A SPECTROGRAPHIC STUDY OF THE SHELL STAR EW LAC (HD 217 050)

I. Radial Velocities of Hydrogen Lines

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Radial velocities of hydrogen lines based on six Victoria (1965) and four Ondřejov (1968) spectrograms are published. It is shown that no noticeable Balmer progression existed in the times of exposures.

Спектрографическое исследование звезды EW Lac (HD 217 050). I. Лучевые скорости линий водорода. Опубликованы лучевые скорости линий водорода полученные из 10 спектрограмм из обсерваторий Виктория (1965 г.) и Ондржеев (1968 г.). Показано, что в моментах экспозиций не существовал выразительный прогресс Бальмера.

1. *Introduction*

EW Lac (HD 217 050, HR 8731, MWC 394, BD+47°3985, Boss 5918) is a well-known shell star of the spectral type B3ne observed since 1882 by many astronomers. Early plates taken in the years 1887, 1904 and 1905 show no emission features. Frost (1919) reported an Hβ emission with shell absorptions on the Yerkes plates of July and August, 1913; on a plate of the 8-inch Draper telescope taken in November, 1913 neither emission nor shell lines were recognized. Emission and shell lines were also missing on the 1918 Yerkes and Victoria spectrograms. In October, 1921 the star resembled a normal B3 star with emission lines. A shell spectrum was again found on the Victoria spectrograms of early autumn 1926. Since then the star appears to show a fully developed shell spectrum. Baldwin (1943) published a rather detailed description of this shell spectrum based on a Michigan spectrogram of November 15, 1940. In more recent papers the appearance of the spectrum is usually found to be similar to the one described by Baldwin.

On the basis of the measurements of radial velocities in Michigan spectrograms Baldwin (1943) suggested that the star might be a spectroscopic double-star with a rather long period (at least 19 years) but, unfortunately, his measurements were never published. All other radial-velocity measurements published so far are in disagreement with this statement. Struve (1944) pointed out that the changes of spectrum take place within a few days and all more recent papers confirm this.

Walker (1953) found the star to be photometrically variable. The light curve has minima with amplitudes of $0{\cdot}2^m$ and durations of approximately $0{\cdot}4^d$ which are repeated more or less peridiocally but with different depths. The period is about $0{\cdot}8^d$ and varies irregularly.

Extensive spectral studies of the star have been published by several authors (Özemre, 1961, 1967; Herman and Duval, 1960; Boyarchuk and Pronik, 1963, 1964; Kupo, 1969).

2. *Observational data and its reduction*

Altogether 10 spectrograms have been studied; six of them were taken by Prof. Plavec during his stay at the Dominion Astrophysical Observatory, Victoria in summer 1965; the remaining four were taken by Prof. Plavec, Mr. Horn and by one of the authors (P. H.) with the cassegrain spectrograph of the Ondřejov 2-m Telescope in autumn 1968. Basic information on all these spectrograms is given in Table 1.

Table 1 — Observational data used

Date (U.T.)	J. D.	Telescope	Spectral		
			dispersion (Å/mm)	region (Å)	observer
1965- 8-17-10^h44^m	2438989·947	coudé 48-inch Victoria	10	3600—4900	Plavec
1965- 9- 2- 6^h33^m	2439005·773	coudé 48-inch Victoria	10	3600—4900	Plavec
1965- 9-18- 7^h48^m	2439021·825	cass. 72-inch Victoria	26—53	3700—4500	Plavec
1965- 9-18- 7^h58^m	2439021·832	cass. 72-inch Victoria	26—53	3700—4500	Plavec
1965- 9-18- 8^h06^m	2439021·838	cass. 72-inch Victoria	26—53	3700—4500	Plavec
1965- 9-18- 8^h10^m	2439021·840	cass. 72-inch Victoria	26—53	3700—4500	Plavec
1968- 9-28-19^h47^m	2440128·324	cass. 2-m Ondřejov	25	3700—4600	Plavec
1968-11-27-21^h35^m	2440188·399	cass. 2-m Ondřejov	10	3600—4600	Harmanec
1968-12-11-18^h42^m	2440202·279	cass. 2-m Ondřejov	10	3600—4600	Harmanec
1968-12-12-18^h20^m	2440203·264	cass. 2-m Ondřejov	10	3600—4600	Horn

Table 2

Radial velocities of Balmer lines (in km/sec) on Victoria and Ondřejov spectrograms. The values in parentheses are extrapolated

