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H_α and H_β Lines in the Spectrum of Spectral Binary Star of HD 206267

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Abstract

The results of the investigation of lines H_α and H_β in the spectrum of the spectral binary HD 206267 have been presented. The observations were carried out at the Cassegrain focus of the 2-m telescope (Zeiss-2000) of N. Tusi Shamakhi Astrophysical Observatory (ShAO) of NAS of Azerbaijan, using echelle-spectrometer, during 2011-2014 years. The equivalent widths and radial velocities of the lines H_α and H_β have been measured. The radial velocity curves for the lines H_α and H_β have been plotted. The moving absorption components from red to violet direction in the core of the profile of line H_α have been revealed. The appearance of discrete components and their movement in the core of line H_α could be explained by the formation and movement of the dense formation (CIR) in the envelope of the star HD206267.

Keywords: X-ray source CepX-4; Close binary systems; H_α and H_β lines.

1. Introduction

The spectral binary star HD 206267 (O 6.5V+O9V, V = $5^m.6$) with the period of P = 3.709784 days is one of the stars of our research program concerning investigation of massive close binary systems (MCBS) at different stages of evolution. As predicted by the general theory of MCBS evolution the massive binary O+O stars are progenitors of WR+O binary systems [1]: O + O $\rightarrow$WR + O $\rightarrow$ C + O $\rightarrow$ C + WR $\rightarrow$ C + C

Due to mass transfer in massive O+O binary system onto the secondary star through the first Lagrangian point, when the more massive O star (primary component) fills its Roche lobe, results with the formation of WR + O system. The star HD 206267 investigated in this paper one of massive O+Ostars which is potentially progenitor of WR+O systems.

HD 206267 is a main (A) and bright (V = $5^m.6$) component of the Trapezium system Trap 857. Besides the bright main component HD 206267A, the Trapezium system harbors three fainter stars: component B(nature unknown, V=$13^m.6$), component C(BIV, V=$8^m.1$) and component D(B2IV, V=$8^m.0$) at angular distances $1''.6$, $11''.7$ and $19''.9$ correspondingly [2,3].

The Trapezium system Trap 857 lies in the nebula IC 1396. The intense ultraviolet radiation of massive stars belonging to this stellar system ionizes the gas of IC 1396 and causes compression denser globules of the nebula, leading to star formation. The stellar wind produced by the stars is strong enough to strip nearby stars of their protoplanetary discs [4].

Spectroscopic studies indicate that the star HD206267A consists of two stars A_1(O 6.5V) and A_2(O9V) with a P = 3.709784 day orbit as well as a third component A_3(O7V or O8V) which may or may not be bound to the binary [3]. One of interesting properties of HD 206267Ais that this star exhibits quite an exceptionally high wind velocity. The terminal velocities of the stellar wind of O6-7 stars are in a range from 1425 to 2420 km/s. However the terminal velocity of HD 206267A is equal to 3225 km/s, exceeds all the O stars investigated [5].Therefore the star HD 206267 exhibits quite an exceptionally high wind velocity. According to [6] B, C and D components are highly variable in X-rays, though such variability is not expected from stars of their spectral type. On the other hand no such variability was seen in any of the main Orion Trapezium stars.

The first spectroscopic observations of star HD 206267 were carried in [7]. Author of [7] found that this star is a spectroscopic binary with single lines, with the period of ~3.7 day. The lines of secondary component were not detected. The complex structure and non ordinary distribution of intensity inside spectral lines have been revealed. In subsequent years, observations of this star were episodic.

The interest to this star considerably rose in connection with the discovery of X-rays from the vicinity of HD 206267. In 1972 the transient X-ray source Cep X-4 was revealed and the star HD 206267 had been suggested to be associated with this X-ray source [8, 9]. The star HD 206267 is situated at $5'$ above the northern part of the error circle of the X-ray source. The spectral type of this star and their binarity of this star made more reasonable this suggestion. Authors Hensberge G and Hammerschlag R.H[10] analyses the possibility that the star HD206267 might be the optical counterpart of Cep X-4, though no observational support find to that suggestion. Although later observations with Einstein demonstrate that the star is indeed a source of X-rays [11], this radiation is ordinary for the O type stars.

More detail spectral investigation of HD 206267 was performed at Crimean Observatory, to confirm the probability of the X-ray source Cep X-4 association with this binary system [12]. These observations show no evidence for the association of HD 206267 with the X-ray source Cep X-4. Strong absorption nuclei within the broad Balmer lines and sometimes at HeI and HeII lines were revealed. Author of [12] searched for possible emission lines in the spectrum however only week emission at the red edge of line λ4686 of the HeII line were find.

The red region of the spectrum of HD 206267 little studied, only a few spectrograms obtained for the searching of emission lines. Our aim was investigating red spectrum of this star, the plotting of the radial velocity curves and revealing variability of spectral lines.

