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A SURVEY OF SEVERAL SPECTRAL LINES IN THE SPECTRA OF THE SUPERGIANT HD 14143

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ABSTRACT. Variations in the H_α, H_β, HeI, CII, SiIII, Al III, FeIII, NII, and OII lines in the spectrum of the star HD 14143 are investigated using observations carried out in 2013 with the 2-m telescope at the Shamakhy Astrophysical Observatory.

It has been revealed an anti-correlation between the variability of the radial velocity and spectral parameters of the absorption and emission components of the H_α line in the spectrum of the star HD 14143. In addition, such anti-correlation has also been found out between the variability of the radial velocities of HeI and CII lines. At the same time the variabilities of the radial velocities of the absorption component of the H_α and CII lines, as well as H_β and HeI lines correlate with each other.

Key words: Supergiant star, the profile of H_α line, HD 14143

1. Introduction

The supergiant star HD14143 belongs to the stars with P Cyg profile of the H_α line. According to (Barlow, 1977; Kraus et al., 2009; Vardya, 1984; Crowther et al., 2006), its spectral class is B2Ia, apparent magnitude is m_v = 6.66 mag, mass is $M/M_\odot$ = 28, radiuse is $R/R_\odot$ = 52.9, luminosity is log $L/L_\odot$ = 5.42, effective temperature is T_{eff} = 18000 K, mass-loss is M = $1.05\cdot10^{-6}$ $M_\odot$/year, acceleration of gravity at the surface is logg=2.25, rotation speed is υ sin$i$ = 76 km/s, distance is D=2.18 kpc. It is believed that this star belongs to Per OB1 association (Lennon et al., 1993).

However, according to other authors (Lamers, 1981; Kudritzki et al., 1999; Tarafdar, 1988), the stellar parameters are somewhat different for HD14143 are:

M_{bol} =–8.6, T_{eff}=17500 K, T_{eff}=20000 K, $R/R_\odot$ = 50.9, $R/R_\odot$ = 47.1, $R/R_\odot$ = 52, $M/M_\odot$ = 32, M = $0.30\cdot10^{-6}$ $M_\odot$/year, log$g$=2.47, log$g$=2.30, log $L/L_\odot$ = 5.51, log $L/L_\odot$ = 5.34, $B–V$=0.50, $E(B–V)$=0.65

All earlier researchers of HD14143 performed only the determination of physical parameters of the supergiant star HD14143. Unfortunately, there are only little investigation concerning to the spectral and photometric observations of HD14143.

Note that due to the variable stellar wind and mass-loss rate, variations of the intensity, radial velocities, and P Cygni profiles of lines of hydrogen, helium, and high-ionization ions are observed in the spectra of hot supergiants. From this point of view a study of the H_α line is an especial interest. It is known that the H_α line in the spectra of B supergiants has a clear P Cyg-type profile.

Generally, researchers noted that, the profile of H_α line in the spectra of HD 14143 indicates variable structure, but the sequence of observations of all researchers was irregular and inadequate to trace in detail the changes in the spectra. Therefore they noted that more and systematic observations are needed to investigate this supergiant.

In the present paper, which is a sort of continuation of the above studies, we analyzed variations of the H_α and H_β lines. In addition, we also investigated the variabilities of the HeI (5875.72, 5047.74, 5015.68, 4921.93 Å), CII (6578.05, 6582.88 Å), SiIII (5739.7 Å), Al III (5722.73, 5696.603 Å), Fe III (5193.91, 5156.11 Å), N II (5710.77, 5686.2, 5679.6, 5676.02, 5666.6, 5045.1, 5025.67, 5007.33, 5005.1, 5001.5, 4994.37, and 4987.38 Å) and OII (5160.02 Å) lines which formed deeper effective layers in the atmosphere of this star.

Our main aim is to study the observed peculiarities of these lines in the spectra. We believe our results will be of interest for further studies of this remarkable star.

2. Observation and processing

Spectral observations of the supergiant HD14143 in 2013 were carried out using a CCD detector in the echelle spectrometer mounted at the Cassegrain focus of the 2-m telescope of the Shamakhy Astrophysical Observatory (Mikailov et al., 2005). The spectral resolution was R = 15000 and the spectral range is λλ4700-6700Å. The Echelle spectra were processed with the standard technique using the DECH20 and DECH20t software (Galazutdinov, 1992).

