Photometry of TIC 230386284, a Recently Found Bright Eclipsing Star in Draco

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Abstract The results of photometry are presented for the star TIC 230386284, of EA+UV type, recently found by the author while mining TESS data. The depth of primary eclipses in the Johnson V band derived from the author's measurements was found to be significantly smaller (0.024 mag) compared to the TESS bandpass (0.11 mag). This was interpreted as a result of light contamination by an extremely close optical companion having a very different color. Estimation of the upper brightness limit of the variable out of eclipses and flares in the Johnson V band and brightness of the contaminating star was done; the contaminating star appeared to be brighter in V than the variable by at least 1.3 mag.

1. Introduction

The TESS spacecraft (Ricker *et al.* 2014), designed to search for new extrasolar planets, generates plenty of data. This huge array is a rich source for mining new variables. A goal of the current work is a refinement of some parameters of the star TIC 230386284 (J2000: 19 03 17.46, +63 59 35.9) found by the author while mining the TESS data. TESS data with two-minute cadence with Presearch Data Conditioning (PDC) correction (Jenkins *et al.* 2016), available through the MAST portal (https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html), were used for the analysis. The star was registered in the AAVSO VSX database (Watson *et al.* 2014) as PMAK V41 (https://aavso.org/vsx/index.php?view=detail.top&oid=1540365). TIC 230386284 is an eclipsing binary system with the primary and the secondary minima of similar depth (depth of the primary minima is 0.11 mag in TESS filter). The star also demonstrates flares, so, taking into account its spectral type (M3.5V), it was classified as EA+UV variable. The flares reach an amplitude of 0.14 mag in the TESS bandpass. The total number of flares was manually counted for TESS data for sectors from 14 to 18, 20, 21, and from 23 to 26 (274 observational days in total), see Table 1.

There were also many low-amplitude flares (< 0.015 mag in the TESS bandpass). They were not counted in this work, since they sometimes look like noise sparks.

A part of the TESS light curve is shown in Figure 1.

Interestingly, SuperWASP (Butters *et al.* 2010) data (unfiltered photometry) show very shallow minima (the primary minimum depth is about 0.03 mag). The minima in ASAS-SN (Kochanek *et al.* 2017) V data were barely visible because the data were too noisy. Combining TESS (sectors from 14 to 18 were available at the time of mining), SuperWASP, and ASAS-SN data, the following parameters of the eclipsing variability were determined: a period of 0.341493 d and epoch of the primary eclipse HJD 2458748.7177. These parameters were published in VSX.

Table 1. Crude estimation of the flare rate for TIC 230386284.

	Total number of flares for 274 days	*Mean number of days between flares*
Flares > 0.1 mag (TESS)	3	91
Flares > 0.03 mag (TESS)	16	17
Flares > 0.015 mag (TESS)	60	5

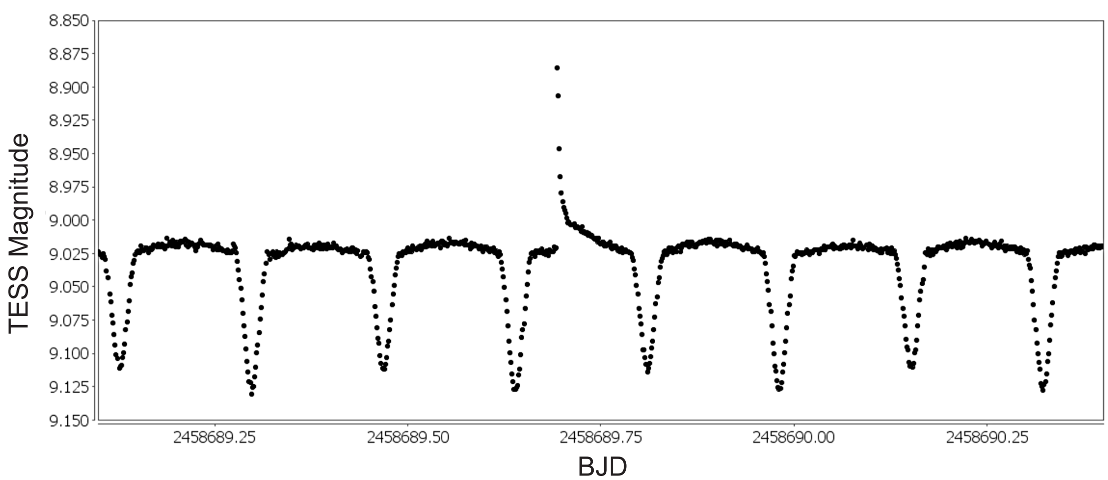

Figure 1. A part of the TESS light curve for TIC 230386284. Eclipsing minima and a sporadic flare are clearly seen. TESS magnitudes were derived from TESS fluxes. The zero level was adjusted to make the median magnitude value equal to the TESS magnitude for TIC 230386284 (9.02 mag) from the *TESS Input Catalog v8* (Stassun *et al.* 2019).

