DISCOVERY AND OBSERVATIONS OF STARS OF CLASS Be[1]

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ABSTRACT

Stars of class B whose spectra contain emission lines of hydrogen.—Three reasons for studying these spectra are suggested: (1) possible assistance in the interpretation of the typical nova spectrum; (2) the bright lines appear to be sensitive indicators of conditions in stellar atmospheres; (3) unusual properties of hydrogen atoms may be involved.

The *discovery* of these stars by other observers has usually been made from the Hβ line, but Hα serves better because of its greater intensity. By photographing the red portion of the spectrum we have discovered 90 early-type stars with hydrogen emission. These are listed in Table I. Eighty-four of the stars were found from objective-prism observations with the 10-inch Cooke telescope on Mount Wilson.

Data concerning the Hα line in *Be stars*, as well as in certain *nebulae*, *Wolf-Rayet stars*, and *novae*, are contained in Tables II, III, and IV. The *ultra-violet hydrogen lines* in the Be stars are usually seen in absorption even when Hα is bright. Estimates of their intensity are included in Table II.

The *blue-violet portion of the spectrum* has been observed with slit spectrographs attached to the large reflectors. Descriptions of Hβ, Hγ, and Hδ, and various other data including *radial velocities* of a few stars, are given in Table V.

The *discussion* brings out the fact that our objective-prism spectrograms have yielded *more new bright-line stars than the number previously known within the areas observed*. It is suspected that in some of these objects the bright lines have come into existence since the Harvard spectroscopic surveys. A study of the *distribution* of Be stars shows a tendency for them to fall into groups near the center line of the Milky Way. Four of these groups occupy areas which are also rich in Wolf-Rayet stars. The *frequency of bright-line stars in the various spectral subdivisions* is examined and classes B0 to B5 are found to be strongly favored.

INTRODUCTION

The sun and nearly all the stars have spectra in which the chief features are absorption lines and bands. This type of spectrum may accordingly be considered the normal one. Less than 0.5 per cent of all the stars whose spectra have been examined are known to possess well-marked emission lines, and these objects have long been regarded as stellar curiosities. It is an interesting fact that most of the bright-line spectra are associated with either the hottest or the coolest stars. More than 95 per cent of the known bright-line stars fall in classes B and O on the one hand, or in classes M, S, and N on the other. Among classes A, F, G, and K, bright-line stars, while

[1] *Contributions from the Mount Wilson Observatory*, No. 294.

not entirely unknown, are decidedly rare. Conditions at the extremes of the stellar temperature sequence appear to be favorable either to extensive atmospheres or to relatively high spectroscopic excitation of the atmospheres. A large proportion of bright-line spectra are variable, indicating a lack of equilibrium in the outer portions of the stars concerned.

Aside from the general interest attaching to any abnormal or imperfectly understood spectrum, there are at least three specific reasons for studying bright-line stars of Class B, namely, (1) they may assist in the interpretation of novae; (2) bright lines apparently serve as sensitive indicators of conditions in atmospheres of B-type stars; (3) they may teach us new properties of the hydrogen atom.

1. It is possible to select stars of Class Be which form a fairly continuous sequence in the structure of the hydrogen lines from ordinary B stars to novae. Circumstances similar to those causing the characteristic nova spectrum, but less violent, may perhaps be responsible for the unsymmetrical bright lines in certain B-type spectra; but even if this is not the case, it seems evident that the conditions in the atmospheres of several Be stars approach in some degree those prevailing in novae, and we may thus hope to use these stars as an aid in the interpretation of novad phenomena.

2. In many instances Be stars appear to differ from ordinary B-type stars only in the presence of bright hydrogen lines. In some stars the bright hydrogen lines have disappeared without notable changes in other features of the spectrum and without appreciable variation of the total light. These facts make it possible to consider bright hydrogen lines as sensitive indicators of the density or other properties of the atmospheres of the hotter stars, and we are thus offered a method of studying variations too small to be otherwise perceptible.

3. Be stars are also of interest from the viewpoint of general physics, because in them we may observe properties of radiating hydrogen (and some other elements) which differ from the properties shown by laboratory experiments. As examples we may mention the frequent wide doubling of the lines (self-reversal?), and the structure of lines in stars of the P Cygni type, which suggests that in the atmospheres of these stars the hydrogen atoms strongly absorb light

having a wave-length somewhat shorter than each of the Balmer lines, but emit these lines in their normal positions.

I. THE Hα LINE

Historical.—The history of bright-line stars of Class B begins with the discovery by Secchi in 1866 of bright hydrogen lines in the spectra of γ Cassiopeiae and β Lyrae. No additional stars of this kind (with the exception of one or two doubtful instances) were found until the inauguration of the spectroscopic surveys of the Harvard College Observatory by Pickering in 1886. These surveys, made by the aid of the objective prism, produced rich results in this as in other fields of stellar spectroscopy. About 120 B-type spectra were found to have bright hydrogen lines. The Hβ line served most frequently for the detection of hydrogen emission, but in numerous spectra a few of the more refrangible lines were also bright. The portion of the spectrum containing Hα was not shown by these photographs, but in 1894 Campbell, observing visually at Mount Hamilton with the 36-inch refractor and attached spectroscope,[1] found that Hα also is bright. He stated the rule that the intensities of the bright hydrogen lines in B-type spectra decrease from Hα toward the violet.

Ordinary photographic plates are practically insensitive to red light, but the discovery of sensitizing dyes, particularly pinacyanol, has made it possible to prepare emulsions which are quite rapid in the region of Hα, and thus to extend to this part of the spectrum the great advantages of photography. Spectrograms obtained by Merrill[2] in 1912 with the Lick 36-inch refractor showed, in confirmation of Campbell's rule, that in B-type spectra bright Hα is much stronger than Hβ, and that, in spite of the smaller prismatic dispersion in the red, it stands out far more prominently from the background of the neighboring continuous spectrum. Comparison of the appearance of the hydrogen lines in various B-type spectra suggested that numerous stars might exist in which Hα alone is bright. Visual observations by Campbell[3] had, in fact, already shown Hα to be bright in Alcyone, a star in whose spectrum the other hydrogen lines

[1] *Astrophysical Journal*, **2**, 177, 1895.

[2] *Lick Observatory Bulletins*, **7**, 162, 1913.

[3] *Loc. cit.*

are dark.[1] Merrill's observations of the Hα region with slit spectrographs at Mount Hamilton in 1912[2] and at Ann Arbor in 1914[3] of about forty B-type stars resulted in the discovery of six bright-line spectra. A few objective-prism spectrograms of known bright-line stars were obtained in February, 1917, by the same observer with the 2-foot reflector of the Harvard College Observatory, using red-sensitive plates.[4] Bright Hα was clearly shown in the spectra of κ Draconis, β Lyrae, and P Cygni.

The Mount Wilson observations.—It thus became evident that the use of the Hα region of the spectrum would be decidedly advantageous for the detection of hydrogen emission in B-type stars, and it was believed that objective-prism observations comparable with those made by the Harvard College Observatory at Cambridge and Arequipa for the purpose of spectral classification, but showing the Hα region, would result in the discovery of a considerable number of bright-line stars of Class B in addition to those already known. This idea was given a practical trial by Merrill during the years 1919 and 1920 with the 10-inch Cooke refractor of the Mount Wilson Observatory. The preliminary exposures showed that the Cooke telescope with a 15° objective prism was suitable for this work: in particular, that the dispersion (about 440 angstroms per mm at Hα) was sufficient for the purpose, that stars at least as faint as the ninth magnitude could readily be photographed, and that stars over an area about 18° in diameter could be obtained in good focus on a single plate. Several new bright-line stars were soon found, making it highly probable that many others having Hα sufficiently bright to observe were awaiting discovery. A general survey of the Milky Way region was then planned, and special observations of some of the brighter B stars were also included. Humason began active participation in the work at this time, and after September, 1920, made nearly all the objective-prism observations. During the past few months Miss Burwell has given the plates a very careful re-examination and has collected the data for publication.

[1] Later photographs have shown feeble bright portions within the broad absorption at Hβ.

[2] *Loc. cit.*

[3] *Publications of the Astronomical Observatory, University of Michigan*, **2**, 181, 1916.

[4] *Scientific Papers of the Bureau of Standards*, **14**, 487, 1918.

The 10-inch telescope used for the objective-prism observations is of the Cooke "Astrographic" type, having an equivalent focal length of 45.5 inches. The prism, with a circular aperture of 10 inches, has a refracting angle of 15° and causes a deviation of 8°. The linear dispersion at Hα is about 440 A per mm. The lens was so designed that it is achromatic in the blue and violet regions. The color-curve turns sharply away from the lens in the red and more gradually in the ultra-violet. The focal plane of Hα coincides with that for λ 3785 and is 4.1 mm farther from the lens than the focal plane of λ 4200. On our photographs, therefore, only the ends of the spectra are in focus. For this particular type of work a lens having the same back focus for Hα and Hβ[1] would be desirable.

