SPECTROGRAPHIC OBSERVATIONS OF PECULIAR STARS. VI*

P. SWINGS AND O. STRUVE
McDonald and Yerkes Observatories

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ABSTRACT

Large changes have recently been observed in the spectrum of T Coronae Borealis. Many absorption lines were measured on spectrograms of January, 1943. The high members of the Balmer series consist of two emission components separated by a central absorption; the blue component is appreciably stronger than the red. Several *He* I, *Ca* II, and *Si* I lines have similar profiles; [*Ne* V] and [*Fe* VII] were weakly present in January, 1943. AX Persei is increasing in excitation, while Z Andromedae is declining, following its peak in the summer of 1942. HD 45677 has changed since 1939. In 1943 the *H* absorption cores were much weaker than in 1939, and the *H* emission lines showed only red components. The shell-absorption lines of *Ca* II had also become weak. Thirty-one Be stars from the Mount Wilson catalogues have been observed. The stars MWC 47, MWC 120, MWC 158, Mt. W. 265, and Mt. W. 275 present interesting shell-absorption spectra. The star MWC 93 has lost most of the expanding-shell characteristics observed by Merrill between 1928 and 1930.

I. NEW OBSERVATIONAL DATA ON PECULIAR BRIGHT-LINE STARS

Nova T Coronae Borealis.—A considerable change has occurred in the early-type part of the composite spectrum of T CBr since it was last described[1] on the basis of spectrograms taken in January, 1942. In 1940, 1941, and 1942 the Balmer lines were present in emission up to *H* 21. On our spectrograms of January 28 and 29, 1943 (Pl. VIII), all the Balmer lines from *H* 14 to *H* 9 show violet and blue emission components, separated by an absorption component. The violet emission component is stronger than the red. In *H* 15, *H* 16, and the higher members (up to *H* 23) the red component is not observed. The regions of *H* 8, $H\epsilon$, and $H\delta$ are complex because of the presence of other emission lines, but $H\gamma$ and $H\beta$ are present only in emission.

Previously the *He* I lines were all bright. In January, 1943, the *He* I lines $2p^3P^0-13$, 12, 11, 10, 9, 8, 7, and $6d^3D$ and $2s^1S-5p^1P^0$ were pure absorption features. The case of λ 3889 and λ 3965 is not clear because of the proximity of strong emissions, but λ 4026 ($2p^3P^0-5d^3D$) and λ 4121 ($2p^3P^0-5s^3S$) are triple, like the ultraviolet Balmer lines. The line λ 4471 ($2p^3P^0-4d^3D$) has a violet emission and a weak absorption. The line *Ca* II 3934 is also triple, whereas *Si* I 3906 has two emission components but no apparent central absorption deeper than the continuous background; *Si* II 3856 and 3863 are present as weak and broad emissions.

Besides the pure emission of *He* II 4686, [*O* II], [*O* III], *O* III (fluor.), *N* III (fluor.), [*Ne* III], and *Fe* II (and [*Fe* II]?), previously reported, the spectrum now shows a trace of [*Ne* V] 3426. There is also a weak emission on the violet edge of *He* I 3587; this emission must be attributed to [*Fe* VII] 3586.3. The two [*S* II] lines are weakly present.

Hence the excitation of the nebular region seems to be higher than it was previously, but the absorption characteristics suggest lower excitation. Such changes are reminiscent of the analogous case of Z And, which is an object of similar geometrical and dynamical complexity.

The pattern near λ 3889 is rather complex. It consists essentially of a strong emission (6E) at λ 3887.1, due to *He* I; of a second emission (4E) at λ 3888.1, due to *H* 8, sepa-

* *Contributions from the McDonald Observatory, University of Texas,* No. 72. This work was interrupted in March, 1943, by the departure of Dr. Swings on a war-research assignment.

[1] *Ap. J.*, **96**, 254, 1942. For previous accounts see *Ap. J.*, **94**, 291, 1941; *Pub. A.S.P.*, **52**, 199, 1940. Spectrograms taken by Dr. John Titus on April 16 and 18, 1943, show that the shell absorptions had almost disappeared and the spectrum had, with minor differences, returned to its former stage. Judging from Minkowski's description (*Pub. A.S.P.*, **55**, 101, 1943), which reached us after this article had been completed, the absorption lines were strongest about March 1.

rated from *He* I by 85 km/sec; of a weak absorption due to *H* 8 and *He* I; and of a broad emission (2En) centered around λ 3890.8 and due to *H* 8, *He* I, and [*Fe* V]. Similarly, the pattern near λ 3965, due to *He* I, [*Ne* III], *Ca* II, and *H*ε is very complex.

