SPECTRAL VARIABILITY OF THE UNUSUAL SOUTHERN Be STAR HD 152478

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ABSTRACT

We present results of the spectroscopic investigation of the unusual southern Be star HD 152478. Five echelle high-resolution spectra of the object were obtained in 2007 - 2009 with the FEROS spectrograph mounted at the 2.2 m telescope of the European Southern Observatory (La Silla, Chile). The star exhibits a specific remarkable variability of the numerous line profiles of such elements as H I, He I, Fe II, etc. The analysis of the spectral behaviour of the object has shown that the assumption of global oscillations in the rotating equatorial gaseous disk is not confirmed by the observations. The alternative hypothesis of a variable magnetized stellar wind of flattened geometry flowing close to the equatorial disk can qualitatively explain the observed profile variations.

Key words: Stars: Be: circumstellar matter; stars: spectroscopy; stars: individual: HD 152478

1. Introduction

The southern Be star HD 152478 was included in a program of identification and investigation of possible past supernovae events taking place in the region of the Scorpius-Centaurus OB association (Hoogerwerf et al., 2001). According to later spectroscopic study by Jilinski et al. (2010), this object may be considered as an eventual runaway star.

Nevertheless, this Be star demonstrates an unusual spectral behaviour. The goal of the present study was to investigate the spectroscopic activity of this star seen in a number of spectral lines.

In this report we consider the large-scale profile variability observed in optically thick Hα and Hβ lines and in several optically thin Fe II lines.

2. Observations

Five high-resolution spectra were obtained in 2007 - 2009 using the echelle Fiberfed Extended Range Optical Spectrograph (FEROS) installed at the 2.2m telescope of ESO at La Silla, Chile. The FEROS spectral resolution is $R = 48\,000$, and the wavelength coverage is from 3600 Å to 9200 Å. A typical S/N ratio was from 100 to 200 depending on the spectral region. The dates of observations are given in Table 1.

Table 1: Observing dates.

N	Date	MJD
I	June 2, 2007	54253.162
II	Feb 23, 2008	54519.356
III	May 25, 2008	54611.154
IV	May 14, 2009	54965.118
V	July 28, 2009	55040.982

3. Spectral classification

We used the echelle spectra of the object to improve its former spectral classification published by Levenhagen & Leister (2006). Contrary to these authors, who used a rather limited number of observational criteria, we analysed a series of spectral parameters, such as:

- profiles of a number of helium lines in the blue part of the spectrum;
- numerous blends of such elements as ionized O, Fe, Si, etc.;
- wide absorption wings of the Balmer lines, free from the circumstellar (CS) influence.

Synthetic spectra, calculated with the code of Piskunov (1992), based on the LTE models of stellar atmospheres of Kurucz, were used for comparison

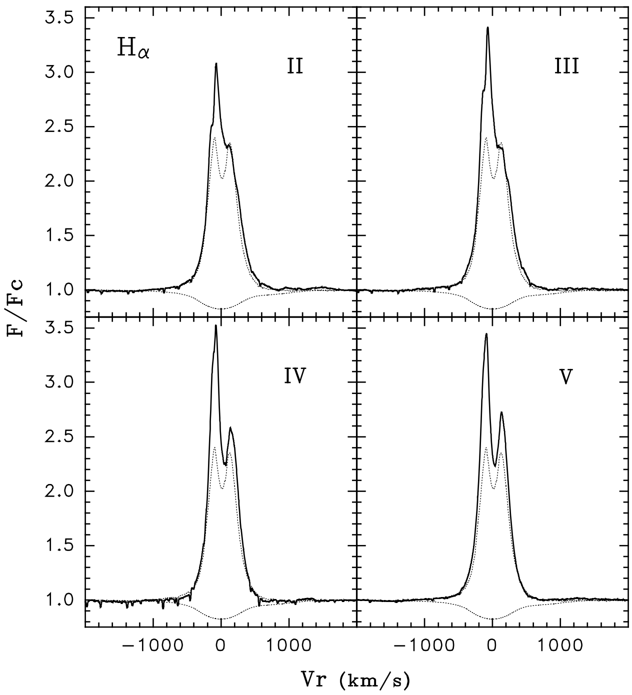

Figure 1: Normalized Hα profiles in dates I - V. The profile for date I is shown by the dotted line.

