SIX-COLOR PHOTOMETRY OF STARS. VIII. THE COLORS OF 409 STARS OF DIFFERENT SPECTRAL TYPES*

JOEL STEBBINS AND GERALD E. KRON
Lick Observatory, University of California
Received January 10, 1956

ABSTRACT

Photoelectric measures in six colors have been obtained for 171 stars in addition to the previous list of 238, making a total of 409 stars. Also the colors of 35 stars from the earlier list have been revised. The new colors determined with the Crossley reflector at the Lick Observatory have been reduced to the system of those with the reflectors at Mount Wilson. The mean colors for the different spectral types have been compared with those of the O stars as nearest to black-body standards. The Paschen and Balmer depressions in the continuum are measures of the hydrogen absorption, most conspicuous in A stars. Our observed Paschen effect agrees with that shown by Hall and Williams, and our Balmer effect is well correlated quantitatively with the measures of Barbier and Chalonge. Deviations from the law of interstellar absorption, previously noted in the case of θ^1 Orionis, are shown to be complicated by the possible presence of unseen companions of later spectral type.

INTRODUCTION

The present work on multicolor photometry of stars with a photoelectric cell is a continuation of that carried on by Stebbins and Whitford (1945) at Mount Wilson from 1940 to 1944. The new results include those obtained in 1945 and 1946 with the 60-inch reflector and from 1949 to 1954 with the Crossley reflector at the Lick Observatory with

TABLE 1

SYSTEMATIC CORRECTIONS TO LICK COLORS, 1949–1954

V−I	U	V	B	G	R	I
−2.5.....	+0.08	+0.08	−0.02	+0 01	+0 01	+0.03
−2.0......	+ .04	+ .04	− .01	+ .005	+ .005	+ .02
−1.0......	− .03	− .03	+ .01	− .01	.00	− .01
0.0	− .08	− .08	+ .04	− .03	− .01	− .05
+1.0... ...	−0.13	− .13	+ .07	− .04	− .03	− .10
+2.0	......	− .19	+ .09	− .05	− .04	− .13
+3.0	......	−0.24	+0.10	−0.06	−0.04	−0.14

a new photometer developed and constructed by Kron. Although the original photocell and set of filters were available at Lick, a slightly better cell of the same type, Western Electric D97087, was used, and the substitution of a quartz-fluorite Fabry lens for the previous glass one at the primary focus gave about double the relative sensitivity in the ultraviolet region. With the addition of a feedback circuit that eliminates drift of the zero reading, the change from a galvanometer to a Brown recorder made it possible to obtain a double run over the six colors in about 5 minutes instead of 8 minutes for a star. Otherwise the methods of observation and reduction remained the same.

The limit of seventh or eighth magnitude attainable with the new installation on the 36-inch Crossley is not very different from that previously found for the 60-inch, but for sixth magnitude and brighter the limit of accuracy for either telescope is set by

* *Contributions from the Lick Observatory, University of California*, Ser. II, No. 59. This work has been supported in part by the Office of Naval Research under a contract with the University of California.

TABLE 2

LIST OF STARS OBSERVED

HD	V, W	Y	R.A. (1900)	Dec.	HD	V, W	Y	R.A. (1900)	Dec.
			h m	° ′				h m	° ′
358n	A0	B9p	0 3.2	+28 32	26356n	B5	B5 V	4 5.0	+83 34
432r	dF2	F2 IV	0 3.8	+58 36	26659n	gG4	.....	4 8.0	+83 6
571	cF2	F2 II	0 5.1	+45 31	27697n	gG8	K0 III	4 17.2	+17 18
886n	B2	B2 IV	0 8.1	+14 38	28305n	gG7	K0 III	4 22.8	+18 58
1064	B9	....	0 9.8	-10 7	29139	gK5	K5 III	4 30.2	+16 18
1337r	O8	O9 III	0 12.5	+50 53	29248n	B2	B2 III	4 31.3	- 3 33
2905	B0	B1 Ia	0 27.3	+62 23	30211n	B5	B5 IV	4 40.5	- 3 26
3627n	gK4	K3 III	0 34.0	+30 19	31398n	gK3	K3 II	4 50.5	+33 0
3651	dK1	K0 V	0 34.2	+20 43	31964r	cF2	F0 Iap	4 54.8	+43 41
3712n	gG7	K0 II-III	0 34.8	+55 59	32068n	cK4	K5 II+B	4 55.5	+40 56
3765	dK5	K2 V	0 35.3	+39 39	32630n	B4	B3 V	4 59.5	+41 6
4406	dG3	.....	0 41.3	+45 49	34029n	gG1	G8 III+F	5 9.3	+45 54
4727	B5	B5 V	0 44.3	+40 32	34085	B8	B8 Ia	5 9.7	- 8 19
5394r	B0	B0 IV:pe	0 50.7	+60 11	34411n	dG0	G0 V	5 12.1	+40 1
5848n	gK2	K2 III	0 55.0	+85 43	34759	B5	B5 V	5 14.7	+41 43
5914r	A5	.....	0 55.6	+88 29	35411n	B0	B1 V	5 19.4	- 2 29
6860n	gM0	M0 III	1 4.1	+35 5	35439n	B3ne	B1 V	5 19.6	+ 1 45
6920	dF7	F8 V	1 4.6	+41 33	35468n	B2s	B2 III	5 19.8	+ 6 16
8538n	A3	A5 V	1 19.3	+59 43	35497n	B8	B7 III	5 20.0	+28 31
8890r	cF7	F8 Ib	1 22.6	+88 46	35715n	B2	B2 IV	5 21.6	+ 3 0
9270	gG3	G8 III	1 26.1	+14 50	36395n	dM3	.....	5 26.4	- 3 42
10204	A9	.....	1 34.7	+42 47	36486r	B0	O9.5 II	5 26.9	- 0 22
10307r	dG0	G2 V	1 35.7	+42 7	36695n	B2	B1 V	5 28.5	- 1 14
10516	B0	B1pe (III, V)	1 37.4	+50 11	36822n	B0	B0 IV	5 29.3	+ 9 25
11443n	dF2	F6 IV	1 47.4	+29 6	36861n	O8	O8	5 29.6	+ 9 52
12533n	gK3	K3 II	1 57.8	+41 51	37018n	B2	B2 III	5 30.4	- 4 54
12929n	gK1	K2 III	2 1.5	+22 59	37022	B0	O6p	5 30.4	- 5 27
14622	dF2	.....	2 16.6	+40 57	37041n	O9	O9.5 Vp	5 30.5	- 5 29
14633	O8	O8	2 16.7	+41 2	37043n	O8	O9 III	5 30.5	- 5 59
14662	cF8	F7 Ib	2 16.9	+54 55	37128r	B0	B0 Ia	5 31.1	- 1 16
15830	dG5	.....	2 27.7	+42 21	37468n	B0	O9.5 V	5 33.7	- 2 39
16397	dG0	.....	2 32.6	+30 24	37742r	B0	O9.5 Ib	5 35.7	- 2 0
16901	cG0	G0 Ib	2 37.6	+43 52	38771n	B0	B0.5 Ia	5 43.0	- 9 42
18411n	A2	A2 V	2 52.1	+39 16	39587n	dF9	G0 V	5 48.5	+20 15
18884n	gM2	M2 III	2 57.1	+ 3 42	39801	gM2	M2 Iab	5 49.8	+ 7 23
18925n	cF7	G8 III:+A3	2 57.6	+53 7	40035n	gG6	K0 III	5 51.3	+54 17
19356r	B9	B8 V	3 1.7	+40 34	40111n	B0	B1 Ib	5 51.8	+25 57
19373n	dG1	G0 V	3 1.8	+49 14	40183n	A2	A2 V	5 52.2	+44 56
20123	cG2	G5 II	3 9.1	+50 34	40312n	A1	B9.5pv	5 52.9	+37 12
20677n	A0	A3 V	3 14.7	+42 58	41074	A8	......	5 57.9	+42 59
20902r	cF4	F5 Ib	3 17.2	+49 30	42995n	gM3	.. ...	6 8.8	+22 32
22928n	B8	B5 III	3 35.8	+47 28	44478n	gM3	.. ...	6 16.9	+22 34
23230n	cF4	F5 II	3 38.4	+42 16	44743n	B1	B1 II-III	6 18.3	-17 54
23249n	dK0	.....	3 38.5	-10 6	46136An	dF6	.. ...	6 26.5	+17 51
23288	B7	B7 IV	3 38.9	+23 59	46136Bn	dF6	... ..	6 26.5	+17 51
23302	B7	B6 III	3 39.0	+23 48	46300n	A0	A0 Ib	6 27.5	+ 7 24
23324	B8	B8 V	3 39.2	+24 32	47105n	A3	A0 IV	6 31.9	+16 29
23338	B7	B6 V	3 39.3	+24 10	47138n	gG4	......	6 32.0	-18 35
23408	B9	B7 III	3 39.9	+24 4	47205n	gK1	K1 IV	6 32.3	-19 10
23432	B8	B8 V	3 40.0	+24 15	47442n	gK1	K1 II-III	6 33.5	-18 9
23441	B9	B9 V	3 40.1	+24 13	47561n	A0	......	6 34.1	-16 47
23480	B6	B6 IV	3 40.4	+23 39	47667n	gK5	K3 III	6 34.7	-14 3
23630	B7	B7 III	3 41.5	+23 48	47839n	O7	O7	6 35.5	+ 9 59
23753	B8	B8 V	3 42.5	+23 8	48329n	cG8	G8 Ib	6 37.8	+25 14
23850	B8	B8 III	3 43.2	+23 45	48737n	dF3	F5 IV	6 39.7	+13 0
23862	B8	B8p	3 43.3	+23 51	48915n	A2	A1 V	6 40.7	-16 35
24398r	B1	B1 Ib	3 47.8	+31 35	49048n	A2	......	6 41.4	-14 41
24504	B7	B6 V	3 48.8	+47 35	49229n	B8	......	6 42.3	-14 19
24760r	B2	B0.5 V	3 51.1	+39 43	51309n	B5	B3 II	6 51.7	-16 55
24912r	O7	O7	3 52.5	+35 30	51802r	gM0	. ....	6 53.7	+87 12

TABLE 2 (Cont'd)