Two spectra of the target star were obtained on each night. The signal-to-noise ratio was S/N =150-200.

The average exposure was 1200-1500 s, depending on the weather conditions.

In addition to the observations of the target star, in order to check the stability of the instrument we also obtained numerous spectra of standard stars, the day and night background, and comparison spectra.

The measurement error for the equivalent widths (W) does not exceed 5%, and error of the radial velocity (Vr) is of the order of ±2 km/s. Here (Vr) are velocities of the

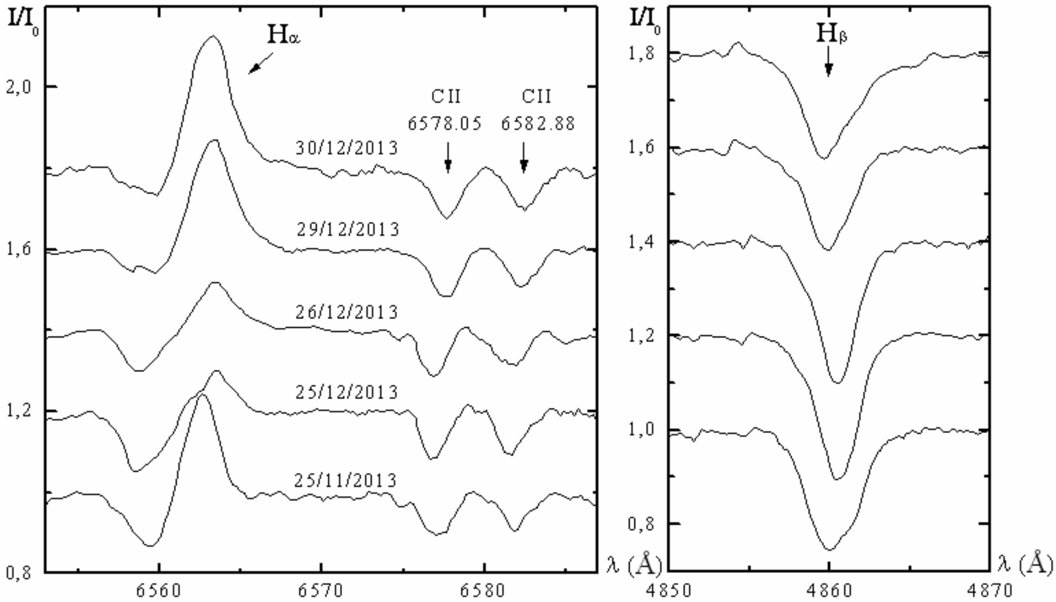

Figure 1: Profiles of the H_α, CII and H_β lines in the spectra of HD 14143 observed in 2013.

