SOME RESULTS OF THE SPECTROSCOPIC STUDY OF FOUR CLOSE BINARY SYSTEMS OF EARLY SPECTRAL TYPES

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It is necessary to have quantitative estimates of the intensity of lines (both absorption and emission) to obtain the physical parameters of the atmosphere of components.

Some years ago at the Crimean observatory we began the spectroscopic investigation of close binary systems of the early spectral type with components WR, Of, O, B to try and obtain more quantitative information from the study of the spectra of the components.

Some results of the spectroscopic investigation of four systems will be reported.

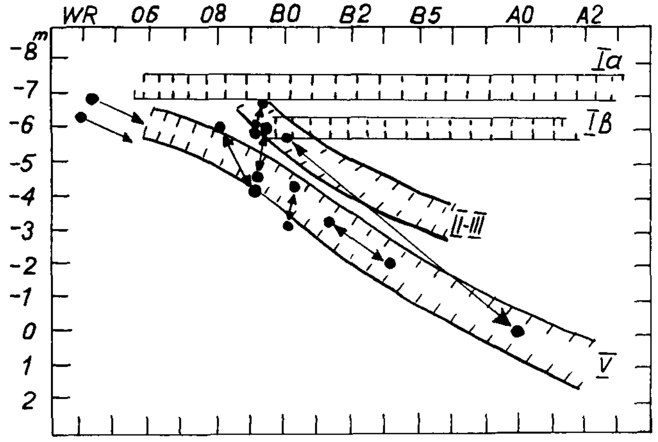

Fig. 1. H-R diagram.

The data about the binary systems are listed in Table I and their position on the H-R diagram is shown in Figure 1.

The spectra were taken during 1964 with the aid of the 50″ reflecting telescope with the dispersion of 36 Å/mm in the regions of $\lambda\lambda$ 4950–3600 Å and $\lambda\lambda$ 6800–5400 Å.

From the consideration of absorption lines of the spectra of the components, the spectral type of each component was estimated. The variations of the spectral type of the primary components with phase were found for the stars AO Cas, HD 47129, HD 190918 (see Figures 2 and 3). Here the radial velocities of the primary and secondary components AO Cas and HD 47129 and the variation of the spectral type of the primary components with phase are presented. The spectral type of the secondary components were estimated as O 7.2 (for AO Cas) and O 6.5 (for HD 47129).

It is interesting to note that the spectral types of primary components become earlier near the conjunction. The variation of the spectral type of one component can be due

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TABLE I

Star	*P* (in days)	*Sp* (*MK*)	*Sp* (Galkina)	$f(\mathfrak{M}_\odot)$ [6]	*A*	Type	Remarks
AO Cas [1]	$3^d.52$	I O9 III	O9.1–O8.0	4.06	$0^m.2$	β	Max I ≠ Max II = $f(\lambda)$ Min I ≠ Min II = $f(\lambda)$
HD 47129 [2]	14.4	I O8*p* II?	O8*f*–O6.5 O 6.5	12.88	0.1	I_{rr}	The γ_2-velocity is variable
HD 190918 [3]	85.0	I WN6 II O9	WN5.5 O9–O8	–	0.2	I_{rr}	
HD 193793 [4]	326^d. [5]	I WC6 II O6	WC5.5 O6	?	?		The emission lines are very, very wide (100 Å)

