

A SEARCH FOR MUTUAL ECLIPSE EVENTS OF THE ASYNCHRONOUS BINARY ASTEROID 1016 ANITRA

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Asteroid 1016 Anitra was observed extensively between 2020 March 13 and April 24. Mutual eclipse events were searched for but none were observed. Data are analyzed in two sub sets. The March subset found two bimodal lightcurves with periods and amplitudes of $P_1 = 5.9292 \pm 0.0002$ h, $A_1 = 0.30$ mag and $P_2 = 2.6092 \pm 0.0002$ h, $A_2 = 0.11$ mag. The April subset found $P_1 = 5.9281 \pm 0.0002$ h, $A_1 = 0.34$ mag and $P_2 = 2.6091 \pm 0.0001$ h, $A_2 = 0.11$ mag.

Numerous photometric investigations have been made of 1016 Anitra: Alkema (2013; 5.929 hours), Kryszczyńska et al. (2012; 5.9288 h), Menke (2005; 5.930 h), Pray et al. (2006; 5.928 h), Schmidt (2016; 5.9301 h), and Klinglesmith III et al. (2017; 5.9295 h). Amplitudes ranged from 0.28 to 0.50 mag. Pilcher et al. (2016), of which this author was a coauthor, demonstrated that the lightcurves of Anitra are two strictly additive components of periods $P_1 = 5.92951$ h, $A_1 = 0.30$ mag and $P_2 = 2.069143$ h, $A_2 = 0.10$ mag. Petr Pravec demonstrated in Pilcher et al. (2016) that there is no signal in the linear combinations of the two frequencies, which might indicate that the asteroid is “tumbling”, *i.e.*, in non-principal axis rotation (NPAR). Thus, Anitra is likely an asynchronous binary. The orbital period of asynchronous binary asteroids is expected to be long (tens of hours) and the chances for observing mutual eclipse events are slim. These mutual eclipse events are deemed necessary to prove the binary nature of a suspected asynchronous binary. Benishek, also a coauthor of Pilcher et al. (2016), had observations of possible mutual eclipse events but unfortunately none of the other observers had data that could confirm these observations.

All observations reported here are made without filters and unbinned. Exposure times were 100 or 150 s. A 0.35-m Newtonian f/4.5 telescope was used with a Moravian G2-3200 camera and Wynne-Riccardi coma corrector. The mount was a friction drive model Mesu-200, a German equatorial type. The camera was thermoelectrical cooled to -30 °C and all images were unfiltered and calibrated with a master dark of same exposure length as the science frames and a master flat using *Astro Art 7.0*. During calibration the time-series was not aligned to avoid interpolation of pixel intensities prior to analysis which was done with *MPO Canopus* v.10.8.1.1 (Warner, 2019). The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color in (V-R) for differential photometry.

Catalog magnitudes were taken from the ATLAS catalog (Tonry et al., 2018). Adjustments of the nightly zero points are small and usually less than ± 0.03 when using the ATLAS catalog. Period analysis is done with *MPO Canopus 10.8*, which implements the FALC algorithm by Harris (Harris et al., 1989). The same algorithm is used in an iterative fashion, as in the case of Anitra, there is more than one period.

The apparition of 1016 Anitra (opposition on 2020-03-05.6) was anticipated with aspiration of detecting mutual eclipse events. From March 13th to April 24th some 2382 exposures with 76.8 hours of open shutter time were accumulated. The observatory of this author is located at latitude 57° North so from the end of twilight to airmass of 2 no single lightcurve was longer than 3.8 h. The final analysis consists of two sets of phased plots one for each rotational period P_1 and P_2 . Figures 1 and 2 are for the March subset and Figures 3 and 4 are for the April subset. A residual plot after subtraction of both periods is shown in Figure 5 for the April subset demonstrates that there is no trace of mutual eclipse events detected above the noise level of 15 and 16 millimagnitudes respectively. A residual plot for the March subset is equally disappointing and the reader is spared the view.

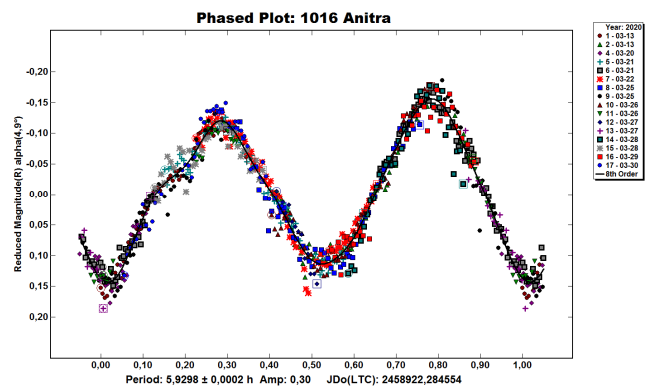


Figure 1. Lightcurve of primary period (P_1) for the interval 2020 Mar 13 to 30. Phase angle between 4.90° and 12.6°.

