PHOTOELECTRIC SPECTROPHOTOMETRY. I. HYDROGEN-LINE INTENSITIES OF O-, B-, AND A-TYPE STARS

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Received October 1, 1955

ABSTRACT

The equivalent widths of the hydrogen lines Hβ, Hγ, and Hδ are given for 99 O-, B-, and A-type stars. The data were secured from photoelectric tracings of objective-prism spectra

INTRODUCTION

With the spectrophotometer of the Warner and Swasey Observatory, previously described by MacRae (1953), several hundred tracings of stars of different spectral types and luminosities were secured during the fall and winter of 1953. For O-, B-, and A-type stars the tracings serve two major objectives: (*a*) determination of the relative intensity distribution in the continuum and (*b*) measurement of the equivalent widths of strong absorption and emission lines. The present paper deals with the line-intensity measurements.

THE OBSERVATIONAL MATERIAL

The material was secured partly with the 4° objective prism and partly with the 6° objective prism. Using the slow-motion motor of the telescope in declination, the spectra have been trailed over a slit in front of the photometer. The variations of the light passing through the slit were registered on a Brown recorder. The tracings cover the spectral region from 3500 to 6000 A. Figure 1 shows a reproduction of one of the tracings. The limiting photographic magnitude, using a 1P21 without refrigeration, is about 5.5. The effective slit-width changes with the wave length. Table 1 gives its value at several positions in the spectrum for both the 4° and the 6° prism.

Each spectrum was first traced from red to blue, while the sensitivity of the amplifier was increased by one or several steps of 0.5 mag. Reversing the direction of the motor, the spectrum was then traced from blue to red, while decreasing the sensitivity of the amplifier. The sky background was measured at all sensitivity steps used for the tracings, before the first recording of the spectrum, then before the second tracing, and, finally, after both recordings of the spectrum were complete. One set of observations requires about 10–12 minutes. After two or three program stars two standard stars at different positions on the sky were observed, using the same procedure. The stars α Lyr, α And, and δ Per served as standards. As far as possible, each program star was observed on two different nights.

THE INTENSITIES OF THE HYDROGEN LINES

The lines $H\beta$ and $H\gamma$ appear well separated on all tracings; Hδ is also clearly separated from the neighboring hydrogen lines, with the exception of A0–A4 stars, where the wings of Hδ and Hϵ merge slightly. This effect, however, is not serious, since the continuum midway between the two lines is lowered by less than 1 per cent, owing to the absorption in the wings of the lines. Figure 1 shows that the interpolation of the continuum across the absorption lines presents little difficulty, perhaps with the exception of Hβ, where the continuum appears to be slightly curved. The equivalent widths of a number of lines were obtained by the usual method of measuring areas after the lines had been reduced to a uniform continuum. In most cases a simplified method has been used. Since the readings on the tracing represent an integration over the spectral range covered by the slit, for lines which are smaller than the slit the central depth as measured on the tracing gives the equivalent width directly as a fraction of the slit-width. For stronger lines the equivalent width is obtained by measuring the depth of the line at several points separated by exactly the slit-width. A consideration of the effect of the time constant shows that the profiles of the lines are distorted but that the equivalent widths obtained by the procedure are not affected. Two different time constants were employed for the observations, and no systematic differences in the equivalent widths were found. A comparison of the results from the 4° and 6° tracings also shows no systematic difference.

The only systematic errors to be expected are caused by unresolved lines. Lines falling in the neighboring continuum will tend to reduce the measured equivalent width, while lines falling within the hydrogen lines will add to it. For most stars, determinations of the equivalent widths were obtained from two pairs of tracings. The average values are listed in Table 3. The mean errors of these values depend somewhat on the equivalent width. Table 2 gives the mean error of the average of four determinations of the equivalent