The question remained about a variability range in the Johnson V band: the ASAS-SN data were not reliable to estimate it (however, even from those noisy data, it was obvious that the variability range in the V band is significantly less than in the TESS one; the reason for this was unclear). This was a motivation to make additional observations of the system.

A side goal was an estimation of the applicability of a simple uncooled 12-bit monochrome CMOS camera with a 0.33-inch sensor for variable star research.

2. Methods

The author used a 6-inch f/5 Newtonian on an equatorial tracking mount. A monochrome uncooled CMOS camera ZWO ASI120MM-S placed in the primary focus of the telescope was equipped with a photometric V filter. The observational place location was in a relatively highly polluted urban area. Scientific frames were collected during seven nights from April to June of 2020.

To extend the effective dynamic range of the 12-bit CMOS camera and improve the signal-to-noise ratio, calibrated scientific frames were separated by groups of four or five images (depending on exposure used for the session), aligned, and stacked. The total exposure of stacked images was 60 s. The author used IRIS astronomical software (Buil 1999–2018) to calibrate and align images plus a set of utilities (Pyatnytskyy 2018) to create master calibration frames and to stack images by small groups.

The ASTROIMAGEJ software (Collins *et al.* 2017) was used to perform differential aperture photometry. One comparison star and a check star from a standard AAVSO sequence were used (Table 2). One-band transformation was applied to the data using the Tv_b-v transformation coefficient obtained from the photometry of the AAVSO Standard Field for M67. The value of Tv_b-v appeared to be rather small (0.0086(0.0042)) so the transformation introduced a minor correction to the data. The value of the (B–V) index for the target variable (1.35) was taken from APASS DR10 (Henden *et al.* 2018). Each point in the resulting light curve is a binned average of three observations; uncertainty is the standard deviation (Figure 2, upper pane). There are 339 binned observations in total.

Further analysis and visualization of the data were done mainly with VSTAR (Benn 2013).

3. Results and discussion

Figure 2 shows the phase plots for TIC 230386284 in different filters. The curve in the Johnson V filter represents the author's observations. The flat region of the curve out of eclipsing minima corresponds to Johnson V magnitude 10.47.

The depth of the primary minima in the TESS filter is 0.11 mag while in the Johnson V filter it is only 0.024 mag.

A search in the Vizier catalog service gave the following result: according to *The Washington Visual Double Star Catalog* (WDS; Mason *et al.* 2019) the star is a component of an optical triple system: there are two very close components (AB) separated by 0.2 arcsec (magnitude 10.60 mag according to the WDS) and a third faint component with a magnitude 14.00 mag, with a separation of 3.6 arcsec. This third component is visible in the author's frames; its location is in a good agreement with the WDS data (see Figure 3). The variable is assumed to be one of the stars of the AB close pair.

The optical binarity of AB component was established by Jódar *et al.* (2013). They used the Lucky Imaging technique to resolve very close optical components. Unfortunately, no information about the components but angular separation and positional angle are given in the article.

We can assume that the second non-variable component of the AB pair has a very different color (more "bluish" than the variable of type M3.5V) so its flux in the TESS filter is substantially smaller than the flux of the eclipsing variable (the TESS filter covers a range of wavelengths from approximately 600 to 1000 nm (Ricker 2014)). Then we can adjust the V magnitude of the contaminating star so that the depths of the minima of the "de-blended" light curve will be the same as for the TESS light curve. This gives us the upper limit of the brightness of the variable and the lower limit of the brightness of the contaminating star (in the V filter).

Such a fitting gives a total V magnitude of 10.745 for the contaminating stars (component C plus the non-variable component of the AB pair). The magnitude of the C component from the WDS is 14.00, which gives the estimated upper limit of the magnitude of the contaminating component of AB pair as 10.80 V. The magnitude out of eclipses (and flares) of the variable in the V filter appears to be greater than 12.09, which is about three magnitudes more than the TESS magnitude from the *TESS Input Catalog v8* (Stassun *et al.* 2019). Note that under this approach the contaminating component is brighter in V than the variable by at least 1.3 mag. The "de-blended" folded light curve along with the TESS data is shown in Figure 4. It is seen that the author's data are in excellent agreement with the period and the epoch previously determined using TESS, SuperWASP, and ASAS-SN V data.

4. Conclusions

Photometric measurements with a simple uncooled 0.33-inch monochrome CMOS camera and a small 6-inch f/5 Newtonian show that the eclipsing range of the EA+BY variable TIC 230386284 (found by the author while mining the TESS

Table 2. Comparison and check stars.

