CALIBRATION IN TEMPERATURE OF PHOTOMETRIC PARAMETERS

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1. INTRODUCTION

It is very easy to use a Planck distribution to show that a color index is a temperature parameter, but it is more difficult to calibrate such a color index in terms of temperature because only a few T_{eff} values are determined. A pioneering work is that of Kuiper (1938), who derived a temperature scale according to spectral type (from A0 to M2 for dwarfs and from G0 to M8 for giants) and a Becker index. The first study giving a relation between T_{eff} and a photoelectric color index is that of Popper (1959) in which the author derives a relation between T_{eff} and B-V for the A and F stars and for G8 to K5 (dwarf and giant) stars. On this occasion, Popper shows the relation between temperature parameters of two photometric systems, R-I from the six-color system of Stebbins and Whitford, and B-V. This work was followed by a quantity of others from numerous authors in various systems, one of the most important being that of Johnson (1966). The purpose of the present study is not to review all the relations to be found in the literature but to define a set of stars which can be used to determine a calibration of a photometric parameter in terms of T_{eff}.

2. DETERMINATION OF T_{eff}

Böhm-Vitense (1981) has published a very important and complete stud of the T_{eff} determination to which the reader may be referred. Böhm-Vitense classes the various methods to determine T_{eff} into direct methods (mainly Code et al. 1976), semi-direct and indirect methods. Semi-direct methods are those of Pottasch et al. (1979) for O stars and those of Underhill et al. (1979) for O and B stars. In both cases angular radii θ are obtained with the help of model atmospheres calculations. Indirect methods are of various kinds: a) comparison of energy distribution (in the visible and/or in the UV) with model energy distribution methods applicable to O, B, A and F stars, b) ionization equilibrium (O stars),

D. S. Hayes et al. (eds.), Calibration of Fundamental Stellar Quantities, 271–284.

c) Balmer lines (G stars), d) synthetic colors (B, A, F, G stars), e) spectrum analysis (F, G, K stars).

Since the publication of the review paper of Böhm-Vitense, some new studies have been published and mention may be made of that of Malagnini et al. (1982) who use for A and F stars a method described by Morossi and Crivellari (1980) for O stars. Malagnini et al. compare UV distributions published in the UV Bright Stars Spectrophotometric Catalog (S2/68 experiment, Jamar et al. 1976) with Kurucz models. The same procedure is also applied by Malagnini et al. (1983) to B5-A stars. Malagnini et al. (1984) give a relation based on 81 B5-F7 non-supergiant stars between $R=\log \frac{F_{1965}}{F_{5445}}$ and T_{eff} derived from the two previous studies:

$$\theta_{eff}=-0.266R + 0.557.$$

Böhm-Vitense (1982) also proposes an indirect method to determine effective temperatures of late A and early F stars from the UV flux obtained in the S2/68 experiment.

Adelman and Pyper (1983) have published T_{eff} values for eleven stars using the same approach as in their earlier studies by comparing energy distributions with Kurucz models.

3. STANDARD STARS

The present purpose is to define a set of standard stars to calibrate various photometric parameters in terms of T_{eff}. There are many papers giving T_{eff} but it is not possible to use all the stars. Reddened stars must be avoided since only a small number of photometric parameters, such as Q in the UBV system and X in the Geneva system, are independent of interstellar reddening. Unreddened or only slightly reddened stars are proposed. A method proposed by Cramer (1982) based on the X and Y parameters to select unreddened stars has been used for O and B stars. Companions are often a source of "pollution" and unresolved visual binaries must be excluded. In addition we must consider only stars belonging to the same luminosity class and having the same chemical composition.