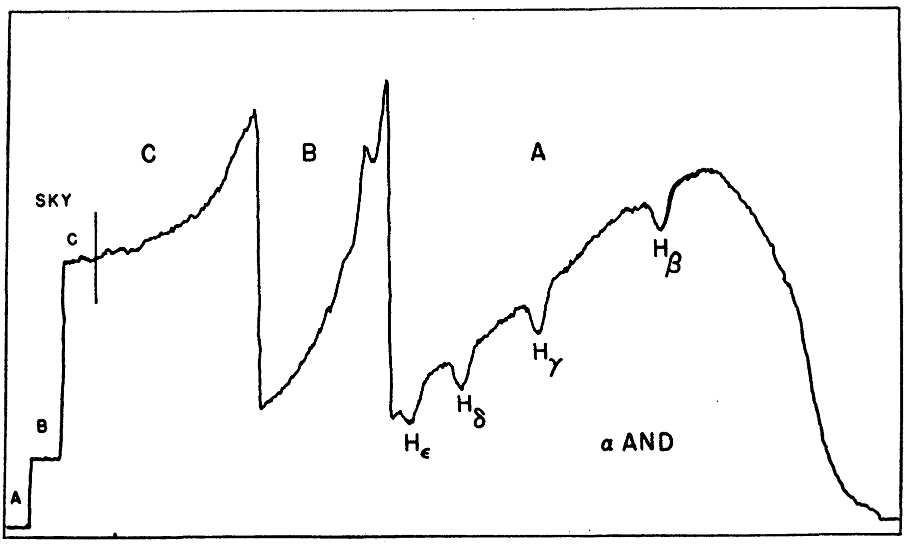

FIG. 1.—Reproduction of a tracing of α And. Three different sensitivities of the photometer were used in this case. *B* is a recording beyond *A* with higher sensitivity, and *C* is still farther to the violet, with still higher sensitivity.

TABLE 1

THE SLIT-WIDTH

Wave Length	6° Prism	4° Prism	Wave Length	6° Prism	4° Prism
Hβ .	52 6 A	78 9 A	Hδ .	28 5 A	42 7 A
Hγ . .	35 3	53 0	3645 A	17 5	26 2

TABLE 2

THE MEAN ERRORS OF EQUIVALENT WIDTHS

LINE	EQUIVALENT WIDTH (A)		
	0–6	6–12	12–20
Hβ	0 3	0 3	0 3
Hγ .	4	.4	.4
Hδ	0.5	0 5	0 4

TABLE 3

THE EQUIVALENT WIDTHS OF HYDROGEN LINES

HD	Name	Hβ	Hγ	Hδ	Sp.	Petrie
358	α And	9.1	9 1	9.4	B8 p	..
432	β Cas	10.0	9.2	8.9	F2 IV	...
886	γ Peg	4.1	5.3	5 6	B2 IV	4.1
1280	θ And	16.5	16.4	16 7	A2 V	...
2905	κ Cas	0.9	1 6	2 0	B1 I*a*	1.2
3360	ζ Cas	4 5	4.7	5 1	B2 V	5 9
3901	ξ Cas	7.1	8.0	7.4	B2 V	5.1
4180	ο Cas	6.7	6.4	6.9	B2 V	4.8
4727	ν And	7.7	7.6	7.8	B5 V	5.4
5394	γ Cas	1.0	0.8	1.4	B0 IVp	....
6961	θ Cas	19.0	17.5	16.0	A7 V	......
7927	φ Cas	8.0	6 4	3.3	F0 I*a*	.....
8538	δ Cas	16 6	18.3	15.4	A5 V	.....
11415	ε Cas	6 8	6.0	6.3	B2 p	5.8
11636	β Ari	18.7	19.0	19 0	A5 V	.....
13161	β Tri	16.2	18 2	16.5	A5 III	....
15089	ι Cas	17.4	17.0	16.0	A5 p	....
16582	δ Cet	5.3	6.5	5.6	B2 IV	....
16908	35 Ari	8 5	8.9	7.7	B3 V	....
17094	μ Cet	13.9	12.5	11.1	F0 IV	....
18331	...	15.4	16 4	15.2	A1 V	....
20902	α Per	7 2	6.7	5 4	F5 I*b*	....
21291	.	1.6	1.6	2.1	B9 I*a*	....
21389	...	2.0	1 9	2 2	A0 I*a*	....
21447	..	19 8	18.9	17.5	A1 V	.....
22928	δ Per	7 3	7 6	6 8	B5 III	5.6
22951	40 Per	5 9	6 9	4 9	B0 5 V	..
23180	ο Per	3.2	3.8	4 0	B1 III	4.4
23288	16 Tau	9.8	10.0	9 7	B7 IV	8.6
23338	19 Tau	7.5	7.6	7 8	B6 V	7.4
23408	20 Tau	7.2	7.2	6 8	B7 III	6.7
23432	21 Tau	14.8	10.9	10.7	B8 V	....
23480	23 Tau	7.1	6.6	6.8	B6 IV	7 0
23630	η Tau	5.1	6.1	6.8	B7 III	5.5
24398	ζ Per	2.2	2.4	3.2	B1 I*b*	2.4
24760	ε Per	3 6	4.1	5.0	B0.5 V	3 5
24912	ξ Per	2.2	1 9	2.0	O7	....
25291	....	10.6	9 6	8.5	F0 II	....
28319	θ² Tau	17.5	16.9	16 1	A7 III	....
30836	π⁴ Ori	5.4	4.5	4 8	B2 III	3.9
31647	4 Aur	21.0	19 1	18 2	A0 V	....
32630	η Aur	8 2	8.7	7 4	B3 III	7 7
33111	β Eri	16 0	17 4	15.2	A3 III	...
34085	β Ori	1 0	1.6	1 8	B8 I*a*	....
34503	τ Ori	7.4	10.2	6.6	B5 III	8.5
34578	19 Aur	10 8	9.1	7 9	A5 II	....
34759	ρ Aur	10 5	10.1	8.9	B5 V	7.5
35411	η Ori	4 4	4.4	5.4	B1 V	4 2
35468	γ Ori	3 5	6 1	5.2	B2 III	4 9
35497	β Tau	8.3	8 5	7.8	B7 III	...
36371	χ Aur	2 1	2 0	2 1	B5 I*ab*	1.6
36486	δ Ori	2 2	3.2	2.9	O9.5 II	....
36512	ν Ori	4 2	5.1	4 2	B0 V	4 4
37043	ι Ori	2.5:	3 6:	2 2	O9 III	..
37202	ζ Tau	2 6	6 0	4.5	B3 p	3 5
37468	σ Ori	3 7	5.0	4 6	O9.5 V	3.0
37742	ζ Ori	2 2	1 8	2.1	O9 5 I*b*	1.7
40183	β Aur	17.7	18 0	16 7	A2 IV	.
40312	θ Aur	11 6	10 9	10 2	A0 p	.