HD	V, W	Y	R.A. (1900)	Dec.	HD	V, W	Y	R.A. (1900)	Dec.
			h m	° ′				h m	° ′
58207n	gG7	K0 III	7 19.5	+28 0	128998	A0	......	14 35.1	+54 27
60179n	A2	A1 V	7 28.2	+32 6	131873n	gK5	K4 III	14 51.0	+74 34
60179Cn	dM1	. ...	7 28.2	+32 6	132813	gM5	......	14 56.0	+66 20
61421n	dF3	F5 IV-V	7 34.1	+ 5 29	133208	gG5	G8 III	14 58.2	+40 47
62345n	gG7	G8 III	7 38.4	+24 38	135722	gG4	G8 III	15 11.5	+33 41
62509n	gG8	K0 III	7 39.2	+28 16	136064r	dF9	F8 V	15 13.5	+67 44
66368	A3	......	7 58.0	+88 56	137422	A1	A3 II-III	15 20.9	+72 11
71369n	gG1	G5 III	8 22.0	+61 3	139006n	A1	A0 V	15 30.5	+27 3
72905n	dG0	......	8 30.3	+65 22	140436n	A0	A0 IV	15 38.6	+26 37
73108n	gK2	K2 III	8 31.5	+64 41	140573n	gK2	K2 III	15 39.3	+ 6 44
76294n	gG5	K0 II-III	8 50.1	+ 6 20	141004n	dG0	G0 V	15 41.6	+ 7 40
81797n	gK5	K4 III	9 22.7	- 8 14	142143	gM7	... ..	15 47.8	+48 47
82210n	dG	G2 IV	9 25.6	+70 16	142267n	dF9	......	15 48.5	+13 31
82328n	dF4	F6 IV	9 26.2	+52 8	142373r	dF7	F9 V	15 49.2	+42 44
84441n	cG3	G0 II	9 40.2	+24 14	143807	A1	A0 III	15 57.4	+30 7
84737n	dG0	G1 V	9 42.1	+46 29	144205	gM6	......	15 59.6	+47 31
87901n	B6	B7 V	10 3.0	+12 27	144206	B8	B9p	15 59.6	+46 19
89025n	gF0	F0 III	10 11.1	+23 55	145328	gK1	K0 III	16 5.3	+36 45
90839n	dF8	F8 V	10 24.2	+56 30	146791n	gG7	G9 III	16 13.0	- 4 27
95128n	dG0	G0 V	10 53.9	+40 58	147365	A9	......	16 16.5	+39 57
95418n	A2	A1 V	10 55.8	+56 55	147379	dM0	M0 V	16 16.5	+67 29
95689n	gG7	K0 III	10 57.6	+62 17	147394	B7	B5 IV	16 16.7	+46 33
97603n	A2	A4 V	11 8.8	+21 4	148387n	gG6	G8 III	16 22.6	+61 44
102212n	gM1	M1 III	11 40.7	+ 7 5	148478	gM1	M1 Ib+B	16 23.3	-26 13
102647n	A4	A3 V	11 44.0	+15 8	148783	gM6	......	16 25.4	+42 6
102870n	dF8	F8 V	11 45.5	+ 2 20	148856n	gG5	G8 III	16 25.9	+21 42
103095n	dG5	G8 Vp	11 47.2	+38 26	149757n	B0	O9.5 V	16 31.7	-10 22
103287n	A0	A0 V	11 48.6	+54 15	150680n	dG0	G0 IV	16 37.5	+31 47
103483	A0	......	11 49.9	+47 2	150997n	gG4	G7 III-IV	16 39.5	+39 7
106591n	A0	A3 V	12 10.5	+57 35	151288	dM0	K7 V	16 41.4	+33 41
107113r	dF4	......	12 13.9	+86 59	152391	dG9	G8 V	16 48.0	+ 0 11
107192r	dF2	......	12 14.4	+88 15	152601	gK3	K2 III	16 49.2	- 5 59
109358r	dG0	G0 V	12 29.0	+41 54	153344	dG4	......	16 53.8	+62 16
110897n	dF8	......	12 40.3	+39 50	153751n	gG1	G5 III	16 56.2	+82 12
111395	dG6	G7 V	12 43.9	+25 23	154345	dK0	......	16 59.8	+47 12
111812	dF5	G0 III	12 46.8	+28 5	155125n	A2	A2.5 V	17 4.6	-15 36
112185n	A2	A0pv	12 49.6	+56 30	156014n	gM5	......	17 10.1	+14 30
112413	A1	B9.5pv	12 51.4	+38 52	156729	A0	A2 V	17 14.2	+37 24
112570	gK0	......	12 52.6	+46 44	157056	B2	B2 IV	17 15.9	-24 54
113139	A6	F2 V	12 56.5	+56 55	157588n	gK1	......	17 19.0	-24 9
113226n	gG6	G9 II-III	12 57.2	+11 30	157779	B9	B9.5 III	17 20.2	+37 14
113865	A3	......	13 1.5	+29 34	157792n	A9	......	17 20.3	-24 5
114282	gK2	......	13 4.5	+88 11	157910	gG2	......	17 21.0	+37 2
114710	dG0	G0 V	13 7.2	+28 23	158704n	B9	......	17 25.6	-26 11
115383n	dF8	F8 V	13 11.8	+ 9 57	158996n	gK2	......	17 27.2	+80 14
115735	A0	......	13 14.0	+50 12	159181	cG2	G2 II	17 28.2	+52 23
116656n	A2	A2 V	13 19.9	+55 27	159561n	B9	A5 III	17 30.3	+12 38
116658n	B2	B1 V	13 19.9	-10 38	159881n	gK5	......	17 31.9	-27 59
118216	dF2	F2 IV	13 30.3	+37 42	161096n	gK1	K2 III	17 38.5	+ 4 37
120315r	B3	B3 V	13 43.6	+49 49	161797n	dG4	G5 IV	17 42.5	+27 47
120933	gM2	......	13 47.4	+34 56	163506	cF5	F2 Ia	17 51.4	+26 4
121370n	dF7	G0 IV	13 49.9	+18 54	163770	cK1	K1 II	17 52.8	+37 16
121409	A0	......	13 50.1	+54 13	163917n	gG9	G9 III	17 53.5	- 9 46
124294n	gK2	K3 III	14 7.6	- 9 48	163993n	gG7	G9 III	17 53.9	+29 16
124897n	gK0	K2 IIIp	14 11.1	+19 42	164058n	gK5	K5 III	17 54.3	+51 30
125162	A0	A0p	14 12.6	+46 33	164514	A6	A5 Ia	17 56.4	-22 54
125351	gK1	K0 III	14 13.8	+35 58	165401n	dF7	......	18 0.7	+ 4 39
126327	gM7	......	14 19.7	+26 11	166182	B2	B2 V	18 4.4	+20 48
127762	A5	A7 III	14 28.1	+38 45	166205	A2	......	18 4.5	+86 37
128165	dK5	K3 V	14 30.2	+53 20	166620	dK2	K2 V	18 6.3	+38 27

TABLE 2 (Cont'd)

HD	V, W	Y	R A. (1900)	Dec.	HD	V, W	Y	R A. (1900)	Dec.
			h m	° '				h m	° '
166734	B0	O9 If	18 6.9	-10 46	194093r	cF7	F8 Ib	20 18.6	+39 56
166926	A3	......	18 7.8	+87 0	194279	B2	B1.5 Ia	20 19.7	+40 26
168723n	gG8	K0 III-IV	18 16.1	- 2 55	194335	B3	B2 Vp	20 20.0	+37 10
169034	B0	B5 Ia	18 17.6	-13 39	194839	B0	B0 5 Ia	20 22.8	+41 3
169454	B1	B1 Ia+	18 19.6	-14 2	195295	cF4	F5 II	20 25.3	+30 2
170740n	B3	B2 V	18 25.9	-10 52	195592	B0	O9.5 Ia	20 27.2	+43 59
171635	cF8	F7 Ib	18 30.8	+56 58	195593	cF5	F5 Iab	20 27.2	+36 36
171779	gG5	......	18 31.7	+52 16	196321	gK5	K4 III	20 31.5	- 2 54
171871	B2	B2 III-IV	18 32.0	+51 2	196787n	gG8	......	20 34.5	+81 5
172167	A1	A0 V	18 33.6	+38 41	197345	A2	A2 Ia	20 38.0	+44 55
173638	cF4	F2 Ib-II	18 41.2	-10 14	197770	B2	B2 IV	20 40.7	+56 46
173648	A9	A7 (m)	18 41.3	+37 30	197989n	gK0	K0 III	20 42.2	+33 36
173649	A3	F0 IV	18 41.3	+37 30	198084	dF9	......	20 42.9	+57 13
175588r	gM4	......	18 51.0	+36 46	198149n	dG7	K0 IV	20 43.3	+61 27
175865	gM5	......	18 52.3	+43 49	198478	B2	B3 Ia	20 45.5	+45 45
178770	gM6	......	19 4.8	+39 0	198781	B1	B0.5 V	20 47.5	+63 40
179406n	B3	B3 IV	19 7.3	- 8 7	198802n	dG1	......	20 47.6	-11 57
180163	B5	B2 IV	19 10.4	+38 58	198846	O9	B0 IV	20 48.1	+34 17
180711n	gG8	G9 III	19 12.5	+67 29	199081	B3	B5 V	20 49.7	+44 0
182640n	A5	F0 IV	19 20.5	+ 2 55	199095n	A0	......	20 49.8	+82 10
182917	gM6	......	19 21.9	+50 3	199216	B1	B1 II	20 50.7	+49 9
183030r	gM1	......	19 22.5	+88 59	199437n	gK1	......	20 52.1	+80 11
183124n	gG5	......	19 22.9	+44 44	199478	B8	B8 Ia	20 52.4	+47 2
183204n	A0	......	19 23.3	+39 45	199579	O6	O6	20 53.1	+44 33
183912	gK0	K3 II:+B:	19 26.7	+27 45	199960n	dG1	......	20 55.3	- 5 7
183914	B9	B8 V	19 26.7	+27 45	200120	B3	B1 IV:e	20 56.4	+47 8
184279	B2	B0.5 IV	19 28.6	+ 3 34	200790n	dF7	......	21 0.5	+ 5 34
184915	B0	B0.5 III	19 31.5	- 7 15	200857	B2	B3 III	21 1.0	+54 51
186791n	gK4	K3 II	19 41.4	+10 22	200905	cK5	K5 Ib	21 1.3	+43 32
186882n	A0	B9.5 III	19 41.8	+44 53	201091n	dK6	K5 V	21 2.4	+38 15
186994	B0	B0 III	19 42.5	+44 43	201092n	dM0	K7 V	21 2.4	+38 15
187076	gM2	M2 II:+B:	19 42.9	+18 17	201601	cF1	F0pv	21 5.5	+ 9 44
187138	gG9	......	19 43.3	+88 41	201819	B1	B1 Vp	21 7.0	+35 53
187642	A1	A7 IV, V	19 45.9	+ 8 36	202109n	gG4	G8 II	21 8.7	+29 49
187691n	dF8	F8 V	19 46.2	+10 10	202751	dK6	......	21 12.9	- 0 15
188209	O8	O9.5 III	19 49.0	+46 47	203064	O8	O8	21 14.8	+43 31
188252	B2	B2 III	19 49 2	+47 41	203280r	A3	A7 IV, V	21 16.2	+62 10
188439	B2	B0.5 IIIp	19 50.1	+47 34	203374	B0	B0 IVpe	21 16.7	+61 25
188512n	dG8	G8 IV	19 50.4	+ 6 9	203938	B1	B0.5 IV	21 20.2	+46 44
188892	B5	B6 III	19 52.3	+38 13	204075r	cG4	G4 Ib p	21 21.0	-22 51
189340n	dF8	......	19 54.4	-10 13	204172	B0	B0 Ib	21 21.7	+36 14
190406n	dG1	......	19 59.6	+16 48	204867	cG1	G0 Ib	21 26.3	- 6 1
+35°3955	B0	B1 Ib	20 2.2	+35 32	205021r	B1	B2 III	21 27.4	+70 7
190919	B1	B1 Ib	20 2.2	+35 24	205139	B1	B1 II	21 28.3	+60 1
191026n	dG3	......	20 2.6	+35 42	205196	B0	B0 Ib	21 28.6	+57 4
191201	B0	B0 III	20 3.6	+35 26	206165	B2	B2 Ib	21 35.2	+61 38
192107	gK5	......	20 8.1	- 1 19	206773	B0	B0 V:pe	21 39.3	+57 17
192281	O5	O5f	20 9.0	+39 58	206778r	cK0	K2 Ib	21 39.3	+ 9 25
192422	B0	B0.5 Ib	20 9.7	+38 28	206859	cG3	G5 Ib	21 39.8	+16 53
192639	O7	O8f	20 10.8	+37 3	206936	gM2	M2 Ia	21 40.4	+58 19
192640	A1	A2 III	20 10.8	+36 30	207198	O9	O9 II	21 42.2	+61 59
192876r	cG5	G3 Ib	20 12.1	-12 49	207538	O9	B0 V	21 44.6	+59 14
192947r	gG8	G9 III	20 12.5	-12 51	209339	B0	B0 IV	21 57.6	+62 0
193183	B2	B1.5 Ib	20 13.8	+37 55	209750	cG1	G2 Ib	22 0.6	- 0 48
193237	B1	Bp	20 14.1	+37 43	209772r	gM5	......	22 0.9	+62 38
193322	O8	O8	20 14.6	+40 25	209975	O9	O9.5 Ib	22 2.1	+61 48
193370	cF5	F5 Ib	20 14.8	+34 40	210745	cK5	K1 Ib	22 7.4	+57 42
193443	O9	O9 III	20 15.2	+37 57	210839	O6	O6f	22 8.1	+58 56
193514	O8	O7f	20 15.5	+38 57	211336	A6	F0 IV	22 11.4	+56 33
193536	B2	B2 V	20 15.6	+46 0	212455	B3	B5 Iab	22 19.3	+54 44

