PUBLICATIONS OF
THE DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO

VOLUME II NUMBER 13

DISTANCES OF 97 OB STARS

BY HARRY H. GUETTER

1964
TORONTO, CANADA

PRINTED AT
THE UNIVERSITY OF TORONTO PRESS

DISTANCES OF 97 OB STARS

BY HARRY H. GUETTER*

ABSTRACT

Equivalent widths of the Hγ line are determined for 97 stars of spectral range B3 and earlier which have been observed spectroscopically at the David Dunlap Observatory. All the equivalent widths were reduced to the system of the Dominion Astrophysical Observatory, Victoria, B.C. The distances of these stars were obtained by the use of the Hγ-M_V calibration determined by Johnson and Iriarte (1958) and the assumption that the ratio of total to selective absorption is 3.0.

The distances of various association members are compared to one another, and it is concluded that the luminosity calibration may be incorrect for very bright stars.

Finally, the effect of duplicity among OB stars on the Hγ-M_V calibration is briefly examined.

INTRODUCTION

The basis of this study is the correlation between the equivalent width of the Hγ line of an early-type stellar spectrum and the star's absolute magnitude, to which attention has been directed by Petrie (1953). This relation has been recalibrated by Johnson and Iriarte (1958) with cluster stars whose luminosities have been determined by zero-age main sequence fits. By a combination of this estimate of absolute magnitude with the apparent magnitude and colour of the star, the distance of the star can be computed.

OBSERVATIONAL DATA

Stars of spectral type no later than B3 and fainter than apparent magnitude 6.0 were considered in this investigation. With these criteria 97 stars were selected from spectrograms already available in the plate files of the David Dunlap Observatory. Upwards to eight usable spectrograms were available for each star.

The spectrograms had all been obtained on Eastman 103aO emulsion with the one-prism spectrograph of the 74-inch telescope at the David Dunlap Observatory. The spectrograph has two cameras giving dispersions at Hγ of 33 A./mm. and 66 A./mm. respectively. The former was used for many stars brighter than $m_{pg} = 7.0$, while the latter was used to obtain fainter spectra. The slit width was chosen between 0.02 mm. and 0.04 mm., depending on the brightness of the star and the seeing and transparency during the time of observation.

---

*Now at the U.S. Naval Observatory, Flagstaff, Arizona.

CALIBRATION AND ERROR DETERMINATION

The measurement of the spectra was carried out with the Dunlap microphotometer (Oke 1957) with the aid of tube sensitometer calibrations. The sensitometer spots, exposed on each plate beforehand, are used to transform density to intensity. The intensity steps were taken from the work of Armstrong (1933), checked by Wellmann (1957).

The mechanical magnification of the microphotometer was calculated from the iron arc comparison lines to be 45.5.

The spectra usually were traced from λ4250 to λ4450 centred about Hγ so that the continuum could be estimated fairly accurately. The mean of density readings taken on the unexposed parts of the plate adjacent to the Hγ line was considered to be zero intensity since many plates showed uneven fog density.

To obtain the line profile, the best-determined side of the Hγ line was drawn, the centre of the profile estimated, and the opposite side of the profile drawn symmetrically to the first. In this way the effects are minimized of other lines which are close to the Hγ line, for example OII λ4349 and λ4351, and also photographic irregularities.

The plates were given weights from zero to unity to denote the quality of the spectrogram. Similarly, the tracings were also given weights from zero to unity. The two weights were then multiplied to give the final weight for a particular measurement. In case of more than one measurement, the square of the final weight was taken to equal the sum of the squares of the individual weights. The weights of spectra obtained with the 33 A./mm. dispersion were doubled with respect to those of the 66 A./mm. dispersion.

CALIBRATION OF THE EQUIVALENT WIDTHS

The Hγ-M_V calibration by Johnson and Iriarte (1958) is based on Victoria equivalent widths. It was therefore necessary to determine the transformation required to convert the Dunlap equivalent widths to the Victoria system. From twenty-one stars in common, it was found for the 33 A./mm. dispersion that

$$H\gamma_{\mathrm{Victoria}} = (1.08 \pm 0.07)\, H\gamma_{\mathrm{Dunlap}}.$$

From twenty-five stars in common, it was found for the 66 A./mm. dispersion that

$$H\gamma_{\mathrm{Victoria}} = (1.07 \pm 0.08)\, H\gamma_{\mathrm{Dunlap}}.$$

The individual points are shown in figures 1 and 2.