The first study in which such stars may be found is that of Code, et al. (1976). It is the only one giving T_{eff} values determined with direct knowledge of the star's diameter. Semi-direct and indirect methods must be used because Code et al. give T_{eff} values only for B and A stars. To complete the sample, data were taken from Adelman (1978), Adelman et al. (1980, 1983), Hayes (1978), Underhill et al. (1979), Perrin et al. (1977) and Oinas (1974). Considering first the main-sequence stars, Table I contains those proposed as standard. We have thus selected 104 stars from B9 to K2. The column contents are as follows: (1) name, (2) BS number, (3) HD number, (4) θ_{eff}, (5) T_{eff}, (6) B2-V1, (7) B-V,

(8) source of T_{eff}, then the various systems in which the star is measured. This information is extracted from the General Catalogue of Photometric Data which is in course of preparation. Table II gives the same information (except B-V) for the giant stars from Oinas' list that are measured in the Geneva system. The number of stars in each system is given in Table III. The first column of this table gives the identification numbers of systems, these also appearing in the last part of each line of Tables I and II.

4. CALIBRATION OF B2-V1 AND B-V

In this section the stars in Table I are used to calibrate B2-V1 (from the Geneva system) and B-V (from the Johnson and Morgan UBV system) for main-sequence stars with a solar chemical composition. The data are plotted in Figures 1 and 2 respectively. A relatively large dispersion is to be noted near both B2-V1=-.150 and B-V=.00 which could be due to a small gravity effect. If we plot the synthetic colors calculated by North and Hauck (1979) for the Kurucz models (1979) we remark this effect clearly, which is maximum near A0. Both linear and polynomial fittings were used for each diagram, giving the following relations:

$$\theta_{eff}=\underset{\pm .014}{0.917} + \underset{\pm 0.057}{2.306}(B2-V1) \qquad -.300 \leq B2-V1 \leq -.160 \qquad (1)$$

$$\theta_{eff}=\underset{\pm .002}{0.632} + \underset{\pm 0.006}{0.640}(B2-V1) \qquad -.160 < B2-V1 \leq .730 \qquad (2)$$

$$\theta_{eff}=\underset{\pm .007}{0.573} + \underset{\pm .049}{1.512}(B-V) \qquad -.22 \leq B-V \leq -.05 \qquad (3)$$

$$\theta_{eff}=\underset{\pm .003}{0.536} + \underset{\pm .005}{0.514}(B-V) \qquad -.05 < B-V \leq 1.20 \qquad (4)$$

$$\theta_{eff}=0.643 + 0.567(B2-V1) -0.597(B2-V1)^2 + + 4.406(B2-V1)^3 - 9.033(B2-V1)^4 + 5.970(B2-V1)^5 \qquad (5)$$

$$\theta_{eff}=0.525 + 0.807(B-V) -1.442(B-V)^2 + 3.194(B-V)^3 - - 3.208(B-V)^4 + 1.153(B-V)^5 \qquad (6)$$

Relation (2) was checked for the main-sequence K stars for which Oinas (1974) and Lambert (1977) have determined the temperature and good agreement was found. We may therefore assume that our calibration is valid from B9 to K2.

The relations obtained are valid for stars on the main sequence with normal of solar chemical composition. Many metal-deficient stars are to be found in the paper of Perrin et al. (1977) and if these stars are

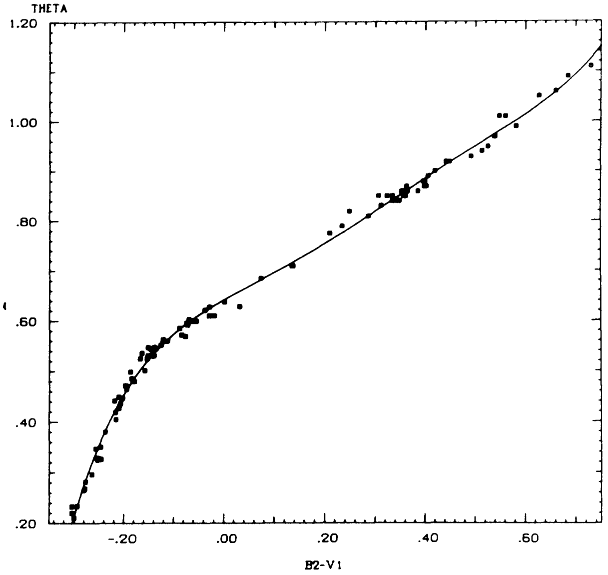

Fig. 1. θ_{eff} *vs B2-V1 for the main-sequence standard stars. The full line is the fitted polynomial function.*