1956ApJ...123..440S

TABLE 2 (Cont'd)

HD	V, W	Y	R. A (1900)	Dec.	HD	V, W	Y	R. A. (1900)	Dec.
			h m	° ′				h m	° ′
212710r	B9	. . . .	22 21.3	+85 36	218342	B1	B0 IV	23 2.1	+62 41
213087	B0	B0 5 Ib	22 23.9	+64 37	218356	cK0	K0 Ibp	23 2.2	+24 56
213306	cF4	. . . . .	22 25.4	+57 54	218376	B1	B0.5 IV	23 2.4	+58 53
213307n	A0	. . . . . .	22 25.4	+57 54	218634	gM4	. . . . . .	23 4.5	+ 8 8
213310	gM0	M0 Iab+B	22 25.4	+47 12	218639	A0	. . . . . .	23 4.5	-15 3
214168	B3	B1 (V) e	22 31.4	+39 7	218753	A9	. . . . . .	23 5.5	+58 47
214665r	gM4	. . . . . .	22 34.7	+56 17	219615n	gG4	G7 III	23 12.0	+ 2 44
214680r	O9	O9 V	22 34.8	+38 32	219659	A0	. . . . . .	23 12.4	-12 16
214868	gK2	K3 III	22 36.1	+43 45	219833	A0	. . . . . .	23 13.8	-12 43
214993	B1	B2 III	22 37.0	+37 43	220020	A0	. . . . . .	23 15.4	- 9 28
214994n	A2	A1 V	22 37.0	+28 48	221356n	dF8	. . . . . .	23 26.4	- 4.38
215182n	gG2	G8 II:+F	22 38.3	+29 42	221525	gF0	. . . . . .	23 27.8	+86 45
215766	A0	. . . . . .	22 42.4	-14 35	221830n	dG0	. . . . . .	23 30.4	+30 27
216131n	gG6	G8 III	22 45.2	+24 4	222574	cG1	G0 II	23 36.6	-18 22
216200n	B3	B3 IV:	22 45.8	+41 26	222661	B9	B9.5 V	23 37.5	-15 6
216411	B1	B1 Ia	22 47.6	+58 28	222847	B9	. . . . . .	23 39.0	-18 50
216446n	gK3	K3 III	22 47.9	+82 37	222935	dK2	. . . . . .	23 40.0	+29 0
216494	B9	. . . . . .	22 48.2	-12 9	223640	B9	B9.5p	23 46.2	-19 28
217014n	dG0	. . . . . .	22 52.6	+20 14	224014	cG0	F8-Mp	23 49.4	+56 57
217101	B2	B2 IV-V	22 53.1	+38 48	224572	B2	B1 V	23 53.9	+55 12
217382n	gK5	K4 III	22 55.2	+83 49	224758n	dF5	. . . . . .	23 55.3	+26 22
217476	cG3	G0 Ia	22 55.9	+56 5	224930n	dG1	G2 V	23 56.9	+26 33
217906n	gM2	M2 II-III	22 58.9	+27 32	225132	A0	B9 IV	23 58.6	-17 54
218045n	A0	B9.5 III	22 59.8	+14 40	225212	cK5	K3 Ib	23 59.4	-11 4
218173	B9	. . . . . .	23 0.7	- 8 29					

the sky; any undetected general or local variation in the extinction will cause larger errors than those caused by concealed defects of the apparatus. The same tables for the mean extinction have been used at Mount Hamilton as at Mount Wilson; any differences between first-class nights at the two stations seem to be negligible.

The later colors obtained with the 60-inch were on the original system, but, because of the different photocell and the more transparent Fabry lens at Lick, there are systematic changes in the colors along the spectral sequence. Even if the exact differences in effective wave lengths between the two systems were evaluated, the best procedure would seem to be to refer all new results to the first system and then, if necessary, to make the proper small changes in the originally assigned wave lengths. Hence we reobserved several dozen stars of all types, enough to establish the differences along the scale. When the new system is made to agree with the old one for polar standards near spectral type A, or V − I = −1.50, the other corrections are as in Table 1. These corrections have already been applied in all printed results in the present paper.

The first list, in what we shall call "Paper III" (Stebbins and Whitford 1945), contained results for 238 stars of different spectral types; the present or second list has new data for 171 stars, for a total of 409 stars; also now included are the colors of 35 stars from the first list that have been revised by additional measures. The combined list of all stars observed is in Table 2. In the first column, the plain HD numbers refer to stars in the first list; those marked "n" and "r" refer to the new and revised colors, respectively. For only these latter colors are the new measures given in Table 3 of the present paper; for the old colors the reader is referred to Paper III. In the second column of Table 2 the spectral types are from the same sources as before, "V" from Victoria, usually for the O to B5 types, "W" from Mount Wilson for the later types. In the third column are the available Yerkes classifications, kindly furnished by Dr. W. W. Morgan.

THE OBSERVATIONS

In Table 3 are the principal new results of the present paper. As before, the HD numbers in the first column are marked with "n" or "r" for new or revised, respectively; an asterisk indicates a note at the end of the table. The "Z" in the third column refers to Hubble's (1934) zone of avoidance of the nebulae; "i" means in, "o" out, and "?" doubtful. The magnitude "m" is Harvard visual. The spectral types are from the same sources as those in Table 2—Victoria, Mount Wilson, and Yerkes. The visual absolute magnitude, "M," for stars of type F or later, are from Mount Wilson. The six colors from U to I are, as usual, referred in magnitude to the mean of BGR; they are arranged in the order of V − I, beginning with the bluest. The figures in the last column refer to the number of nights.

DISCUSSION

Since the bluest stars are listed first in each type in Table 3, we select the first two or three, in order to minimize interstellar reddening, and compare them with the O stars, which are probably as nearly like black bodies as we can find. In Table 4 the groups are arranged according to the Victoria and Mount Wilson spectral types; those from Yerkes were not available for all the later types. The mean spectral types of the dwarfs and giants were selected, with the stars available, to be as nearly as possible of the same type.