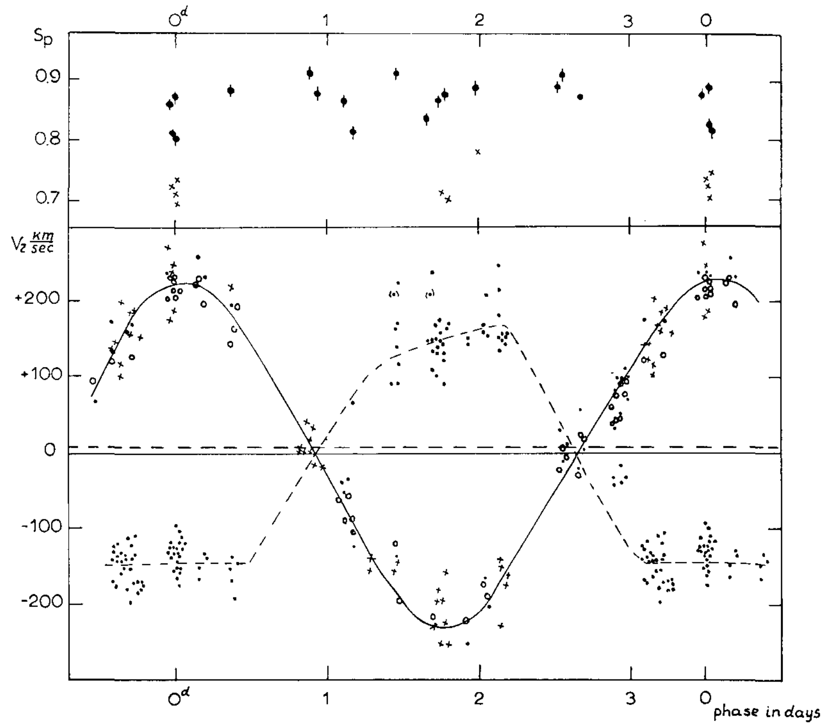

Fig. 2. The radial velocities of the primary and secondary components AO Cas (bottom) and the variation of the spectral class of the primary component with phase (top).

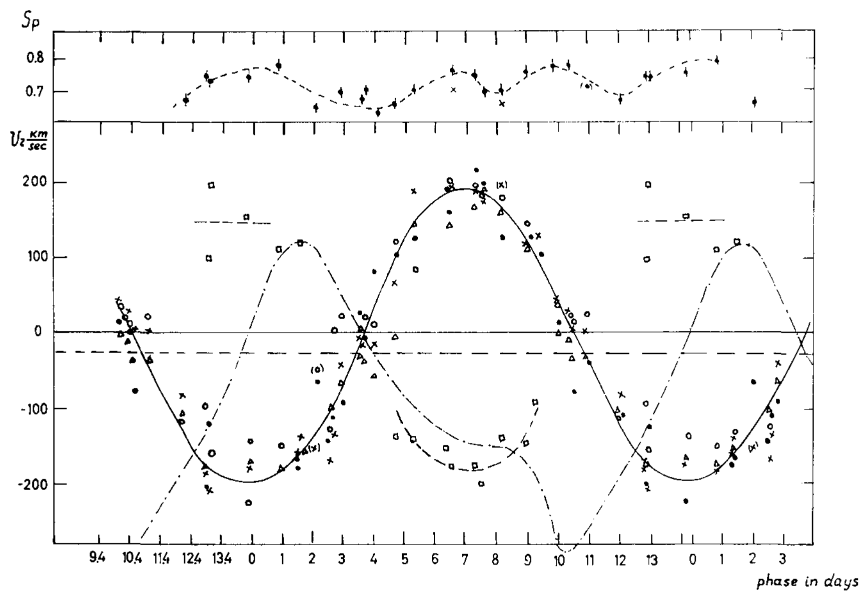

Fig. 3. The radial velocities of the primary and secondary components HD 47129 (bottom) and the variation of the spectral class of the primary component with phase (top).