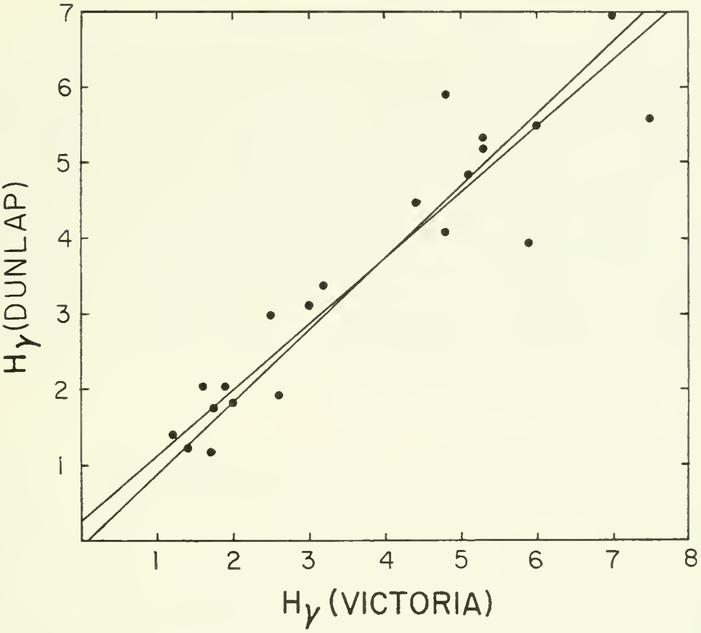

FIG. 1—Comparison of the Hγ equivalent widths from spectra obtained at the David Dunlap Observatory and the Dominion Astrophysical Observatory (Victoria) for the 33 A./mm. dispersion.

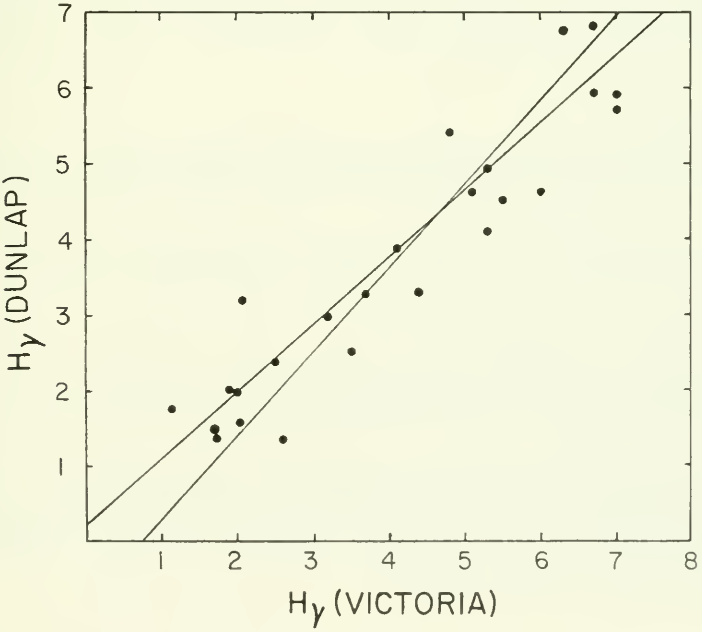

FIG. 2—Comparison of the Hγ equivalent widths from spectra obtained at the Dunlap Observatory and Victoria for the 66 A./mm. dispersion.

ABSOLUTE MAGNITUDES

The data for the stars which were studied in the present programme are listed in Table I. The designations of the columns are self-explanatory except for the following. Column 8 (Ref.), is the reference to the source of the photometric data: (a) Hiltner (1956), (b) Hiltner and Johnson (1956), (c) Hiltner and Iriarte (1955), (d) Author's observations obtained with the photometer attached to the 19-inch reflector at the David Dunlap Observatory (Marlborough 1964); column 9 (W), is the equivalent width of the $H\gamma$ line; column 10(Wt.), is the combined weights of the plate-tracing combination; column 11 ($\pm\Delta W$), is the standard error of the equivalent width in units of 0.01 A.