An auxiliary telescope inclined 8° to the axis of the Cooke lens serves for guiding. In a few cases the guiding star has been held at exactly the same point throughout the exposure so that very narrow spectra might be obtained, but in most exposures a small east-and-west motion (parallel to the refracting edge of the prism) was purposely allowed in order to widen the spectra, which aids greatly in detecting a feeble Hα line. Several excellent plates were obtained without any guiding whatsoever. The average exposure time for the large plates is about three hours, but a few exposures have exceeded four hours.

Plates 14×17 inches in size are employed for most of the long exposures. The definition is reasonably good over practically the entire area. Very wide spectra of bright stars are obtained on smaller plates. On moonlight nights the fogging usually caused by the sky light can be avoided by the use of a red color filter; for the exposures on 4×5 plates we often use an Eastman "A" or "F" gelatine filter supported in a cardboard frame immediately in front of the plate-holder.

The emulsions employed are either Seed 23 sensitized by pinacyanol, or Ilford Special Rapid Panchromatic hypersensitized by ammonia. The pinacyanol is applied by the well-known Wallace procedure. The sensitizing bath in which the plates are immersed for four and one-half minutes is made up as follows:

[1] That is, having the same color correction as an ordinary visual objective.

	cc
Distilled water	260
Ethyl alcohol	200
Pinacyanol solution 1:1000	12
Concentrated ammonia	15

This is followed, before drying, by a thorough rinsing in pure ethyl alcohol. The ammoniating bath for the Ilford plates consists of

	cc
Distilled water	375
Ethyl alcohol	125
Concentrated ammonia	13

The subsequent alcohol rinse has usually been omitted. The Ilford plates are perhaps slightly faster in the sense of a lower threshold value, but the Seed 23 plates have somewhat more contrast and finer grain.

Two examples of widened spectra obtained with the ten-inch telescope and objective-prism are shown in Plate XI. (*a*) is copied from a plate taken on January 25, 1922, exposure time $2^h\ 55^m$, emulsion Ilford Special Rapid Panchromatic, hyper sensitized with ammonia. The enlargement is three times. The position of the center of the illustration is R.A. $6^h\ 25^m$, Dec. $+5.^\circ2$ (referring to the red end of the spectrum which lies toward the right). North is toward the right. The brighter stars shown are as follows:

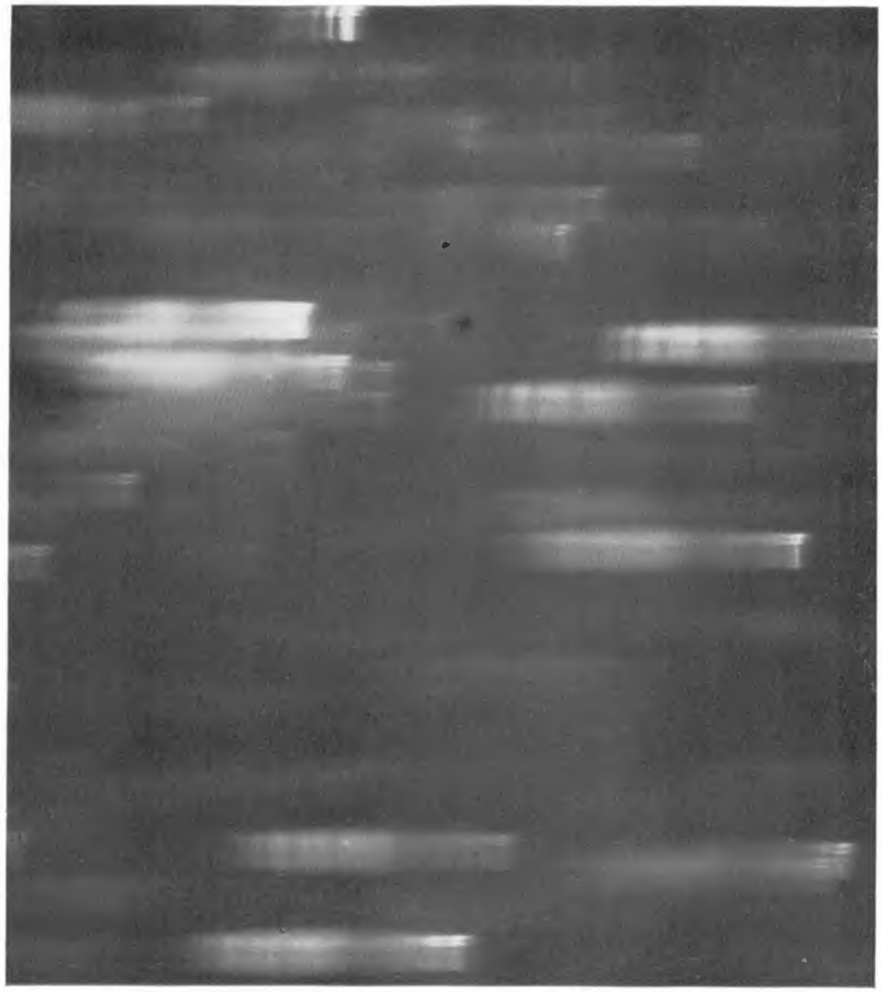
H.D. No.	Mag.	Spect.	Distance of red end from		Remarks
46612	7.1	Mb	Top 2 mm	Left 40 mm	
46241	6.0	Ko	Top 36	Left 35	
46150	6.8	B2	Top 42	Left 39	
46179	6.7	B9	Top 39	Right 0	
46105	6.8	Ao	Top 46	Right 15	
45910	6.7	Be	Bottom 50	Right 9	Bright Hα
45530	7.2	B9	Bottom 15	Right 42	
45431	6.7	Fo	Bottom 3	Right 48	

(*b*) β Piscium, 1900 R.A. $22^h\ 58^m.8$, Dec. $+3^\circ\ 17'$; Mag. 4.6, spectrum B5e August 4, 1919, exposure 46 minutes. Emulsion Seed 23 sensitized with pinacyanol. Enlargement five times. The Hα line is bright, while the ultra-violet hydrogen lines are dark.

Table I contains a list of stars in which we have found the Hα

PLATE XI

a



b

(a) Portion of an objective-prism spectrogram taken with the ten-inch Cooke telescope. See description on page 394.

(b) Objective-prism spectrogram of β Piscium. See page 394.

TABLE I

DISCOVERY LIST OF STARS HAVING THE Hα LINE BRIGHT

No.	H.D.	α 1900	δ 1900	Mag.	Sp.	Ref.	Remarks
1....	108	$0^h\ 0^m9$	+63° 7′	7.4	O6e	1	
2....	698	0 6.3	+57 39	7.1	B8seα	1	
3....	2789	0 26.3	+66 36	8.2	B2ne	6	
4....	7636	1 11.2	+57 6	7.6	B2ne	1	
5....	B.D.+62°271	1 27.9	+63 7	8.2	B(8)eα	3	Near H.D. 9105
6....	B.D.+54°398	1 45.9	+54 50	8.6	B(2)e	3	
7....	12882	2 1.1	+64 33	7.5	B(2)e	1	
8....	19243	3 0.7	+62 0	6.5	B2e	1	
9....	22298	3 30.3	+54 50	8.4	B2ne	4	
10....	23302	3 39.0	+23 48	3.8	B5neα	7	Electra
11....	23480	3 40.4	+23 39	4.2	B5neα	7	Merope
12....	25348	3 56.6	+53 3	8.2	B(1)e	4	
13....	29866	4 37.3	+40 36	6.1	Beα	2	
14....	30614	4 44.1	+66 10	4.4	O9eα	1	9 Camelop.
15....	33152	5 3.2	+36 53	7.8	B2e	2	
16....	33232	5 3.7	+40 53	8.1	Bepv	2	
17....	33461	5 5.3	+41 6	8.0	B(1)e	3	
18....	33604	5 6.3	+40 5	7.3	B2e	2	
19....	37115	5 31.0	− 5 41	8.2	B(5)e	1	Brighter comp. β.G.C. 2850
20....	37490	5 33.9	+ 4 4	4.5	....	7	ω Orionis B3e
21....	37657	5 35.1	+43 0	7.0	B3ne	2	
22....	37967	5 37.2	+23 10	6.1	B3ne	2	
23....	38191	5 38.9	+21 25	9.5	Be	4	
24....	39340	5 46.9	+26 25	8.1	B3e	3	
25....	B.D.+25°1019	5 47.3	+25 43	8.5	Be	3	
26....	39478	5 47.8	+26 24	8.4	B2ne	4	
27....	41117	5 58.0	+20 8	4.7	B1seα	3	χ^2 Orionis
28....	B.D.+20°1309	6 6.3	+20 7	9.1	Be	3	
29....	43285	6 10.3	+ 6 6	6.0	B(1)e	6	
30....	44637	6 17.7	+15 9	7.7	B3e	3	
31....	45314	6 21.6	+14 57	7.1	B(0)e	3	
32....	45542	6 23.0	+20 17	4.1	....	8	ν Geminorum B5eα
33....	45910	6 25.2	+ 5 57	6.7	Beqv	2	
34....	45995	6 25.6	+11 19	5.8	B2ev	1	
35....	50138	6 46.7	− 6 51	6.6	B8ev	2	
36....	50209	6 47.1	− 0 10	8.3	B(5)e	3	
37....	51354	6 51.9	+18 2	7.1	B4e	.....	
38....	55135	7 6.6	−10 16	7.2	B3ne	2	
39....	55271	7 7.1	−21 38	6.7	Be	2	Brighter comp. β.G.C. 3887
40....	56806	7 13.4	−18 39	9.3	Be	4	