The radial velocities measured on our spectrogram of January 28, 1943, are as follows:

Hydrogen.—Violet emission (using all lines from *H* 16 to *H*ε, but excluding *H* 8:

$$V_{\mathrm{v\,em}} = -71.3 \text{ km/sec} ;$$

central absorption (from the eight lines *H* 16 to *H* 9):

$$V_{\mathrm{abs}} = +24.0 \text{ km/sec} ;$$

red emission (from the six lines *H* 14 to *H* 9):

$$V_{\mathrm{r\,em}} = +116.6 \text{ km/sec} ;$$

emission at $H\gamma$:

$$V_{\gamma} = +32.2 \text{ km/sec} .$$

Helium I.—Violet emission (from λλ 4026, 4121, and 4471):

$$V_{\mathrm{v\,em}} = -70.9 \text{ km/sec} ;$$

absorption (from the pure absorption lines λλ 3497, 3513, 3540, 3554, 3587, 3614, 3634, and 3705):

$$V_{\mathrm{abs}} = +24.5 \text{ km/sec} ;$$

central absorption (from λ 4026 and λ 4121):

$$V_{\mathrm{c\,abs}} = +55.1 \text{ km/sec} ;$$

red emission (from λ 4026 and λ 4121):

$$V_{\mathrm{r\,em}} = +175.7 \text{ km/sec} .$$

Calcium II (K).—

$$V_{\mathrm{v\,em}} = -125 \text{ km/sec} ;$$
$$V_{\mathrm{abs}} = -13 \text{ km/sec} ;$$
$$V_{\mathrm{r\,em}} = +117 \text{ km/sec} .$$

Silicon I.—

$$V_{\mathrm{v\,em}} = -85 \text{ km/sec} ;$$
$$V_{\mathrm{r\,em}} = +60 \text{ km/sec} ;$$

Pure emission lines.—

Fe II:	$V_{\mathrm{em}} = +44$ km/sec ;
Si II:	$V_{\mathrm{em}} = -3$ km/sec ;
O III (fluor.):	$V_{\mathrm{em}} = -1$ km/sec ;
[*Ne* III]:	$V_{\mathrm{em}} = +5$ km/sec ;
[*Fe* VII]:	$V_{\mathrm{em}} = +27$ km/sec .

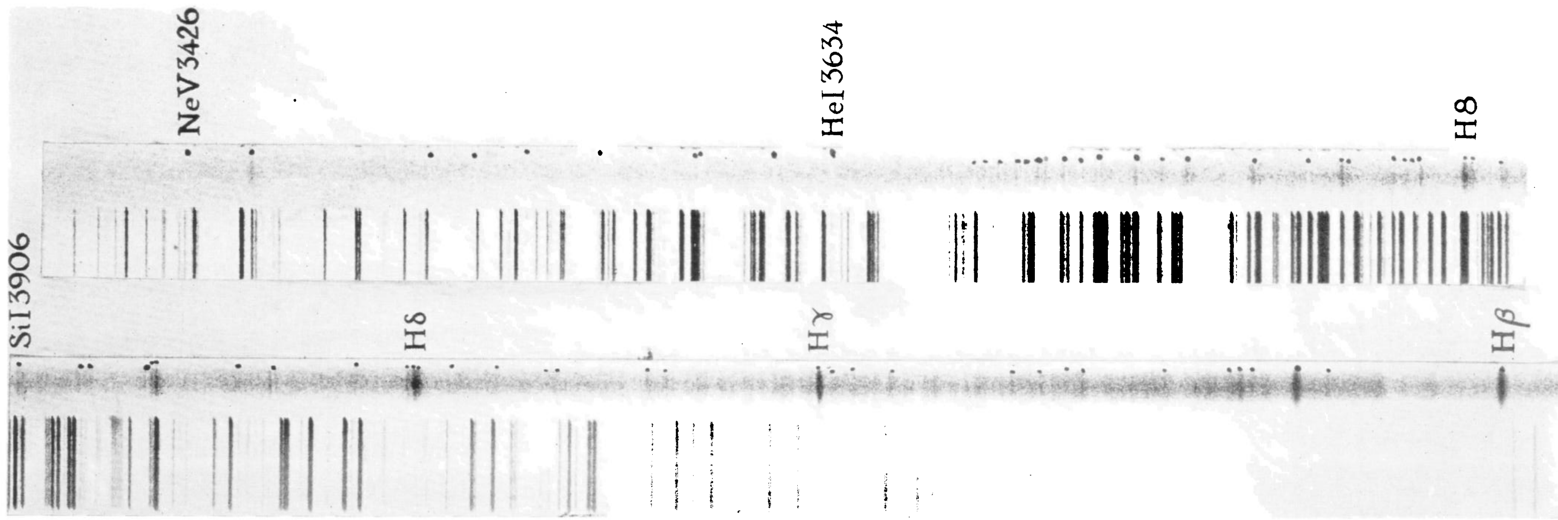
It will be interesting to follow the spectroscopic transformation now taking place in T CBr, and it is important in this connection that an accurate light-curve be obtained.