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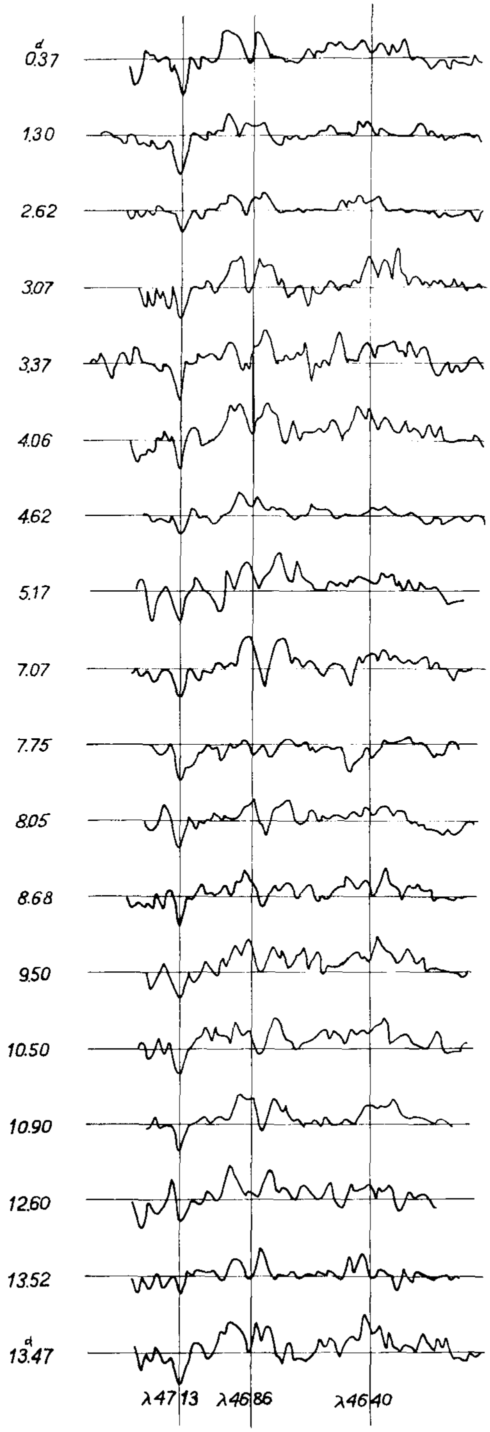

Fig. 4. The region of the spectrum at λ 4686 He II is shown in different phases.

to the corpuscular radiation of the other, hotter component, or due to the stream of gas coming out of the surface of the other component.

At the present time it is difficult to say what is the principal cause of this variation. The spectral observations concerning HD 47129 give some evidence of the presence of the gas stream in the system. In fact, if we look at Figure 4, where the region of the spectrum at λ 4686 He II is shown at different phases, we will see a faint emission of He II λ 4686 with the absorption core overlapping on the emission. This absorption core changes its place with the phase. The results of measurements of the shifts of this absorption core are shown in Figure 3 where the radial velocities of the components of HD 47129 are presented.

We see that the absorption core is not connected with the primary or secondary components, it originates, probably, in the stream of gas around the system.

This stream can be formed out of the irregular gaseous prominences coming out of the surface of the secondary component.

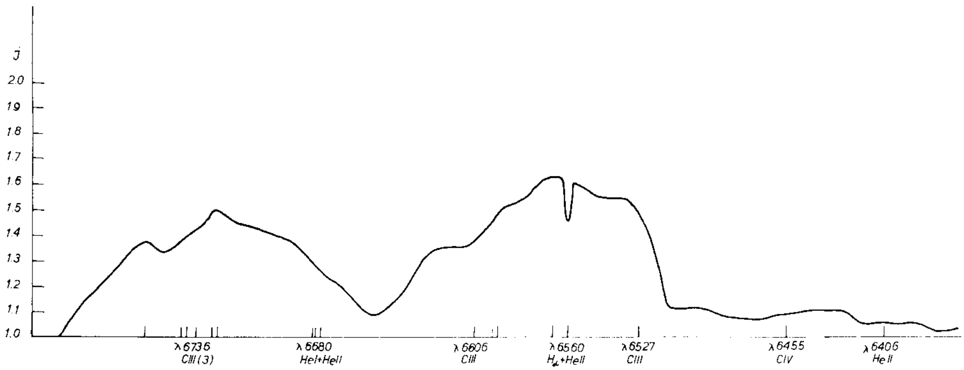

Fig. 5a–d. The tracings of the intensities of the spectrum of HD 193793 in the regions of λλ 6800–6400 Å – 5950–5400 Å, λλ 4900–3650 Å.