AAVSO UID	*Type*	*R. A. (2000)* *h m s*	*Dec. (2000)* *° ′ ″*	*B*	*V*	*B–V*
000-BNM-079	Comparison	19 02 54.86	+63 56 56.0	10.693	10.168	0.525
000-BNM-081	Check	19 03 42.04	+64 11 15.0	11.773	10.795	0.978

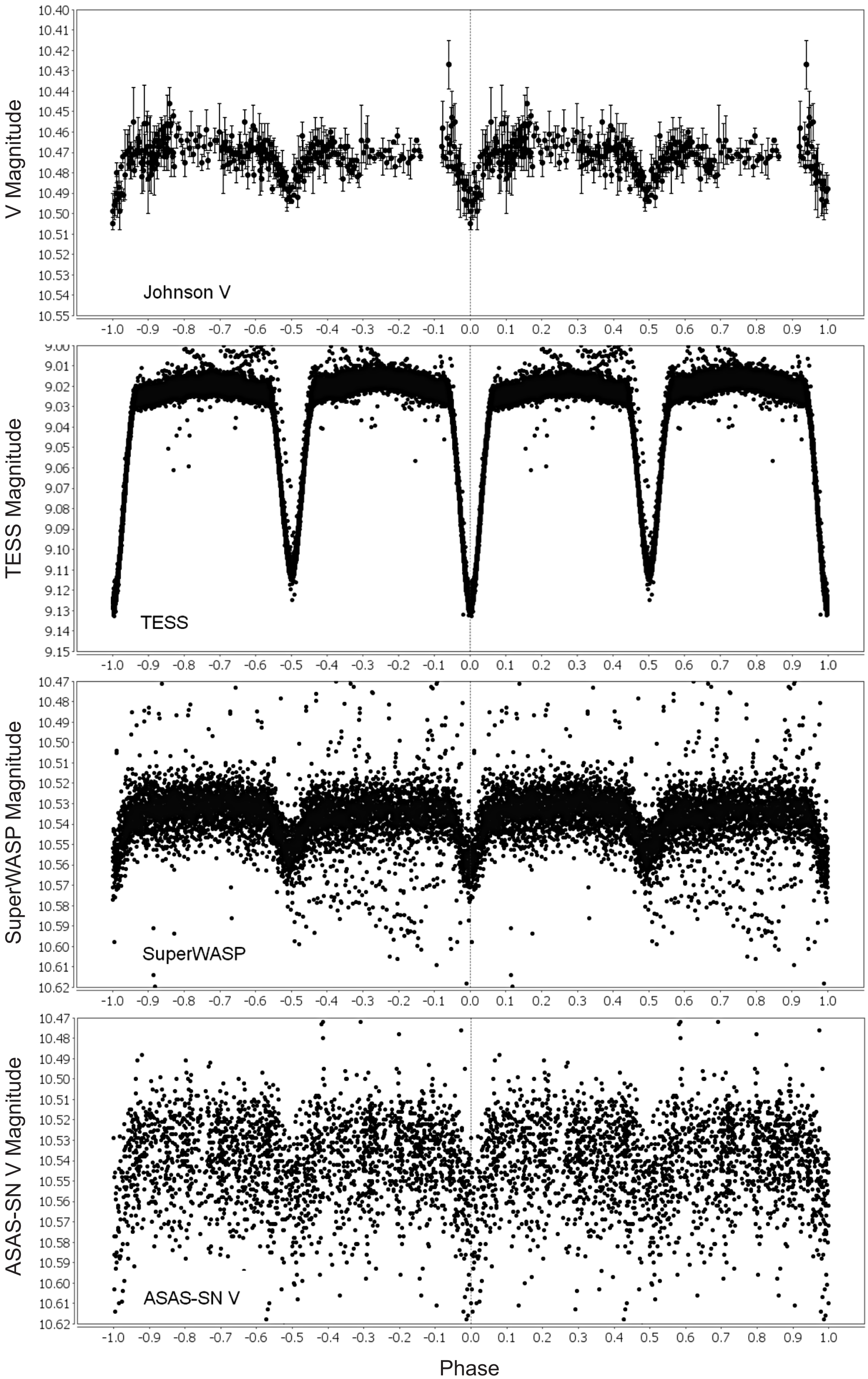

Figure 2. Phase plots for TIC 230386284 (period 0.341493, epoch 2458748.7177) in different filters. Data in the Johnson V filter (top panel) are the author's observations. TESS data are for sectors from 14 to 18.

data archive) in the Johnson V filter is significantly smaller (more than four times smaller in terms of magnitude) compared to the TESS filter. This was interpreted as a result of light contamination by a nearby (in the sense of angular distance) star having a very different color. The upper limit of the brightness of the target variable in the V band was estimated to be 12.09 mag, while the observed magnitude of the triple optical star that includes the variable was measured as 10.47 mag in the Johnson V band (out of eclipses and flares of the variable).

