An asteroseismic study of the β Cephei CoRoT main target HD 180642: results from the ground-based campaign


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Abstract. The β Cephei star HD 180642 was observed by the CoRoT satellite during a run of 156 days in 2007. The space white light photometry revealed the rich frequency spectrum of the star (Degroote et al. 2009). In the present study, we provide additional information on the target, based on both ground-based multi-colour photometry and high-resolution spectroscopy. We place our object in the (Teff, log g) diagram. In addition, we derive the chemical abundances of several elements as well as the metallicity of HD 180642. Finally, we put constraints on the identification of some modes. All these observational constraints will be used to compute stellar models of the target.

Keywords: stars: oscillations – stars: early-type – stars: individual: HD 180642 – stars: abundances
PACS: 90

INTRODUCTION

The B 1.5 II–III star HD 180642 (V1449 Aql, HIP 94793, V = 8.29 mag) was discovered as a candidate β Cephei star by means of Hipparcos measurements (Waelkens et al. [1]). Its β Cephei nature was afterwards confirmed by Aerts [2] who used Geneva photometry to identify its dominant mode as a radial one.

Recently, this object was observed by the CoRoT satellite during a run of 156 days between May and October 2007. A detailed modeling and interpretation of the space white-light photometry was presented in Degroote et al. [3] and revealed the star to be multi-periodic with at least 11 independent frequencies.

To complement the CoRoT information, ground-based multi-colour photometry and high-resolution spectroscopy were collected for selected primary and secondary CoRoT targets, and we refer to Poretti et al. [4] and Uytterhoeven et al. [5][6] for a description of this project. In this paper, we report on the analysis results based on the ground-based datasets of HD 180642. A more detailed description can be found in Briquet et al. [7].

The results of both the space-based and ground-based observations will be used to perform an asteroseismic modeling of our studied target. This will be presented in a forthcoming paper (Thoul et al., in prep.).

PHOTOMETRY

Several telescopes with multi-colour photometric instruments are involved in this work. Strömgren ubvy photometry was collected with the 90cm telescope at Sierra
data, respectively. Finally, we also constructed a more extensive visual band lightcurve by adding also the Johnson $V$ data to the Geneva $V$ and Strömgren $y$ data.

By applying the SCARGLE (Scargle [8]) method to the combined datasets, we first detected the variations due to the main mode with $f_1 = 5.48694 \, \text{d}^{-1}$, $2f_1$ and $3f_1$. The corresponding amplitudes in the combined $U$ filter are $82.7(7)$, $8.2(7)$ and $4.3(7)$ mmag. Afterwards, we also found two additional significant frequencies $f_2 = 0.30818(5) \, \text{d}^{-1}$ and $f_3 = 7.36673(7) \, \text{d}^{-1}$ with an amplitude of $4.9(7)$ and $4.5(7)$ mmag in the combined $U$ filter, respectively.

To identify the modes, we applied the usual method of photometric amplitude ratios, using the formalism of Dupret et al. [9]. We computed the non-adiabatic eigenfunctions and eigenfrequencies by using the code called MAD (Dupret et al. [10]). To this end, all the models were computed with the Code Liégeois d’Évolution Stellaire (CLES, Scuflaire et al. [11]). We refer to Briquet et al. [7] for details of the input physics adopted. The outcome of the photometric mode identification confirms that the dominant mode is a radial one as already ascertained by Aerts [2]. In addition, we conclude that $f_2^* = 0.30818(5) \, \text{d}^{-1}$ and $f_3^* = 7.36673(7) \, \text{d}^{-1}$ with an amplitude of $4.9(7)$ and $4.5(7)$ mmag in the combined $U$ filter, respectively.

SPECTROSCOPY

In the framework of the CoRoT ground-based Large Programme (e.g., Uytterhoeven & Poretti [12]; Uytterhoeven et al. [5][6]), aimed at the follow-up of selected CoRoT targets, HD 180642 was observed with the FEROS spectrograph at the 2.2m telescope at ESOn La Silla. The target was also monitored with the SOPHIE (1.93m telescope) and Aurélie (1.52m telescope) spectrographs, both situated at the Haute-Provence observatory. A logbook of the observations is shown in Table 2 of Uytterhoeven et al. [5].

To increase the frequency precision, we combined datasets for given filters whenever possible. First, we merged the Strömgren data of both sites. Second, we constructed ultraviolet, blue, and visual ground-based lightcurves (combined $U, B, V$ data hereafter) by merging the Geneva $U$ and Strömgren $u, B$ and $v$, and $V$ and $y$ data, respectively. Finally, we also constructed a more extensive visual band lightcurve by adding also the Johnson $V$ data to the Geneva $V$ and Strömgren $y$ data.

As explained and illustrated in Zima [20] and Briquet et al. [7], usual spectroscopic mode identification techniques, as implemented in FAMIAS, cannot be applied in case of a large pulsation velocity relative to the projected rotational velocity, i.e., if the radial velocity amplitude is above $0.2 \, \text{vsin}i$, as for HD 180642. However, a successful outcome for one of the modes was achieved by means of the moment method of Aerts [21], which we slightly adapted to our case. We used the discriminant of the latter author but taking into account only the amplitudes denoted by C, D, F, and G (see Aerts [21]). In this way we avoid the amplitudes involving the width $\sigma$ of the intrinsic profile which is not constant in time, in contrast to the assumption in Aerts [21]. The discriminant values for the identified mode are given in Table 1. We found the frequency $8.4079 \, \text{d}^{-1}$ to correspond to a $(\ell, m) = (3, 2)$. Finally, we derived a value for the equatorial rotational velocity of $\nu_{eq} = 38 \pm 15 \, \text{km s}^{-1}$.  

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TABLE 1. The bestfit solutions of the spectroscopic mode identification for the mode with frequency 8.4079 d^{-1} determined by the adapted discriminant $\Sigma$, based on the definition in Aerts [21]. The inclination angle $i$ is expressed in degrees; $\sin i$ is the projected rotational velocity, expressed in km s^{-1}; $v_r\max$ and $v_t\max$ are, respectively, the maximum radial and tangential surface velocity due to the mode, expressed in km s^{-1}.

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<th>$\sin i$</th>
<th>$v_r\max$</th>
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