2. Observations and Data Reductions

Spectral observations of HD 206267 were carried out at the Cassegrain focus of the 2-meter telescope (Zeiss-2000) of the N.Tusi Shamakhi Astrophysical Observatory (ShAO) of National Academy of Sciences of Azerbaijan (NAS), in 2011-2014. An echelle-spectrometer with a 530x580 pixel CCD matrix was used. Spectral range λλ4000-7000 Å, spectral resolution R=13600 and signal-to-noise ratio S/N~100. The instruments used for the observations are described in detail in [13]. The echelle-spectrograms were obtained and processed by using the DECH20 and DECH20T program packages developed at the Special Astrophysical Observatory (SAO) of the Russian Academy of Sciences [14]. Thirty seven echelle-spectrograms of HD 206267were obtained. The exposure time was 15 min. Cosmic-ray traces were removed by averaging two echelle-spectrograms obtained one after the other during night. In addition to the spectra of the star being studied, we obtained a day air glow spectrum, a flat field spectrum from a lamp, and a reference spectrum. The presence of three telluriclines (λ6547.693Å,λ6548.622Å,λ6552.627Å)in the first order enable dustodetermine the radial velocity of the line $H_\alpha$with a high accuracy, since this feature is a lsoin the first order.

In the spectrum of HD 206267 in the spectral range of λλ4000-7000 ÅÅ following spectral lines have been identified: λ4861Å (H_β),HeII 5411, HeI 5875,NaI (5889,953 Å и 5895,923 Å) and λ 6562 Å (H_α).

The equivalent widths (W_λ)and radial velocities(Vr)of lines H_α and H_β in the spectrum of HD 206267have been determined (Table1).In the first and second columns of these tables the Julian date of observation and phases of period P = 3.709784 days were given respectively. We determined the radial velocities of lines by bringing the direct and mirror images of these lines into coincidence a thalf of the central intensity. The laboratory wavelength was taken to be λ 4861.337 Å and λ 6562.816 Å for the lines and H_β and H_α respectively. Thermserrors are3km/s and 10% for ther a dial velocities and equivalent widths correspondingly.

When the program objects are observed, it is very important to study the stability of the operating telescope-detector system. To perform such studies, apart from the spectra of our programs tar, we also took a day light spectrum, a dark spectrum, flat-field spectra from a lamp, and a comparison spectrum. As the comparison spectrum, we used the solar spectrum taken in the day time before and after our observations. To measure theradial velocity, it is necessary to plot the dispersion curve with a high accuracy for each order. The daylight spectrum was used to plot the dispersion curve. The shifts in each order were determined by bringing hetelluriclinesin the comparison and stellar spectra into coincidence.

The catalog of wave lengths for the solar spectrum with an accuracy of 0.0001 Åisavailable in the DECH20 soft ware package. Indetermining the radial velocity, we applied the heliocentric correction for the Earth's orbital motion, its diurnal rotation, and the perturbing effects from the Moonandma jor planets of the Solar system.

Table 1: The radial velocities and equivalent widths of lines H_α and H_α measured by us in the spectrum of HD 206267.

JD245000 0+..	ϕфаза	H_α		H_β	
		V_r км/с	W_λ Å	V_rкм/с	W_λ Å
5745.388	0.06	-66.12	2.00	-42.99	1.55
5749.379	0.14	-42.15	2.29	-13.42	1.57
5757.342	0.28	19.63	1.80	59.96	1.28
5762.360	0.63	-65.99	2.26	-49.62	1.71
5764.319	0.16	-49.31	1.95	-21.56	1.45
5764.340	0.17	-41.47	2.09	-34.16	1.50
5764.366	0.17	-46.85	1.94	-23.53	1.31
5768.409	0.26	9.89	1.76	22.91	1.43
5769.416	0.54	-29.11	2.30	10.82	1.29
5771.341	0.06	-62.53	2.22	-42.99	1.31
5771.364	0.06	-65.39	1.99	-50.49	1.21
5807.228	0.73	-95.02	2.07	-88.28	1.26
5807.251	0.74	-97.23	2.10	-74.90	1.15
5807.262	0.74	-91.72	2.21	-75.67	1.29
5808.249	0.00	-1.82	1.72	44.92	1.37
5808.272	0.01	15.73	1.62	44.37	1.44
5808.288	0.02	10.83	1.90	49.14	1.40
6850.318	0.90	-116.48	1.76	-113.86	1.39
6855.154	0.21	-10.04	1.85	16.44	1.60
6874.157	0.33	54.64	1.87	65.01	1.61
6874.179	0.33	51.26	1.80	69.08	1.41
6874.201	0.34	58.18	1.88	58.92	1.50
6875.167	0.60	-70.95	2.42	42.35	1.6
6876.185	0.87	-121.93	1.96	-128.66	1.42
6877.165	0.14	-28.76	2.25	-27.16	1.68
6878.192	0.41	51.36	1.86	55.43	1.53
6891.130	0.90	-109.09	1.95	-102.64	1.29
6892.152	0.18	-43.32	2.16	18.11	1.50
6893.162	0.45	29.75	2.10	64.07	1.64