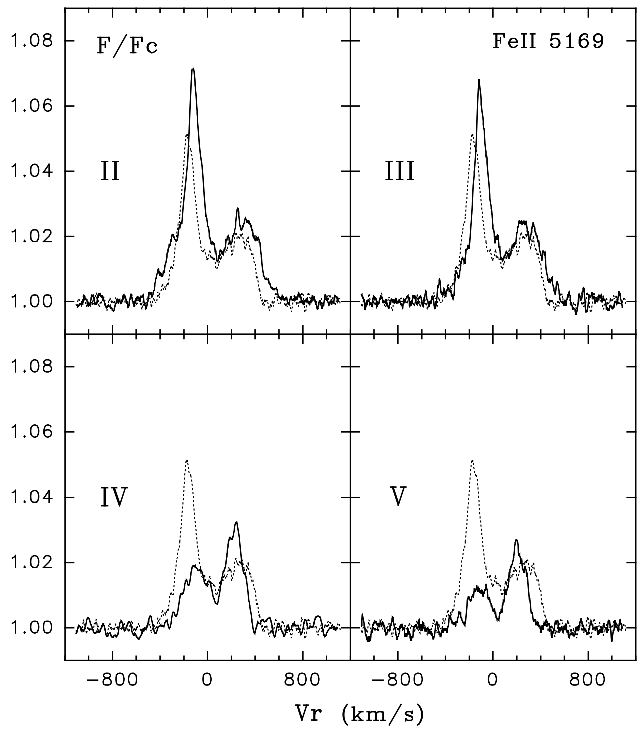

Figure 2: The same as in Fig. 1 but for the Fe II 5169 Å line profile.

with the observed spectra. Results of our estimates as well as the model parameters of Levenhagen & Leister (2006) are given in Table 2.

Table 2: Parameters of the atmosphere.

Model	$T_{\rm eff}$ (K)	$\log g$	$V \sin i$ (km s^{-1})
Former result	19 800	3.75	295
Our result	25 000	4.25	370

According to our estimates, the star is considerably hotter and rotates more rapidly than it was recognized earlier. Besides of that, a notable He overabundance of about [He/H] = +0.35 has been found.

4. Variability of line profiles

The temporal behaviour of the Hα profile is shown in Fig. 1. Four fragments illustrate the profiles observed in dates II - V as compared with the double-peaked and symmetric profile obtained on date I (dotted line). The synthetic atmospheric profile is also given in this Figure (marked by the dotted line too). One can see that on dates II and III the emission profile becomes very asymmetric. The blue peak increases strongly in intensity, and the red wing shows an increase in its extension. In turn, on dates IV and V the red emission peak starts to rise while the red wing looks again as on date I.

The temporal behaviour of the Hβ line profile is similar to the behaviour of the Hα profile.

Nevertheless, the character of the variations observed in the optically thin Fe II lines is quite different. The emission profiles of these lines are asymmetric already on date I with the blue peak being of greater intensity than the red one. On dates II and III the profiles remain approximately the same, but on dates IV and V the intensity of the lines decreases and the blue peak becomes even lower than the red one. As an example, this variability is illustrated in Fig. 2 for the Fe II 5169 Å line.

5. Possible interpretations of the spectral behaviour

The variability observed in HD 152478 is typical for a classical rapidly rotating Be star. In recent times, a prominent change of the V/R ratio is most commonly interpreted as a result of a drift of a so-called one-armed perturbation arising in the equatorial gaseous disk. According to the theory of global oscillations in disks of classical Be stars, a large-scale density and velocity inhomogeneities can be formed in the disk which is not co-rotating with the gas but is precessing ret-

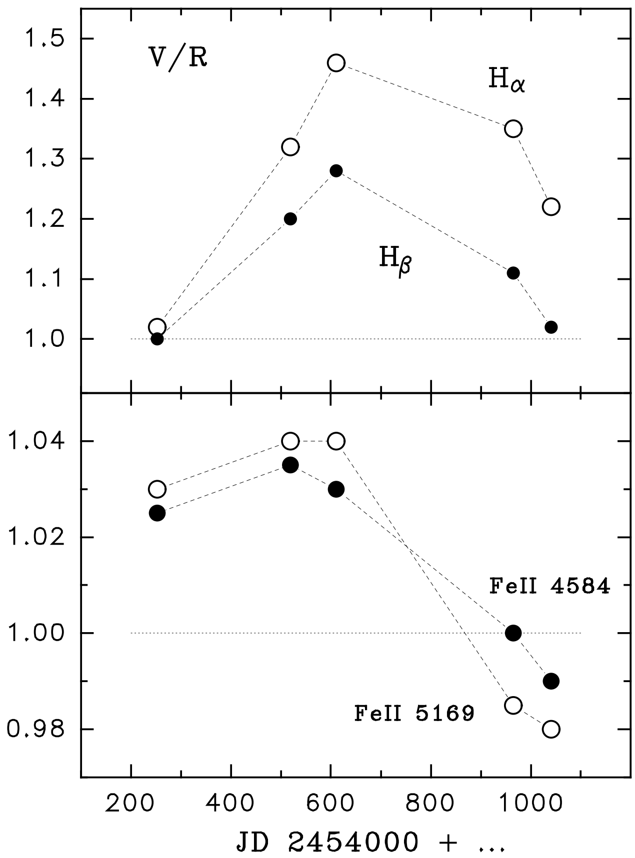

Figure 3: The V/R ratio variations observed in the Balmer and the Fe II lines.