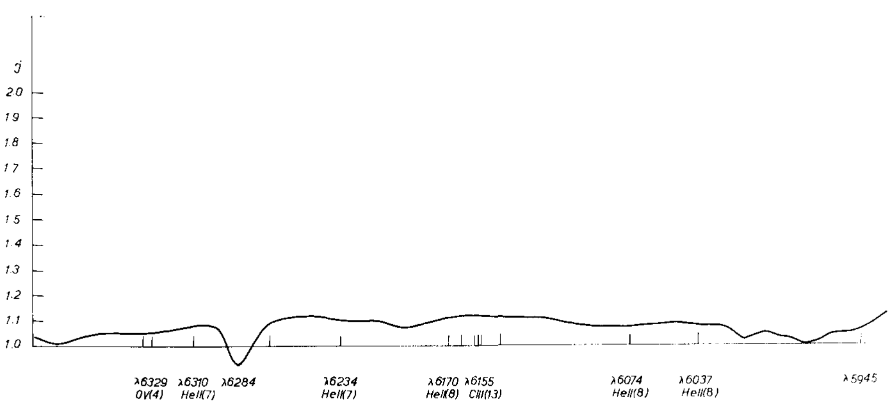

Fig. 5b.

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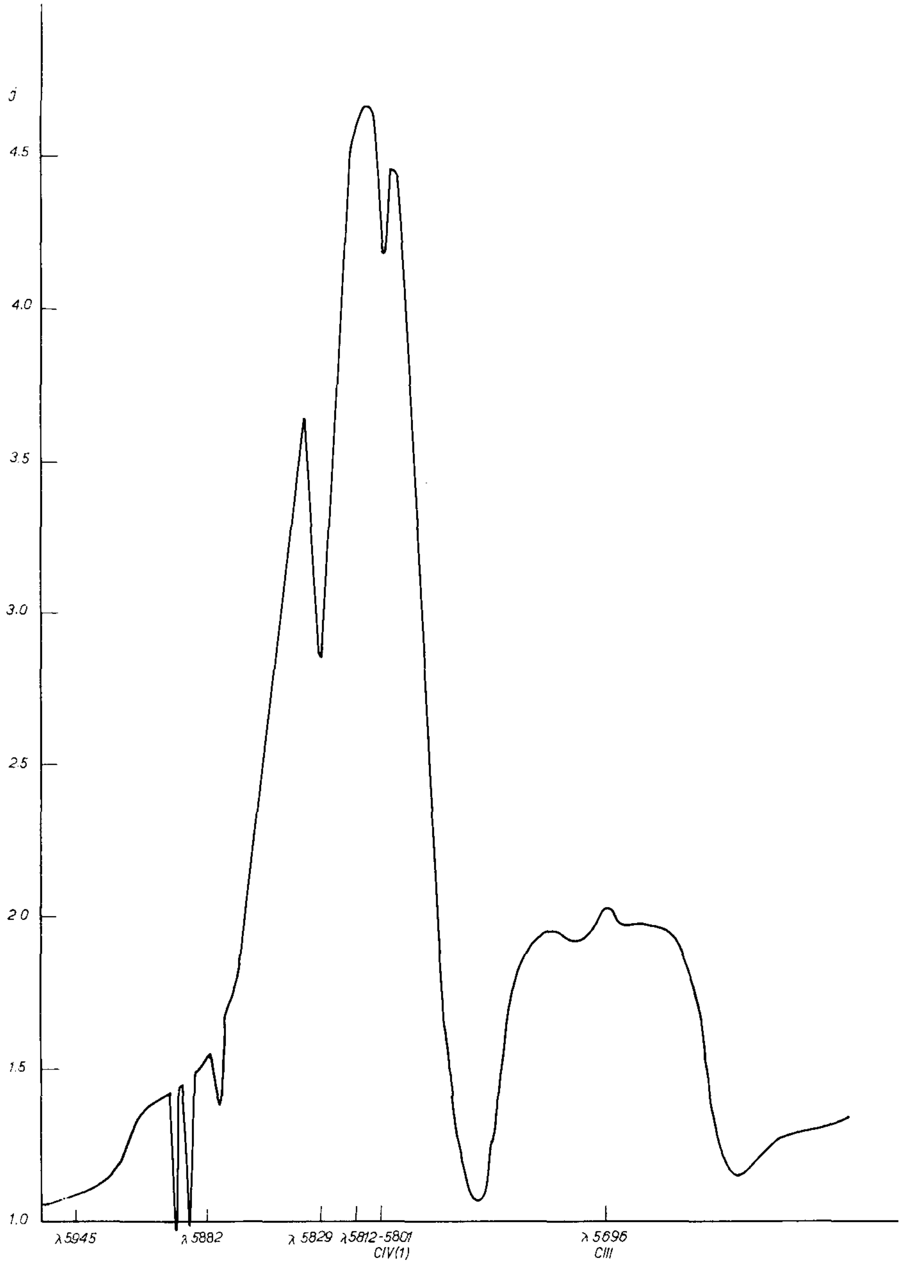

Fig. 5c.