3. Data Analysis and Discussion

Line Profile Variations: The variability of spectral lines in the spectrum of HD 206167 firstly has been investigated in [15]. Authors Crampton D and Redman RO [15]revealed weak emission due to NIIIλ4634-4641Å visible at all phases, and very weak emission on the red wing of HeIIλ4686 Å when the primary is receding, at phases 0.95-0.20 of the period of P = 3.709784 days (T_0 = 2441818.64). These emission details could be caused by the shell surrounding the main component. Authors Crampton D and Redman RO[15] also reported doubling of the HeII lines and inferred the presence of a companion 0.8 mag fainter than the primary. The observed spectrum of HD 206267 is completely normal for an early-O star near the main sequence.

In this study we have investigated the variability of lines H_α and H_β. For this purpose the profiles of lines H_α and $H_\beta$obtained at different nights have been plotted and the variability of these profiles was revealed. Firstly it was clear that the wings of these lines appear asymmetrical. For the revealing the short-term variability of these linesfive echelle-spectrograms of HD 206267 during two nights (five spectrums for each night)has been obtained. In Figures1-4shows profiles of line $H_\alpha$and $H_\beta$obtained during two nights respectively. Signal to noise ratio in all echelle-spectrograms same. In each figure shown the corresponding phase.

The following properties of line $H_\alpha$in the spectrum of HD 206267have been revealed by us firstly:

1. Non-variable weak emission in the violet wing of H_α (Figure 2);
2. Discrete absorption component in the core of H_α. This feature indicated with the arrow in Figure 2.

As seen from Figure1during the first night the significant chances of profiles do not detected. However, in the profiles of these lines obtained inthe night appearance of discrete absorption component, in the core of line H_α (Figure2), indicating with the arrow, have been revealed. The discrete absorption component firstly have been emerged in the red side of the core of the line H_α (Figure2)and moved toward the violet side of core of line $H_\alpha$and at the end appeared in the violet part of the core during night. This movement takes place within about one hour. We believe that the emergence of discrete components and their movement in the core of line $H_\alpha$can be explained by the formation and movement of the dense formation, corotating interacting regions (CIR) in the shell of the star HD 206267.

We checked the possibility of the appearance of telluric lines at the wavelengths where discrete absorption components were detected. However no telluric lines were detected. This observational fact is in favor of reality observed discrete absorption components.

Strong absorption nuclei of broad Balmer lines, the week emission at the red edge of HeII 4686 lines revealed by the author of [12] could be manifestation of the presence of an irregular density envelope, surrounding the primary component.

Radial Velocities: By using values of radial velocities of lines H_α and $H_\beta$measured by us (Table 1) we plotted radial velocity variations as a function of phase of period 3.709784 (Figure5 and Figure 6). The zero epoch adopted JD_0 = 2441818.64 as in [15]. If we compared the radial velocity curves constructed by different authors [7, 12] and by us we could conclude that these curves constructed by using different elements had different velocity amplitudes. This observational fact may be manifestation of those different lines forms in various areas of the envelope surrounding primary component.

According to [12] the radial velocity of the primary component varies within ±80 km/s from hydrogen and HeII lines. The radial velocity of secondary component varies from - 120 km/s to + 120 km/s. The lines of secondary component are clearly seen in the lines HeII.

By the comparison the radial velocity curve which plotted by us and the authors of [7, 12] found the different feature near the phase 0.00 i.e., when the primary star is between us and the secondary component. In radial velocity curve plotted by us revealed second minimum (indicated by the arrow 1 in Figure 5 and Figure 6) around phase 0.1. This minimum does not exist in radial velocity curves plotted by other authors.

Note that minimum at phase near 0.1 obtained due to points indicated by the arrow 2, near phase 0.00 (Figure 5 and Figure 6). Therefore, we carefully checked the accuracy of measurement of these points and were convinced of the reliability of these measurements. We believe that the revealed second minimum in radial velocity curve indicated by the arrow 1 could be associated with the presence of the third component in a star system of HD206267.

In Figure 6 shown dependence of radial velocities of line H_β as a function of phase of P = 3.709784 days period. In this case also revealed second minimum near the phase 0.00. This observational fact may be in favor of reality of this minimum, since in both cases (for H_α and H_β) we obtained same result.

The dependence of equivalent widths of lines H_α and H_β also plotted (Figure 7 and Figure 8) also have been plotted. As could be seen from the Figure 5 and Figure 7 the radial velocities and equivalent widths of line H_α vary in antiphase. The equivalent widths of line H_β does not depend from the phase of P = 3.709784 days period (Figure 8).

