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HARVARD COLLEGE OBSERVATORY

CIRCULAR 348

A SPECTROPHOTOMETRIC STUDY OF A STARS*

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The object of this study has been to reclassify the brighter A stars on a more nearly physical basis, thus to discover, if possible, a physical explanation of the "peculiar" spectra, and also to find reliable criteria for temperature, pressure, and absolute magnitude.

For this purpose the most logical line of attack was a study of the contours of the hydrogen lines and the K line — first, on account of the instrumental equipment available, then again on account of the supposed anomalous behaviour of the hydrogen lines and the possibility of detecting the Stark effect in them and finally because only the hydrogen lines and the K line are available in extending the results to faint stars. Of the Balmer lines only the contours of $H\gamma$ and $H\delta$ were studied, since $H\beta$ falls in a poor part of the spectrum for photometry, $H\epsilon$ is blended with H, and later members of the Balmer series are difficult to measure on account of the depression of the continuous background by the confluence of the wings of the lines.

Throughout the investigation care has been taken that the data should be homogeneous. Thus it has been possible to establish relative differences, but in the main the results are qualitative only. The one result which gives quantitative information is the criterion found for absolute magnitude.

Description of Observations

List.— The 119 stars listed in Table I include all stars north of −10° declination brighter than photometric magnitude 4.0 which belong to spectral classes B5 to F2 inclusive according to the Henry Draper Catalogue, with the exception of Boss 877 ("Atlas") and Boss 5052. Boss 877 was omitted because neighboring bright stars made it difficult to obtain spectra of sufficient width with the instrument used. Boss 5052 was omitted because the composite spectrum is predominately Class M. In addition Table I includes all stars north of −10° declination brighter than photometric magnitude 5.0 which belong to spectral classes B5 to F2 and are marked "peculiar" in the Henry Draper Catalogue. The table also includes Sirius.

Spectrograms.— The spectrograms were made with the 11-inch Draper telescope and one objective prism (designated "A"). This combination gives a dispersion of about 50 A per mm at $H\gamma$, the resolving power being about 2000. The spectra were

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in good focus from about λ 4600 to λ 3900. In general the spectrum of each star on the list was photographed on three or more different nights.

Emulsion.— About 350 of the 360 spectra used were on plates having the same emulsion number: — Cramer Dry Plate Co., Presto, 26,791^4. The emulsion had a very slight isochromatic character. The set of plates chosen turned out to be unfortunate, as about one plate in six was streaked. The streaks could not be detected in ruby light before the plate was exposed, hence after exposure and development a number of plates had to be discarded. The streaks are believed by the manufacturer to be due to the glass plate not being clean when the emulsion was laid on.

Exposure times.— The exposures averaged about twenty five to thirty minutes for one spectrum. This gave a spectrum about one and a half mm wide of satisfactory density for a star of magnitude 4.2 to 4.6, when the full aperture of the telescope was used. For stars brighter than 4.2, smaller apertures were used so that the exposure times remained about the same. For stars between magnitudes 4.6 and 5.0 the exposure times were somewhat longer. With this total exposure and width of spectrum, the true exposure on a particular grain of the plate is about ten to fifteen seconds — it takes the image about that time to travel completely across a distance equivalent to its own width.

Standardization.— Within an hour after any spectrum was photographed the plate was standardized. A contact print of a calibrated photographic wedge (E 13362) was impressed on a region of the film which had been exposed to sky fogging, fairly near to the spectrum. The exposure for this was about twelve seconds. The source was an Argand lamp with a blue filter in front of it at a distance of thirty six inches. The plate remained out of doors from about half an hour before the spectrum was made until the standardized wedge had been printed on it. The plates were allowed to stand from twelve to twenty four hours after standardization before development.

The photographic wedge (E 13362) was calibrated in the manner described by Dunham,[1] except that the exposures through the various apertures of the Argand were made out of doors using the same apparatus which was mentioned in connection with printing the wedge on the spectrum plates. The values found for the successive "steps" are the following:

Step	Mags.	Step	Mags.	Step	Mags.
1	not used	6	1.13	10	2.63
2	0	7	1.50	11	3.00
3	0.16	(step 7 is wide)		12	3.48
4	0.39	8	1.85	13	4.00
5	0.73	9	2.21	14	4.60

The above method of standardization was used for eighty per cent of the plates (all after C 19354). The earlier plates were standardized indoors, sometimes five or six hours after the spectrum was made; a different wedge made by Dr. Dunham was used and the plates were sometimes developed immediately after standardization.

It is not thought that this method of standardization is so desirable as the method of aperturing[2] or the double star method[3], but it is considerably quicker. The size of the residuals partly justifies its use for line contours; the rest of the justification lies in the fact that it has been found[3] that the gradation of the plate is approximately constant over the range of wave length used. The method was not designed to be used for color measures.

Development.— The plates prior to C 19710 were developed in Rodinal 1/32 with temperature between 65° and 70° for 10 minutes. The later plates were developed for six minutes.

Microphotometer settings.— From each spectrum together with the standardizing wedge beside it a microphotometer tracing was made with the Moll machine. The width of the analyzing beam was always 0.03 mm, corresponding to about 1½ A at Hγ. All the spectra were put through at the same rate of speed, it taking about 40 seconds for the analyzing beam to travel one millimeter. Care was taken that the total galvanometer deflection from total darkness to clear film should be about five centimeters. This was not always possible, however, as sometimes the spectrum was of such irregular density due to poor driving, or the spectral lines were so crooked, that the length of the analyzing beam had to be shorter than could be compensated by increasing the voltage. The height of the analyzing beam was usually about 0.6 mm, but on occasion it was as short as 0.3 mm. If the voltage fluctuated more than 0.05 volts during the interval of making a tracing, the tracing was discarded.

MEASURES

Measures on absorption lines.— Figure 1 gives a reproduction, reduced to one-half actual size, of a microphotometer tracing of ζ Leonis. It illustrates the difficulty of drawing the background and wings properly. For classes earlier than A5 it is fairly obvious where they should be drawn; but in Figure 1 the background and hydrogen wings at the K line are very possibly drawn too low; it is possible that they should

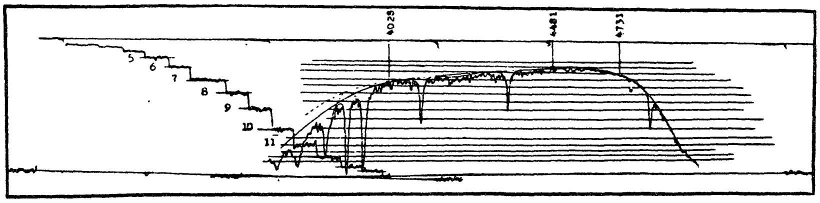

FIGURE 1. Typical microphotometer tracing, showing method of drawing the background, and of standardizing. A fuller description is found in the text.

TABLE I

Boss (1)	Name (2)	H D Class (3)	Sub-division of H D Class (4)	Line Grade (5)	Sp. Bi. (6)	m (HR) (7)	M trig. or cluster (8)	M_{sp} (Wms.) (9)	H (10)	c_2/T compiled (11)	Wt. for c_2/T comp. (12)	Williams Observed c_2/T (13)	Hγ					
													$2(\nu-\nu_0)$ at r =				Depth in Mags. (18)	Total Abs. (19)
													.96 (14)	.83 (15)	.69 (16)	.48 (17)		
10	α And	A0p	*.4*	**3**	o1+	2.15	<*0.4*	*0.3*	3.7	1.46	189	1.55	230	115	72	28	1.02	59
203	μ And	A2	1.0	**5**	. .	3.94	1.5:	. .	4.7	1.77	80	1.70	370:	217	135	55	1.43	106
314	δ Cas	A5	. .	**5**	. .	2.80:	<0.2	. .	5.2	1.85	85	1.88	362	214	142:	57	1.41	106
422 423	γ Ari$^{\mathrm{N}}_{\mathrm{S}}$	A0p	* .5:	* **3:**	 . .	4.83 4.75	. . . .	. . 0.1:	5.5 5.4	1.53	52	1.59	296	171	117	51:	.89	83
428	β Ari	A5	. .	**5½**	o1	2.72	1.7	. .	3.4	1.90	177	1.90	385:	205	131	51	1.28	103
463	α Psc	A2p	*.5:* . .	**3:** .	s .	4.33 5.23	. . . .	0.1: . .	2.4 . .	1.62	35	1.62	245	162	94	46	1.29	75
482	β Tri	A5	. .	**6**	s2	3.08	<0.5	. .	4.8	1.86	68	2.01	356:	205:	112	45	1.14	93
550	ι Cas	A5p	. .	**5½**	s	4.76 7.0 8.1	<2.2	. . . . . .	0.6	1.95	35	1.94	279	210	126	51	1.20	91
622	γ Cet	A2	.5 . .	**6** . .	. . .	3.69 6.16	1.9 . .	2.0 . .	5.3 . .	1.75	48	1.72	410	233	149	60	1.33	115
643	. .	B8	. .	**4½**	s?	3.68	1.2:	0.4	4.1	1.53	68	1.49	200	129	71	26	.90	54
694	γ Per	A3* F5	. .	. .	s	3.08	<0.5	. .	*1.9*	2.80	50	2.85	176	91	45	. .	.73	39
708	β Per	B8	. .	**3**	o1	2.30*	*0.9:*	*0.3*	*2.9*	1.49	181	1.43	208	126	75	35	1.08	60
781	. .	cB9	. .	**−1**	s	4.42	. .	*5:*	*2.6*	2.22	46	2.21	75	35	. .	. .	.41	14
784	ξ Tau	B8	. .	**5**	s2	3.75	. .	0.6	3.0	1.49	78	1.45	280;	137;	83;	17;:	88;	66;
786	. .	cA0	.3	**−1**	s	4.76	. .	*5:*	0.0	2.47	42	2.44	72	38	. .	.	.45	15
817	ψ Per	B5ε	. .	**6**	. .	4.26	*0.6:*	. .	2.5	1.50	75	1.49	134	85	. .	. .	.39	27
838	δ Per	B5	. .	**3½**	. .	3.10	*1.8:*	. .	1.4	1.52	208	1.52	186	88	54	. .	.75	42
852	Electra	B5ε	. .	**4**	. .	3.81	<1.2	. .	2.4	1.44	73	1.36	168;	99;	60;	. .	.80;	44;
869	η Tau	B5ε	. .	**3**	. .	2.96	<0.4	. .	1.6	1.53	187	1.41	152	77	46	. .	.69	36
932	ν Tau	A0	.3	**6**	. .	3.94	<1.3	1.4	*1.9*	1.52	73	1.48	387	191	135	54	1.18	100
1046	θ² Tau	F0	. .	**4½**	o1+	3.62	0.6*	. .	3.7	1.80	67	1.81	331;	183;	103;	43;	1.17;	88;
1220	β Eri	A3	. .	**5½**	. .	2.92	1.5*	. .	3.2	1.81	35	1.80	339:	186	111	49	1.15	88:
1250	β Ori	cB8	. .	**−1**	o1	0.34 6.66	<*3.0*	*5:*	*9.7*	1.46	60	1.52	57	31	. .	. .	.49	11
1262	τ Ori	B5	. .	**3**	s	3.68	<1.1	. .	*0.3*	1.32	28	1.32	159	85	52	11	.81	40
1304	β Tau	B8	. .	**2½**	. .	1.78	<*0.2*	*0.5*	3.0	1.48	75	1.50	186	91	54	23	.89	43
1478	β Aur	A0p	.9	**4**	o2	2.8* 2.8	0.0 0.0	0.7 0.7	1.1 1.1	1.71	75	1.75	362	193	131	63	1.40	103
1482	θ Aur	A0p	*.2*	**2**	. .	2.71 7.5	<0.1	*0.9*	2.8	1.54	75	1.51	211	112	69	32	1.08	56
1657	. .	cA0	.0	**0**	. .	4.50	. .	*3:*	*0.5*	1.63	33	1.63	140	65	40	. .	.72	30
1690	γ Gem	A0	.8	**3**	o1	1.93	0.1	0.1	1.0	1.62	178	1.57	273	163	108	52	1.39	84:
1732	α CMa	A0	.1	**6**	o1	*1.58* 8.44	1.3	1.2	4.0	1.56	19	1.56	325	193	125	57	1.20	94
1763	θ Gem	A2	.8	**3½**	s	3.64	<1.0	0.4	2.3	1.75	71	1.82	270	168	100:	43	1.26	78:
1886	λ Gem	A2	1.0	**5**	s	3.65	1.5:	. .	2.8	1.83	58	1.98	307;	191;:	116;	59;	1.24;	89;:
1898	δ Gem	F0	. .	**3**	s	3.51	2.4	. .	0.5	2.21	88	2.22	242	108	57	. .	.86	53

