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THOMAS KELSALL

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Thomas Kelsall
Laboratory for Space Physics
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

September 1972

ABSTRACT

Color excesses in B-V are determined indirectly from a study of Strömgren's b-y color for a sample of F0 - K5 supergiants. The resulting E(B-V)'s are estimated to have an expected precision of $\pm 0\overset{m}{.}05$. With the calculated color excesses and the observed values of B-V given in various catalogs, the run of B-V with spectral type is obtained. This B-V/(spectral type) relationship is compared with those found previously by other investigators.

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Thomas Kelsall
Theoretical Studies Branch
NASA-Goddard Space Flight Center
Greenbelt, Maryland 20771

I. INTRODUCTION

The supergiant F0-K5 subgroup is of much importance for three basic reasons. First, they are useful in the determination of galactic structure and kinematics, either as a self-enclosed unit (Bidelman 1958), or as a sub-unit to a larger sample (Humphreys 1970). Their worth in such studies is somewhat limited by the difficulty of assigning to individual stars accurate absolute magnitudes and reddening corrections. In addition, these stars are not of zero age and some have moved appreciably away from their place of origin. However, as evolutionary models for stars become more precise it is possible that they will be fine markers for the determination of a galactic diffusion constant. A second asset of the group, which results from their extreme brightness, is their detectability to great distances, even in extra-galactic objects. Thus, they can be used to determine both the galactic contribution and the projected-space variations of the internal reddening in extra-galactic objects, and to evaluate distance modulii (Dachs 1972). Finally, they are a class of stars whose atmospheres are inherently interesting:

a/ They are the stable equivalents of the cepheid variables, which they resemble closely; in fact, the correspondence is so tight that some appear to reside within the instability strip, but they themselves are stable (Schmidt 1972a).

b/ The combination of physical conditions in their atmospheres is unique and an understanding of it is most intriguing - high radiation pressure, extended atmospheres, very low gravity, micro- and macro-turbulent motions, mass loss by stellar winds, radiative diffusion, effectiveness of convection, etc.

Recently, the attacks on the understanding of the physical make-up of supergiant atmospheres are of ever increasing sophistication and completeness (see, for example, Bell and Rogers 1969; Auman 1969; Parsons 1969, 1971; Böhm-Vitense 1972; Schmidt 1972b,c).

To implement fully projects in any of the above three categories it is essential to have accurate observational assessments of intrinsic colors. The UBV system's B-V color is one of prime importance. It is measurable to a faint limit, either photoelectrically or photographically; is used extensivly, and have a large body of data already carefully cataloged (Blanco et al. 1968). Theoretically B-V is a color reasonably easily simulated from atmospheric model results, and thus it is a useful fiducial mark to tie theory to observation.

There have been numerous efforts to ascertain $(B-V)_o$ as a function of spectral type (see, for example, Kraft and Hiltner 1961; Fernie 1963; Schmidt-Kaler 1965; Johnson 1966; FitzGerald 1970). The results, while in general accord, are divergent up to $0^m.1$ or more at a single spectral type. Most of the troubles doubtless arise from the insufficiency of U-B, B-V and spectral type data as a complete set, an aspect of the problem succinctly analyzed by FitzGerald (1970).

In this paper we approach the finding of $(B-V)_o$ by an indirect route. Using a G-band measure and a blue-minus-yellow color gives precise color excesses which are transformable to E(B-V)'s. With these excesses and values of B-V listed in catalogs, a first value for $(B-V)_o$ for particular stars is found. We determine an additional estimate for $(B-V)_o$ using the linear correlation between the intrinsic value of our blue-minus-yellow color and B-V. A $(B-V)_o$ for a given star is the simple average of the two estimates. The $(B-V)_o$'s so determined are averaged for stars of the same spectral type to give the run of $(B-V)_o$ with spectral type. The findings are compared to those found by investigators.

II. THE DATA

Kelsall (1971) observed F-K supergiants on a composite photometric system made up of the four-color Strömgren system (1966) and the ABC system of Crawford (1961). From these results we utilize the yellow magnitude, y, the blue-minus-yellow color, b-y, and the G-band index, $G = B-A = 2.5 \mathrm{Log}\ (I_{4297}/I_{4377})$. The UBV data consists of the V magnitude and the B-V color. These are from the catalog of Blanco et al. (1968), and for four stars from the listing of Humphreys (1970). In the cases where there are multiple listings in the Blanco et al. catalog, a simple unweighted average is taken.

The yellow magnitude of the Strömgren system is linearly related to the V of the UBV system, as is seen in Fig. 1. The RMS deviation about the straight line y = V (which is as adequate as any fit), is $0\overset{m}{.}04$, and with average deviation of $+0\overset{m}{.}004$ which is below significance. In fact, the fit y = V is at the expected noise level of $\sim 0\overset{m}{.}02$, if only seven of the one hundred and six stars are removed from the sample. Recognizing that some supergiants exhibit small fluctuations in V, and that the 1-to-1 fit is near perfect, we accept the yellow magnitude y as identical to V, and list it as such here. The comparison between the colors b-y and B-V is illustrated in Fig. 2. There is an obvious linear relationship. The differential reddening effect on the two colors is evidenced by the successive sliding of the earlier spectral types under the later spectral types.

III. THE DETERMINATION OF THE E(B-V)'S.

The dependence of the G-band index on b-y is clearly linear, as is shown in Fig. 3. The diffusion of the points toward the right is the result of reddening. The slope of the reddening line is 0.15, with an estimated error of ± 0.02. It appears that a linear blue-most envelope is viable. The simple linear approximation is supported by: (1) the data plotted in Fig. 3; (2) the tightness of the G/(b-y) loops for cepheids, all of whose semi-major axes have approximately identical inclinations in the G,b-y plane (Willians 1966; Kelsall 1971); (3) the determination of G on b-y found by convoluting atmospheric simulations with the filter functions appropriate for these colors (Bell and Parsons 1972). From the data shown in Fig. 3 we find reasonable the relation --

$$G_o = 0.532(b-y)_o - 0.091. \qquad (1)$$

The zero point is a revision of that given earlier (Kelsall 1971) which appears, from various evidences, to give a too conservative estimate for the blueward position (Kelsall 1972). An excess in b-y is obtained by simply extrapolating the observed position of the star back along the reddening trajectory until it intersects the thermal locus --

$$E(b-y) = (b-y)_{obs} - 2.618(G_{obs} - 0.15(b-y)_{obs} + 0.091). \qquad (2)$$

Clearly from the coefficient of the second term on the rhs of Eq. (2) we see that small errors in the observed quantities and the zero point contribute significantly to errors in the excess. We should expect the excess for a particular star to be accurate to the order of three or four hundreths of a magnitude. Of course, this is all within the simplex frame work of a line thermal locus. Doubtless the locus is a band of finite width, but the implementation of such a refinement in the analysis is presently beyond us.