The lines marked with a dot in Plate VIII are as follows:

Top

[*Ne* V] 3426 em	*H* 18 abs	*H* 11
O III 3444 em	*H* 17 abs	*H* 10
He I 3499 abs	*H* 16	*He* I 3820 abs
He I 3512 abs	*He* I 3705 abs	*H* 9
He I 3530 abs	*H* 15	*Si* II 3856 em
He I 3554 abs	*Cr* II 3713	*Si* II 3862 em
[*Fe* VII] 3586 em	*H* 14	*He* I 3868 abs
He I 3587 abs	[*O* II] 3726 em	[*Ne* III] 3869 em
He I 3614 abs	*H* 13	*H* 8 + *He* I
He I 3634 abs	*H* 12	[*Fe* V] 3891 em
H 19 abs	*O* III 3760 em	*Si* I 3906 em

PLATE VIII



SPECTRUM OF T CORONAE BOREALIS ON JANUARY 28, 1943

Bottom

Si I 3906 em	*He* I 4121 abs + em	*Fe* II 4508 em
Ca II 3934 abs + em	*He* I 4144 em	*Fe* II 4520, 4523 em
Fe II 3938 em	*Fe* II 4173 em	*Fe* II 4584 em
He I 3965 abs	*Fe* II 4179 em	*Fe* II 4629 em
[*Ne* III] 3967 + *Ca* II em	*Fe* II 4233 em	*N* III 4634 em
$H\epsilon$ abs + em	[*Fe* II] 4244 em	*N* III 4640 em
He I 4009 em	$H\gamma$ em	*He* II 4686 em
He I 4026 abs + em	*Fe* II 4352 em	*He* I 4713 em
[*S* II] 4068 em	[*O* III] 4363 em	$H\beta$ em
N III 4097 em	*He* I 4388 abs	*He* I 4922 abs + em
$H\delta$ em	*He* I 4471 em	
N III 4103 em	*Fe* II 4489, 4491 em	

AX Persei.—Some differences between the spectrograms of January, 1943, and those of January, 1942, are worth mentioning. There has been a considerable change in the intensity ratio of the *He* I triplets and singlets, in the sense that the singlets were much stronger in January, 1943, than they were in January, 1942, or even in November, 1942. This is especially striking when one compares the triplet line λ 4471 with the singlet line λ 4388. This type of variation has been discussed previously.[2]

The [*Fe* VII] lines are of about the same intensity as they were in January, 1942, and the [*Fe* V] lines are still present, although weaker than in January or July, 1942. The line [*Ne* III] is much weaker than it was in January, February, and July, 1942; it has even declined in intensity since November, 1942. On the other hand, the ratio [*Ne* V]/O III (fluor.) is larger than it was in July, 1942, but it is similar to those of January, February, and November, 1942.

On the whole, AX Per has increased in excitation since last summer, continuing the fluctuations which have been observed since 1939.

Z Andromedae.—Following the peak in excitation reached last summer,[3] Z Andromedae has continued its slow decline in excitation. The lines of [*Fe* VII] and [*Fe* V] were still present in January, 1943, but they were weaker than in July, 1942, or even than in November, 1942. The intensity ratio [*Ne* V]/O III (fluor.) was much smaller than in July or even in November, 1942.

Incidentally, this intensity ratio [*Ne* V]/O III (fluor.) should be used only with caution, since its variation may not necessarily be related to a variation in excitation. It is known[3] that the intensity of the fluorescence lines of *O* III is sensitive to the velocity and density gradients in the envelope. The atmospheres of objects like Z And or AX Per expand rather slowly, as is shown by the sharp character of the emission lines; yet even small changes in velocity or density distribution may affect the efficiency of the mechanism of monochromatic fluorescence.