DISTANCES OF VARIOUS ASSOCIATIONS

Some of the stars in the present programme are members of associations. Since most associations are fairly rich in early-type stars, only a few stars in each association were studied spectroscopically.

The information obtained for four associations is given in Table II. First the name of the association and its distance (as determined by other workers) are given. For each association, the individual stars are listed as to: the spectral type; the equivalent width of the $H\gamma$ line; the total weight given to the spectrum-tracing combination; the number of plates used; the internal dispersion or standard error of the equivalent width in milliangstroms; the distance modulus; and the distance in kiloparsecs.

Table II shows that the four stars of III Cygni agree fairly well with one another, giving an average distance of 1.6 kpc., which is only a little smaller than the distance given by Schmidt (1958). The three stars of III Cephei yield an average distance of 0.85 kpc., corresponding closely to that estimated by Blaauw, Hiltner and Johnson (1959). For the other two associations significant discrepancies are found, in that the computed distances of the three stars with equivalent widths smaller than about 2.0 angstroms are much greater than those with larger equivalent widths. Three possible explanations suggest themselves: (a) that the Johnson and Iriarte calibration is over-luminous for small equivalent widths, (b) that the three discordant stars are not association members, but background stars and (c) that incipient emission at $H\gamma$ in the spectra of these stars has reduced the value of the equivalent widths. It is not possible to choose among these explanations because of the small sampling.

TABLE I

DATA FOR THE OB STARS

B.D. or H.D.	l^{II}	b^{II}	Sp.	V	B−V	U—B	Ref.	W (A.)	Wt.	ΔW (0.01A.)	Dist. (kpc.)
+ 61° 39	119°.3	−0°.2	B0.5V	8.52	+0.30	−0.75	a	2.0	0.9	3	3.60
+ 61° 40	119.3	− 0.2	B2pI–II	9.55	+0.47	−0.51	a	2.3	1.4	20	4.32
3264	120.3	−14.2	B2V	7.50	−0.05	−0.63	d	9.2	1.8	35	0.20
4694	122.8	+ 1.7	B3Ia	8.50	+0.72	−0.16	a	2.8	1.0	10	1.72
5551	123.7	+ 0.9	B1.5Ib	7.71	+0.62	−0.36	a	2.0	0.7	13	1.85
13841	134.4	− 3.9	B2Ib	7.37	+0.23	−0.65	a	3.9	1.1	23	1.20
14302	135.1	− 4.4	B1II–III	8.57	+0.26	−0.56	a	3.9	1.4	36	1.69
20134	140.2	+ 2.2	B3V	7.46	+0.14	−0.51	d	7.9	1.0	3	0.23
21483	158.9	−21.3	B3III	7.03	+0.35	−0.33	a	4.7	0.9	19	0.51
1502 #3*	143.7	+ 7.6	B3III	9.30	+0.49	−0.28	d	5.3	1.2	85	0.88
1502 #4*	143.7	+ 7.7	B3III	9.43	+0.45	−0.38	d	5.1	1.5	35	1.14
35633	173.2	− 0.2	B0.5IV	8.04	+0.32	−0.66	a	2.3	1.1	18	2.33
35921	172.8	+ 0.6	O9.5III	6.81	+0.20	−0.78	a	2.8	1.0	8	1.15
43818	188.5	+ 3.9	B0II	6.92	+0.29	−0.69	a	2.0	0.8	20	1.70
57682	224.4	+ 2.6	O9V	6.44	−0.19	−1.04	b	2.3	1.2	23	2.17
149363	9.8	+26.7	B0.5III	7.81	+0.05	−0.80	d	2.2	1.2	10	3.19
161961	23.6	+13.1	B0.5III	7.89	+0.23	−0.67	d	2.3	1.3	16	2.47
166628	11.3	− 0.5	B3Ia	7.17	+0.59	−0.29	a	2.9	0.7		1.07
167263	10.8	− 1.6	O9II	5.98	+0.04	−0.88	a	2.3	0.9		1.28
168021	12.7	− 1.5	B0Ib	6.82	+0.30	−0.66	d	1.3	0.9		3.10
−13° 4930	17.0	+ 0.8	O9.5V	9.44	+0.30	−0.70	a	4.5	0.8	15	1.54
168161	18.6	+ 1.3	O8IV	9.54	+0.68	−0.42	a	1.8	0.6		3.75
168894	16.7	− 0.4	B1II	9.38	+0.64	−0.39	a	1.5	0.6		5.10

