CHANGES IN THE BETA-LYRAE SPECTRUM AND THE SEARCH FOR THE SECONDARY SPECTRAL LINES

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Received 26 May 1980

ABSTRACT. It was found that spectral lines, previously identified by some authors as lines of the secondary component, belong to the primary or to interstellar matter.

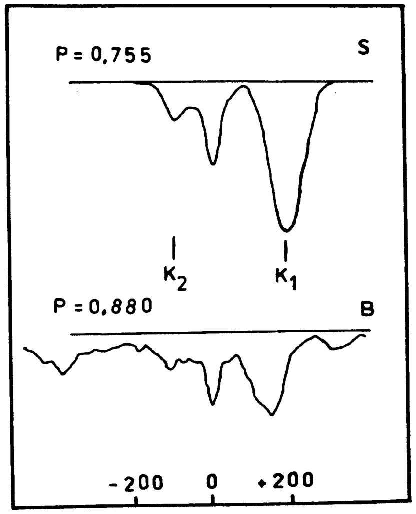
The changes of the profiles of some selected spectral lines, which have been qualitatively studied, indicate that they were generated in a non--stationary environment.

The phase dependence of equivalent width of some hydrogen spectral lines reflect, with high probability, the influence of the radiation of the secondary component on the primary spectrum.

ИЗМЕНЕНИЯ В СПЕКТРЕ β ЛИРЫ И ПОИСК СПЕКТРАЛЬНЫХ ЛИНИЙ ВТОРНОГО КОМПОНЕНТА. Было найдено, что спектральные линии идентифицированные некоторыми авторами как принадлежащие вторной звезде системы принадлежат либо главном звезде, либо межзвездной среде.

Квалитативное изучение изменений избранных спектральных линий показывает на нестационарность среды их возникновения.

Зависимость эквивалентных ширин от фазы для некоторых водородных спектральных линий является правдоподобно непосредственным проявлением вторьной звезды на спектр системы.



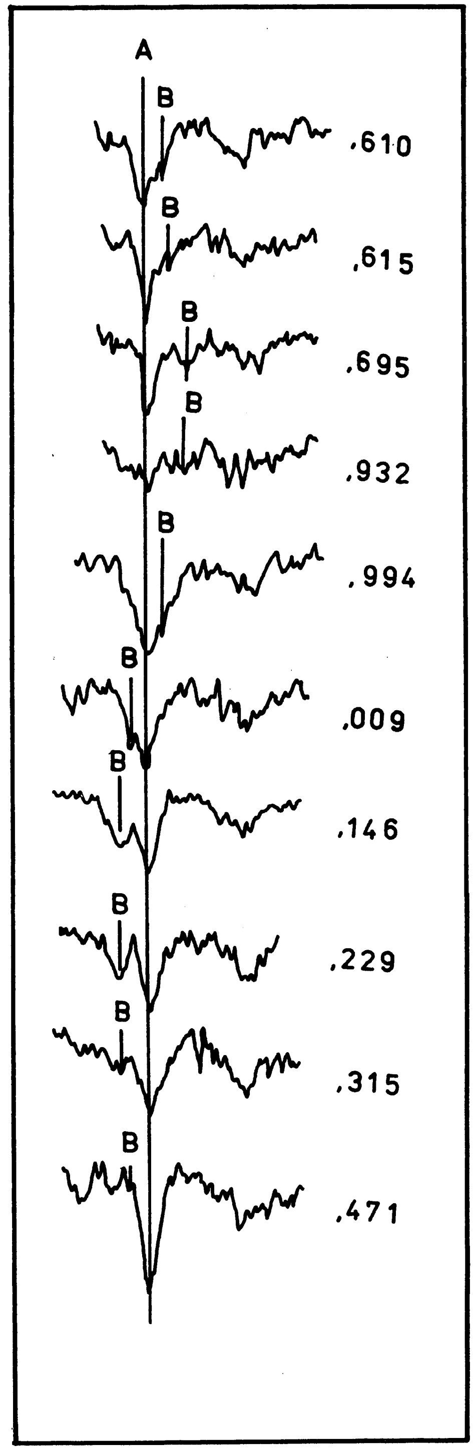


Fig. 1 Up. The part of β Lyrae spectrum near Ca II K copied from Batten's et all (1974) paper (denoted B) and from Skulskij's paper (1971) (denoted S).