HD 45677 = MWC 142.—This star has been described by Merrill[4] and by the present writers.[5] The spectrum has greatly changed since 1939. At that time the emission lines of *H* were double, with $V/R = 0.5$. The emission could be seen as far as $H\epsilon$. Beginning with $H\gamma$, the higher members of the Balmer series had strong central cores, characteristic of absorption shells; and these could be seen as far as *H* 29 or *H* 30. The *Ca* II K line was very strong and sharp, but the *Ca* II H line was exceedingly weak. This important observation, reminiscent of a similar observation in HD 190073[6] proves that in MWC 142 the shell absorption of *Ca* II is effectively obscured by the emission of $H\epsilon$.

[2] Swings and Struve, *Ap. J.*, **96**, 254, 1942; **97**, 194, 1943.

[3] *Ap. J.*, **97**, 194, 1943.

[4] *Ap. J.*, **67**, 405, 1928.

[5] *Ap. J.*, **91**, 598, 1940.

[6] *Ap. J.*, **96**, 475, 1942.

It will be recalled that in HD 190073 the weakening of the A1 line of *Ca* II H was explained as being produced by $H\epsilon$ wing absorption in the reversing layer. The radial velocities of several relevant absorption lines measured on a plate of December 2, 1939, at 10^h01^m U.T. are as follows:

$H\epsilon$..................	−0.2 km/sec
H 8..................	−3.5
H 9..................	−3.8
Ca II K..............	+7.9

They show that the excessive weakness of *Ca* II H is probably not caused by differential motion of the *Ca* II and *H* atoms, causing a blending with the core of $H\epsilon$. The relative velocity of 10 km/sec corresponds to only one-twelfth of the normal separation between *Ca* II H and $H\epsilon$. It is clear that only the weak violet emission component of $H\epsilon$ can be responsible for the phenomenon.

It is doubtful that mere mechanical superposition of the normal absorption line of *Ca* II H with the weak emission wing of $H\epsilon$ could produce the observed weakening. Hence it is probable that the λ 3968 transition of *Ca* II is somehow suppressed by a physical cause. If the shell rotated like a solid body, all emission of $H\epsilon$, as seen from the calcium atoms, would be concentrated in a narrow line at λ 3970, and there could be no such effect. But differential rotation might shift an appreciable fraction of the $H\epsilon$ quanta, as seen from the calcium atoms, to λ 3968, in which case these quanta would cause an excess of emissions in the line *Ca* II H and correspondingly tend to suppress the absorption line.

In 1943 the absorption cores of the *H* lines, though still very narrow, had become quite weak and could be seen only to *H* 15. The emission lines of *H* have strong red components, but the violet components are vanishingly weak. Instead, there appears to be a second, weaker, and slightly more diffuse absorption component on the violet side of the main core. The line *Ca* II K is sharp but very much weaker than in 1939, and there may be a normal absorption line of *Ca* II H blended with the violet absorption component of $H\epsilon$.

The narrow emission lines of *Fe* II, [*Fe* II], etc., are essentially similar to those observed by Merrill on plates taken between 1923 and 1927.[7] On our plates the intensity of the blend *Fe* II 4352 + [*Fe* II] 4353 is similar to that of [*Fe* II] 4359, while Merrill gives intensities 1 and 3, respectively. Our plates also show emission between $H\gamma$ and λ 4352, which may be [*Fe* II] 4347, observed by Merrill in η Carinae[8] but not in HD 45677. The ultraviolet emission lines, measured on the plates of March, 1943, and uncorrected for the radial velocity of the star, are as shown in the accompanying table.

λ	Int.	λ	Int.	λ	Int.	λ	Int.
3334.69........	0	3422.35......	1	3442.10......	3	3483.65......	1
3348.78........	1	3423.73......	1	3452.56......	0	3494.57......	0
3359.78........	2	3436.25......	0	3474.54......	0		
3408.09........	1	3439.10......	5	3482.64......	0		

The strongest line, λ 3439.10, has also been observed as a strong emission in B 1985 and WY Gem. If, as is likely, the line is due to *Mn* II, it shows a very pronounced enhancement relative to the *Mn* II lines of higher excitation potential. Such an effect is well known in the case of *Fe* II.