*NGC 1502, third and fourth stars listed in appendix of *Publ. U.S. Naval Obs.*, vol. 17, part 7, p. 510, 1961.

TABLE I *(continued)*

B.D. or H.D.	l^{II}	b^{II}	Sp.	V	B−V	U−B	Ref.	W (A.)	Wt.	ΔW (0.01A.)	Dist. (kpc.)
170177	18.3	− 1.2	B0.5Ia	9.44	+0.80	−0.34	c	2.6	0.9	40	2.13
171012	14.5	− 4.4	B0.5Ia	6.82	+0.45	−0.57	d	1.4	1.2	15	2.37
172028	31.0	+ 2.8	B3II	7.83	+0.55	−0.26	d	4.2	1.3	41	0.81
173637	25.3	− 2.5	B1V	9.35	+0.28	−0.66	c	2.4	0.6		4.23
173783	24.2	− 3.4	O9I	9.31	+0.51	−0.52	b	2.3	0.7	26	3.22
173987	26.9	− 2.3	B0.5Ia	8.92	+0.36	−0.64	c	2.0	1.1	4	4.45
175514	41.7	+ 3.4	O8:Vnn	8.59	+0.59	−0.45	a	4.2	0.6		0.83
+28° 3434	64.3	+ 3.2	B1Ibp	8.50	+0.20	−0.71	a	2.6	1.0	10	3.25
+28° 3438	64.2	+ 2.9	B2IV	8.93	+0.01	−0.70	a	5.3	1.5	26	1.31
186841	60.4	− 0.3	B1Ia	7.85	+0.79	−0.29	a	2.3	1.2	14	1.28
+27° 3512	64.1	+ 1.7	O7.5	8.77	+0.20	−0.78	a	2.6	1.3	35	3.03
+28° 3485	64.8	+ 1.6	B2V:n	9.40	+0.10	−0.57	a	5.6	1.5	13	1.25
188439	77.4	+ 7.8	B0.5II	6.30	−0.10	−0.86	d	4.5	0.8		0.67
+25° 4083	64.4	− 2.6	B1III	8.94	+0.63	−0.31	a	4.5	0.7		0.82
+31° 3921	69.4	+ 0.5	B1Ib	8.70	+0.46	−0.45	a	2.6	1.0	24	2.49
+35° 3956	72.6	+ 2.0	B0.5V	8.85	+0.19	−0.62	a	5.7	1.5	52	0.74
227704	72.0	+ 1.5	B0III	8.60	+0.34	−0.63	a	4.0	0.9	4	1.37
193536	82.8	+ 5.8	B2V	6.46	−0.09	−0.66	d	5.2	0.9	75	0.50
193855	77.0	+ 1.4	B2III	7.78	+0.27	−0.42	d	5.5	1.6	37	0.49
229227	76.9	+ 0.6	B0II	9.38	+0.80	−0.15	a	3.1	0.8	35	1.45
229234	76.9	+ 0.6	O9.5III	8.92	+0.77	−0.19	a	2.4	1.1	8	1.67
229238	76.9	+ 0.6	B0Ib	8.88	+0.90	−0.06	a	2.3	0.9	15	1.68
229239	76.9	+ 0.6	B1Iab	8.92	+0.87	−0.15	a	2.5	1.0	60	1.64
+45° 3230	84.5	+ 3.1	B0III	9.40	+0.75	−0.27	a	2.6	0.8	10	1.95
+45° 3246	84.8	+ 2.2	B1Vn	9.67	+0.17	−0.64	a	5.3	1.0	62	1.37