Fig. 2 Right. The vicinity of Ca II K line in the Dadaev's (1975) spectrograms. A denotes the primary and B the secondary line component.

ZMENY V SPEKTRE β LYRAE A HĽADANIE SPEKTRÁLNYCH ČIAR SEKUNDÁRNEJ ZLOŽKY.

Zistilo sa, že spektrálne čiary identifikované niektorými autormi ako prislúchajúce sekundárnej zložke sústavy, prináležia alebo primárnej zložke alebo medzihviezdnej hmote.

Kvalitatívne skúmanie zmien vybraných spektrálnych čiar ukazuje na nestacionárnosť procesov, pri ktorých vznikli.

Závislosť ekvivalentných šírok od fázy niektorých spektrálnych čiar vodíka je spôsobená pravdepodobne pôsobením žiarenia sekundárnej hviezdy na spektrum sústavy.

β Lyrae is known not only for its lengthening of period and for the changes of its light curve, but also for the changes in its spectrum. The β Lyrae spectrum has one other peculiarity. Only the lines of the primary component can be observed in it.

The observed changes in the β Lyrae spectrum have led in the past and present to an effort to find the secondary spectral lines in it. Among others, Miss Maury (1933) has studied the β Lyrae spectrum in detail in the past. She has identified a number of lines attributed to the secondary spectrum. But Struve later identified these lines as lines generated in the extensive gaseous stream surrounding the whole system (Kříž,1974).

Skulskij (1971), Batten et al. (1974) and Dadaev (1975) recently returned experimentally to this problem. Batten et al. contradicts Skulskij in the sense that, the incidental identification of the secondary spectral lines is considerably complicated by the presence of satellite spectral lines or by the presence of metallic lines.

In both papers (Skulskij,1971; Batten et al.,1974) the fact that the line, which Skulskij has identified as the secondary one was seen well by both authors is conspicious. In Figure 1 are copied the mentioned parts of the intensity tracings. In other phases, the Ca II K_2 line is present and can only be seen well in Skulskij´s tracings. The change of the central intensity of the line Ca II K_1 relative to the central intensity of the Ca II K_{Int} line with time can also be seen in Figure 1.

The last of the mentioned papers (Dadaev,1975) is only the first of a series of papers in which the author has treated and interpreted his observational material in detail. In Figure 5 of (Dadaev,1975) we are surprised at first sight by the fact that the Ca II K_{Int} component there is completely invisible. This figure was included in this paper as Figure 2. In it we can see the high intensity Ca II K_1 component together with the Ca II K_2 component, which is sometimes more intensive. Owing to the absence of the Ca II K_{Int} line and having in mind the rather low dispersion of Dadaev´s spectrograms (2.3 nm/mm), we have concluded that in this case the line identified as the Ca II K_2 is in fact the interstellar component of the Ca II K line only. To be sure, we have measured the wavelength of our identification of the Ca II K_{Int} line on Ondřejov spectrograms (dispersion = = 0.8 nm/mm) with the aid of an Abbé comparator. We have found that its mean