The data of Table 4 are shown graphically in Figure 1, where the scale of ordinates in the left half for the B stars is drawn to ten times the magnitude scale of the right half for the later types. If we exclude for the moment the possibility of space reddening, we see at once that the Balmer depression in the ultraviolet, referred to the O stars, already sets in at B0 and increases with the temperature reddening for the later B's. In fact, this Balmer absorption is not a bad criterion for the spectral classification of the early types, though we have not been able to find enough nonreddened B stars to evaluate a possible effect of absolute magnitude. Corresponding to the Balmer effect in the ultraviolet, there

Table 3

Colors of 210 Stars

HD	Name	Z	m	V, W	Y	U	V	B	G	R	I	V-I	Obs.
						O							
47839n	15 Mon	?	4.68	O7s	O7	-2.29	-1.20	-0.53	-0.06	+0.59	+1.38	-2.58	3
37043n	ι Ori	1	2.87	O8	O9 III	-2.21	-1.17	-0.55	-0.05	+0.60	+1.39	-2.56	2
14633 *	....	o	7.3	O8	.....	-2.27	-1.17	-0.53	-0.03	+0.57	+1.38	-2.55	4
214680r	10 Lac	o	4.91	O9s	O9 V	-2.25	-1.16	-0.52	-0.05	+0.57	+1.32	-2.48	6
36861n	λ Ori	1	3.66	O8	O8	-2.16	-1.12	-0.51	-0.04	+0.55	+1.26	-2.38	3
1337r	HR 65	1	6.12	O8n	O9 III	-2.10	-1.06	-0.45	-0.06	+0.51	+1.18	-2.24	2
37041n	θ^2 Ori	1	5.17	O9	O9.5 Vp	-1.97	-0.98	-0.41	-0.02	+0.43	+0.92	-1.90	2
24912r	ξ Per	1	4.05	O7n	O7	-1.85	-0.90	-0.36	-0.04	+0.40	+0.89	-1.79	2
						B0							
36486r	δ Ori	?	2.48	B0	O9.5 II	-2.24	-1.16	-0.54	-0.05	+0.59	+1.37	-2.53	6
37468n*	σ Ori	1	3.78	B0	O9.5 V	-2.18	-1.15	-0.53	-0.06	+0.59	+1.38	-2.53	2
5394r*	γ Cas	1	2.25	B0ne	B0 IV:pe	-2.21	-1.16	-0.54	-0.05	+0.59	+1.31	-2.47	4
37742r	ζ Ori	1	2.05	B0neα	O9.5 Ib	-2.18	-1.12	-0.52	-0.05	+0.57	+1.33	-2.45	4
35411n	η Ori	?	3.44	B0	B1 V	-2.05	-1.10	-0.52	-0.05	+0.57	+1.30	-2.40	2
38771n	κ Ori	1	2.20	cB0	B0.5 Ia	-2.12	-1.10	-0.50	-0.05	+0.55	+1.29	-2.39	2
37128r	ε Ori	1	1.75	cB0eα	B0 Ia	-2.14	-1.10	-0.50	-0.05	+0.55	+1.28	-2.38	3
36822n	ϕ^1 Ori	1	4.53	B0ss	B0 IV	-2.09	-1.12	-0.50	-0.04	+0.54	+1.24	-2.36	3
40111n	139 Tau	1	4.90	B0	B1 Ib	-1.85	-0.94	-0.43	-0.05	+0.48	+1.08	-2.02	2
149757n	ζ Oph	?	2.70	B0nn	O9.5 V	-1.68	-0.89	-0.36	-0.04	+0.40	+0.94	-1.83	2
						B1							
44743n*	β CMa	o	1.99	cB1	B1 II-III	-2.11	-1.16	-0.56	-0.05	+0.61	+1.39	-2.55	2
205021r*	β Cep	1	3.32	B1	B2 III	-2.12	-1.15	-0.54	-0.07	+0.61	+1.35	-2.50	5
24398r	ζ Per	1	2.91	cB1	B1 Ib	-1.60	-0.79	-0.32	-0.05	+0.37	+0.79	-1.58	3
						B2							
886n	γ Peg	o	2.87	B2ss	B2 IV	-2.00	-1.14	-0.54	-0.06	+0.60	+1.39	-2.53	2
116658n	α Vir	o	1.21	B2	B1 V	-2.08	-1.17	-0.53	-0.06	+0.59	+1.34	-2.51	6
35715n	ψ Ori	o	4.66	B2	B2 IV	-2.06	-1.14	-0.54	-0.04	+0.58	+1.36	-2.50	2
35468n	γ Ori	o	1.70	B2s	B2 III	-2.01	-1.15	-0.54	-0.05	+0.59	+1.34	-2.49	3
24760r	ε Per	1	2.96	B2	B0.5 V	-2.11	-1.15	-0.52	-0.07	+0.59	+1.31	-2.46	3
29248n	ν Eri	o	4.12	B2s	B2 III	-2.01	-1.12	-0.52	-0.06	+0.58	+1.30	-2.42	2
37018n	42 Ori	1	4.65	B2	B2 III	-2.06	-1.12	-0.52	-0.05	+0.57	+1.27	-2.39	2
36695n	VV Ori	?	5.37	B2n	B1 V	-2.00	-1.10	-0.51	-0.06	+0.57	+1.25	-2.35	2

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	U	V	B	G	R	I	V-I	Obs.
						B3							
35439n*	25 Ori	o	4.73	B3ne	B1 V	-2.03	-1.12	-0.53	-0.06	+0.59	+1.33	-2.45	2
120315r	η UMa	o	1.91	B3n	B3 V	-1.79	-1.11	-0.52	-0.06	+0.58	+1.28	-2.39	4
194335 *	HR 7807	i	5.68	B3ne	B3 V	-2.05	-1.11	-0.50	-0.06	+0.56	+1.22	-2.33	2
32630n	η Aur	i	3.28	B4	B3 V	-1.73	-1.09	-0.50	-0.07	+0.57	+1.21	-2.30	2
216200n	14 Lac	?	5.84	B3	B3 IV:	-1.35	-0.80	-0.33	-0.04	+0.37	+0.70	-1.50	2
179406n	20 Aql	i	5.37	B3n	B3 IV	-1.17	-0.74	-0.31	-0.03	+0.34	+0.68	-1.42	1
170740n	HR 6946	i	5.80	B3	B2 V	-1.10	-0.62	-0.23	-0.03	+0.26	+0.52	-1.14	3
						B5-B9							
30211n	μ Eri	o	4.18	B5	B5 IV	-1.60	-1.04	-0.50	-0.04	+0.54	+1.19	-2.23	2
35497n	β Tau	i	1.78	B8	B7 III	-1.49	-1.05	-0.49	-0.05	+0.54	+1.12	-2.17	2
22928n	δ Per	i	3.10	B8n	B5 III	-1.50	-1.04	-0.47	-0.06	+0.53	+1.12	-2.16	1
26356n	HR 1289	o	5.39	B5n	B5 V	-1.54	-1.05	-0.49	-0.05	+0.54	+1.09	-2.14	1
87901n	α Leo	o	1.34	B6	B7 V	-1.30	-1.02	-0.46	-0.07	+0.53	+1.08	-2.10	3
51309n	ι CMa	i	4.39	B5	B3 II	-1.67	-0.98	-0.44	-0.04	+0.48	+1.04	-2.02	2
158704n	HR 6520	i	6.01	B9	.....	-1.23	-0.91	-0.41	-0.05	+0.46	+1.02	-1.93	1
19356r*	β Per	o	2.3	B9n	B8 V	-1.28	-0.95	-0.44	-0.04	+0.47	+0.94	-1.89	4
212710r	NPS 2	o	5.38	B9	.....	-0.91	-0.91	-0.44	-0.06	+0.49	+0.95	-1.86	4
49229n	11 CMa	i	5.19	B8	.....	-1.01	-0.90	-0.38	-0.06	+0.44	+0.90	-1.80	2
159561n*	α Oph	o	2.14	B9.5n	A5 III	-0.52	-0.69	-0.32	-0.04	+0.36	+0.70	-1.39	4
						A0							
358n	α And	o	2.15	A0.5	B9p	-1.44	-1.00	-0.48	-0.05	+0.53	+1.11	-2.11	2
218045n	α Peg	o	2.57	A0	B9.5 III	-0.83	-0.92	-0.43	-0.05	+0.48	+1.00	-1.92	2
213307n	δ Cep B	i	7.5	A0	.....	-1.20	-0.94	-0.40	-0.05	+0.45	+0.93	-1.87	2
199095n	76 Dra	o	5.69	A0	......	-0.83	-0.85	-0.42	-0.07	+0.49	+0.99	-1.84	1
183204n	......	o	7.22	A0	......	-0.93	-0.89	-0.42	-0.06	+0.48	+0.94	-1.83	1
186882n	δ Cyg	o	2.97	A0.5n	B9.5 III	-0.86	-0.90	-0.43	-0.04	+0.47	+0.92	-1.82	2
103287n	γ UMa	o	2.54	A0n	A0 V	-0.76	-0.88	-0.42	-0.05	+0.47	+0.94	-1.82	2
140436n	γ CrB	o	3.93	A0.5n	A0 IV	-0.75	-0.85	-0.41	-0.05	+0.46	+0.95	-1.80	2
47561n	HR 2448	?	5.93	A0	......	-0.64	-0.84	-0.40	-0.05	+0.44	+0.86	-1.70	1
20677n	32 Per	o	4.98	A0.5	A3 V	-0.70	-0.82	-0.39	-0.05	+0.44	+0.85	-1.67	6
46300n	13 Mon	i	4.50	cA0	A0 Ib	-0.94	-0.89	-0.38	-0.03	+0.41	+0.76	-1.65	2
106591n	δ UMa	o	3.44	A0n	A3 V	-0.65	-0.79	-0.38	-0.05	+0.43	+0.83	-1.62	2

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	U	V	B	G	R	I	V-I	Obs.
						A1-A4							
40312n	θ Aur	o	2.71	A1sp	B9.5pv	-1.01	-0.93	-0.44	-0.06	+0.50	+1.00	-1.93	3
48915n*	α CMa	i	-1.4	A2s	A1 V	-0.86	-0.87	-0.43	-0.05	+0.48	+1.02	-1.89	7
95418n	β UMa	o	2.44	A2s	A1 V	-0.81	-0.88	-0.43	-0.05	+0.48	+0.97	-1.85	3
112185n	ε UMa	o	1.68	A2s	A0pv	-0.77	-0.90	-0.43	-0.05	+0.48	+0.94	-1.84	3
139006n	α CrB	o	2.3	A1n	A0 V	-0.82	-0.89	-0.42	-0.05	+0.47	+0.94	-1.83	5
214994n	o Peg	o	4.85	A2.5s	A1 V	-0.78	-0.90	-0.41	-0.05	+0.46	+0.90	-1.80	2
116656n*	ζ UMa	o	2.40	A2.5s	A2 V	-0.74	-0.84	-0.41	-0.05	+0.46	+0.94	-1.78	2
60179n	α Gem	o	1.99	A2.5s	A1 V	-0.77	-0.84	-0.41	-0.04	+0.45	+0.92	-1.76	3
40183n	β Aur	o	2.8†	A2n	A2 V	-0.72	-0.84	-0.40	-0.06	+0.46	+0.91	-1.75	5
47105n	γ Gem	?	1.93	A3s	A0 IV	-0.71	-0.86	-0.42	-0.04	+0.46	+0.89	-1.75	2
166205	NPS 1	o	4.44	A2	......	-0.72	-0.85	-0.41	-0.05	+0.46	+0.88	-1.73	Stand.
155125n	η Oph	i	3.1†	A2s	A2.5 V	-0.58	-0.80	-0.39	-0.05	+0.44	+0.81	-1.61	2
102647n	β Leo	o	2.23	A4n	A3 V	-0.61	-0.76	-0.36	-0.06	+0.42	+0.84	-1.60	4
18411n	π Per	o	4.62	A2	A2 V	-0.61	-0.81	-0.38	-0.04	+0.42	+0.79	-1.60	6
49048n	HR 2498	i	5.30	A2	......	-0.62	-0.80	-0.36	-0.05	+0.41	+0.79	-1.59	2
97603n	δ Leo	o	2.58	A2n	A4 V	-0.55	-0.73	-0.35	-0.04	+0.39	+0.76	-1.49	2
8538n	δ Cas	i	2.80	A3n	A5 V	-0.51	-0.70	-0.34	-0.04	+0.38	+0.74	-1.44	4
166926	NPS 4	o	5.86	A3n	......	-0.49	-0.60	-0.29	-0.04	+0.33	+0.68	-1.28	Stand.
203280r	α Cep	i	2.60	A3n	A7 IV, V	-0.49	-0.61	-0.29	-0.04	+0.33	+0.62	-1.23	6
						A5-A9							
5914r	NPS 5	o	6.43	A5	......	-0.62	-0.76	-0.36	-0.05	+0.41	+0.80	-1.56	3
157792n	44 Oph	i	4.28	A9s	......	-0.33	-0.48	-0.19	-0.05	+0.25	+0.59	-1.07	1
182640n	δ Aql	i	3.44	A5n	F0 IV	-0.48	-0.49	-0.20	-0.03	+0.23	+0.48	-0.97	13