SYNOPSIS OF OBSERVATIONS

Hδ						K						Line depth in hundredths of magnitudes								
$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	Mg+	He	Fe+	Ca	Sr+	Si+	Sr+	Fe	He
.96 (20)	.83 (21)	.69 (22)	.48 (23)	(24)	(25)	.96 (26)	.83 (27)	.69 (28)	.48 (29)	(30)	(31)	4481 (32)	4471 (33)	4233 (34)	4227 (35)	4216 (36)	4128–31 (37)	4078 (38)	4046 (39)	4026 (40)
220	112	70	29	1.13	58	26	..	..	..	.11	2	7	5	..	..	..	7	..	..	7
336	207	122	56	1.60	99	91	56	39	20	1.29	29	14	..	..	13	..	6	9	11	..
355	210	127	56	1.49	102	94	55	39	21	1.34	29	12	..	..	13	..	7	8	7	8
270	158	107	51:	.95	77	49	..	..	..	.12	4	..	..	..	..		14	8		..
337	204	116:	49	1.41	96	82	46	31	..	1.13	23	8	..	..	9		9	14	12	..
240	151	89	42	1.34	71	51	..	..	..	.19	6	7	..	..	5	5	19	16	..	
360	180	111	47	1.27	92	82	54	36	16	1.00	25	6;	..	..	6;		6;	6;	6;	..
311	197	130	53	1.31	94	97	55	34	..	.64	23	5	..	..	8	7	9	21	..	..
356	222	134	59	1.40	105	75	41	25	..	.66	18	10	..	..	..	..	..	..	..	..
200:	126	85	32	1.00	57	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9
184	95	52	..	.78	42	215	106	59	19	1.01	51	..	..	..	31	16	..	22	22	..
206;	126;	74;	36;	1.15;	57;	29	..	..	..	.11	2	8	8	..	..	..	5	..	..	13
59	32	16	..	.51	13	49	14	..	..	.24	7	12	6	5	..	..	12	..	..	7
278	125	82	36	.99	65	..	..	..	..	.08	2	6	7	..	..	..	..	..	..	9
59	36	21	..	.53	14	41	..	..	..	.26	6	15	..	10	..	..	17	..	..	6
143	81	42	..	.56	32	..	..	..	..	.06	..	6	13	..	..	..	..	..	..	18
144	84	53	14	.85	38	..	..	..	..	.05	..	7	12	..	..	..	5	..	..	18
156;	99;	63;	22;	.94;	45;	..	..	..	..	..	..	5;	8;	..	..	..	..	..	..	17;
155	82	49	..	.84	39	..	..	..	..	..	..	5	6	..	..	..	8	..	..	14
367	193	123	56	1.34	98	48	23	..	..	.39	9	6	..	..	..	..	..	..	..	..
313;	152;	100;	40;	1.27;	79;	89	64	45	27	1.46	32	..	..	..	16;	..	..	15;	10;	..
332	193	108	53	1.26	91	82	55	36	14	.93	24	9	..	..	..	..	9	..	7	..
53	27	..	..	.53	11	34	14	..	..	.24	4	18	14	..	..	..	14	..	..	16
159	85	58	23	.96	41	..	..	..	..	..	..	9	12	..	..	..	5	..	..	21
181	84	53	23	.96	44	..	..	..	..	.05	1	6	10	..	..	..	5	..	..	15
308	184	125	62	1.48	95	61	29	..	..	.48	12	10	..	..	..	..	5	..	..	..
197	106	64	37:	1.17	54	..	..	..	..	.06	..	..	..	..	..	..	17	..	..	..
116	59	40	15	.95	30	26	..	..	..	.24	3	6	..	5	..	..	8	..	..	9
266	163:	111	53:	1.51	85:	50	25	16	..	.63	11	9	..	..	..	..	7	..	..	..
307	185	122	62	1.28	91	36	..	..	..	.18	4	7	..	..	..	..	8	..	..	..
274	153	90	42	1.34	75	86	46	36	..	1.08	25	9	..	..	7	..	5	7	..	..
307;	191;	121;	62;	1.37;	91;	76	48	36	..	1.13	24	9;	..	..	..	..	8;	..	..	..
229:	103	55	18	.95	51	161	81	59	32	1.58	47	..	..	..	20;	6;	..	21;	16;	..

Boss (1)	Name (2)	H D Class (3)	Sub-division of H D Class (4)	Line Grade (5)	Sp. Bi. (6)	m (HR) (7)	M trig. or cluster (8)	M_{sp} (Wms.) (9)	H (10)	c_2/T compiled (11)	Wt. for c_2/T comp. (12)	Williams Observed c_2/T (13)	Hγ					
													$s(\nu-\nu_0)$ at r =				Depth in Mags. (18)	Total Abs. (19)
													.96 (14)	.83 (15)	.69 (16)	.48 (17)		
1944	β CMi	B8ε	..	**5**	s?	3.09	0.5:	0.2	2.2	1.44	77	1.40	200	117	75	..	.87	55
1979	α Gem	A0	.3: ..	**6:** ..	o1 o1	1.99: 2.85	1.3 2.2	1.4: ..	3.5 4.4	1.59	186	1.55	400	209	142:	65:	1.27	110
2237	..	A0	.3	**5**	..	3.95	<1.4	0.7	3.1	1.52	36	1.48	331	190	125	57	1.23	95
2404	ι UMa	A5	..	**5**	..	3.12	2.3:	..	6.6	1.94	101	1.89	360	196	106	45	1.22	91
2424	κ UMa	A0	.8	**2**	..	3.68*	..	_0.8_*	3.0	1.60	78	1.58	240;	139;	91;	48;	1.30;	71;
2443	..	A3p	..	**3½**	..	4.54	..	..	5.2	2.17	70	2.07	297:	171	97	34	1.05	78
2479	θ Hya	A0	.0	**4**	s2	3.84	<1.2	0.3	6.5	1.52	61	1.56	288	157	105	57	1.26	82
2495	..	A2	.2	**5:**	..	4.00 5.85	1.3: ..	1.4: ..	4.6 6.4	1.76	90	1.74	358:	186	122	55	1.25	96:
2540	..	F0	..	**3**	..	3.75 9	1.0: ..	.. ..	4.0 ..	2.20	89	2.27	213	112	62	22	.95	52
2602	ο Leo	A3 F5	..	..	o2	3.76	1.4:	..	4.6	2.54	55	2.60	213	94	46	..	.86	45
2632	υ UMa	F0	..	**2½**	..	3.89	..	..	1.3	2.06	87	2.05	271	128	69	31	1.13	65
2694	η Leo	cA0	.1	**0**	..	3.58	..	_3½_:	_1.1_	1.50	94	1.48	103	60	39	..	.74	26
2698	α Leo	B8	..	**4**	..	1.34	_0.1_	_0.1_	3.3	1.45	105	1.41	193	106	66	23	.87	49
2729	λ UMa	A2	.1	**4**	..	3.52	<0.9	0.8	4.6	1.66	91	1.65	331	180	119	51	1.35	93
2730	ζ Leo	F0	..	**2**	s	3.65	<1.0	..	0.8	2.04	91	2.11	243	111	62	26	1.09	58
2930	β UMa	A0	.5	**4**	s?	2.44:	0.8	0.6	2.2	1.57	196	1.47	293	182:	122	60	1.38	91
2972	δ Leo	A3	..	**5**	..	2.58	2.0	..	4.2	1.84	185	1.67	373	211:	137	57	1.37	107
2974	θ Leo	A0	.9	**2½**	s?	3.41	<0.8	_0.3_	3.5	1.61	76	1.57	257	149	103	57	1.48	80
3101	β Leo	A2	.6	**6**	..	2.23	2.2	2.0	5.8	1.75	91	1.67	407;	220;	140;	62;	1.31;	113;
3117	γ UMa	A0	.7	**4½**	s?	2.54	<0.6	0.9	2.4	1.63	95	1.59	316	177	119	54	1.23	90
3190	δ UMa	A2	.4	**5**	..	3.44	1.7	1.4	3.6	1.71	104	1.67	368	200	128	59	1.32	100
3210	η Vir	A0	.8	**3**	o2	4.00	..	0.1	3.1	1.59	41	1.59	285	165	108	57	1.33	83
3281	κ Dra	B5ε	..	**4**	o1	3.88	<1.3	..	2.8	1.45	76	1.52	176	86	46	..	.62	36
3307	γ Vir	F0 F0	.. ..	**3:** **3:**	 s?	3.65 3.68	2.9: 2.9:	.. ..	7.4 7.4	2.20	48	2.26	236	114	65	..	.72	52
3363	ε UMa	A0p	.3	**3**	o2*	1.68:	_0.2_	0.0	1.9	1.59	200	1.50	257	154	102	51	1.43	78:
3370-1	α CVn	A0p	.0 ..	**2:** ..	* ..	2.90: 5.39	<0.3 ..	_0.8_: ..	4.7 ..	1.58	95	1.54	205	100	64	28	.96	50
3474	ζ¹ UMa	A2p	.1	**4:**	o2	3.1:* 3.1:	1.3 1.3	0.8: 0.8:	3.6 3.6	1.70	189	1.74	328	193	137	55	1.34	99
3475	ζ²	A2	..	..	s?	3.96	..	..	4.5									
3506	..	A2p	.5	**4**	s	4.93	0.8*	0.8*	3.5	1.65	86	1.83	262	168	109	57	1.27	80
3508	ζ Vir	A2	.6	**6**	..	3.44	1.3:	2.0	5.7	1.72	80	1.67	370	205	139	60	1.30	105
3626	α Dra	A0p	.3	**2**	o1	3.64:	..	_0.8_	2.3	1.57	83	1.56	230	135	94	48	1.52	72
3639	..	A0p	_.4_	**4**	s	4.90	..	0.2	3.8	1.45	45	1.52	205	122	75	29	.92	55
3722	γ Boo	F0*	..	**6**	..	3.00:	..	..	4.3	1.93	108	1.96	325	173	94	..	.97*	79*
3772	..	A0	.3	**4**	..	3.76	<1.2	0.5	4.1	1.53	75	1.56	297	160	109	59	1.31	85
3890	β Lib	B8	..	**3½**	s	2.74	..	_0.2_	2.8	1.30	33	1.27	176	91	57	..	.81	41
3928	γ UMi	A2	.5	**1**	o1*	3.14:	..	_2_:	_0.8_	1.70	98	1.78	177	115	71	42	1.35	58
3940	β CrB	F0p	..	**3**	o1*	3.72	..	..	5.1	2.09	99	2.08	310	179	103	48	1.37	85
3961	α CrB	A0	.5	**4**	o1	2.31	0.4	0.6	3.3	1.55	198	1.69	297;:	177;	123;	60;	1.48;	92;

Hδ						K						Line depth in hundredths of magnitudes								
$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	Mg+	He	Fe+	Ca	Sr+	Si+	Sr+	Fe	He
.96 (20)	.83 (21)	.69 (22)	.48 (23)	(24)	(25)	.96 (26)	.83 (27)	.69 (28)	.48 (29)	(30)	(31)	4481 (32)	4471 (33)	4233 (34)	4227 (35)	4216 (36)	4128–31 (37)	4078 (38)	4046 (39	4226 (40)
188	121	81	..	1.00	55	..	..	..	..	.05	..	6	6	..	..	..	..	..	..	8
348:	206	129	63	1.38	101	53	34	..	..	.32	9	6	..	..	..	..	6	..	..	..
325	180	122	60	1.35	94	40	..	..	..	.22:	5	6	..	..	..	..	..	..	..	..
341	180:	108	45	1.27	89	99	64	46	27	1.61	34	13	..	..	15	..	10	11	9	..
211	123	88	48	1.41	66	68	34	..	..	.41	12	8	..	..	..	..	..	..	..	..
278	136	78	29	1.16	68	131	55	34	..	.88	29	15;*	..	..	18	7	21*	27	20	..
259	152	112	59	1.38	81	..	..	..	..	.12	2	..	..	..	..	..	5	..	..	..
314	175:	112	58	1.30	88	91	46	28	..	.55	19	9	..	..	..	..	..	..	..	..
215	105	59	19	.94	51	175	94	65	39	1.67	53	..	..	..	22;	8;	..	19;	18;	..
178	88	45	..	.87	40	216	87	61	26	1.30	52	..	..	..	21	13	23	41	23	..
262	123	71	26	1.11	62	104	75	56	34	1.95	42	..	..	..	22	8	..	21	17	..
100	58	34	15	.92	26	38	..	..	..	.22	5	10	..	5	..	..	10	..	..	7
185	103	70	25	.93	49	..	..	..	..	.05	..	6	7	..	..	..	..	..	..	10
321	177	116	58	1.44	92	61	29	..	..	.62:	13	9	..	..	6	..	5	5	..	..
215	111	75	26	1.16	57	181	99	74	49	>2.00	>59	..	..	..	24	12	..	25	16	..
285	173:	125	63	1.48	90	46	24	..	..	.38	8	6	..	..	..	..	5	..	..	..
325	180	125	58	1.41	95	86	53	36	17	1.13	26	9	..	..	10	..	7	6	6;	..
244	155	111	64	1.67	82	70	31	..	..	.62	14	8	..	..	..	..	6	..	..	..
352;	212;	138;	59;	1.44;	106;	73	39	33	..	.88	19	13;	..	..	7;	..	7;	6;	6;	..
316	174	119	56	1.34	91	51	25	..	..	.33	9	7*	..	..	..	..	5*	..	..	..
332	184	123	63	1.40	96	65	42	..	..	.68	17	10	..	..	6	..	..	..	5	..
284	163	116	58	1.52	86	64	28	..	..	.60	12	10	..	..	..	..	8	5	..	..
148	82	52	..	.80	37	..	..	..	..	..	..	6	14	..	..	..	..	..	..	20
203	100	62	..	.73	46	179	91	64	39	>1.20	>51	..	..	..	20: 18:	.. ..	.. ..	26: 26:	22: 20:	.. ..
232	152	105	53	1.57	78	..	..	..	..	.16:	3	9;	..	..	..	..	6;*	..	..	..
174	105	64	30	1.04	49	..	..	..	..	.05	..	..	..	..	..	..	14	..	..	..
297	192	132	62	1.47	97	48	27	19	..	.63	11	15	..	..	6	..	..	8	..	..
274	167	111	56	1.44	83	150	70	..	..	.45	24	7	..	..	5	7	19	21	..	..
358	218	133	66	1.42	107	84	49	33	..	.79	21	9	..	..	..	..	7	5	..	..
210	134	96	53	1.61	70	39	..	..	..	.27	5	13	..	*	..	..	..	..	..	5
212;	122;	73;	37;	1.03;	56;	29	..	..	..	.09	2	..	..	..	..	..	19	..	..	..
292	167	99	34	1.04*	75*	96	60	..	..	1.14*	29*	..	..	..	12	6	..	14	11	..
264	169	114	66	1.34	85	58	..	..	..	.24	7	5	..	..	..	..	7	..	..	..
161	93	62	19	.89	43	..	..	..	..	..	..	7	6	..	..	..	6	..	..	12
147	105	73	41	1.37	52	69	48	31	10	.89	21	12	..	5	..	..	..	..	..	..
..*	..	..	..	1.35	..*	244	107	66	36	1.22	59	..	..	..	21	19	..	34	18	..
302;	182;	119;	62;	1.54;	93;	58;	..	..	..	.32;	9;	10;	..	..	..	..	7;	..	..	5;