TABLE I—*Continued*

No.	H.D.	α 1900	δ 1900	Mag.	Sp.	Ref.	Remarks
41....	58715	$7^h21^m.7$	+ 8°29′	3.1	B8neα	8	β Can. Min.
42....	B.D.−13°2040	7 24.5	−13 34	9.0	B(2)e	4	
43....	59497	7 25.1	−21 38	8.4	B2e	4	
44....	59773	7 26.4	−21 35	8.1	B(3)e	4	
45....	62753	7 40.4	−40 5	6.7	B(2)ne	4	
46....	154218	16 59.0	−36 36	7.7	Be	4	
47....	154243	16 59.2	−36 27	8.3	B2e	5	
48....	154450	17 0.4	−35 37	8.5	Boe	5	
49....	156468	17 12.6	−37 54	8.0	B2e	5	
50....	160095	17 32.9	−33 29	8.7	B8ep	6	
51....	160202	17 33.5	−32 9	6.9	B(1)eβ	5	
52....	161103	17 38.5	−27 12	7.9	Bne	5	
53....	161306	17 39.7	− 9 46	8.3	B(o)e	5	
54....	D.M.−27°11944	17 41.9	−27 59	9.0	Beq!	5	
55....	163181	17 49.7	−32 27	6.6	B2e	6	
56....	163296	17 50.3	−21 56	6.6	A2e	.....	
57....	163454	17 51.1	−31 0	7.9	B1e	6	
58....	163868	17 53.3	−33 24	7.2	B2e	5	
59....	164906	17 58.3	−24 24	9.0	B(o)e	6	
60....	166566	18 6.1	−15 42	8.1	B2se	5	
61....	166666	18 6.6	−15 36	9.4	B2e	.....	
62....	166734	18 6.9	−10 46	8.3	Beα	.....	
63....	168229	18 13.6	−18 16	9.7	B(1)e	5	
64....	168607	18 15.5	−16 25	8.9	Aose	6	
65....	169226	18 18.6	−12 15	9.1	Be	.....	Brighter comp. β.G.C. 8523
66....	169454	18 19.6	−14 2	6.8	Boe	6	
67....	169515	18 19.9	−12 45	8.3–9.2	Pec	6	RY Scuti
68....	169805	18 21.3	−19 1	8.7	B(1)ne	6	
69....	170061	18 22.4	−14 47	10.6	Be	.....	
70....	172694	18 36.5	−15 57	8.3	Bep	.....	
71....	174105	18 43.8	+15 17	6.9	B8e	.....	
72....	175863	18 52.4	+59 53	6.9	B3e	.....	
73....	180398	19 11.3	+12 56	7.7	B(1)e	.....	
74....	B.D.+14°3887	19 17.0	+14 42	9.5	Pec	.....	
75....	B.D.+22°3687	19 20.5	+22 35	8.6	B2e	.....	Brighter comp.
76....	183143	19 23.0	+18 6	6.9	B9seα	.....	
77....	187399	19 44.7	+29 10	7.7	B9eβ	.....	
78....	187567	19 45.4	+ 7 39	6.4	B1e	.....	
79....	B.D.+35°3950	20 2.0	+35 37	8.8	Be	.....	
80....	192445	20 9.8	+36 1	7.1	B2e	.....	
81....	B.D.+36°3946	20 10.1	+36 18	8.5	B(o)e	.....	
82....	195407	20 26.0	+36 39	7.7	B1e	.....	
83....	198512	20 45.7	+53 32	8.0	B(2)e	.....	
84....	199218	20 50.6	+40 19	6.5	B5e	1	Brighter comp. β.G.C. 10606
85....	203025	21 14.6	+58 11	6.4	B2e	.....	

TABLE I—*Continued*

No.	H.D.	α 1900	δ 1900	Mag.	Sp.	Ref.	Remarks
86....	207232	21^h42^m4	+50° 13′	7.0	B8e	.....	
87....	209409	21 58.1	− 2 38	4.7	....	7	o Aquarii B5e
88....	212044	22 16.5	+51 22	7.1	Be	.....	
89....	214748	22 35.1	−27 34	4.2	B8ea	1	ε Pisc. Austr.
90....	224559	23 53.7	+45 51	6.5	B3ne	.....	
	Stars of Classes F and M						
91....	B.D.+61°8	0 4.4	+62 6	9.2	Mep	.....	
92....	42474	6 5.8	+23 14	7.4	Mep	11	
93....	193182	20 13.8	+39 16	6.6	F5e	9	
94....	198287, 8	20 44.2	+38 55	7.0	cF5e	9	
95....	214369	22 32.6	+57 54	8.6–9.3	Mep	10	W Cephei

REFERENCES

1. *Publications of the Astronomical Society of the Pacific*, **32**, 336, 1920.
2. *Ibid.*, **33**, 112, 1921.
3. *Ibid.*, p. 264, 1921.
4. *Ibid.*, **34**, 223, 1922.
5. *Ibid.*, p. 294, 1922.
6. *Ibid.*, p. 351, 1922.
7. *Lick Observatory Bulletins*, **7**, 179, 1913.
8. *Publications of the Astronomical Observatory, University of Michigan*, **2**, 181, 1916.
9. *Publications of the Astronomical Society of the Pacific*, **35**, 263, 1923.
10. *Ibid.*, **34**, 59, 1922.
11. *Ibid.*, p. 133, 1922.

NOTES TO TABLE I

Electra, Merope, ω Orionis, and o Aquarii were found with a slit spectrograph at Mount Hamilton.

ν Geminorum and β Canis Minoris were found with a slit spectrograph at Ann Arbor.

All the remaining stars were found on objective-prism spectrograms taken at Mount Wilson. For dates of observation and other data see Table II.

H.D. 25348: Remark in H.D., "The line Hβ is suspected to be bright."

H.D. 33152: Remark in H.D., "The line Hβ is not seen as a dark line and is suspected to be bright. The other lines are hazy."

H.D. 44637: Remark in H.D., "The line Hβ is not clearly seen and is suspected to be bright."

H.D. 62753: Remark in H.D., "The line Hβ is not distinctly seen and is suspected to be bright."

H.D. 198512: Remark in H.D., "The exact character of the spectrum is not well defined. On the best plates it is nearly continuous with the presence of bright lines suspected. It is apparently of a late division of Class O, or of an early Class B."

H.D. 212044: Remark in H.D., "The presence of a bright Hβ, suspected on the Harvard plate, has been found on photographs taken at Mt. Wilson."

line to be bright.[1] In the second column is given the *H.D.* number (from the *Henry Draper Catalogue*), or the Durchmusterung number in case the star does not appear in *H.D.* The spectral types given in column five are determinations from Mount Wilson slit spectrograms.[2]

The five stars placed by themselves at the end of the table are the only ones falling outside the spectral interval O6 to A2.

Details of the objective-prism observations are collected in Table II. Estimates of the intensity of the bright Hα line are given in the second column on the following scale:

1 = very weak—observable only with widened spectrum and proper exposure
2 = weakest ordinarily observable
3 = medium
4 = strong
5 = very strong—bright Hα strongly exposed even when the adjacent continuous spectrum is very weak

Estimates of the intensity of the dark hydrogen lines in the ultraviolet are given in the third column on the following scale:

0 = absent or barely visible
1 = weak
2 = medium
3 = strong (as in an A0 star)

The chief lines concerned are Hζ, Hη, Hθ, Hι, and Hκ.

In the fourth column, headed "Dates of Observation," are given the last four figures of the Julian Day numbers of representative observations. The material is more extensive than this tabulation indicates, because poor and inconclusive observations have been omitted, and of several observations of the same star made within a few days, only one has been listed in most cases.

Our objective-prism plates show a well-marked bright Hα line in the spectra of most of the "bright Hβ" stars previously announced by other observers. The comparatively few instances in which this is not the case are collected on pages 401 and 402. The spectra of the first five stars have probably changed since the previous observations.

[1] Six stars found at Mount Hamilton or Ann Arbor with slit spectrographs are included for completeness.

[2] See Table V and page 413.