F Dwarfs

HD	Name	Z	m	V, W	Y	M	U	V	B	G	R	I	V-I	Obs.
432r	β Cas	i	2.7†	F2	F2 IV	+2.2	-0.38	-0.47	-0.20	-0.02	+0.22	+0.46	-0.93	4
107192r*	NPS 2s	o	6.28	F2	......	+3.0	-0.50	-0.47	-0.20	-0.02	+0.22	+0.45	-0.92	Stand.
61421n	α CMi	o	0.48	F3	F5 IV-V	+3.1	-0.43	-0.38	-0.14	-0.03	+0.17	+0.39	-0.77	5
46136Bn	20 Gem	i	7.00	F6	......	+2.2	-0.40	-0.40	-0.16	-0.03	+0.19	+0.36	-0.76	2
107113r	NPS 3s	o	6.33	F4	......	+3.2	-0.52	-0.35	-0.13	-0.02	+0.15	+0.33	-0.68	Stand.
48737n	ξ Gem	o	3.40	F3	F5 IV	+2.2	-0.35	-0.33	-0.13	-0.02	+0.15	+0.31	-0.64	2
82328n	θ UMa	o	3.26	F4	F6 IV	+3.3	-0.40	-0.33	-0.11	-0.02	+0.13	+0.28	-0.61	2
11443n	α Tri	o	3.9†	F2	F6 IV	+2.4	-0.33	-0.30	-0.10	-0.03	+0.13	+0.28	-0.58	2
224758n	HR 9078	o	6.38	F5	......	+3.2	-0.30	-0.28	-0.07	-0.03	+0.10	+0.21	-0.49	1
90839n	36 UMaA	o	4.84	F8	F8 V	+3.5	-0.40	-0.25	-0.08	-0.02	+0.10	+0.22	-0.47	3

1956ApJ...123..440S

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	M	U	V	B	G	R	I	V-I	Obs.
						F Dwarfs (Continued)								
221356n	HR 8931	o	6.50	F8	......	+3.6	-0.35	-0.20	-0.06	-0.01	+0.07	+0.20	-0.40	1
46136An	20 Gem	i	6.36	F6	......	+2.1	-0.25	-0.25	-0.08	-0.02	+0.10	+0.21	-0.46	2
102870n	β Vir	o	3.80	F8	F8 V	+4.0	-0.21	-0.19	-0.06	-0.03	+0.09	+0.21	-0.40	3
187691n	o Aql	?	5.22	F8	F8 V	+3.9	-0.25	-0.19	-0.07	-0.02	+0.09	+0.20	-0.39	3
136064r	HR 5691	o	5.23	F9	F8 V	+3.1	-0.24	-0.21	-0.07	-0.01	+0.08	+0.18	-0.39	3
200790n	4 Eql	o	6.03	F7	......	+3.1	-0.30	-0.18	-0.07	-0.02	+0.09	+0.18	-0.36	2
121370n	η Boo	o	3.1†	F7	G0 IV	+3.2	-0.09	-0.14	-0.05	-0.03	+0.08	+0.18	-0.32	3
115383n	59 Vir	o	5.22	F8	F8 V	+3.7	-0.18	-0.15	-0.05	-0.01	+0.07	+0.17	-0.32	1
142373r	χ Her	o	4.61	F7	F9 V	+3.6	-0.32	-0.18	-0.04	-0.01	+0.05	+0.13	-0.31	3
110897n	10 CVn	o	5.97	F9	......	+4.3	-0.37	-0.18	-0.04	-0.02	+0.06	+0.09	-0.27	2
39587n	χ^1 Ori	ı	4.62	F9	G0 V	+4.0	-0.24	-0.12	-0.02	-0.01	+0.03	+0.12	-0.24	2
142267n	39 Ser	o	6.16	F9	......	+3.7	-0.21	-0.11	-0.01	-0.01	+0.01	+0.12	-0.23	1
189340n*	HR 7637	o	5.91	F8	......	+3.8	(-0.19)	-0.11	-0.04	-0.02	+0.06	+0.12	-0.23	2
165401n	....	ı	6.83	F7	......	+4.5	-0.24	-0.12	-0.02	0.00	+0.02	+0.09	-0.21	1
						G Dwarfs								
109358r	β CVn	o	4.32	G0	G0 V	+4.2	-0.26	-0.15	-0.04	-0.02	+0.06	+0.16	-0.31	3
141004n	λ Ser	o	4.42	G0	G2 V	+4.4	-0.13	-0.10	-0.03	-0.01	+0.03	+0.17	-0.27	1
190406n	15 Sge	o	5.89	G1	......	+4.4	-0.21	-0.11	-0.05	0.00	+0.05	+0.14	-0.25	2
19373n	ι Per	o	4.17	G1	G0 V	+3.9	-0.16	-0.12	-0.03	-0.02	+0.05	+0.13	-0.25	2
10307r	HR 483	o	5.10	G0	G2 V	+4.4	-0.21	-0.14	-0.03	-0.02	+0.05	+0.11	-0.25	3
34411n	λ Aur	ı	4.85	G0	G0 V	+4.4	-0.14	-0.09	-0.02	-0.01	+0.03	+0.13	-0.22	2
95128n	47 UMa	o	5.14	G0	G0 V	+4.2	-0.17	-0.11	-0.01	-0.02	+0.03	+0.11	-0.22	2
84737n	HR 3881	o	5.20	G0	G1 V	+3.8	-0.13	-0.09	-0.02	-0.02	+0.04	+0.12	-0.21	2
199960n	11 Aqr	o	6.26	G1	......	+4.0	-0.04	-0.07	-0.01	-0.02	+0.03	+0.13	-0.20	2
72905n	π^1 UMa	o	5.69	G0	......	+4.2	-0.18	-0.09	-0.01	-0.02	+0.03	+0.11	-0.20	2
150680n	ζ Her	o	3.00	G0	G0 IV	+3.7	-0.05	-0.10	-0.01	-0.02	+0.03	+0.10	-0.20	2
221830n	......	o	6.72	G0	......	+4.4	-0.22	-0.13	-0.02	-0.01	+0.03	+0.04	-0.17	2
217014n	51 Peg	o	5.59	G0	......	+4.3	+0.02	-0.03	-0.01	-0.01	+0.02	+0.10	-0.13	2
198802n*	HR 7994	o	6.40	G1	......	+3.8	(-0.04)	-0.06	0.00	-0.01	+0.01	+0.06	-0.12	2
224930n*	85 Peg	o	5.85	G1	G2 V	+4.7	-0.20	-0.05	+0.04	-0.01	-0.03	-0.09	+0.04	3
161797n	μ Her	o	3.48	G4	G5 IV	+4.2	+0.27	+0.06	+0.06	-0.03	-0.03	0.00	+0.06	2
82210n*	24 UMa	o	4.57	F9	G2 IV	+3.7	+0.30	+0.11	+0.07	-0.02	-0.05	-0.08	+0.19	2
103095n*	Gr 1830	o	6.46	G5	G8 Vp	+6.3	+0.04	+0.08	+0.09	-0.02	-0.07	-0.19	+0.27	3
188512n	β Aql	o	3.90	G8	G8 IV	+4.0	+0.47	+0.23	+0.11	-0.01	-0.10	-0.19	+0.42	24
191026n	27 Cyg	i	5.52	G3	.....	+4.5	+0.57	+0.25	+0.12	-0.02	-0.10	-0.17	+0.42	4