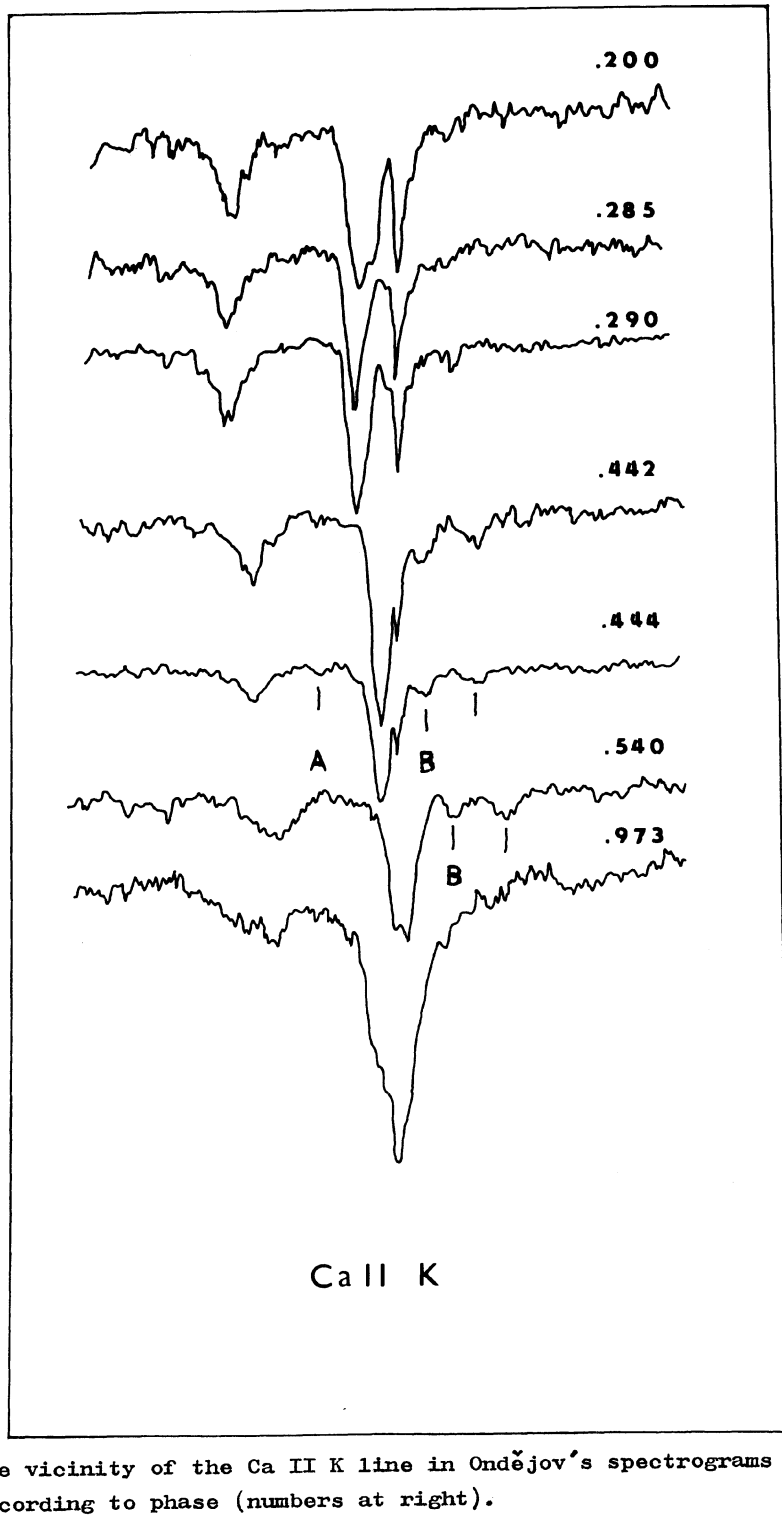


Fig. 3 The vicinity of the Ca II K line in Ondějov's spectrograms filled up according to phase (numbers at right).