TABLE II

OBJECTIVE-PRISM OBSERVATIONS OF STARS OF CLASS Be

H.D.	Hα	U.V. Hyd.	Dates of Observation*	Remarks
108	3	(0)	2548, 2566	
698	3	(2)	2548, 2569	
2789	3	....	2548	
5394	4	0	2139, 2232, 2580, 2893, 2957	γ Cass.
7636	4	2	2176, 2550, 2586	
B.D.+62°271	4	(0)	2586, 2624	
10516	4	1	2580	φ Persei
B.D.+54°398	(1)	....	2524, 2586	
12882	3	(0)	2586, 2623	
19243	3	....	2233, 2578	
20336	3	....	2233, 2578, 2623	
22192	4	(2)	2232, 2579, 2602, 2776	ψ Persei
22298	(3)	0	2730	
23630	1	3	2141, 2175, 2995	Alcyone
25348	3	0	2730, 2776	
25940	4	2	2586, 2776, 3103	c Persei
26906	3	2	2730, 2776	
29866	2	2	2688, 2740	
30614	1−	(1)	2602, 2605, 2624, 2969	9 Camelop.
32343	(2)	(0)	2776	11 Camelop.
33152	3	0	2688	
33232	3	....	2688	
33461	2	1	2688	
33604	3	2	2688	
34921	3	0	2688, 3104	
35345	2	0	2688	
36576	3	1	2728, 2729	
37115	3	....	2586, 2606	
37202	3	2	2362, 2728, 2995	ζ Tauri
37657	2	1	2688	
37967	2	2	2728, 3104	
38010	3	0	2728, 3104	
38191	4	0	2729	
39340	2	0	2729, 3104	
B.D.+25°1019	3	0	2729, 3104	
39478	2	0	2729, 3104	
41117	1−	(1)	2728, 2745	χ^2 Orionis
41335	3	0	2586, 2669, 3080	
B.D.+20°1309	4	0	2729	
43285	2	2	3080	
44637	2	0	2728, 3081	
45314	2	0	2728, 3081	
45725	3	1	2602, 2669	Brightest comp. β Monoc.
45910	3	1	2669, 2687	
45995	3	2	2390, 2728, 3081	
B.D.+10°1172	2	....	2729	N.G.C. 2247
50083	3	1	2669, 3080	
50138	3	2	2669, 3080	
50209	(2)	2	2669	
51354	2	2	3081	
51480	4	0	2700	

* The last four figures of the Julian Day number.

TABLE II—*Continued*

H.D.	Hα	U.V. Hyd.	Dates of Observation	Remarks
55139	3	0	2700	
55271	4	2	2700	
56014	?	1	(2410), (2700)	27 Can. Maj.
56139	2	2	2410	ω Can. Maj.
56806	3	(0)	2700	
57150	4	(0)	2763	ν′ Puppis
58011	(2)	1	2700	
58343	1?	1	(2700)	
B.D.−13°2040	(3)	2	2700	
59497	3	1	2700	
59773	(2)	2	2700	
60606	4	1	2763, 2764	z Puppis
62753	3	0	2764	
68980	4	(0)	2763	r Puppis
109387	4	2	2403, 2439, 2518	κ Draconis
127972	3	2	2407, 2475	η Centauri
154218	3	....	2877, 2878	
154243	(3)	....	2877, 2878	
154450	3	....	2877, 2878	
155806	3	0	2877, 2878	
155851	4	....	2877, 2878	
156468	3	....	2877, 2878	
160095	2	....	2877, 2878	
160202	3	....	2540, 2877	
161103	4	....	2541, 2878	
161306	3	(1)	2903	
D.M.−27°11944	5!	....	2412, 2546, 2878	
163181	3	0	2539, 2877	
163296	2	3	2903	
163454	3	(0)	2541, 2878	
163868	3	1	2539, 2878	
164906	3	....	2877, 2878	
166566	3	1	2903	
166666	3	0	2903	
166734	1−	1	(2411), (2903)	
167362	4	....	2541, 2878	
168229	3	0	2903	
168607	3	....	2903	
169226	2	....	2903	
169454	3	0	2903	
169515	4	(0)	2903	RY Scuti
169805	3	1	2903	
170061	3	....	2903	
170235	4	....	2546	
172694	3	0	2903	
173219	2	0	2903	
174105	2	2	2938	
174638	4	1	2548, 2556	β Lyrae
175863	3	3	2548	
180398	4	1	2938	
B.D.+14°3887	4	....	2587, 2938	
B.D.+22°3687	5	....	2587, 2939	
183143	2	0	2587, 2938	
187399	3	1	2939	
187567	3	0	2938	

TABLE II—*Continued*

H.D.	Hα	U.V. Hyd.	Dates of Observation	Remarks
B.D.+35°3950......	4	(0)	2961	
190944.............	3	....	2580, 2961	
191610.............	3	1	2579, 2961	b² Cygni
192445.............	3	(1)	2579, 2580	
B.D.+36°3946......	2	0	2579, 2961	
193009.............	3	0	2580, 2939	
193237.............	4	0	2140, 2580, 2893, 2961	
195407.............	3	0	2579, 2961	
198512.............	2	....	2996	
199218.............	2	2	2579, 2580	
199356.............	3	0	2579, 2580	
200775.............	4	....	2487, 2518	N.G.C. 7023
202904.............	3	2	2580	υ Cygni
203025.............	2	2	2996	
203374.............	3	0	2996	
203467.............	3	0	2487	6 Cephei
206773.............	4	0	2996	
207232.............	1	2	2996	
209409.............	3	(1)	2602	ο Aquarii
212044.............	1	0	2996	
212076.............	1	3	2995	31 Pegasi
212571.............	4	1	2602	π Aquarii
214748.............	1	3	2141, 2175, 2578	ε Pisc. Austr.
217891.............	3	3	2140, 2175	β Piscium
224559.............	Rem	(1)	2542, 2567, 2647	
225095.............	4	0	2542, 2569, 2997	

NOTES TO TABLE II

H.D. 22192, ψ Persei: The ultra-violet hydrogen lines may vary in intensity.

H.D. 29866: The ultra-violet hydrogen lines may vary in intensity.

H.D. 45314: Bright Hα may have increased in intensity between J.D. 2422390 and J.D. 2423081.

H.D. 45910: The ultra-violet hydrogen lines may vary in intensity.

D.M.−27°11944: Bright Hα appears broad but is sharply bounded on the short wave-length side. It probably is of the P Cygni type. This star has an extraordinary spectrum.

H.D. 174638, β Lyrae: Bright λ 6678 He is clearly seen on plates taken on J.D. 2422548 and J.D. 2422556.

H.D. 224559: Bright Hα appears to vary in intensity.

References to bright lines in the spectra of the remaining three objects have been published by other observers, but it is not clear that the present observations constitute evidence of variability.

SPECTRA IN WHICH Hα APPEARS TO VARY

H.D. 9105: See *Publications of the Astronomical Society of the Pacific*, **34**, 180, 1922.

H.D. 58978: Bright Hα is very weak or absent on a plate taken 1921, January 10.

H.D. 181615, υ Sagittarii: The spectrum appears continuous at Hα on a plate taken 1919, July 1. This spectrum is known to be variable.

H.D. 193516: Hα is not seen as a bright line on three plates taken between 1920, September 11, and 1921, September 28.

H.D. 217050: Bright Hα is very weak or absent on a plate taken 1920, November 18. This spectrum is known to be variable.

DOUBTFUL CASES

H.D. 47129: Bright Hα is very weak or absent on several plates taken between 1920, March 6, and 1922, January 22.

H.D. 162586: Hα is not seen as a bright line on several plates taken between 1920, August 2, and 1921, July 7. On two plates it appears dark.

H.D. 193443: Hα is not seen as a bright line on three plates taken between 1920, September 11, and 1921, September 28. A slit spectrogram taken 1924, June 11, shows Hβ, Hγ, Hδ, and Hε as absorption lines.

Numerous bright-line spectra of various kinds, including gaseous nebulae, Wolf-Rayet stars, and novae, are shown by our objective-prism photographs, and, as the bright Hα line is an interesting feature in nearly all cases, it seems worth while to make a record of its appearance, especially as the red portion of the spectra of these objects has seldom been observed. In Table III are given the dates of observation and notes chiefly concerning the bright Hα line. For several stars having numerous observations, intermediate dates have been omitted.

The right ascension and declination for 1900 of the objects which are not in the *H.D.* are given below.

T Pyxidis: $9^h0^m.5$, $-31^\circ57'$. See *Publications of the Astronomical Society of the Pacific*, **32**, 200, 1920.

N.G.C. 6334: $17^h13^m.7$, $-35^\circ58'$.

N.G.C. 6357: $17^h18^m.1$, $-34^\circ6'$. Near the Wolf-Rayet star $-34^\circ11675$.

$-29^\circ13988$: $17^h41^m.5$, $-29^\circ57'$. See *Publications of the Astronomical Society of the Pacific*, **33**, 176, 1921.

Trifid nebula: $17^h56^m.6$, $-23^\circ2'$.

Dumbbell nebula: $19^h55^m.3$, $+22^\circ26'$.

Nova Cygni: $19^h55^m.6$, $+53^\circ21'$. See illustration, *Publications of the Astronomical Society of the Pacific*, **32**, 321, 1920.

I.C. 1470: $23^h1^m.0$, $+59^\circ42'$. See *ibid.*, **33**, 176, 1921.

The Hα region of a number of Be stars has been observed with single-prism slit spectrographs attached to one of the large reflectors.