													Hγ					
													$2(\nu-\nu_0)$ at r =					
Boss (1)	Name (2)	H D Class (3)	Sub-division of H D Class (4)	Line Grade (5)	Sp. Bi. (6)	m (HR) (7)	M trig. or cluster (8)	Msp (Wms.) (9)	H (10)	c_2/T com. piled (11)	Wt. for c_2/T comp. (12)	Williams Observed c_2/T (13)	.96 (14)	.83 (15)	.69 (16)	.48 (17)	Depth in Mags. (18)	Total Abs. (19)
3998	γ CrB	A0	.7	**3½**	s2	3.93 7.0	<1.3	0.5	4.0	1.61	82	1.60	302	171	109	49	1.25	84
4009	β Ser	A2	.4	**5**	..	3.74	0.7	1.4	3.5	1.69	91	1.58	323	193	134	59	1.37	97
4016	μ Ser	A0	.3	**3**	..	3.63	<1.0	0.0	3.4	1.58	33	1.61	268;	163;	105;	51;	1.38;	80;
4026	ε Ser	A2	1.0p	**5**	..	3.75	1.1:	..	4.3	1.81	72	1.78	367	205	140	60	1.48	105
4112	φ Her	B9p	..	**3**	..	4.26	<1.7	*0.2*	1.8	1.53	101	1.60	239	131	85	37	1.12	65
4162	τ Her	B5	..	**3**	..	3.91	..	..	1.5	1.39	103	1.33	216	106	60	18	.87	50
4165	γ Her	F0	..	**4**	..	3.79	<1.2	..	2.8	2.06	95	2.04	285	165	83	38	1.19	75
4182	ω Her	A0p	.2	**3**	..	4.53	..	0.1	3.9	1.69	46	1.74	263	159	106	52	1.28	81:
4203	λ Oph	A0	.5	**5**	s	4.0 6.1	<1.4	1.1	4.0	1.53	65	1.54	345;	197;	132;	57;:	1.31;	99;
4213	..	B8p	..	**2½**	s2	4.98	2.6::	..*	3.1	1.58	72	1.65	271	137	91	48	1.18	73
4284	..	A2p	.7	**5**	..	4.86 10.	<2.3	1.6	4.2	1.75	50	1.77	314	186	132	60	1.31	96
4328	ε Her	A0	.3	**4**	o2	3.92	<1.3	0.5	2.5	1.57	78	1.65	294	182	120	63	1.45	91
4368	ζ Dra	B5	..	**2½**	..	3.22	1.2:	..	0.1	1.43	97	1.45	193	100	63	21	.98	50
4376	δ Her	A2	.4	**5**	s	3.16 8.	0.5:	1.4	4.3	1.77	84	1.87	362	189	118	48	1.17	96
4459	α Oph	A5	..	**6:**	s2	2.14	0.6	..	4.1	1.78	102	1.64	362	194	111	43	1.16	94
4500	γ Oph	A0	.2	**6**	s2	3.74	<1.1	1.3*	3.3	1.45	47	1.44	364;	214;	140;	65;	1.31;	106;
4548	..	cB5	..	**0**	s?	3.92	<1.3	..	*0.4*	1.58	43	1.59	117	51	26	..	.58	23
4581	..	A3	..	**6**	s2	3.73	1.6:	..	3.8	1.82	51	1.84	425	237	139	54	1.38	114
4584	o Her	A0	.4	**2½**	..	3.83:	<1.2	*0.3*	*3.2*	1.60	112	1.67	240	140	88	40	1.19	68
4670	φ Dra	A0p	.0	**4:**	s2 ..	4.4 6.5	.. ..	0.3 ..	1.9 ..	1.52	45	1.56	226	129	86	34	1.07	63
4722	α Lyr	A0	.5	**4**	..	0.14:	0.6	0.6	2.8	1.60	199	1.58	322:	188	125	55	1.39	96
4824	γ Lyr	A0p	.2	**1**	s2?	3.30:	<0.7	*2:*	*2.2*	1.58	112	1.64	190	106	69	34	1.22	54
4858	ζ Aql	A0	.5	**5**	s	3.02	1.0:	1.1	3.0	1.62	96	1.55	341	177	120	55	1.26	93
4859	λ Aql	B9	..	**4**	..	3.55	1.4:	0.1	3.4	1.46	44	1.41	236	146	91	43	1.17	69
4953	δ Aql	F0	..	**3**	s	3.44	2.2	..	5.6	2.16	91	2.32	290	146	66	32	1.16	69
4988	ι Cyg	A2	1.0	**5**	..	3.94	<1.3	..	4.4	1.81	81	1.83	330	192	109	46	1.18	91
5048	δ Cyg	A0	.3	**2**	..	2.97:	..	*0.8*	2.0	1.53	111	1.46	230	135	88	45	1.34	69
5062	α Aql	A5	..	**5½**	..	0.89	2.4	..	5.0	1.99	208	2.01	382	216	125:	46	1.20	102
5171	θ Aql	A0	.1	**2**	o2	3.37	<0.8	*0.8*	0.9	1.54	43	1.53	234	142	91	51	1.40	72
5272	ε Del	B5	..	**2**	s	3.98	<1.4	..	1.2	1.43	49	1.43	182	102	58	25	1.02	49
5310	α Del	B8	..	**2**	..	3.86	<1.3	*0.8*	2.9	1.52	91	1.49	223	137	85	48:	1.31	68
5320	α Cyg	cA2	.0	**−1**	s	1.33:	*<2.0*	*5:*	*8.7*	1.66	211	1.61	77	48	29	..	.69	20
5337	ε Aqr	A0	.7	**3½**	..	3.83	<1.2	0.5	2.0	1.43	27	1.43	300	191	122	60	1.42	93
5443	γ Equ	F0p	..	**5**	..	4.76	<2.4	..	5.9	2.23	51	2.16	364	214	123	49	1.25	99
5460	τ Cyg	F0	..	**3**	o1 ..	3.82 7.5	2.3	..	7.1	2.33	100	2.24	210	108	57	..	.90	51
5469	σ Cyg	cA0	.2	**−½**	s	4.28	<1.7	*4:*	*1.2*	1.90	49	1.92	89	48	28	..	.65	21
5480	α Cep	A5	..	**5½**	..	2.60	2.2	..	3.6	1.93	63	2.04	288	191:	106:	45	1.12	83:
5608	ν Cep	cA2	.0	**−1**	..	4.46	..	*5:*	*4.0*	2.56	43	2.56	79	52	32	..	.68	21
5663	o Aqr	B5ε	..	**6**	..	4.66	..	..	0.8	1.39	43	1.41	183	95	51	..	.57	40

Hδ						K						Line depth in hundredths of magnitudes								
$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	Mg+	He	Fe+	Ca	Sr+	Si+	Sr+	Fe	He
96 (20)	.83 (21)	.69 (22)	.48 (23)	(24)	(25)	96 (26)	.83 (27)	.69 (28)	.48 (29)	(30)	(31)	4481 (32)	4471 (33)	4233 (34)	4227 (35)	4216 (36)	4128–31 (37)	4078 (38)	4046 (39)	4026 (40)
289	166	111	60	1.38	85	54	24	..	..	.35	9	8	..	..	..	..	6	..	..	..
315	197	122	59	1.41	95	79	48	30	..	.68	19	10;	..	..	..	..	9	..	6	..
256;	158;	96;	55;	1.51;	77;	39;	..	..	..	.28;	5;	10;	..	..	..	..	5;	..	..	.
355	215:	129	59	1.59	104:	64	34	19	..	.75	15	12	..	13	16	11*	16	19	14	..
219	129	89	42	1.27	66	35	..	..	..	.17	4	7	7	..	..	..	10	..	..	11
185	97	56	22	.94	45	..	..	..	..	..	..	10	20	..	..	..	..	..	..	27
262	142	92	34	1.21	71	179	91	66	42	1.90	56	..	..	..	20	5	..	20	18	..
237	148	100	49	1.49	77	..	..	..	..	.09	..	..	..	..	..	..	7	5	..	..
321;	189;	127;	59;	1.43;	96;	55;	26;	..	..	.46;	10;	8	..	..	..	..	5	..	..	..
218	130	92	49	1.30	67	44	..	..	..	.21	5	8	..	..	..	..	7	..	..	9
338	182	127	55	1.41	96	116	50	..	..	.44	21	8	..	..	..	11	23	25	..	..
290	169	116	63	1.53	89	39	..	..	..	.23:	5	10	..	..	..	..	..	*	..	9
169	100	64	26	1.06	48	..	..	..	..	.06	..	9	11	..	..	..	6	..	..	17
328	182	108	51	1.21	88	73	35	..	..	.45	13	6	..	..	..	..	..	..	..	..
344	182	110	47	1.21	90	96	60	37	19	1.06	28	10	..	..	10	..	10	..	7	..
307;	200;	129;	66;	1.42;	97;	54	..	..	..	.21	6	8	..	..	..	..	..	..	..	..
81	45	25	..	.61	18	31	..	..	..	.23	4	9	21	..	..	..	9	..	..	25
388	220	127	56	1.47	107	85	59	41	20	1.29	29	12	..	..	12	..	9	7	9	..
208	126	81	45	1.27	63	46	..	..	..	.18	5	7	..	..	..	..	5	..	..	..
218	131	85	37	1.13	63	35	..	..	..	.12	3	11	..	..	..	..	11	..	..	..
308:	188	127	64	1.52	96:	46	15	..	..	.31:	6	8	..	..	..	..	..	..	..	..
163	103	67	34	1.31	51	39	..	..	..	.13	3	8	..	5	..	..	..	..	..	..
308	182	119	62	1.32	91	55	31	..	..	.14	5	5	..	..	..	..	..	..	..	..
237	136	89	45	1.24	68	..	..	..	..	.06	..	10	6	..	..	..	7	..	..	8
254	126	75	29	1.13	63	179	89	64	39	>1.75	>54	..	..	..	25	11	..	18	16	..
290	164	103	45	1.23	81	87	54	36	..	.84	24	8	..	..	6	..	11	6	..	..
199	130	90	49	1.39	66	51	16	..	..	.24	7	11	..	..	..	..	6	..	..	7
337	171	103	42	1.25	86	107	64	46	24	1.20	33	11	..	..	11	..	9	7	10	..
207	130	92	51	1.52	68	31	..	..	..	.21	4	15	5	..	..	..	8	..	..	8
152	96	59	29	1.12	45	31	..	..	..	.11	3	10	14	..	..	..	9	..	..	25
201	133	92:	53	1.44	68	44	..	..	..	.20	5	8	6	..	..	..	7	..	..	11
70	38	25	..	.72	17	56	24	12	..	.50	11	18	..	18	..	..	19	..	..	..
260	166	112	63	1.61	86	61	32	..	..	.45	12	11	..	..	..	..	6	..	..	..
298:	163:	99:	42	1.35	82:	231	152	94	44	1.15	69	..	..	..	18	29	..	44	14	..
202	96	45	..	.90	45	219	109	74	46	1.79	63	..	..	..	28	8	..	21	16	..
85	51	30	..	.78	22	36	..	..	..	.27	5	17	..	13	..	..	18	..	..	12
311:	163	96	42	1.16	80	97	64	50	35	1.21	33	11	..	..	12	..	9	6	6	..
79	45	30	..	.77	20	65	27	..	..	.39	11	17	..	17	..	..	16	..	..	..
169	94	53	..	.73	41	..	..	..	..	.06	..	7	9	..	..	..	6	..	..	12

Boss (1)	Name (2)	H D Class (3)	Sub-division of H D Class (4)	Line Grade (5)	Sp. Bi. (6)	m (HR) (7)	M trig. or cluster (8)	Msp (Wms.) (9)	H (10)	c_2/T compiled (11)	Wt. for c_2/T comp. (12)	William^{S} Observed c_2/T (13)	Hγ					
													$2(\nu-\nu_0)$ at r =				Depth in Mags. (18)	Total Abs. (19)
													.96 (14)	.83 (15)	.69 (16)	.48 (17)		
5703	θ Peg	A2	.1	**6**	s2	3.70	..	1.8	5.9	1.66	83	1.86	376	224	152	63	1.45	109:
5761	γ Aqr	A0	.1	**4**	s	3.97	*	0.4	4.4	1.43	69	1.41	279	176	119	57	1.36	87
5779	..	cB8	..	**0**	..	4.64	..	*3½:*	0.3	1.75	60	1.73	112	59	35	..	.76	27
5793-4	ζ Aqr	F2	..	**2:** **2:**	.. ..	4.42 4.59	1.4: 1.6:	.. ..	5.9 6.0	2.20	38	2.14	191	88	45	..	.82	41
5813	α Lac	A0	.7	**6**	..	3.85	1.5:	1.6	4.6	1.61	76	1.56	398:	222	146	69	1.45	114:
5853	ζ Peg	B8	..	**3½**	..	3.61	<1.0	0.0	3.1	1.48	90	1.49	225	134	91	43	1.19	67
5933	o And	B5* cA2	..	**3½**	s	3.63	<1.0	..	1.2	1.40	105	1.33	143	75	45	..	.71	35
5939	β Psc	B5ϵ	..	**5½**	..	4.58	..	..	0.1	1.36	38	1.33	208	112	66	..	.70	50
5944	α Peg	A0	.2	**2½**	s2	2.57	0.4:	*0.4*	1.9	1.41	82	1.38	232	146	97	48	1.35	72
6031	κ Psc	A2p	.0	**5**	..	4.94	3.0:	1.3	5.4	1.65	47	1.68	322	192	129	59	1.26	96

EXPLANATION OF TABLE I

Column 4, see page 24. This gives simply a finer subdivision of the very large classes A0 and A2, made with regard to total absorption of the K line and to c_2/T; thus: —.1 in connection with an A2 star indicates an early A2, i.e. A2.1; *.1*, in connection with an A2 star indicates a very late A0, i.e. A0.9; 1.1 in connection with an A0 star indicates that it probably should be classified as A2.1, (there being no class between A0 and A2).