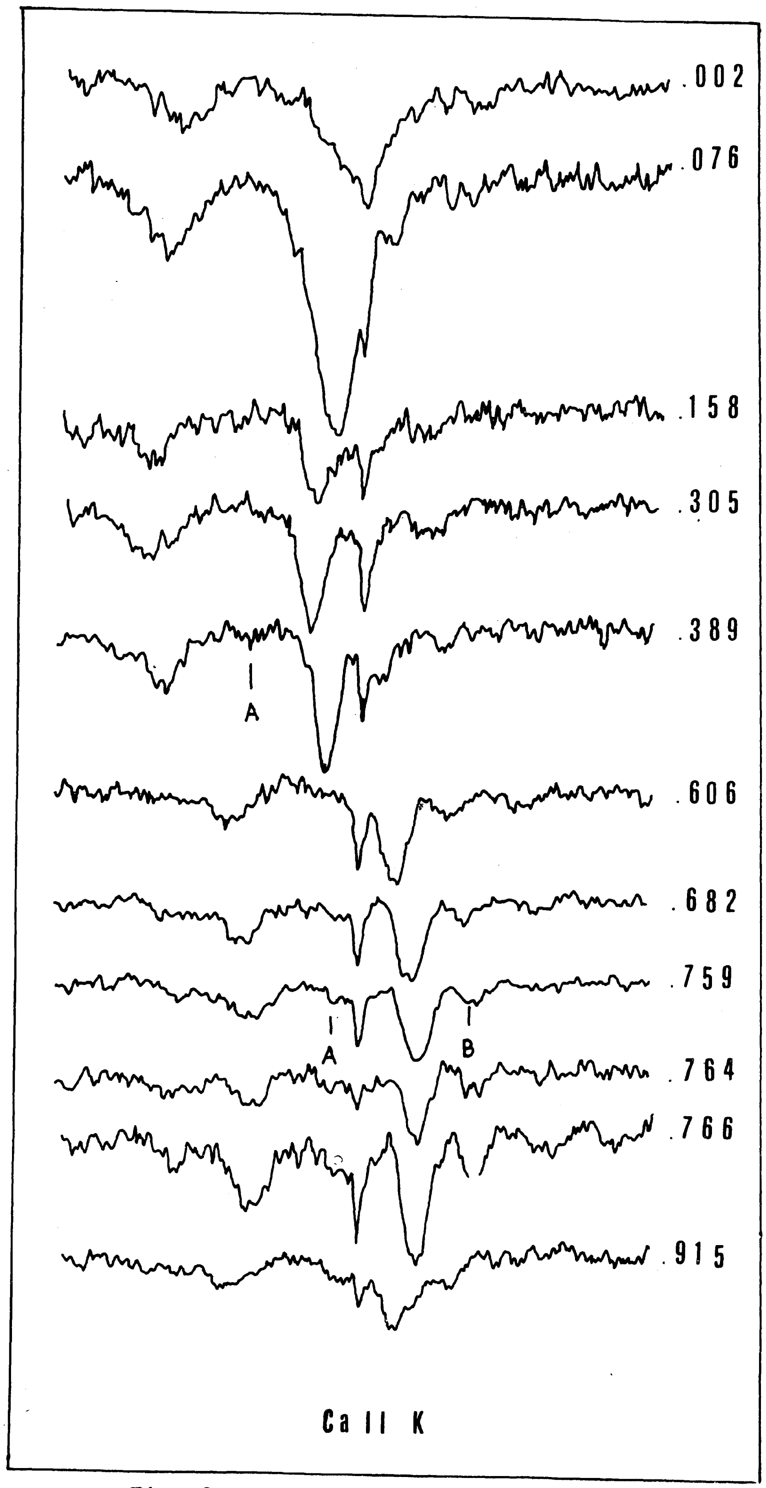


Fig. 4 The same as Fig. 3.

wavelength, not corrected for the Earth's motion around the Sun, is λ = = (393.34667 ± 0.007) nm. We have not treated other lines identified by Dadaev as secondary spectral lines. He has not published their intensity tracings for various phases yet. On the basis of the Ondřejov spectrograms, we have concluded that the satellite lines or metallic lines have been misinterpretted as secondary spectrum lines.