TABLE III

OBJECTIVE-PRISM OBSERVATIONS OF NEBULAE, WOLF-RAYET STARS, AND NOVAE

H.D.	Object	Dates of Observation and Remarks*
37024....	Orion nebula	2605. Hα image strong.
62166....	N.G.C. 2440	2700. Hα image strong.
	T Pyxidis	2436–2441. Hα very strong.
153919....	−37°11206	2877. Hα rather weak.
155520....	N.G.C. 6302	2877. Hα image appears stronger than the combined images of N1 and N2.
	N.G.C. 6334	2877, 2878. Remarkable group of gaseous nebulae near here.
	N.G.C. 6357	2877, 2878. Hα bright.
	−29°13998	2541, 2878. Hα strong.
161944....	N.G.C. 6445	2903. Hα bright.
164270....	−36°12130	2540, 2878. Hα strong.
	Trifid nebula	2877, 2903. Hα image differs from the appearance of ordinary photographs.
164740....	N.G.C. 6523	2412, 2877. Interesting detail in Hα image.
165763....	−21°4864	2903. λ 5653 extremely strong; λ 5813 very strong.
166449....	N.G.C. 6563	2541, 2878. Hα bright.
166468....	N.G.C. 6565	2541, 2878. Hα strong.
166802....	N.G.C. 6572	2845. Hα very strong.
167276....	Nova Ophiuchi	2550. Hα very strong.
168206....	−11°4953	2903. Hα probably bright but not strong.
168520....	Omega nebula	2411, 2903. Much fine detail in Hα image.
170124....	Gaseous nebula	2877, 2878. Hα bright.
174107....	Nova Aquilae	2140, 2524, 2542, 2845. Hα very strong. On last plate continuous spectrum strong in violet and weak in red.
175353....	Ring nebula	2546. Hα strong
184738....	+30°3639	2939. The combined image of Hα and λλ 6548, 6583 is extremely strong.
186924....	N.G.C. 6826	2487. Hα bright.
	Dumb-bell nebula	2938, 2939. Interesting detail in Hα image. Fairly strong image in ultra-violet, perhaps λ 3727.
	Nova Cygni	2566, 2570, 2602, 2623. Hα very strong.
191765....	+35°4001	2579, 2961. Hα strong.
191916....	N.G.C. 6884	2961. Hα bright.
192103....	+35°4013	2579, 2961. Hα strong.
192163....	+37°3821	2579, 2961. Hα strong.
192641....	+36°3956	2579. Hα bright.
193077....	+36°3987	2579, 2961. Hα bright.
193576....	+38°4010	2579, 2961. Hα bright.
193793....	+43°3571	2487, 2579, 2961. Hα bright.
201272....	N.G.C. 7027	2580. The combined image of Hα and λλ 6548, 6583 is very strong.
	I.C. 1470	2997. Hα strong.

* The last four figures of the Julian Day numbers of the dates of observations are given. The remarks refer entirely to emission lines.

The dispersion at Hα is about 170 angstroms per millimeter. The results are collected in Table IV.

II. THE BLUE-VIOLET SPECTRAL REGION

The objective-prism spectrograms obtained with the 10-inch telescope yield little information concerning the lines Hβ, Hγ, and Hδ, as the part of the spectrum containing them is much out of focus. We have observed this spectral region, therefore, with single-prism slit spectrographs attached to one of the large reflectors. The program included all the stars found with the 10-inch telescope to have the Hα line bright, and in addition a number of previously known "bright Hβ" stars, particularly those for which there is no published record of observations with a slit spectrograph. An 18-

TABLE IV

OBSERVATIONS OF Hα WITH SLIT SPECTROGRAPHS

H.D.	Object	Date	Character of Hα
698......	....	1923 February 6	Strong bright
23302......	Electra	1919 November 8	Weak bright on absorption
23480......	Merope	1919 November 8	Very weak bright on absorption
23630......	Alcyone	1919 November 8	Strong bright
23862......	Pleione	1919 November 8	Absorption
		1921 November 12	Absorption
24534......	X Persei	1923 September 1	Strong bright
29866......	....	1923 February 5	Strong bright
30614......	9 Camelop.	1921 February 28	Very weak bright
		1924 March 12	Very weak bright
		March 13	Very weak bright
41117......	χ^2 Orionis	1921 February 28	Weak bright
		March 30	Weak bright
51354......	....	1923 January 7	Strong bright
58715......	β Can. Min.	1921 March 29	Bright
109387......	κ Draconis	1924 March 12	Strong bright
155806......	....	1923 April 30	Very strong bright
166734......	....	1922 October 8	Bright. Not sharp
183143......	....	1922 October 7	Probably bright
		October 8	Probably bright
		1923 September 1	Bright
214748......	ε Pisc. Austr.	1921 November 12	Strong bright

NOTES TO TABLE IV

H.D. 166734: The continuous spectrum is strong in the red.

H.D. 183143: The continuous spectrum is very strong in the red. The first two plates are overexposed.

inch camera was used in practically every exposure, the dispersion being as follows: at Hβ, 57 A per mm; at Hγ, 36; and at Hδ, 28. The data from these plates are collected in Table V and the accompanying notes.

In the first column is given the *H.D.* number (from the *Henry Draper Catalogue*), or the Durchmusterung number in case the star does not appear in *H.D.* The common names of a few bright objects, and, for double stars, the numbers in Burnham's *General Catalogue of Double Stars* (β.G.C.), are added in the notes. Descriptions of the hydrogen lines are found in the next three columns. The character of the lines (Ch.) is described by means of the following symbols:[1]

A = absorption
C = continuous
P = P Cygni type, i.e., a bright line with a dark line on its short wave-length edge.
S, D refer to bright components
S = single
D = double

The intensities (Int.) refer only to the bright components and are on the following basis:

0.5 = very weak
1 = weak
2 = medium
3 = strong
4 = very strong

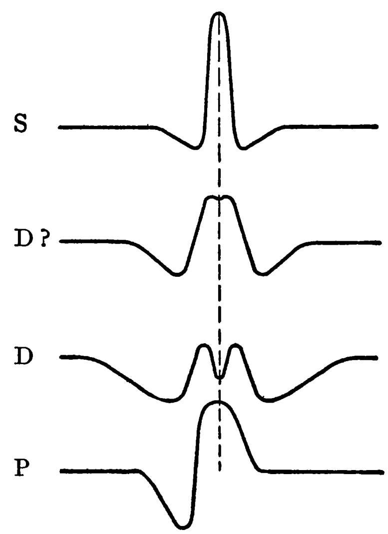


FIG. 1.—Typical intensity curves of hydrogen lines.

The bright lines are nearly all superposed on wider dark lines. Typical intensity-curves of the different types of lines are shown in Figure 1. The structure of a complex line is usually symmetrical about the normal position of the line, but there are a few exceptions. Aside from lines of the P Cygni type, which are of course decidedly unsymmetrical, there are complex lines of the ordinary type in which the two bright components are of unequal intensity. All definite instances of this kind are mentioned in the notes following Table V.

[1] The notation is similar to that employed by Lockyer, *Monthly Notices*, **84**, 409, 1924.

TABLE V

DATA FROM SLIT SPECTROGRAMS OF THE BLUE AND VIOLET REGION

H.D.	Hβ		Hγ		Hδ		TYPE	RADIAL VEL.
	Ch.	Int.	Ch.	Int.	Ch.	Int.		
108	S	3	S	3	S	2	O6e	−60.
698	A	....	A	....	A	....	B8seα	Variable.
2789	C	....	A	....	A	....	B2ne	
7636	S	3	S	2	S	0.5	B2ne	−15.
9105	A	....	A	....	A	....	B4s	−43:
+62°271	S	1	A	....	A	....	B(8)eβ	
+54°398	S	1	C	....	C	....	B(2)e	
12882	D?	1	C	....	A	....	B(2)e	
15325	A	....	A	....	A	....	B1	−34.
15450	S	3	S	2	S	1	B(0)ne	
19243	S	2	S	1	C	....	B2e	−29:
22298	D?	0.5	C	....	A	....	B2ne	
23862	A	....	A	....	A	....	B8n	
24534	D?	1	C	....	C	....	B(0)e	
25348	D?	1	D	0.5	C	....	B(1)e	
29866	A	....	A	....	A	....	Beα	
30614	A	....	A	....	A	....	O9eα	
33152	S	3	S	2	S	1	B2e	−4.
33232	....	....	....	....	....	....	Bepv	
33461	D	0.5	A	....	A	....	B(1)e	
33604	S	2	S	1	S	0.5	B2e	
34921	D?	2	D?	1	C	....	B(0)e	
36576	D?	1	C	....	A	....	B1ne	
37115	D	3	D	1	A	....	B(5)e	
37657	D?	1	C	....	A	....	B3ne	
37967	S	1	A	....	A	....	B3ne	
38010	D?	2	D	1	C	....	Be	
38191	D?	2	D	1	C	....	Be	
39340	D?	2	C	....	A	....	B3e	
+25°1019	S	2	D?	0.5	C	....	Be	
39478	D?	1	D	0.5	A	....	B2ne	
41117	A	....	A	....	A	....	B1seα	
+20°1309	S	2	C	....	A	....	Be	
43285	D?	0.5	A	....	A	....	B(1)e	
44637	S	2	C	....	....	....	B3e	
45314	D?	1	C	....	C	....	B(0)e	
45677	....	....	....	....	....	....	Bep	
45910	P	....	P	....	P	....	Beqv	
45995	....	....	....	....	....	....	B2ev	
50083	D?	2	D	1	C	....	B1e	
50138	....	....	....	....	....	....	B8ev	
50209	S	1	A	....	....	....	B(5)e	
51354	C	....	A	....	A	....	B4e	
51480	P	4	P	3	P	2	B8eq	
55135	S	2	A	....	A	....	B3ne	
55271	D?	1	D	0.5	....	....	Be	
56806	D?	2	C	....	C	....	Be	
−13°2040	S	3	S	1	D	0.5	B(2)e	
59497	D?	2	D?	0.5	A	....	B2e	
59773	D?	1	A	....	....	....	B(3)e	