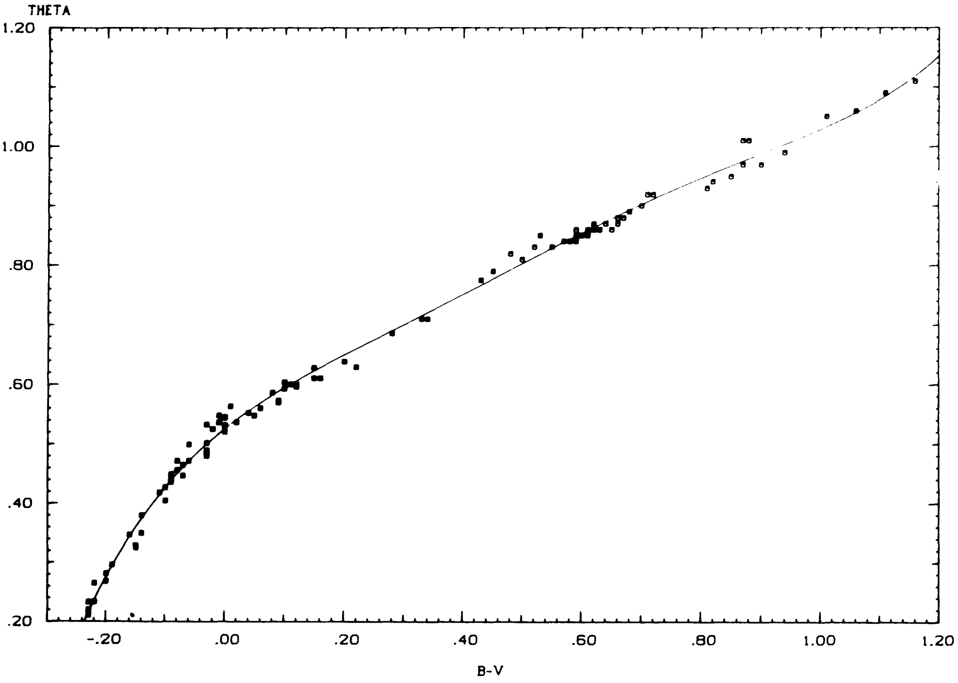

Fig. 2. Same as Fig. 1 for θ_{eff} *vs B-V*

plotted in a θ_{eff} vs B2-V1 diagram there is a clear blanketing effect, all these stars being shifted to the left. But B2-V1 can be corrected (Hauck 1973) and the corrected values bring about a good fitting of these stars with the relation for the normal stars.

For the giant stars hotter than the Sun, we have noticed that only the few for which the temperature is known do not show any deviation from the relation for main-sequence stars. Using the data Oinas (1974) has published for some K0-K3 giants we obtain the following relation:

$$\theta_{eff}=0.634 + 0.548\ (B2-V1) \tag{7}$$

5. OTHER CALIBRATIONS

In the previous section we have seen that the stars proposed as standard can be used to calibrate B2-V1 and B-V in terms of effective temperature. These stars are also measured in some other systems and many calibrations could be determined. We can also use relations between B2-V1 and some other photometric parameters established by Meylan et al. (1981). But it should be remembered that these relations can be sensitive to gravity and blanketing effects.

Various calibrations can be found in Golay's book (1974) and in the proceedings of the workshop on Problems of Calibration of Multicolor Photometric Systems (A.G. D. Philip, ed. 1979). Among those that have been published more recently I would mention Cramer's (1984) study of the B stars, in which we found the following relation:

$$\log T_{eff} = 4.586 - 1.038\ X + 1.094\ X^2 - 0.646\ X^3 + 0.139\ X^4$$

where $X = 0.3788 + 1.376\ U - 1.2162\ B1 - 0.8498\ B2 - 0.1554\ V1 + 0.8450\ G$

is a temperature parameter (in the Geneva system) for the hot stars independent of reddening.