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	M	U	V	B	G	R	I	V-I	Obs.
						G Dwarfs (Continued)								
198149n	η Cep	i	3.59	G7	K0 IV	+2.6	+0.69	+0.32	+0.14	-0.01	-0.13	-0.26	+0.58	4
						K and M Dwarfs								
23249n	δ Eri	o	3.72	K0	......	+3.0	+0.78	+0.32	+0.14	-0.04	-0.10	-0.22	+0.54	2
201091n	61 CygA	i	5.57	K6	K5 V	+7.7	+1.49	+0.65	+0.35	+0.03	-0.39	-0.71	+1.36	1
201092n	61 CygB	i	6.28	M0	K7 V	+8.6	.....	+0.97	+0.49	+0.04	-0.53	-1.04	+2.01	1
60179Cn	YY Gem	o	9.0	M1e	......	+8.3	.....	+1.24	+0.68	-0.02	-0.66	-1.39	+2.63	1
36395n	-3°1123	i	8.0	M3	......	....	.....	+1.11	+0.63	+0.03	-0.66	-1.58	+2.69	2
						F Giants								
89025n	ζ Leo	o	3.9†	F0	F0 III	+1.3	-0.29	-0.50	-0.20	-0.03	+0.23	+0.45	-0.95	2
23230n	ν Per	?	3.93	cF4	F5 II	-1.0	-0.06	-0.37	-0.12	-0.03	+0.15	+0.26	-0.63	1
20902r	α Per	i	1.90	cF4	F5 Ib	-1.2	+0.10	-0.28	-0.11	-0.02	+0.13	+0.22	-0.50	7
8890r*	NPS 1s	o	2.1	cF7	F8 Ib	-2.2	+0.13	-0.16	-0.07	-0.03	+0.09	+0.21	-0.37	Max.
31964r	ε Aur	i	3.3	cF2	F0 Iap	-1.7	+0.14	-0.22	-0.03	-0.02	+0.05	-0.06	-0.16	3
194093r	γ Cyg	i	2.32	cF7	F8 Ib	-2.1	+0.39	-0.05	-0.02	-0.02	+0.04	+0.09	-0.14	5
18925n*	γ Per	i	3.4	cF7	G8 III:+A3:	-0.3	+0.34	-0.01	+0.06	-0.01	-0.05	-0.11	+0.10	2
						G Giants								
47138n	ν^1 CMa	o	5.81	G4	......	+0.8	+0.32	+0.10	+0.08	-0.03	-0.05	-0.06	+0.16	1
34029n	α Aur	i	0.7†	G1	G8 III:+F	+0.1	+0.37	+0.14	+0.08	-0.03	-0.05	-0.08	+0.22	4
84441n	ε Leo	o	3.12	cG3	G0 II	-1.3	+0.46	+0.18	+0.07	-0.03	-0.04	-0.08	+0.26	3
215182n	η Peg	o	3.4†	G2	G8 II:+F ?	+0.6	+0.61	+0.20	+0.11	-0.02	-0.09	-0.16	+0.36	2
71369n	o UMa	o	3.47	G1	G5 III	+0.5	+0.51	+0.22	+0.09	-0.01	-0.08	-0.15	+0.37	2
26659n	HR 1304	o	5.70	G4	......	+1.0	+0.53	+0.20	+0.11	-0.01	-0.10	-0.20	+0.40	1
153751n	ε UMi	o	4.7†	G1	G5 III	+0.3	+0.59	+0.25	+0.13	-0.02	-0.11	-0.18	+0.43	1
148387n	η Dra	o	2.89	G6	G8 III	+0.7	+0.73	+0.29	+0.12	-0.02	-0.10	-0.21	+0.50	3
113226n	ε Vir	o	2.95	G6	G9 II-III	+0.4	+0.83	+0.30	+0.14	-0.04	-0.10	-0.21	+0.51	3
163993n	ξ Her	o	3.82	G7	G9 III	+0.6	+0.79	+0.31	+0.15	-0.03	-0.12	-0.22	+0.53	2
150997n	η Her	o	3.61	G4	G7 III-IV	+1.0	+0.64	+0.28	+0.13	-0.02	-0.11	-0.25	+0.53	3
204075r	ζ Cap	o	4.2†	cG4	G4 Ib ?p	-1.3	+0.74	+0.40	+0.14	-0.03	-0.11	-0.15	+0.55	3
148856n	β Her	o	3.1†	G5	G8 III	+0.1	+0.73	+0.32	+0.14	-0.03	-0.11	-0.23	+0.55	2
62345n	κ Gem	o	3.68	G7	G8 III	+0.6	+0.79	+0.32	+0.14	-0.03	-0.11	-0.24	+0.56	3
219615n	γ Psc	o	3.85	G4	G7 III	+1.2	+0.67	+0.29	+0.16	-0.02	-0.14	-0.29	+0.58	2
216131n	μ Peg	o	3.67	G6	G8 III	+0.9	+0.70	+0.31	+0.13	-0.02	-0.11	-0.27	+0.58	3

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	M	U	V	B	G	R	I	V-I	Obs.
						G Giants (Continued)								
192947r	α^2 Cap	o	4.1†	G8	G9 III	+0.3	+0.81	+0.34	+0.15	-0.03	-0.12	-0.25	+0.59	4
168723n	η Ser	1	3.42	G8	K0 III-IV	+1.4	+0.72	+0.33	+0.16	-0.03	-0.13	-0.28	+0.61	3
202109n	ζ Cyg	o	3.7†	G4	G8 II	-0.6	+0.91	+0.40	+0.16	-0.04	-0.12	-0.24	+0.64	3
146791n	ε Oph	o	3.34	G7	G9 III	+0.7	+0.92	+0.37	+0.17	-0.03	-0.14	-0.28	+0.65	2
27697n	δ Tau	1	3.93	G8	K0 III	+0.6	+0.96	+0.39	+0.14	-0.01	-0.13	-0.26	+0.65	2
196787n	75 Dra	?	5.62	G8	.....	+0.6	+1.04	+0.40	+0.19	-0.03	-0.16	-0.26	+0.66	1
163917n	ν Oph	1	3.50	G9	G9 III	+0.5	+1.07	+0.40	+0.17	-0.04	-0.13	-0.27	+0.67	2
76294n	ζ Hya	o	3.30	G5	K0 II-III	+0.3	+1.00	+0.42	+0.18	-0.03	-0.15	-0.29	+0.71	3
62509n	β Gem	o	1.21	G8	Ko III	+0.9	+1.03	+0.41	+0.17	-0.03	-0.14	-0.31	+0.72	3
28305n	ε Tau	1	3.63	G7	K0 III	+0.7	+1.05	+0.44	+0.16	-0.03	-0.13	-0.29	+0.73	2
180711n	δ Dra	o	3.24	G8	G9 III	+0.4	+0.94	+0.41	+0.18	-0.02	-0.16	-0.32	+0.73	2
40035n	δ Aur	o	3.88	G6	K0 III	+0.8	+1.02	+0.43	+0.18	-0.03	-0.15	-0.31	+0.74	3
183124n	......	o	6.72	G5	.....	.....	+0.97	+0.43	+0.20	-0.02	-0.18	-0.34	+0.77	1
58207n	ι Gem	o	3.89	$\overline{G7}$	K0 III	+0.7	+1.08	+0.46	+0.19	-0.03	-0.16	-0.37	+0.83	2
95689n	α UMa	o	1.95	G7	K0 III	0.0	+1.15	+0.49	+0.22	-0.02	-0.20	-0.40	+0.89	3
192876r	α^1 Cap	o	4.55	cG5	G3 Ib	-2.7	+1.08	+0.50	+0.22	-0.02	-0.20	-0.40	+0.90	2
3712n	α Cas	1	2.5	G7	K0 II-III	-0.4	+1.49	+0.65	+0.27	-0.04	-0.23	-0.46	+1.11	3
48329n	ε Gem	o	3.18	cG8	G8 Ib	-2.1	.....	+0.97	+0.37	-0.02	-0.35	-0.69	+1.66	2
						K Giants								
47205n	ν^2 CMa	o	4.14	K1	K1 IV	+0.7	+1.15	+0.50	+0.22	-0.03	-0.19	-0.35	+0.85	1
197989n	ε Cyg	?	2.9†	K0	K0 III	+0.7	+1.08	+0.49	+0.20	-0.02	-0.18	-0.37	+0.86	2
157588n	HR 6474	1	6.26	K1	......	+0.8	+1.50	+0.50	+0.25	-0.02	-0.23	-0.41	+0.91	2
199437n	HR 8016	?	5.58	K1	......	+0.8	+1.41	+0.65	+0.28	-0.03	-0.25	-0.47	+1.12	1
161096n	β Oph	1	2.94	K1	K2 III	+0.5	+1.59	+0.65	+0.29	-0.03	-0.26	-0.47	+1.12	3
47442n	ν^3 CMa	?	4.65	K1	K1 II-III	+0.4	+1.38	+0.63	+0.27	-0.01	-0.26	-0.50	+1.13	1
12929n	α Ari	o	2.23	K1	K2 III	+0.4	+1.40	+0.64	+0.25	0.00	-0.25	-0.52	+1.16	2
140573n	α_2 Ser	o	2.75	K2	K2 III	+0.5	+1.77	+0.69	+0.27	-0.02	-0.25	-0.48	+1.17	2
73108n	π^2 UMa	o	4.76	K2	K2 III	+0.5	+1.67	+0.73	+0.30	-0.01	-0.29	-0.55	+1.28	1
5848n	HR 285	o	4.52	K2	K2 III	+0.4	+1.73	+0.73	+0.31	-0.01	-0.29	-0.56	+1.29	1
12533n*	γ And	o	2.28	K3	K3 II	-0.2	+1.36	+0.61	+0.34	-0.02	-0.32	-0.69	+1.30	2
124897n	α Boo	o	0.24	K0	K2 IIIp	+0.2	+1.63	+0.73	+0.35	+0.01	-0.35	-0.59	+1.32	3
216446n	HR 8702	?	4.97	K3	K3 III	+0.1	+1.81	+0.79	+0.34	0.00	-0.35	-0.67	+1.46	1
3627n	δ And	o	3.49	K4	K3 III	+0.5	.....	+0.83	+0.35	-0.02	-0.33	-0.68	+1.51	3
124294n*	κ Vir	o	4.31	K2	K3 III	+0.6	.....	.....	+0.40	0.00	-0.40	-0.78	.....	1
32068n*	ζ Aur	o	4.4†	cK4	K5 III+B	-2.5	+0.78	+0.66	+0.47	+0.01	-0.48	-1.08	+1.74	2

Table 3 (Continued)

