Searching for new white dwarf pulsators for TESS observations at Konkoly Observatory

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ABSTRACT
We present the results of our survey searching for new white dwarf pulsators for observations by the TESS space telescope. We collected photometric time-series data on 14 white dwarf variable-candidates at Konkoly Observatory, and found two new bright ZZ Ceti stars, namely EGGR 120 and WD 1310+583. We performed the Fourier-analysis of the datasets. In the case of EGGR 120, which was observed on one night only, we found one significant frequency at 1332 µHz with 2.3 mmag amplitude. We successfully observed WD 1310+583 on eight nights, and determined 17 significant frequencies by the whole dataset. Seven of them seem to be independent pulsation modes between 634 and 2740 µHz, and we performed preliminary asteroseismic investigations of the star utilizing six of these periods. We also identified three new light variables on the fields of white dwarf candidates: an eclipsing binary, a candidate delta Scuti/beta Cephei and a candidate W UMa-type star.

Key words: techniques: photometric – stars: individual: WD 1310+583, EGGR 120 – stars: oscillations – stars: interiors – white dwarfs

1 INTRODUCTION

The main goal of the TESS (Transiting Exoplanet Survey Satellite; Ricker et al. 2015) all-sky survey space project, as part of NASA’s Explorer programme, is to detect exoplanets at nearby and bright (up to about 15 magnitude) stars, applying the transit method. The telescope is planned to obtain data during a two-year time span, utilizing four CCD cameras, which provide a 24×96 degree field-of-view altogether. It will allow data acquisition with time samplings of 2 min for selected targets, with the possibility for 20 s sampling after commissioning. The shorter sampling times make the project feasible to obtain data for the investigations of the light variations of the short-period pulsating white dwarf (WD) and subdwarf stars, too.

In the frame of this ground-based photometric survey presented, we selected for observations white dwarf pulsator-candidates listed by the TESS Compact Pulsators Working Group (WG#8), which do not lie far from the ZZ Ceti or V777 Her instability domains. We note that a more extensive search has been presented by Raddi et al. (2017), where they have compiled an all-sky catalogue of ultraviolet, optical and infrared photometry, and presented data for almost 2000 bright white dwarfs and six ZZ Ceti candidates.

ZZCeti (or DAV) stars are short-period and low-amplitude pulsators with 10 000–13 000 K effective temperatures, while their hotter siblings, the V777 Her (or DBV) stars can be found at effective temperatures of roughly 22 000–31 000 K. Both show light variations caused by non-radiative g-mode pulsations with periods between ~100–1500 s, typically with ~1 mmag amplitudes. For reviews of the theoretical and observational aspects of pulsating white dwarf studies, see the papers of Fontaine & Brassard (2008), Winget & Kepler (2008), Althaus et al. (2010), and the recent review on ZZ Ceti pulsations based on Kepler observations of Hermes et al. (2017). We also refer to the theoretical work of Van Grootel et al. (2013), concerning the reconstruction of the boundaries of the empirical ZZ Ceti instability strip up to the domain of the extremely low-mass DA pulsators. In addition, we also mention the observations of the so-called ‘outburst’ events, which means recurring increases in the stellar flux in DAV stars being close to the red edge of the instability strip (see e.g. Bell et al. 2017).

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2 OBSERVATIONS AND DATA ANALYSIS

We performed the observations with the 1-m Ritchey-Chrétien-Coudé telescope located at Pizskésető6 mountain station of Konkoly Observatory, Hungary. We obtained data with an Andor iXon+888 EMCCDD and an FLI Proline 16803 CCD camera in white light. The exposure times were between 5 and 40 s, depending on the weather conditions and the brightness of the target.

Raw data frames were treated the standard way utilizing IRAF\(^1\) tasks: they were bias, dark and flat corrected before performing aperture photometry of field stars and low-order polynomial-fitting to the resulting light curves correcting for low-frequency atmospheric and instrumental effects. This latter smoothing of the light curves did not affect the known frequency domain of pulsating DA and DB stars. The comparison stars for the differential photometry were checked for variability or any kind of instrumental effects. Then, we converted the observational times of every data point to barycentric Julian dates in barycentric dynamical time (BJD\(_{\text{TDB}}\)) using the applet of Eastman et al. (2010)\(^2\).

