B-type stars of Schlesinger's catalogue ; the results are given in the last line of Table VIII.

The K term remains practically unaltered by the introduction of the rotational term.

In the paper last referred to, Plaskett and Pearce gave as the reason, for the high value (5 km./sec.) of the K term for B-type stars, the inclusion in the statistics of 132 galactic stars between longitudes 210° and 330°. Kapteyn * had noticed, twenty years earlier, that these stars apparently formed an extensive cluster for which he found the convergent. Plaskett and Pearce, redetermining the convergent, place it at R.A. 84°, Dec. −23°, which is but 8° away from their adopted position of the solar antapex. It is not easy to see how a cluster of distant stars spread over 120° of galactic longitude could be maintained against the shearing effect of the galactic rotation. However, supposing that the stars have a common and parallel velocity, V_0, relative to the Sun, and rewriting their equation in the form

$$V_0 \cos \lambda + K = \overline{V}, \quad (12)$$

where $\overline{V}$ is the mean radial velocity in a region and λ is the angular distance of the centre of the region from the convergent C, it is found from the solution of (1) that $K = 8{\cdot}3$ km./sec. and $V_0 = 15{\cdot}0$ km./sec. It would seem that, in this equation, K must be regarded as a systematic correction to the radial velocities of B-type stars, just as in the ordinary equation of condition for the solar motion. Later, Plaskett and Pearce remove the value (8·3) of K from the stars concerned, and in the subsequent general solution for all the stars round the galactic equator, the K term is found to be 1·1 km./sec., agreeing approximately with their estimate of the relativity correction for the B-type stars. However, this procedure appears to be erroneous.

The "cluster" stars are probably very nearly at rest, as a whole, with respect to the centroid of all the stars observed.

Observatory, Cambridge :
1936 *March* 7.

THE VARIABLE SPECTRUM OF π (52) AQUARII.

William J. S. Lockyer, M.A., Ph.D., Major (late R.A.F.).

The spectrum of the star π (52) Aquarii (H.D. 212571, R.A. $22^h\ 20^m{\cdot}2$, Dec. +0° 52′, 1900, Ptg. Mag. 4·42, Sp. Type B1emnη) has been photographed yearly at the Norman Lockyer Observatory since 1923 August, with the exception of the years 1925 to 1927. This star was included in a special investigation to re-photograph the spectra of the brighter stars of type Be, which P. W. Merrill had photographed in the years 1911 and 1912 with the 36-inch Lick refractor to record any possible changes.

The results obtained from the 1923 and 1924 observations have been previously published.†

* *Ap. J.*, **40**, 43, 1914. † *M.N.*, **84**, 421, 1924 ; **88**, 693, 1928.

Since 1924 eighty-four more photographs have been secured, and the present communication describes the results that have been obtained from this series.

The available months of observation during a year cover the months July to the following January, both months inclusive, and the programme set out was to secure at least one photograph each month.

All the photographs have been taken with the same instrument as before, namely, the Kensington Prismatic camera of 9-inch aperture and 120 inches focal length, with a 9-inch prism of 45° angle, giving a dispersion of 46·0 mm. between $H\beta$ and $H\delta$.

The chief characteristics of the spectrum of this star are as follows. The hydrogen lines consist of broad absorption bands. Sometimes double and sometimes single bright lines are superimposed on them, and again sometimes no bright lines are seen at all. The neutral helium lines are always strong and nebulous. The [K] line of ionised calcium is moderately strong and very sharp. The ionised magnesium absorption line at λ 4481 is always weak and nebulous. Other bright lines of the ionised metals, similar to those that appear in φ Persei or γ Cassiopeiæ, are visible in the best negatives. (See Plate 7.)