Column 5, see page 26. Grade **6** contains lines which are widest for their depth; grade $-$**1** contains the lines which are narrowest for their depth. In the case of certain visual double stars, corrections have been applied to the lines measures listed in columns (14) to (25) in order to get a better idea of the line grade of the brighter component, but even so, the line grade is so uncertain that it is followed by a colon.

Column 6, o2 indicates that orbits have been derived for two components of spectroscopic binary; o1 indicates an orbit derived for one component; o1 + indicates orbit derived for one component and second spectrum seen or suspected; s indicates that star is a spectroscopic binary but no orbit has been derived; s2 indicates that a second spectrum is visible but no orbits have been derived. Most of the data were obtained from Lick Bulletin No. 355.

Column 7, a colon after the item in this column indicates that the star is a variable with a small range according to Guthnick and Prager [34] or Prager's catalog.

Column 8, absolute magnitudes derived from the Yale General Catalogue of Stellar Parallaxes supplemented by the card catalogue of parallaxes of the Leander McCormick Observatory. Negative absolute magnitudes are printed in italics. When a parallax was very small, (except in the case of cluster parallaxes) the absolute magnitude is given as less than an upper limit corresponding to a parallax of $0''.030$.

Column 9, see page 28. Negative absolute magnitudes are printed in italics.

Column 10, reduced proper motions. Negative values are in italics.

Columns 11 and 12, see page 20.

Column 13, see page 17.

Columns 14 to 40, see page 14. A semicolon following the item indicates that only two measures of an item were available, instead of the usual three. A colon indicates that the residuals were very large.

Columns 32, 34 and 37, lines 4481, 4233 and 4128–31 are so heavily blended with other lines in F0 stars that no measures have been listed. Perhaps the 4128–31 line is heavily blended in some earlier stars, too — see Remark on Boss 3363.

An asterisk in any column refers to "Remarks" for the star.

REMARKS

Boss	
10	Mn + lines unusually strong, cf. Baxandall [25, 36]; no series relationships nor excitation potentials yet known for these lines. See also Remarks for Boss 5310 and page 29.
203	All lines are deep.
422–3	Bu 993. On the microphotometer tracings the lines of the two components are 1 mm apart, Boss 422 gives 48% of the total light. In estimating the line grade it has been assumed that 422 is slightly earlier than A0 since λ4026 is well marked in it. The K line in 422 barely shows, whence, allowing for superposition of spectra, it follows that the K line of 423 is really about 0.25 mag deep with a total absorption of 8. Si + lines 4128–31 very strong in 423; but do not show in 422.
463	Bu 1061; The separation on microphotometer tracings is 0.2 mm. Faint component gives 30% of total light. Sr + very strong, also $\lambda\lambda$4128–31.
550	Bu 1262; Component B gives 11% of total light. Its lines are separated by 0.1mm from lines of component A on microphotometer tracing; Component C gives 4% of total light; its lines are separated by 0.3 mm from the lines of A.

Hδ						K						Line depth in hundredths of magnitudes								
2(ν−ν₀) at r =				Depth in Mags.	Total Abs.	2(ν−ν₀) at r =				Depth in Mags.	Total Abs.	Mg+	He	Fe+	Ca	Sr+	Si+	Sr+	Fe	He
.96 (20)	.83 (21)	.69 (22)	.48 (23)	(24)	(25)	.96 (26)	.83 (27)	.69 (28)	.48 (29)	(30)	(31)	4481 (32)	4471 (33)	4233 (34)	4227 (35)	4216 (36)	4128–31 (37)	4078 (38)	4046 (39)	4026 (40)
348	234	149	68	1.56	112	64	34	21	..	.64	14	9	..	..	5	..	..	..	..	..
256	168	114	58	1.50	84	39	..	..	..	.18	4	9;	..	..	..	..	6;	..	..	7;
86	53	34	..	.87	24	42	..	..	..	.21	5	15	12	7	..	..	15	..	..	15
148	86	37	..	.84	35	251	116	74	46	1.86	68	..	..	..	20	9	..	20	18	..
344	212	137:	70:	1.56	106:	58	25	..	..	.41	10	9	..	..	..	..	..	..	..	..
204	125	85	45	1.28	63	..	..	..	..	.06	..	7	..	..	..	..	6	..	..	9
125	73	45	..	.75	32	..	..	..	..	.06	..	..	13	..	..	..	5	..	..	19
189	105	67	..	.84	50	..	..	..	..	.05	..	9;	15;	..	..	..	6	..	..	24
212	136	97	48	1.42	69	41	14	..	..	.25	6	9	..	..	..	..	5	..	..	5
273:	181	125	58	1.34	88	84	24	..	..	.26	12	7	..	..	..	6	16	17	..	..

Boss	
	Probably the brightest component is an A2 star with abnormally strong Sr+, although Si+ is not abnormally strong. Broad character of K line probably due partly to composite spectrum.
622	Bu 1401; Component B gives 10% of total light; its lines are separated by 0.4 mm from the lines of A on the microphotometer tracings.
694	More probably a combination of gG5 and A0 of about eaual luminosities.
708	Eclipsing binary; three bodies; the lines have been identified by Baxandall.[37]
817	The helium lines are very broad as well as the hydrogen lines. Perseus cluster. M is derived from the cluster parallax.
838	The He lines are rather broad. Perseus cluster. M is derived from the cluster parallax.
852	Pleiades. The H.D. Catalogue remarks that λλ 4128–31 and 4481 are more intense than type whereas they do not seem to be according to these measures.
869	Pleiades. The He lines are broad.
1046	The brightest star of the Taurus cluster. H. D. Curtis [38] remarks that the velocity curve resembles that of a Cepheid. The total absorption of the K line and of the H lines would place this star in class A5 and so would the c_2/T value. It was classified as A5 in H.A. **28**, but when the recent plates were shown to Miss Cannon she again classified it as F0. Possibly it is a combination of an F0 star of M = 1.2 and an A2 star of M = 1.6.
1220	If this is a member of the Ursa Major cluster, which is doubtful, M = 0.5.
1250	Bu 2605. Component B gives ½% of total light. The lines of this star have been identified by Baxandall[37, 39].
1478	Spectroscopic Binary with components of approximately equal brightness; partially eclipsing. Combined magnitude 2.07. Ursa Major cluster. The cluster parallax makes the M of each component equal to −0.2 ± 0.2; the trigonometric parallaxes make M = 0.5 ± 0.5.
1482	Bu 3074. Component B gives 1% of total light. Si+ very strong.
1732	Bu 3596. Component B gives less than ½% of total light. Ursa Major cluster. The lines of the star have been identified by Baxandall[37,39].
1944	He lines broad.
1979	Bu 4122. Component B gives 31% of total light. Its lines are separated by 0.6 mm from lines of component A on microphotometer tracings.
2424	The H.D. Catalogue remarks that the lines are wide, whereas the H line grade is distinctly narrow. The K line is a bit wide. The star is a close double discovered by Aitken[40] in 1907 when the magnitudes of the two components were estimated as 4.0 and 4.2. The distance of the components then was 0″.21. In 1921 according to Merrill[41] the distance was only 0″.08.
2443	According to the H.D. Catalogue this is probably a composite spectrum on account of the great strength of the metal lines. On this supposition the narrow K line is hard to explain. The ratio of Ca+ to Ca is much smaller than average, and according to Milne[42] this indicates that g is larger than the average. In the paper referred to, Milne treats the case of much lower temperatures, but in a conversation he indicated that this conclusion would also hold with higher temperatures. The large line depths of λ 4481 and λλ 4128–31 are doubtless due to blends, as in F stars. See also ε Serpentis Boss 4026.
2495	Bu 5014. Component B gives 15% of the total light. Its lines are separated by 0.2 mm from the lines of A on the microphotometer tracings. The very broad K line represented by the measure is doubtless due to the strong K line of component B.
2540	Bu 5104. Component B gives 1% of total light.
2698	Bu 5331. Component B gives less than ½% of total light. He lines broad.
2930	Ursa Major cluster.
2972	Ursa Major cluster.
3117	Estimates of the depths of the fine lines based on 1 tracing only. Ursa Major cluster parallax makes M = 0.6 while trigonometric parallax makes it considerably brighter.
3190	Ursa Major cluster.
3281	He lines broad.
3307	Bu 6243. Component B gives 49% of the total light. Its lines are separated from the lines of A by 0.6 mm on the microphotometer tracings.

Boss

3363 Ursa Major cluster. Second spectrum faint. Three bodies (?). The lines in this star have been identified by Baxandall.[43] He finds Cr+ very much stronger here than in either α Canis Majoris or α Cygni. But a different set of Cr+ lines are strong from the ones which appear in α Persei and in the Sun (cf. Dunham and Moore[44]). Baxandall finds that the Si+ lines at 4128–31 are much weaker than in Sirius, but that two other lines at 4128.9 and 4132.6 are very strong. The first may be due to Fe+; the second may correspond to the unidentified line at 4132.540 of intensity 3 in the solar spectrum. Also other lines of unknown origin.[36]

3371 Bu 6313. α^1 gives 9% of total light. Its lines are separated from the lines of α^2 by 1.7 mm. In the spectrum of the brighter star there are three groups of lines:— a group with constant velocity H, Si+, Fe, and Mg+; two groups with variable velocity and variable intensities, each group being of maximum intensity at maximum velocity of approach, the maximum intensity of one group occurring at the time of minimum intensity of the other. Many lines in one group being identified as being due to Europium. Period 5.5 days. Since 1927 fine bright lines have appeared in the spectrum. Cf. Belopolsky[45,46], Kiess[47], Baxandall[48]. Total light from star also varies in period of 5.5 days.

3474–5 ζ^2 gives 19% of total light. Its lines are separated from the lines of ζ^1 by 1.6 mm on the microphotometer tracings. The two spectroscopic components of ζ_1 are of about equal brightness. Ursa Major cluster.

3506 Si+ and Sr+ very strong. Possibly the very wide shallow K line is due to a composite spectrum — it appears double on two plates. If that is so, the classification should be more like A0 and A5, and the spectroscopic absolute magnitude would be brighter. Ursa Major cluster.

3626. The H.D. Catalogue remarks that 4128–31 are strong whereas on these plates they seem a bit less intense than the average. The plates on which the H.A. **28** classification was made were reviewed. It was concluded that the Si+ lines are certainly no stronger than in the average A0 star but that the narrowness of the wings of Hδ (line grade 2) might lead to an overestimate of the strength of 4128–31. See also the similar case of γ Lyrae Boss 4824. The Fe+ lines are stronger than usual, although λ 4233 was not quite intense enough to be listed in the table.

3639 Si+ lines strong. On one plate λ 4026 of He shows very plainly, but it barely shows on three other plates.

3722 Variable according to Guthnick and Prager[34] with an amplitude of 0.05 magnitude and a period of 0.3 day but Frl. Dr. Güssow[49, 50] who has followed it more recently finds the variations sporadic and decreasing. The line measures showed such large residuals that additional spectrograms were obtained to determine whether the absorption lines vary: — six taken on a single plate on one night; five taken on another plate on another night; and eleven taken on two plates on a third night, twenty-two in all. The exposures were twenty-five minutes each with five minutes in between so that the run of eleven spectrograms covered about five and one half hours. The evidence is none too convincing. If the "variation" be regarded as due to accidental errors, then the residuals from the twenty two supplementary spectrograms for the H lines of γ Bootis are only about 75% greater than the average residuals for A5 and F0 stars. And the residuals for the K line are about equal to the average. Results are shown in Figure 8. According to the measures of the H and K lines and to c_2/T this star is closer to A5 than to F0.

3772 The K line is so wide that a composite spectrum is suspected.

3928 Range and shape of velocity curve varies. Period $2\frac{1}{4}$ hrs. Mass function 0.00003. Probably not a real binary (Struve[51]). The Ti+ and Fe+ lines are unusually strong for an A2 star.

3940. Triple system (?). It was impossible to measure the contour of Hδ on account of strong superimposed lines. Sr+ lines very strong and several multiplets believed due to neutral Vanadium are conspicuous. If the identification is correct the multiplets originate from the a^6D and a^4F' levels (E.P. <0.3 volts!). The Ti+, Fe+, and Fe lines seem no stronger than the other F0 stars. The K line is relatively very shallow for its width. It is difficult to suggest a composite spectrum to account for all these peculiarities. See also γ Equ, Boss 5443.

3961 Ursa Major cluster. Eclipsing binary with 0.1 mag. variation.

3998 Bu 7368. Component B gives $2\frac{1}{2}$% of total light. Its lines are separated from the lines of component A by less than 0.1 mm on the microphotometer tracings.

4009 Ursa Major cluster. The cluster parallax gives $M = 0.5 \pm 0.2$. The trigonometric parallax gives $M = 1.3 \pm 0.6$.

4026 The metal lines are extraordinarily strong for an A2 star. Probably the intensity of the lines at 4128–31 is caused by the Fe lines, for the Si+ lines at 3854–62 are not particularly intense. The ratio of Ca+ to Ca is much smaller than the average. This star is hotter than Boss 2443 but its peculiarities look as if they might be laid to the same cause, perhaps a large g? See remarks for Boss 2443.

4112 The H.D. Catalogue calls this peculiar because of its strong K line together with strong He lines. This also occurs in α Delphini, B8 and α Andromedae A0p although the Mn+ lines are not seen in this star.

4182 The K line is very weak considering that the He lines do not show. The line at 3918 which does not seem to have been satisfactorily identified is as intense as the K line. The Fe+ lines show fairly well.