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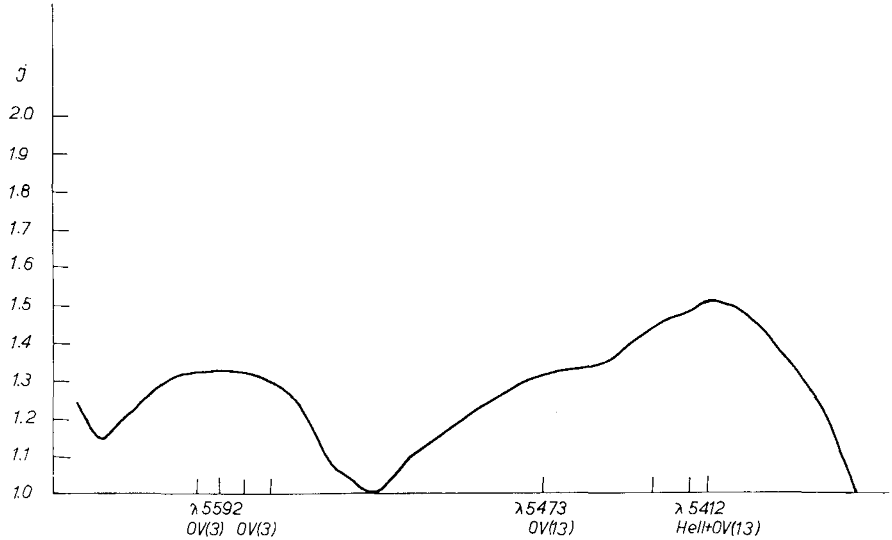

Fig. 5d.

The instability of the secondary component of the system HD 47129 is indicated by the variation of γ_2-velocity with time as shown in Table II:

TABLE II

	$\gamma_2 - \gamma_1$
Plaskett (1922) [7]	= − 60 km/sec
Struve (1947) [8]	= − 100 km/sec
Struve *et al.* (1957) [9]	= − 30 km/sec
Galkina (1964) [2]	= − 25 km/sec

The spectra of HD 190918 and HD 193793 are very complicated. They consist of absorption lines characteristic for the early spectral type O or B and of very wide emission lines. The interesting results come out of the examination of the emission spectrum of HD 193793. Here we have the lines belonging to very different states of ionization such as: He I, He II, C II, C III, C IV, O II–O V. The range of ionization potentials is: 24.48 eV (He I)–113.78 eV (O V). The next Figures 5 (a, b, c, d), and 6 (a, b, c), show the tracings of the spectrum of HD 193793 in the regions of $\lambda\lambda$ 6800–6400 – 5950–5400 Å and $\lambda\lambda$ 4900–3650 Å. The intensity of some lines is three-four times more than that of the continuous spectrum. The most interesting detail of this spectrum is the emission line λ 5696 C III. Its profile is rather rectangular and flat-topped like the contours of emission lines in the spectra of novae. The question arises whether the contours of the observed lines of ions are similar to that of the C III line λ 5696 in the emission spectrum of HD 193793. Figure 7 shows the line profiles: (a) λ 5696 C III, (b) λ 5875 (C III + He I), (c) λ 4686 He II, (d) λ 5806 C IV, on the same scale of $\Delta\lambda$, and it is clear that these profiles have different form and width from the line C III λ 5696.