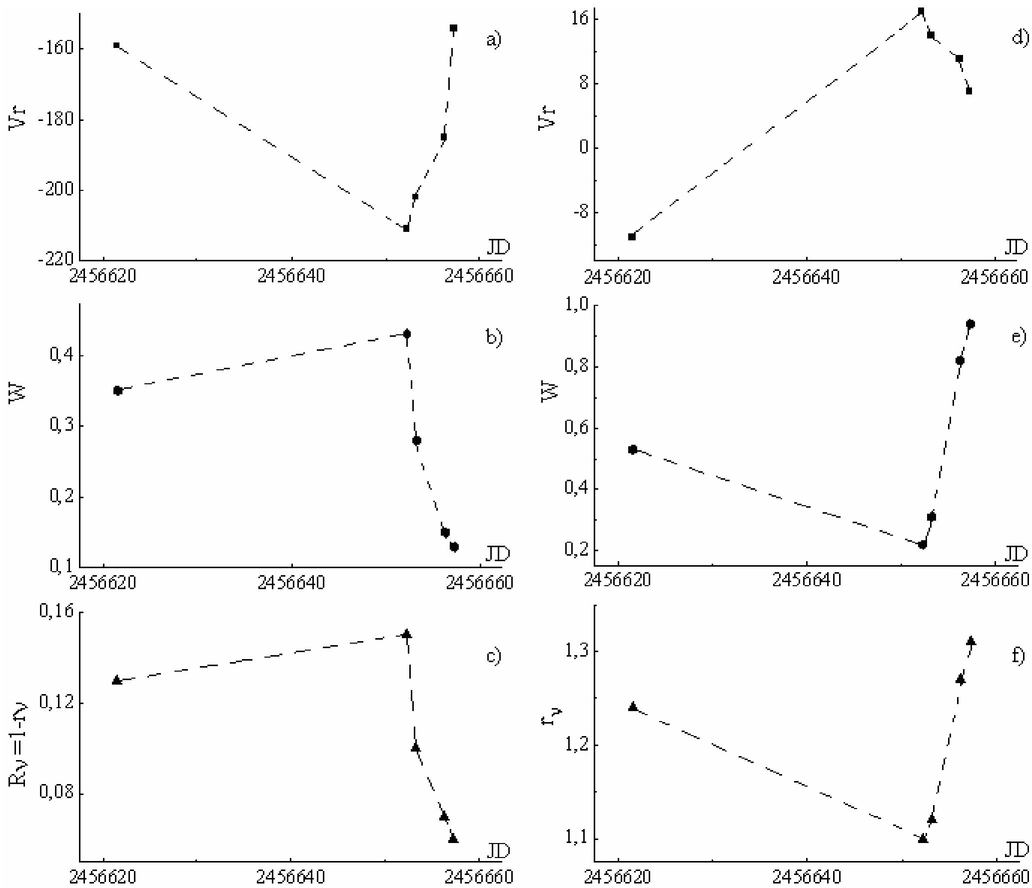

Figure 2: Variation with time of the radial velocities, equivalent widths, and depths (or residual intensities) in the H_α line in the spectra of HD 14143. a), b), c) in the absorption; d), e), f) in the emission.

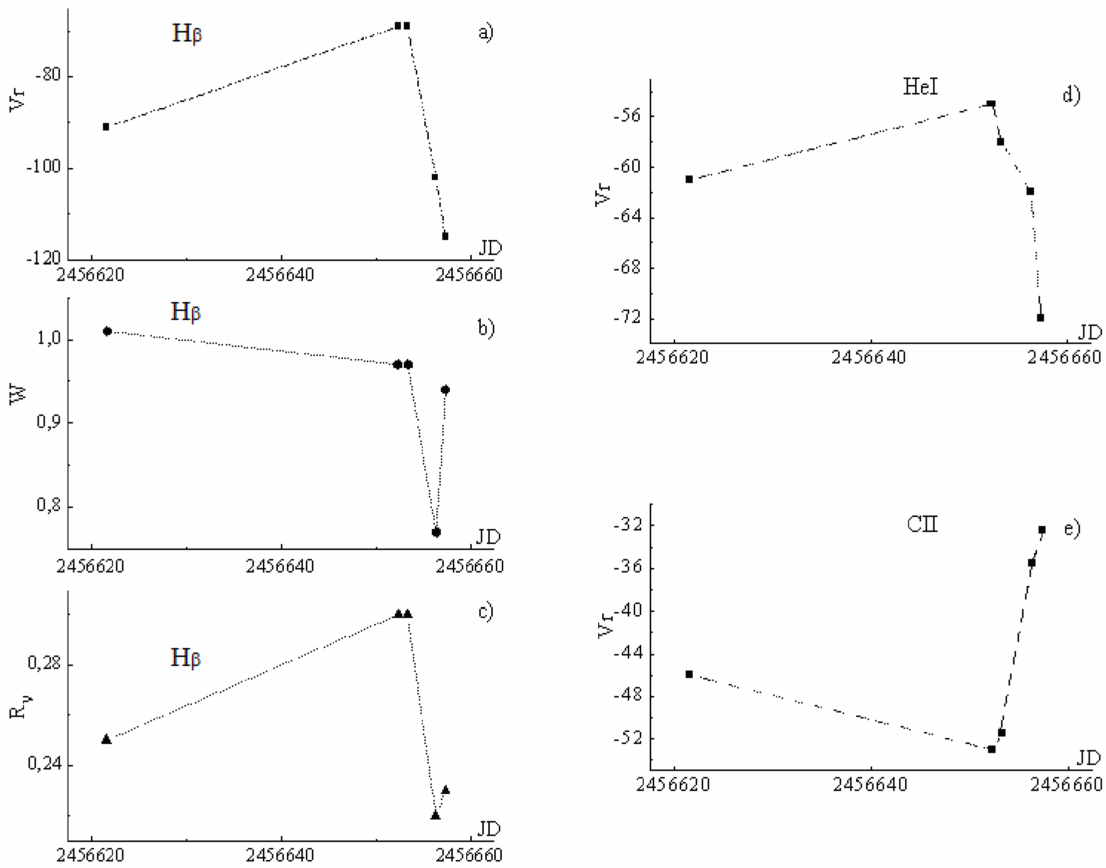

Figure 3: Variations of the radial velocities, and spectral parameters in the H_β, HeI and CII lines.