Stone (1983) has published the following relation for extremely metal-deficient red giants:

$$T_{eff} = 7101 - 3768\ (V-R)_o + 848\ (V-R)_o^2$$

while Straižys et al. (1982) give tabulated relations between log T_{eff} and the indexes U-P, P-V, X-Y, Y-Z, Z-V, Z-S of the Vilnius system.

Another approach to the determination of T_{eff} may now be mentioned. Some authors have calculated synthetic colors from model atmospheres and then constructed a photometric diagram (color or parameter vs color or parameter) with loci of constant T_{eff} and log g. Releya and Kurucz (1978) calculated theoretical uvby and UBV colors from the Kurucz grid of model atmospheres for O, B, A, F and G stars, while Philip and Releya (1979) used these synthetic colors to propose three large-scale $(c)_o$ vs $(b-y)_o$ grids calculated for [Fe/H] values of 0.0, -1.0 and -2.0. These authors claim rms errors of the calculated values of ±0.2 in log g and ± 250 K in T_{eff}. Philip and Egret (1980) applied these grids to the whole uvbyβ catalogue (Hauck and Mermilliod, 1980). Synthetic colors for the RGU system have been published by Buser (1978), while Buser and Kurucz (1978) give synthetic UBV colors and derive an effective temperature scale as a function of $(B-V)_o$, $(U-B)_o$ and $(U-V)_o$. North and Hauck (1979) have also published synthetic colors in the Geneva system from Kurucz models and also given an effective temperature scale as a function of B2-V1, while Lub and Pel (1977) have published a set of theoretical two-color diagrams in the VBLUW system calculated from the first set of Kurucz models (1975).

Theoretical colors in various photometric systems (UBVR, Geneva, uvby, DDO, gnkmf, Uppsala, 13-color (Arizona)) were calculated for the G and K giant stars by Bell and Gustafsson (1978, 1979) using their own set of model atmospheres (Gustafsson et al. 1975, Bell et al. 1976)

6. TEMPERATURES FOR THE Ap AND Am STARS

Several attempts have been made to determine effective temperatures, one being that of Babu and Shylaja (1981), who determined θ_{eff} for 125 Ap and Am stars. Their method is semi-direct, since they use flux distributions in the λλ4000-7800 wavelength region and Mihalas models. Shallis and Blackwell (1979) determined effective temperatures for five Ap stars using a semi-direct method (Blackwell et al. 1977, 1979) in the IR range. Floquet (1981) derived effective temperatures for 69 mostly cool Ap stars taking the intensity of the CaII line as a temperature indicator. More recently Lanz (1984) has determined effective temperature for six Ap and six He-weak stars, employing the Shallis and Blackwell method. We thus have a lot of effective temperatures for Ap and Am stars but the basic problem is that color indexes are generally affected by the peculiar characteristics of the star. B2-V1 is not affected in the case of Am stars (Hauck and Van't Veer, 1970) but B-V is affected and also b-y, but to a lesser extent. In the case of Ap stars, many photometric parameters are affected because one filter is in the spectral interval of one of the continuum depressions, mainly that at λ 5200 Å. B2-V1, B-V and b-y are strongly affected, but one of the less affected photometric parameters is B2-G (see Gerbaldi et al., 1974) and recently Lanz (1984) obtained a calibration of $(B2-G)_o$ in terms of effective temperature for the Ap stars.