The present investigation is devoted entirely to the recorded changes in the appearances of the hydrogen lines, although variations in the intensities of other lines were also noted during the examination of the negatives. The method of determining the difference of intensity between the two bright components (when present) of each of the hydrogen lines was the same as adopted in previous investigations of this kind, namely, by eye estimate with a magnifying glass (×2).* Thus it was estimated whether the violet component was *equal* to ($V=R$), a *little brighter* than ($V > R(L)$), *brighter* than ($V > R$), *much brighter* than ($V >> R$) and lastly *very much brighter* than ($V >>> R$), the red component. A similar procedure was adopted as regards the red component in relation to the violet, namely, ($R=V$), ($R > V(L)$), etc. In order to simplify the printing of the table figures were adopted to replace the letters, and the resulting notation was as follows :—

R alone	+14	*V* alone	−14
$R >>> V$	+11	$V >>> R$	−11
$R >> V$	+8	$V >> R$	−8
$R > V$	+5	$V > R$	−5
$R > V(L)$	+2	$V > R(L)$	−2
$R=V$	0	$V=R$	0

In cases where the red (R) or violet (V) components appeared alone the figures (+14) or (−14) respectively were used.

When the bright components of the hydrogen lines were strong they could be observed as far down the spectrum as $H\eta$, but when they were weak they were restricted more or less to the lines $H\beta$, $H\gamma$ and $H\delta$. Estimates were therefore only made throughout on their appearance in those three lines. In the case of some of the negatives, when the bright lines were faint, the

* *M.N.*, **93**, 365, 1933.

estimates for $H\beta$ were not quite so good as those for $H\gamma$ because the sensitiveness of the plates fell off a little to the red side of $H\beta$. Further, the estimates for $H\delta$ were also less trustworthy than those for $H\gamma$, and more so than $H\beta$ under the same conditions because the bright components fell off greatly in intensity towards the violet. Thus the order of procedure in accuracy of the estimates may be stated to be (1) $H\gamma$, (2) $H\beta$ and (3) $H\delta$.

The following table (Table I) contains the estimates for each of the three hydrogen lines mentioned above. In column 1 is given the number of the Sidmouth negative, and in column 2 the year and day and month on which each photograph was taken. Columns 3, 5 and 7 contain the eye-estimate values, and columns 4, 6 and 8 their quality. In columns 3, 5 and 7 blank spaces indicate that the spectrum was not sufficiently dense at the wave-lengths of those particular lines to warrant any deduction being made as to details in those lines, and the letters NBL mean that there were "no bright lines" to be seen at all. In columns 4, 6 and 8 blank spaces represent "good" estimates, (M) moderate and (P) poor estimates.

Column 9 is the estimated intensities of the general appearance of the bright lines *as a whole*, using the notation strong (S), weak (W), moderate (M) and very (V). Where the symbol (VW) appears this applies also to the instances when the bright lines are recorded as absent in all three hydrogen lines.

With reference to Table I it should be pointed out that there was no difficulty in determining the estimates of the intensities of the bright lines when they were strong, such as for the years 1923, 1924, 1928 to 1931. In the years 1932, 1933 and 1935 the bright lines were exceedingly faint or not visible at all. It was at first thought that satisfactory photographs of the spectrum in those years were not being secured. This, however, was not the case, for when these photographs were compared with those that contained strong bright lines, the intensity of the continuous spectrum in each case being selected as equal, they still displayed no bright lines. This showed conclusively that the bright lines had faded out.

While the bright lines were strong in the year 1934 it was very surprising to find that the first photographs taken in 1935 showed no bright lines at all. Several extra photographs were taken between July and November but none of them showed any trace of bright lines.

Thus it will be seen from Table I that the bright components of the hydrogen lines gradually diminished in intensity from 1928 to vanishing point in 1933, became prominent again in 1934 and disappeared again in 1935.

All the values given in Table I, with the exception of those for the years 1923 and 1924, are graphically shown in fig. 1. The filled-in circles represent the "good and moderate" estimates and the open circles "poor" estimates, each of them being the mean value derived from the negatives secured during any one month.