The transformation of the b-y excesses to excesses in B-V is not as trivial as expected. Epstein (1969) in a fine study of the RR-Lyrae stars finds the ratio of the color excesses, $r_E = E(B-V)/(b-y)$, to be 1.82; while Strömgren (1966) and Crawford et al. (1971), working mainly with B-F stars, use an r_E of 1.43. Crawford et al. do point out that this ratio does not appear good for their supergiant results, though, of course, these results are for supergiants of much earlier types than those considered here. Kelsall (1972) finds for the cepheids that a fine compromise for r_E is 1.22. This ratio brings his excesses in b-y onto the excellent base of the Kraft-Sandage-Tammann system of B-V colors for cepheids (Sandage and Tammann 1971). To decide on an r_E suitable for the F-K supergiants we have five pieces of information. First is the result for the cepheids stated above, a result which should be applicable to the range F3 to G2 for the supergiants. A second point is that the convolution of the filter functions, simulated spectra in the range early F's to early G's, and van de Hulst's curve #15 for the interstellar reddening leads to a predicted r_E of 1.27 (Bell and Kelsall 1973. Third is a comparison of our E(b-y)'s against the theoretical/observational evaluations for E(B-V) made recently by Schmidt (1972b). Unfortunately, the overlap in the projects is only ten stars, but from these we find an r_E of 1.18, a value germane to stars of spectral types F0 to G2. We should note that Schmidt found it difficult to reconcile our results for the supergiants and cepheids with his predictions. However, he compared an $E(B-V)_{\text{Kelsall}}$, not our measured quantity E(b-y), to an $E(B-V)_{\text{Schmidt}}$. The transformation $E(b-y) \rightarrow E(B-V)$ is not stated in his article.

Probably an ad hoc transformation was used ($R_E \sim 1.4$) with no effort made to ascertain a more appropriate regression line. However, a puzzle remains in attempting to coalesce Schmidt's and our work for the regression lines linking our excesses are not identical for the cepheids ($r_E \sim 1.0$) and the supergiants ($r_E \sim 1.2$), but this might arise simply from there being too few stars in common in both groups (see also Kelsall 1972). The fourth datum is the comparison of our E(b-y)'s with the extensive observational compilation of E(B-V)'s by Buscombe (1970). The scatter is quite large, but the evaluation of r_E is in the range of 1.3, whether all the stars in common (92) are used or the comparison is made for limited spectral type groupings. Except for Buscombe's results which cover the full range F0-K5, the other clues to the proper transformation of the excesses are restricted to the F through the early G stars. To include the late G and K stars we use as our fifth indicator the dependence of B-V on b-y at a particular spectral type. Here, of course, the assumptions are that the spectral type designations are accurate, and that the differential positioning of the stars in the (B-V), (b-y) plane is purely a result of reddening. The G5 stars give an $r_E = 1.24$, and the K3 stars require an $r_E = 1.21$. It should be noted that groupings of stars of earlier spectral types produce r_E's more in the range of 1.3. All five evidences presented above appear to indicate that the compromise used for the cepheids (Kelsall 1972) is also eminently suitable for the supergiants. Thus, we accept the relation --

$$E(B-V) = 1.22E(b-y). \tag{3}$$

We can use the linear dependence of B-V on b-y to give us a second, though not totally independent, estimate for E(B-V). From the reddening-corrected (b-y)'s for the stars least reddened in b-y and the unreddened values of B-V using Eq. (3), we find that --

$$(B-V)_o = 1.594(b-y)_o + 0.053. \tag{4}$$

A relation virtually identical to that found by Kelsall (1971) for the cepheids, when that relation is modified to our new zero point in b-y --

$$(B-V)_o = 1.606(b-y)_o + 0.071. \tag{5}$$

The relation (4) is quite insensitive to the imposed reddening corrections, for if no corrections are made in either color we find for the blueward-most stars --

$$(B-V) = 1.596(b-y) + 0.033. \tag{6}$$

Once the intrinsic b-y is fixed we determine our second, smoothing estimate for E(B-V) from --

$$E(B-V) = (B-V)_{obs} - (1.594(b-y)_o + 0.053). \tag{7}$$

The errors here should be comparable to those for the transformed excesses in b-y, which we estimate to be of the order of $\pm 0\overset{m}{.}05$.

We adopt as a final E(B-V) for any star the arithmetic average of Eq. (3) and Eq. (7). These accepted values for the excesses are compared in Fig. 4 to those given by Buscombe (1970) and Schmidt (1972b). The agreement in trend is satisfactory in both cases, as is demonstrated by the distribution of the points about the line of slope = 1. Relative to Buscombe's results we systematically estimate lower reddening values. There is no clear cut dependence on spectral type, but such correlations are hard to discern because of the large scatter. Comparison with Schmidt is limited by the few stars in common, but we note the obvious discrepant values for the two G supergiants α and β Aqr, while the F stars are in total agreement except for zero point. This discord in the excesses for these two stars is in common with the estimates for the excesses made by Parsons and Bell (1972) using spectrum synthesis techniques. However, Schmidt does consider his method to be difficult to apply to stars with $(B-V)_o$'s greater than ~0.8, a value close to that which we predict for these two stars (α Aqr, 0.90; β Aqr. 0.72).

IV. THE RESULTS

In Table I we present the results for our 115 stars. A brief description of the columns is as follows:

Col. 1 - name of the star;

Col. 2 - HD or BD catalog number;

Col. 3 - MKK classification;

Cols. 4-5 - new galactic coordinates;

Col. 6 - yellow magnitude from Kelsall (1971);

Col. 7 - B-V as listed in Blanco et al. (1968), or Humphreys (1970);

Col. 8 - our adopted value for E(B-V), enclosed in parentheses if it is purely a direct transformation of E(b-y) via Eq. (3) (all subsequent entries are also enclosed in parentheses);

Col. 9 - visual magnitude corrected for reddening, $V_c = V - 3.3E(B-V)$, following Martin (1971);

Col. 10 - intrinsic value for B-V;

Col. 11 - calculated distance from the sun based on Blaauw's (1963) calibration of absolute magnitudes.

