

Data Mining Analysis for Eclipsing Binary TrES-Cyg3-04450

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Abstract A data mining algorithm was utilized to analyze Johnson V-band charge-coupled device (CCD) photometric data of an object that were taken during a wide field survey of a region in the constellation Cygnus. That algorithm was the Date Compensated Discrete Fourier Transform (DC DFT) which is part of the AAVSO *vSTAR* applications software. This analysis clearly indicated that the object under study is a detached eclipsing binary, specifically an EA β Persei-type (Algol) eclipsing system, with an orbital period of 2.0664 days. Neither the type nor period of this eclipsing binary had been characterized up to this point. This object has been given the AAVSO designation TrES-Cyg3-04450 and the AUID 000-BLL-484.

1. Introduction

TrES-Cyg3-04450 is one of 10,000 stars imaged during a wide field survey of a region in the constellation Cygnus. A field of $6^\circ \times 6^\circ$ was centered on R.A. $19^h 54^m 00^s$, Dec. $+37^\circ 00' 00''$. The survey was conducted by the Transatlantic Exoplanet Survey (TrES; Alonzo *et al.* 2007), which was designed to search for exoplanetary transits using three wide-field optical telescopes of 10-cm diameter located at three different observatories (Lowell Observatory, Palomar Observatory, and the Canary Islands). The array incorporated 10-cm Schmidt telescopes having CCD cameras capable of obtaining precise differential photometry on thousands of stars simultaneously and automated search routines, thereby increasing the light curve coverage in a given observing season by effectively increasing the length of the night as well as improving weather statistics. As the result of the high cadence photometry, several hundred hours of observing time at each target maximized the visibility of an event.

Using the VizieR search engine, it was determined that this object has other catalog names or identifications including: UCAC4 642-085405; 2MASS J20051693+3814518 ($J-K = 0.1930$ where $J = 10.263$, $K = 10.070$); USNO-B1.0 1282-0444845; USNO-A2.0 1275-13314390; NSVS ID 5709370, NSVS ID 8460067, and NSVS ID 8481682. The optical image for TrES-Cyg3-04450 is shown in Figure 1 (directly in the center of the image).

2. Methods

The V data for TrES-Cyg3-04450 obtained by the TrES survey are shown in Table 1.

In addition to the TrES data, survey data from the AAVSO Photometric All Sky Survey (APASS; Henden *et al.* 2014) and the Northern Sky Variability Survey (NSVS; Wozniak *et al.* 2004) sources were incorporated. These additional photometric data improve the estimate of the period and epoch for TrES-Cyg3-04450 as discussed below.

2.1. Analysis method

The 3,890 Johnson V-band CCD photometric data observations of TrES-Cyg3-04450 were downloaded from the “Stellar Photometry Data from TrES” database (Lowell Obs.

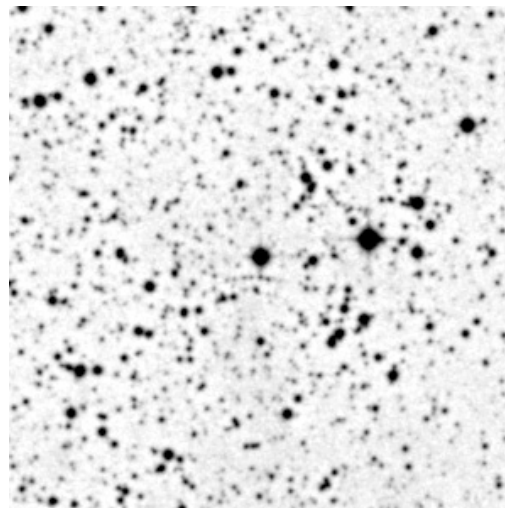


Figure 1. Optical image for TrES-Cyg3-04450 (directly in center of image). Digitized Sky Survey (STScI 1993-1995) UKSTU Red image from VSX (Watson *et al.* 2006–2014).

