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SPECTROSCOPIC OBSERVATIONS OF β CEPHEI STARS AT ROZHEN OBSERVATORY

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Abstract. We present the first results of the ongoing project in which we observe spectroscopically bright β Cephei stars with the aim of seismic modelling of these stars. The spectroscopic data were collected with the Coudé spectrograph attached to the 2-m telescope at Rozhen Observatory. We present the first high-resolution ($\sim$30 000) time-resolved spectra for KP Per and V986 Oph. They clearly show spectral line variations due to pulsations and have a quality sufficient to apply mode identification methods that take advantage of the shape of line profiles.

1. INTRODUCTION

β Cephei stars are massive variable stars with late O and early B spectral types whose light, radial-velocity and line-profile variations are caused by the low-order pressure and gravity modes (Stankov and Handler 2005). The pulsations in these stars are driven by the classical κ-mechanism, operating in the layer of the metal opacity bump induced by a large number of absorption lines of the iron-group elements (Dziembowski et al. 1993). While the variability in some bright β Cephei stars was discovered through their radial-velocity variations (see, e.g., Sterken and Jerzykiewicz 1993), the photometric variability is nowadays the most efficient way of finding them. However, the high resolution time-resolved spectroscopy is another way of detecting this type of variability. This way of detection is especially efficient for high-degree modes which are difficult to detect in photometry due to the cancellation effect. The high-resolution spectra can also be used for the mode identification which is a prerequisite for successful asteroseismology of these stars. Seismic modelling of selected bright β Cephei stars is the main purpose of the ongoing project we have recently initiated. In the present paper we show the first spectroscopic observations obtained within this project.

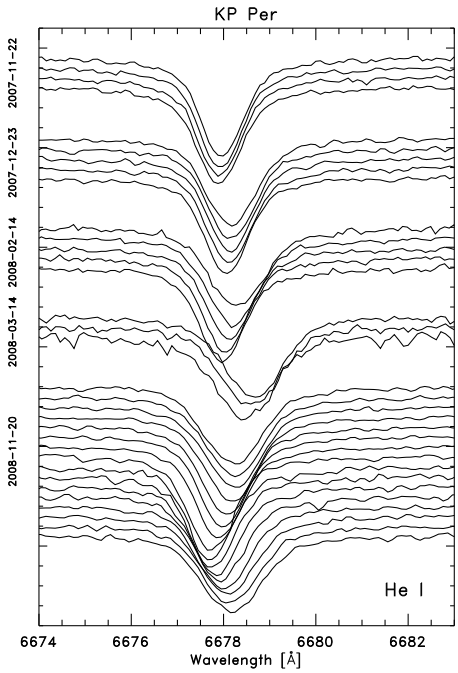

Figure 1: The He I 6678 Å line profile variations of KP Per. These are normalized spectra shifted vertically for better separation. The dates of observation are indicated in the ordinate.

1. 1. OBSERVATIONS

The high resolution, high signal-to-noise time-resolved spectroscopic observations for the project were obtained using the 2-m telescope of Rozhen Observatory, Bulgaria. The Coudé spectrograph is equipped with the Photometrics AT200 camera used as a detector providing spectra with a resolution between 25 000 and 30 000.

We observed stars in two spectral regions: 4500–4600 Å and 6630–6730 Å. They were chosen to cover the region where Si III 4552, 4567, 4574 Å triplet and He I 6678 Å line are located, respectively. The exposure was equal to 900 seconds resulting in the signal-to-noise of the order of 200. The IRAF standard procedures were applied for bias subtracting, flat-fielding and wavelength calibration.

1. 2. PRELIMINARY RESULTS AND FUTURE PLANS

Up-to-date we collected spectra for three β Cephei stars: KP Per, V986 Oph and β Sco A. The He I 6678 Å line spectra of KP Per and V986 Oph are presented in Figs. 1 and 2, respectively.