TABLE V—*Continued*

H.D.	Hβ		Hγ		Hδ		Type	Radial Vel.
	Ch.	Int.	Ch.	Int.	Ch.	Int.		
62753	D?	2	D	0.5	A	....	B(2)ne	
65875	S	3	D?	1	C	....	B3e	
120324	A	....	A	....	A	....	B2	
127972	A	....	A	....	A	....	B(0)n	
152236	P	1	P	1	A	....	B(2)eq	
154218	D?	2	D	0.5	....	....	Be	
154243	S	2	D?	1	....	....	B2e	
154450	S	3	S	2	....	....	B0e	See note.
155806	S	1	C	....	....	....	O8e	
156468	S	2	S	1	....	....	B2e	See note.
160095	....	....	....	....	....	....	B8ep	
160202	D?	1	A	....	....	....	B(1)eβ	
161103	D?	2	D	1	....	....	Bne	
161114	....	....	....	....	....	....	Bep!	
161306	S	3	D?	2	C	....	B(0)e	
−27°11944	P	4	P	3	....	....	Beq!	
163181	....	....	....	....	....	....	B2e	Variable.
163296	....	....	....	....	....	....	A2e	
163454	S	2	D?	1	....	....	B1e	
163868	S	2	A	....	A	....	B2e	
164906	S	1	C	....	C	....	B(0)e	
166566	S	1	A	....	....	....	B2se	
166666	D?	1	C	....	....	....	B2e	
166734	A	....	....	....	....	....	Beα	
168229	S	2	D?	0.5	....	....	B(1)e	
168607	S	3	S	1	....	....	A0se	
169226	P	2	....	....	....	....	Be	
169454	P	1	A	....	....	....	B0e	
169515	S	3	S	2	....	....	Pec	
169805	D?	2	D	1	....	....	B(1)ne	
170061	S	2	C	....	....	....	Be	
172694	....	....	....	....	....	....	Bep	
174105	D?	1	A	....	A	....	B8e	
175863	D?	1	A	....	A	....	B3e	−27.
180398	D?	1	A	....	A	....	B(1)e	
+14°3887	S	3	S	2	....	....	Pec	
+22°3687	S	3	D	2	....	....	B2e	−3.
183143	A	....	A	....	A	....	B9seα	+13.
187399	S	1	A	....	A	....	B9eβ	
187567	S	2	C	....	A	....	B1e	See note.
+35°3950	S	2	D?	1	C	....	Be	
192445	S	2	C	....	A	....	B2e	
+36°3946	S	2	D	0.5	C	....	B(0)e	
193009	S	1	D	0.5	C	....	B1ne	
195407	D	....	D	....	A	....	B1e	
198512	S	2	D?	1	C	....	B(2)e	
199218	D	1	A	....	A	....	B5e	
199356	D?	2	D	0.5	C	....	Be	
203374	S	2	S	1	C	....	Be	
206773	D	2	D	1	C	....	Be	
207232	D	0.5	A	....	A	....	B(8)e	

TABLE V—*Continued*

H.D.	Hβ		Hγ		Hδ		Type	Radial Vel.
	Ch.	Int.	Ch.	Int.	Ch.	Int.		
207757......	S	5	S	4	S	3	Bepv	
212044......	S	2	D?	1	C	....	Be	See note.
214748......	A	....	A	....	A	....	B8eα	
224559......	D	2	D	1	A	....	B3ne	0.
225095......	S	3	S	2	D?	1	B1e	

DATES OF OBSERVATION AND NOTES

H.D. 108: 2596, 2624, 2625, 2914, 3245, 3629. The hydrogen lines from Hβ to Hε consist of rather narrow bright lines superposed on faint dark lines. The dark components on the violet sides of the bright lines are slightly stronger than those on the red sides, and as they are near the positions of the lines which belong with the Pickering series, they are probably due in part to He+. The Pickering series appears wholly dark; the following lines are seen: λλ 4025.64?, 4199.87, 4541.63, and 5411.57. The velocity from the bright lines Hβ, Hγ, and Hδ is −58, and from the dark Pickering lines λλ4199.87 and 4541.63, −63 km/sec. These values are in substantial agreement with Plaskett's results in *Monthly Notices of the Royal Astronomical Society*, **84**, 84, 1923. λ4686 He+ is bright. D3 and λ4471 He are bright, the latter with a dark companion on the violet side. λ4552 Si is bright and there is a trace of bright λ4567 Si. There are several bright lines in the region λ 4640–50. H and K are fairly strong dark lines. This is a very interesting spectrum, well worth further study.

H.D. 698: 2626, 3244, 3245, 3809. Spectroscopic binary. Velocities from individual plates are +58, (+29), +20, and −10 km/sec., respectively.

H.D. 2789: 2916, 3339.

H.D. 7636: 2596, 3810. Sharp H and K.

H.D. 9105: 2594, 2624, 2746, 2925, 2927, 3245. This spectrum is evidently variable, as the bright hydrogen lines have disappeared since the Harvard observations. See *Publications of the Astronomical Society of the Pacific*, **34**, 180, 1922. The velocities from individual plates range from −29 to −60 km/sec., but the mean value, −43, agrees with that reported by Plaskett in *Monthly Notices of the Royal Astronomical Society*, **84**, 84, 1923.

B.D.+62°271: 2897.

B.D.+54°398: 2667, 2907. Aside from bright Hβ, the spectrum is nearly continuous.

H.D. 12882: 2719, 2917, 3988. The bright line at Hβ is stronger on the violet side.

H.D. 15325: 3307. In Praesepe cluster. Brighter component of β.G.C. 1277. The bright lines noted by Harvard seem to have disappeared.

H.D. 15450: 4018. Observed with 10-inch camera.

H.D. 19243: 2596, 2951, 3335, 3652, 3778. Sharp H and K.

H.D. 22298: 2926.

H.D. 23862, Pleione: 2271, 3006, 3339, 4046. The first two plates include Hα, which is a strong absorption line. The Balmer series, once partially bright, now consists of broad, strong, dark lines, as in 1912 (*Lick Observatory Bulletin*, **7**, 167, 1913).

H.D. 24534, X Persei: 2719, 3064, 3664. Sharp H and K. The dark lines, aside from H and K, are faint and indistinct.

H.D. 25348: 2926. H and K are probably present as weak, narrow, dark lines. The other dark lines are indistinct. Remark in H.D., "The line Hβ is suspected to be bright."

H.D. 29866: 2689, 2695, 3335. Aside from the hydrogen lines, the spectrum is nearly continuous.

H.D. 30614, 9 Camelopardalis: 2631. Sharp H and K. See description of spectrum by Lee, *Astrophysical Journal*, **37**, 1, 1913.

H.D. 33152: 2689, 3360, 3806, 3808. The bright hydrogen lines are unusually narrow. Remark in H.D., "The line Hβ is not seen as a dark line and is suspected to be bright. The other lines are hazy." On our plates the helium lines are distinct.

H.D. 33232: This variable spectrum is under observation and will be described in a future *Contribution*.

H.D. 33461: 2694, 4047. The violet component of bright Hβ is the stronger. The edges of Hγ are probably faintly bright.

H.D. 33604: 2690, 3335, 3456, 3908. The bright hydrogen lines seem to have become weaker since the first observation. On the last photograph the bright components of Hγ and Hδ are weak and indistinct.

H.D. 34921: 2973, 3692.

H.D. 36576, 120 Tauri: 2973.

H.D. 37115, brighter component of β.G.C. 2850: 2626. The measured separations of the bright components are: Hβ, 3.8 A; Hγ, 3.1 A.

H.D. 37657: 2694.

H.D. 37967: 2746.

H.D. 38010: 3653. Aside from the hydrogen lines, the spectrum is nearly continuous.

H. D. 38191: 2969. Aside from the hydrogen lines, the spectrum is nearly continuous.

H.D. 39340: 2759, 3338, 3808. The plates apparently show a slight change in the bright Hβ line: on the first plate the component of longer wave-length is the stronger, but on the other plates the two components are of nearly equal intensity. The measured separations of the bright components of Hβ on the three plates are respectively, 4.2, 3.2, and 3.1 A.

B.D.+25°1019: 2779, 2790, 2981.

H.D. 39478: 2953.