We analysed the daily measurements with the command-line light curve fitting program LCfit (Sódor 2012). LCfit has linear (amplitudes and phases) and non-linear (amplitudes, phases and frequencies) least-squares fitting options, utilizing an implementation of the Levenberg-Marquardt least-squares fitting algorithm. The program can handle unequally spaced and gapped datasets and is scriptable easily.

We performed the standard Fourier analyses of the whole dataset on WD 1310+583 with the photometry modules of the Frequency Analysis and Mode Identification for Asteroseismology (FAMIAS) software package (Zima 2008). Remaining traditional (see Breger et al. 1993), we accepted a frequency peak as significant if its amplitude reached the 4 signal-to-noise ratio (S/N).

2.1 Target selection strategy

Our list of targets selected for observations is primarily based on the list of DAV and DBV candidate variables collected by the TESS Compact Pulsators Working Group No. 8 (WG#8) proposed for 20 s cadence observations. This list of targets were compiled by the Montréal White Dwarf Database (MWDD)\(^3\), which is a collection of white dwarf stars with their physical parameters, in many cases, originate from different authors. Thus, it presents an overall view on a target queried, including their atmospheric parameters, coordinates and brightness values in different bandpasses, and an optical spectrum. For a more detailed description of the MWDD, we refer to the paper of Dufour et al. (2017).

We chose variable candidates close to the DAV or DBV empirical instability strips considering their effective temperature (\(T\)\(_{\text{eff}}\)) and surface gravity (\(\log g\)), and altogether, 14 white dwarf variable candidates were observed in the March–November, 2017 term.

3 STARS SHOWING NO LIGHT VARIATIONS

12 out of the 14 stars in our sample were not observed to vary (NOV stars). We list the log of their observations in Table 1. We did not find any significant frequencies in their Fourier transform which would suggest that pulsation operates in them.

The significance levels for the different light curves were calculated by computing moving averages of the FTs of the measurements, which provided us an average amplitude level ((A)). If a target was observed on more than one night, we utilized the FT of all the available data. We considered a peak significant if it reached or exceeded the 4(A) level. Table 1 also summarizes these 4(A) significance levels in parentheses and in mmag units, found to be around 1–2 mmag in most cases.

We present representative light curves of these NOV stars and the FTs of the observations in Fig. 1 and in Appendix A1, respectively.

4 NEW VARIABLES

We successfully identified two new DA white dwarf variables (EGGR 120 and WD 1310+583) in our sample, and three new light variables of other types amongst the field stars: a candidate delta Scuti/beta Cephei, a candidate WUMa-type star and an eclipsing binary.

Table 2 shows the journal of observations of the new WD light variables.

4.1 EGGR 120

EGGR 120 (\(V = 14.8\) mag, \(\alpha_{2000} = 16^h39^m28^s\), \(\delta_{2000} = +33\deg 25\arcmin 22\arcsec\)) was found to be a light variable by one night of observation.

Figure 2 shows its light curve and the corresponding FT. We detected only one significant frequency at 1332 \(\mu\)Hz with 2.3 mmag amplitude. This frequency value corresponds to \(\sim 751\) s periodicity, which places this star in the class of cool DAV stars (Mukadam et al. 2006), in agreement with its low estimated effective temperature. We plan to observe the star during the next observing season to obtain a more complete picture on its pulsation properties.

4.2 WD 1310+583

WD 1310+583 (\(B = 13.9\) mag, \(\alpha_{2000} = 13^h12^m58^s\), \(\delta_{2000} = +58\deg 05\arcmin 11\arcsec\)) was observed on eight nights during the March–July, 2017 term. We performed most of the measurements in July, when during a one-week observing session six out of the seven nights were clear.

Figure 3 and Appendix B1 shows the light curves of observations and their FTs, respectively.

Considering the FTs, it is conspicuous that the amplitudes of frequencies vary from night-to-night. It might indicate real amplitude variations, that is, the energy content of some frequencies may vary in short time scales. Amplitude

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\(^1\) IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

\(^2\) http://astroouils.astronomy.ohio-state.edu/time/utc2bjd.html

\(^3\) http://dev.montrealwhitedwarfdatabase.org/home.html
Table 1. Summary of our observations of NOV stars performed at Piszkestetői mountain station. ‘Exp’ is the integration time used, \( N \) is the number of data points and \( \delta T \) is the length of the dataset including gaps. In the comment section, we list the \( 4\sigma \) significance levels in parentheses in mmag unit.