HD	Name	Z	m	V, W	Y	M	U	V	B	G	R	I	V-I	Obs.
						K Giants (Continued)								
217382n	HR 8748	o	4.96	K5	K4 III	+0.1	.....	+1.01	+0.45	0.00	-0.45	-0.88	+1.89	1
81797n	α Hya	o	2.16	K5	K4 III	-0.8	.....	+1.08	+0.45	-0.07	-0.38	-0.83	+1.91	1
131873n	β UMi	o	2.24	K5	K4 III	-0.5	.....	+1.07	+0.48	-0.01	-0.47	-0.93	+2.00	3
206778r	ε Peg	o	2.54	cK0	K2 Ib	-2.3	.....	+1.15	+0.48	-0.02	-0.46	-0.90	+2.05	4
158996n	HR 6529	o	5.91	K2	......	...	.....	+1.09	+0.51	0.00	-0.51	-0.98	+2.07	1
47667n	HR 2450	i	4.97	K5	K3 III	-0.7	.....	+1.13	+0.50	-0.01	-0.49	-0.94	+2.07	3
186791n	γ Aql	?	2.80	K4	K3 II	-0.8	.....	+1.17	+0.47	-0.01	-0.46	-0.91	+2.08	2
31398n	ι Aur	i	2.90	K3	K3 II	-0.5	.....	+1.14	+0.49	-0.02	-0.47	-0.99	+2.13	2
164058n	γ Dra	o	2.42	K5	K5 III	-0.1	.....	+1.19	+0.51	+0.02	-0.53	-1.11	+2.30	3
159881n*	......	i	7.02	K5	......	....	.....	(+1.48)	+0.86	+0.04	-0.90	-2.00	(+3.48)	2
						M Giants								
102212n	ν Vir	o	4.20	M1	M1 III	-0.5	.....	+1.16	+0.56	+0.04	-0.60	-1.31	+2.47	2
6860n	β And	o	2.37	M0	M0 III	+0.2	.....	+1.26	+0.59	+0.01	-0.60	-1.30	+2.56	2
51802r	NPS 1r	o	5.3	M0	......	-0.1	.....	+1.28	+0.62	+0.03	-0.65	-1.42	+2.70	4
18884n	α Cet	o	2.82	M2	M2 III	-0.1	.....	+1.46	+0.64	+0.03	-0.67	-1.50	+2.96	2
42995n	η Gem	i	3.2	M3	......	-0.8	.....	+1.30	+0.69	+0.08	-0.77	-1.80	+3.10	2
183030r	NPS 2r	o	6.55	M1	......	-0.3	.....	+1.35	+0.69	+0.07	-0.76	-1.76	+3.11	4
217906n	β Peg	o	2.61	M2	M2 II-III	-0.6	.....	+1.43	+0.72	+0.07	-0.79	-1.83	+3.26	3
44478n	μ Gem	i	3.19	M3	......	-0.6	.....	+1.44	+0.76	+0.08	-0.84	-1.88	+3.32	2
209772r	18 Cep	i	5.5	M5	......	0.0	.....	+1.35	+0.79	+0.12	-0.91	-2.22	+3.57	3
214665r	HR 8621	i	5.5	M4	......	-0.4	.....	+1.42	+0.80	+0.13	-0.93	-2.25	+3.67	2
175588r	δ^2 Lyr	o	4.5	M4	......	-1.6	.....	+1.48	+0.85	+0.11	-0.96	-2.33	+3.81	5
156014n	α Her	o	3.6	M5	......	-1.9	.....	....	+1.05	+0.17	-1.22	-2.93	.....	2

NOTES TO TABLE 3

HD

5394—Magnitude and color variable
8890—Polaris, variable, colors at maximum
12533—Color is composite
14633—Included to complete list of bluest stars
18925—Color is composite
19356—Algol near maximum
32068—Color is composite
35439—Color agrees with spectral type B1
37468—Combined A, B, C, and D
44743—Small variation in magnitude and color
48915—Visual magnitude from photoelectric measures
82210—Color indicates G-type spectrum

HD

103095—Color apparently composite
107192—Keenan calls it a normal giant, F2 III
116656—Includes companion at 14″
124294—Violet missed
159561—Color agrees with spectral type A5
159881—Violet doubtful
189340—Ultraviolet discordant
194335—Included to complete list of bluest stars
198802—Ultraviolet discordant
205021—Variable, mean colors
224930—Color is composite

TABLE 4

RELATIVE COLORS REFERRED TO O-TYPE STARS

V, W	Y	U	V	B	G	R	I	V−I	No.
O7.5....	O8	0.000	0.000	0 000	0.000	0 000	0 000	0 000	2
B0... .	O9.5	+0.040	+0 030	+0 005	.000	−0 005	−0 010	+0 040	2
B1.5....	B1	+0.155	+0.020	−0 005	.000	+0 005	−0 020	+0.040	2
B1.7....	B2	+0.190	+0 042	0 000	− .002	+0.002	−0 018	+0 060	3
B3... .	B3	+0 330	+0 075	+0 030	− .005	−0 025	−0.135	+0 210	2
B6... .	B5	+0 63	+0.12	+0 04	.00	−0 04	−0 19	+0 31	4
A0.1....	... ..	+1.31	+0.24	+0.10	.00	−0 10	−0 39	+0 63	4
A7.7....	......	+1 81	+0 62	+0.28	+ .02	−0 30	−0 79	+1 41	6
dF7.0....	... .	+1 96	+0 94	+0.46	+ .03	−0.49	−1.17	+2 11	4
dG1.5....	....	+2.13	+1.10	+0.52	+ .04	−0 56	−1.33	+2 43	4
cG1.7....	..... .	+2.78	+1.36	+0.61	+ .03	−0 64	−1.48	+2.84	3
dK1.7....	......	+2 66	+1.38	+0.60	+ .07	−0.67	−1.57	+2 95	3
gK0.5....	....	+3 27	+1.64	+0.74	+ .03	−0.77	−1.75	+3.39	4
dK5.7....	......	+3.31	+1.70	+0.77	+ .08	−0.85	−1.92	+3 62	3
cK5.0....	....	+4.86	+2.41	+1.07	+ .05	−1.12	−2.43	+4 84	3
dM0.....	....	....	+2.13	+1.04	+ .10	−1.14	−2.47	+4 60	3
gM0......	....	....	+2.44	+1.15	+0.07	−1.22	−2.75	+5.19	4

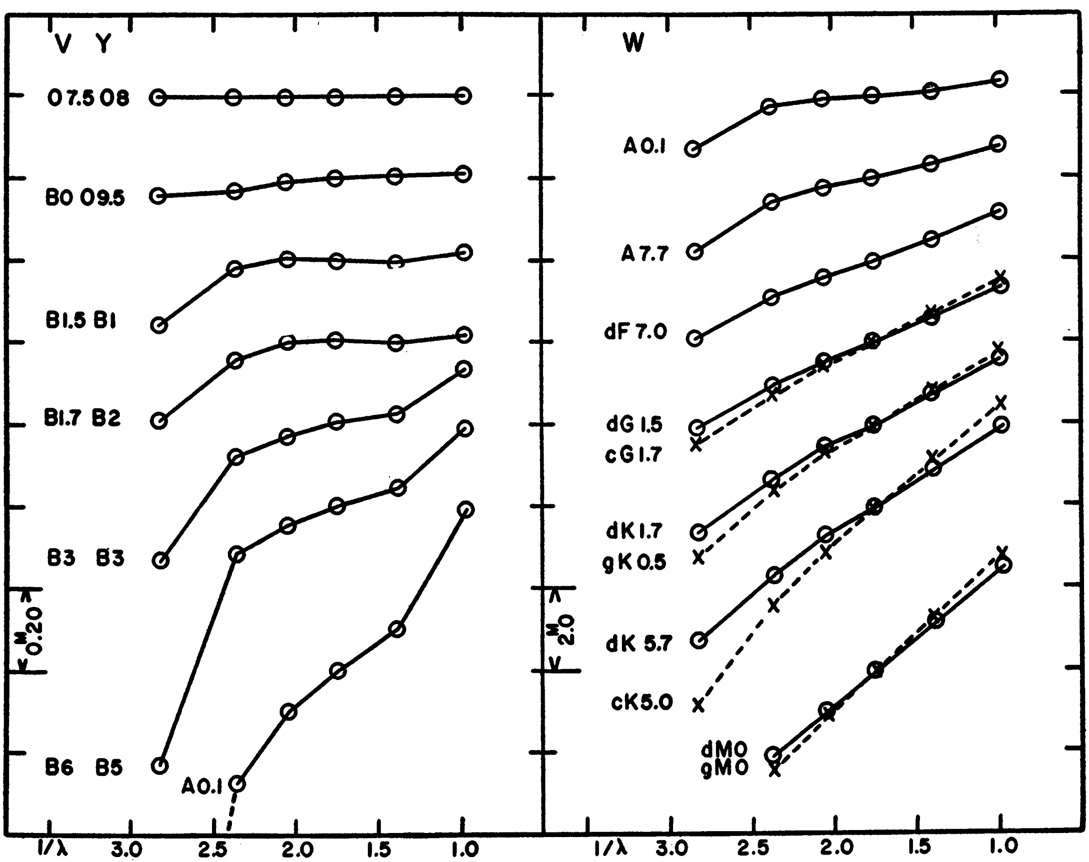

FIG. 1.—Colors referred to O type

TABLE 5

OBSERVATIONS OF B STARS BY HALL

1/λ	1.54	1.44	1.34	1.26	1.19	1.12	1.07	1.02
Obs. Δ*m*...	0 288	0 238	0.205	0.200	0.180	0 110	0 032	0.000
Comp. Δ*m*.. .	.288	230	.179	.133	095	.059	.029	000
O−C..... ..	0.000	0.008	0.026	0.067	0.085	0 051	0.003	0 000

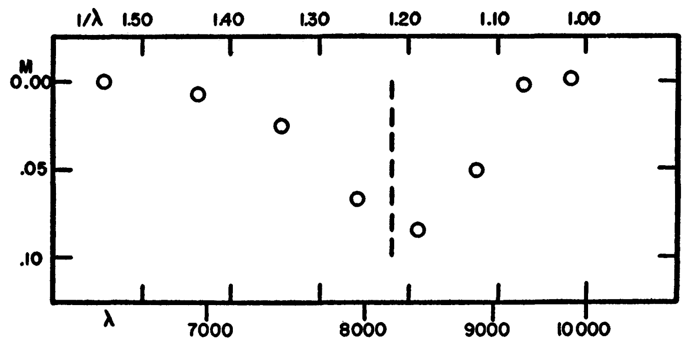

FIG. 2.—Paschen depression in A stars by J. S. Hall

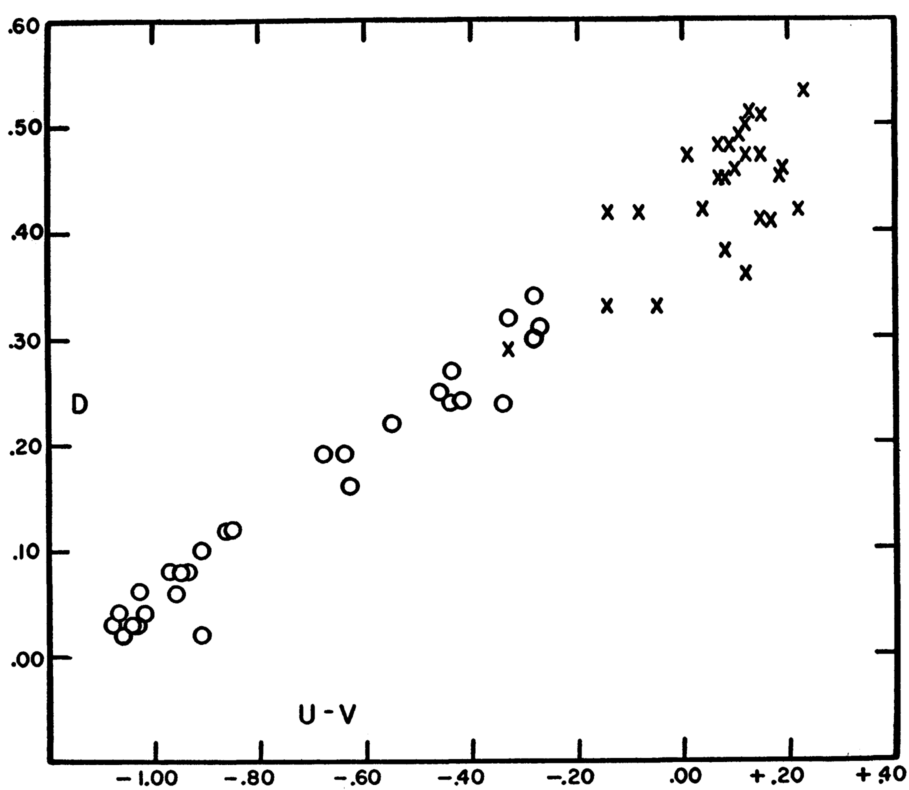

FIG. 3.—Relation between U − V and Barbier and Chalonge's *D; circles,* O and B stars; *crosses,* A stars.

