

PERIOD DETERMINATION FOR 168 SIBYLLA: A COLLABORATION TRIUMPH

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The synodic rotation period and amplitude of 168 Sibylla are found to be 47.009 ± 0.003 h and 0.16 ± 0.02 magnitudes, respectively.

Prior to this investigation, only two lightcurve papers about 168 Sibylla appear to have been published. DiMartino et al. (1994) obtained three lightcurves in March 1991 that showed a rounded minimum followed by a rapid brightening with total amplitude > 0.3 magnitudes. They estimated the period to be 23.82 hours. Wang and Gu (2003) obtained lightcurves on four consecutive nights 2003 Mar. 28-31, each of which showed the magnitude increasing uniformly by about 0.2 magnitudes; they claimed a 24.41 hour period. Because there were no features on their lightcurves, linking the separate sessions was difficult and subject to substantial error.

Due to the long period, which was nearly synchronous with an Earth day, a collaboration was formed among the three authors. Benishek obtained lightcurves 2007 Oct. 16, 17 at Belgrade Observatory with a Meade 16" LX200 GPS f/10 SC and Apogee AP47p CCD. Brinsfield obtained lightcurves 2007 Dec. 2, 11, 16 at Thousand Oaks CA, USA, with a 12" Takahashi Cassegrain at prime focus, effective focal ratio f/11.5, and Alta U6 CCD. Pilcher obtained the other 20 lightcurves from 2007 Oct. 6 to 2008 Jan. 11 at Organ Mesa Observatory with a Meade 14" LX200 GPS f/11 SC and SBIG STL 1001-E CCD. Differential photometry and lightcurve construction were made with MPO Canopus. This software made much easier sharing and linking of the data by all three observers. A total of 4626 data points were binned in sets of 10 with a maximum time difference of 20 minutes to make a more readable lightcurve of only 479 points.

Observations were started 2007 Oct. 6, more than a month before opposition. By the end of October it was apparent that extrema observed on successive nights had different appearances, but those on alternate nights looked the same, and corresponding features appeared about one hour earlier on alternate nights. This indicated a period near 47 hours, twice that presumed by the earlier observers. It was desired to continue observations until full phase coverage was achieved with multiple overlap.

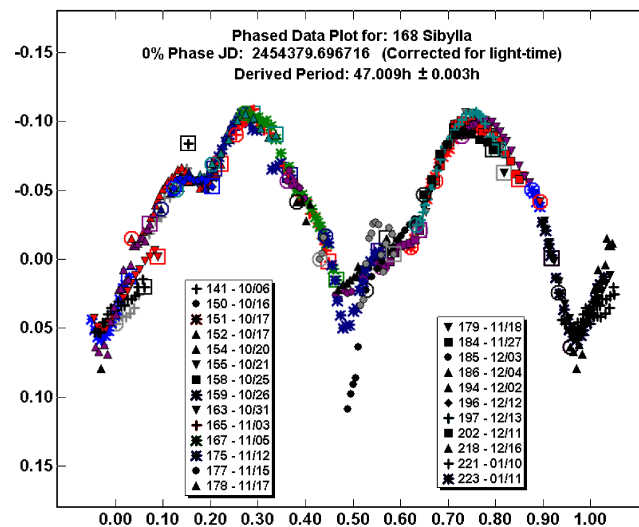
It is straightforward to link specific features near the maxima and minima which are separated by up to three months. This establishes a mean synodic period for the entire interval of observation of 47.009 ± 0.003 h, which we consider reliable. The interval between minimum and maximum is greater than can be

covered in a single night. The amplitude of 0.16 ± 0.02 magnitudes requires instrumental magnitude adjustments to match lightcurve segments showing only the rising or falling sections. These may not be as reliable as determinations for shorter period objects in which maximum and minimum are observed on the same night.

Over the large range of phase angles 1.0 to 16.1 degrees encountered in this study, the synodic period and shape and amplitude of a lightcurve can change, with the amplitude often increasing with phase angle. The difficulty of accurately adjusting instrumental magnitudes over the rising and descending parts of the lightcurve precludes accurately establishing the change in amplitude. The two maxima retained nearly the same shape throughout the apparition, but significant changes in the shape of the minima were found. On 2008 Jan. 11, phase angle 16.1 degrees, the minimum at phase 0.50 was deeper than on 2007 Nov. 15 and 17 at phase angle 1.2 degrees. Petr Pravec (2008) considers this change as likely due to shadowing effects of topographic features at increased phase angle. He also states that the 47 hour period is secure.

An even deeper minimum at phase 0.5 was observed only on 2007 Oct. 16 about 23h UT at phase angle 9.7 degrees, but that part of the lightcurve was not sampled again until Nov. 15. The descending part of this deep minimum was unfortunately lost as Sibylla passed close to a bright star. This feature seems excessively deep for a shadowing effect, but we are unable to find a physical or instrumental cause.

The amplitude of 0.16 magnitudes observed in 2007-2008, at longitudes 55 to 43 degrees, is considerably smaller than those observed by Di Martino et al. (1994) at longitude 160 degrees and Wang and Gu (2003) at longitude 131 degrees. Since both of these authors observed only part of the ascending branches, the actual amplitudes are greater than their observed ranges of 0.3 and 0.2 magnitudes, respectively. This indicates that longitude 49 degrees, the mean of the 2007-2008 observations, is considerably closer to the rotational pole.