| Run   | UT Date   | Start time (BJD-2 450 000) | Exp. (s) | \( N \) | \( \delta T \) (h) | Comment |
|-------|-----------|----------------------------|----------|-------|----------------|---------|
| EGGR 116: | 01 Mar 21 | 7834.377                   | 30       | 1505  | 6.70           | NOV(1)  |
|       | 02 Mar 30 | 7843.371                   | 10       | 2350  | 6.54           |         |
| EGGR 162: | Sep 15   | 8012.298                   | 10       | 807   | 2.97           | NOV(1)  |
| EGGR 311: | Nov 14   | 8072.259                   | 30       | 679   | 6.28           | NOV(2)  |
|       | Nov 22   | 8080.188                   | 30       | 384   | 3.55           |         |
| GD 190:    | Apr 25   | 7869.336                   | 30       | 409   | 4.07           | NOV(4)  |
| GD 426:    | Oct 20   | 8047.431                   | 30       | 591   | 5.44           | NOV(2)  |
| GD 83:     | Nov 22   | 8080.339                   | 30       | 964   | 8.81           | NOV(2)  |
| HG 8-7:    | Oct 21   | 8048.480                   | 15       | 588   | 3.32           | NOV(2)  |
| PG 1026-024: | Mar. 16 | 7829.324                   | 10       | 1078  | 4.26           | NOV(3)  |
| WD 0129+458: | Oct 19 | 8046.221                   | 30       | 1131  | 10.84          | NOV(1)  |
|       | Oct 31   | 8058.353                   | 15       | 502   | 5.52           |         |
|       | Nov 15   | 8073.184                   | 30       | 1209  | 11.07          |         |
| WD 0145+234: | Oct 20 | 8047.219                   | 30       | 533   | 4.94           | NOV(2)  |
| WD 0449+252: | Oct 29 | 8056.401                   | 40       | 294   | 3.72           | NOV(2)  |
|       | Oct 30   | 8057.321                   | 30       | 827   | 8.79           |         |
| WD 0454+620: | Nov 15 | 8072.529                   | 10       | 1108  | 4.02           | NOV(1)  |

and phase variations are well-known phenomena amongst pulsating white dwarf stars, observed both from the ground (see e.g. the short overview of Handler 2003) and from space (e.g. GD 1212, Hermes et al. 2014). However, we have to be cautious in the interpretation of these phenomena as true changes in the amplitudes and phases, as the beating of closely spaced frequencies could also be a possible explanation.

The Fourier analysis of the whole dataset resulted in the determination of 17 frequencies, which are listed in Table 3. Considering the frequencies in Table 3, we determined closely spaced peaks with frequency separations of 0.08, 4.6 and 4.7 µHz. There are at least two possibilities: these are the results of short-term amplitude variations, or in the case of the similar, 4.6 and 4.7 µHz separations, rotationally split frequencies can be found at these domains.

There are also a bit widely spaced doublets, which could also originate from rotational splitting of frequencies. Their separations are 25.8, 27.6 and 29.8 µHz, that is, close to each other. Assuming that these are rotationally split \( l = 1 \) frequencies \((m = 0, 1 \text{ or } m = -1, 0 \text{ pairs})\), the star’s rotational period may be around 5 h, applying the equation as follows:

\[
\delta f_{k,\ell, m} = \delta m (1 - C_{k,\ell}) \Omega,
\]

where the coefficient \( C_{k,\ell} \approx 1/\ell(\ell + 1) \) for high-overtone \((k > \ell)\) g-modes and \( \Omega \) is the (uniform) rotation frequency.

Considering the 4.6 and 4.7 µHz separations, the star’s rotational period could be 1.3 d. As both rotation period values are acceptable for a white dwarf (see e.g. Fontaine & Brassard 2008 or Hermes et al. 2017), we cannot decide yet, which frequency separations we should consider as results of rotational splitting, if any. We also note that...
the daily (1 d\(^{-1} \approx 11.6 \mu Hz\)) alias problem also makes the determination of independent pulsation modes difficult.

In the case of the peaks around 1060 \(\mu \)Hz, we found many closely spaced frequencies in the FT of the whole dataset. Thus, we fitted the peaks with a Gaussian and decided to list the resulting maximum frequency and the function’s standard deviation at \(f_2\) in Table 3.