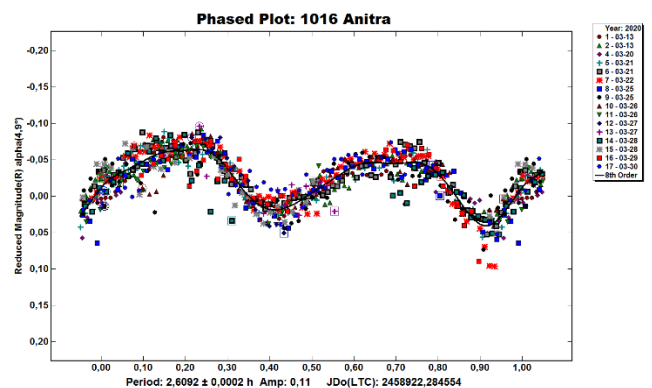


Figure 2. Lightcurve of secondary period (P_2) for the interval 2020 March 13 to 30.

Number	Name	2020 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1016	Anitra	2020 03/13-03/30	4.90,12.6	165	3	5.9298	0.0002	0.30	0.02	MB-M
						2.6092	0.0002	0.11	0.02	
1016	Anitra	2020 04/09-04/24	16.6,21.4	168	1	5.9281	0.0002	0.34	0.02	
						2.6091	0.0001	0.11	0.02	

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

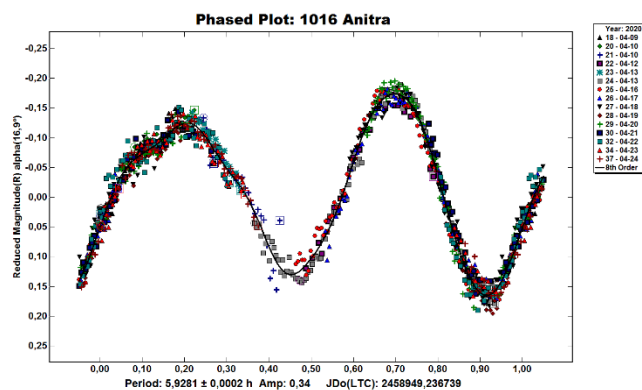


Figure 3. Lightcurve of primary period (P1) for the interval 2020 April 9 to 24. Phase angle between 16.6° and 21.4°.

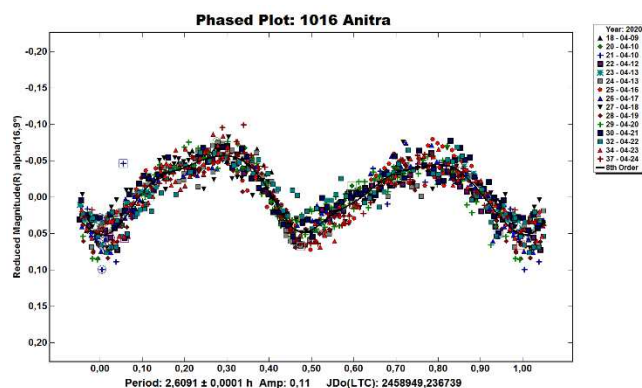


Figure 4. Lightcurve of secondary period (P2) for the interval 2020 April 9 to 24.

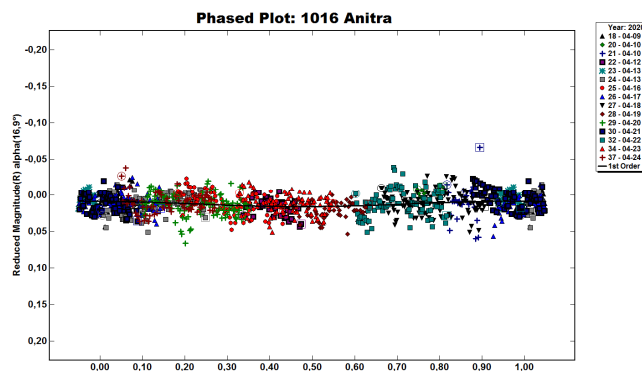


Figure 5. Residual plot after subtracting both periods P1 and P2 from the lightcurves for the interval 2020 April 9 to 24. An interval from 9 h to 100 h was searched with only 1 harmonic term.

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