Let us go back to the papers of Skulskij (1971) and Batten et al. (1974). 36 spectrograms of the β Lyrae system were taken at Ondřejov Observatory in the years 1971 and 1972 as part of the international β Lyrae 1971 campaign. These spectrograms have been kindly lent to us for further study. The method of observations and the spectrogram data were published in the paper of Kříž and Žďárský (1974). Intensity tracings of these spectrograms were made at the Skalnaté Pleso Observatory with the aid of a SENAS 2 servomultiplier (Zverko,1973), and were then further treated. Skulskij's secondary lines are visible on our tracings, too. Parts of our intensity records from the neighbourhood of λ = 393.34 nm are arranged in rows in Figs 3 and 4. The misinterpreted secondary Ca II K lines (Skulskij, 1971) are marked with a weak vertical line and denoted A and B. We have identified these (marked) spectral lines as Fe II lines; λ = 393.031 nm (line A), λ = 393.8289 nm (line B), λ = 393.896 nm (line C). In connection with the hypothetical Ca II K_2 line, we have to pay attention to lines A and B. A sharp interstellar line does not change its place with phase. But all others lines do. Figures 3 and 4 document this quite clearly. Therefore, if the value of the radial velocity is negative, the B line may be misinterpreted as the Ca II K_2 line. If the radial velocity amplitude is positive, the line A is again misinterpreted as the Ca II K_2 component. In this way, we may find the appropriate explanation for the line Skulskij (1971) found to be the secondary Ca II K component.

The β Lyrae spectrum is well-known for its large emission component of some hydrogen and helium lines, which change with phase, too. A number of papers has been published on this subject (Kříž and Žďárský,1974; Sanyal, 1976; Skulskij,1972 and Svolopoulos,1967). No interest was shown in the lines without emission. But this does not mean that these lines do not change with phase. To illustrate the changes of the pure absorption lines with phase, Figures 5 and 6 were included in this paper. Parts of the spectrum of Lyrae in the neighbourhood of λ = 383.00 nm are in Fig. 5, shown in various phases with H 10, He I (22), H 9 and Si II (1) lines. The most conspicuous features in this figure are the lines Si II (1) in phase $0^{P}.290$, which are unusually sharp in their centres.

Sections of the β Lyrae spectrum from H 15 to H 11 are shown in Figure 6. The changes in it can also be seen. We suppose that the envelope of the whole system and the gaseous streams between the components whose spectral lines are convolved with the lines of the primary star, are responsible for this change in the profiles of the absorption lines. The whole character of these changes may serve as evidence that environment of its origin is not in equilibrium.