absorption minima or emission maxima in the selected lines. Appropriate heliocentric corrections were included during data processing.

The profiles of the H_α line in the spectra of this star shows normal P Cyg profile in mainly. Our observations and measurements show that the most variability in the spectrum of HD14143 is displayed by the equivalent width, radial velocity and structures of the H_α line. Table 1 shows that the radial velocity and equivalent width of the absorption component of the H_α line varied between –227÷–159 km/s and 0.13÷0.43Å, the emission component varied between –11÷+17 km/s and 0.22÷0.94Å, and H_β line varied between –115÷–69 km/s and 0.77÷1.01Å, respectively. In addition, the depths of the absorption components of the H_α and H_β lines varied between 0.06÷0.15 and 0.22÷0.30, and the residual intensity of the emission component of the H_α line varied between 1.10÷1.31, respectively.

As is shown from the measurements, in the radial velocity and spectral parameters of the H_α line, as well as the H_β line significant changes happened, but the variability of the depth of the H_β line is weaker.

In Table 1 the values of the radial velocity and spectral parameters of the H_α line and Figure 1 show that the intensity of emission component of the H_α line is stronger than the absorption one and both of the them changed substantially during observations.

We analyzed the spectra on December 29-30, 2013, and it is revealed that the second weaker components were observed in the violet side of the absorption component of H_α line. Table 1 shows that the depth and equivalent width of the absorption component of the H_α line are decreased and the residual intensity and equivalent width of the emission component of this line are increased substantially at that time.

Figure 1 and Table 1 also show that when the second weaker components were observed at the absorption component of H_α line, the H_β line contours were shifted toward the violet, and its depth and equivalent width are relatively decreased.

At the same time the HeI line is displaced to the relatively violet side, but the CII lines shifted toward the red of the spectrum.

We also investigated the HeI, CII, Al III, FeIII, NII, NaID and OII lines in the spectra. We determined that the radial velocity of the CII lines vary between –54÷ –31 km/s. On the other hand, Figure 1 clearly shows that small components are observed and disappeared on the profiles of CII lines.

Unfortunately, the sequence of our observations was irregular, as well as because of a small number and due to low resolution we could not reveal in detail the structure of the H_α and CII profiles.

Table 1: Measurements of the parameters of the H_α and H_β lines.

Date and JD	HD14143								
	H_α (abs)			H_α (em)			H_β		
	Vr (km/s)	W (Å)	R_v	Vr (km/s)	W (Å)	r_v	Vr (km/s)	W (Å)	R_v
25.11.2013 2456621,54	–159	0.35	0.13	–11	0.53	1.24	–91	1.01	0.25
25.12.2013 2456652,30	–211	0.43	0.15	17	0.22	1.10	–69	0,97	0.30
26.12.2013 2456653,28	–202	0.28	0.10	14	0.31	1.12	–69	0.97	0.30
29.12.2013 2456656,31	–210 –185	0.15	0.07	11	0.82	1.27	–102	0.77	0.22
30.12.2013 2456657,30	–227 –154	0.13	0.06	7	0.94	1.31	–115	0.94	0.23

Table 2: Measurements of parameters of the CII, HeI and NaI lines.

Date and JD	HD14143				
	Vr (km/s)				
	CII 6578.05Å	CII 6582.88Å	HeI 5875.72Å	NaI D1	NaI D2
25.11.2013 2456621,54	–46	–46	–61	–30	–25
25.12.2013 2456652,30	–52	–54	–55	–31	–27
26.12.2013 2456653,28	–51	–52	–58	–30	–27
29.12.2013 2456656,31	–33	–38	–62	–29	–28
30.12.2013 2456657,30	–31	–34	–72	–28	–25

Investigation of the HeI and NaID lines showed that the radial velocities of these lines vary between –72÷-55 km/s and –27.5±2.5 km/s (Table 2), respectively, but profiles remain unchanged.