The scales on the left show the original method of making the eye estimates, and those on the right the corresponding figures adopted. The scale of years is given at the top and bottom, subdivided into months, and each monthly mean value is plotted exactly underneath each subdivision, the vertical lines representing the month of January.

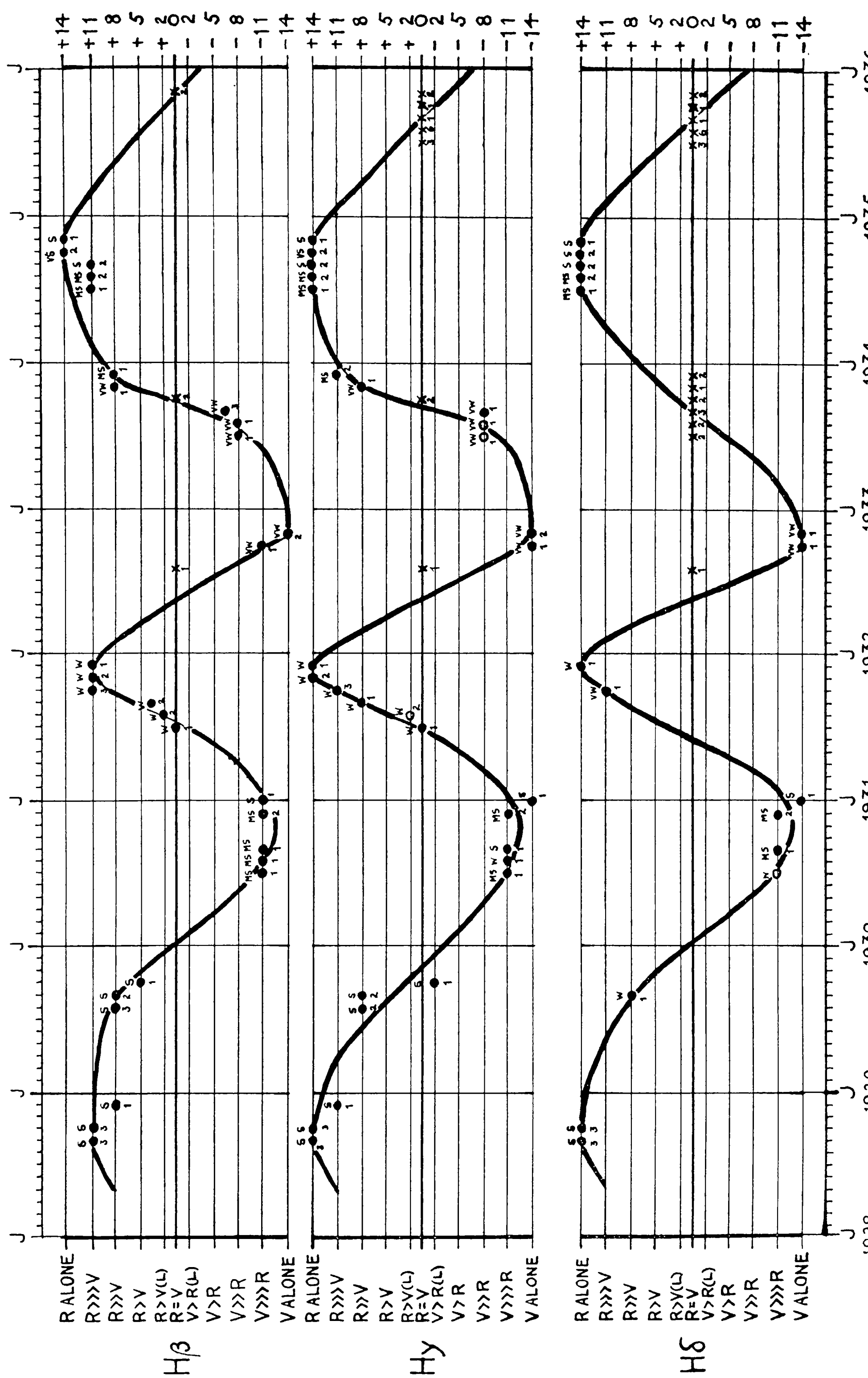


Fig. 1.