In Fig. 5 we show our approximation for the run of $(B-V)_o$ on spectral type. At each spectral type the values for $(B-V)_o$ are the average of the data given in Table I. Most data points are given a weight of one, except those in parentheses which are given half weight. The results for the luminosity class II stars are excluded totally; our data is too scant on this group for any conclusions, except to say that they do appear different from the luminosity class I stars. The large circles in Fig. 5 are these weighted average points, which we call the "raw" run. The series of connected straight lines in the figure are our eye-estimate for the run, which we designate as the "smooth" run. If the values of the smooth run in B-V are plotted against their b-y equivalents, it is found that the points in the (B-V),(b-y) plane are scattered about the intrinsic relationship given by Eq. (4). Assuming equal errors in the two colors we can adjust the runs on spectral type so each spectral type point falls on this intrinsic line of Eq. (4). We call such an adjustment the photometrically "perfect" run. In Table II we compare our three runs to those previously determined by other investigators. Our findings are in accord in rough aspect with the others, with the largest divergences occurring in the early K results.

V. CONCLUSIONS

Adequate transformations can be found to convert the results in the Stromgren-Crawford system onto the UBV system; in particular, the color excesses for B-V. The usefulness of the inclusion of Crawford's G-band index in conjunction with a blue-minus-yellow color is the ability to determine precise color excesses for F-K supergiants. As B-V and b-y are linearly related it then would appear reasonable for UBV observationalists to consider carefully the option of expanding their system to the UBV:AB system. In addition the index G is a measure of a physically important parameter.

The ultimate aim of finding an improved run of $(B-V)_o$ on spectral type is accomplised. The run, while considered precise, does not support any other single previous determination. Our run must be considered as yet another approximation to a difficult, but important problem.

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______________ 1972b, Astrophys. J. 174,595.

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VII. FIGURE CAPTIONS

Fig. 1 The V magnitude from Blanco et al. (1968) versus the y magnitude from Kelsall (1971).

Fig. 2 Comparison of the two blue-minus-yellow colors B-V and b-y.

Fig. 3 The G-band index versus b-y.

Fig. 4 Relationship between the B-V color excesses of Kelsall to those of Buscombe (1970) and Schmidt (1972b).

Fig. 5 The run of $(B-V)_o$ with spectral type.