4203 Bu 7649. Component B gives 13% of total light. Its lines are separated by less than 0.1 mm from the lines of component A.

4213 Probably A0 and B8 combined. K line is broad. Very roughly $M = -0.4$ for each component.

4284. Bu 7779. Component B gives 1% of total light. Sr+ very strong. K very shallow for its width.

4328 λ 4078 shows rather intensely (line depth = .18 mags.) on one plate, but scarcely at all on the other two.

4376 Bu 7922. Component B gives 1% total light.

4459 The relative velocities of the two spectra is 200 km and there being no orbit, two photographs seem to have been taken when the lines were apart. Hence the line grade is probably too wide.

4500 K line wide. Probably due to spectrum of fainter late type star. Thus probably M_{sp} is not bright enough.

Boss	
4670	Bu 8578. Component B gives 12% of total light. Its lines are separated from the lines of component A by less than 0.1 mm on the microphotometer tracings. Si+ strong. Perhaps the strong 4481 belongs to the other component of the spectroscopic binary.
4824	The remark under α Draconis Boss 3626 about the lines at 4128–31 applies also to γ Lyrae, except that on one of the four plates from which γ Lyrae was originally classified the lines 4128–31 do look somewhat more intense than in the average A0 star. On the other three plates the lines were certainly not more intense than the average. Like α Draconis, γ Lyrae shows the Fe+ lines more intense than usual. And both stars are variables of small amplitude according to Guthnick.[34] Both stars have narrow line grades.
5048	Many characteristics in common with γ Lyrae and α Draconis. Fe+ lines show slightly more intense than average.
5310	A fairly intense line at λ 3944 shows on one plate, very possibly the Mn+ line which is so conspicuous in α Andromedae. The two stars are similar in other respects: — both have strong K lines together with well marked He lines; both have narrow H line grades, etc.
5320	The lines of this star have been identified by Baxandall [37,39]; and also by Waterman[53] and Wright.[52]
5443	Sr+ abnormally intense. The lines have about the same central intensity as the Sr+ lines in α Persei but are about twice as wide. Ti+ lines not so intense as in most F0 stars. The K line is very broad and shallow similar to that of δ Cephei at minimum. This spectrum is very similar to that of α Circini (Boss 3739, $m = 3.4$, F0, $\delta = -65°$) and both have large reduced proper motions ($H = +5.9$ in each case). The trigonometric parallax of α Circini would be expected to be large enough to be worth getting — say between 0″.060 and 0″.100. Cf. Shapley[54] and Luyten [55]. β Coronae Borealis, Boss 3940, also has strong Sr+ and a large reduced proper motion ($H = +5.1$) but the strong lines of Vanadium (?) of β Coronae Borealis are not prominent in γ Equulii.
5460	Bu 10846. Component B gives 4% of total light. Its lines are separated from the lines of component A by 0.1 mm on the microphotometer tracings. Very short period Spectroscopic Binary with mass function = 0.000006.
5608	Strikingly similar to α Cygni in all its lines. See page 23.
5663	He lines very broad.
5761	Just one trigonometric parallax exists for this which makes $M = 3.0 \pm 0.3$! But there were only three comparison stars and the dependences were $D_1 = 0.634$, $D_2 = 0.295$ and $D_3 = 0.071$.
5779	The spectrum is at a lower degree of ionization than that of β Orionis. Thus the Fe+ lines and H lines are stronger and the C+ line at 4267 is weaker than in β Orionis.
5793–4	Bu 11743. Component B gives 46% of total light. Its lines are separated from the lines of component A by less than 0.1 mm on the microphotometer tracings.
5933	The spectrum of this star has changed remarkably. A one-prism plate taken in February, 1890, and three one-prism plates taken in August and September, 1890, show Fe+ lines as strong as in α Cygni but much more diffuse, and a K line about as strong and diffuse as in α Piscium (Boss 6031, A2p). In addition the lines of a normal B5 star appear. None of the spectra which were taken subsequently show either the strong Fe+ lines or the strong K line. The plates examined include three two-prism plates taken in September and October, 1893, two one-prism plates taken in September and October, 1927, and three one-prism plates taken in July, 1928. On the recent plates the star does not seem particularly different from other B5 stars. He lines are very broad. The remark in H.A., **28** concerning this star attributed the changed appearance in the spectrum from 1890 to 1893 to the difference in dispersion, which seems improbable in view of the above. Guthnick and Prager [34] suspect a light variation amounting to 0.06 magnitudes.
5944	The lines of this star have been identified by Baxandall.[37]
6031	Sr+ lines very intense. The K line is broad and shallow.

be as high as the position indicated by the dashed lines. Another difficulty is that the density of the center of the K line in Figure 1 is much too small for accurate measurement of the depth, yet if the exposure were made sufficiently long to avoid this, the spectrum would be overexposed in the region of Hγ due to the contrastiness of the plate.

The parallel lines are ruled at intervals of 0.2 magnitudes; really they are not quite parallel, allowance being made for variation in clear film deflection between the two ends of the spectrum.

Measures were made by placing a scale photographed on glass, film down, on the tracing and reading through an eyepiece or handglass. The scale was graduated in units of 0.4 mm and readings were made to the nearest fifth of a unit, i.e. to 0.2 A at Hγ. Measures were recorded for Hγ, Hδ and K of the total width of the line

TABLE II

H. D. Class	No. of Stars	Msp	H	c_2/T compiled	Hγ					
					$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.
					.96	.83	.69	.48		
B5	5	..	0.8	1.42	187	96	57	..	.89	46
B5ε	6	..	1.7	1.44	170	92	..	..	.63	39
B8	9	*0.1*	2.4	1.47	200	119	73	..	.98	56
A0	34	0.2	2.6	1.56	292	165	109	52	1.31	84
A2	16	1.1*	4.0	1.74	341	194	126	55	1.32	97
A3	3	..	3.7	1.82	379	211	129	53	1.30	103
A5	7	..	4.7	1.89	356	203	119	47	1.22	96
F0	10	..	3.5	2.10	272	141	76	..	1.08	68

* Mean of 12 Stars only, whose mean H = 4.0

at depths 0.05, 0.20, 0.40, and 0.80 magnitudes below the continuous background across the line — i.e., at residual intensity, r, = .96, .83, .69, and .48. Also the central light loss was estimated to the nearest hundredth of a magnitude.

The total absorption was calculated from these measures together with a necessarily rough estimate of a "width at zero depth" appropriate for the calculation. It was assumed that these points on the line contour were connected by straight lines, as in Figure 2, which is probably as accurate as the measures justify, besides being expeditious; for, given the measures of width, it required less than a minute to obtain the total absorption of a line on the calculating machine. The unit of total absorption is the one suggested by Dunham[1]:— the width (expressed in frequency units) of a hypothetical section of continuous spectrum in the neighborhood of the line containing an amount of energy equivalent to that blocked off by the absorption line. Such a section is illustrated by the shaded area in Figure 2. Minnaert's unit[4] is similar to this except that it is in Angstrom units.

The central light loss of the following lines was measured: — λλ 4481 Mg +, 4471 He, 4233 Fe +, 4227 Ca, 4216 Sr +, 4128–31 Si +, 4078 Sr +, 4046 Fe, and 4026 He. These probably have little more physical significance than intensity estimates because of the low resolving power, but a rough estimate of corresponding numbers of atoms may be made by combining these suitably with the data in Table II of a recent paper by Miss Payne[5].

These various measures are to be found in Table I. In general, each tabulated

MEANS FOR H. D. CLASSES; C–STARS EXCLUDED

Hδ						K						Line depth in hundredths of magnitudes								
$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	$2(\nu-\nu_0)$ at r =				Depth in Mags.	Total Abs.	Mg+ 4481	He 4471	Fe+ 4233	Ca 4227	Sr+ 4216	Si+ 4128–31	Sr+ 4078	Fe 4046	He 4026
.96	.83	.69	.48			.96	.83	.69	.48											
162	92	58	23	.99	43	..	..	..	..	.06	..	9	14	..	..	..	6	..	..	22
160	91	54	..	.78	41	..	..	..	..	.04	..	6	11	..	..	..	4	..	..	17½
200	115	76	34	1.07	56	..	..	..	..	.08	..	6	6	..	..	..	5	..	..	11
266	160	107	55	1.42	82	..	..	..	..	.29	7	8	..	..	..	..	6	..	..	3
314	190	119	57	1.41	93	..	..	..	..	.74	19	10	..	..	6	..	6	5	..	..
348	198	120	56	1.38	98	84	56	38	17	1.12	26	10	..	5	8	..	8	6	7	
341	184	110	47	1.29	91	94	58	41	..	1.22	29	10	..	..	11	..	8	8	8	
249†	125†	74†	..	1.11	62†	163	87	..	..	1.65	49	..	..	..	21	7	..	19	15	

† Mean of 9 stars only, excluding β Coronae Borealis.

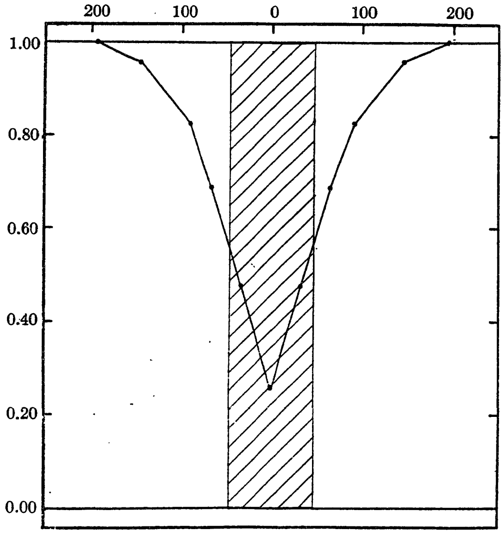

FIGURE 2. Illustrating calculation of total absorption for Hγ of α Lyrae, Plate C19809. Ordinate and abscissa, residual intensity (r) and units of frequency counted from the line center. Total absorption = ½(392 × 0.04 + 288 × 0.17 + 181 × 0.27 + 129 × 0.35 + 63 × 0.43) = 93.

quantity represents the mean of measures from three or more tracings. The cases in which the tabulated quantity represents the mean of two measures only are denoted by a semicolon. The cases in which the residuals are unduly large are denoted by a colon. Line widths are expressed in frequency units, 10^{-8} cm. These are total line widths, i.e. 2 $(\nu - \nu_0)$ if the line is symmetrical. Line depths are expressed in magnitudes. Line depths less than 0.05 have not been listed, as they are very uncertain.

Errors of line measures.— The average probable error of each of the various measures is given in Table III. The errors in line depth are expressed in per cent light loss rather than in hundredths of magnitudes, because the former remains fairly constant with varying depth and the latter does not.

TABLE III

AVERAGE PROBABLE ERRORS

	p.e. in line width				p.e. in line depth	p.e. in total absorption
Line	at r=0.96	0.83	0.69	0.48	(%)	
Hγ	13	6	5	3	2	3
Hδ	10	5	4	3	2	2
K (A0 stars)	2	—	—	—	2	1
K (F0 stars)	12	3	3	2	2	2

The probable errors in Table III are simply derived from the residuals. The relation of the quantities measured to the true widths and depths of the lines cannot be given very accurately; much more accurate line photometry with very high resolving power is necessary for this. But a comparison of the measures for Hγ of α Canis Majoris from this series with measures of a microphotometer tracing with about nine times the resolution, made from a slit spectrogram taken with the 40-inch Yerkes telescope, shows that at r = 0.96 and r = 0.83 the differences between the two sets of measures were less than the probable errors; at r = 0.69 and r = 0.48 the differences were eleven and fourteen frequency units, respectively. Thus it seems likely that in cases of hydrogen line widths greater than 150, the probable errors indicated are not far from right; when the line width is less than 100 the value tabulated in Table I is apt to be too small by at least 10 frequency units.

As to the relation of the tabulated depths to the true depths, it is even more indefinite. Miss Payne has pointed out[5] that if lines have "similar contours" then the line depths measured on these small dispersion spectra may be satisfactorily correlated with log NH and hence have a definite physical meaning; this is useful for weak narrow lines where the line contour is chiefly instrumental, but in the case of the hydrogen lines and of the K line for certain stars it is shown from the material herein presented that these lines do not have "similar contours." Hence we are not sure precisely what we have measured in the "line depth," but it seems plausible that, given two lines having the same width at r = 0.83, say, then at least we can tell qualitatively from these measures which line is really the deeper.

It is believed that the total absorption measure of Hγ and Hδ are not systematically in error by an amount as large as the probable error given above. No reason is seen for believing that they are systematically too large or too small.

But in the case of the K line in F0 stars and perhaps in some A5 stars the tabulated quantities are probably considerably in error on account of the background being drawn systematically too low or too high. It is possible that for a few stars such as ζ Leonis the total absorption should be increased by as much as 30–40 per cent, and perhaps for a few A5 stars it should be increased by as much as 5 per cent; and in such cases the line widths at r = 0.96 and r = 0.83 should also be increased, of course.

Spectroscopic binary stars which show two spectra were usually photographed when the lines were together. In the case of β Aurigae, where the two spectra are similar, one plate was taken when the lines were furthest apart and two when the lines were together. The measures of the second and third plates show deeper lines than the measures of the first, but the residuals for the hydrogen lines are very little larger than the residuals for average stars. The residuals for the depth of the K line of β Aurigae are considerably larger than average, as would be expected.

In the case of visual double stars, the spectra of which are superposed, the measures are given uncorrected in Table I. The calculated distance between the lines of the two spectra on the microphotometer tracing, and the approximate relative intensities of the backgrounds are given in "Remarks." (See, for instance, Boss 422–23.)