Finally, the frequencies we regard as independent modes are the following seven frequencies out of the 17 determined: \(f_1\), \(f_2\), \(f_4\), \(f_5\), \(f_6\), \(f_7\) and \(f_{12}\). We denoted them in the Fourier transform of the whole dataset in Fig. 4. Considering the large uncertainty in the frequency determination of \(f_2\), we did not use it as an input for asteroseismic investigations, but performed asteroseismic fits with the six remaining modes.

### 4.2.1 Preliminary asteroseismology

We built a model grid for the preliminary asteroseismic investigations of WD1310+583 utilizing the White Dwarf Evolution Code (\texttt{wdec}; Kutter & Savedoff 1969; Lamb 1974; Lamb & van Horn 1975; Winget 1981; Kawaler...
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Figure 3. Normalized differential light curves of the observations of WD 1310+583.

Figure 4. Fourier transform of the whole dataset obtained on WD 1310+583. We marked the frequencies that can be regarded as independent pulsation modes with blue dashed lines (cf. Table 3).

The wdec evolves a hot polytrope model (~ 10^5 K) down to the requested temperature, and provides an equilibrium, thermally relaxed solution to the stellar structure equations. Then we are able to calculate the set of possible eigenmodes according to the adiabatic equations of non-radial stellar oscillations (Unno et al. 1989).

We utilized the integrated evolution/pulsation form of the wdec code created by Metcalfe (2001) to derive the pulsation periods for the models with the given stellar parameters.

We calculated the periods of dipole (l = 1) and quadrupole (l = 2) modes for the model stars considering the limited visibility of high spherical degree (l) modes due to geometric cancellation effects. The goodness of the fit between the observed (P_{obs}) and calculated (P_{calc}) periods was characterized by the root mean square ($\sigma_{rms}$) value calculated for every model with the fitper program of Kim (2007):

$$\sigma_{rms} = \sqrt{\frac{\sum_{i=1}^{N} (P_{calc} - P_{obs})^2}{N}}$$  \hspace{1cm} (2)

where $N$ is the number of observed periods.

We built our model grid using the core composition pro-
files of Salaris et al. (1997) based on evolutionary calculations. We varied three input parameters of the WDEC: \( T_{\text{eff}} \), \( M_1 \) and \( M_2 \). The grid covers the parameter range 10200 – 12000 K in \( T_{\text{eff}} \), 0.55 – 0.85 \( M_1 \) in stellar mass, \( 10^{-4} – 10^{-9} M_1 \) in \( M_2 \), and we fixed the mass of the helium layer at the theoretical maximum value of \( 10^{-2} M_1 \). We used step sizes of 100 K (\( T_{\text{eff}} \)), 0.01 \( M_1 \) (\( M_1 \)) and 0.2 dex (\( \log M_2 \)).

The mass of WD 1310+583 (\( \log g = 8.17 \) by optical spectroscopy) was determined utilizing the theoretical masses calculated for DA stars by Bradley (1996), which resulted 0.7 \( M_1 \). The effective temperature of the star is derived to be 10 460 K with about 200 K uncertainty value in the optical. However, based on far-ultraviolet (FUV) spectroscopy, it turned out that WD 1310+583 may be a double degenerate binary system, in which one component with about 11 600 K effective temperature is close to the middle of the ZZ Ceti instability strip, while the other component may be much cooler, about \( T_{\text{eff}} = 7900 \) K (Gentile Fusillo et al. 2018). Furthermore, utilizing the time-tag information in the FUV spectrum, Gentile Fusillo et al. (2018) determined two pulsation frequencies of WD 1310+583 at 391 and 546 s, respectively. We did not find them in our measurements, thus these may represent new pulsation frequencies besides our findings.

We found, that utilizing our model grid, the best-fitting model (model with the lowest \( \sigma_{\text{rms}} \) value) has stellar mass higher than the value determined by optical spectroscopy (0.78 \( M_1 \)), but its effective temperature is close to the value calculated from the optical spectrum (10 400 K). However, note that in this case the dominant mode is \( l = 2 \). Assuming that at least four of the modes is \( l = 1 \) (including the dominant frequency), considering the better visibility of \( l = 1 \) modes over \( l = 2 \) ones, the best-fitting model has \( T_{\text{eff}} = 11 600 \) K and \( M_1 = 0.74 \( M_1 \) (\( \sigma_{\text{rms}} = 1.3 \) s). That is, this solution has stellar mass close to the value determined by optical spectroscopy, but its effective temperature fits better to the value calculated from the FUV fitting.