H.D. 41117, χ^2 Orionis: The orbit of this spectroscopic binary (*Lick Observatory Bulletins*, **6**, 144, 1911) is under investigation by Mr. Sanford.

B.D.+20°1309: 2779, 3782.

H.D. 43285: 3127, 3336, 3809.

H.D. 44637: 2748.

H.D. 45314: 2747, 3692. Sharp H and K. The other lines are very faint.

H.D. 45677: This peculiar spectrum is under observation and will be described in a future *Contribution*.

H.D. 45910: The remarkable variations in this spectrum have been described by Plaskett, *Publications of the Astronomical Society of the Pacific*, **35**, 145, 1923, and by Merrill, *ibid.*, p. 303, 1923.

H.D. 45995, brighter component of β.G.C. 3427: The structure of the bright hydrogen lines varies. This spectrum is under observation and will be described in a future *Contribution.*

H.D. 50083: 3725. Measured separation of the bright components of Hγ, 1.8 A.

H.D. 50138: The structure of the bright hydrogen lines varies in a period of about twelve days. This spectrum is under observation and will be described in a future *Contribution.*

H.D. 50209: 2694.

H.D. 51354: 3126, 3134, 3337. Trace of a double bright line at Hβ.

H.D. 51480: This spectrum, which is of the P Cygni type, is under observation and will be described in a future *Contribution.*

H.D. 55135: 2720. There is probably a very weak double bright line superposed on the broad absorption line at Hγ.

H.D. 55271, brighter component of β.G.C. 3887: 2718.

H.D. 56806: 2981.

B.D.−13°2040: 2979.

H.D. 59497: 2980.

H.D. 59773: 3038.

H.D. 62753: 3036, 3810. On the first plate the violet components of bright Hβ and Hγ are stronger than the red components. The structure of Hβ may vary, as the bright components of Hβ appear to be more nearly equal in intensity on the second plate than the first. The second plate is under-exposed at Hγ.

H.D. 65875: 3039, 3725.

H.D. 120324, μ Centauri: 3951. The recent disappearance of bright hydrogen lines from this spectrum, noted by several observers, is confirmed by our photograph.

H.D. 127972, η Centauri: 3951. This spectrum is known to vary.

H.D. 152236, ζ′ Scorpii: 3928.

H.D. 154218: 2897.

H.D. 154243: 2897. This star is very near the preceding star, H.D. 154218.

H.D. 154450: 3248, 3927, 3986. The apparent radial velocities from the bright Hβ and Hγ lines for the three plates are +24, +2, and +7 km/sec., respectively. The divergence of the first plate from the other two probably indicates a change in the structure of the lines or in the radial velocity of the star.

H.D. 155806: 3540.

H.D. 156468: 3220, 3951. The displacement of the narrow bright Hβ line corresponds to a velocity of about −50 km/sec., but it is not certain that this is the actual radial velocity of the star.

H.D. 160095: 3245. The hydrogen lines are peculiar. This spectrum will be described in a future *Contribution,* after further observation.

H.D. 160202: 2769, 3664.

H.D. 161103: 2914. The measured separation of the bright components of Hγ is 2.8 A.

H.D. 161114: The spectrum of this "iron" star is under observation and will be described in a future *Contribution.* See *Publications of the Astronomical Society of the Pacific,* **36,** 225, 1924.

H.D. 161306: 2913.

D.M.−27°11944: This P Cygni-type spectrum is under observation and will be described in a future *Contribution.*

H.D. 163181: 2914, 3247, 3605, 3960. Hβ, Hγ, and Hδ are chiefly absorption lines, but at Hβ and possibly at Hγ there appear to be indistinct bright edges. Spectroscopic binary. Approximate velocities from the last three plates are +90, +116, and −226 km/sec., respectively.

H.D. 163296: The structure of the hydrogen lines is very peculiar and appears to vary. This spectrum is under observation and will be described in a future *Contribution*.

H.D. 163454: 3190, 3928, 3987.

H.D. 163868: 2926, 3960.

H.D. 164906: 3307.

H.D. 166566: 2917.

H.D. 166666: 3221, 3976.

H.D. 166734: 3245, 3927, 3947.

H.D. 168229: 3220.

H.D. 168607: 2952, 3951.

H.D. 169226, brighter component of β.G.C. 8523: 3664, 3960, 3987. All the spectrograms are under-exposed.

H.D. 169454: The spectrum of this star, which contains strong dark lines of He, Si, and O, will be described in a future *Contribution*.

H.D. 169515, RY Scuti: This peculiar spectrum, in which a bright line is seen in the position of the nebular line λ 4658, has been described in the *Publications of the Astronomical Society of the Pacific*, **34**, 134 and 295, 1922. A more complete description will be published in a future *Contribution*.

H.D. 169805: 2979. The measured separation of the bright components of Hγ is 3.2 A.

H.D. 170061: 3244. Plate under-exposed.

H.D. 172694: This peculiar spectrum, which somewhat resembles that of H.D. 33232, is under observation and will be described in a future *Contribution*.

H.D. 174105: 2951, 3894.

H.D. 175863: 2566, 2567, 2570, 3191, 3984. The bright portions of Hβ appear weaker on the last two plates than on the others.

H.D. 180398: 2951, 3986. The bright portion of Hβ may be weaker on the second plate than on the first.

B.D.+14°3887: This spectrum, which contains some unusual bright lines, is under observation and will be described in a future *Contribution*.

B.D.+22°3687, brighter component of β.G.C. 9287: 2652, 2956, 3951, 3976. The measured separation of the bright components of Hγ is 2.3 A.

H.D. 183143: 2951, 3338, 3988. Remark in H.D., "The spectrum appears to be nearly continuous." On our plates several lines are strong and well defined, notably Hγ, λ 4471, and λ 4481. Thus it is possible that the spectrum has changed since the Harvard photographs were taken.

H.D. 187399: 3895.

H.D. 187567: 2953, 3336, 3337, 4015. Sharp H and K, measured on three plates, give a velocity of −2 km/sec. The other lines do not yield reliable results.

B.D.+35°3950: 2977, 3960. Sharp H and K.

H.D. 192445: 2834, 3984.

H.D. 193009: 2951, 3896.

H.D. 195407: 2952, 3897, 3930, 3952. The radial velocities derived from the hydrogen lines of the first, second, and fourth plates are −68, −82, and −82 km/sec. respectively, giving a mean value of −77 km/sec. The intensities of the bright portion of the hydrogen lines vary.

H.D. 198512: 3307, 3928.

H.D. 199218, brighter component of β.G.C. 10606: 2853, 2925, 3247, 3896. Measured separation of bright components of Hβ (mean value from three plates) 3.9 A.

H.D. 199356: 2973. The separation of the bright components of Hγ is not accurately measurable on this plate, but is approximately 4.2 A. Sharp H and K.

H.D. 203374: 3013. Sharp H and K.

H.D. 206773: 2955, 3947. The measured separation of the bright components of Hβ is 4.0 A; of Hγ, 4.3 A. Sharp H and K. Aside from the hydrogen and calcium lines, the spectrum is very nearly continuous.

H.D. 207232: 3039, 3926. The measured separation of the bright components of Hβ on the second plate is 4.0 A.

H.D. 207757: This spectrum, which has shown a remarkable change in the past few years (see *Harvard College Observatory Bulletin*, 762) is under observation and will be described in a future *Contribution*.

H.D. 212044: 3014, 3984. Approximate radial velocity from sharp H and K, −16 km/sec. Results from the other lines are not reliable.

H.D. 214748, ε Piscis Australis: 2179, 2576.

H.D. 224559: 2596, 2656, 2953, 3604, 3779. Measured separation of the bright components of Hβ, 3.1 A; of Hγ, 3.1 A; of Hδ, 2.8±. The bright portions of Hδ are feeble and indistinct; it is chiefly an absorption line. Sharp H and K.

H.D. 225095: 2955, 3952.

It is impossible wholly to eliminate photographic effects from the classification of the character of the hydrogen lines. Better photographs might in some instances change the description from D? to D, or even, in the case of very faint bright components, from C or A to D. In this connection, however, it must be borne in mind that the symbols C and A may include lines in which bright portions probably exist, provided the bright components exhibit a degree of distinctness less than that required for the intensity 0.5. Photographic conditions such as the width of the spectrum or the effective contrast of the emulsion might, of course, alter one's judgment on this point. In view of the fact that the bright lines of these stars are subject to change, and because it is in the weak lines that changes may first become obvious, it will perhaps be worth while to describe exactly the significance we have attached to the intensities 1 and 0.5. A line of intensity 1 is a clearly marked bright line, seen at a glance, but of the lowest intensity at which a reliable setting can be made with the measuring-microscope (magnifying-power 26). Intensity 0.5 denotes a line fainter than 1 but of whose reality one becomes convinced after careful inspection. Doubtful bright lines have been omitted from Table V.