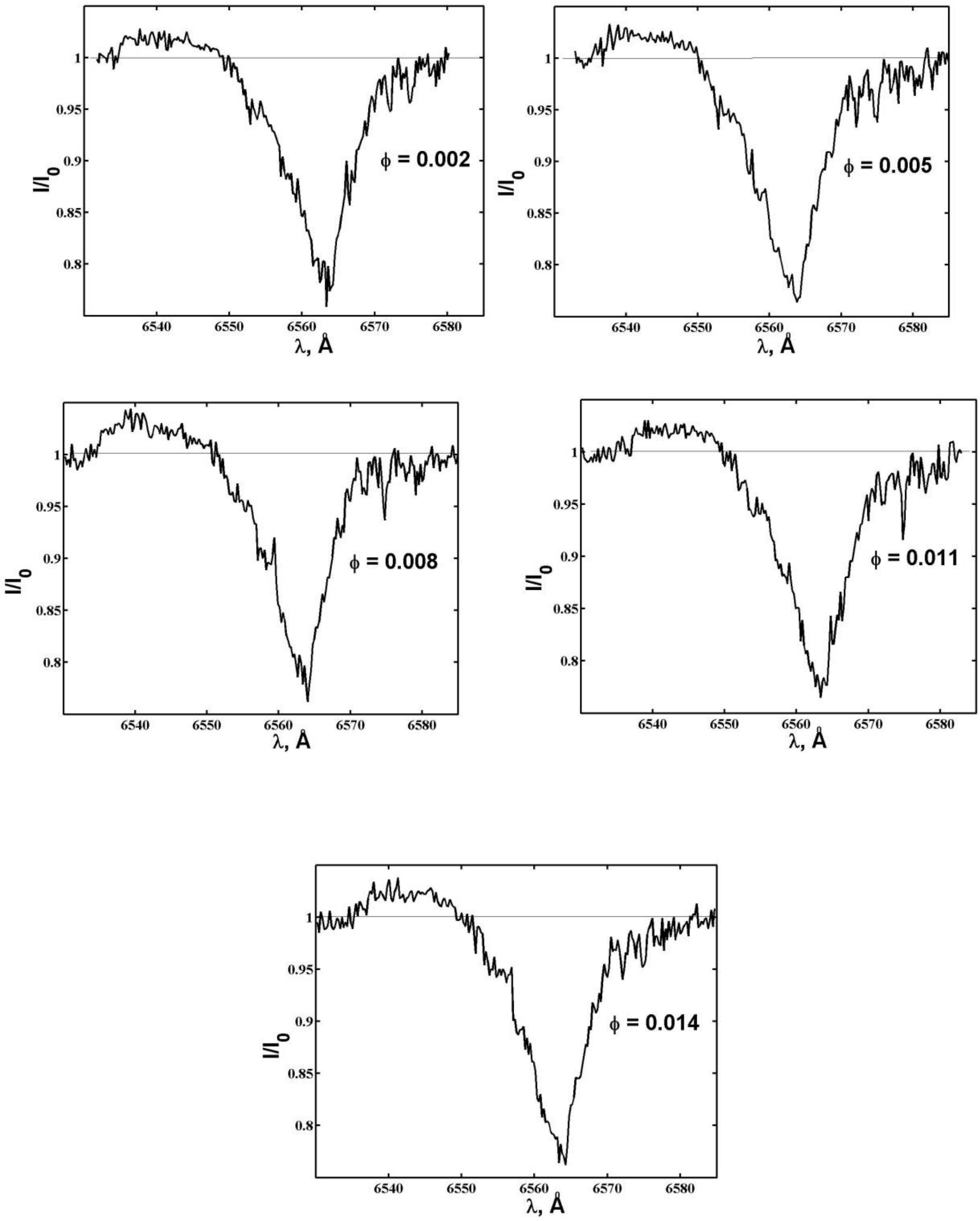


Figure 1: Five profiles of line H_α obtained at first night for the phases of period P = 3.709784 days indicated in each profile.