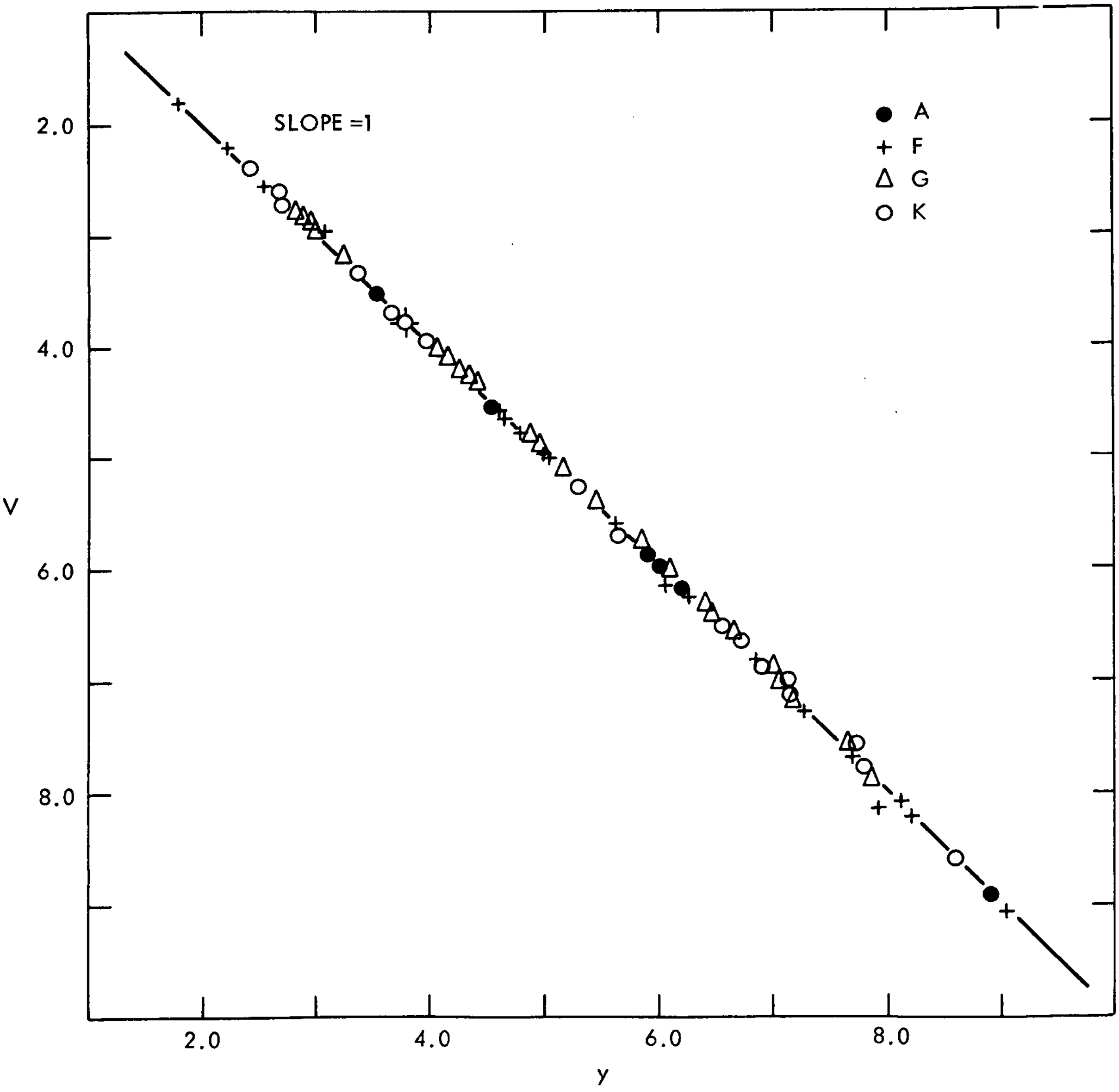


Fig. 1

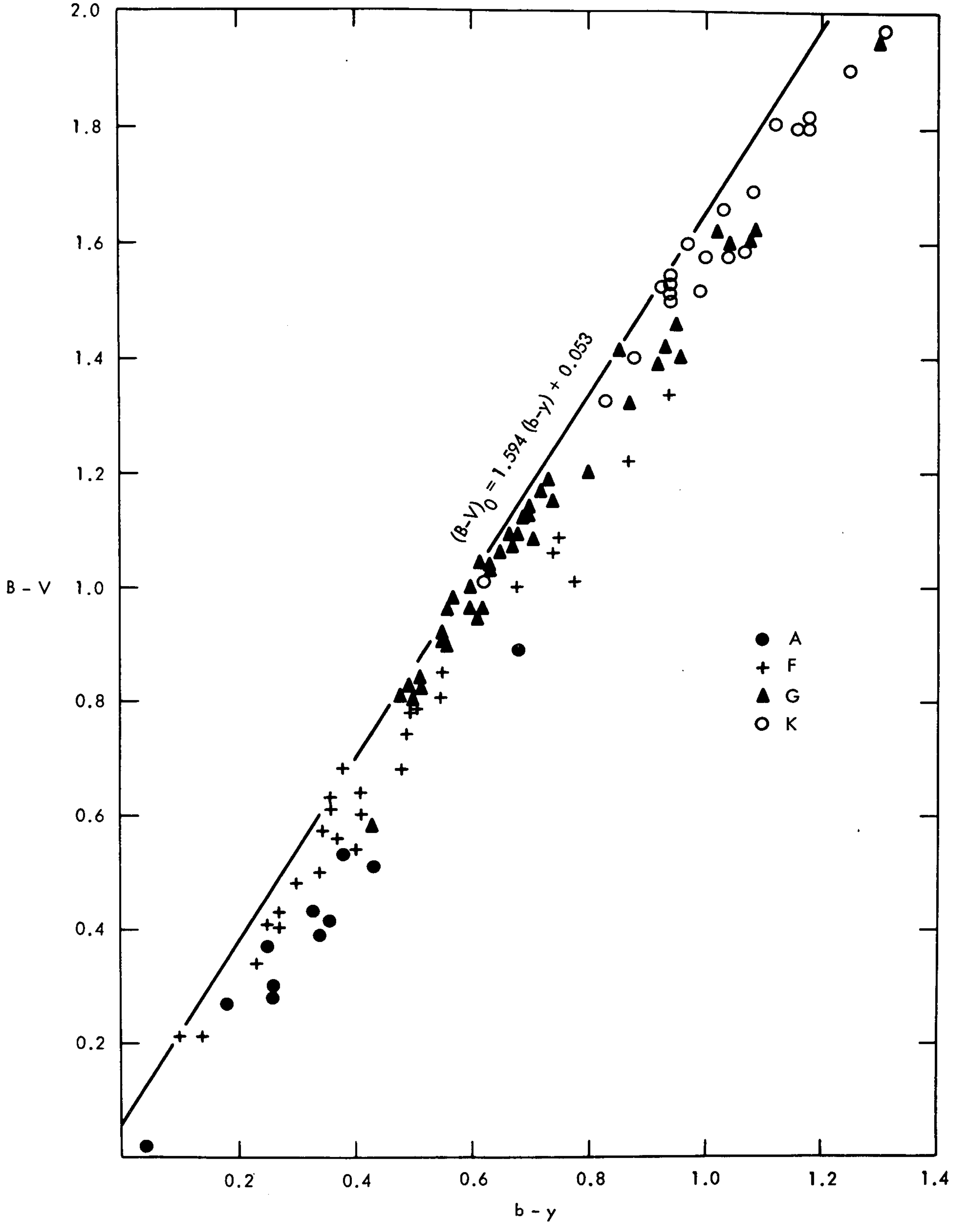
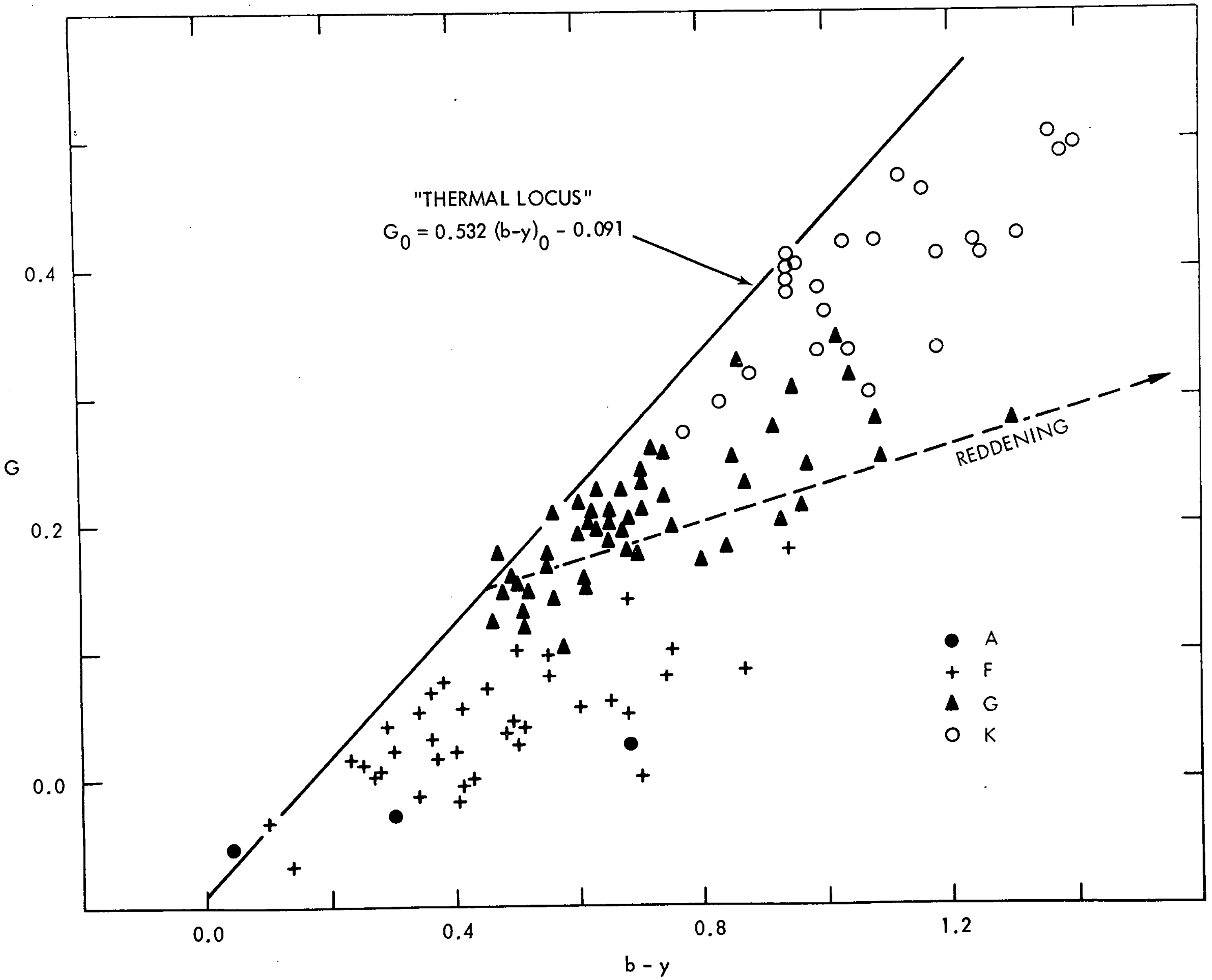