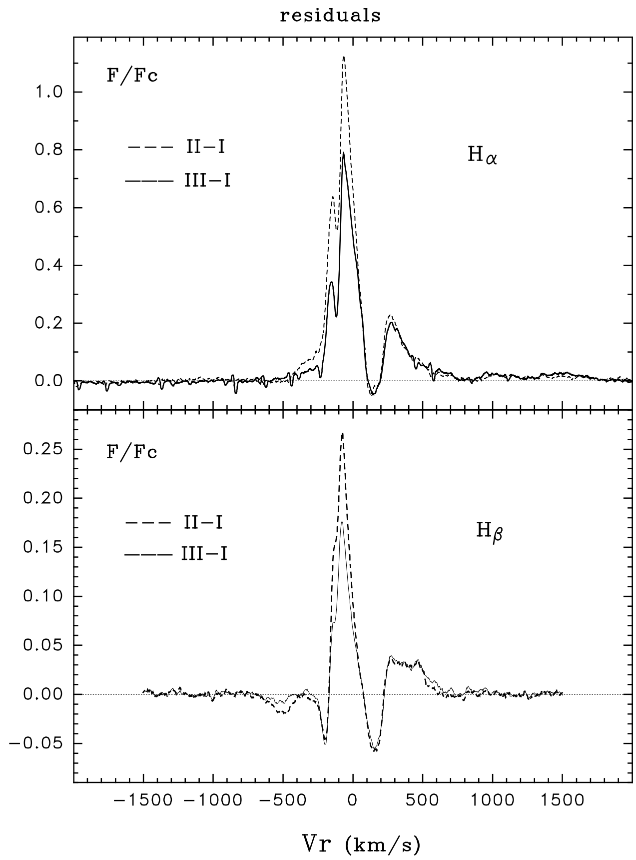

Figure 4: Residual Hα and Hβ profiles for dates II and III constructed by subtraction of the profiles for date I.

rograde with a period of several years (Kato 1983, Okazaki 1991). Its drifting modulates profiles of CS lines, and a cyclic V/R ratio variability is observed.

In the paper of Hanuschik et al. (1995) it has been shown that:

- the V/R ratio variability takes place in the same phase in the optically thick Hα and Hβ lines as well as in optically thin Fe II lines;

- the V/R ratio variability is followed by no change of the EW of emission lines.

As seen in Fig. 3, the V/R ratio observed in the Balmer and Fe II lines in the spectrum of HD 152478, shows variations which can be assumed as long-term cyclic variations connected with the drifting of a large-scale perturbation. But they do not occur in the same phase. A phase shift is clearly seen here. The model of drifting perturbation alone cannot explain this phenomenon. Moreover, the observed profile transformations are followed by a high-amplitude change of EW (see Figs. 1 and 2). Besides, these variations are also not predicted by the oscillation theory. Finally, on dates II and III, when the Balmer line profiles become very asymmetric, the red emission wing becomes very extended (up to 1800 km s^{-1} for Hα). Such high velocities cannot exist in a nearly-Keplerian disk. The maximum velocity of the rotating gas near the inner boundary of the disk is only 650 km s^{-1} for a typical star of B1V spectral type. But such large velocity can be achieved in the radiatively-driven stellar wind flowing from a Be star at intermediate latitudes. This circumstance allows us to consider an alternative interpretation of the spectral behaviour of HD 152478 in the frame of the assumption on a variable stellar wind.

Some time ago it was shown that the Wind-Compressed Disk (WCD) theory of disk formation around Be stars (Bjorkman & Cassinelli 1993) together with a magnetic field of the order of 100 G introduced into the WCD model by Porter (1997), leads to a better agreement between the theory and observational data of Be stars. It should be mentioned, that such fields were already revealed in several classical Be stars using the spectropolarimetric method (Hubrig et al. 2009). According to calculations of Porter (1997), the wind zone in the WCD model with the presence of the magnetic field becomes flattened and concentrated towards the equator.

We tried to estimate a contribution of such magnetized wind in the whole emission line profile in a qualitative level. It is clear that the red wing of the profile formed in the wind must be more intense and extended than the blue wing because the optically thick gas flowing towards the observer screens the star. And even the P Cyg-type structure is expected in the blue wing. If the orientation of the object is close to "edge-on", as it is likely to be the case of HD 152478 with large $V \sin i$ (370 km s^{-1}), a local fall in intensity at moderate positive velocities can be expected in the red emission wing. It is connected with the fact that a considerable amount of the emitting gas flowing outwards the observer is screened by the stellar limb. This effect can be notable in the case of flattened magnetized winds and negligible for spherically symmetric geometry of the wind zone.

Fig. 4 shows the observational profiles of Hα and Hβ for dates II and III corresponding to the wind contribution to the whole emission profile by simple subtraction of the observed profile for date I. It is assumed that namely on date I the symmetric double-peaked profiles were formed mainly in the disk, and on dates II and III the wind contribution was maximum. One can see that the constructed residuals contain all principal features expected for a flattened magnetized stellar wind.

Therefore, we put forward the assumption on a variable magnetized wind as a possible interpretation of the spectral behaviour of HD 152478.

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