is an obvious Paschen depression in the infrared. The Paschen limit at $\lambda = 8206$ A, $1/\lambda = 1.22$, is caught by the toe of the curve of the red filter. These two strong effects of hydrogen absorption will obviously complicate any effort to determine color temperatures from the six-color data.

From A0 on, the Balmer depression gets less until it is about gone at G0, but, from there, we have the well-known ultraviolet absorption like that of the sun in both dwarfs and giants. The over-all difference between dwarfs and giants, as shown in the figures, probably is greatest in the M's, but there our measures become less certain in the weak ultraviolet.

The Paschen depression in the near infrared was detected in the spectrum of Vega by Hall and Williams (1942) in a comparison of this A0 star with a standard lamp, but Hall (1941) had already measured infrared regions that showed the Paschen absorption differentially between A0 and early B stars. In Table 5 under each $1/\lambda$ the first line gives the mean Δm, referred to standard A0, of four stars averaging B1, taken from Hall's Table 7, with zero point at $1/\lambda = 1.02$. The second line gives the linearly interpolated values between $1/\lambda = 1.02$ and $1/\lambda = 1.54$. Hence the last line, (O − C), gives the deviations from a uniform continuum between those limits. These deviations are plotted in Figure 2, and the Paschen depression is shown even better than in the results for Vega by Hall and Williams. The first good spectrograms showing the Paschen series in A stars seem to have been obtained by Merrill (1934) and by Merrill and Wilson (1934).

The Balmer depression in our ultraviolet results is well correlated with the quantity D that Barbier and Chalonge (1941) used to indicate the size of the Balmer discontinuity in their spectrophotometric measures. The relation between their D and our U − V for nonreddened B and A stars is shown in Figure 3. When the types are later than A, the relation is complicated by the presence of metallic lines in the spectra and becomes confused. In Figure 3 the discordant star, 25 Orionis, at U − V = −0.91, may be anomalous, since it is known to have variable bright hydrogen lines (Dodson 1940).

In Paper III it was found that the combined light of the four stars in the Trapezium of Orion gave what appeared to be the only clear-cut case of deviation from the law of interstellar absorption that obtains in reddened early-type stars in other parts of the sky. These deviations are shown in Table 9 and Figure 4 of that paper. We now have two additional stars that show the same anomalous absorption, θ^2 Orionis, not far from θ^1 in the nebula, and ϕ Persei, previously overlooked as being in the same class. The color of the Trapezium stars was discussed by Baade and Minkowski (1937), but neither they nor we looked into the possibility that undetected late-type companions might be affecting the colors of the early-type primaries. All four components of θ^1 seem to be spectroscopic binaries with single lines, and the same holds for both θ^2 Orionis and ϕ Persei (Moore and Neubauer 1948). Although such redder companions might show little effect in the photographic and visual regions, their light could be conspicuous in the infrared at 10000 A. We can find by trial what combination of a yellow star and a small amount of reddening will change the light of an O or B star to the quality observed in one of these anomalous objects.

This procedure is exemplified in Table 6, where under the proper headings the first line gives the six colors of a normal O star referred differentially to the infrared. The second and third lines give six-color data for B0 and gK0 spectral types, while the fourth line gives the usual interstellar absorption when reduced to V − I = 1.00 (Stebbins and Whitford 1943). To represent the colors of θ^2 Orionis, we add to the colors of the normal O star those of a K0 star, which is 0.75 mag. fainter in the infrared than the O star, as indicated in the column Δm_i in the table. We then apply the absorption proportional to V − I = 0.25, as in the last column of the table, and when the resulting colors are referred to the mean of BGR, we have the computed values in the line below θ^2 Orionis. The practically perfect agreement with the observed colors of this star could also have been obtained by assuming the companion to be a later K or an earlier G star, with different proportions of the magnitude difference and the absorption. Hence we find no need to draw upon anomalous absorption to satisfy the measured colors of θ^2 Orionis.

The cases of θ^1 Orionis and ϕ Persei are not so clear. Various trials for each of them always gave a discordant residual in the red. As noted, all four bright components of θ^1 Orionis have spectroscopic companions, while the spectrum of ϕ Persei is anomalous (Hynek 1940) and has bright hydrogen lines of the Paschen series (Hiltner 1947). Therefore, until we can be sure that there is no effect of companions or of idiosyncrasies in the spectra, there is little point in attempting to evaluate a subtle deviation from the law of absorption for either of these stars.

The possibility that undetected companions may affect the colors of other O and B stars used to determine the law of interstellar absorption is always present, but it is

TABLE 6

EFFECTS OF COMPANIONS AND INTERSTELLAR ABSORPTION ON COLORS OF EARLY-TYPE STARS

	U	V	B	G	R	I	V−I	Δm_i	Absorption V−I
O.	−3 64	−2 57	−1 93	−1 44	−0 80	0 00	−2 57	. . .	. .
B0.	−3 59	−2 53	−1 92	−1 43	− 79	00	−2.53	. . .	. . .
gK0	+1 38	+0 82	+0 56	+0 34	+ 18	.00	+0 82	.	. . . .
Absorption	+1 22	+1 00	+0 82	+0 61	+ 33	00	+1 00	. .	1.00
θ^2 Orionis. .	−1 97	−0 98	−0 41	−0 02	+ 43	+ 92	−1 90	. . .	. . .
O+K0+Abs.	−1 99	−0 98	−0 42	−0 03	+ 44	+ 92	−1 90	0 75	0.25
O−C.	+0 01	0.00	+0 01	+0 01	− 01	00	0 00	. . .	. .
θ^1 Orionis . .	−1 68	−0 76	−0 29	+0 02	+ 27	+ 57	−1 33	. . .	. . .
B0+K0+Abs	−1 68	−0 77	−0 31	−0.01	+ 32	+ 56	−1 33	00	0 50
O−C	0 00	+0 01	+0 02	+0 03	− 05	+ 01	0 00		.
ϕ Persei	−1 88	−0 91	−0.36	0 00	+ 36	+ 80	−1 71	. . .	. . .
B0+K0+Abs.	−1 89	−0 91	−0 38	−0 02	+ 41	+ 80	−1 71	0 25	0 23
O−C	+0 01	0 00	+0 02	+0 02	−0 05	0 00	0 00	. .	.

probably of little significance. The very blue B0 star, δ Orionis, is a single-lined binary showing eclipses (Stebbins 1915), but the companion has nearly the same surface brightness and hence nearly the same color as the primary. Since strong reddening by absorption is far greater than any possible effect of an unknown companion, we can dismiss the latter as of little importance in color comparisons.

GENERAL REMARKS

The newly observed stars of the present study were added to round out the earlier list; two-thirds of them are brighter than visual magnitude 5.0, and about 50 are brighter than 3.0. Hence many can be studied spectroscopically with high dispersion. These additional early O–B3 stars strengthen the list at the top of each type, as shown in Table 4, but it is probable that a further search will uncover still bluer stars to serve as non-reddened standards in studies of space absorption. The additional stars of types A, F, G, and K do not furnish any striking differences from the conclusions in Paper III, but they are available for comparisons with color systems like that set up by Morgan, Harris, and Johnson (1953). The extra number of F and G dwarfs was obtained in order to place the sun on the stellar scale of colors, but this study will be the subject of another paper.

We are much indebted to Dr. W. W. Morgan for furnishing the latest classification of many of our stars on the revised system of the Yerkes spectral *Atlas*. The inauguration of this work at the Lick Observatory was supported by two grants from the American Philosophical Society.

REFERENCES

Baade, W., and Minkowski, R. 1937, *Ap. J.*, **86**, 119; *Mt. W. Contr.*, No. 571
Barbier, D., and Chalonge, D. 1941, *Ann. d'Ap*, **4**, 30.
Dodson, H. W. 1940, *Ap. J.*, **91**, 126.
Hall, J. S. 1941, *Ap. J.*, **94**, 71.
Hall, J. S., and Williams, R C. 1942, *Ap. J.*, **95**, 225.
Hiltner, W. A. 1947, *Ap. J.*, **105**, 212.
Hubble, E. P. 1934, *Ap. J.*, **79**, 41; *Mt. W. Contr.*, No. 485.
Hynek, J. A. 1940, *Perkins Pub.*, **2**, 1.
Merrill, P. W. 1934, *Ap. J.*, **79**, 183; *Mt. W. Contr.*, No. 486.
Merrill, P. W., and Wilson, O. C. 1934, *Ap. J.*, **80**, 19; *Mt. W. Contr.*, No. 494.
Moore, J. H., and Neubauer, F. J. 1948, *Lick Obs. Bull.*, **20**, 1 (No. 521).
Morgan, W. W., Harris, D. L., and Johnson, H. L. 1953, *Ap. J.*, **118**, 92; *McDonald Contr*, No. 224
Stebbins, J. 1915, *Ap. J.*, **42**, 133.
Stebbins, J., and Whitford, A. E. 1943, *Ap. J.*, **98**, 20; *Mt. W. Contr.*, No. 680.
———. 1945, *Ap. J.*, **102**, 318; *Mt. W. Contr.*, No. 712.