The previously determined period and epoch of the eclipsing variability of TIC 230386284 were confirmed by the author's data.

The nature of the contaminating object is not clear yet. It appears to be very blue. What it can be—a white dwarf, O- or B- star as a part of the multiple star system, or a background source—remains unknown. Additional spectroscopy and multi-color photometry research could shed light on this question.

It was also demonstrated that a simple uncooled CMOS camera (ZWO ASI120MM-S) can be used as a precise instrument for differential aperture photometry of bright stars.

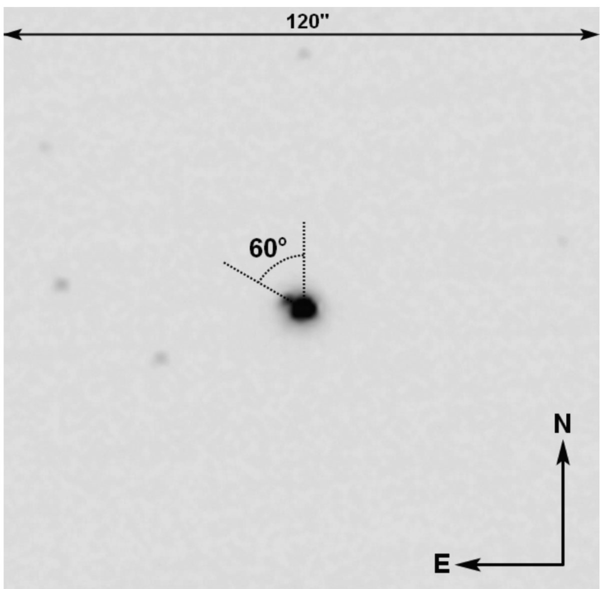

Figure 3. The image of TIC 230386284. A faint "C" component is clearly visible, the estimated positional angle is shown. A positional angle from WDS is 67° for the year 2006 and 65° for 2015.

5. Acknowledgements

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Also, this research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France (DOI: 10.26093/cds/vizier). The original description of the VizieR service was published in *Astron. Astrophys., Suppl. Ser.*, **143**, 23.

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This research has made use of the International Variable Star Index (VSX) database, operated at AAVSO, Cambridge, Massachusetts, USA.

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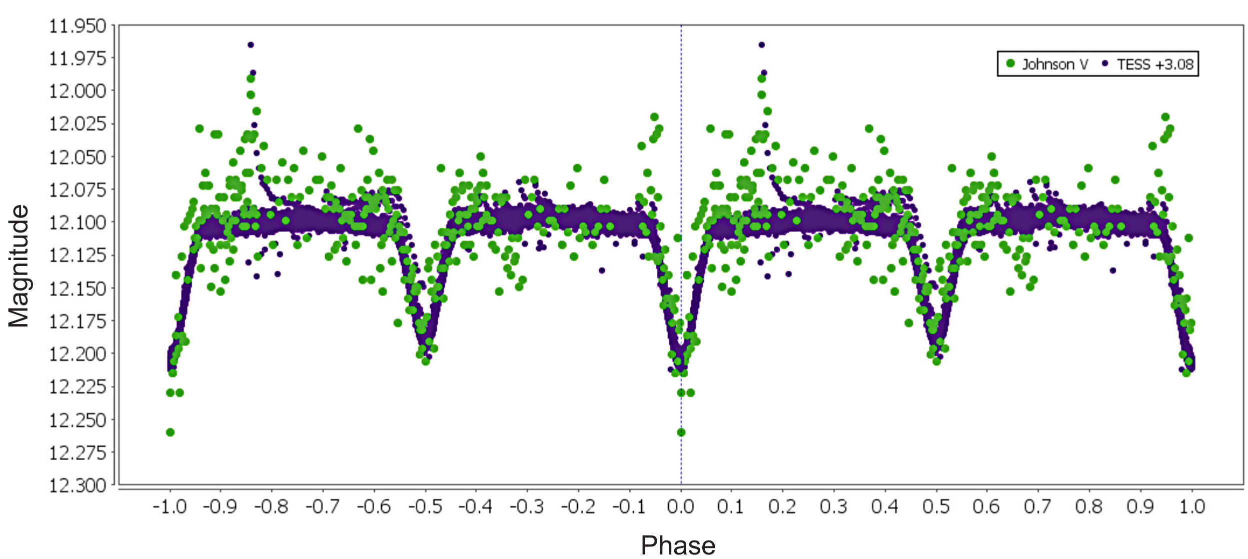

Figure 4. Phase plot for TIC 230386284 (period 0.341493, epoch 2458748.7177). The "de-blended" Johnson V light curve and the TESS light curve (baseline is shifted by 3.08 mag).

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