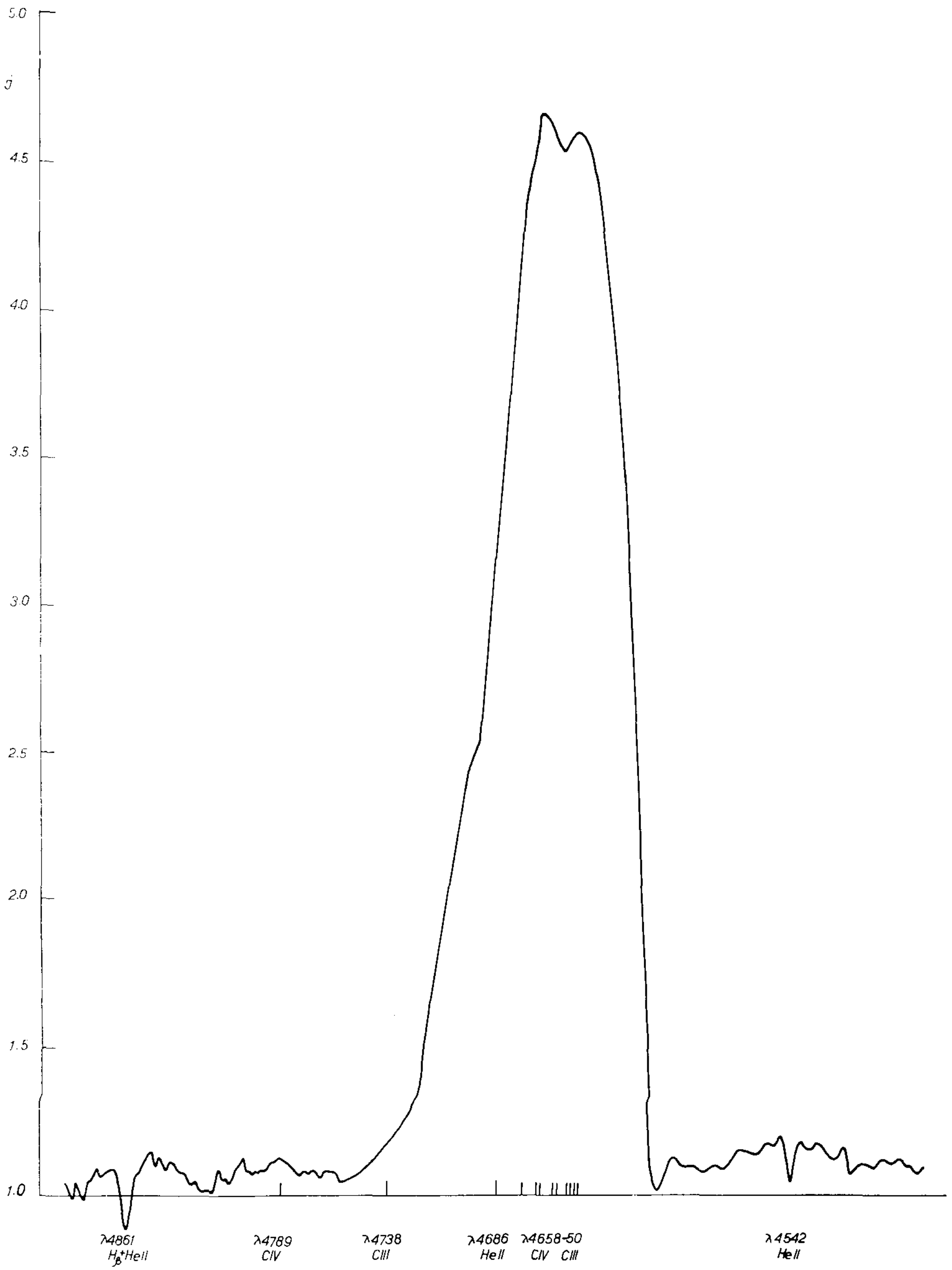

Fig. 6a–c. The tracings of the intensities of the spectrum of HD 193793 in the regions of λλ 6800–6400 Å – 5950–5400 Å, λλ 4900–3650 Å.