[7] *Ap. J.*, **67**, 408, 1928.

[8] *Ap. J.*, **67**, 392, 1928.

TABLE 1

OBSERVATIONS OF Be STARS

Star	Dates of Observation 1943	Description
MWC 47.......	I 29	This spectrum was classified by Merrill as B8e*a*, while the *Henry Draper Catalogue* gives "B" with the remark "perhaps B0." The spectrum is that of a typical shell. The *H* lines have sharp, deep cores superposed over very faint, broad, Stark-effect wings. The *He* I lines are exceedingly broad and shallow, due to rotation; *Fe* II is weak and fairly sharp. The ultraviolet lines of *Si* II are visible and are fairly narrow. They must belong to the shell and show, by comparison with *Fe* II, that the dilution factor is not very small. The lines of *Ca* II are sharp and fairly strong; *Mg* II 4481, though faint, is present and is much narrower than *He* I. It must also come from the shell
MWC 51.......	I 29	$H\beta$ is fairly strong in absorption. Merrill had found $H\alpha$ bright and $H\beta$ continuous. The spectrum shows many faint, metallic lines, including *Fe* I, while *Mg* II and *Fe* II are relatively weak; *Ca* II is fairly strong
MWC 76.......	I 28	Probably no change. Spectrum B3ne
MWC 79.......	III 3, 4	The spectrum is B3ne. There is no emission at $H\beta$, but the corresponding absorption line is faint; the lines of *He* I and *H* are strong and broad
MWC 82.......	I 21, 23	No change
MWC 91.......	I 25	The emission lines are fairly narrow, and the absorption lines are intermediate between *n* and *s; H*δ shows a narrow emission line, but $H\epsilon$ is in absorption
MWC 93.......	I 20, 28	The appearance of this spectrum suggests that the expanding shell observed by Merrill (*Ap. J.*, **77**, 103, 1933) between 1928 and 1930 has disappeared. Our plates show very strong emission lines of *H* which can be seen to *H* 11 or *H* 12. They are not very sharp and may be double. The violet absorption wing is somewhat stronger than the red, suggesting a possible vestige of the strong violet cores observed by Merrill in 1928–1930; *Ca* II K is present as a very weak narrow line, while on Merrill's plates it was strong; *Mg* II 4481 is weak and fairly narrow. There are no lines of *He* I or of *Fe* II
MWC 100.....	I 21, 23, 25	The appearance of this spectrum agrees with Merrill's description (*Ap. J.*, **79**, 343, 1934). The sharp lines originate in a shell, while the broad *He* I lines come from a normal B3n star
MWC 103.....	I 25	No change. The *H* lines are very broad and shallow, but the *He* I lines are fairly narrow. The star is of moderate luminosity
MWC 114.....	III 6	$H\beta$ is strong in emission, but $H\gamma$ is seen only in absorption. Probably no change
MWC 116.....	I 29	No change
MWC 120.....	I 28	Probably no change. The sharp absorption cores of $H\beta$, γ, δ, etc., are probably produced in a shell. There is a suspicion of a broad, shallow line of *He* I 4026. The lines of *Fe* II are very sharp in absorption, while *Mg* II 4481 is somewhat broader and rather fainter than should be expected for class A0; *Si* II is very faint and somewhat broad; *Ca* II is strong and sharp. The broad Stark-effect wings of *H* show that the star is not a supergiant
MWC 146.....	III 9	$H\beta$ and $H\gamma$ are in emission; the interstellar *Ca* II lines are very strong
MWC 147.....	III 9	The emission lines of *H* are strong and extend to *H* 15; they are fairly narrow, as are also the absorption lines of *He* I. The absorption lines of *H* and *He* I are weak. The type is B3e
MWC 153.....	III 8	$H\beta$ is weak in emission. The type is B3ne

THE SPECTRUM OF 48 LIBRAE (HD 142983)*

OTTO STRUVE
Yerkes and McDonald Observatories
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ABSTRACT

The star 48 Librae shows a strong metallic absorption spectrum which has developed during the last ten or twenty years. This spectrum shows appreciable dilution in the intensities of *Mg* II and *Si* II. The *H* lines consist of sharp cores superposed over broad wings. $H\beta$ and $H\alpha$ are bright. The sharp-line spectrum is attributed to a shell which resembles in the relative intensities of *Ni* II, *Fe* II, *Cr* II, and *Mn* II the shell of Pleione as observed in 1940. But the Balmer jump in the shell of 48 Librae is much more conspicuous than in Pleione. The shell of 48 Librae is fairly transparent in the ordinary photographic region but is essentially opaque on the violet side of λ 3650. The strong shell lines are sharp but unsymmetrical, while the weaker lines, especially of *Ti* II and *Fe* I, are somewhat diffuse. This suggests stratification. The emission lines of *H* have shown a marked variation in *V*/*R*. The radial velocity is variable.