Line	1965-8-17 10^h44^m	1965-9-2 6^h33^m	1965-9-18 7^h48^m	1965-9-18 7^h58^m	1965-9-18 8^h06^m	1968-9-18 8^h10^m	1968-9-28 19^h47^m	1968-11-27 21^h35^m	1968-12-11 18^h42^m	1968-12-12 18^h20^m
H 4	−18·4	−16·8						−16·8	−17·7	−17·3
H 5	−19·2	−18·6		− 9·3	−15·6		−14·3	−15·2	−18·8	−16·2
H 6	−15·5	−16·5	−13·5	−14·0	−10·9	− 9·6	−17·8	−15·4	−16·8	−17·3
H 7	−16·5	−17·4	−13·8	− 9·3	−15·5	−14·2	−20·6	−20·8	−19·7	−16·0
H 8	−17·3	−17·8	−15·1	−22·4	−10·1	−15·5	−22·4	−14·9	−17·5	−17·1
H 9	−16·5	−16·2	− 8·2	−19·3	−14·6	− 7·4	−20·4		−16·3	−15·6
H10	−11·9	−15·3		−17·4	−18·6		−15·4		−18·2	−15·0
H11	−18·5	−17·5	−12·8	−13·4	−21·8		−17·3		−15·5	−14·0
H12	−14·2	−15·6	−19·6	−16·4			−20·9		−16·8	−14·6
H13	−20·7	−14·9	−16·4	−15·1			−14·8		(−14·9)	−15·5
H14	−17·0	−16·4					−21·4		(−19·4)	(−15·0)
H15	−18·1	−20·0					− 8·4		(−15·6)	(−15·8)
H16	−20·2	−16·4							(−15·4)	(−15·8)
H17	−18·1	−17·6							(−17·1)	(−15·4)
H18	−16·6	−16·4							(−14·8)	(−14·5)
H19	−17·6	−14·9							(−15·2)	(−19·2)
H20	−15·8	−16·5							(−17·5)	(−15·3)
H21	−15·4	−20·2							(−18·2)	(−14·8)
H22	−18·0	−16·2							(−18·1)	(−15·8)
H23	−19·2	−16·1							(−21·5)	(−17·3)
H24	−18·7								(−21·3)	(−14·5)
H25	−15·7	−15·5							(−21·3)	(−14·3)
H26	−20·2	−14·2							(−17·8)	(−17·3)
H27	−17·8	−15·4							(−14·6)	
H28	−12·4	−16·4								
H29	−12·7	−19·1								
H30	−16·5									
H31	−16·8									
H32	−11·2									
H33	−15·9									
mean	−16·8 ± 0·4	−16·8 ± 0·4	−14·2 ± 1·2	−15·2 ± 1·5	−15·3 ± 1·5	−11·7 ± 2·3	−17·6 ± 1·3	−16·6 ± 1·1	−17·5 ± 0·5	−15·8 ± 0·3

