BRITE photometry of seven B-type stars

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We present the time series analysis of seven B-type stars observed with the BRITE satellites. Furthermore, we located these stars in the Hertzsprung-Russell-diagram. One rotational induced variable (HD 122980, $P \approx 80$ d) and one binary (HD 145502, $P \approx 5.6$ d) showing variability due to ellipsoidal variation and/or reflection were detected.

1 Introduction

For B-type stars on the Main Sequence (MS) without any signs of activity, we find pulsators, rotational and binarity induced variability. There are β Cephei stars with periods between 3 and 8 hours of spectral type O9 to B3 which pulsate in low-order pressure (p) or gravity (g) modes (Neilson & Ignace, 2015). In addition, Slowly Pulsating B-type stars are objects which exhibit multi-periodic, high-order, and low-degree g-modes with periods of about 1 d (Jerzykiewicz et al., 2013).

The magnetic chemically peculiar (CP) stars of the upper MS are characterized by peculiar and often variable line strengths as well as photometric variability with the same periodicity and coincidence of extrema. Due to the chemical abundance concentrations at the magnetic poles, the show photometric variabilities correlated to the rotational period (Bernhard et al., 2015).

Binaries show all types of variability from eclipses, ellipsoidal or reflection variables, just to mention a few.

We investigated the BRITE light curves of seven B-type stars for variability.

2 Reduction and data analysis

The reductions of the photometric data of the BRITE satellites were carried out with a pipeline that takes into account bad pixels, median column counts, image motion, and PSF variations (Popowicz et al., 2016). The photometry still needs to be decorrelated for several factors, for example temperature variations within the satellites and detectors during the orbit and on longer time scales, before a scientific analyses of the intrinsic stellar variability can be done. We applied the basic process of decorrelation as has been described in detail by Pigulski et al. (2016).

The data were obtained with four out of the five satellites: BRITE-Austria (hereafter BAb), BRITE-Heweliusz (BHr), BRITE-Toronto (BTr), and UniBRITE (UBr). The first satellite observes through the blue filter, the latter three use the red one.

The light curves were examined in more detail using the PERIOD04 program (Lenz & Breger, 2005). The results were checked with those from the CLEANEST and

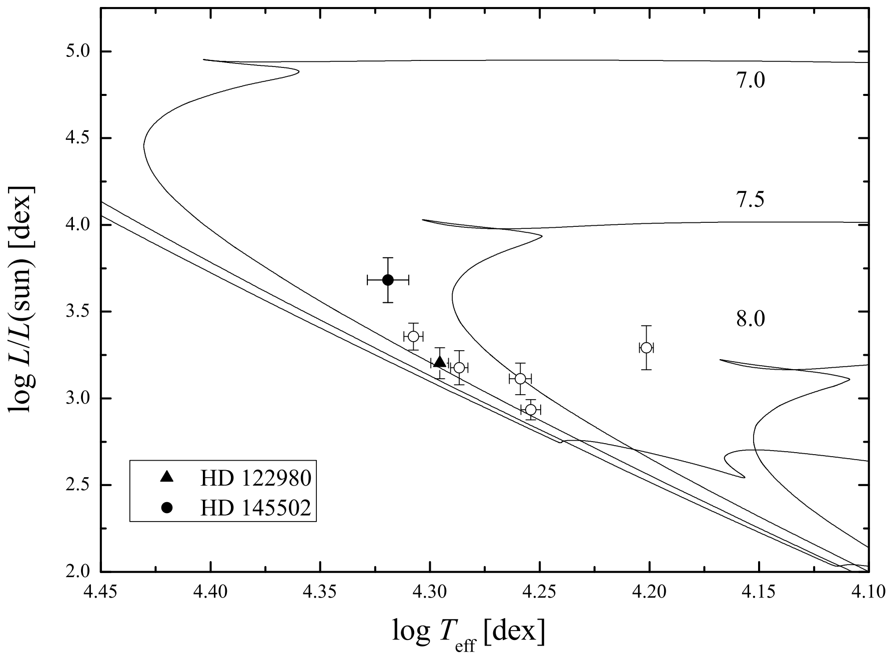

Fig. 1: The location of the targets stars (Table 1) in a $\log L/L_{\odot}$ versus $\log T_{\mathrm{eff}}$ diagram together with the PARSEC isochrones (Bressan et al., 2012) for solar metallicity ([Z] = 0.019). HD 122980 and HD 145502 are the stars for which we detected variability.

Phase-Dispersion-Method computed within the programme package Peranso (Paunzen & Vanmunster, 2016). The differences for the these methods are within the derived errors depending on the time series characteristics, i.e. the distribution of the measurements over time and the photon noise. If several data sets for one satellite were available, they were split and also separately analysed.