TABLE I (*continued*)

B.D. or H.D.	l^{II}	b^{II}	Sp.	V	B−V	U—B	Ref.	W (A.)	Wt.	ΔW (0.01A.)	Dist. (kpc.)
199140	72.8	−10.5	B2III	6.52	−0.12	−0.80	d	4.7	1.5	33	0.71
+45° 3339	86.8	+ 0.6	B1IV	9.93	+0.42	−0.42	a	5.2	1.0	27	1.14
201345	78.5	− 9.5	B0IV	7.66	−0.13	−0.95	d	3.3	1.2	23	2.14
202349	82.5	− 7.5	B0.5V	7.37	−0.20	−0.95	d	5.2	1.0	67	0.81
239767	99.7	+ 2.7	B0.5V:p	9.25	+0.70	−0.35	a	4.4	0.9	22	0.92
235618	98.7	+ 1.4	B1IV	9.66	+0.68	−0.31	a	3.4	1.1	44	1.85
207563	75.4	−25.1	B3V	6.31	−0.10	−0.64	d	6.0	0.9		0.36
235673	98.4	− 1.6	O7	9.14	+0.21	−0.77	a	3.0	1.3	26	2.95
209008	65.9	−36.5	B3V	5.97	−0.04	−0.50	d	5.7	0.9		0.33
+53° 2790	100.6	− 1.1	O9.5III	9.86	+0.25	−0.71	a	2.8	1.0	15	4.38
210809	99.9	− 3.1	O9.5III	7.54	+0.05	−0.89	a	2.1	1.2	8	3.01
+53° 2820	101.3	− 1.7	B0IV:n	9.95	+0.10	−0.78	a	3.4	0.7		4.47
+54° 2718	102.0	− 0.9	B2III	10.15	+0.19	−0.62	a	4.2	0.6		3.40
+54° 2726	102.2	− 1.0	B1II	9.38	+0.33	−0.54	a	3.1	0.9	29	2.98
235783	101.6	− 1.9	B1Ib	8.68	+0.17	−0.71	a	3.4	1.0	9	2.67
+53° 2843	101.7	− 2.2	O8	9.50	+0.21	−0.75	a	1.8	0.8	2	7.05
+60° 2380	105.4	+ 3.2	B2III	9.04	+0.39	−0.50	a	2.9	1.0	48	2.69
239923	104.4	+ 1.6	B3Ib	8.89	+0.83	−0.12	a	1.7	0.8	26	3.37
235807	102.7	− 1.3	B0.5IVn	9.56	+0.21	−0.67	a	2.7	0.8	3	4.34
235813	102.3	− 2.0	B0III	8.84	+0.22	−0.74	a	1.8	0.9	2	5.20
T.B. 5–21†	103.0	− 1.3	O5	10.29	+0.27	−0.73	a	2.9	0.4		4.83
235825	102.9	− 1.7	O9V	9.28	+0.24	−0.73	a	2.2	0.4		4.63
+54° 2761	103.2	− 1.4	O5f	9.98	+0.34	−0.68	a	2.3	1.0	11	5.25
+54° 2764	103.0	− 1.6	B1Ib	9.54	+0.28	−0.62	a	3.1	0.6		3.73

†*Boletin de los Observatorios Tonantzintla y Tacubaya*, no. 5.

TABLE I (*continued*)