$(B-V)_0 = 1.594\,(b-y) + 0.053$
B - V
b - y
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
1.0
1.2
1.4
● A
+ F
▲ G
○ K

Fig. 2


"THERMAL LOCUS"
$G_0 = 0.532\,(b-y)_0 - 0.091$
REDDENING
G
0.4
0.2
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b - y
0.0
0.4
0.8
1.2
● A
+ F
▲ G
○ K

Fig. 3

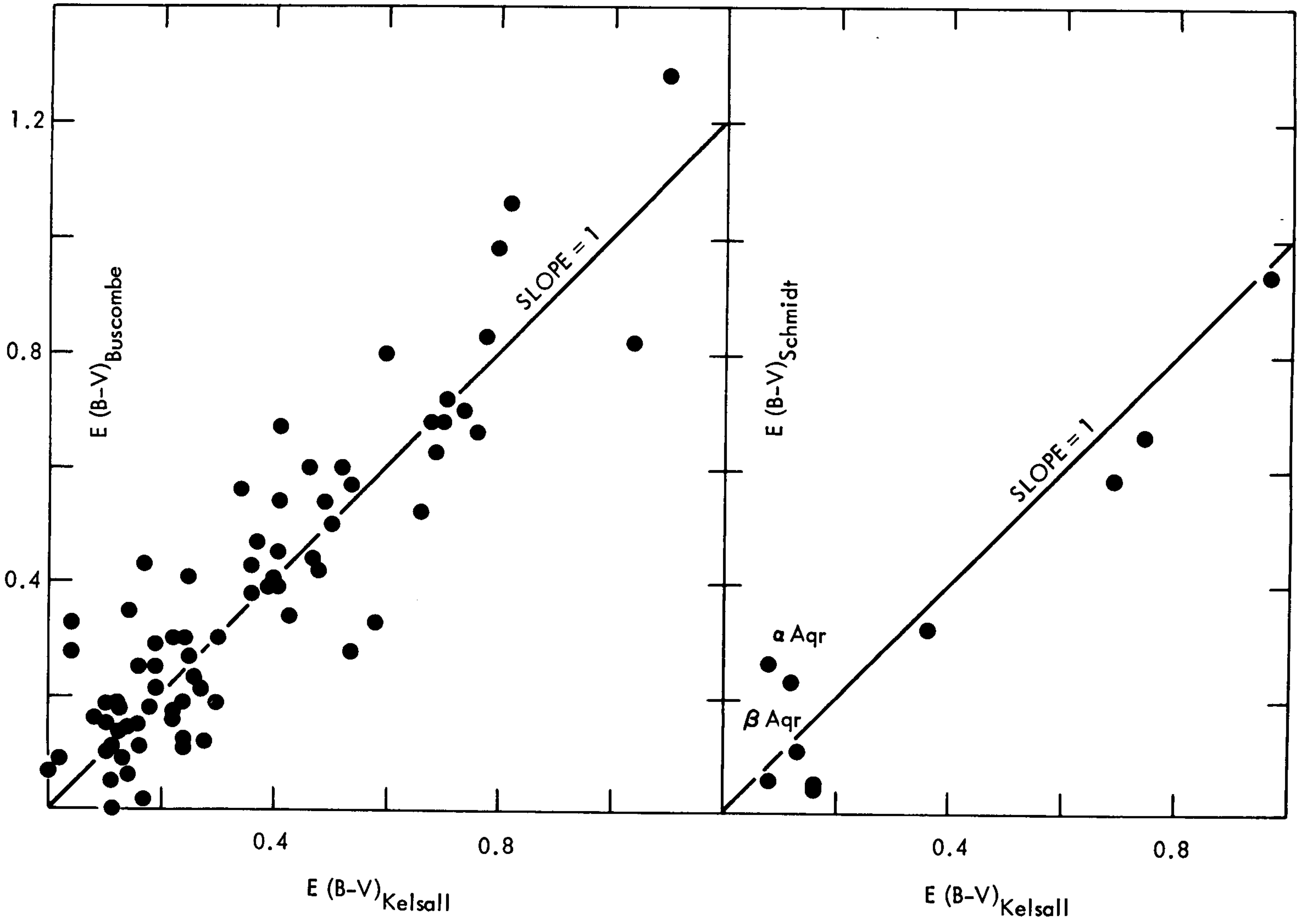
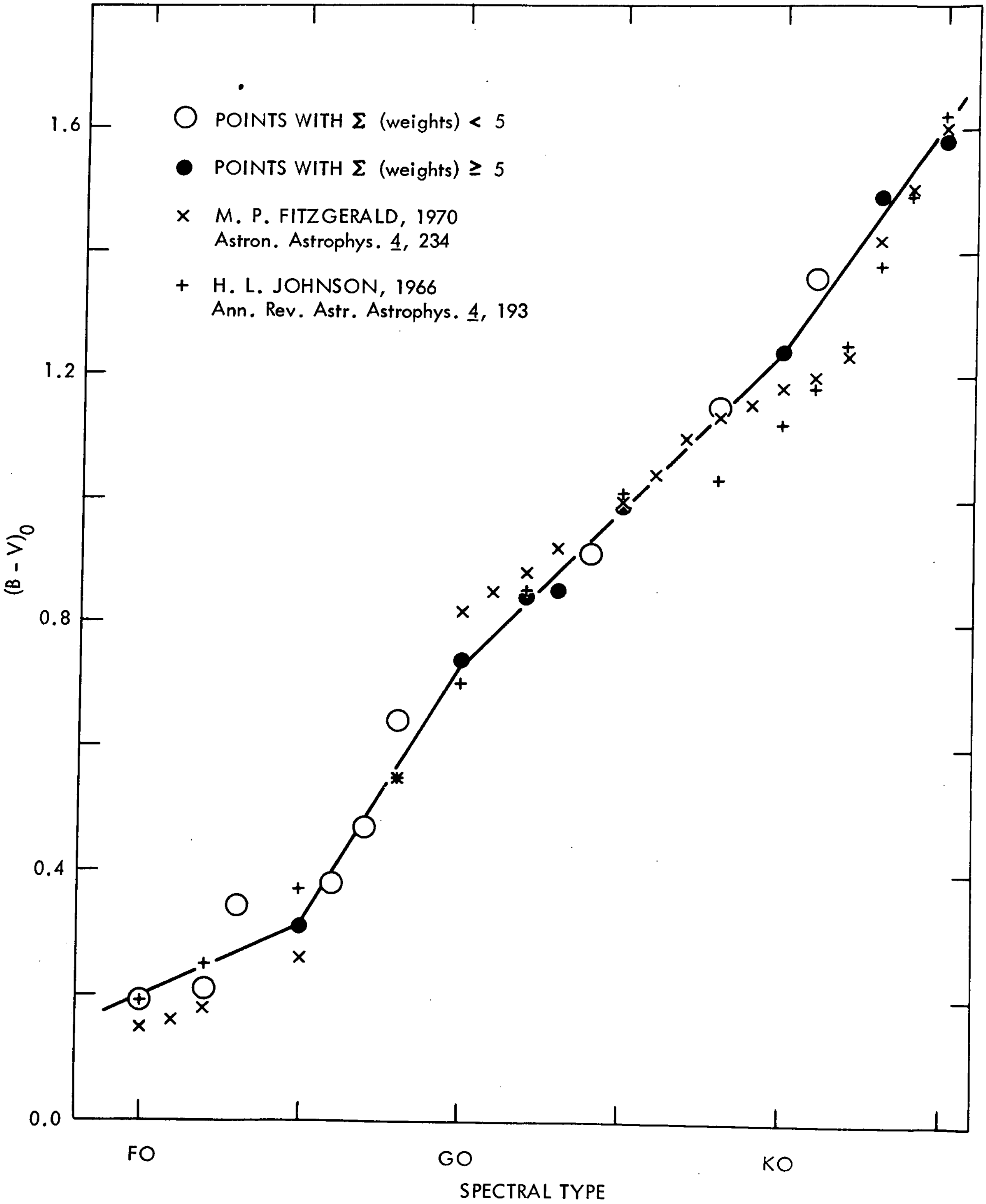