As next step, for the location of our programme stars in the Hertzsprung-Russell-diagram, the effective temperature (T_{eff}) and luminosity ($\log L/L_{\odot}$) has to be derived.

First of all, the reddening (or total extinction A_{V}) was estimated using photometric calibrations in the Strömgren-Crawford $uvby\beta$ (Crawford, 1978) and the Q parameter within the Johnson UBV system (Johnson, 1958). These methods are only based on photometric indices and do not take into account any distance estimates via parallax measurements. The agreement is very good indicating that photometric measurements within both systems are intrinsically consistent.

The T_{eff} for the individual stars were calibrated by using the measurements in the Johnson, Geneva 7-colour, and Strömgren-Crawford photometric systems. This approach was chosen because it guarantees the most homogeneous result. Taking T_{eff} values from the literature, for example on the basis of spectroscopy, introduces all types of unknown biases. Those are the usage of different stellar atmospheres, spectral resolution, analytic methods and so on. For the estimation of T_{eff}, the following calibrations were used:

- Geneva 7-colour system: Cramer (1984, 1999); Kunzli et al. (1997), based on

Table 1: Characteristics and astrophysical parameters of the targets.

HD	HIP	Spec.	A_V [mag]	$\log T_{\rm eff}$ [dex]	$\log L/L_\odot$ [dex]	$v\sin i$ [km s^{-1}]
121790	68282	B2 V	0.048	4.307(4)	3.36(8)	124
122980	68862	B2 V	0.064	4.296(4)	3.20(9)	18
129116	71865	B3 V	0.073	4.254(4)	2.93(6)	
133242	73807	B5 V	0.081	4.201(3)	3.29(13)	140
144294	78918	B2.5 V	0.071	4.259(5)	3.11(9)	295
145482	79404	B2 V	0.169	4.287(4)	3.18(10)	183
145502	79374	B2 V	0.842	4.319(9)	3.68(13)	155

the reddening free parameters X and Y which are valid for spectral types hotter than approximately A0. The results are therefore independent of the estimation of A_V for the program stars.

- Johnson system: based on the Q values for luminosity class III and V objects according to the Tables listed by Aller et al. (1982). The $(B-V)_0$ values for those luminosity classes were transformed into effective temperatures using the results by Code et al. (1976, Table 7).
- Strömgren-Crawford system: Napiwotzki et al. (1993), based on the unreddened $[u-b]$ colour.

The individual effective temperature values within each photometric system were first checked for their intrinsic consistency and then averaged.

The absolute magnitude ($M_{\rm V}$) were directly calculated from the astrometric parallaxes (π) of the Hipparcos mission (van Leeuwen, 2007) using the basic formula $M_{\rm V} = m_{\rm V} + 5\,(\log\pi + 1) - A_{\rm V}$.

We used the $m_{\rm V}$ magnitudes as given by Kharchenko (2001) who transformed the Tycho data to the Johnson system. This is the most homogeneous available sample for this data type. The bolometric corrections were taken from Flower (1996) and an absolute bolometric magnitude of the Sun as $M_{\rm Bol}(\odot) = 4.75$ mag was used. For the error estimate of $\log L/L_\odot$, only the error of the parallax was taken into account.

The given spectral types are the best estimates from the extensive compilation by Skiff (2014) whereas the projected rotational velocities ($v\sin i$) are based on an updated version of the catalogue by Glebocki et al. (2000).

3 Discussion

The derived astrophysical parameters about the target stars is listed in Table 1. The errors in the final digits of the corresponding quantity are given in parentheses.

Figure 1 shows the location of the targets stars (Table 1) in a $\log L/L_\odot$ versus $\log T_{\rm eff}$ diagram together with the PARSEC isochrones (Bressan et al., 2012) for solar metallicity ($[Z] = 0.019$ dex). Only one star, HD 133242, is evolved on the Zero Age MS but still is well before the Terminal Age MS. All other stars have ages $\log t < 7.5$ dex. In the following we discuss the individual objects in more detail.

HD 121790: Telting et al. (2006) during their survey for β Cephei pulsation of bright stars, found indications of spectroscopic variability with a line depth of 3%,

