1803 ZWICKY
A CONFIRMED BINARY ASTEROID

Tom Polakis
Command Module Observatory
121 W. Alameda Dr.
Tempe, AZ 85282
tpolakis@cox.net

Robert D. Stephens
Center for Solar System Studies / MoreData!
Rancho Cucamonga, CA 91730

(Received: 2021 March 25, Revised: 2021 May 1)

Observations made from February through March 2021 led to the discovery that 1803 Zwicky is an asynchronous binary system. The primary body has a rotation period of 2.7329 ± 0.0002 h, and the orbital period is 28.46 ± 0.02 h. The small lightcurve amplitude suggests a spherical shape. From the mutual event depths we infer a minimum secondary-to-primary mean diameter ratio of 0.26 ± 0.02.

During the course of CCD photometric observations of 21 main-belt minor planets from 2020 December through 2021 March, 1803 Zwicky stood out with data points that departed from a typical rotational phased lightcurve. An inspection of a raw lightcurve from TESS satellite data published by Pal et al. (2020) showed periodic sharp drops in brightness. This led to four additional nights of observations, during which the asteroid's binary nature was confirmed, and rotation and revolution periods computed.

Observations were performed at Command Module Observatory (MPC V02) in Tempe, AZ and the Center for Solar System Studies (MPC U81) in California. Images were taken at V02 using a 0.32-m f/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a 'clear' glass filter. Exposure time for all the images was 2 minutes. The image scale after 2×2 binning was 1.76 arcsec/pixel. Images at U81 were taken with a 0.40-m f/10 Schmidt-Cassegrain telescope and FLI Proline 1001 camera, also with a clear filter. Those frames have an image scale of 1.22 arcsec/pixel.

Table I shows the observing circumstances and results.

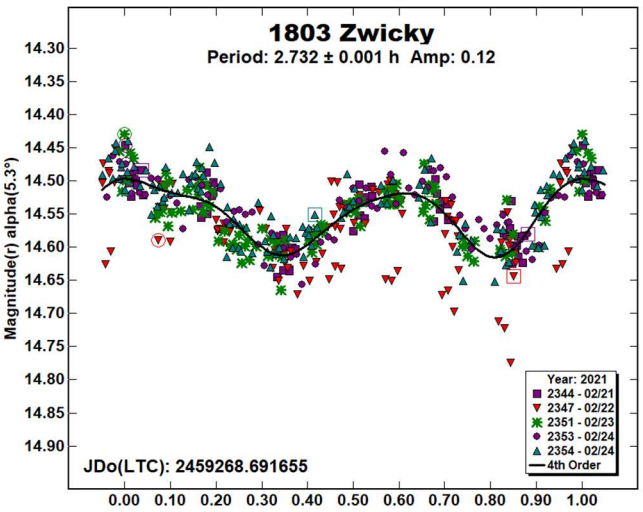
The data reduction and period analysis were done using *MPO Canopus* (Warner, 2020). For each set of images, the asteroid and five comparison stars were measured. Comparison stars were selected with colors within the range of 0.5 < B-V < 0.95 to correspond with color ranges of asteroids. *MPO Canopus* plots instrumental vs. catalog magnitudes for solar-colored stars, which is useful for selecting comp stars of suitable color and brightness.

Clear-filtered images were reduced to Sloan r′ to minimize error with respect to a color term. Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *MPO Canopus*. The ATLAS catalog derives Sloan griz magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color-indices allowed the separate nightly runs to be linked with no zero-point offset.

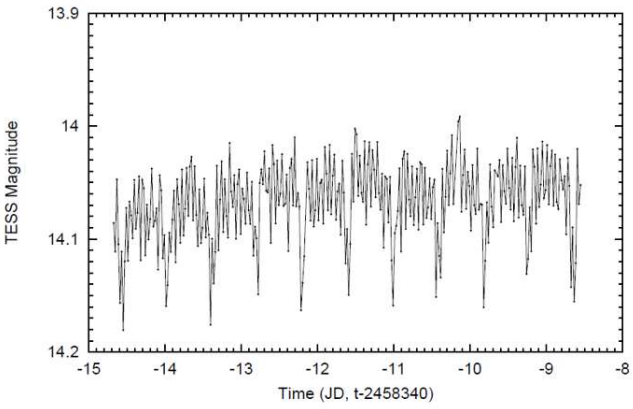
It was typically necessary to employ star subtraction to remove contamination by field stars. Initial period determination was done using the *MPO Canopus* Fourier-type FALC fitting method (cf. Harris et al., 1989). Magnitudes in these plots are apparent and scaled by MPO Canopus to the first night. After reaching a satisfactory rotation and orbit solution, data files were sent to Petr Pravec, who refined the results.

The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. New data for this asteroid can be found in the ALCDEF database.