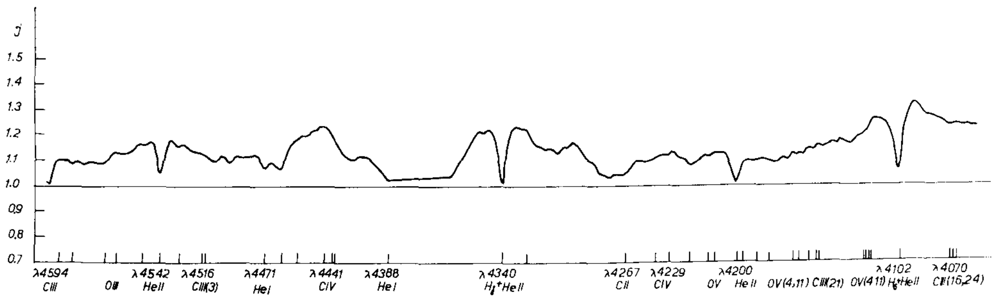

Fig. 6b.

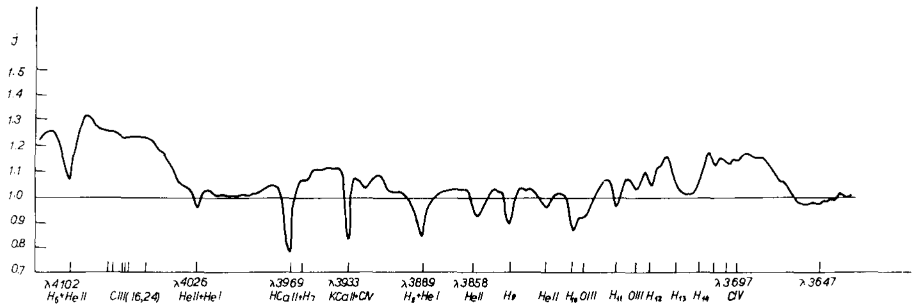

Fig. 6c.

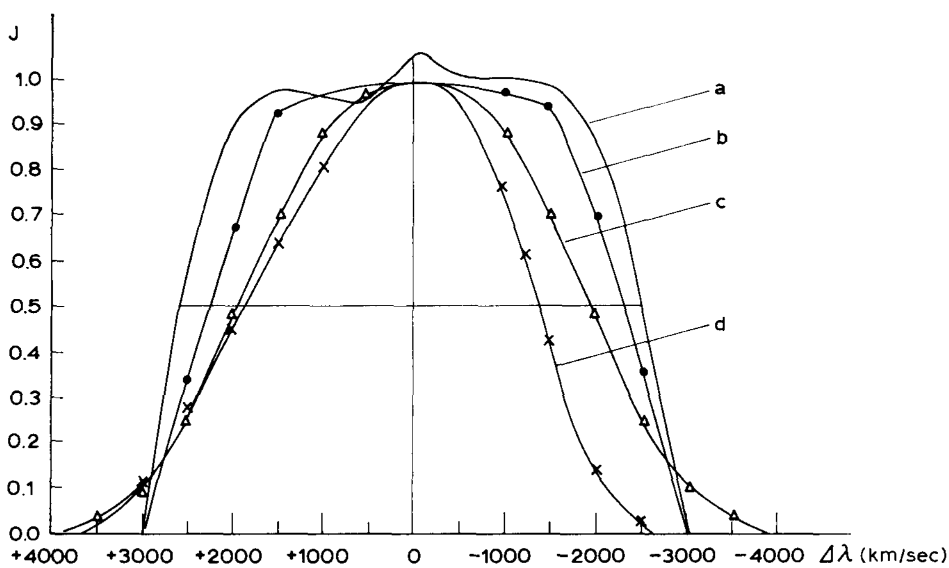

Fig. 7. The line profiles: (a) λ 5696 CIII, (b) λ 5875 (CIII + HeI), (c) λ 4686 HeII, (d) λ 5806 CIV.

The line profiles of the ions of the low ionisation potential (He I, C III) are rectangular, flat-topped and have a large halfwidth (5000 km/sec) while the line profiles of the ions of the higher ionisation degree (He II, C IV, O V) are rounded in form (Gaussian) and they have a smaller halfwidth (3600–4000 km/sec).

If we now suppose that the shell around the system is formed of the matter flowing from the star one may conclude that the expansion velocity varies at different distances from the star. To explain the connection between the halfwidth and the stage of ionisation we may suppose the existence of a positive gradient of velocity, from 1800–1900 km/sec (O v, C iv) to 2400–2500 km/sec (C iii, He i). Figure 8 shows the qualitative model of the atmosphere of HD 193793.