TABLE 3—*Continued*

HD	Name	Hβ	Hγ	Hδ	Sp.	Petrie
46300	13 Mon	4.8	5.0	5 6	A0 I*b*	....
47105	γ Gem	15 1	15.6	14.4	A0 IV	....
48915	α CMa	21.0:	18 2	18 4	A1 V	....
56537	λ Gem	18 3	19 1	17.9	A3 V	....
58946	ρ Gem	11 2	12 9	9 6	F0 V	
71155	30 Mon	18 6	17.4	17.7	A0 V	....
74280	η Hya	5.7	6.4	6.1	B3 V	....
83754	κ Hya	10.4:	13 8:	11.2:	B5 V	....
87901	α Leo	8 4	9.8	8 5	B7 V	....
103287	γ UMa	14 5:	17 4:	17 0:	A0 V	....
106591	δ UMa	18.4:	17.0:	15.6:	A3 V	....
107276	....	18.7	17.5	17.1	A4 m	....
108283	14 Com	9.2:	8.6:	8.5:	F0 p	....
108382	16 Com	17.6:	18.4	16.9	A4 p	....
108651	.. ...	16 1:	18.7:	17 0:	A0 p	....
108662	17 Com	14.6:	12.7:	13 5:	A0 p	....
118098	ζ Vir	22 8:	17.2:	18 5:	A3 V	....
128167	σ Boo	10.8:	9 7:	9.1:	F2 V	....
170073	39 Dra	18 4	19.0	17.8	A1 V	....
172167	α Lyr	17.7	17.6	17.5	A0 V	....
186882	δ Cyg	11.6	10 9	12 4	B9.5 III	....
196867	α Del	11.6	10 6	11 0	B9 V	....
197345	α Cyg	2.4	2.3	2.1	A2 I*a*	....
198001	ε Aqr	14 4	15.3	15.7	A1 V	....
202850	σ Cyg	3.2	2 6	3.4	B9 I*ab*	....
203280	α Cep	13 6	15.4	13 8	A7 V	...
205021	β Cep	4 2	5 4	5 0	B2 III	3.5
207260	ν Cep	3.2	1 6	2 7	A2 I*a*	....
209481	14 Cep	4.0	1.8	2.5	O9 V	....
209975	19 Cep	1.8	1.9	2.5	O9.5 I*b*	...
211336	ε Cep	13 0	13 4	11.7	F0 IV	..
212593	4 Lac	5 0	4.1	4.3	B9 I*ab*	....
213420	6 Lac	4 7	5 9	5.4	B2 IV	4 0
214680	10 Lac	4 0	3 3	3 8	O9 V	3.6
214923	ζ Peg	9.9	10.0	10.4	B8 V	.. .
214993	12 Lac	5.6	6.5	5 0	B2 III	3.7
218045	α Peg	13 8	13.6	13 0	B9 V	....
219688	ψ^2 Aqr	7 2	7 6	7.2	B5 V	..
222173	ι And	9.6	9.6	8 7	B8 V	....
222661	ω^2 Aqr	14.8:	15 6:	15 6:	B9.5 V	.....