Table 3

Available radial-velocity measurements of EW Lac

J. D.	R. v. hel. (km/sec)	Source	Lines used
2419977·286	−11	Frost 1919	H3, H4, H5, H6
984·228	−15	Frost 1919	H3, H4, H5, H6
2424727·926	−20·3	Plaskett 1931	13 lines
732·946	−8·7	Plaskett 1931	14 lines
761·896	−12·3	Plaskett 1931	14 lines
768·864	−18·3	Plaskett 1931	16 lines
2425771·867	−12·1?	Struve 1944	H3—H6, CaII K, some FeII
2430252·805	−20·1	Struve 1944	H3—H6, CaII K, some FeII
263·794	−13·0	Struve 1944	H3—H6, CaII K, some FeII
264·573	−15·4	Struve 1944	H3—H6, CaII K, some FeII
273·601	−12·6	Struve 1944	H3—H6, CaII K, some FeII
283·553	−21·5	Struve 1944	H3—H6, CaII K, some FeII
316·592	−18·6	Struve 1944	H3—H6, CaII K, some FeII
317·585	−27·2	Struve 1944	H3—H6, CaII K, some FeII
348·505	−22·4	Struve 1944	H3—H6, CaII K, some FeII
513·763	−24·6	Struve 1944	H3—H6, CaII K, some FeII
603·712	−19·5?	Struve 1944	H3—H6, CaII K, some FeII
618·623	−13·1	Struve 1944	H3—H6, CaII K, some FeII
619·635	−22·5	Struve 1944	H3—H6, CaII K, some FeII
627·751	−19·0	Struve 1944	H3—H6, CaII K, some FeII
629·715	−21·3	Struve 1944	H3—H6, CaII K, some FeII
630·617	−19·9	Struve 1944	H3—H6, CaII K, some FeII
638·588	−30·2	Struve 1944	H3—H6, CaII K, some FeII
639·559	−23·0	Struve 1944	H3—H6, CaII K, some FeII
640·581	−23·9	Struve 1944	H3—H6, CaII K, some FeII
651·575	−20·7	Struve 1944	H3—H6, CaII K, some FeII
660·517	−24·9	Struve 1944	H3—H6, CaII K, some FeII
676·542	−19·7	Struve 1944	H3—H6, CaII K, some FeII
690·500	−20·0	Struve 1944	H3—H6, CaII K, some FeII
697·529	−19·4	Struve 1944	H3—H6, CaII K, some FeII
698·544	−17·6	Struve 1944	H3—H6, CaII K, some FeII
705·536	−23·9	Struve 1944	H3—H6, CaII K, some FeII
822·924	−17·8	Struve 1944	H3—H6, CaII K, some FeII
872·839	−26·7	Struve 1944	H3—H6, CaII K, some FeII
886·810	−21·2	Struve 1944	H3—H6, CaII K, some FeII
927·755	−25·9	Struve 1944	H3—H6, CaII K, some FeII
927·797	−25·9	Struve 1944	H3—H6, CaII K, some FeII
933·674	−18·0?	Struve 1944	H3—H6, CaII K, some FeII
933·722	−10·8?	Struve 1944	H3—H6, CaII K, some FeII
946·658	−21·1	Struve 1944	H3—H6, CaII K, some FeII
946·710	−29·9	Struve 1944	H3—H6, CaII K, some FeII
953·743	−20·8	Struve 1944	H3—H6, CaII K, some FeII
954·696	−23·4	Struve 1944	H3—H6, CaII K, some FeII
960·640	−29·9	Struve 1944	H3—H6, CaII K, some FeII
960·703	−20·8	Struve 1944	H3—H6, CaII K, some FeII
988·559	−23·8	Struve 1944	H3—H6, CaII K, some FeII
990·581	−28·8?	Struve 1944	H3—H6, CaII K, some FeII
991·565	−15·1	Struve 1944	H3—H6, CaII K, some FeII
995·607	−23·4	Struve 1944	H3—H6, CaII K, some FeII
996·563	−27·2?	Struve 1944	H3—H6, CaII K, some FeII
2431003·557	−19·7	Struve 1944	H3—H6, CaII K, some FeII
004·562	−27·3	Struve 1944	H3—H6, CaII K, some FeII
005·546	−27·4	Struve 1944	H3—H6, CaII K, some FeII
012·569	−19·2	Struve 1944	H3—H6, CaII K, some FeII
017·535	−11·1	Struve 1944	H3—H6, CaII K, some FeII

Table 3 (continued)