Each monthly mean has, printed above it, the mean intensity of the bright lines taken from column 9 in Table I and, below it, the number of estimates

TABLE I

Neg. No.	Year and Month	Hβ E	Hβ Q	Hγ E	Hγ Q	Hδ E	Hδ Q	Int. Br. L.
1	2	3	4	5	6	7	8	9
	1923							
323	Aug. 5	0		...		...		S
328	,, 7	0		− 2		− 2		S
367	Sept. 16	− 5		− 5		...		VS
	1924							
462	July 26	− 5	M	− 5		− 8	M	MS
467	Aug. 7	− 8	M	− 11		− 11		MS
481	,, 20	− 11	P	...		...		MS
484	,, 25	− 11	P	− 11		− 8	P	MS
	1928							
1057	Sept. 4	+ 11		+ 14		+ 14		S
1064	,, 6	+ 11		+ 14		+ 14		S
1079	,, 20	+ 11		+ 14		+ 14		S
1090	Oct. 5	+ 11		+ 14		+ 14		S
1104	,, 21	+ 11		+ 14		+ 14		S
1106	,, 30	+ 11		+ 14		+ 14		S
1134	Dec. 14	+ 8		+ 11		...		S
	1929							
1236	Aug. 2	+ 8	P	+ 11	P	...		S
1237	,, 2	+ 8	M	+ 8	P	...		MS
1246	,, 25	+ 8	M	...		...		MS
1258	Sept. 2	+ 8		+ 8		+ 8		S
1266	,, 6	+ 8		+ 8		...		S
1313	Oct. 31	+ 5		+ 2		...		S
	1930							
1411	July 8	− 11	M	− 11	M	− 11	M	MS
1438	Aug. 30	− 11		− 11	M	...		MS
1457	Sept. 27	− 11		− 11		− 11		MS
1499	Dec. 8	− 11		− 11		− 11		S
1505	,, 21	− 11		− 11		− 11		MS
	1931							
1520	Jan. 9	− 11		− 14		− 14		S
1636	July 9	0		0	M	...		W
1647	Aug. 16	+ 2	M	+ 2	P	...		W
1650	,, 17	+ 2	M	+ 2	P	...		W
1659	Sept. 5	+ 2	M	+ 8	M	...		W
1674	,, 11	+ 5	M	...		...		VW
1679	Oct. 7	+ 11		+ 11		+ 11	M	W
1683	,, 11	+ 11		+ 11		...		VW
1709	,, 30	+ 11		+ 14		...		W
1719	Nov. 12	+ 11		+ 14		...		W
1720	,, 14	+ 11		+ 14		+ 14		MW
1728	Dec. 7	+ 11		+ 14		+ 14		MW
	1932							
1827	Aug. 31	...		NBL		NBL		VW
1838	Oct. 1	...		NBL		NBL		VW
1841	,, 3	− 5		NBL		NBL		VW
1857	,, 31	− 11		− 14	M	− 14	M	VW
1865	Nov. 21	...		− 11	M	− 11	M	VW