We tried another fit adding the two frequencies found by Gentile Fusillo et al. (2018), that is, we fitted eight periods with the calculated ones. In this case, the best-fitting model has \( T_{\text{eff}} = 11 900 \) K and \( M_1 = 0.80 \( M_1 \) (\( \sigma_{\text{rms}} = 1.6 \) s). This is also the best-fitting model assuming that at least five of the modes is \( l = 1 \).

We summarized our model findings in Table 4. Considering the effective temperatures of the best-fitting models, they seem to confirm the higher value determined by FUV observations. The relatively large amplitude pulsations also support the idea that the pulsating component of the WD 1310+583 system may be closer to the middle of the ZZ Ceti instability strip, than it is at the red edge (cf. Hermes et al. 2017).

### 4.3 New variables of other types

We identified an eclipsing binary on the field of WD 0129+458, a delta Scuti/beta Cephei candidate on the field of WD 0454+620, and a W UMa variable candidate on the field of GD 83. Their distances to the white dwarfs are \( \sim 4.4, 3.2 \) and 1.5 arcmin, that is, they do not contaminate the large (\( \sim 21 \) arcsec) TESS pixels.

### Table 2. Summary of our observations performed at Piszkesteti mountain station on the new light variable WD stars. ‘Exp’ is the integration time used, \( N \) is the number of data points and \( \delta T \) is the length of the data sets including gaps.

| Run | UT Date | Start time (BJD-2 450 000) | Exp. | \( N \) | \( \delta T \) (h) |
|-----|---------|--------------------------|------|------|------------------|
| WD 1310+583: | | | | | |
| 01 | Mar 31 | 7844.296 | 10 | 2778 | 8.40 |
| 02 | Apr 24 | 7868.332 | 10 | 782 | 3.13 |
| 03 | Jul 13 | 7948.331 | 20 | 831 | 5.48 |
| 04 | Jul 14 | 7949.405 | 30 | 388 | 3.61 |
| 05 | Jul 16 | 7951.316 | 30 | 618 | 5.67 |
| 06 | Jul 17 | 7952.342 | 20 | 465 | 2.98 |
| 07 | Jul 18 | 7953.326 | 20 | 824 | 5.23 |
| 08 | Jul 19 | 7954.314 | 20 | 705 | 4.53 |
| Total: | | | | | 7391 | 39.02 |

EGGR 120: | | | | | |
| 01 | Apr 3 | 7847.407 | 10 | 2002 | 5.56 |

Figure 5. Light curve of the eclipsing binary found on the field of WD 0129+458.

Figure 6. Light curve and its Fourier transform of the variable found on the field of WD 0454+620.

Figure 7. Light curve and its Fourier transform of the WUMa-type variable candidate found on the field of GD 83.
Table 3. WD 1310+583: result of the Fourier-analysis of the whole dataset. The frequencies are listed in the order of the pre-whitening procedure. Error value for $f_2$ is the standard deviation of the Gaussian fitted to the peaks found around this frequency, while in the other cases errors were derived by Monte Carlo simulations.

| $f$ | $\delta f$ | $P$ | Ampl. | Phase | S/N | Comment |
|-----|------------|-----|-------|-------|-----|---------|
| $f_1$ | 1439.858 | 0.001 | 694.51 | 12.8 | 0.63 | 16.4 |
| $f_2$ | 1063.102 | 45 | 940.64 | – | – | – |
| $f_3$ | 1451.478 | 0.003 | 688.95 | 8.1 | 0.87 | 10.5 | $\sim f_1 + 1 \text{ d}^{-1}$ |
| $f_4$ | 1958.452 | 0.001 | 510.61 | 6.9 | 0.16 | 9.8 |
| $f_5$ | 1751.226 | 0.009 | 571.03 | 6.3 | 0.79 | 8.8 |
| $f_6$ | 2739.544 | 0.002 | 365.02 | 6.3 | 0.79 | 10.2 |
| $f_7$ | 963.032 | 0.003 | 1038.39 | 7.0 | 0.86 | 9.9 |
| $f_8$ | 967.347 | 0.004 | 1033.76 | 5.9 | 0.27 | 8.1 | close to $f_1$ |
| $f_9$ | 1751.155 | 0.010 | 571.05 | 5.4 | 0.88 | 7.6 | close to $f_1$ |
| $f_{10}$ | 1469.611 | 0.003 | 680.45 | 3.6 | 0.69 | 4.6 | close to $f_1$ |
| $f_{11}$ | 1037.324 | 0.002 | 964.02 | 5.0 | 0.72 | 5.7 | close to $f_2$ |
| $f_{12}$ | 633.984 | 0.005 | 1577.33 | 6.6 | 0.11 | 8.1 |
| $f_{13}$ | 632.088 | 0.006 | 1582.06 | 5.6 | 0.83 | 6.8 | close to $f_{12}$ |
| $f_{14}$ | 2767.140 | 0.003 | 361.38 | 3.0 | 0.91 | 4.8 | close to $f_{6}$ |
| $f_{15}$ | 2890.388 | 0.003 | 345.97 | 2.6 | 0.17 | 4.7 | $2 f_1 + 1 \text{ d}^{-1}$ |
| $f_{16}$ | 3197.877 | 0.004 | 312.71 | 2.3 | 0.22 | 4.3 | $\sim f_1 + f_2$ |
| $f_{17}$ | 4493.635 | 0.005 | 222.54 | 1.6 | 0.97 | 4.4 | $\sim f_5 + f_6$ |