The spectrum of 48 Librae is at the present time that of a typical shell surrounding a normal, rapidly rotating B star. The star is listed as No. 239 in the Mount Wilson catalogue of Be and Ae stars[1] and is there classified as Apeα. The *Henry Draper Catalogue* lists it as B3p with the remark: "The spectrum is peculiar in combining sharply defined hydrogen lines with wide and ill-defined helium lines. In this respect it resembles the spectrum of ϵ Capricorni." It is evident that the spectrum has undergone a change, since in recent years the metallic lines have been very strong, and the type now more nearly resembles A2 or A5 than B3. Although at the time of the Harvard observations the sharp hydrogen lines already gave indications of a shell, the metallic lines have greatly increased in intensity since that time. Emission at $H\beta$ was found by Struve on plates taken in 1904, but *Fe* II 4549 was only suspected as a weak, narrow absorption line.[2] In 1915 the narrow metallic lines were again suspected, but the remarkable development of the metallic spectrum shown in Plates IX and X probably took place between 1924, when the star was observed at the Chilean station of the Lick Observatory, with the remark "good hydrogen lines,"[3] and 1930, when Merrill classified it as A3seα.[4] In 1935 Struve and Wurm[5] found that the broad *He* I lines were weak, while sharp *Fe* II was fairly strong; *Mg* II was probably present as a very weak line, broader than *Fe* II, but not as broad as *He* I. It is quite certain that in 1935 the metallic lines were not nearly as strong as they are at the present time. Incidentally, in 1935 the red component of the bright line at $H\beta$ was stronger than the violet component. In recent years the violet component has been the stronger of the two.

Although in the past 48 Librae had shown little or no indication of variation in the radial velocity,[6] Merrill and Sanford found that "between 1935 and 1939 the velocity derived from the displacements of the metallic lines and the ultraviolet members of the Balmer series decreased about 100 km/sec and then returned to its previous value. The Balmer lines $H\beta$, γ, δ were displaced only about one-half as much. The velocities from both groups of lines are now (1940) showing a tendency toward algebraically higher values."[7]

The observations discussed in this paper were started at the Yerkes Observatory in

* *Contributions from the McDonald Observatory, University of Texas*, No. 73.

1 *Ap. J.*, **78**, 96, 1933.

2 *Ap. J.*, **76**, 210, 1932.

3 *Pub. Lick Obs.*, **16**, 233, 1928.

4 *Ap. J.*, **74**, 195, Pl. VIII, 1931.

5 *Ap. J.*, **88**, 91, Pl. IV, 1938.

6 *Pub. Lick Obs.*, **18**, 125, 1932.

7 *Pub. A.S.P.*, **52**, 279, 1940.