1803 Zwicky was discovered by Paul Wild at Zimmerwald in 1967. This Phocaea-family asteroid has a high eccentricity of 0.247, and a large inclination of 22º. The only period in the LCDB is that of Pal et al. (2020), 2.73364 ± 0.00005 h. A simple period analysis using V02 data from 2021 February 21 through 24 yielded a rotation period of 2.732 ± 0.001 h. Data points from February 22 showed a troublesome departure from the lightcurve that could not be explained by any data-gathering anomalies.



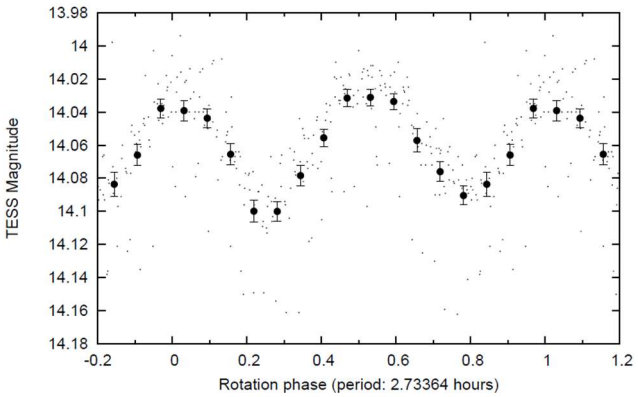
The raw lightcurve for 1803 Zwicky provided with the Pal et al. (2020) paper revealed deep, evenly spaced minima overlaid on a shorter cycle with smaller amplitude.



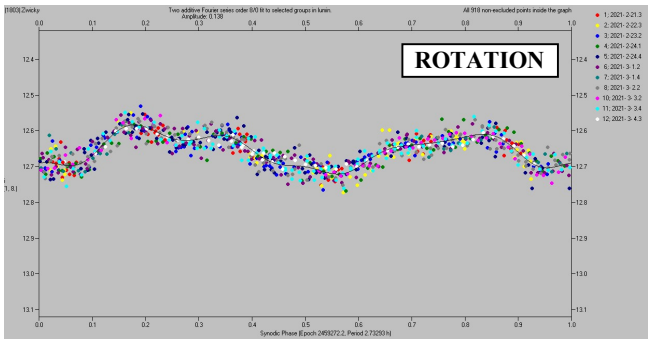
Their phased lightcurve also features data points displaced downward that mimic the rotational lightcurve.

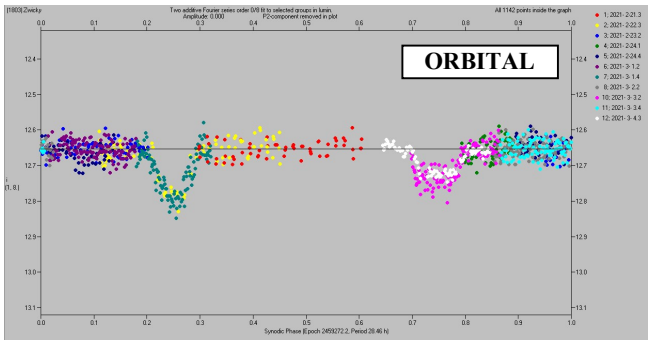
Number	Name	yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1803	Zwicky	21/02/21-03/04	5.3,10.9	145	4	2.7329	0.0002	0.14	0.01	MB-O
						28.46	0.02	0.14	0.01	

Table I. Observing circumstances and results. Period is rotation and orbital for each body. The first line gives the primary period for the system. The second line gives the secondary period. 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).



Additional dense photometric data was taken at V02 during three full nights from 2021 March 1 through 3, and at U81 on March 4. All of the data was sent to Petr Pravec, who determined the rotation period of 2.7329 +/- 0.0002 h for the primary body and orbital period of 28.46 ± 0.02 h for the secondary. Mutual event depths are 0.07 and 0.14 mag., suggesting a minimum secondary-to-primary mean diameter ratio of 0.26. Phased lightcurves for rotation and orbital periods are shown.





Acknowledgements

The author would like to express his gratitude to Petr Pravec for his indispensable data reduction effort. Thanks also go out to Brian Warner for his helpful advice relating to binary asteroids and support of his MPO Canopus software package.

References

Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

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.; Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Pal, A.; Szakáts, R.; Kiss, C.; Bódi, A.; Bognár, Z.; Kalup, C.; Kiss, L.L.; Marton, G.; Molnár, L.; Plachy, E.; Sárneczky, K.; Szabó, G.M.; Szabó, R. (2020). "Solar System Objects Observed with TESS - First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey." *Ap. J. Supl. Ser.* **247**, 26-34.

Tonry, J.L., Denneau, L., Flewelling, H., Heinze, A.N., and five additional co-authors. (2018). "The ATLAS all-sky stellar reference catalog." *Astrophys. J.* **867**, 105.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2020 Aug. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner. B.D. (2020). *MPO Canopus* software. *http://bdwpublishing.com*