The spectral types are those estimated from the Mount Wilson plates. For types earlier than B0 the system suggested by H. H. Plaskett[1] has been employed. When the spectral subdivision is uncertain, it is either omitted or placed in parentheses. The following additional symbols recommended at the Rome meeting of the International Astronomical Union[2] have proved convenient:

e = emission lines
n = diffuse lines
s = sharp lines
p = peculiar
v = variable
q = lines of the P Cygni type

The bright parts of the hydrogen lines grow weaker from Hα toward the violet in all cases. The letters α and β indicate which is the last line to exhibit bright components. In many stars the transition along the series from bright lines to wholly dark lines is so gradual that it is impracticable to specify the line at which it occurs.

III. DISCUSSION

Table I shows that our observations have added 90 early-type stars to the list of those known to possess hydrogen emission lines. Eighty-four of these discoveries have resulted from photographing the Hα region with the 10-inch telescope and objective prism. These observations are largely confined to the Milky Way north of declination $-40°$. The areas covered by plates having fairly good definition and about the standard effective exposure are charted in Figure 2. Within these areas 60 bright-line stars[3] were previously known, and 80 additional ones[4] have been found from our objective-prism observations. The Harvard spectrographic survey showed 49 bright-line stars in the same areas.

[1] *Publications of the Dominion Astrophysical Observatory*, 1, 366, 1922.

[2] *Transactions of the International Astronomical Union*, 1, 95, 1922.

[3] This includes two stars listed in Table I which were previously detected by Merrill from slit spectrograms.

[4] Not counting χ^2 Orionis and 9 Camelopardalis, in which the bright Hα line is too weak to show on our regular plates.

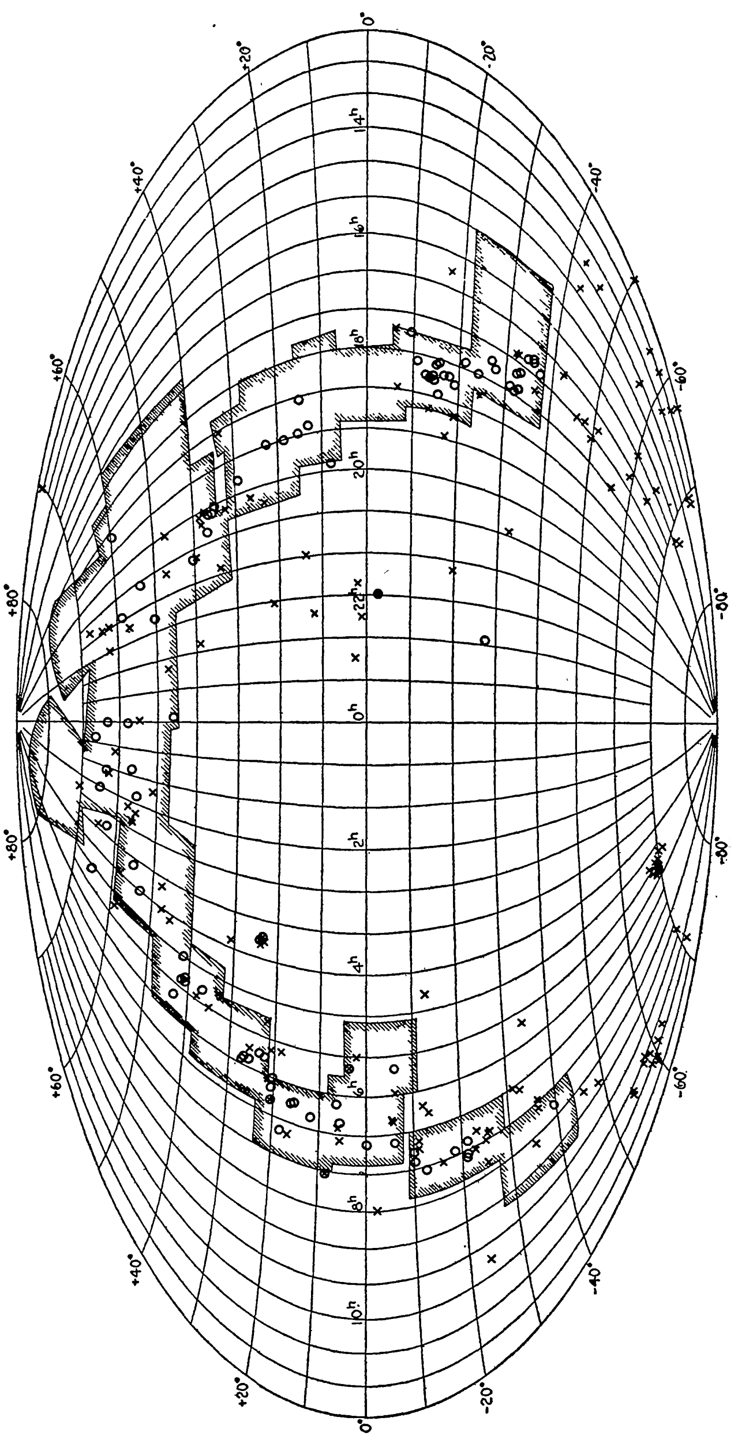


Fig. 2.—Chart of stars of class Be. Circles represent those discovered in the present investigation; crosses those previously known. Six stars found by one of the writers with slit spectrographs at Mount Hamilton or Ann Arbor are marked by crosses within circles. The areas indicated by shading were covered by the Mount Wilson objective-prism observations.

In 41 of our 84 stars, the bright Hβ line is so weak that it could scarcely have been detected on the Harvard plates. This illustrates the advantage of working with the Hα line. The average intensity of the Hβ line in the remaining 43 stars is probably nearly the same as in those discovered at Harvard, and some explanation of the non-appearance of the bright lines on the Harvard plates must be sought. Eight stars are not in the *Henry Draper Catalogue*, leaving 35 which were classified at Harvard. In a few cases the bright lines may have been missed at Harvard because of unfavorable observing circumstances, but the number appears too great to be accounted for entirely in this manner, and the question arises whether some of our additional stars are not ones in which the bright hydrogen lines have come into existence, or at least have become more intense, since the epoch of the earlier observations. Such an explanation is in harmony with the fact that variations in the intensity of the bright hydrogen lines are known to occur in numerous Be stars. A re-examination of the Harvard plates and comparison of the appearance of the hydrogen lines with the data in Table V might throw considerable light on this problem. A better attack would be the repetition of some of the Harvard observations or our own after five years or more have elapsed.

Several stars have experienced a decline in the intensity of the bright hydrogen lines in recent years, notable examples being Pleione and μ Centauri. The list on pp. 401 and 402 adds a few stars to those previously recorded.

It would be desirable to ascertain whether stars of class Be are approximately in statistical equilibrium, that is, whether in a given interval of time the B stars *entering* the bright-line stage are about as numerous as those *leaving* it. We should expect this to be true, but until recently the only known instances of progressive change were those in which the bright lines were growing weaker. This may have been caused partly by the fact that bright-line stars are more closely watched than ordinary stars and hence changes in them are more likely to be detected. A few instances of the appearance of bright lines or of an increase in their strength have, however, been announced by Miss Cannon[1] and by Perrine,[2] and the present

[1] *Harvard Bulletin*, No. 779, 1922. [2] *Popular Astronomy*, **27**, 91, 1919.

observations may contain numerous examples of the same phenomenon. It will not be many years before this matter can be discussed much more adequately than at present, because of the increased attention being devoted to the Be stars by a number of observers. This remark also applies to a related question, namely, whether a B-type star can pass into the bright-line stage more than once.

Distribution.—Figure 2 shows the distribution of all known Be stars. There is a tendency for them to fall into groups which in nearly every instance lie near the center line of the Milky Way. The strong general condensation near the galaxy is evident from the chart. The material at hand is not suitable for an exact study of this phenomenon.

Four groups of Be stars are in regions which are also rich in Wolf-Rayet stars. The approximate centers of these regions are:

R.A.	Dec.	
5^h20^m	$-68°$	Greater Magellanic cloud
10 30	−58	
20 10	+36	
17 30	−35	

The last three regions are near the center line of the Milky Way.

Why should Wolf-Rayet and Be stars be concentrated in the same regions of space? Are the conditions in these regions such as to provoke emission lines in stars passing through them, or have the stars therein a common origin which favors emission lines?

The distribution of the bright-line stars in Table V among the various spectral subdivisions is as follows:

Class	No. in Table V	Class	No. in Table V
O6	1	B5	3
O8	1	B8	9
O9	1	B9	2
B0	10	A0	1
B1	16	A2	1
B2	23	B	24
B3	9	Pec.	2
B4	2		

The relatively high frequency of emission lines among classes B0 to B3, inclusive, is evident. It becomes still more striking when compared with the total number of stars in corresponding groups. We may use for this purpose the Harvard counts of the stars brighter than 8.25 in the *Henry Draper Catalogue.*

Class	All	No. in Table V	Ratio
B0–B5	2061	63	1:N
B8	1604	9	1:5N
B9	2752	2	1:40N
A0	6320	1	1:200N

The actual values of the ratio are not of interest, because Table V contains but a small part of the total number of bright-line stars. These stars do, however, appear to represent a fair sample of the whole as far as spectral classes are concerned, and the relative proportions constitute direct evidence of the preference of bright-line stars for classes B0 to B5.

Mount Wilson Observatory
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