The $\beta$ Cephei star HD 167743

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Abstract. The $\beta$ Cephei star HD 167743 was observed from three different observatories in the years 2006 and 2007. The data sets were collected through the filters Johnson UBV and Strömgren $uvy$. First analyses show six independent and five combination frequencies. We present mode identifications, which are simplified by the rather high amplitudes of the star. No evidence for rotational splitting was found yet.

1. Introduction

$\beta$ Cephei stars are low-order $p$- and $g$-mode pulsators with spectral types between B0 and B3. According to the Catalogue of Galactic $\beta$ Cephei stars [5] the periods of pulsation span 1.6 to 7.7 hours. These stars are situated on the main-sequence with a mean projected rotational velocity of 100 kms$^{-1}$. Their driving mechanism is the classical $\kappa$ mechanism acting in the partial ionization zone of elements of the iron group. Simultaneously excited radial and nonradial pulsation modes and the lack of convection on the surface make these stars well suited for asteroseismology. Additionally, $\beta$ Cephei variables show a simple spectrum of pulsation, which favours unambiguous mode identifications.

Extensive photometric surveys in our Galaxy as well as in the LMC and SMC increased the number of known $\beta$ Cephei stars significantly (see the review of [3]). Nevertheless, the number of sufficiently studied stars of this type is by far not big enough to answer open questions about the overshooting parameter, metallicity, differential rotation, etc. Long-term photometric and spectroscopic observing campaigns for single objects need to be done in order to ascertain accurate mode identification.

2. HD 167743

The ASAS (All Sky Automated Survey, see [4]) project was an extensive survey to monitor the sky for variable stars. During the ASAS 3, HD 167743 was classified as a $\beta$ Cephei star [2]. The same authors detected a nonequidistant frequency triplet. The dominant frequency at 4.8237 cd$^{-1}$ and two other signals at 5.0969 cd$^{-1}$ and 4.9758 cd$^{-1}$ were found to be significant.

A multisite observing campaign during the years 2006 and 2007 was devoted to HD 167743. The major part of the data was gathered at the Fairborn Observatory in Arizona with the Vienna Automated Photoelectric Telescope (APT) in the $uvy$ Strömgren filters. CCD photometry
V Serpentis, a so-called "neglected" semidetached eclipsing binary, a by-product of the SSO campaign.

is available from SSO (Siding Spring Observatory) and SAAO (South African Astronomical Observatory) in the Johnson filters UBV. The data set consists of 295 hours of observation.

As a by-product of the SSO observing campaign, data from the so-called "neglected" semidetached eclipsing binary V Serpentis (see Fig. 1) was collected. Two new \( \delta \) Scuti stars could be identified. Variability in other stars still has to be confirmed.

Table 1. Preliminary results of frequency analyses of the combined Strömgren \( y \) and Johnson V data. Six independent and five combination frequencies were found to be significant. The estimated error of the amplitude values is 0.3 mmag. In the last column the spherical degree \( \ell \) is presented.

| \( f_i \) | Frequency [cd\(^{-1}\)] | Amplitude [mmag] | Spherical degree \( \ell \) |
|----------|--------------------------|-------------------|--------------------------|
| \( f_1 \) | 4.82                     | 41.7              | 1                        |
| \( f_2 \) | 5.10                     | 27.9              | 2                        |
| \( f_3 \) | 4.98                     | 15.7              | 1 or 2                   |
| \( f_4 \) | 6.31                     | 6.9               | 1                        |
| \( f_5 \) | 5.01                     | 4.8               | 0, 1 or 2                |
| \( f_6 \) | 5.59                     | 4.6               | 0                        |
| \( 2f_1 \) | 9.65                     | 5.5               |                          |
| \( f_1+f_2 \) | 9.92                     | 5.1               |                          |
| \( f_1+f_4 \) | 11.13                    | 2.5               |                          |
| \( 2f_1+f_2 \) | 14.75                    | 2.2               |                          |
| \( f_3 - f_1 \) | 0.15                     | 4.3               |                          |
3. Analyses and Results

The analyses were carried out with Period04 [1], a tool based on Fourier transformations and multiple least-squares algorithms.

Preliminary results indicate six independent and five combination frequencies (see Table 1). In Fig. 2 we show the amplitude spectra before and after prewhitening the relevant frequencies. Additionally we delineated the adopted significance amplitude signal-to-noise criterion of 4 for independent and of 3.5 for combination frequencies. Further signals may be present, but only additional data would reveal them.

A first attempt to mode identification by comparing theoretical and observed $uvy$ and UBV amplitude ratios was done (Fig. 3). The spherical degree of all six modes is lower than $\ell = 2$. The dominant mode $f_1$, as well as $f_4$ are dipole modes, whereas $f_2$ is $\ell = 2$ and $f_6$ is radial. For $f_3$ and $f_5$ an unambiguous mode identification is not possible yet. Table 1 summarizes the results.

Ongoing analyses of spectra obtained with the MPG/ESO-2.20m telescope with FEROS will measure abundances and the $v \sin i$ value of the star. However a rough estimate suggests a $v \sin i$ value of about 50 kms$^{-1}$ (Niemczura, priv. comm.). Taking the high amplitudes into account, this value most likely means slow intrinsic rotation.

4. Conclusions

The $\beta$ Cephei star HD 167743 was the main target for a multisite photometric campaign. The analyses of 295 hours of data in $uvy$ and UBV revealed six independent and five combination
Figure 3. Mode identification from comparison of observed and theoretical amplitude ratios, normalized to unity at $u$. The filled circles represent the observed amplitude ratios, including error bars. Radial modes predicted by theory are delineated in full lines, dipole modes in dashed lines, dashed-dotted lines show the $\ell = 2$ and dashed-dot-dot-dotted lines give the $\ell = 4$ modes.

frequencies. Preliminary mode identification shows that all observed modes have a spherical degree lower than $\ell = 2$. The high amplitudes and a $v \sin i$ value of approx. 50 km s$^{-1}$ point towards slow intrinsic rotation. Ongoing analyses of spectroscopic data will measure abundances, $T_{\text{eff}}$ and $\log g$ with high accuracy.

The radial mode at 5.59 c d$^{-1}$ constrains parameters for asteroseismic modelling significantly, since the mean density of the star can be derived. Furthermore the dipole modes $f_1$ and $f_4$, are very unlikely to be split by rotation, therefore they must be consecutive radial overtones. Nevertheless, it needs to be clarified whether or not any of the present splittings in the pulsation spectrum of HD 167743 are caused by rotation effects.

Acknowledgments
This work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung under grant P18399-N08.

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