The averaged radial velocities of other ions are given in Table 3. Note that the considered spectra contain a lot of absorption lines formed in deeper layers of atmosphere. We measured the radial velocities of the selected absorption lines. As seen from the Table 3 averaged value of velocities of the selected absorption lines is –45.8 km/s. This value is very close to the (V_{sys}=–47.0) velocity of center of mass of the star HD14143 (*Simbad Astronomical Database*).

Table 3: Averaged radial velocities in the selected lines.

Elements	Vr, km/s Mean velocities
Si III	–45
Al III	–45
Fe III	–43
NII	–47
OII	–49

In addition, some results of the measurements in the spectra of HD14143 presented on a time scale in Figure 2 and 3. It has been revealed an anti-correlation between the radial velocity and spectral parameters of the absorption and emission components of the H_α line, respectively (Fig.2). At the same time, such anti-correlation has been found out between the radial velocities of the HeI and CII lines (Fig.3d, e).

The variability of radial velocity, equivalent widths and depths of H_β line indicate repeating features too. But it shows that sometimes the variability of these quantities correlate with each other, but sometimes not (Fig. 3a, b, c).

Besides that, it has been revealed correlation between the variability of the radial velocities of the absorption component of the H_α and CII lines, as well as between H_β and HeI lines.

3. Discussion

The H_α line shows a P Cygni profile and is the only Ballmer line showing emission in the spectrum. We have found out that all spectral parameters of the absorption and emission components of the H_α observed in the atmosphere of the star HD14143 are significantly variable.

Table 1, 2 and Fig.1 show that on December 29-30, 2013, when the second weaker components were at the absorption component of the H_α line the H_β and the HeI (5875.72 Å) lines shifted toward the violet, but the CII (6578.05, 6582.88 Å) lines shifted toward the red of the spectrum. This event can be explained by the complicated structure of the stellar wind.

On the other hand the formation small details in the profile of CII lines, as well as occasional shifts or disappearances of these components are interesting observational facts. As seen the deeper layers of the atmosphere of the star HD 14143 is an active variability. Detailed to investigate it is necessary to obtain many systematic observations with high resolution.

We noted above that there are correlations between the variabilities of the radial velocities and spectral parameters of the H_α, CII, H_β, and HeI lines, respectively. Variabilities occur synchronously, or sometimes in an antiphase. We assume that these variabilities are caused by the pulsation or can be formed by the strong variable wind in the upper atmosphere of this star, i.e., in layers where the stellar wind is generated (Sobolev, 1947; Sobolev, 1985; De Jager, 1984; Cox, 1983). But a number of the observational materials is not enough, therefore it is not possible to reveal the quasiperiodicity of this variability.

In addition, Table 1 shows that when comparing with V_{sys}, on all dates H_α and H_β absorption components are displaced to shorter wavelengths. But the averaged radial velocities of the all other selected absorption lines is very close to V_{sys}. We suppose it appears therefore that this star has an expanding outer envelope, whose density and velocity vary irregularly. The behavior of the inner atmosphere is peculiar, showing irregular changes in all line velocities. This star should be studied intensively for a full documentation of such changes.

4. Conclusions

Sometimes the absorption component of H_α line in the spectra of the star HD14143 is observed to be double. At that time the H_β and HeI (5875.72Å) lines shifted toward the violet, and the CII (6578.05, 6582.88Å) lines shifted toward the red of the spectrum. In addition, the small components are observed and disappeared on the profiles of CII lines. These events can be explained by the complicated structure of the stellar wind.

It has been revealed an anti-correlation between the variabilities of the radial velocity and spectral parameters of the absorption and emission components of H_α line in the spectra of the star HD 14143. There is such anti-correlation between the variability of radial velocities of the HeI and CII lines. In addition, it has been revealed that the variabilities of the radial velocities of the absorption component of the H_α and CII lines, as well as H_β and HeI lines correlate each other.

We assume that these variabilities are caused by the pulsation or can be formed by the strong variable wind in the upper atmosphere of this star, i.e., in layers where the stellar wind is generated

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