width. Comparisons have been made with a number of photographic determinations of equivalent widths. The comparisons with Günther (1933) and Petrie (1953) are shown in Figures 2*a* and 2*b*. The values given by Petrie are also listed in Table 3, which includes some additional unpublished material. A discussion of the line intensities and their relations to spectral types and luminosities will be postponed until additional material, which is now being obtained at several observatories, becomes available.

REFERENCES

Günther, S. 1933, *Zs. f. Ap.*, **7**, 106.
MacRae, D. A. 1953, *A.J.*, **58**, 43.
Petrie, R. M. 1952, *Pub. Dom. Ap. Obs. Victoria*, **9**, 251.

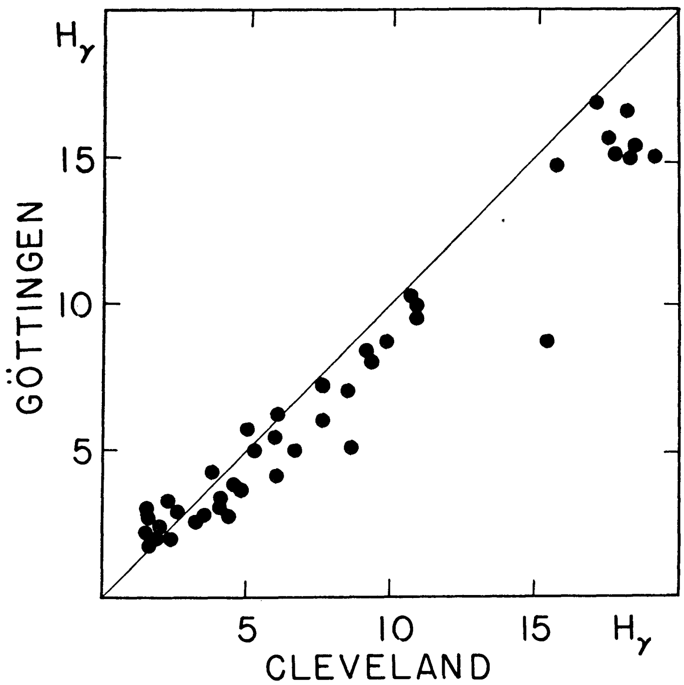

FIG. 2a.—Comparison of the photoelectric measurements of the Hγ intensities with those by Günther (Göttingen).

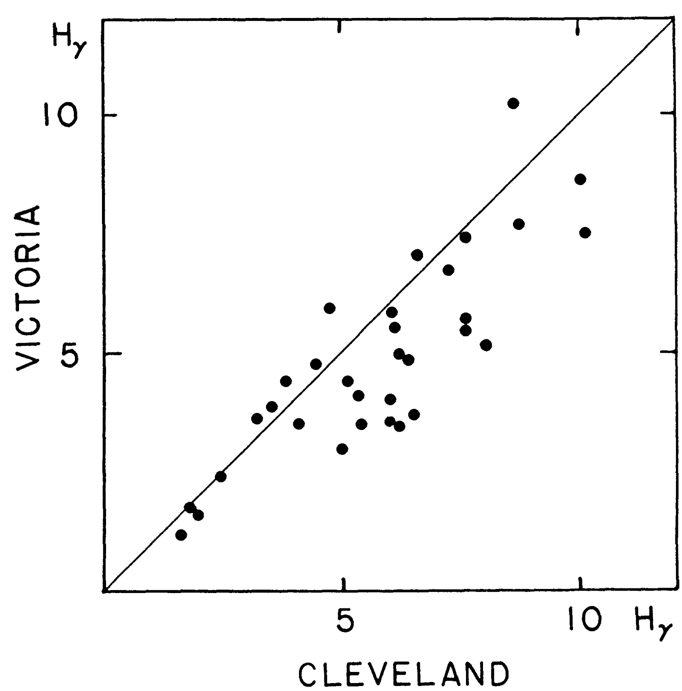

FIG 2b.—Comparison of the photoelectric measurements of the Hγ intensities with those by R M Petrie (Victoria).