The papers describing some spectral lines of the secondary component are

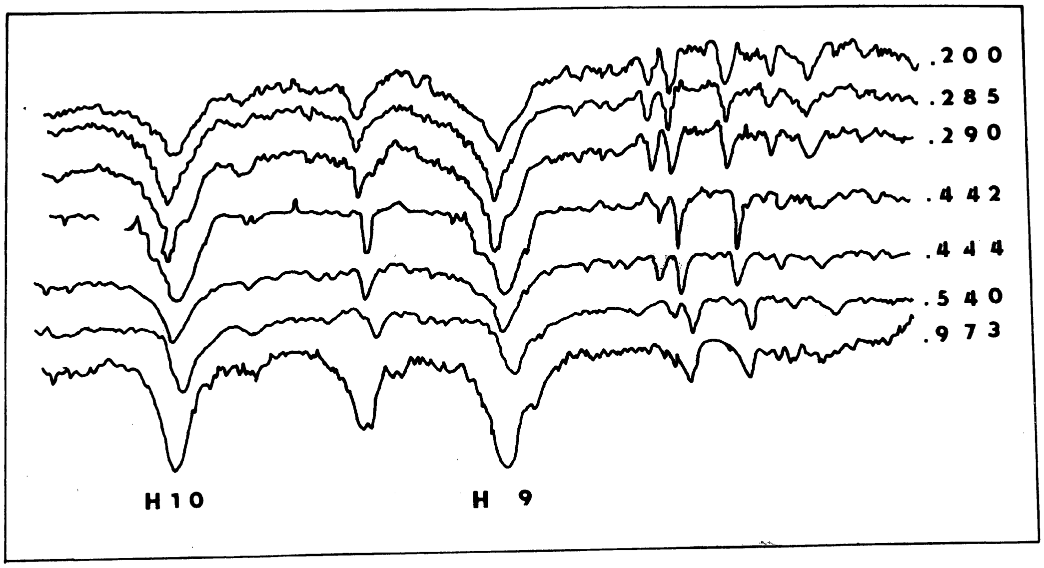


Fig. 5 The part of β Lyrae spectrum from H 10 to Si II (1) lines in Ondřejov's spectrograms filled up according to phase. Conspicuous is the sharpness of the lines in the phase $0^{P}.29$.

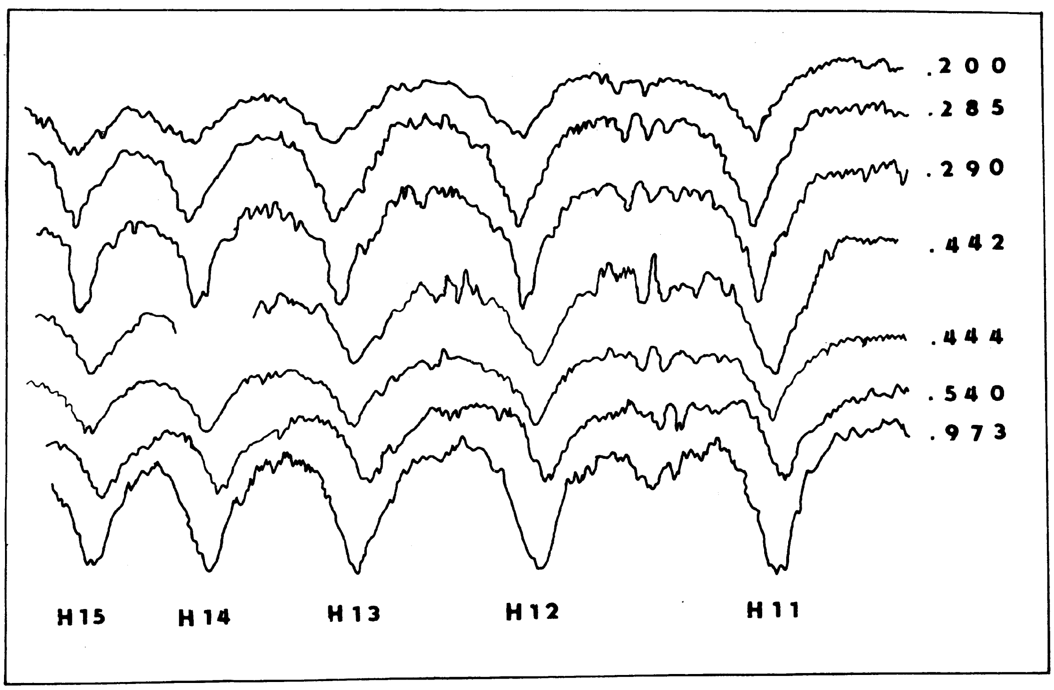


Fig. 6 The lines from H 15 to H 11 in Ondřejov's spectrograms. Next the same as Fig. 5.

in contradiction with our results. The results of photometric research and some theoretical treatements of the β Lyrae model do not agree, either (Kříž, 1974; Huang and Brown, 1976). According to the photometric results, the secondary component is responsible for 30 - 40% of all the light of the system. Due to the difference between the continuous radiation of the primary and secondary component, the central intensity of the Ca II K_2 line is then only 20% of the central intensity of the Ca II K_1 line. But as the relation of rotational velocities of the both components is approximately 45/300, the rotational broadening will diminish the central intensity of the Ca II K_2 component only to 3% of the primary one. It is almost impossible to detect so shallow a line with todays observational instruments and it is quite clear, why the effort to identify the secondary spectrum has so far been in rain.