Neg. No.	Year and Month	$H\beta$		$H\gamma$		$H\delta$		Int. Br. L.
		E	Q	E	Q	E	Q	
1	2	3	4	5	6	7	8	9
	1932							
1866	Nov. 26	−14	P	−11	P	...		VW
1867	,, 28	−14		−14		−14		VW
	1933							
1993	July 22	− 8	M	− 8	M	...		VW
1994	,, 24	...		− 8	P	...		VW
1996	,, 26	...		NBL		NBL		VW
2002	Aug. 14	...		NBL		NBL		VW
2004	,, 16	− 8	M	− 8	P	NBL		VW
2001	,, 21	NBL		NBL		NBL		VW
2013	,, 23	...		NBL		NBL		VW
2017	,, 25	NBL		NBL		NBL		VW
2033	Sept. 9	− 8	M	− 8	M	NBL		VW
2035	,, 13	− 5	M	NBL		NBL		VW
2037	,, 14	− 5	M	NBL		NBL		VW
2043	,, 20	NBL		NBL		NBL		VW
2064	Oct. 8	...		NBL		...		VW
2076	,, 16	NBL		NBL		NBL		VW
2091	Nov. 12	+ 8		+ 8	M	...		VW
2098	,, 17	...		NBL		NBL		VW
2108	Dec. 9	...		+11	M	NBL		MS
2115	,, 14	+ 8		+11		NBL		MS
	1934							
2255	July 21	+11		+14		+14	M	MS
2263	Aug. 13	+11		+14		+14	P	MS
2265	,, 14	+11		+14	M	+14	P	MS
2273	Sept. 1	+11		+14		+14		MS
2274	,, 4	+11		+14		+14		S
2287	Oct. 3	+14		+14		...		VS
2289	,, 5	+14		+14		+14		S
2304	Nov. 1	+14		+14		+14		S
	1935							
2430	July 30	...		NBL		NBL		VW
2442	Aug. 9	...		NBL		NBL		VW
2448	,, 19	...		NBL		NBL		VW
2450	,, 20	...		NBL		NBL		VW
2458	Sept. 7	...		NBL		NBL		VW
2482	Oct. 29	...		NBL		NBL		VW
2488	Nov. 17	NBL		NBL		NBL		VW
2489	,, 18	NBL		NBL		NBL		VW

of which it is the mean. Where the photographs exhibited *no bright lines*, these are indicated by crosses placed on the horizontal line $V=R$, and below them the number of negatives used to form the mean. The reason why these crosses were placed in this $V=R$ line was because it seemed that they fell in place at the time when the bright components should be of about equal intensity.

For each of the three hydrogen lines smooth curves were drawn through the mean estimate values to satisfy, as far as possible, the observations in each case. It will be seen that all the curves are of a very similar nature, having maxima towards the latter half of the years 1928, 1931 and 1934, and minima about the latter part of the years 1930 and 1932. It has been stated previously that the estimates for $H\gamma$ were considered to be more accurate than those for the other lines, so that the curve for this line would be the most appropriate for finding the epochs of maxima and minima for the determination of the period of variation.

Taking the dates of the maxima first those are, as near as can be determined, 1928 October 1, 1931 December 1 and 1934 September 15, which correspond to the Julian day numbers 2425521, 2426677 and 2427696 respectively. The intervals between the consecutive maxima are therefore 1156 and 1019 days, the mean being 1087·5 days. In the case of the two minima their dates are approximately 1930 November 15 and 1933 February 15, corresponding to the Julian day numbers 2426296 and 2427119 respectively. The interval between them is thus 823 days.

The last-mentioned interval from minimum to minimum is very much less than that between the maxima, indicating that the period of variation for these years is by no means regular.

While it is not necessary to refer here to the very early observations of this star, it may be of interest to draw attention to the bibliographical and observational record, from the date of its discovery as a bright-line star by Miss Maury in 1890 down to the year 1929, which has been published by Charles D. Higgs * in 1930.

The first statement regarding a period assigned to this star was given by R. H. Curtiss † in 1925 from observations made at Ann Arbor, who listed this star as a ϕ Persei variable with a period of 2000 days. Later on, in 1929, he revised ‡ this period to 2700 days. In both cases the variation was obtained from the changes in the relative intensity of the two bright components of the hydrogen lines.

In 1930 Higgs § made a study of some of the Lick Observatory negatives. These negatives were very few in number, amounting to only thirteen between the years 1915 to 1930. The conclusions he came to were that the attempts to correlate the separations of the bright components of the hydrogen lines or their radial velocity shifts, with the variations in relative intensity, or to establish a period for the latter, proved futile.