1.2
0.8
0.4
E (B-V)$_{Buscombe}$
SLOPE = 1
0.4
0.8
E (B-V)$_{Kelsall}$
E (B-V)$_{Schmidt}$
SLOPE = 1
α Aqr
β Aqr
0.4
0.8
E (B-V)$_{Kelsall}$

Fig. 4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● POINTS WITH Σ (weights) ≥ 5
× M. P. FITZGERALD, 1970
Astron. Astrophys. 4, 234
+ H. L. JOHNSON, 1966
Ann. Rev. Astr. Astrophys. 4, 193
1.6
1.2
0.8
0.4
0.0
$(B - V)_0$
FO
GO
KO
SPECTRAL TYPE

Fig. 5

TABLE I. Data for the 115 supergiants.

Name	HD/BD	MK Class	l	b	V	B-V	E(B-V)	V_c	$(B-V)_o$	r(kpc)
22 And	571	F2 II	115.5	-16.2	5.04	0.40	0.15	4.54	0.25	0.26
	4362	G0 Ib	122.3	-3.3	6.41	1.09	0.25	5.58	0.84	1.04
	6474	G0 Ia	124.6	1.0	7.64	1.62	0.80	5.00	0.82	3.98
φ Cas	7927	F0 Ia	126.7	-4.4	5.00	0.68	0.41	3.64	0.27	2.68
	8906	F3 Ib	127.6	-2.5	7.13	0.74	0.41	5.77	0.33	1.19
	8992	F6 Ib	127.9	-3.7	7.78		(0.54)	(6.00)	(0.29)	(1.32)
	9250	G0 Ib	127.5	1.1	7.18	1.42	0.71	4.90	0.73	0.76
	9366	K3 Ib	128.7	-7.8	6.92		(0.48)	(5.34)	(1.41)	(0.89)
	10494	F5 Ia	129.1	-0.4	7.28	1.22	0.96	4.17	0.28	2.98
	11092	K5 Iab-Ib	129.2	2.7	6.57	2.08	0.50	4.98	1.60	1.50
	11800	K5 Ib	131.1	-1.6	7.79	2.04	0.37	6.57	1.67	1.56
	12014	K0 Ib	131.6	-2.5	7.72	1.97	0.58	5.80	1.39	1.10
	59° 389	F0 Ib	131.7	-1.4	9.05	1.01	1.04:	5.61:	-0.05:	1.15:
	14662	F7 Ib	135.9	-5.2	6.28	0.85	0.36	5.09	0.49	0.87
14 Per	16901	G0 Ib	143.3	-14.1	5.45	0.90	0.22	4.72	0.68	0.70
	17378	A5 Ia	138.5	-2.2	6.25	0.89	0.78	3.67	0.11	1.88
η Per	17506	K3 Ib	139.1	-3.2	3.77	1.69	0.19	3.14	1.50	0.32
	17958	K3 Ib	136.0	4.7	6.22	2.06	0.46	4.70	1.60	0.66
	17971	F5 Ia	137.8	1.2	7.74	1.06	0.74	5.29	0.32	4.99
	18391	G0 Ia	139.5	-1.0	6.94	1.95	1.10	3.31	0.85	1.83
	20123	G5 II	144.9	-5.7	5.05	1.15	0.27	4.16	0.88	0.20
α Per	20902	F5 Ib	146.6	-5.9	1.81	0.48	0.16	1.28	0.32	0.15
υ Per	23230	F5 II	153.8	-9.6	3.80	0.43	0.16	3.27	0.27	0.13
	25030	K1 Ib	149.8	-0.5	8.60	1.50	0.04	8.47	1.46	3.75
	25056	G0 Ib	148.8	0.8	7.05	1.20	0.54	5.27	0.66	0.90
	25291	F0 II	145.5	5.0	5.05	0.50	0.34	3.93	0.16	0.19
μ Per	26630	G0 Ib	154.0	-1.8	4.15	0.96	0.25	3.32	0.71	0.37
	31118	K5 Ib	162.4	0.0	7.09	1.81	0.11	6.72	1.70	1.67
ι Aur	31398	K3 II	170.6	-6.2	2.68	1.53	0.00	2.68	1.53	0.10
β Cam	31910	G0 Ib	149.6	11.4	4.05	0.90	0.12	3.65	0.78	0.43
ε Aur	31964	F0 Iap	162.8	1.2	3.05	0.54	0.30	2.06	0.24	1.29
	33299	K1 Ib	174.2	-5.3	6.72	1.58	0.40	5.40	1.18	0.91
α Lep	36673	F0 Ib	220.9	-25.1	2.59	0.21	0.00	2.59	0.21	0.29
	36891	G3 Ib	169.5	4.4	6.11	1.03	0.16	5.58	0.87	1.04
	37819	F5 Ib	179.6	-0.5	8.12	0.56	0.30	7.13	0.26	2.22
	38247	G8 Iab	188.7	-5.4	6.64	1.62	0.36	5.45	1.26	2.04
	38808	G3 Ib-II	184.5	-1.7	7.55		(0.15)	(7.06)	(0.90)	(1.35)