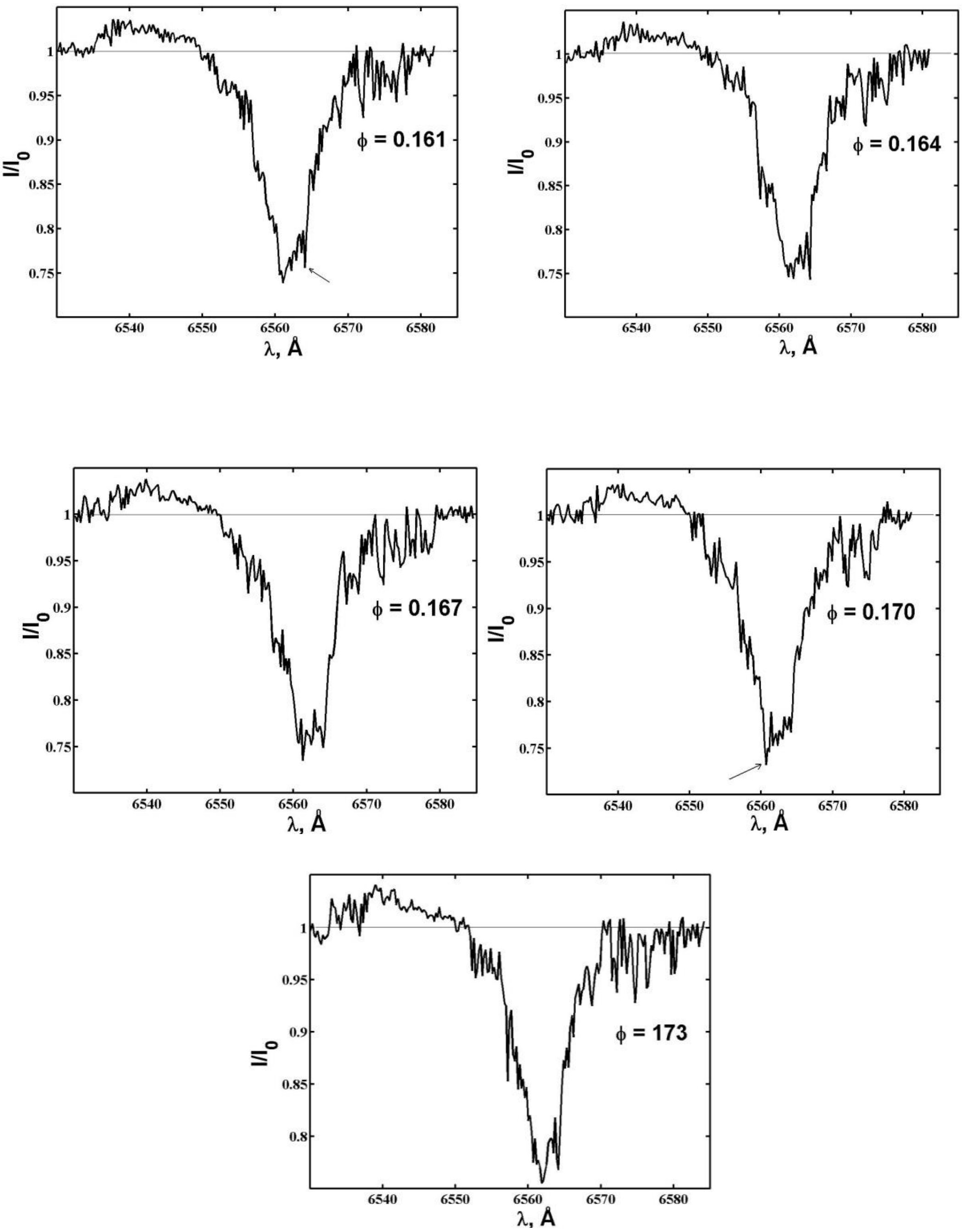
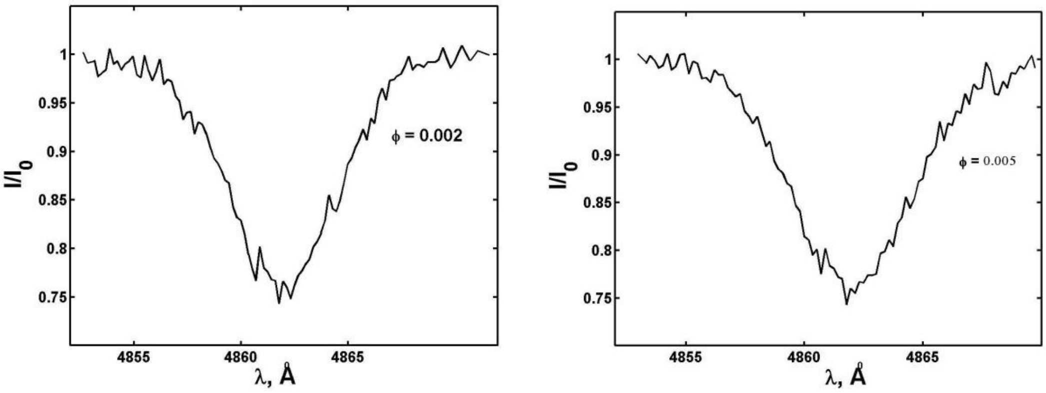


Figure 2. Five profiles of line H_α obtained at second night for the phases of period P = 3.709784 days indicated in each profile.