Higgs, however, drew attention to the fact that the type of variability of the relative intensity of the bright hydrogen components in the years 1928 and 1930 was very different from that in the years 1915 and 1919. This star had been under observation at Sidmouth during the years 1925, 1929 and 1930, and I pointed out || that my observations corroborated those of Higgs for the years 1928 and 1930, but no data were available at Sidmouth for the previous years, with the exception of 1923 and 1924, to show that any radical changes had occurred.

Since the above observations were published three papers have appeared

* *Ap. J.*, **72**, 190, 1930. † *Pop. Ast.*, **33**, 537, 1925.
‡ *Pop. Ast.*, **37**, 579, 1929. § *Ap. J.*, **72**, 187, 1930. || *Ap. J.*, **73**, 55, 1931.

by Dean B. McLaughlin * discussing observations made at Ann Arbor between 1924 and 1932. He states that the values for the relative intensities of the bright hydrogen components of $H\beta$ and $H\gamma$ "appeared to follow a curve with steep rise and gentle decline with a period of about 1900 days." It may be mentioned here that there is a gap in the observations extending from 1926 December to 1928 August. He mentions further that the plates taken in 1931 "showed that the period of 1900 days was not being followed at all."

In the third of the papers mentioned above he states: "Plates taken in 1932 gave still another surprise and forced the writer to conclude that probably π Aquarii is purely irregular in its variations." In his paper he publishes curves for the emission ratios of $H\beta$ and $H\gamma$ for the years 1925 to 1932. That portion of the curve for the years 1928 to 1932 agrees very closely with the Sidmouth curves.

The only prior Sidmouth observations relate to the years 1923 and 1924, which suggest a rapid decline in 1923 August and September to a minimum in 1924 August. If those were the only available observations made between 1923 and 1928, then they would indicate that possibly another maximum occurred in the latter part of 1925 followed by a minimum in 1927. Thus my curves for the years 1928 to 1935 could be extended backwards to the year 1923 with a period of about the same order of magnitude.

The observations made at Ann Arbor in 1925 and 1926 rule out, however, the suggested maximum in 1925 and possibly the suggested minimum in 1927.

It has been pointed out previously that the bright hydrogen components gradually diminished in intensity from 1928 to vanishing point in 1933, became prominent again in 1934 and disappeared again in 1935.