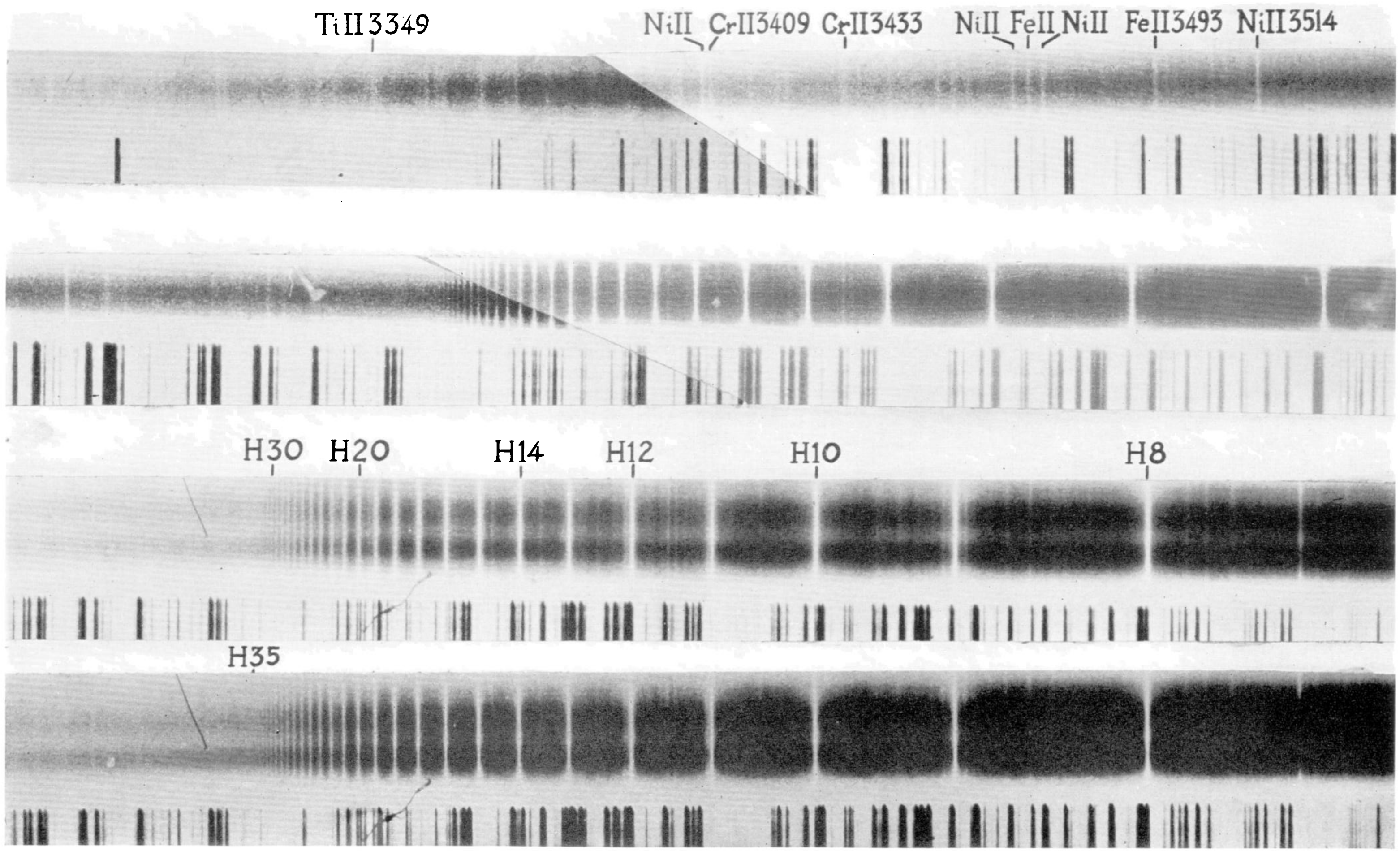
TABLE 1—*Continued*

Star	Dates of Observation 1943	Description
Mt.W. 257......	I 30	No change. The *He* I lines are very weak; *Ca* II K is sharp but is probably interstellar
Mt.W. 265......	I 28	Probably no change. The *H* lines have violet-displaced cores of considerable intensity, suggesting that there is an expanding shell; *Ca* II K is double, with the violet component the stronger; *Mg* II 4481 is present but probably does not share the violet displacement of the *H* and *Ca* II lines. The lines of *Si* II are very weak and look diffuse. Merrill has already remarked upon the similarity of this star to HD 31293. Other similar objects are 17 Leporis and HD 190073. The structure of *Ca* II K bears a definite resemblance to that of HD 190073
Mt.W. 275......	I 21, 24	$H\beta$ is a narrow emission line. The other *H* lines show narrow cores superposed over broad Stark-effect wings. The *He* I lines are greatly broadened by rotation; *Mg* II 4481 and the *Si* II lines are weak and of intermediate width. A few lines of *Fe* II are weakly present and are very sharp; *Ca* II K is sharp and strong. The sharp absorption features indicate a shell, but the central intensities of the sharp *H* cores are not so low as is usually the case. The *Mg* I lines, which are surprisingly strong in many shells, are probably present and are sharp. The rotational broadening of the *He* I lines corresponds to about 300 km/sec
Mt.W. 277......	III 8	$H\beta$ and $H\gamma$ are in emission. The plate is underexposed
Mt.W. 287......	I 21	$H\beta$ and $H\gamma$ are in emission. The higher *H* lines are broad and shallow. *H* 14 or *H* 15 is the last member seen in absorption. The type is B5ne. The interstellar *Ca* II K line is either absent or very weak

Table 1 is a continuation of our observations of Be stars.[9] The stars designated by their MWC numbers refer to the Mount Wilson catalogue of Be stars. Those listed by their Mt. W. numbers will be found in several later lists published by Merrill from Mount Wilson. These stars have not yet been supplied with MWC numbers.