Table 1. Data for TrES-Cyg3-04450 from TrES database.

<i>Parameter</i>	<i>Data</i>
Location	R.A. $20^h 05^m 17.0^s$, Dec. $+38^\circ 14' 52''$
Nominal magnitudes	
V	11.530
B–V	0.2470
Magnitude statistics	
Number of measurements	3,890
Mean Magnitude	0.03649
Minimum Magnitude	–0.05931
Maximum Magnitude	0.70207
Magnitude Variance	0.01522
Magnitude Standard Deviation	0.12336
Error statistics	
Mean Error	0.10901
Minimum Error	0.00201
Maximum Error	1.70185
Error Variance	0.02053
Error Standard Deviation	0.14328
Time statistics	
Observation span	2,356 days
Nights observed	120
Maximum nightly observations	76
Minimum nightly observations (> 0)	1
Average nightly observations	32.4

2015). Either text or Comma Separated Variable (CSV) format was available. The V data from APASS (Henden *et al.* 2015) and NSVS (Wozniak *et al.* 2004) brought the total number of observations to 4,143. Since the TrES observations are in the Johnson V-band, the zero point was adjusted and calibrated using APASS Johnson V data. NSVS added data points corresponding to TrES data points as well as extending the time baseline. Since the NSVS data also showed several eclipses, they helped to improve the estimation of the period. NSVS data were also shifted to the zero point. Finally, the ascending and descending branches of all eclipses and all data sets were matched such that the epoch of the minimum corresponded exactly to the midpoint of mid-eclipse (Otero 2015).

These combined calibrated data were then input to the Date Compensated Discrete Fourier Transform (DC DFT) algorithm which is part of the AAVSO *vstar* applications software (Benn 2013). The DC DFT algorithm (Ferraz-Mello 1981) yields a power spectrum and a table of “top-hits” given a specified series, frequency (or period) range, and resolution. The “date compensated” part of the name indicates that gaps in the data, common for variable star observations, are compensated for by the algorithm. The light curve for TrES-Cyg3-04450 is shown in Figure 2.

From the raw combined calibrated light curve data as shown in Figure 2, the *vstar* DC DFT algorithm performed the period analysis of TrES-Cyg3-04450 with the power spectrum shown in Figure 3.

2.2. Analysis results

The period computed from the power spectrum analysis in Figure 3 (the strongest signal or “top-hit”) is 1.0332 ± 0.045 days. However, this is only one half of the full orbital period since 1.0332 days is the time between two consecutive minima. Since there are two eclipses per orbit the full orbital period is twice as long. Therefore, the full period is 2.0664 days with an epoch (midpoint of mid-eclipse) of HJD 2452121.587 (31 July 2001) as shown below in Figure 4. The magnitude range is 11.33–12.0V and the computed eclipse duration is 9% based on the results shown in Figure 4; TrES, NSVS, and APASS data points are indicated in the composite light curve. The TrES, NSVS, and APASS data are plotted individually in the phase plots, Figures 5, 6, and 7, respectively. It can be seen how these three data sets combine to enhance the estimate of the period and epoch of TrES-Cyg3-04550.

3. Conclusions

This analysis clearly indicated that the object under study is a detached eclipsing binary, specifically an EA β Persei-type (Algol) eclipsing system, with an orbital period of 2.0664 days and with an epoch of HJD 2452121.587 (31 July 2001). The magnitude range is 11.33–12.0V and the computed eclipse duration is 9%. Neither the type nor period of this eclipsing binary had been characterized up to this point. This object has been given the AAVSO designation TrES-Cyg3-04450 and the AUID 000-BLL-484.