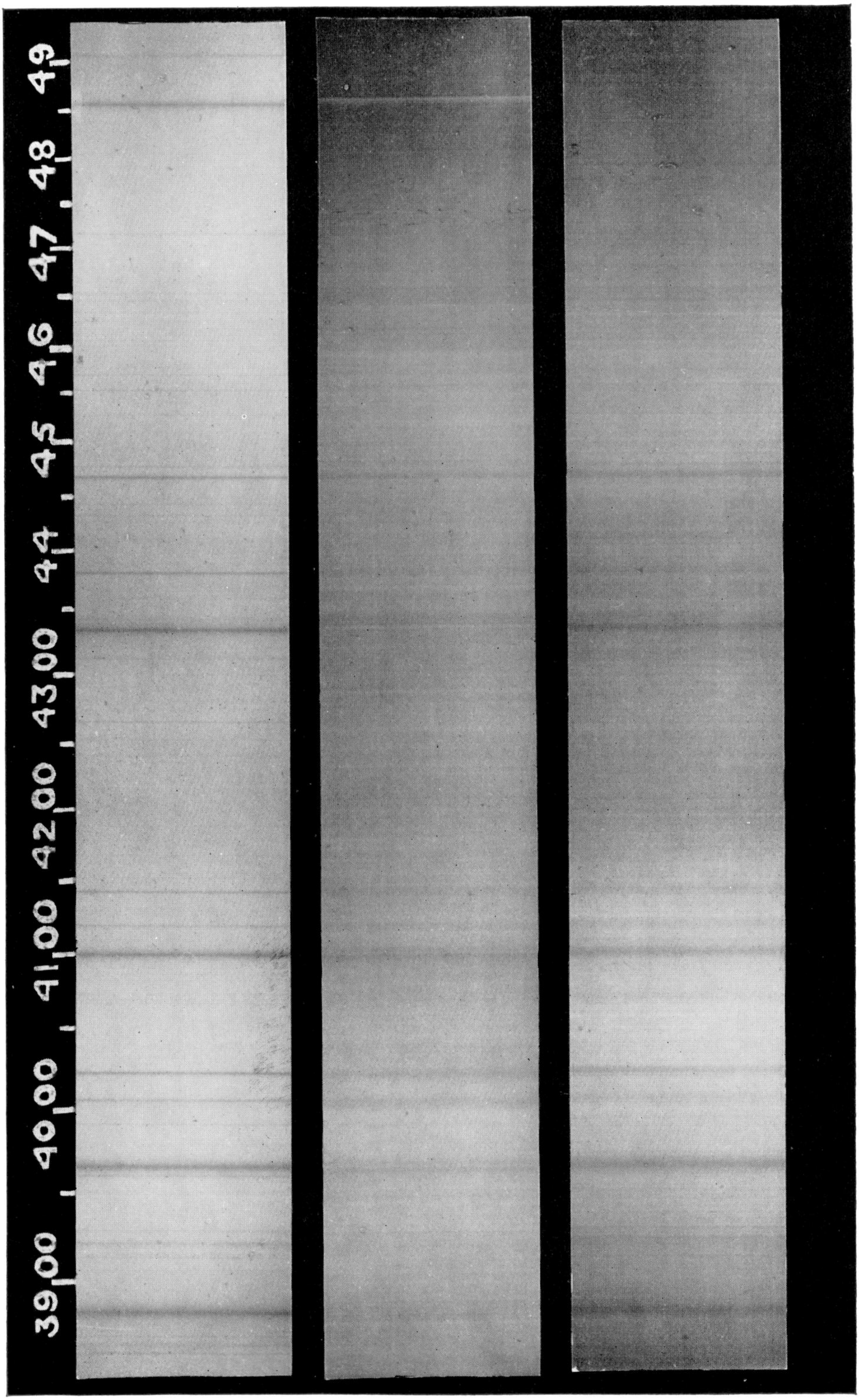
The disappearance of bright lines in Be-type stars has been noticed before, and Curtiss,† as long ago as 1923, showed that the evidence then available indicated that such stars eventually lose their emission lines and become normal stars of class B. The reappearance of emission in f^1 Cygni caused him ‡ to raise the question whether any of these stars permanently lose their emission.

McLaughlin § gives an interesting table of numerous Be-type stars showing the behaviour of the intensities of the bright hydrogen components before and after the year 1921. This indicates how the bright components wax or wane but not necessarily disappear. He is inclined to the view that "changes in total intensity of the emission lines are cyclic in character."

Merrill, Humason and Burwell || raised the question "whether a B-type star can pass into the bright-line stage more than once." In the case of π Aquarii this question can be definitely answered in the affirmative.

Another Be-type star which has been, and still is, under observation at Sidmouth since the year 1923 is H.D. 20336.¶ This star has always been

* *Pub. Obs. Univ. Michigan*, **4**, 37, 1931; **4**, 190, 1932; *Ap. J.*, **77**, 221, 1932.
† *Pub. Obs. Univ. Michigan*, **3**, 2, 1923.
‡ *M.N.*, **88**, 205, 1928.
§ *Pub. Obs. Univ. Michigan*, **4**, 196, 1932.
|| *Ap. J.*, **61**, 415, 1925.
¶ *M.N.*, **91**, 215, 1930.



1 2 3

W. J. S. Lockyer *The Variable Spectrum of π (52) Aquarii.*