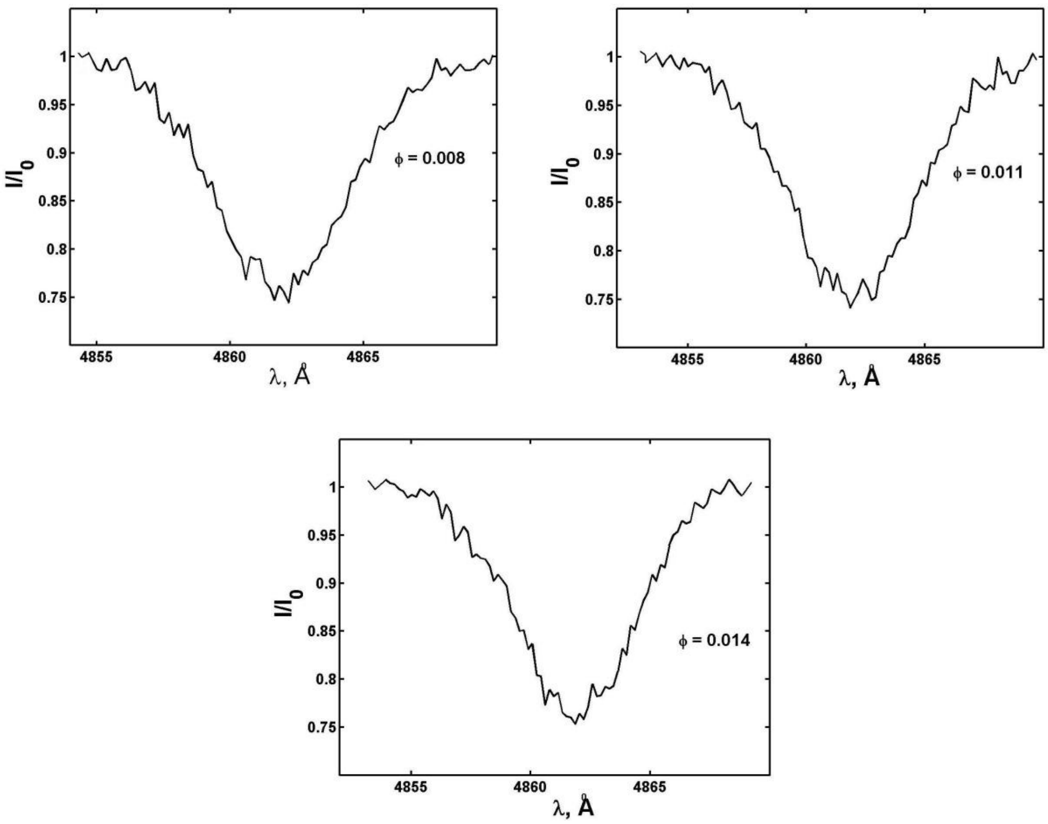
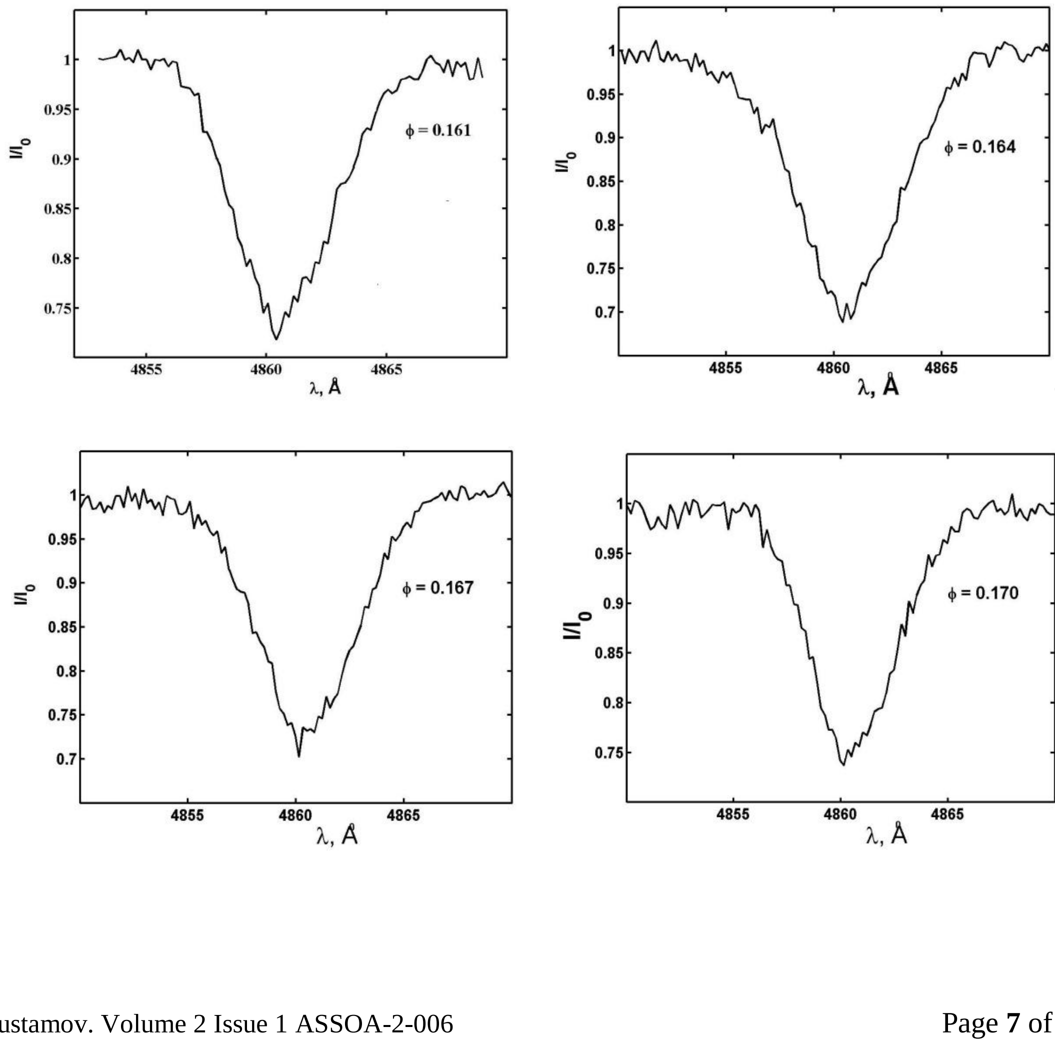