4. Acknowledgements

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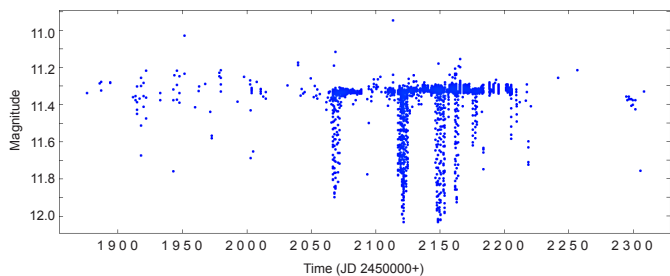


Figure 2. Light curve for TrES-Cyg3-04450.

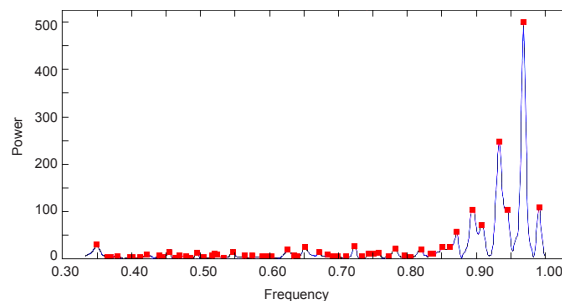


Figure 3. Power spectrum period analysis for TrES-Cyg3-04450.

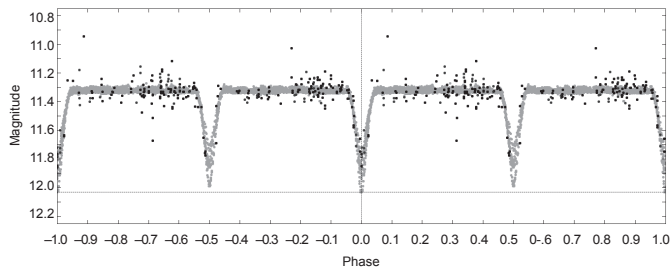


Figure 4. Phase plot for TrES-Cyg3-04450, with NSVS and APASS data superimposed. Period: 2.066486, epoch: 2452121.587.

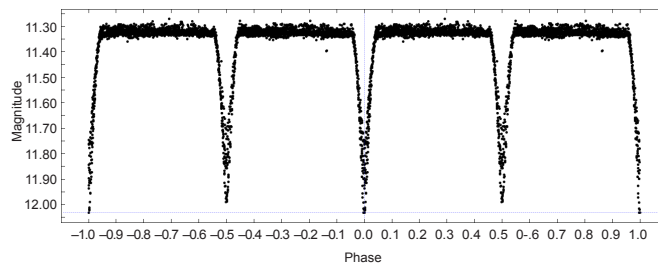


Figure 5. Phase plot for TrES-Cyg3-04450. Period: 2.066486, epoch: 2452121.587.

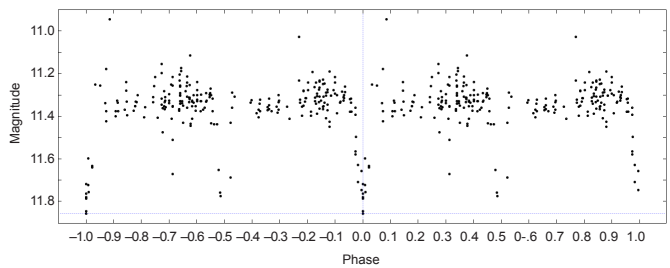


Figure 6. Phase plot for NSVS data. Period: 2.066486, epoch: 2452121.587.

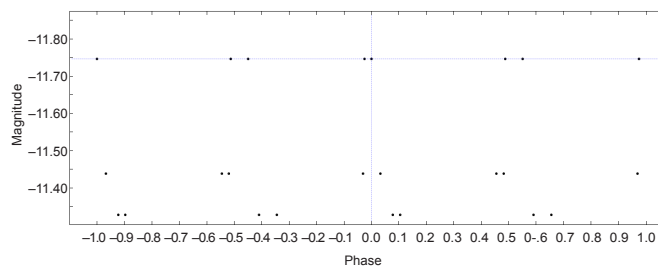


Figure 7. Phase plot for APASS data. Period: 2.066486, epoch: 2452121.587.