overall accuracy of the quoted amplitudes. Preliminary results were posted on the CALL website on April 13, 2001.

Discussion

Using AAVSO variable star software, a period search was made using data from all seven nights. The results agree well with the graphical method discussed above. The best frequency was found to be 3.0889 (cycles/day), which is the same 7.768 hour period.

To a first approximation, the maximum amplitude of 0.25 magnitudes implies a ratio a/b of approx 0.8, where a, b and c are the axes of a tri-axial ellipsoid and the rotation is about the shortest axis, c. The very small difference of around 0.02 magnitudes in the two maxima implies little difference in albedo between the opposite hemispheres. Slight variations in the shape and depth of the extrema from night to night indicate that there are topographic and/or shadowing effects present. A small positive anomaly in the lightcurve between 0.1 and 0.2 phase and also a flattening of the light curve between 0.4 and 0.5 phase are seen to repeat over several nights, suggesting the presence of small topographic features. On individual night lightcurves these are quite distinct, but tend to be less obvious in the stacked curve of Figure 1. Other small anomalies between 0.6 and 0.7 phase appear on the lightcurve, but these do not appear to repeat from night to night. Their cause is not known at this time.

Using the methodology of Schober et al (1980) it is possible to gain some idea of the linear dimensions of the surface features that are responsible for these anomalies. Their extent can be measured from the individual night lightcurves in terms of both delta phase and delta magnitude. These can then be turned into two separate estimates of the linear dimensions of the small-scale features present. In Table 2, the linear dimension L' is derived from delta phase and the linear dimension L is derived from the delta magnitude of the lightcurve anomaly. As can be seen, these two estimates give reasonably consistent values for the small-scale features present at two different points on the lightcurve (estimates from delta phase seem to give the best consistency). This gives some confidence that real features are being mapped here. The nature of these feature remains unresolved – they may be high albedo, young craters or craters with dark floors or other topographic &/or shadow effects.

Conclusion

Minor planet 640 Brambilla was observed over 46 rotational cycles and the synodic period determined as 7.768 ± 0.006 hours. This is believed to be a secure result as all rotational phases of the light curve were observed. The light curves show the doubly periodic features typical of an irregularly shaped, tri-axial

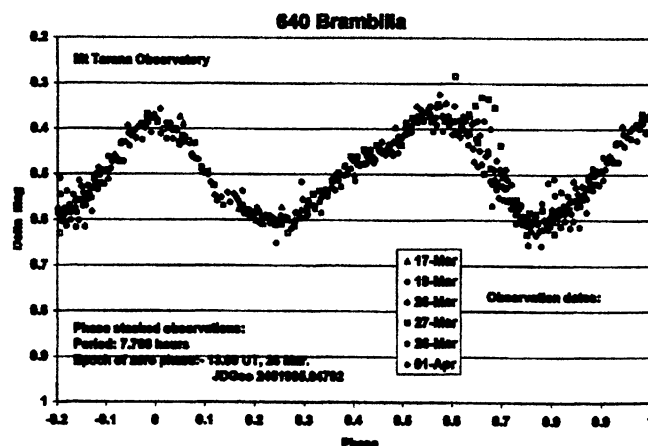


Figure 1. Lightcurve for asteroid 640 Brambilla.