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Ground-based observations of the β Cephei CoRoT main target HD 180642

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Abstract

We present the preliminary results of a detailed study of ground-based photometric and spectroscopic observations dedicated to the β Cephei CoRoT main target HD 180642. Besides the non-linear dominant radial mode several low-amplitude modes are detected in both kinds of datasets. Our aim is to derive the wavenumbers (ℓ, m) of these modes, as additional constraints to the CoRoT pulsation frequencies, for forthcoming asteroseismic modelling of the star.

Individual Objects: HD 180642

Introduction

The B 1.5 II-III star HD 180642 (V1449 Aql, HIP 94793, m_v = 8.27) is the only known β Cephei star in CoRoT's core programme. It has been observed by the satellite during a long run (some 150 days) from May to October 2007. The star presents a dominant non-linear mode with an amplitude of ~40 mmag together with several modes of much lower amplitudes (below 4 mmag). Fourier periodograms of its CoRoT lightcurve are displayed in Michel et al. (2008) and are not repeated here. Numerous frequencies are found in the CoRoT lightcurve, among which harmonics and combination frequencies. Its full analysis will be published elsewhere (Degroote et al., in preparation).

To complement the space white light data, both ground-based photometric and spectroscopic data were collected, to which we added several archival observations. In total, we

Table 1: Logbook of the spectroscopic observations. For each instrument we give the number of spectra N, the time-span ΔT in days, the average S/N-ratio and the resolution of the spectrograph.

Instrument	N	ΔT	<S/N>	resolution
FEROS	223	967.5	186	48 000
SOPHIE	35	10.1	106	40 000
Aurélie	22	8.1	93	25 000

made use of 507 high-quality multi-colour photometric data, 172 white light data, and 280 high-resolution high S/N spectra. In this paper, we describe the first results of the analysis of these datasets.

Ground photometry

Several telescopes with multi-colour photometric instruments are involved in this project. Strömgren *ubvy* photometry was collected with the 90cm telescope at Sierra Nevada Observatory and with the 1.5m telescope at San Pedro Mártir Observatory; Geneva 7-colour photometry (UB_1BB_2V1VG) with the 1.2m Mercator telescope at the Observatorio Roque de los Muchachos and with the 70cm Swiss telescope at La Silla Observatory; and Johnson V photometry with the 50cm telescope at Konkoly Observatory. Hipparcos measurements are also available. A logbook of the observations is shown in Table 2 of Uytterhoeven et al. (2008).

We combined the datasets for the filters that allow to do so, as follows. 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 and the Hipparcos H_p data to the Geneva V and Strömgren y data.

As an illustration of our frequency analysis of the merged datasets, Scargle periodograms calculated from the combined U data are shown in Fig. 1. The variations due to the main mode occur with $f_1 = 5.48694$ d^{-1}, $2f_1$ and $3f_1$. The corresponding amplitudes in the combined U filter are 82.8, 8.3 and 4.3 mmag. Note that HD 180642 has one of the highest amplitudes among the known β Cephei stars (see catalog of Stankov & Handler 2005 for comparison). The dominant mode of HD 180642 was already identified by Aerts (2000) as a radial mode by means of Geneva photometry.

In the combined Strömgren and ultraviolet datasets, we also detect two additional significant frequencies, i.e. their corresponding amplitudes reach at least 4 times the noise level in the periodogram, following the criterion derived empirically by Breger et al. (1993). The results from the CoRoT data (Michel et al. 2008) allow us to pick out the right peak. The second frequency present in our photometric data is $f_2^p = 0.30818(5)$ d^{-1} instead of its one-day-alias whose amplitude is higher in the periodogram (see Fig. 1). Afterwards, we find the frequency $f_3^p = 7.36673(7)$ d^{-1}.

Spectroscopy

In the framework of the CoRoT ground-based Large Programme (e.g. Uytterhoeven & Poretti 2007; Uytterhoeven et al. 2008), aimed at the follow-up of selected CoRoT targets, HD 180642 was observed with the FEROS spectrograph at the 2.2m telescope at ESO 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. The logbook of the observations is shown in Table 1.

A phase diagram of the first moment $< v^1 >$ (radial velocity placed at average zero) is displayed in Fig. 2 and clearly shows the non-linear behaviour of the dominant pulsation f_1 in HD 180642. The peak-to-peak amplitude is $\sim$90 km s^{-1} and harmonics up to $5f_1$ are present in $< v^1 >$. This makes HD 180642 the β Cephei star with the third largest radial-velocity amplitude, BW Vul having a peak-to-peak amplitude of $\sim$200 km s^{-1} (Aerts et al. 1995) and σ Sco of $\sim$110 km s^{-1} (Mathias et al. 1991).

In the radial velocity measurements, we also clearly detect $f_2^s = 8.408(1)$ d^{-1} as well as f_2^p, with an amplitude of 1.5 km s^{-1} and 1.1 km s^{-1}, respectively. In a 2D frequency search across the line profile, we additionally find $f_3^s = 6.325(1)$ d^{-1}. The amplitude and phase distributions for the Si III 4553 Å line for f_2^s and f_3^s, also detected in the CoRoT lightcurve, are shown in Fig. 3.