Future Studies

For 168 Sibylla obtaining a reliable spin/shape model will require a large commitment of telescope time at future oppositions. Full phase coverage at a single site requires observations on successive nights, or separated by an odd number of dates, to sample both

halves of the lightcurve. Both will need resampling at intervals not exceeding 8 to 12 days and continuing for a minimum of about 50 days. Differential photometry alone will suffice to obtain the period and shape of extrema, but as in this investigation, adjusting the instrumental magnitudes to match rising or falling segments may be less reliable.

To overcome this limitation, it is suggested that two observers separated by longitude of 5-8 hours (75-120 degrees) collaborate. Their combined sessions on a single night should overlap in real time and cover a total time of at least 12 hours, the time between successive extrema of Sibylla. As soon as an extremum is found, the known 47 hour period enables prediction of times of future extrema. The overlapping sessions can be conducted on a night when one extremum occurs early in the session of the eastern observer and the next occurs late in the session of the western observer. If the collaborating observers use the same comparison stars and identical filters, then their two combined lightcurves can establish the amplitude with differential photometry alone. This method of two observers widely separated in longitude obtaining overlapping lightcurves with identical filters is recommended for

all long period rotators and is useful even without prediction of extrema. These studies are of special importance because rotation statistics have become skewed as observers often fail to obtain secure results for long period rotators.

Acknowledgments

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CCD PHOTOMETRY OF SIX ASTEROIDS FROM THE UNIVERSIDAD DE MONTERREY OBSERVATORY

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CCD photometry of six asteroids was obtained at the Universidad de Monterrey Observatory during January and February 2008. The resulting synodic rotation periods and amplitudes are as follows: 1292 Luce, 6.9541 ± 0.0002 h, 0.20 ± 0.01 mag; 1303 Luthera, 5.878 ± 0.003 h, 0.08 ± 0.01 mag; 1900 Katyusha, 9.4999 ± 0.0001 h, 0.72 ± 0.02 mag; 2807 Karl Marx, 8.842 ± 0.001 h, 0.40 ± 0.05 mag; 3409 Abramov, 7.791 ± 0.002 h, 0.55 ± 0.02 mag; and 9117 Aude, 2.8156 ± 0.0001 h, 0.20 ± 0.01 mag.

The observations reported here were made with the Meade 36-cm LX200GPS telescope of the Universidad de Monterrey Observatory (MPC 720). The telescope is permanently mounted in a 6-foot fiberglass dome that has recently been automated and is operated from a nearby warm room. The CCD camera used was an SBIG STL-1301E with a 1280x1024_16 μ m KAF-1301E/LE chip. The field-of-view is $\sim 21.1 \times 16.9$ arcminutes with an image scale of about 1 arcseconds/pixel. This new instrument was obtained thanks to a grant from the Consejo Nacional de Ciencia y Tecnología of Mexico to upgrade the equipment of the observatory. With it we can now perform more efficient asteroid photometry on fainter targets. These are the first results published with the use of the upgraded equipment.

The targets were selected from the list of asteroid photometry opportunities published by Brian Warner on his Collaborative Asteroid Lightcurve Link (CALL) website (Warner, 2007). The selection criteria used were not stringent since we were testing the new imager. Some asteroids were bright, others faint, some with provisionally known periods, others with unknown ones, and still others were targets of opportunity. In all cases the images were obtained unfiltered, binned 2x2, and the detector temperature set to -20 C. Exposure times were 120 seconds (guided) and standard dark-current and flat-field field corrections were applied. The image measurements and period analysis was performed using MPO Canopus (Warner, 2008).

The results for each asteroid are summarized and commented below. The individual plots are presented afterwards.

1292 Luce. This asteroid was observed on five nights over a four-week interval. The resulting synodic period was 6.9541 ± 0.0002 h and the amplitude 0.20 ± 0.01 mag. The lightcurve was well sampled and shows an irregular shape. The only other report for this asteroid corresponds to R. Behrend (2008) who reports a provisional period of 6.696 ± 0.216 hours from only one night of observations by R. Roy on February 13, 2008.

1303 Luthera. This asteroid was observed on only two nights separated by four days in February 2008. The resulting synodic period was 5.878 ± 0.003 h and the amplitude 0.08 ± 0.01 mag. Although the amplitude was small, we are confident of the result since the lightcurve was well-sampled on both nights. No other reports were found for this asteroid.

1900 Katyusha. This asteroid was observed on four nights over a three-week interval. The resulting synodic period was 9.4999 ± 0.0001 h and the amplitude 0.72 ± 0.02 mag. The observed lightcurve was well-sampled and exhibits a nominal bimodal shape with large amplitude. This asteroid is also found on the website maintained by R. Behrend (2008). He reports a provisional rotation period of 9.312 ± 0.096 h from one night of observations on February 11, 2005 by R. Poncy. Their lightcurve shows a magnitude variation of about 0.5 magnitudes, a bit lower than our observed amplitude from observations three years later.