Color measures.— As a matter of pure curiosity in the first place, color measures were made on all the tracings for several stars to see if by any chance they would be at all consistent. That the residuals turned out to be small was unexpected, and gave hope of deriving some sort of color indices from the series of tracings. The method consisted simply of measuring the difference in height of three points in the continuous background curve. The points selected were at λλ 4731, 4481 and 4026. Thus in Figure 1 the background at λ 4481 is eighteen hundredths of a magnitude higher than at λ 4731 and thirty-seven hundredths higher than at λ 4026. Since the stars were usually photographed on the meridian it was possible to find the average residuals before applying a zenith distance correction. These turned out to be three or four hundredths of a magnitude. The Washington zenith distance corrections[6] were applied. Later, empirical corrections were made for seasonal effect (see below) and daily variation.

Seasonal effect in color indices.— When the zenith distance corrections had been applied a systematic variation was immediately detected in both sets of the color measures. Stars of a given spectral class which were photographed in July and August were redder than stars of the same class photographed in the winter months.

This accords with a finding of Guthnick and Prager[7] in their work with atmospheric extinction. "Die Durchsichtigkeit der Luft für das violette Ende des Spektrums ist in der Regel am Abend kurz nach dem Ende der Dämmerung am geringsten, nimmt dann zuerst schnell und nicht sehr regelmässig, später langsamer und gleichmässig zu bis zur Morgen. Dies gilt insbesondere für Nächte die auf *warme heitere Tage folgen.*" (Italics ours). Usually all the spectrograms for any one star were made within three or four weeks. Hence the variation with time of night and the seasonal variation would not swell the size of the residuals for any one star.

Figure 3 shows that the amount of the effect was considerable. Each plotted point represents a spectrogram. The dots are the A0 stars and the crosses are A2 stars. The full line connects the mean points for A0 stars; the dashed line connects the mean points for A2 stars. It is seen that an A0 star apparently changes color with season by an amount equal to the difference in color between A0 and A2.

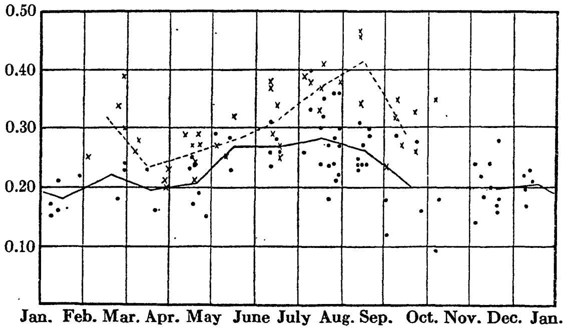

FIGURE 3. Seasonal effect on color measures. Ordinates are colors measured in terms of (4481–4026). Dots represent Class A0, crosses, Class A2. "Peculiar" stars are excluded.

A possible correlation between this variation and vapor pressure* was investigated. Since vapor pressures in the immediate vicinity of the observatory were not available, the mean vapor pressure for each night from the Boston weather bureau records was used. There was a fair correlation (r =0.58) and there was also a correlation between the variation and temperature, but the data were not good enough to determine the true cause of the variation.

The material was examined to see whether the variation had any connection with position in the sky. This seems unlikely in view of the fact that a given star photographed at different seasons usually showed an appropriate variation. In particular there seems to be little if any connection between this reddening and galactic latitude.

The color measures of various investigators were examined for an analogous

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* For Fowle has shown[8] that an increase in the water vapor content of the atmosphere decreases the transmission coefficients — the shorter the wave length, the greater the decrease.

effect. One would expect to find the effect only in data obtained by a method which does not involve comparing the color of the star with the color of one or more standard stars.

The only series of color measures in which such an effect would be expected and which has a sufficient number of stars observed accurately enough is that of Bottlinger,[9] and this series does seem to show a similar seasonal effect. Bottlinger made almost no observations during July and August, but during the last half of May and during June the stars were redder than in other months. The amount of the maximum effect in his observations is only about two-thirds as great as that shown in Figure 3, which might be expected since he made no observations during the months in which the effect has its maximum.

This seasonal effect will presumably distort all color measures obtained by the exposure ratio method, although in even climates the distortion is probably not large. And it means also that zenith distance corrections for atmospheric absorption in summer, differ to some extent from the winter corrections.

TEMPERATURE CLASSIFICATION

Combination of various color temperatures.— The two sets of color measures obtained from the microphotometer tracings were, of course, none too reliable. They were compared with the color indices of various other investigators, in particular with those of Greaves, Davidson and Martin[10], Bottlinger[9], Hertzsprung compilation[11], Hertzsprung-observed[12], Fessenkoff[13], Sampson[14], and Yü[15]. To express all the measures on the same scale, the color measures from a given source were plotted as ordinates against the corresponding c_2/T from the Hertzsprung compilation as abscissae; a smooth curve was drawn, and the color measure for each star converted into the Hertzsprung c_2/T by reading off the abscissa corresponding to the given ordinate. In the case of the color measures by Sampson and of those by Yü the scattering of the points was very great, and since the number of points was small it was impossible to draw a reliable curve — hence their measures were not used.

After a preliminary consideration of the residuals from unweighted means it was decided to combine the various measures with the following weights:

Source	Weight
Greaves, Davidson and Martin	100
Bottlinger	30 if only one observation (Bottlinger weight 6) 45 if two observations (Bottlinger weight 12) 50 if more than two observations.
Hertzsprung compilation	10% of the numerical weight listed by Hertzsprung along with c_2/T, i.e. the weights ranged from 4 to 21 and averaged about 11.

Source	Weight
Hertzsprung — observed	6 if two observations. 8 if three or four observations. 10 if five or more observations.
Williams 4481–4026	Weight assigned according to number of observations and size of residuals from the mean of these observations etc.; ranged from 10 to 30 and averaged about 25.
Williams 4481–4731	Similar to above except that weights ranged from 3 to 8 and averaged about 7.
Fessenkoff	3 if one observation. 5 if two observations. 6 if three or more observations.

The residuals of the Greaves, Davidson, and Martin measures from the mean of the other measures were very small — hence the large weight. There were only 15 stars which they had measured. Fessenkoff's data came to hand later and was used only when the other material was meagre.

The resulting values of c_2/T on a scale corresponding roughly to that of Hertzsprung, i.e. in reality on a scale corresponding to that of Wilsing[16], are given in column 11 of Table I. In the following column is the sum of the weights of all the constituents. In cases where the total weight is about 200 the probable error of the weighted mean derived from the residuals averages $0.01\frac{1}{2}$; where the total weight is 80 it averages 0.03; where the total weight is less than 50 it averages 0.04.

As a matter of fact, the scale differs to some extent from Hertzsprung's scale derived from all the A stars on his list; but it agrees very well with the scale derived from the stars common to both lists, as shown in Table IV: —

TABLE IV

Class	Stars brighter than 4.0 on both lists			All stars on Hertzspring's list	
		Average c_2/T			
	No. of stars	Table I Column 11	Hertzsprung Compilation	No. of stars	Average c_2/T
B5	8	1.47	1.40	37	1.36
B8	8	1.49	1.51	21	1.44
A0	33	1.56	1.55	82	1.48
A2	17	1.73	1.71	58	1.59
A5	7	1.89	1.90	35	1.89
F0	10	2.10	2.12	37	2.20

There seems to be a magnitude equation among the A stars of Hertzsprung's list, as Hertzsprung himself pointed out, the faint A stars being bluer. In fact, this is one reason why the weights assigned above to the Hertzsprung-compilation c_2/T values are relatively small.

Temperature range of the H.D. classes.— Examination of the c_2/T values in

Table I shows that fairly definite temperature boundaries exist between the later H.D. classes. Thus: —

Between	c_2/T boundary
F0 and A5	2.00
A5 and A3	1.84
A3 and A2	1.81
A2 and A0	1.64

The non-peculiar stars which are out of bounds are:

Boss	Name	H.D. class	c_2/T	Prob. error	c_2/T of star *minus* boundary c_2/T
3722	γ Boo	F0	1.93	±.02	−.07
1046	θ^2 Tau	F0	1.80	.03	−.20
4459	α Oph	A5	1.78	.05	−.06
1886	λ Gem	A2	1.83	.04	+.02

It is believed that it would have been more consistent to assign γ Bootis and θ^2 Tauri to earlier H.D. classes on the basis of line criteria; hence these two stars are not far out of bounds. The peculiar stars which are out of bounds are:

Boss	Name	H.D. class	c_2/T	Prob. error	c_2/T of star *minus* boundary c_2/T	Remarks
2443	—	A3p	2.17	±0.04	+0.33	"Probably composite"
781	—	cB9	2.22	0.04	+0.71	Faint c-stars; space reddening?
786	—	cA0	2.47	0.03	+0.83	
5469	σ Cyg	cA0	1.90	0.02	+0.26	
5608	ν Cep	cA2	2.56	0.04	+0.75	
5779	—	cB8	1.75	0.02	+0.24	
463	α Psc	A2p	1.62	±0.01	−0.02	
1478	β Aur	A0p	1.71	0.02	+0.07	
4182	ω Her	A0p	1.69	0.04	+0.05	According to the K line this is a late A0

All the other 77 stars in classes A0 to F0, inclusive, fall within the boundaries given above — a remarkable attribute of the Henry Draper classification. The reason that this classification of A stars is a temperature classification will be given in a succeeding paragraph. It can also be shown that most other existing classifications of A stars are not temperature classifications.

For the sake of completeness the positions of corresponding boundaries between the earlier classes are given, although they should not be taken too seriously as there are so many stars out of bounds.

Between	c_2/T boundary
A0 and B8	1.51
B8 and B5	1.46

Thus, 17 stars out of the 66 in the classes B5, B8 and A0 lie on the wrong side of the above boundaries. Two of the 17 are faint c-stars given in the above list.

A number of the other discrepancies may be ascribed to errors of observation — perhaps all of the others may be explained thus.

Deviation from the black body curve.— Of the five faint c-stars listed in the preceding section which are conspicuously red for their spectral class, Bottlinger measured the color of all except Boss 786. In every case Bottlinger's value of c_2/T was much smaller than the weighted mean,as can be seen from the residuals in Table V, column (6).

TABLE V

		Wtd. mean of 5 values	Wtd. mean of 4 values	Bottlinger			Hertzsprung compilation		Hertzsprung observed		Williams 4481–4026		Williams 4481–4731		c_2/T of star column (4) — boundary c_2/T for class
Boss (1)	Name (2)	(3)	(4)	c_2/T (5)	r^5 (6)	r^4 (7)	c_2/T (8)	r^4 (9)	c_2/T (10)	r^4 (11)	c_2/T (12)	r^4 (13)	c_2/T (14)	r^4 (15)	(16)
781		1.99	2.22	1.76	−.23	−.46	2.18	−.04	2.30	+.08	2.15	−.07	2.44	+.22	.71
786		—	2.47	—	—	—	2.55	+.08	2.49	+.02	2.41	−.06	2.55	+.08	.83
5469	σ Cyg	1.77	1.90	1.55	−.22	−.35	1.84	−.06	1.84	−.06	1.92	+.02	1.95	+.05	.26
5608	ν Cep	2.41	2.56	2.18	−.23	−.38	2.47	−.09	2.64	+.08	2.52	−.04	2.72	+.16	.75
5779		1.66	1.75	1.51	−.15	−.24	1.73	−.02	1.90	+.15	1.72	−.03	1.79	+.04	.24

r^5 is the residual from the weighted mean of the 5 values given in columns (5), (8), 0), (12), and (14); r^4 is the residual from the weighted mean excluding Bottlinger's value.

Among the 83 other stars on this program which Bottlinger measured, the average residual from the weighted mean was 0.05, and there was just one star with a residual of 0.15, and no stars with larger residuals. The very large residuals in column (6), then, are not errors of observation, but indicate that there is not a unique relation for all stars between color measures in one part of the spectrum and color measures in another. If most of the stars have black body energy curves, then these stars have not. The effective wave length of Bottlinger's violet measures, although it is not known precisely, is considerably shorter than any used by other investigators. Evidently the blue part of the spectrum of these faint c-stars is depressed with respect to the violet as well as with respect to the yellow regions as compared with other stars on the program. Also there seems to be a systematic trend in the residuals of the other observers which points toward the same conclusion. An obvious explanation would be that the violet is relatively strong as compared with the blue because the continuous absorption at the end of the Balmer series is relatively weak. If this were the complete explanation, then β Orionis, α Cygni and η Leonis should show the same effect, whereas they do not seem to show it to anything like the same extent; neither are they red for their spectral classes. Nor would this explain why the Williams 4481–4731 residuals are positive whereas the 4481–4026 residuals are negative. Evidently these are instances of what Gerasimovič[17] calls reddened stars with an "ultraviolet appendage."

In this connection it is interesting that the spectral lines of α Cygni which does not show the effect, are almost identical with those of ν Cephei which does show it; and furthermore measures on the microphotometer tracings indicate that to the violet of λ 4000, i.e. from λ 4000 to λ 3800 at any rate, the relative energy distribution of the two stars is very nearly the same; but from λ 4000 to λ 5000 the background of ν Cephei rises steadily relative to the background of α Cygni, it being relatively three quarters of a magnitude more intense at λ 5000 than at λ 4000. A comparison of the energy distribution of these two stars in other wave lengths is desirable.

The values of c_2/T given in Table I for these five faint c-stars are the weighted means excluding Bottlinger's determination, so that the value for Boss 786 is comparable with the other four.

Correlation of various line measures with temperature.— It is immediately obvious, of course, that the hydrogen line measures are sensitive functions of other variables, beside temperature. Examples are numerous. In the following illustration the average deviations of the measures of each plate from the mean for each star are included to give an idea of the limits of error.

Boss	Name	c_2/T	Wt.	Total width of Hγ at:— r = 0.96	r = 0.83	Depth of Hγ	Total Abs. of Hγ	Total width of Hδ at:— r = 0.96	r = 0.83	Depth of Hδ	Total Abs. of Hδ
3508	ζ Vir	1.72	80	370±19	205±5	1.30±.11	105±4	358±11	218±4	1.42±.09	107±3
3928	γ UMi	1.70	98	177± 6	115±9	1.35±.06	58±2	147± 6	106±6	1.37±.05	52±2

Thus, ζ Virginis and γ Ursae Minoris have about the same color temperature, but the width and total absorption of the hydrogen lines have widely different values. Had α Cygni or β Orionis been chosen as example, the variation would of course have been even more striking.