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Table I - Main sequence standard stars

Name		BS	HD	θ_e	T_e	B2-V1	B-V	ref	Photometric systems
GAM	PEG	39	886	.233	21600	-.304	-.23	2	1 4 6 8 9 12 13 14 18 19 21 23
THE	AND	63	1280	.560	9000	-.113	.06	3	1 4 6 8 12 13 14 18 21 23 26
54	PSC	166	3651	.949	5309	.526	.85	6	1 4 6 8 9 12 13 14 19 21 23
			3765	.990	5093	.582	.94	6	1 4 6 13 14 19
PHI2	CET	235	4813	.810	6223	.286	.50	6	1 2 4 8 12 13 14 23 54
		244	5015	.850	5929	.306	.53	6	1 4 8 9 13 14 18 23
ALF	ERI	472	10144	.347	14510	-.257	-.16	1	1 2 6 8 9 13 19 23 54
		483	10307	.870	5794	.362	.62	6	1 4 6 8 9 12 13 18 21 23
		511	10780	.930	5420	.492	.81	6	1 6 8 13 14 19
58	AND	620	13041	.600	8400	-.055	.12	2	1 4 8 13 14 18 23
PI	CET	811	17081	.380	13250	-.237	-.14	2	1 2 4 8 11 13 18 23 54
41	ARI	838	17573	.405	12450	-.216	-.10	3	1 4 8 13 14 18 23
IOT	PER	937	19373	.850	5929	.334	.61	6	1 4 6 8 9 12 13 14 18 19 23
KAP	CET	996	20630	.890	5662	.405	.68	6	1 2 4 6 8 12 13 14 18 19 23 54
17	ERI	1070	21790	.436	11550	-.207	-.09	3	1 2 4 8 13 14 18 23 54
		1197	24167	.636	7900	.001	.20	2	1 4 13 23
51	TAU	1331	27176	.686	7350	.073	.28	2	1 4 6 8 11 12 13 21 23
64	TAU	1380	27819	.611	8250	-.030	.15	3	1 4 6 8 11 12 13 14 18 23
PI3	ORI	1543	30652	.790	6383	.233	.45	6	1 4 6 8 9 12 13 18 19 23 54
		1614	32147	1.060	4753	.661	1.06	6	1 2 6 8 12 13 14 19 54
		1639	32608	.622	8102	-.038		2	4 13 23 26
LAM	AUR	1729	34411	.860	5861	.361	.63	6	1 4 6 8 9 12 13 14 18 19 23
RHO	AUR	1749	34759	.329	15300	-.254	-.15	2	1 4 6 13 23
GAM	ORI	1790	35468	.234	21580	-.294	-.22	1	1 4 6 8 9 13 18 19 21 23 26 54
DZE	LEP	1998	38678	.593	8500	-.072	.10	2	1 2 4 6 8 13 14 18 19 23 54
134	TAU	2010	38899	.465	10850	-.195	-.07	2	1 4 6 8 13 14 18 19 23 26
CHI1	ORI	2047	39587	.840	5998	.347	.59	6	1 4 6 8 9 11 12 13 14 18 19 23
ETA	LEP	2085	40136	.710	7100	.134	.33	2	1 2 4 8 9 11 12 13 14 18 23 54
		2209	42818	.533	9450	-.145	.03	3	1 4 8 13 18 23
		2244	43445	.472	10689	-.197	-.08	5	1 2 4 8 13 14 18 23 54
GAM	GEM	2421	47105	.544	9260	-.146	.00	1	1 4 6 8 9 12 13 14 18 19 23
21	LYN	2818	58142	.525	9600	-.168	-.02	4	1 4 8 13 14 18 23
64	GEM	2857	59037	.600	8400	-.061	.11	2	1 4 13 14 23 26
27	LYN	3173	67006	.548	9200	-.140	.05	2	1 4 8 13 14 18 23
16	PUP	3192	67797	.326	15460	-.246	-.15	5	1 2 4 8 13 18 23 54

Table I - (continued)