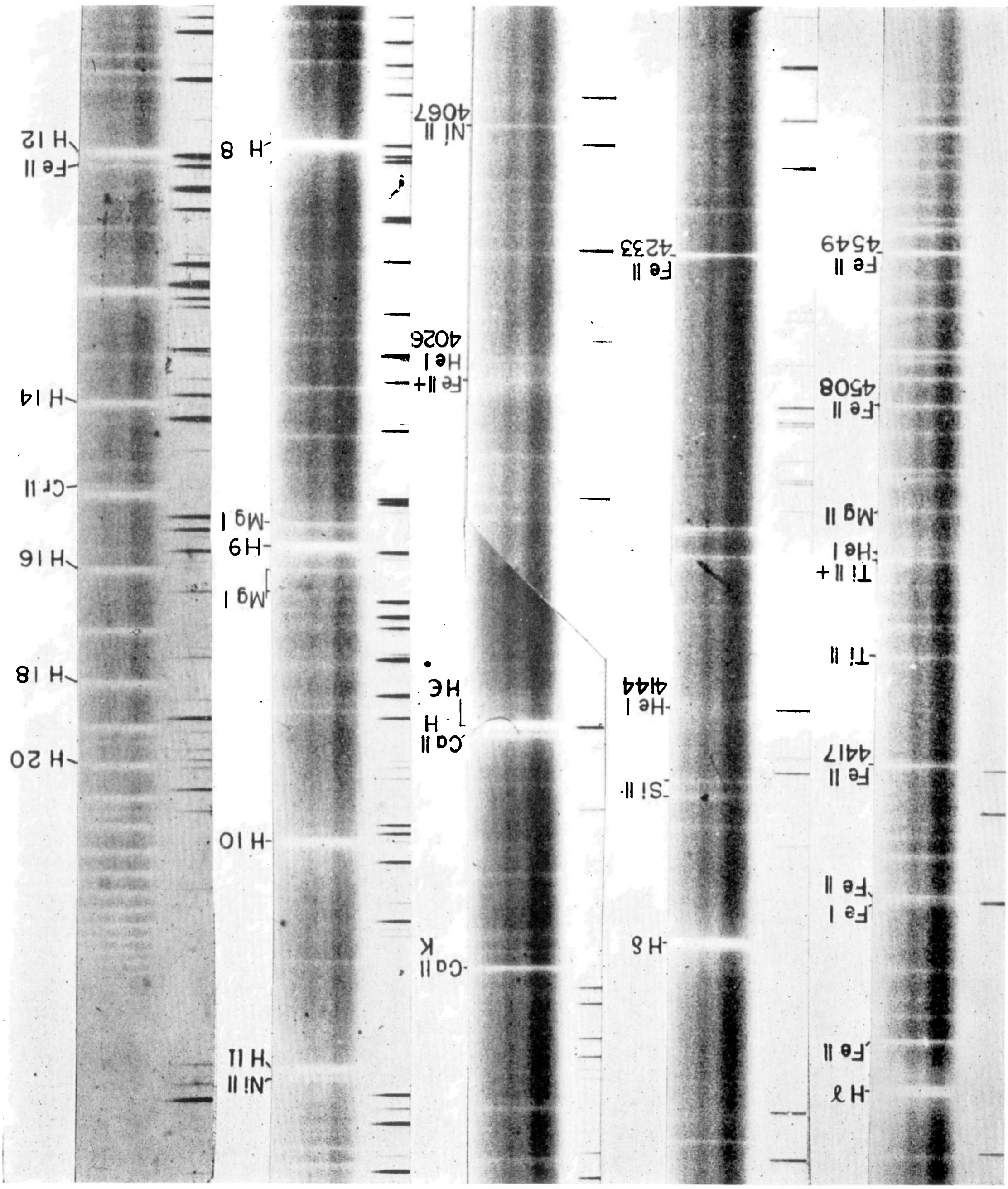
[9] *Ap. J.*, 97, 219, 1943.

PLATE IX



ULTRAVIOLET SPECTRA OF 48 LIBRAE IN MARCH, 1943
The two spectra at the bottom are reproductions of the same original

PLATE X



SPECTRUM OF 48 LIBRAE IN MARCH, 1943