Among other line measures made, there are several, however, which correlate fairly closely with the c_2/T values. The most satisfactory correlation is that between c_2/T and the total absorption of the K line. There seems to be an almost linear relationship. If we omit the stars with composite spectra and the 5 faint c-stars listed in Table V, then the amount of scattering of points around the line is only slightly greater than would be expected if a rigorous mathematical relationship should hold. Other measures on the K line correlate fairly closely with c_2/T as does also the depth of λ 4227 of Calcium.

Evidently neither the K line nor λ 4227 is sensitive to absolute magnitude. This conclusion had been arrived at from a consideration of the observations before the writer knew of a paper Professor Milne had in preparation[18] where he found that this is precisely what is to be expected according to his theory. Thus at 8000° a change in surface gravity g from 10^2 to 10^4 results in only a 30 per cent increase in the number of atoms absorbing the K line; at 9000° it is only a $1\frac{1}{2}$ per cent increase and at 10,000° the increase is less than 0.01 per cent. And the 4227 line of Calcium is even more insensitive to changes in g at these temperatures.* This explains, of course, why the H.D. classification is such a good temperature classification from A0 to F0 — it is based largely on the strength of the K line.

The measures of the K line enable us to subdivide the very large H.D. classes A0 and A2 on a temperature basis. This subdivision appears in column 4 of Table I, and is based on a consideration of the two temperature indices: c_2/T and the total absorption of the K line. Thus, .1 in connection with an A2 star indicates an early A2, i.e. A2.1; *.2* in connection with an A2 star indicates a late A0 — i.e. A0.8 (there being no H.D. class between A0 and A2); 1.1 in connection with an A0 star indicates that it probably should be classified as A2.1.

PRESSURE CLASSIFICATION

General considerations.— The width of a hydrogen line at a point in the wing of given residual intensity (r_1) is, broadly speaking, an unknown function of

a) the number of hydrogen atoms in the second quantum state (N_2) above the photosphere corresponding to $r = r_1$, and
b) the number of charged particles per cm^3 (q).

Thus: —

$$(\nu - \nu_0)_{r = r_1} = X\,(N_2, q)$$

If q is negligible, then, according to Unsöld[20]

$$(\nu - \nu_0) \propto \sqrt{N_2}$$

assuming monochromatic radiative equilibrium, and assuming also that pressure and temperature are constant throughout the stellar atmosphere. N_2 in turn is a function of temperature and pressure for which Fowler and Milne[21] have found expressions. Later, Milne[22] has given expressions which determine the relation between $(\nu - \nu_0)_{r = r_1}$ and the pressure and temperature at a corresponding level in the stellar atmosphere. Finally, Milne has found theoretically[18] that when T is greater than 10,000° the effect of g (and hence of P) on the hydrogen line contours is very small, provided that various complicating influences, including radiation pressure and q, are assumed negligible.

But q is certainly not negligible. The electric fields between charged particles undoubtedly modify very considerably the hydrogen line contours. The best evidence for this lies in two recently established facts. The first, due to Struve[23, 24], and Elvey[25], is that the Stark effect (mol electric) is detectable in the helium lines in the B stars; this being so, it would be expected to show even more prominently in the

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* It should be noted that Öhman[19] compares the total absorption of the K line to color measures in A stars in the Pleiades, the Perseus cluster, and a Greenwich zone, and the correlation is not very close. Perhaps this may be due to his method of finding the total absorption of the K line — the continuous background measures for a star with wide H lines not being comparable with the measures for a star with narrow H lines.

hydrogen lines. The second, due to Unsöld[26] is that the Stark effect (which he calls pressure effect) accounts satisfactorily for the broad shallow character of the later members of the Balmer series in the solar spectrum, and that all the hydrogen line contours are somewhat modified by the Stark effect — $H\alpha$ slightly, $H\beta$ considerably, etc. Of course q is also a function of temperature and pressure. Consequently we are reduced to the statement: —

$$(\nu - \nu_0)_{r=r_1} = Y\,(P_1, T_1)$$

where Y is an unknown function.

Then if we assume that all stars are built on the same model, and that the mass-luminosity law is rigorously true, given the absolute luminosities of a number of stars, we can discover qualitatively the effect of pressure on the hydrogen line contours at various temperatures.

It is already well established that in the late type stars the hydrogen lines are more intense in the supergiants than in the dwarfs, and that on the contrary in the early spectral classes the total absorption of the hydrogen lines in the c-stars is much less than in stars of the main sequence. We proceed to discover whether the stars of the main sequence show slight differences in the contours of the hydrogen lines due to small variations in pressure.

Line-character classification (*line grade*).— To disentangle to some extent the effects of N_2 from the effects of q, the hydrogen lines were grouped with arbitrary "line-character" grades 1 to 6, grade 1 containing lines which are very narrow at $r = 0.75$ for their central depth, grade 6 containing lines which are very broad for their depth. The justification for this is obvious — other things being equal the higher the pressure the more Stark effect, hence the shallower and broader the lines; and also the higher the pressure the greater any possible shallowing at the line center due to collisions. When the hydrogen lines become even narrower than grade 1, as in the case of the c-stars, a slight variation of the procedure was adopted and the lines were assigned to classes −1 and 0.

Assuming the line contour is a function of two parameters only and assuming c_2/T is a measure of one parameter and the line grade is a measure of the other, then any other measures made on the absorption lines — in particular the measure of total absorption — should be uniquely determined for a given c_2/T and a given line grade. This consideration was useful in guarding against observational errors in assigning line grades.* The line grades of four stars were corrected by one unit and the line grades of 13 stars were corrected by $\frac{1}{2}$ unit. The corrected line grade is given

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* The observed central depth of a line is very sensitive to seeing conditions, hence bad seeing tends to put a star in too wide a line grade. Total absorption, on the other hand, is not so sensitive to seeing conditions. Moreover in spectroscopic binaries with large relative velocities, if the plates are taken at maximum separation the central depth will be too shallow but the total absorption will remain unaltered.

in column 5 of Table I. Figure 4 shows the relation between H.D. class, corrected line grade and total absorption for stars from B8 to A2. The numerical entries represent the mean between the total absorption of Hγ and the total absorption of Hδ for a given star.

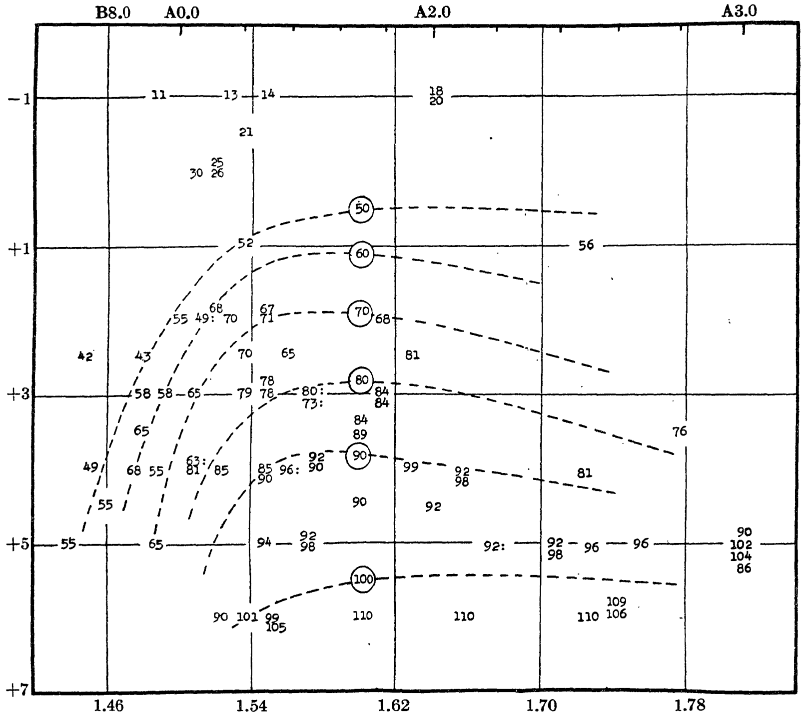

FIGURE 4. Relation between Henry Draper Class (abscissae, marked along upper margin), line grade for hydrogen (ordinates), and total absorption of hydrogen lines (numerical entries in the figure). Values of c_2/T are inserted along the lower margin. Numbers in circles are attached to the presumed loci of the corresponding total absorptions.

On examining the data in Table I it is immediately obvious that even excluding c-stars there is a wide range in line grade among stars earlier than A3, but that for A3 and A5 stars the line grade is always 5 or 6, and for most F0 stars the line grade varies only between 2 and 4. Apparently the hydrogen lines in the A3 to F0 stars are not so sensitive to pressure changes as in the B5 to A2 stars. In view of the fact that the absolute magnitude behavior of the hydrogen lines in late stars is directly contrary to that in the early stars, as mentioned in the preceding section, it is only to be expected that somewhere around Class F the hydrogen lines would be insensitive to change in absolute magnitude. Unfortunately, very few reliable parallaxes are available for stars earlier than A3, and more than half of them are for members of the Ursa Major cluster; but all of those stars for which good parallaxes do exist* are plotted in Figure 5. The bold-face numeral above each point indicates the line

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* Excepting α Gem and ζUMa whose line grades are very uncertain due to superposed spectra.

grade. The smaller numerals at the left indicate the total hydrogen absorption. The arrows indicate the direction in which certain points should most probably be moved due to inaccuracies in the determination of the parallaxes.

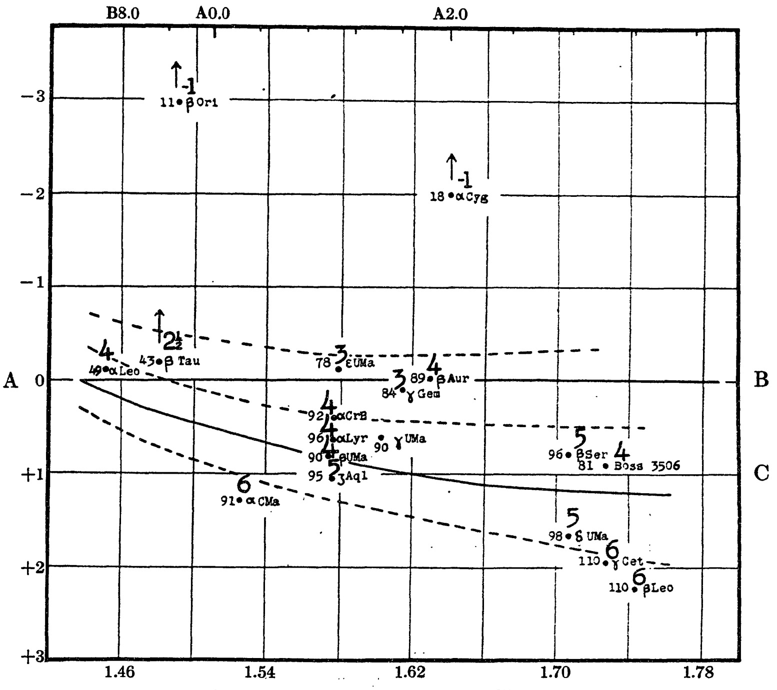

FIGURE 5. Relation between Henry Draper Classes (abscissae, upper margin), absolute magnitudes (ordinates), line grades (large numerals), and total absorptions (small numerals). The names of the stars concerned follow the small numerals. Values of c_2/T are indicated on the lower margin.

When it is remembered that any point on the diagram, except the ones representing α Lyrae and α Canis Majoris, can be moved vertically by 0.2 to 0.4 magnitudes, it is obvious that a fairly regular set of the zones may be sketched in, each zone containing practically all of the stars of a given line grade.

To investigate more fully the connection between absolute magnitude and line grade, reduced proper motions (corrected as explained below) were plotted against line grade in Figure 6. From the reduced proper motions a temperature correction ΔH has been subtracted. ΔH is obtained from Figure 5 and is simply the segment of ordinate included between lines AB and AC at the corresponding temperatures. Had the correction ΔH not been applied, the curve in Figure 6 would have been steeper. It seems clear that the line grade increases with decreasing absolute magnitude,*

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* The evidence in Figure 6 is not so very different from that in Figure 2 of a paper by Miss Fairfield.[27] She classified the hydrogen lines of 302 A stars (mostly southern) according to line width from measures on unstandardized microphotometer tracings.

which leads to the inference that the Stark effect plays an important role in the broadening of the H lines in A stars.*

In fact Vasnecov [29] has recently found that the great widths of the H lines in A stars may be satisfactorily accounted for as due largely to the Stark effect, it being unnecessary to assume improbably high pressures, as was formerly supposed. A total pressure somewhere between 10^{-3} and 10^{-4} atmospheres will produce an Hβ of the width found in Sirius, according to his tables.

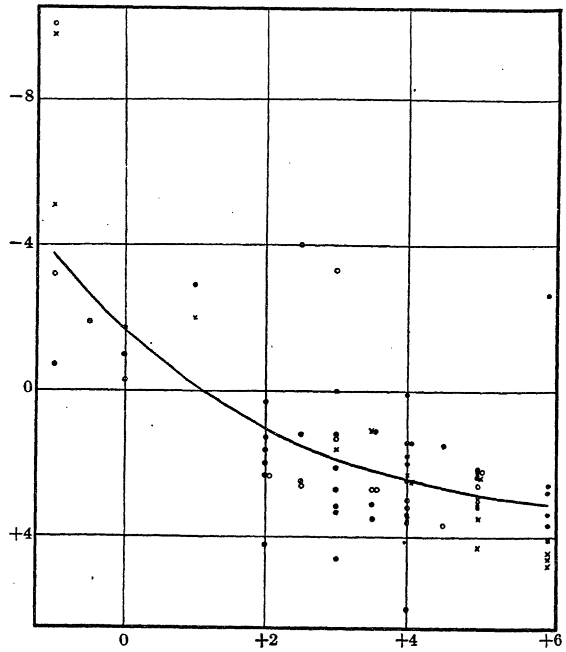

FIGURE 6. Relation between line grade (abscissa) and reduced proper motion, corrected to one temperature. Circles refer to Class B8 or B9, dots to Class A0; crosses to Class A2.

