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FUNCTIONAL RELATIONSHIPS FOR $T_{\rm eff}$ AND log g IN F-G SUPERGIANTS FROM $uvby-\beta$ PHOTOMETRY

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RESUMEN

A partir de datos fotoeléctricos en el sistema $uvby-\beta$ y de valores precisos sintéticos y espectroscópicos de $T_{\rm eff}$ y log g en 50 supergigantes de tipos espectrales F-G, hemos calculado relaciones funcionales que permiten la estimación inicial de la temperatura efectiva y la gravedad en este tipo de estrellas. Se demuestra que aunque las calibraciones de $T_{\rm eff}$ fueron calculadas con los datos de estrellas supergigantes jóvenes y masivas, también son válidas para estrellas evolucionadas post-AGB y RV Tau de temperaturas similares. La gravedad superficial también puede calcularse a partir del índice $\Delta[c_1]$ con una precisión de 0.26 dex. Aunque se puede distinguir una correlación entre M_V y $\Delta[c_1]$, no hemos encontrado una correlación que prediga M_V de manera suficientemente precisa.

ABSTRACT

From photoelectric $uvby-\beta$ data and recent accurate synthetic and spectroscopic values of $T_{\rm eff}$ and log g for 50 F-G supergiants, we have calculated functional relationships that lead to initial estimates of effective temperature and gravities for these types of stars. It is shown that while the $T_{\rm eff}$ relationships are calculated using the data on young massive supergiants, they are also valid for evolved stars of similar temperatures like post-AGB and RV Tau stars. The gravity can also be predicted from the $\Delta[c_1]$ index with an uncertainty of about 0.26 dex. Although a clear and significant trend between M_V and $\Delta[c_1]$ is seen, no calibration is found that predicts accurate values of M_V.

Key Words: stars: AGB and post-AGB — supergiants — techniques: photometric

1. INTRODUCTION

Back in the mid 1990's we calculated a set of functional relationships between several reddening-free indices in the Strömgren $uvby-\beta$ system and the effective temperature for 41 supergiants of luminosity classes I and II and with spectral types between A0 and K0. The main goal of those relationships was to provide initial values of the effective temperature for our own spectroscopic work aimed at calculating detailed atmospheric abundances for stars of intermediate temperatures. At that time we used the temperatures calculated by Bravo-Alfaro, Arellano Ferro, & Schuster (1997) from 13-color photometry and the $uvby-\beta$ data from the catalogue of Arellano Ferro et al. (1998).

The relationships turned out to be quite useful for several problems related to the estimation of the temperature for these types of stars. However they remained unpublished mainly because the intrinsic scatter was rather large, probably due to the limited quality of the temperature data used.

Very recently a set of accurate temperatures, gravities and distances for 48 near ($d \leq 700$ pc) and 15 distant ($d \geq 700$ pc) A-G supergiants, were published (Lyubimkov et al. 2010). In the present paper functional relationships are worked out in view of these new values of physical parameters, with the aim of providing a tool to estimate initial values of $T_{\rm eff}$ and log g in yellow supergiants for subsequent spectroscopic work.

The paper is organized as follows: in § 2 the sources of the $uvby-\beta$ data are described, in § 3 the calibrations for the temperature as a function of the $[c_1]$, $[m_1]$ and Hβ photometric indices are dis-

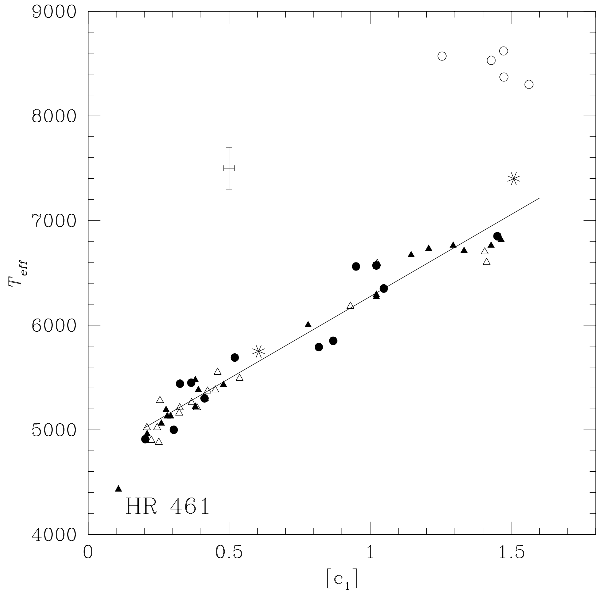

Fig. 1. Temperature dependence of the reddening free $[c_1]$ index. The open circles correspond to five A type stars which, along with the K1 star HR 461, are not included in the fit. The fit is valid for F-G type stars. Filled circles represent variable stars, empty triangles double stars and filled triangles non-variables. Asterisks correspond to two possible post-AGB stars in the sample of Lyubimkov et al. (2010). The error bars correspond to typical uncertainties of ± 200 K and ± 0.019 mag in $T_{\rm eff}$ and $[c_1]$, respectively.