B.D. or H.D.	l^{II}	b^{II}	Sp.	V	B—V	U—B	Ref.	W (A.)	Wt.	ΔW (0.01A.	Dist. (kpc.)
+55° 2748	103.7	− 1.0	B0.5V	9.96	+0.44	−0.52	a	2.9	0.8	2	3.47
+60° 2405	107.1	+ 3.2	B3nnV	9.91	+0.54	−0.19	a	6.4	0.6		0.69
+55° 2770p	104.8	− 1.4	B1II	10.10	+0.37	−0.54	a	6.6	0.5		0.75
+55° 2770f	104.8	− 1.4	B1.5III	9.70	+0.35	−0.54	a	5.2	0.7		1.15
+55° 2771	105.0	− 1.3	B1IV	9.70	+0.48	−0.45	a	3.0	0.7		2.86
214240	101.8	− 7.2	B3V	6.30	−0.06	−0.53	d	5.8	0.8		0.38
214652	96.1	−17.8	B3V	6.81	−0.15	−0.71	d	6.6	1.4	23	0.39
240068	107.3	− 0.5	B0III	9.64	+0.49	−0.52	a	4.4	0.6		1.43
216658	109.7	+ 2.3	B0V	8.89	+0.70	−0.29	a	4.6	1.5	21	0.66
216711	109.9	+ 2.7	B1V	9.05	+0.62	−0.33	a	4.7	1.4	13	0.76
218407	104.8	+13.0	B3IV	6.62	−0.02	−0.71	d	5.2	0.9		0.54
218941	110.9	+ 0.1	B1.5II	9.71	+0.83	−0.20	a	1.4	0.4		5.08
+61° 2408	111.9	+ 1.2	B0III?p?	9.7	+0.79	−0.21	a	2.6	0.5		2.1
+63° 1962	112.8	+ 2.8	B1III	8.40	+0.32	−0.56	a	4.3	1.5	42	1.13
+63° 1964	112.9	+ 3.1	B0II	8.46	+0.71	−0.38	a	1.5	1.5	13	2.83
+60° 2553	113.2	+ 0.0	B2II	10.08	+0.45	−0.43	a	4.1	1.0	73	2.59
T.B. 5–36†	114.9	− 0.3	B0.5IV	9.78	+0.53	−0.45	a	3.6	0.7	17	2.14
+61° 2509	115.1	+ 0.3	B0.5Ib	8.42	+0.46	−0.55	a	2.5	1.1	30	2.23
+60° 2615	115.1	− 0.1	B0.5Ib	9.10	+0.60	−0.45	a	1.9	1.1	13	3.63
+61° 2515	115.4	+ 0.4	B0.5V	9.95	+0.43	−0.51	a	4.6	0.9	40	1.60
+61° 2526	115.5	+ 0.1	B2Ib	8.77	+0.39	−0.50	a	3.4	1.1	2	2.21
+61° 2529	115.5	+ 0.1	B1Ib	8.65	+0.53	−0.47	a	2.7	1.2	22	2.11
+61° 2550	116.1	+ 0.0	B0IV	9.29	+0.33	−0.63	a	2.7	1.1	16	3.16
+61° 2559	116.3	+ 0.3	O9V	9.72	+0.29	−0.66	a	3.4	1.2	11	3.05
T.B. 5–39†	116.6	− 1.1	B1V	10.22	+0.29	−0.59	a	6.0	0.9	21	1.08

†*Boletin de los Observatarios Tonantzinlla y Tacubaya*, no. 5.

TABLE II

DISTANCES OF VARIOUS ASSOCIATIONS BY MEANS OF INDIVIDUAL STELLAR DISTANCES

Star Number	Spectral Type	W	wt.	n	ΔW	$m_0 - M$	Distance (kpc.)
III Cygni, distance = 1.93 kpc. (Schmidt 1958)							
H.D.E. 229227	B0II	3.1	0.8	2	35	10.8	1.45
H.D.E. 229234	O9.5III	2.4	1.1	3	8	11.1	1.67
H.D.E. 229238	B0Ib	2.3	0.9	3	15	11.1	1.68
H.D.E. 229239	B1Iab	2.5	1.0	3	60	11.1	1.64
II Cephei, distance = 3.9 kpc. (Schmidt 1958)							
H.D.E. 235673	O7	3.0	1.3	3	26	12.4	2.95
B.D. +54°2726	B1II	3.1	0.9	3	29	12.4	2.98
H.D.E. 235783	B1Ib	3.4	1.0	3	9	12.1	2.67
B.D. +53°2843	O8	1.8	0.8	2	2	14.2	7.05
H.D.E. 235813	B0III	1.8	0.9	2	2	13.6	5.20
H.D.E. 235825	O9V	2.2	0.4	1		13.3	4.63
B.D. +54°2764	B1Ib	3.1	0.6	1		12.9	3.73
III Cephei, distance = 0.725 kpc. (Blaauw, Hiltner, and Johnson 1959)							
H.D. 216658	B0V	4.6	1.5	5	21	9.1	0.66
H.D. 216711	B1V	4.7	1.4	4	13	9.4	0.76
B.D. +63°1962	B1III	4.3	1.5	5	42	10.3	1.13
I Cassiopeiae, distance = 2.5 kpc. (Morgan, Code and Whitford 1953)							
B.D. +61°2509	B0.5Ib	2.5	1.1	3	30	11.7	2.23
B.D. +60°2615	B0.5Ib	1.9	1.1	4	13	12.8	3.63
B.D. +61°2526	B2Ib	3.4	1.1	3	2	11.7	2.21
B.D. +61°2529	B1Ib	2.7	1.2	3	22	11.6	2.11
B.D. +61°2550	B0IV	2.7	1.1	3	16	12.5	3.16
B.D. +61°2559	O9V	3.4	1.2	3	11	12.4	3.05