It is interesting to note in this connection that the partial pressures due to hydrogen, if derived by the method recently suggested by Unsöld[26] is roughly 2×10^{-5} atmospheres in Sirius and about half that large in α Andromedae.

ABSOLUTE MAGNITUDES

Magnitudes for B8–A2 stars in this program.— It is a simple matter, once the zones in Figure 5 are sketched in, to obtain fairly reliable absolute magnitudes for the B8 to A2 stars in Table I.† They are given in column 9 of Table I. The problem

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* It develops, then, that as far as the data on hydrogen lines were concerned, the paper by Miss Payne and the writer [28] was irrelevant as a test of the Milne theory, on account of the very large influence of the Stark effect in determining hydrogen line contours. This was intimated in the next to last paragraph of that paper.

† B5 stars were omitted because of several considerations: — there are comparatively few of them in Table I and accurate relative temperatures are not available for all, the K line being useless as a temperature index on account of interstellar calcium; no good absolute magnitudes are available; and finally the problem is complicated by the emission lines. But the two members of the Perseus cluster and the two members of the Pleiades seem to indicate that here also there is a connection between line grade and absolute magnitude.

is slightly complicated by composite spectra which are, of course, very frequent among A stars and rather difficult to detect. Thus the combination of a B8.0 **3** star with an A0.1 **4** star will give a spectrum of about B8.4 **3½** and the M_{sp} will be *0.2* whereas the true combined M of the two components will be *0.8*. This complication has been ignored except in the case of spectroscopic binaries whose two components are known to be of about equal brightness.

Methods for fainter stars.— It is possible to extend these methods to fainter stars, working with standardized microphotometer tracings of shorter dispersion, using the K line as a temperature index and the depth and width of the hydrogen lines for estimating pressure. Perhaps B8 stars should be omitted on account of the possible confusing influence of the interstellar calcium K line. Again, it is possible by using the total absorption of the hydrogen lines obtained by Öhman's method[19] or even by visual estimate, to derive the absolute magnitudes. The chief difficulty with this is the very accurate determination of temperature which is necessary in stars earlier than A0.4. Thus from Figure 4 we see that an A0.4 star with total hydrogen absorption equal to seventy is a full magnitude brighter than a B8.9 star with he same hydrogen absorption.

"PECULIAR" STARS

A few of the peculiarities of these stars are now readily understandable; for instance, the stars in which the helium lines are strong and the K line is strong too.[*] All these stars have narrow H line grades, i.e. they are stars of low atmospheric pressure. The average temperature of the stars is A0.1 according to the combined evidence of the K line and the c_2/T value. The explanation according to the Milne theory, then, is that the greater depth of atmosphere in these stars increases the strength of the helium lines considerably whereas the strength of the K line is unaffected. Parenthetically α Delphini is suspected of showing the ionized manganese lines which α Andromedae shows (cf. Remarks after Table I) and it is possible that some others do too, although the resolving power is not great enough to be sure.

None of the "peculiar" stars of Class A0 have line grades broader than 4; most of them are 3 or less. This is what might have been expected since the type star for A0, α Canis Majoris, is a star of relatively high pressure (line grade 6).

While the peculiarities of the Si+ stars of Class A0[†] and the Si+ and Sr+ stars of Class A2 [**] are not explained, the evidence seems to be conclusive that a simple "abnormal abundance" explanation will not suffice because there are too many as-

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[*] α Andromedae, B8.6 **3** ; α Delphini, A0.1 **2** ; ϕ Herculis, A0.0 **3** ; δ Cygni, A0.3 **2** ; θ Aquilae, A0.1 **2** ; α Draconis, A0.3 **2** ; γ Lyrae, A0.2 **1** , etc., and probably ϵ Delphini, B5, **2**.

[†] Boss 3639, B8.6 **4** ; θ Aurigae, B8.8 **2**, α^2 Canum Venaticorum, A0.0 **2**: ; ϕ Draconis, A0.0 **4**: ; γ Arietis, S, A0.5: **3** :.

[**] α^2 Piscium, A0.5: **3**: ; κ Piscium, A2.0 **5** ; Boss 3506, A2.5 **4** ; Boss 4284, A2.7 **5**.

sociated peculiarities. The most striking of these is the extraordinary broad shallow character of the K line.* Again in the earlier stars the Mg+ line is weaker than usual * and according to Adams and Joy [30] the Cr+ lines are stronger and the Fe+ and Ti+ lines are weaker than usual in the A2 stars. Unfortunately four of the nine cases in the program were complicated by superposed or composite spectra, but they seem to be fairly well scattered among the stars of slightly less than average pressure for a given temperature. This agrees with the statement in the report of the I.A.U. for 1922 (p. 102) that they are brighter than the average star of the same spectral class, and also with the findings of Gerasimovič and Strashny.[31]

Discussion of Various Classifications of A Stars

Henry Draper Classification.— Probably the H.D. classification for classes B5 and B8 is not strictly a temperature classification, since it is based largely on the strength of the helium lines which according to the Milne theory are very sensitive to absolute magnitude at these temperatures. If the Milne theory closely approximates the true conditions then the best temperature criterion would be the intensity of a line well past its maximum, but a suitable line is difficult to suggest. The definition of Class B8 is that λ 4481 of Mg+ shall be of the same intensity as λ 4471 of helium. This results in classifying α Delphini, for instance, as B8, whereas its temperature is probably about that of an early A0 star.

A general survey of some of the characteristics of an "average" star of each of the H.D. classes is given in Table II.† It is interesting to note the connection between eye estimates and various measured quantities. The introduction to the H.D. catalogue contains a number of estimates of the relative intensities of two lines. Thus in connection with the definition of Class F0 is the estimate that the K line is about three times as intense as $H\delta$, but none of the measures given in Table I make the ratio anything like as large. The evidence presented in Table VI indicates that

TABLE VI

Class	Line Ratio	Ratio of intensity according to H.D. eye estimates	Total Abs.	Ratio of Measures of Line depth in Mags.	Line depth in % light loss
B8	4481/4471	1	—	1	1
A2	K/$H\delta$	0.3−0.5	0.2	0.5	0.7
A3	K/$H\delta$	0.8	0.3	0.8	0.9
A5	K/$H\delta$	0.9	0.3	0.95	1.0
F0	K/$H\delta$	3.0	0.8	1.5	1.2

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* An exception is ϕ Draconis. This may be because of the composite nature of the spectrum. In all events the Si+ lines are only fairly strong in this star.

† Except for the B5e stars, only stars brighter than magnitude 4.0 have been included in the measures, in order not to give undue weight to the "peculiar" stars.

the ratio of line depths expressed in magnitudes most nearly approximates the eye estimate ratios.

Upsala Classification.— The Upsala classification by Lindblad and Schalén[32] follows the H.D. system closely as to the first two symbols (i.e. the A0 part of their classification "A0σ −"). Hence it gives a fairly good idea of temperature.

Their line character classification (τ, $\tau-$, etc.) is not at all the same as the line grades used in this paper. Öhman [19] has shown that for stars hotter than about A3 their line character classes correspond to definite measure numbers of the total absorption of the H lines. In terms of the units of total absorption used herein we find: —

L. and S. class	τ	$\tau-$	$\sigma+$	σ	$\sigma-$	ρ	μ	$\kappa-$	κ
Average total absorption	15	23	53	74	80	92	—	107	—

They found the average absolute magnitude of stars in each of the nine line character classes from statistical considerations involving the characteristics of the velocity ellipsoids of the various classes. Examining the stars brighter than 4th magnitude with M_{sp} given in Table I for which Lindblad and Schalén have also obtained absolute magnitudes we find the systematic difference shown in Figure 7 where each plotted point represents a star. The reason for this is found in Figures 4 and 5; as mentioned before an A0.4 star with total hydrogen absorption equal to 70 (L. and S. class σ) is a full magnitude brighter than a B8.9 star with the same hydrogen absorption. This tends to make M_{Wms} brighter than $M_{L.,S.}$ for the stars of the narrower line grades, and fainter for the wide line grades.

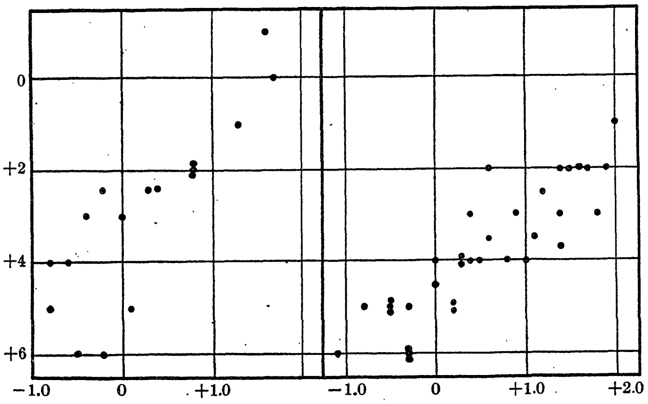

FIGURE 7. Relation of difference in absolute magnitude (abscissa) and line grade (ordinate). Abscissae are (left) $M_{L\,\&\,S}-M_{Wms}$; (right) $M_{A\,\&\,J}-M_{Wms}$.

Mount Wilson Classification.— Examination of the stars of this program which were classified by Adams and Joy [33] seems to show quite definitely that their classification was not a very good temperature classification as can be seen from Table VII.

TABLE VII

A and J Class	No. of Stars	c_2/T values			A and J Class	No. of Stars	c_2/T values			Mean of n stars *minus* mean of s stars
		min.	max.	mean			min.	max.	mean	
B9s	2	1.54	1.58	1.56	B9n	4	1.58	1.76	1.64	.08
A0s	1	1.58	1.58	1.58	A0n	8	1.55	1.78	1.67	.09
A1s	3	1.54	1.60	1.57	A1n	9	1.46	1.93	1.67	.10
A2s	7	1.56	1.70	1.62	A2n	6	1.43:	2.06	1.82	.20
A3s	3	1.57	1.95	1.72	A3n	2	1.85	1.93	1.89	.17
A4s	2	1.65	1.80	1.73	A4n	3	1.94	2.21	2.08	.25
A5s	2	1.81	1.82	1.82	A5n	2	2.06	2.20	2.13	.31

Not only is there more overlapping, some of which would be expected, of course, on account of the smaller subdivisions, but there is a systematic difference in temperature between the "n" classes and the "s" classes, the "n" stars of a given spectral class being decidedly cooler. Thus the mean temperature of the A5s stars is about equal to that of the A2n stars.

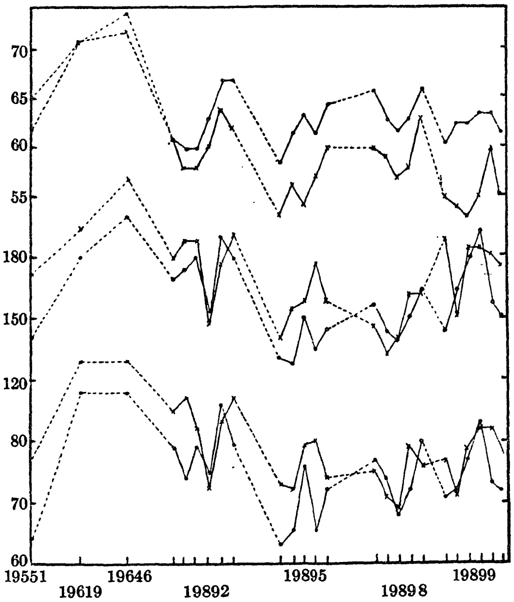

FIGURE 8. Variations in line contour of γ Bootis. Ordinates are (upper section) percentage light loss at line center; (middle section) width in frequency units at r = 0.83; (lower section) total absorption. The plates used are indicated along the axis of abscissae. The corresponding dates are as follows: 19551, 1928 April 10; 19619, 1928 May 9; 19646, 1928 May 25; 19892 (6 exposures) 1929 Feb. 12; 19895 (5 exposures) 1929 March 29; 19898 (5 exposures) 1929 April 10; 19199 (6 exposures) 1929 April 10.

Their line character designations, s and n, while having some relation to the line grades used herein, are not very closely connected, as is shown by the following:

Number of B8 — A2 stars

Line grade

	1	2	3	4	5	6
A and J classification n	0	3	3	5	8	2
s	1	5	3	4	1	2

A comparison of their determinations of absolute magnitude with those found herein is shown in Figure 7b. The systematic trend here is even more marked than in Figure 7a. It is quite possible that M_{Wms} is systematically too bright for the stars with narrow line grades, but even if these were modified to the point of doing violence to the observations, the systematic trend would persist.

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Summary

1. A photometric analysis of the hydrogen line contours in A stars shows that among A stars of any given temperature hotter than A3 the lines become continuously broader in the sequence from more luminous to less luminous stars. This is interpreted as being a manifestation of the Stark effect.
2. This provides a criterion for fairly reliable determinations of the absolute magnitudes of stars from B8 to A2.
3. An analysis of the observational data led to the conclusion that the K line of Ca+ and λ 4227 of Ca are relatively insensitive to absolute magnitude effects at these temperatures, and hence are good temperature indices. This confirms a theoretical prediction of Professor Milne. The conclusion was arrived at before the prediction was published or known to the writer.
4. Some of the characteristics of "peculiar" stars are now understandable.
5. A seasonal variation in color measures was detected which affects all color measures obtained by the exposure ratio method.
6. Instances are found of definite deviation of the continuous background of certain stars from a black body curve.
7. The characteristics of various classifications of A stars are discussed.

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