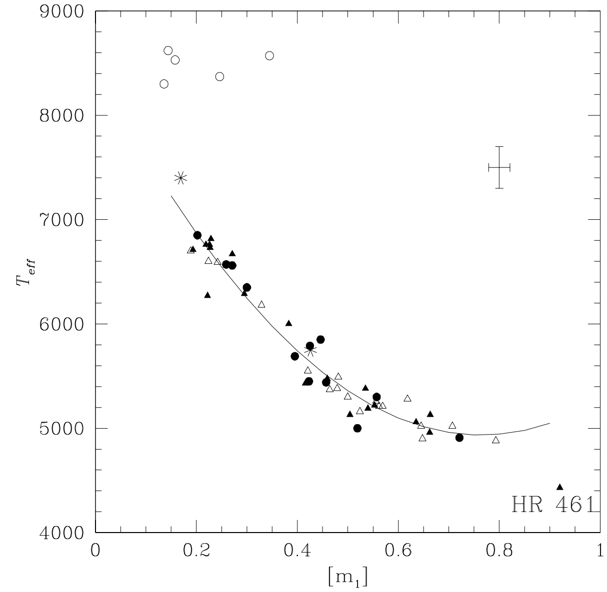

Fig. 2. Temperature dependence of the reddening free $[m_1]$ index. Symbols are as in Figure 1. The error bars correspond to typical uncertainties of ± 200 K and ± 0.021 mag in $T_{\rm eff}$ and $[m_1]$, respectively.

cussed, in § 4 the gravity calibration in terms of the $\Delta[c_1]$ index is calculated, in § 5 we discuss the validity of the calibrations for post-AGB and RV Tau stars, in § 6 the attempts at a calibration of the absolute magnitude and its limitations are presented, and in § 7 we summarize our conclusions.

2. THE PHOTOMETRIC $uvby-\beta$ DATA

The $uvby-\beta$ photometric data were taken from the catalogue of Arellano Ferro et al. (1998). For about a dozen of stars photometric data were not available in that source and their data were obtained from the sources given in the Simbad database. When several measurements exist a simple average was calculated. In Table 1 we present for the sample stars the reddening free indices $[c_1] = c_1 - 0.16(b-y)$ and $[m_1] = m_1 + 0.33(b-y)$, and values for their distance, effective temperature and gravity taken from Lyubimkov et al. (2010).

3. THE $T_{\rm eff}$ CALIBRATIONS

Plots of $T_{\rm eff}$ as a function of $[c_1]$ and $[m_1]$ are shown in Figures 1 and 2, respectively. Variable, double and non-variable stars have been plotted with different symbols to check whether their nature contributes to the scatter or if they appear as outliers. For the variable stars we used averages from rather scarce photometry not covering the full variational cycles; nevertheless, they follow the trends as well as the non-variable and double stars.

The $T_{\rm eff}$-$[c_1]$ correlation is good for F-G type stars. Five A-type stars included in the sample of Lyubimkov et al. (2010): HR 825, HR 1740, HR 2874, HR 3183 and HR 6081, identified with open circles, and the K1 star HR 461 (Yoss 1961) were not included in the fit. The line has the form:

$$T_{\rm eff} = 1566.6(\pm 50.7)[c_1] + 4704.0(\pm 40.5)\,, \qquad (1)$$

with a standard deviation of 152 K and a correlation coefficient of $R = 0.98$.

We can confirm from the models of Lester, Gray, & Kurucz (1986) that the c_1 index is temperature sensitive for $T_{\rm eff} \leq 7000$ K and that for hotter stars the sensitivity of the index changes and becomes more gravity dependent. This explains why the A-type stars do not follow the smooth correlation displayed by the F-G stars.

The $T_{\rm eff}$-$[m_1]$ correlation shows a non-linear form that can be represented by:

$$T_{\rm eff} = 6081.3(\pm 817.0)[m_1]^2 - 9294.9(\pm 731.8)[m_1] + 8486.7(\pm 149.5)\,. \qquad (2)$$