Table 4. Best-fitting models for WD 1310+583 derived by seven periods (first two rows) and nine periods (third row).

| $T_{\text{eff}}$ (K) | $M_*/M_{\odot}$ | $-\log M_\text{BH}$ | Periods in seconds (l) | $\sigma_{\text{ms}}$ |
|---------------------|-----------------|----------------------|-----------------------|------------------|
| 10 400              | 0.78            | 8.2                  | 364.9(1) 510.6(2) 569.9(1) 694.2(2) 1038.7(2) 1579.8(1) | 1.1 |
| 11 600              | 0.74            | 4.0                  | 364.5(1) 508.9(2) 569.9(1) 694.5(1) 1037.1(2) 1576.2(1) | 1.3 |
| 11 900              | 0.80            | 7.6                  | 362.1(1) 511.3(1) 572.2(2) 692.3(1) 1038.2(1) 1575.7(1) | 389.2(2) 545.7(2) 1.6 |

Observations:

|              | $T_{\text{eff}}$ (K) | $M_*/M_{\odot}$ | $-\log M_\text{BH}$ |
|--------------|----------------------|-----------------|----------------------|
| 365.0        | 510.6                | 571.0           | 694.5                |
| 10 400       | 13100                | 7.87$^d$        | 13.6(l)             |
| 11 600       | 13100                | 8.02$^d$        | 15.6                |
| 11 900       | 13100                | 7.95$^d$        | 14.5                |
| 10 400       | 13100                | 8.03$^d$        | 14.9(l)             |
| 11 600       | 13100                | 8.05$^d$        | 13.6(l)             |
| 11 900       | 13100                | 7.93$^d$        | 14.9(l)             |
| 10 400       | 13100                | 8.02$^d$        | 14.9(V)             |
| 11 600       | 13100                | 8.06$^d$        | 14.1(V)             |
| 11 900       | 13100                | 7.99$^d$        | 14.3(l)             |
| 10 400       | 13100                | 8.13$^d$        | 14.2                |
| 11 600       | 13100                | 8.09$^d$        | 14.9(V)             |
| 11 900       | 13100                | 8.02$^d$        | 14.9(V)             |
| 10 400       | 13100                | 8.02$^d$        | 14.9(V)             |

4.3.1 Eclipsing binary

We could observe one eclipse only (see Fig. 5). We tried to catch another minimum during further observations, but we did not succeed. Thus, we cannot tell at this moment, whether we saw a main or a secondary minimum in our light curve. The star’s 2MASS identifier is 01323981+4600441 ($J = 12.4 \text{ mag}$, $\alpha_{2000} = 0^h32^m40^s$, $\delta_{2000} = +46^d00^m44^s$; Cutri et al. 2003).

4.3.2 Delta Scuti/beta Cephei variable candidate

We found one significant frequency of the light variation of this star at 15.7 d$^{-1}$ ($\sim$1.5 h) with 13 mmag amplitude (Fig. 6). This pulsational behaviour could be typical both for delta Scuti and beta Cephei stars, respectively. Colour or spectroscopical measurements could help to decide which type of pulsating variables this object belongs to, however, none of them are available at this moment. Its 2MASS identifier is 05458888+6212098 ($J = 12.0 \text{ mag}$, $\alpha_{2000} = 0^h45^m38^s49^s$, $\delta_{2000} = +62^d12^m10^s$).