But it is quite clear that the radiation of the secondary component does influence the primary spectrum. The way to determine this influence has been shown by Buerger (1969, 1972) and Hutchings (1973), who have published the results of line-profile computations for single-spectrum binaries. For the phase dependence of the equivalent width of the spectral line, they obtained a double-waved curve with maxima at phases $0^P.25$ and $0^P.75$. For most spectral lines of the β Lyrae system, we obtain the double-waved curve for the change of the equivalent width of the line with phase with maxima at $0^P.0$ and $0^P.5$. The phase dependence of the equivalent width of some Balmer lines are plotted in Figure 7. It is worth noticing that, in the agreement with the theoretical results of Buerger (1969, 1972) and Hutchings (1973), the equivalent width phase dependences of the H 11 and H 12 lines have been found to be double-waved with maxima at $0^P.25$ and $0^P.75$.

From this we conclude that we have found an expression of the secondary radiation influence on the primary spectrum. The fact that we do not observe the same equivalent-width phase dependence for other members of the series can be explained in this way. For the lower members of the series (H 9 and H 10) the profiles are strongly influenced by the envelope. According to the results of Flora and Hack (1975), the radial velocities of the hydrogen Balmer lines are inversely proportional to their esrial member. This implies that there must exist some stratification of layers in which the individual lines mostly originate. The H 11 and H 12 lines originate deep in the atmosphere and are not influenced by the envelope. For the higher members of the series it is impossible to find this dependence owing to the rather large scatter of the points in the graph due to the errors of the equivalent-width measurements.

ACKNOWLEDGEMENTS

This paper was written on the basis of spectroscopic observational material kindly provided by Dr. Kříž. The author wishes to express his thanks for this and for the valuable advice, he received. He is also indebted to the Slovak Astronomical Society for the support he was granted.