KP Per (HD 21803, $V = 6.41$ mag, B2 IV) is a multiperiodic β Cephei star discovered by Lynds (1959a). Following the discovery, more variability studies were carried out. In particular, three modes were detected by Jarzebowski et al. (1981). The most recent photometric observations were performed with the 1.2-m Mercator telescope at

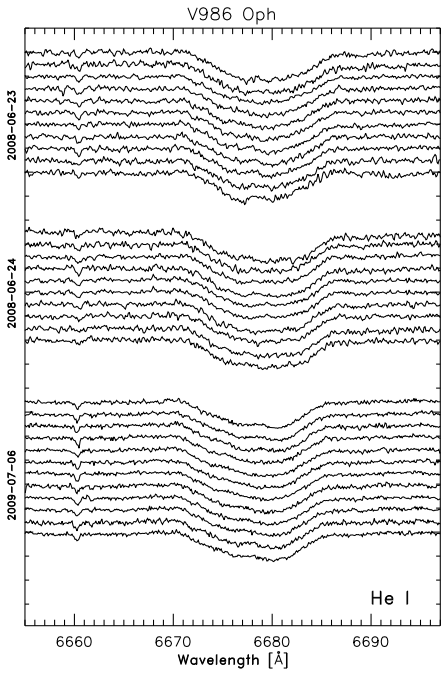

Figure 2: The same as in Fig. 1 but for V986 Oph.

La Palma (Saesen et al. 2007). Saesen et al. (2007) confirmed the three known modes and, using the photometric ratio method, identified two modes as dipole (ℓ =1) ones. The identification for the third mode was ambiguous.

The spectroscopic data for KP Per were collected between November 2007 and November 2008 (see Fig. 1). These high-resolution, high signal-to-noise spectra, together with the data collected with the TLS spectrograph (mounted at the 2-m telescope in Tautenburg, Germany) and the HERMES spectrograph (1.2-m Mercator telescope on La Palma) will allow us to identify unambiguously all three modes. In addition, we hope that this identification could be used as an independent constraint for the forthcoming stellar modelling of this star (Briquet et al., in preparation).

V986 Oph (HD 165174, $V = 6.15$ mag, B0 IIIn) is one of the hottest, most massive and most luminous β Cephei stars. It is also the β Cephei star with one of the longest periods known. The variable nature of this star was discovered by Lynds (1959b) who found a single periodicity and classified the star as a candidate β Cephei variable. After many years of investigation there is still a problem with the number of modes detected in this star. Cuypers et al. (1989) indicated the existence of at least two periodicities: one (with a period of 0.303 d) was already known and is the result of a non-radial pulsation (NRP). The exact value and nature of the longer period remains uncertain. It can be another NRP mode or a rotational modulation. For this star, the new photometric observations taken with the Mercator telescope exist. We are going to perform spectroscopic mode identification for this star as well. The

first set of spectroscopic data for V986 Oph was taken in June 2008 (Fig. 2). These observations will help us to verify the existence of two suggested pulsational modes in this star.

β Sco A (HD 144218, $V = 4.90$ mag, B2 V) is a candidate β Cephei star with a tentative period of 0.1733 d, and a member of a binary system. The variability of β Sco A was discovered by Holmgren et al. (1997), who present spectroscopic data and physical parameters for this early-type binary system, including the parameters of the orbit, the distance and the fundamental parameters of both components. However, both the short-period variability attributed to pulsations and the possible eclipses in the system suggested by Holmgren et al. (1997) require independent verification. Spectral-line variations of β Sco A were also observed by Telting et al. (2006) in their high-resolution spectra.

The three stars presented here are not the only ones that were selected for observations in our project. During the next three years we intend to continue the observations of V986 Oph and to observe a few other bright β Cephei stars suitable for spectroscopic mode identification and subsequent modelling. We will therefore observe mainly those stars that are known to have relatively large amplitudes.

Acknowledgments

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References

Cuypers, J., Balona, L.A., Marang, F.: 1989, *Astrophys. J. Suppl. Series*, **81**, 151.
Dziembowski, W. A., Moskalik, P., Pamyatnykh, A. A.: 1993, *Mon. Not. R. Astron. Soc.*, **265**, 588.
Holmgren, D., Hadrava, P., Harmanec, P. et al.: 1997, *A&A*, **322**, 565.
Jarzebowski, T., Jerzykiewicz, M., Rios-Herrera, M., Rios-Berumen, M.: 1981, *Rev. Mex. Astron. Astrof.*, **5**, 61.
Lynds, C. R.: 1959a, *Astrophys. J.*, **129**, 674.
Lynds, C. R.: 1959b, *Astrophys. J.*, **130**, 577.
Saesen, S., Briquet, M., Cuypers, J. et al.: 2007, *CoAst*, **150**, 197.
Stankov, A., Handler, G.: 2005, *Astrophys. J. Suppl. Series*, **158**, 193.
Sterken, C., Jerzykiewicz, M.: 1993, *SSRv*, **62**, 95.
Telting, J. H., Schrijvers, C., Ilyin, I. V. et al.: 2006, *A&A*, **452**, 945.