Figure 3: Five profiles of line H_β obtained at first night for the phases of period P = 3.709784 days indicated in each profile.



0

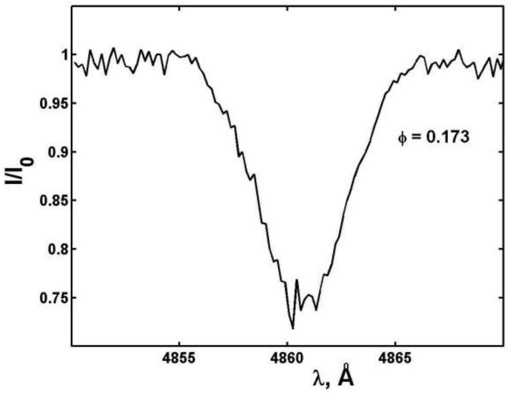


Figure 4: Five profiles of line H_β obtained at second night for the phases of period P = 3.709784 days indicated in each profile.

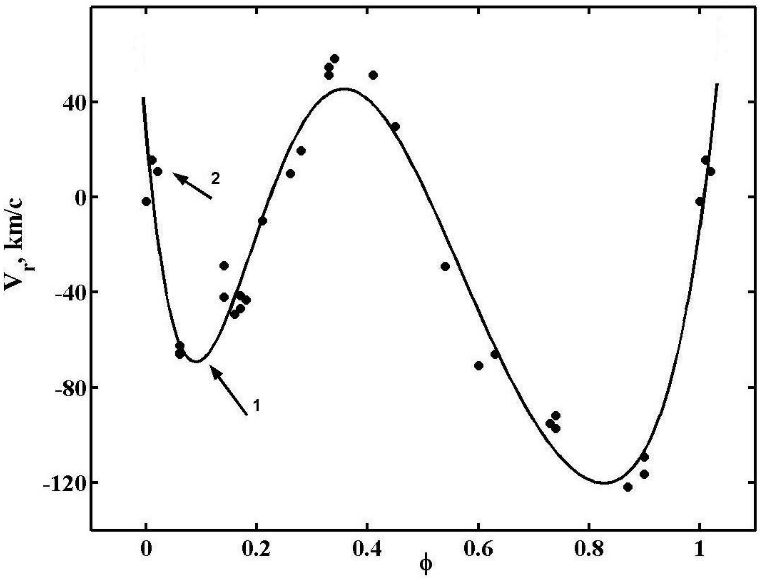


Figure 5: The dependence of radial velocity of line H_α from the phases of period P = 3.709784 days.