Supposing that the line-contours only of the same ion are similar and that the relative

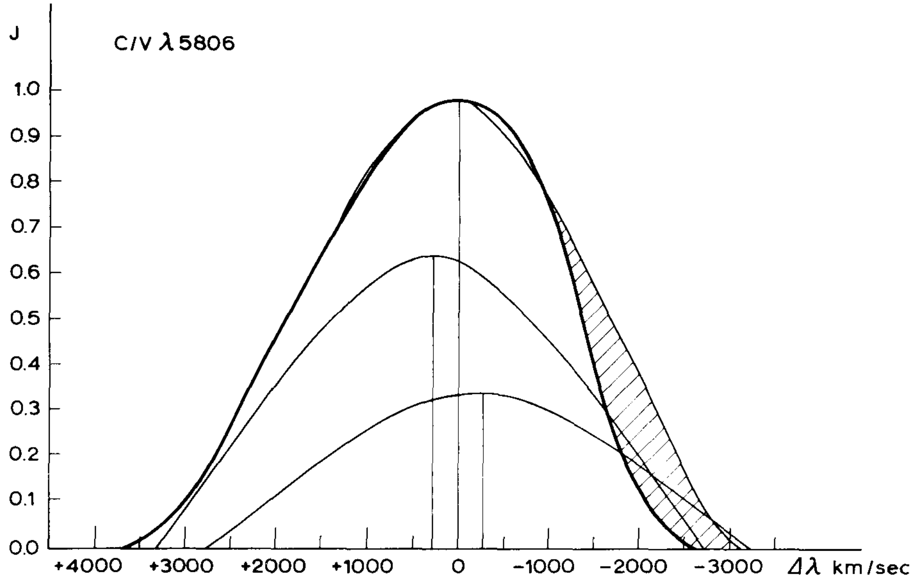

Fig. 8. The qualitative model of the atmosphere of HD 193793.

intensities of emission lines in the multiplet of the same ion are determined by LS-coupling, one might distinguish 40 emission lines and estimate their relative intensities using the energy distribution in the spectrum of HD 193793 found by Kuhi (1966) [10].

In the spectrum of HD 193793 shortward displaced absorption components of He i λ 5876 (2 ^3P), He i λ 3888 (2 ^3S), C iv λ 5806, λ 4441 and C iii, C iv λ 4658–50 Å are present. Their displacements are about 2400–2500 km/sec. These velocities are in agreement with the velocities from emission lines. These shortward displaced absorption components are probably due to absorption in the expanding shell.

To solve the problems connected with the origin and evolution of binary stars one must have the results of both photometric and spectroscopic observations, as well as a detailed study of the profiles and intensities of lines.

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Discussion

Batten: Apparent spectral type changes of hot components of close binaries may be due to gaseous streams impinging on the photosphere, and causing local heating. As the aspect of the star changes we see regions of different temperatures.

Galkina: Yes. I told about it in the communication.

Sahade: Le question de l'émission connectée avec le jet de gaz dans HD 47129 très joliment en Hα suggère la direction du jet. Au regard des variations de γ_2–γ_1 nous devons prêter attention parce qu'au cas des deux premières étoiles de la liste de Mme Galkina le comportement des vitesses radiales de l'étoile secondaire est très particulier et indique que la vitesse radiale de l'étoile la moins lumineuse est perturbée par la matière des jets. – Maintenant à propos des binaires Wolf-Rayet, nous savons que ces systèmes ont deux enveloppes, l'une qui est proche de l'étoile WR et l'autre autour du système. Les profils carrés viennent de l'enveloppe extérieure, les profiles pointus de l'enveloppe intérieure.

Strand: There were two investigations, by Struve and by Sahade, showing a considerable difference of the systemic radial velocity. Was that the same material?

Sahade: The material was different. In a later paper (1962) I suggested an interpretation of the radial velocity distribution of the secondary. Clearly the value γ_2–γ_1 depends on such an interpretation. It is doubtless that $\gamma_2 < \gamma_1$.

Rösch then summarizes the mass determinations obtainable from different kinds of binaries. He comments on the importance of the electronic camera, its design, and on possibilities of future improvements of this technique.