Name	BS	HD	θ_e	T_e	B2-V1	B-V	ref	Photometric systems
LAM CNC	3268	70011	.489	10300		-.03	3	1 4 23
	3348	71906	.486	10375	-.184	-.03	3	1 4 13 23 26
GAM CNC	3449	74198	.536	9400		.02	3	1 4 8 14 18 23
ETA HYA	3454	74280	.268	18792	-.278	-.20	5	1 2 4 6 8 11 12 13 14 18 19 23 26 45 54
RHO1 CNC	3522	75732	.969	5200	.539	.87	6	1 6 13 14 19
BET CAR	3685	80007	.545	9240	-.136	.00	1	1 2 4 8 9 13 14 19 23 54
26 UMA	3699	82621	.563	8950	-.122	.01	3	1 4 8 13 14 18 23 26
KAP HYA	3849	83754	.327	15398	-.250	-.15	5	1 2 4 8 13 18 23 54
	3881	84737	.860	5861	.362	.62	6	1 4 6 8 9 13 14 18 23
20 LMI	3951	86728	.880	5728	.399	.66	6	1 4 6 12 13 14 21 23
ALF LEO	3982	87901	.419	12040	-.217	-.11	7	1 4 6 8 9 13 14 18 19 21 23
BET SEX	4119	90994	.350	14400	-.247	-.14	4	1 4 8 13 18 21 23 54
37 UMA	4141	91480	.710	7100	.137	.34	4	1 4 8 13 14 21 23 26
47 UMA	4277	95128	.860	5861	.364	.61	6	1 4 6 13 23
BET UMA	4295	95418	.525	9600	-.154	-.02	4	1 4 6 8 9 13 18 21 23
THE LEO	4359	97633	.548	9200	-.152	-.01	3	1 4 8 9 12 13 14 18 23 26
61 UMA	4496	101501	.919	5483	.449	.72	6	1 4 6 8 9 12 13 18 19
BET LEO	4534	102647	.570	8850	-.077	.09	1	1 2 4 6 8 9 11 12 13 14 18 19 21 23 26
BET VIR	4540	102870	.831	6067	.311	.55	6	1 2 4 6 8 9 11 12 13 14 18 19 21 23 26 45 54
GAM UMA	4554	103287	.531	9500	-.151	.00	3	1 4 6 8 9 13 18 21 23
DEL CRU	4656	106490	.220	22906	-.304	-.23	5	1 2 4 6 8 11 13 19 23 54
DEL UMA	4660	106591	.586	8600	-.088	.08	4	1 4 6 8 9 13 14 18 21 23
GAM MUS	4773	109026	.325	15506	-.253	-.15	5	1 4 8 9 13 23 54
BET CVN	4785	109358	.860	5861	.352	.59	6	1 4 6 8 9 12 13 14 18 19 21 23
14 CVN	4943	113797	.456	11050		-.08	3	1 4 14
BET COM	4983	114710	.840	5998	.334	.57	6	1 4 6 8 9 11 12 13 14 18 19 21 23 45
		115043	.850	5929	.356	.60	6	1 4 6 8 12 13 21 23
59 VIR	5011	115383	.850	5929	.323	.59	6	1 4 6 11 12 13 14 19 23 54
ALF VIR	5056	116658	.211	23930	-.300	-.23	1	1 2 4 6 8 9 12 13 18 19 23 54
80 UMA	5062	116842	.611	8250	-.020	.16	3	1 4 6 8 13 18 21 23
70 VIR	5072	117176	.919	5483	.442	.71	6	1 4 6 8 9 11 12 13 14 18 19 23
	5169	119765	.521	9675		.00	3	1 4 14 21 23
ETA UMA	5191	120315	.296	17000	-.264	-.19	4	1 4 6 8 9 12 13 18 21 23
TAU VIR	5264	122408	.604	8350	-.069	.10	3	1 2 4 8 11 12 13 14 18 21 23 26 54
	5332	124683	.502	10050	-.158	-.03	3	1 2 4 11 13 23

Table I - (continued)