We note that the difference between f_2^p, f_2^s and f_3^s is $\sim$1.041 d^{-1}. The frequency precision of our observations as well as the uninterrupted CoRoT photometry exclude the possibility of dealing with one-day-aliases.

Conclusions

Besides the dominant radial mode, low-amplitude non-radial modes are detected in our ground-based observations of HD 180642. Our aim is to perform a careful mode identification for them. Because of the highly non-linear behaviour of the radial mode, available mode identification techniques cannot be applied straightforwardly, as they are implemented for a linear pulsation. In particular for spectroscopy, the moment method (Briquet & Aerts 2003) and the FPF method (Zima 2006) need to be adapted. This work is ongoing and the final results will be described in a forthcoming paper.

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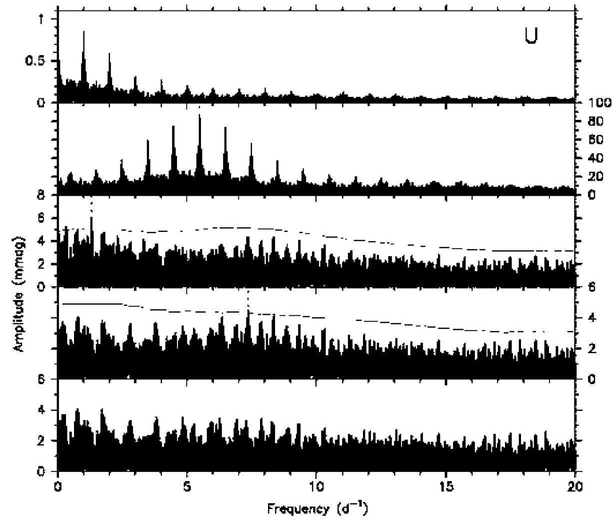

Figure 1: Scargle periodograms calculated from the combined Geneva *U* and Strömgren *u* data. The uppermost panel shows the spectral window of the data. All subsequent panels show the periodograms at different stages of prewhitening. From top to bottom: periodogram of the observed light variations, of the data prewhitened with f_1 and its two harmonics $2f_1$ and $3f_1$, of the data subsequently prewhitened with f_2^p, and of the data subsequently prewhitened with f_3^p. The three frequencies found are indicated by dashed gray lines. The light gray lines indicate the 4 S/N level.

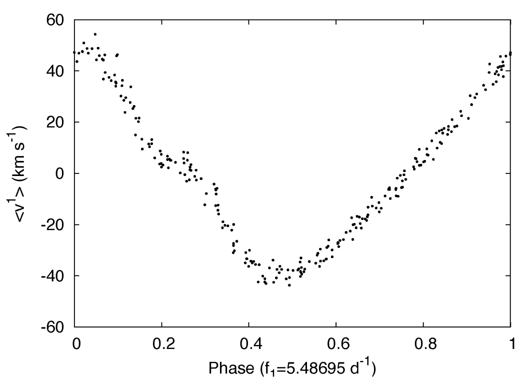

Figure 2: Phase diagram of the first moment computed from the Si III 4553 Å line, for $f_1 = 5.48695$ d^{-1}.

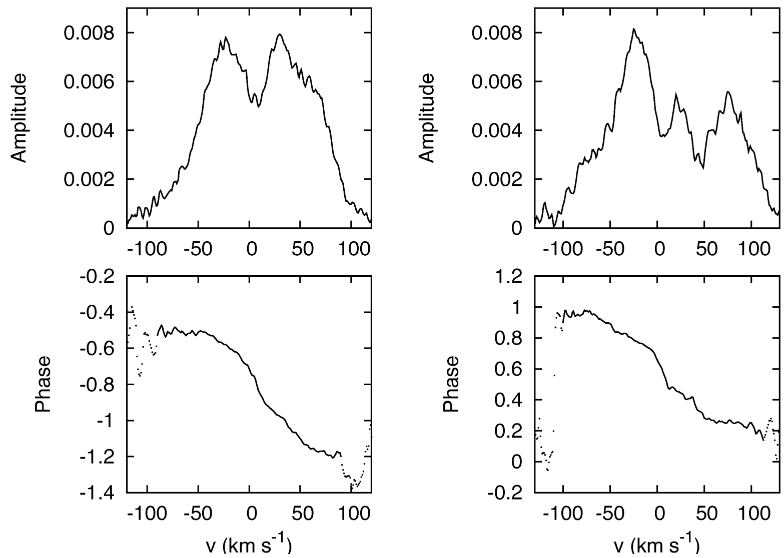

Figure 3: Amplitude and phase distributions for $f_2^s = 8.408$ d^{-1} (left) and $f_3^s = 6.325$ d^{-1} (right) for the Si III 4553 Å line. The amplitudes are expressed in units of continuum and the phases in π radians.