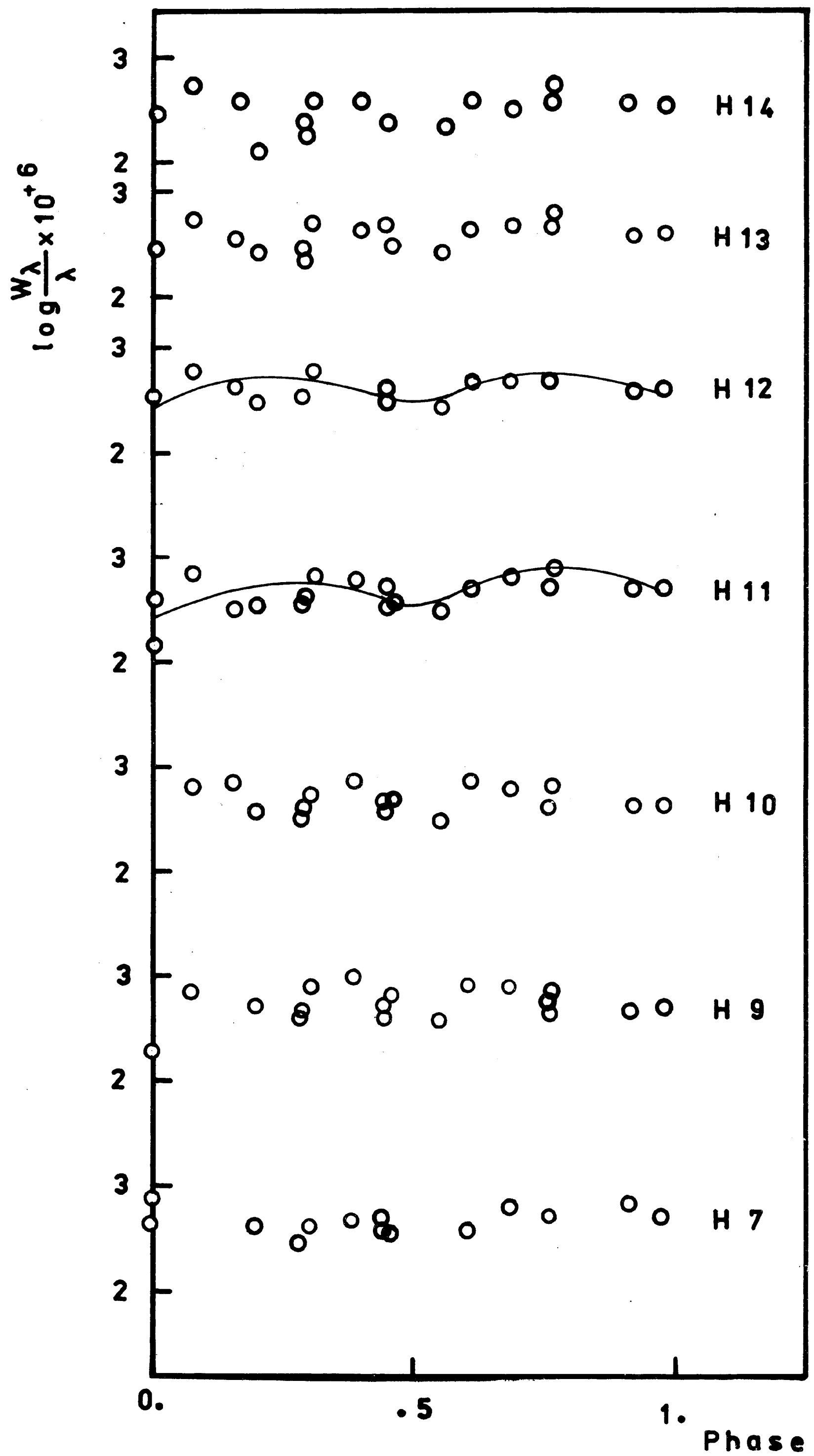


Fig. 7 The diagrams of the equivalent width dependence on phase for some hydrogen lines.

REFERENCES

Batten, A. H., Diamond, G. L., Fisher, W. A.: 1974, Publ. Astron. Soc. Pacific 86, 511.

Buerger, P.F.: 1969, Astrophys. J. 158, 1151.

--: 1972, Astrophys. J. 177, 657.

Dadaev, A. N.: 1975, Izv. Glav. Astron. Obs. Pulkovo 193, 41.

--: 1976, Izv. Glav. Astron. Obs. Pulkovo 194, 18.

Flora, U., Hack, M.: 1975, Astron. Astrophys. Suppl. 19, 75.

Huang, S. -S., Brown, D. A.: 1976, Astrophys. J. 208, 780.

Hutchings, J. B.: 1973, Astrophys. J. 180, 501.

Kříž, S.: 1974, Bull. Astron. Inst. Czechosl. 25, 6.

Kříž, S., Ždárský, F.: 1974, Bull. Astron. Inst. Czechosl. 25, 1.

Moore, C. E.: 1945, A multiplet table of astrophysical interest. Princeton Obs. Publ. № 20.

Sanyal, A.: 1976, Astrophys. J. 210, 853.

Skulskij, M. Ju.: 1971, Astron. Zh. 48, 766.

--: 1972, Izv. Krym. Astrofiz. Obs. 45, 135.

Svolopoulos, N.: 1967, Astron. Nachr. 290, 155.

Zverko, J.: 1973, Thesis (Astron. Inst. Slovak Acad. Sci), unpubl.