Name	BS	HD	θ_e	T_e	B2-V1	B-V	ref	Photometric systems
	5422	127304	.480	10500	-.179	-.03	4	1 4 13 14 21 23 26
	5568	131977	1.090	4624	.685	1.11	6	1 2 6 8 9 12 13 14 19 54
45 BOO	5634	134083	.775	6500	.209	.43	4	1 4 6 8 9 13 14 18 19 21 23 26
LAM SER	5868	141004	.850	5929	.360	.60	6	1 2 4 6 8 9 11 12 13 14 18 19 21 23 54
GAM SER	5933	142860	.819	6152	.248	.48	6	1 2 4 6 8 9 11 12 13 14 18 19 21 23 45
		145675	.969	5200	.540	.90	6	1 12 13 14 21
18 SCO	6060	146233	.860	5861	.385	.65	6	1 2 4 12 13 14 19 23 54
12 OPH	6171	149661	.941	5358	.514	.82	6	1 4 6 8 9 12 13 14 19 54
		156026	1.110	4539	.730	1.16	6	1 6 8 12 13 14 54
ALF OPH	6556	159561	.628	8020	-.030	.15	1	1 4 6 8 9 13 14 18 19 21 23
MU ARA	6585	160691	.900	5598	.419	.70	6	1 2 8 12 13 14 19 54
GAM OPH	6629	161868	.552	9125	-.126	.04	3	1 2 4 6 8 11 12 13 14 18 19 21 23 45 54
	6806	166620	1.010	4989	.548	.87	6	1 4 6 8 9 12 13 14 19 21
EPS SGR	6879	169022	.533	9460	-.142	-.03	1	1 2 4 8 9 13 14 19 23 54
ALF LIR	7001	172167	.531	9490	-.152	.00	7	1 4 6 8 9 12 13 14 18 19 21 23 26
SIG SGR	7121	175191	.265	18987	-.280	-.22	5	1 2 4 8 13 23 54
LAM AQL	7236	177756	.442	11414	-.219	-.09	5	1 4 8 9 13 14 18 21 23 54
16 SYG	7503	186408	.870	5794	.398	.64	6	1 4 6 8 9 12 13 18 21 23 45
	7504	186427	.870	5794	.402	.66	6	1 4 6 8 9 12 13 18 21 23 45
ALF AQL	7557	187642	.629	8010	.031	.22	1	1 4 6 8 9 13 14 18 19 21 23 26 54
	7722	192310	1.010	4989	.561	.88	6	1 2 6 8 12 13 14 19 54
	7783	193664	.840	5998	.344	.58	6	1 6 13 21 45
ALF PAV	7790	193924	.282	17880	-.277	-.20	1	1 2 4 6 8 13 19 23 54
ALF DEL	7906	196867	.472	10681	-.196	-.06	5	1 4 6 8 11 13 14 18 19 21 23 26 45
IOT AQR	8418	209819	.447	11284	-.203	-.07	5	1 2 4 8 13 14 18 23 54
SIG AQR	8573	213320	.499	10100	-.187	-.06	2	1 2 4 8 9 13 14 18 23 54
ETA AQR	8597	213998	.449	11218	-.211	-.09	5	1 4 8 13 14 18 23 54
	8607	214279	.596	8450	-.074	.12	2	1 4 13 21 23
OMI PEG	8641	214994	.536	9400	-.164	-.01	2	1 4 6 8 13 14 18 23 26
ALF PSA	8728	216956	.573	8800	-.085	.09	1	1 4 8 9 13 14 19 23 54
51 PEG	8729	217014	.880	5728	.396	.67	6	1 4 6 8 9 11 12 13 14 18 19 21 23
	8832	219134	1.051	4797	.628	1.01	6	1 4 6 8 9 12 13 14 18 19 21 45
	8853	219623	.831	6067		.52	6	1 4 14 21 23
IOT AND	8965	222173	.427	11800	-.210	-.10	2	1 4 8 13 14 18 21 23