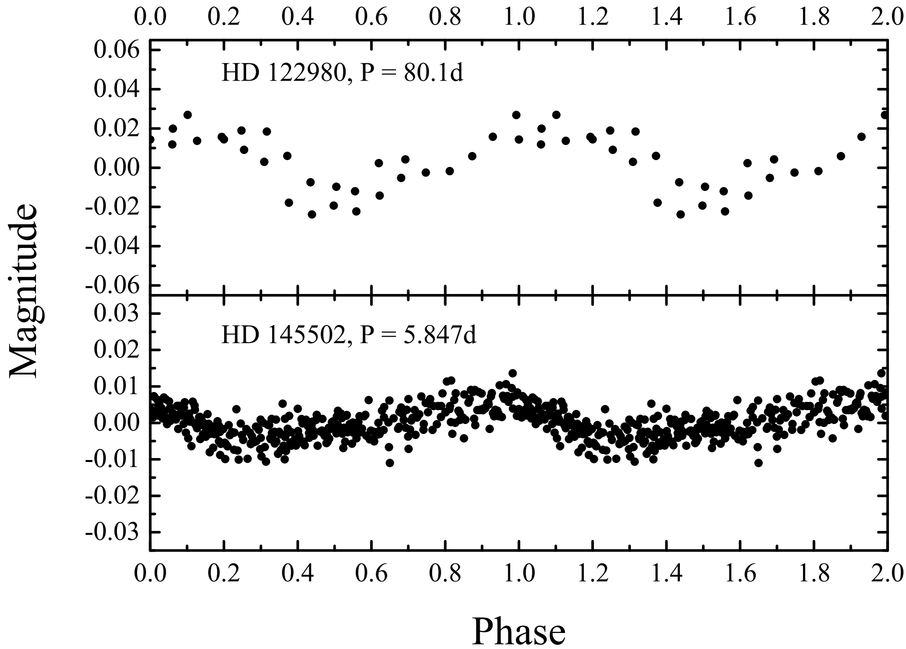

Fig. 2: The phase binned light curves for HD 122980 (5 d binning of data) and HD 145502 (90 min binning of data). HD 145502 is known spectroscopic binary system has an orbital period of 5.5521 d (0.18 d^{-1}).

only. They published a $v \sin i$ value of 124 $\mathrm{km\,s}^{-1}$. Only following upper limits for photometric variability were found: BAb: 2 mmag; BTr: 0.9 mmag, and UBr: 5 mmag. No signs of β Cephei type pulsations could be detected within the available data sets.

HD 122980: with a $v \sin i$ value of only 18 $\mathrm{km\,s}^{-1}$, one is tempted to think of a chemically peculiarity for this star. If so, it would fall in the group of magnetic Helium peculiar stars (Cidale et al., 2007). And indeed, Slettebak (1968) found that the forbidden He I 4469.9Å line is very strong in HD 122980, but still this classification has to be confirmed. However, no magnetic field measurements are available, yet. For a B2 V star (Table 1), seen equator-on, we estimate a rotational period of about 140 d (0.007 d^{-1}) which is the time base of the longest data set (UBr). We therefore binned the data from 0.1 to 10 d and searched for rotational induced variability. Figure 2 shows the phase binned data (5 d) for a period of 80.1 d (0.0125 d^{-1})). The variation is clearly visible implying $i \approx 35^{\circ}$. Furthermore, Percy (1974) listed a possible β Cephei type variability with a period of 0.035 d (28.6 d^{-1}). This period is very close to two times of the satellites orbital period and therefore very hard to detect. However, Balona (1982) presented time series of five nights in Johnson B and concluded that it is constant within a few thousands of magnitudes over several hours. We detected no signs of variability in this period domain with the following upper limits: BAb: 2 mmag, BTr: 0.8 mmag, and UBr: 5 mmag.

HD 129116: This star was often used as standard star for several photometric systems (Strauss & Ducati, 1981). Up to now, no report about apparent variability was published, yet. No significant frequencies were detected with upper limits of: BAb: 3 mmag, BTr: 0.8 mmag, and UBr: 4 mmag.

HD 133242: A close binary system, resolved by speckle observations (Horch et al., 2006). No variations with an upper limit of 0.8 mmag (BTr) were detected.

HD 144294: It has the highest $v \sin i$ value (295 $\mathrm{km\,s^{-1}}$) among the sample. No variability was reported so far. The six data sets show only upper limits between 0.9 to 4.6 mmag, respectively.

HD 145482: This spectroscopic binary system was also investigated by Telting et al. (2006) who found no traces of variability. This result is confirmed with the available photometry. An upper limit of 1.2 mmag (BHr) was deduced.

HD 145502: Only an upper limit (45 G) for a magnetic field was detected (Bychkov et al., 2009) for this spectroscopic binary system. The orbital period is determined by Levato et al. (1987) as 5.5521 d (0.18 $\mathrm{d^{-1}}$). The BLb data only yield upper limits between 30 and 60 mmag, but the UBr data clearly show a variation with a period between 0.17 and 0.18 $\mathrm{d^{-1}}$. Figure 2 shows the phase binned light curves for one of the data sets. For the time series analysis, the original data were binned to a time resolution of 90 min. We assume that ellipsoidal variation and/or reflection are the causes of the photometric variability. Further spectroscopic data are needed to further analyse the reasons of variations for HD 145502.

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