J. D.	R. v. hel. (km/sec)	Source	Lines used
243018·577	−19·0?	Struve 1944	H3—H6, CaII K, some FeII
024·528	−25·3	Struve 1944	H3—H6, CaII K, some FeII
026·508	−29·7	Struve 1944	H3—H6, CaII K, some FeII
056·550	−19·1	Struve 1944	H3—H6, CaII K, some FeII
063·628	−24·1	Struve 1944	H3—H6, CaII K, some FeII
082·617	−16·0	Struve 1944	H3—H6, CaII K, some FeII
084·491	−23·1	Struve 1944	H3—H6, CaII K, some FeII
092·590	−27·4?	Struve 1944	H3—H6, CaII K, some FeII
099·542	−26·3	Struve 1944	H3—H6, CaII K, some FeII
107·497	−28·0?	Struve 1944	H3—H6, CaII K, some FeII
2433093·603	−18·3	Burbidges 1951	H5—H11, CaII K, some FeII
094·608	−24·4	Burbidges 1951	H5—H11, CaII K, some FeII
096·478	−28·6	Burbidges 1951	H5—H11, CaII K, some FeII
096·531	−22·2	Burbidges 1951	H5—H11, CaII K, some FeII
096·613	−21·0	Burbidges 1951	H5—H11, CaII K, some FeII
098·574	−23·8	Burbidges 1951	H5—H11, CaII K, some FeII
131·592	−24·8	Burbidges 1951	H5—H11, CaII K, some FeII
131·636	− 9·9?	Burbidges 1951	H5—H11, CaII K, some FeII
134·606	−21·4	Burbidges 1951	H5—H11, CaII K, some FeII
897·968	−21·8	Walker 1953	not given
910·892	−20·4	Walker 1953	not given
911·858	−23·3	Walker 1953	not given
917·896	−20·4	Walker 1953	not given
925·967	−18·3	Walker 1953	not given
2434237·883	−21·7	Walker 1953	not given
326·608	−14·4	Walker 1953	not given
326·619	−14·1	Walker 1953	not gvine
326·631	−20·0	Walker 1953	not given
326·642	−16·3	Walker 1953	not given
326·653	−17·4	Walker 1953	not given
326·665	−17·4	Walker 1953	not given
326·676	−17·5	Walker 1953	not given
326·688	−14·9	Walker 1953	not given
326·699	−14·3	Walker 1953	not given
327·600	−19·0	Walker 1953	not given
327·612	−15·7	Walker 1953	not given
327·624	−16·3	Walker 1953	not given
327·636	−14·8	Walker 1953	not given
327·649	−15·3	Walker 1953	not given
327·660	−16·5	Walker 1953	not given
327·672	−12·6	Walker 1953	not given
327·685	−19·6	Walker 1953	not given
327·697	−13·8	Walker 1953	not given
2438989·947	−16·8	present work	H4—H33
2439005·773	−16·8	present work	H4—H23, H25—H29
021·825	−14·2	present work	H6—H9, H11—H13
021·832	−15·2	present work	H5—H13
021·838	−15·3	present work	H5—H11
021·840	−11·7?	present work	H6—H9
2440128·324	−17·6	present work	H5—H15
188·399	−16·6	present work	H5—H9
202·279	−17·5	present work	H5—H12
203·264	−15·8	present work	H5—H14

The question mark shows the values classified as "poor" by authors quoted.

Since an oscilloscope measuring machine is only just being prepared at the Ondřejov Observatory, we measured the radial velocities of hydrogen lines on all the plates visually with a Zeiss Abbe Comparator and therefore the results are more or less preliminary.

Computer programme for the automatic reduction of the radial-velocity measurements (written by J. K.) was employed. The programme approximates the real dependence between wavelengths and a linear scale by a polynomial of the third, fourth or fifth degree according to the type of the spectrum. The polynomial was fitted to the measured lines of the iron comparison spectrum by the least-squares method. If the deviation of any comparison line from the polynomial is larger than a certain limit (usually 0·02–0·1 Å for grating spectra), the following procedure is applied: The comparison line whose deviation from the polynomial computed is largest, is excluded and a new polynomial is computed. If several lines are to be excluded by this procedure, a check is made at the end whether some of the lines excluded previously cannot be adopted again. As a result of the whole computation heliocentric radial velocities of all measured (and identified) stellar lines are obtained.

3. *Results*

Heliocentric radial velocities of centres of hydrogen lines measured visually are in Table 2. The unequal number of Balmer lines measured in different spectrograms is due to the varying quality of the plates and does not represent any real variability. Actually, about thirty members of the Balmer series can be seen on each plate but comparison iron lines are in some cases too weak in the neighbourhood of the Balmer jump to be measured. The extrapolated values of radial velocities are given in brackets.

It is clear that no noticeable Balmer progression existed at the times of the exposures. Moreover, the radial velocities of the Ca II H and K lines and some Fe II and Ti II shell lines give radial velocities quite similar to those of the Balmer lines.

We attempted to collect all radial-velocity measurements published previously in Table 3 together with our own mean values. It can readily be seen that the radial-velocity range remains practically unchanged during the whole observing period. Small changes of radial velocity with amplitude of about 20 km/sec – provided they are real – take place within about two days, but we were not able to find any definite period. One must keep in mind that the observational errors are nearly comparable with the semi-amplitude of the radial-velocity changes observed and therefore it is not easy to find any period – even if such a period really existed.

The provisional conclusion is that the star in question has had a stationary (non-expanding) shell for the last fifty years. A more comprehensive study of this star is intended by the Ondřejov team and it is expected to be published later on.

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