4.3.3 W UMa variable candidate

Further finding is a W UMa-type variable candidate. Figure 7 shows its light curve and Fourier spectrum. The dominant periodicity is at 6.75 d$^{-1}$ ($\sim$0.15 d). The star’s 2MASS identifier is 07131730+2135152 ($J = 14.5 \text{ mag}$, $\alpha_{2000} = 0^h13^m17^s$, $\delta_{2000} = +21^d35^m15^s$).
5 SUMMARY AND CONCLUSIONS

We aimed to perform survey observations to find new white dwarf pulsators for the TESS mission. For this purpose, we collected photometric time-series data on 14 white dwarf variable-candidates at Konkoly Observatory during the March–November term in 2017. Besides the visual inspection of the light curves, we performed Fourier analysis of all datasets and successfully identified two new ZZ Ceti stars: EGGR 120 and WD 1310+583. In the case of EGGR 120, which was observed on one night only, we found one significant frequency at 1332 µHz with 2.3 mmag amplitude. We could observe WD 1310+583 on eight nights altogether, and determined 17 significant frequencies by the whole dataset. Seven of them seems to be independent pulsation modes between 634 and 2740 µHz frequencies, and we performed preliminary asteroseismic investigations of the star utilizing six of these periods.

We also identified three new variables on the fields of white dwarf candidates: an eclipsing binary, a delta Scuti/beta Cephei candidate and a W UMa-type star. The periods of their light variations are long enough that the 30 min time sampling of the full-frame images (FFIs) of TESS will be enough to study their pulsations and eclipses.

Figure 8 shows the classical ZZ Ceti instability strip with plots of the known DAV stars (red filled dots) and the stars presented in this paper (green and blue dots with errorbars, respectively). We collected the atmospheric parameters of known DAV stars utilizing the database of Bognár & Sógor (2016), in which the authors listed corrected $T_{\text{eff}}$ and log $g$ values for the three-dimensional dependence of convection for most of the objects. In Table 5 we summarize the physical parameters of the 14 targets observed in our survey.

The newly discovered, relatively bright WD variables are excellent targets for small telescopes, especially WD 1310+583, which shows larger amplitude light variations than EGGR 120. Considering Fig. 8, they lie close to the middle and the red edge of the ZZ Ceti instability domain, respectively, with good agreement with their pulsational properties: relatively long periods, non-sinusoidal light curves, and in the case of the longer observed WD 1310+583, the closely spaced frequencies suggests the presence of amplitude and phase variations. With space photometry and additional ground-based follow-up observations planned, hopefully, we will learn much more about they pulsation behaviour in the near future.

Considering all the proposed white dwarf targets for TESS observations, almost all of them have only been observed from the ground up to now. Sometimes these observations are even limited to the usually short discovery light curves. The 27-d or longer, uninterrupted TESS measurements will outperform most of the available data on these bright pulsators. Data simulations also show, that in terms of signal-to-noise ratio, considering equal monitoring time, TESS data are expected to be roughly equivalent to Kepler data obtained for stars five magnitudes fainter. Besides, taking into account that pulsating white dwarfs down to magnitude 19 have successfully been observed with $K_2$, this suggests that TESS can provide useful data at least down to magnitude $\sim 15$.

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Figure 8. Known variable stars (red filled dots) and the newly observed ZZ Ceti candidates and DAVs (green and blue dots, respectively) in the $T_{\text{eff}} - \log g$ diagram. Blue and red dashed lines denote the hot and cool boundaries of the instability strip, according to Tremblay et al. (2015). In the case of WD 1310+583, the double degenerate solution assumes two white dwarfs with fixed $\log g = 8.0$ dex values. The effective temperature was determined by the simultaneous fitting of both the optical spectrum and the FUV to near-infrared photometric data with two white dwarf models (Gentile Fusillo et al. 2018).

APPENDIX B:

Figure B1: Fourier transforms of the nightly observations of WD 1310+583. Blue lines denote the 4(A) significance levels.

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APPENDIX A:

Figure A1: Fourier transforms of the light curves of NOV stars. Blue lines denote the 4(A) significance level for the detection of possible pulsation frequencies.

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Figure A1. Fourier transforms of the light curves of NOV stars. Blue lines denote the 4(A) significance level for the detection of possible pulsation frequencies.
Figure B1. Fourier transforms of the nightly observations of WD 1310+583.