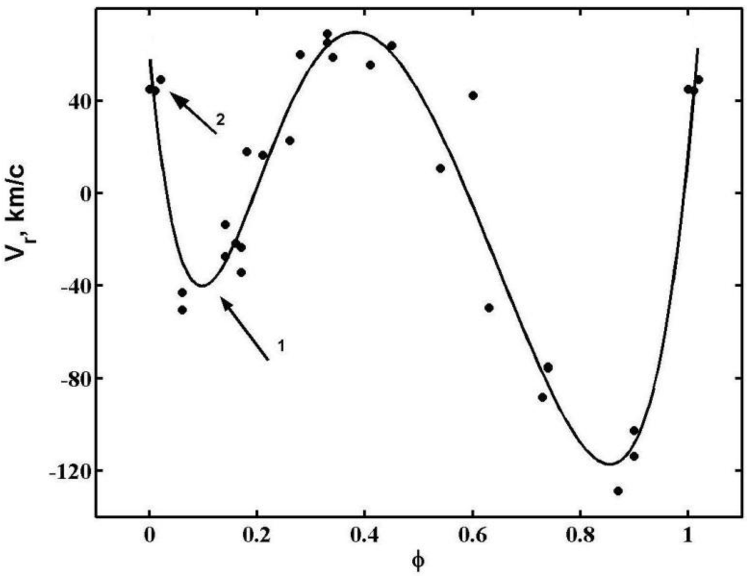


Figure 6: The dependence of radial velocities of line H_β from the phases of period P = 3.709784 days.

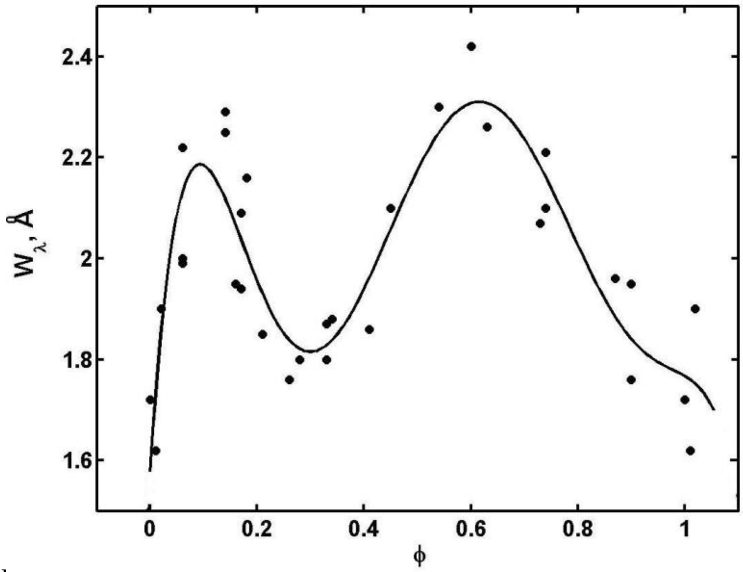


Figure 7: The dependence of equivalent widths of line H_α from the phases of period P = 3.709784 days.

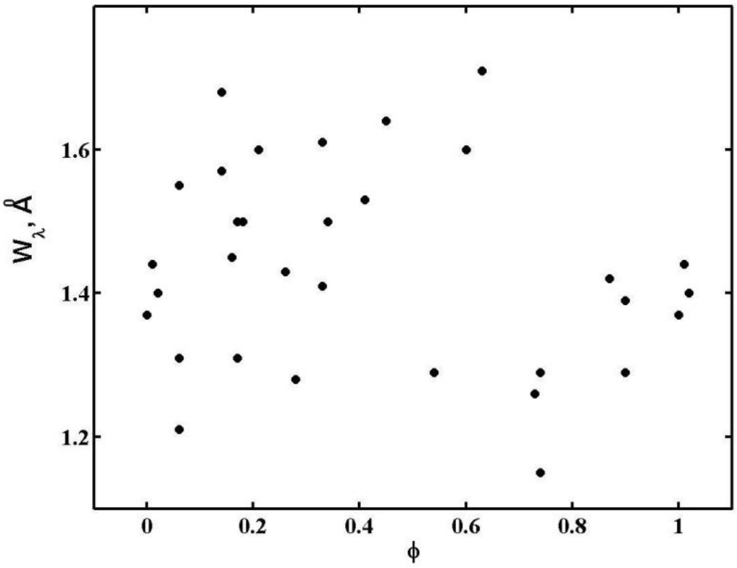


Figure 8: The dependence of equivalent widths of line H_β from the phases of period P = 3.709784 days.

5. Conclusions

From the spectral studies of spectral binary star HD 206267 the following results have been obtained for the first time:

1.Non-variable weak emission in the violet wing of line H_α;

2.Appearancediscrete absorption component in the core of H_α and moving this component from red site of core to the violet, during approximately 1 hour;

3. Second minimum in the radial velocity curve plotted for the lines $H_\alpha$and H_β;

4. The antiphase variation of radial velocity and equivalent widths of line $H_\alpha$and independence the equivalent widths of H_β from the phase of period of P = 3.709784 days.

These observational facts could be interpreted with the presence of an irregular density envelope, surrounding the primary component. The appearance discrete absorption component in the core of H_α and moving this component from red site of core to the violet explained by the presence of CIR (corotating interacting regions) in the envelope of primary component.

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