TABLE I. Data for the 115 supergiants (continued)

Name	HD/ BD	MK Class.	l	b	V	B-V	E(B-V)	V_c	$(B-V)_o$	r
	39416	G3 Ib-II	184.2	-0.5	7.52		(0.23)	(6.76)	(0.80)	(1.18)
	39949	G2 Ib	182.7	1.3	7.25	1.08	0.36	6.06	0.72	1.29
	43282	G5 Ib-II	192.0	1.2	7.74		(0.35)	(6.58)	(0.95)	(1.08)
	44033	K3 Ib	196.4	0.0	5.65	1.60	0.00	5.65	1.60	1.02
	45829	K0 Iab	203.5	-1.1	6.66	1.58	0.26	5.80	1.32	2.40
25 Gem	47731	G5 Ib	186.5	10.4	6.44	1.09	0.13	6.01	0.96	1.26
ε Gem	48329	G8 Ib	189.6	9.6	3.00	1.41	0.14	2.54	1.27	0.26
	48616	F5 Ib	209.4	-0.1	6.85	0.79	0.48	5.26	0.31	0.94
	58526	G3 Ib	222.0	5.0	5.99	0.92	0.11	5.62	0.81	1.06
	59067	G8 Ib+B	227.4	2.7	5.86	0.58	0.28	4.93	0.30	
ζ Mon	67594	G2 Ib	223.1	16.5	4.37	0.96	0.02	4.30	0.94	0.58
	74395	G2 Ib	233.3	21.0	4.64	0.84	0.17	4.08	0.67	0.52
	77912	G8 Ib-II	184.3	42.1	4.56	1.04	0.07	4.33	0.97	0.34
ε Leo	84441	G0 II	206.8	48.2	2.97	0.80	0.08	2.70	0.72	0.09
	148743	A7 Ib	8.0	26.7	6.52	0.37	0.22	5.79	0.15	1.31
β Dra	159181	G2 II	79.6	33.3	2.81	0.96	0.11	2.44	0.85	0.08
	161796	F3 Ib	77.4	31.0	7.11		(0.07)	(6.88)	(0.42)	(1.98)
89 Her	163506	F2 Ia	51.4	23.2	5.45	0.34	0.02	5.38	0.32	5.70
108 Her	168913	F9 Ib	57.4	19.2	5.62	0.21	0.15	5.12	0.06	0.88
45 Dra	171635	F7 Ib	86.2	25.0	4.78	0.61	0.10	4.45	0.51	0.65
	172365	F9 Ib	36.3	5.1	6.36	0.79	0.24	5.57	0.55	1.08
	173638	F2 Ib-II	23.4	-3.6	5.72		(0.46)	(4.20)	(0.09)	(1.38)
	174104	G0 Ib	58.6	13.4	8.37		(0.10)	(8.04)	(0.65)	(3.22)
	179784	G5 Ib	48.8	2.1	6.68	1.39	0.40	5.36	0.99	0.94
	180028	F6 Ib	41.0	-2.4	6.93	0.81	0.39	5.64	0.42	1.12
	180583	F6 Ib-II	60.6	7.5	6.06	0.63	0.28	5.13	0.35	1.18
	182296	G3 Ib	44.3	-3.1	7.02	1.32	0.47	5.47	0.85	0.99
ν Aql	182835	F2 Ib	37.3	-7.6	4.66	0.60	0.43	3.24	0.17	0.37
	183864	G2 Ib	59.6	3.2	7.33		(0.56)	(5.48)	(0.66)	(0.99)
α Sge	185758	G0 II	54.5	-2.1	4.40	0.81	0.08	4.13	0.73	0.18
γ Aql	186791	K3 II	48.7	-7.1	2.71	1.53	0.08	2.44	1.45	0.09
	187203	G0 Ib	49.1	-7.5	6.44	0.96	0.27	5.55	0.69	1.02
	187299	G5 Iab-Ib	61.5	-0.3	7.14	1.60	0.66	4.96	0.94	1.24
	226223	F6 Ib	73.7	6.0	9.16		(0.43)	(7.74)	(0.14)	(2.94)
	190113	G5 Ib	72.1	2.7	7.84	1.46	0.34	6.71	1.12	1.75
	331777	F8 Ia	69.1	0.5	7.92	1.54	0.82:	5.21:	0.72:	4.39:
	190323	G0 Ia-Iab	54.7	-8.6	6.85		(0.22)	(6.12)	(0.65)	(4.85)
	190446	F6 Ib	76.2	4.9	8.22	0.57	0.14	7.75	0.43	2.95

TABLE I. Data for the 115 supergiants (continued)