Table II - K0-K3 giant standard stars

Name	BS	HD	θ_e	T_e	B2-V1	ref	Photometric systems
ALF ARI	617	12929	1.084	4650	.797	8	1 4 6 8 9 12 13 14 18 21
GAM TAU	1346	27371	0.998	5050	.645	8	1 4 8 11 12 13 19 23
EPS TAU	1409	28305	0.998	5050	.678	8	1 4 6 8 9 11 12 13 18 19 21 45
THE1 TAU	1411	28307	0.979	5150	.628	8	1 4 6 8 9 11 12 13 18 19 21 45
NU AUR	2012	39003	1.061	4750	.785	8	1 8 9 13 14 18
MU LEO	3905	85503	1.084	4650	.840	8	1 8 9 12 13 14 18 45
NU UMA	4377	98262	1.200	4200	1.023	8	1 4 8 9 12 13 14 18 21
ALF SER	5854	143333	1.061	4750	.797	8	1 4 13 14 19 23
11 CEP	8317	206952	1.050	4800	.754	8	1 8 12 13 14 18
	8924	221148	1.029	4900	.727	8	1 12 13 14 19 21 54

Sources for tables I and II.

1. Code et al. (1976)
2. Adelman (1978)
3. Adelman et al. (1980)
4. Adelman and Pyper (1983)
5. Underhill et al. (1979)
6. Perrin et al. (1977)
7. Hayes (1978)
8. Oinas (1974)

Table III - Number of standard (n_1=m.s., n_2=giant) stars measured in some photometric systems

System		Source of data	n_1	n_2
1 UBV		Nicolet (1978), Mermilliod J.C. (1983)	103	10
2 UBV CAPE		Nicolet (1975)	31	-
4 UVBY		Hauck and Mermilliod M. (1980)	94	6
6 UVBGRI	Stebbins, Whitford	Nicollier and Hauck (1978)	60	3
8 UBVRI	Johnson	Mermilliod J.C. and Mermilliod M. (1984)	82	8
9 JKLMN	Johnson	Mermilliod J.C. and Mermilliod M. (1984)	45	6
11 WUBVL	Walraven	Python (1979)	19	3
12 DDO		Meylan (1982)	45	8
13 UBVB1B2V1G	Geneva	Rufener (1981)	99	10
14 UBV	Eggen	Mermilliod J.C. and Mermilliod M. (1984)	72	7
18 13-COLOR		Magnenat (1977)	63	7
19 RI	Kron and Eggen	Jasniewicz (1982)	47	5
21 UPXYVTZ	Vilnius	North (1980)	42	5
23 β		Hauck and Mermilliod M. (1980)	89	2
26 C1 ...C8	Barbier, Morguleff	Morguleff and Gerbaldi (1975)	19	-
45 CMT1T2V	Canterna	Mermilliod J.C. and Mermilliod M. (1984)	10	3
54 RI	Cousins	Cousins (1980)	39	1

DISCUSSION

PAPOULAR: Is there any hope of extending this effort to M giants and supergiants?

HAUCK: The problem is not with the colors but with effective temperatures and at the present time we need more effective temperature determinations for these stars.

CODE: What is the basis of the effective temperatures for metal deficient stars?

HAUCK: Perrin et al. (1977) have obtained the effective temperatures from detailed analysis based on model atmosphere calculations.

POPPER: Effective temperature is defined in terms of bolometric flux. This quantity is known only for stars with measured angular diameters determined, which are, unfortunately, very few in number. Temperatures derived by comparing synthetic spectra with observations should, perhaps, be termed "hypothetical" effective temperatures. This distinction, usually overlooked, has been pointed out many times in the past. It is typical for those who interpret IUE observations, for example, to quote temperatures from models without reference to the calibration of these models against ultraviolet observations of stars with known effective temperatures from angular diameter measurements.

TOBIN: To reinforce Dr. Popper's comment, can I say that I would classify the Underhill et al. method as indirect, rather than semi-direct, as what it really does when strictly applied is to compare the dereddened value of(monochromatic, visual or infrared flux/observed integrated flux) with model values, and it is just as dependent on the Kurucz models as anyone else's "effective temperatures".

CODE: To follow up the remarks by Popper, I wish to remind you that another assumption the concept of effective temperature is that the star is spherical and the atmosphere thin. For hot main sequence stars and supergiants this may not be true and some other concept must be substituted for effective temperature.