CONCLUSIONS

The conclusions reached in this paper are only tentative. The derived distances may be incorrect for the following reasons: First, the spectra of some stars may have at Hγ a little emission which is difficult to distinguish on the tracings from the grain of the photographic emulsion. This would cause the equivalent width to be under-estimated and the distances obtained would be too large. Secondly, there is the fact that according to Blaauw and van Albada (1963) approximately half the stars of the nearest associations are spectroscopic binaries.

Heard (private communication), in a study of five stars in the association III Cephei, found one definite, and three probable spectroscopic binaries. It may be shown that in the present method of determining absolute magnitude, the effect of an unresolved binary is to lead to an absolute magnitude which is intermediate between the absolute magnitudes of the two components. The distance of such a binary is therefore underestimated.

However, due to the high incidence of spectroscopic binaries among OB stars and the relative frequency of line emission, it seems doubtful that the stars used for their calibration by Johnson and Iriarte were all single stars without any Hγ emission. Hence the Hγ-M_V relation is probably overluminous where derived from single stars, and underluminous where derived from binaries. Therefore, by assuming that the sample of stars used in this paper is similar to those used by Johnson and Iriarte, one would expect that on the average their calibration is valid for use in this study. This statistical conclusion, however, may be invalid for the most luminous stars because of the small number of such objects.

ACKNOWLEDGEMENTS

The author would like to express his gratitude to the following persons: to Dr. J. F. Heard for providing the necessary facilities at the David Dunlap Observatory; to Mr. J. M. Marlborough for obtaining some photometric observations; to Dr. A. A. Hoag for several valuable discussions; and especially to Dr. J. D. Fernie for suggesting this problem and for his guidance and advice throughout. This research was supported in part by a grant from the National Research Council, Ottawa.

REFERENCES

Armstrong, W. S. 1933, M.A. Thesis, University of Toronto.
Blaauw, A., Hiltner, W. A., Johnson, H. L. 1959, *Ap. J.*, vol. 130, p. 69.
Blaauw, A., and Albada, T. S. 1963, *Ap. J.*, vol. 137, p. 791.
Hiltner, W. A. 1956, *Ap. J. Suppl.* vol. 2, p. 389.
Hiltner, W. A., and Iriarte, B. 1955, *Ap. J.*, vol. 122, p. 185.
Hiltner, W. A., and Johnson, H. L. 1956, *Ap. J.*, vol. 124, p. 367.
Johnson, H. L., and Iriarte, B. 1958, *Low. Obs. Bull.*, vol. 4, p. 47.
Marlborough, J. M. 1964, *A. J.*, vol. 69, p. 215.
Morgan, W. W., Code, A. D. and Whitford, A. E. 1953, *Ap. J.*, vol. 118, p. 318.
Oke, J. B. 1957, *R.A.S.C. Journal*, vol. 51, p. 133.
Petrie, R. M. 1953, *Publ. D.A.O.* vol. 9, p. 251.
Schmidt, K. H. 1958, *A. N.*, vol. 284, p. 76.
Wellmann, P. 1957, *Ap. J.*, vol. 126, p. 30.