Name	HD/BD	MK Class	l	b	V	B-V	E(B-V)	V_c	$(B-V)_o$	r
	191010	G3 Ib	64.2	-3.5	8.17		(0.12)	(7.77)	(0.89)	(2.84)
	37^o 3827	F3 Ib	75.6	2.3	8.13		(0.63)	(6.05)	(0.27)	(1.35)
22 Vul	192713	G2 Ib	63.5	-6.3	5.16	1.04	0.18	4.56	0.86	0.65
α^1 Cap	192876	G3 Ib	32.3	-24.2	4.25	1.07	0.24	3.45	0.83	0.39
o^2 Cyg	192909	K3 Ib-II	83.7	7.0	3.96	1.52	0.31	2.93	1.21	0.17
35 Cyg	193370	F5 Ib	73.4	0.5	5.16	0.64	0.24	4.37	0.40	0.62
	193469	K5 Ib	76.8	1.7	6.38	1.90	0.54	4.59	1.36	0.63
γ Cyg	194093	F8 Ib	78.2	1.9	2.23	0.67	0.13	1.80	0.54	0.19
41 Cyg	195295	F5 II	70.9	-5.0	4.01	0.41	0.10	3.68	0.31	0.16
44 Cyg	195593	F5 Iab	76.4	-1.4	6.21	1.00	0.76	3.70	0.24	1.05
47 Cyg	196093/4	K2 Ib+B	75.4	-2.9	4.59	1.59	0.58	2.67	1.01	
θ Del	196725	K3 Ib	58.0	-16.6	5.66	1.53	0.10	5.33	1.43	0.88
	200102	G1 Ib	86.1	-0.7	6.63	1.06	0.22	5.90	0.84	1.20
	200805	F5 Ib	86.8	-1.2	8.31		(0.47)	(6.76)	(0.23)	(1.87)
ξ Cyg	200905	K5 Ib	86.0	-2.1	3.68	1.66	0.11	3.31	1.55	0.35
ζ Cyg	202109	G8 II	76.8	-12.4	3.22	1.00	0.06	3.02	0.94	0.12
	202314	G2 Ib	76.7	-12.9	6.16	1.12	0.12	5.76	1.00	1.13
	204022	G0 Ib	92.9	0.1	7.43		(0.58)	(5.52)	(0.84)	(1.01)
β Aqr	204867	G0 Ib	48.0	-37.9	2.91	0.84	0.12	2.51	0.72	0.25
	205349	K1 Ib	90.8	-4.3	6.23	1.82	0.41	4.87	1.41	0.71
	206312	K1 II	93.9	-2.6	7.13		(0.15)	(6.64)	(1.08)	(0.62)
ε Peg	206778	K2 Ib	65.6	-31.5	2.40	1.54	0.04	2.27	1.50	0.22
9 Peg	206859	G5 Ib	72.0	-26.5	4.34	1.17	0.12	3.94	1.05	0.49
12 Peg	207089	K0 Ib	76.6	-22.8	5.27	1.40	0.19	4.64	1.21	0.64
	207489	F5 Ib	88.3	-11.3	7.23		(0.24)	(6.44)	(0.45)	(1.61)
	207647	G4 Ib	95.4	-3.2	7.02		(0.36)	(5.83)	(0.78)	(1.16)
	208606	G8 Ib	103.5	5.5	6.12	1.60	0.49	4.50	1.11	0.63
α Aqr	209750	G2 Ib	59.9	-42.0	2.94	0.98	0.08	2.67	0.90	0.27
ζ Cep	210745	K1 Ib	103.1	1.7	3.37	1.58	0.17	2.81	1.41	0.28
	216206	G4 Ib	104.1	-7.7	6.25	1.14	0.16	5.72	0.98	1.11
	216946	K5 Ib	104.6	-7.0	4.98	1.80	0.19	4.35	1.61	0.56
	217476	G0 Ia	108.2	-2.7	5.00	1.40	0.70	2.69	0.70	1.37

TABLE I. Data for the 115 supergiants.

Name	HD/BD	MK Class	l	b	V	B-V	E(B-V)	V_c	$(B-V)_o$	r
56 Peg	218356	K0 Ibp	95.1	-31.7	4.76	1.33	0.19	4.13	1.14	0.51
	219135	G0 Ib	109.6	-3.8	7.62		(0.30)	(6.63)	(0.73)	(1.68)
	60° 2532	F7 Ib	112.8	0.4	8.30	1.09	0.69	6.02	0.40	1.33
	221861	K0 Iab	116.9	9.7	5.84	1.80	0.68	3.59	1.12	0.87
104 Aqr	222574	G0 II	59.4	-71.4	4.80	0.82	0.05	4.63	0.77	0.22
ψ And	223047	G5 Ib	111.3	-15.0	4.96	1.12	0.24	4.17	0.88	0.54
ρ Cas	224014	F8 Iap	115.3	-4.5	4.58	1.30	0.52:	2.86:	0.74:	1.49:
	224165	G8 Ib	113.2	-14.5	6.00	1.19	0.14	5.53	1.05	1.01

TABLE II. The dependence of $(B-V)_o$ on spectral type for supergiants.

Spectral	---	Kelsall	---	FitzGerald	Johnson	Schmidt-Kaler	Fernie	Kraft & Hiltner
Type	"Raw"	"Smooth"	"Perfect"	(1970)	(1966)	(1965)	(1963)	(1961)
FO	0.19	0.20	0.19	0.15	0.19	0.17	0.25	
1		0.22	0.22	0.16			0.28	
2	0.21	0.25	0.25	0.18	0.25	0.25	0.31	
3	0.34	0.27	0.28				0.34	
4		0.29	0.30				0.37	
5	0.31	0.31	0.33	0.26	0.37	0.36	0.40	0.36
6	0.38	0.40	0.41				0.46	0.42
7	0.47	0.48	0.48			0.48	0.52	0.48
8	0.64	0.57	0.56	0.55	0.55	0.58	0.61	0.56
9		0.65	0.64				0.70	0.68
GO	0.74	0.73	0.72	0.82	0.70	0.67	0.77	0.72
1		0.78	0.77	0.85			0.86	
2	0.84	0.83	0.83	0.88	0.85	0.84	0.93	0.87
3	0.85	0.88	0.88	0.92			0.96	0.94
4	0.91	0.93	0.92				1.00	0.98
5	0.99	0.98	0.97	1.00	1.01	1.08	1.03	1.00
6		1.03	1.01	1.04				
7		1.08	1.05	1.10				
8	1.15	1.14	1.10	1.14	1.03		1.11	1.06
9		1.19	1.14	1.16				
KO	1.24	1.24	1.19	1.18	1.12		1.16	1.11
1	1.36	1.32	1.27	1.20	1.18	1.45	1.24	1.17
2		1.39	1.36	1.23	1.25	1.50	1.34	1.24
3	1.49	1.46	1.44	1.42	1.38	1.55	1.46	1.40
4		1.53	1.53	1.50	1.49		1.56	
5	1.58	1.61	1.62	1.60	1.62	1.60	1.66	1.62