TABLE 1

PHYSICAL PARAMETERS AND PHOTOMETRIC INDICES FOR THE SAMPLE F-G SUPERGIANTS

Star	D (pc)	$T_{\rm eff}$ (K)	log g (dex)	$[c_1]$	$[m_1]$	Hβ	$E(b-y)$	M_V	$\Delta[c_1]$	Sp. T.	Comment
HR27	380	6270	2.10	1.022	0.222	2.668	0.100	−3.3	−0.236	F2 II	
HR 157	259	5130	2.15	0.293	0.504	2.585	−0.031	−1.5	−0.130	G2.5 IIa	
HR 207	935	5220	1.55	0.380	0.145	2.626	0.553	−3.9	0.000	G0 Ib	
HR 792	397	5020	2.09	0.245	0.645		0.034	−1.8	−0.062	G5 II	D
HR 849	538	5020	1.73	0.209	0.707	2.605	0.019	−8.6	−0.068	G5 Iab:	D
HR 1017	156	6350	1.90	1.048	0.300	2.681	0.097	−5.1	0.114	F5 Ib	V,S
HR 1135	170	6560	2.44	0.950	0.271	2.684	0.046	−2.6	−0.093	F5 II	V,RRL
HR 1242	629	6815	1.87	1.464	0.229	2.730	0.310	−5.3	0.236	F0 II	
HR 1270	427	5060	1.91	0.260	0.635	2.580	0.045	−2.1	−0.050	G8 IIa	
HR 1303	275	5380	1.73	0.451	0.479	2.609	0.097	−3.5	−0.018	G0 Ib	D,SB
HR 1327	98	5440	2.89	0.326	0.457	2.574	−0.024	+0.4	−0.183	G5 IIb	S
HR 1603	265	5300	1.79	0.414	0.500	2.607	0.002	−0.6	−0.009	G1 Ib-IIa	D
HR 1829	49	5450	2.60	0.366	0.423	2.576	0.007	−0.6	−0.232	G5 II	S
HR 1865	680	6850	1.34	1.451	0.202	2.730	0.121	−7.1	0.086	F0 Ib	V,S
HR 2000	224	5000	2.45	0.304	0.519	2.568	−0.045	−0.4	−0.105	G2 Ib-II	S
HR 2453	633	4900	1.70	0.224	0.648	2.582	−0.033	−2.4	−0.083	G5 Ib	D
HR 2597	935	6710	2.00	1.333	1.777	2.721	0.193	−4.3	−0.071	F2 Ib-II	
HR 2693	495	5850	1.00	0.869	0.446	2.660	0.013	−6.7	0.337	F8 Ia	V,S
HR 2786	386	5260	1.90	0.367	0.556	2.619	0.003	−2.7	−0.003	G2 Ib	D,S
HR 2833	375	5380	2.21	0.391	0.535	2.586	−0.010	−1.8	−0.005	G3 Ib	
HR 2881	461	5300	1.66	0.413	0.557	2.622	−0.029	−3.6	0.042	G3 Ib	S
HR 3045	370	4880	1.21	0.251	0.793	2.625	−0.030	−4.4	0.000	G6 Ia	D,S
HR 3073	338	6670	2.61	1.145	0.271	2.700	0.080	−2.2	0.106	F1 Ia	
HR 3102	161	5690	2.17	0.520	0.395	2.651	−0.005	−1.8	−0.144	F7 II	S
HR 3188	325	5210	1.75	0.325	0.569	2.589	−0.026	−3.1	−0.035	G2 Ib	D
HR 3229	267	5130	2.04	0.281	0.663	2.584	−0.003	−2.1	−0.016	G5 II	
HR 3291	900	6600	1.25	1.413	1.996	2.703	0.224	−7.2	0.165	F3 Ib	D
HR 3459	236	5370	2.08	0.424	0.464	2.609	0.005	−2.3	−0.072	G1 Ib	D
HR 4166	177	5475	2.36	0.380	0.459	2.586	−0.028	−1.4	−0.129	G2.5 IIa	
HR 5143	166	5190	2.75	0.277	0.540	2.543	−0.023	+0.2	−0.113	G5 II:	
HR 5165	253	5430	2.37	0.480	0.416	2.591	0.069	−1.7	−0.135	G0 Ib-IIa	
HR 6144	330	7400	1.80	1.509	2.277		0.169	−5.3	0.000	A7 Ib	pAGB?
HR 6536	117	5160	1.86	0.323	0.524	2.598	0.016	−2.6	−0.359	G2 Ib-IIa	D
HR 6978	649	6000	1.70	0.780	0.383	2.636	0.020	−4.4	0.075	F7 Ib	
HR 7014	1000	6760	1.66	1.429	2.043		0.226	−5.8	0.195	F2 Ib	
HR 7094	855	6730	1.75	1.208	1.460	2.711	0.227	−5.2	−0.026	F2 Ib	
HR 7264	156	6590	2.21	1.025	0.242	2.701	0.042	−3.2	−0.140	F2 II	D,S
HR 7387	880	6700	1.43	1.406	1.976	2.715	0.189	−6.7	0.015	F3 Ib	D
HR 7456	370	5550	2.06	0.459	0.421	2.611	0.087	−2.2	−0.143	G0 Ib	D
HR 7542	376	5750	2.15	0.605	0.426	2.633	0.185	−2.2	0.017	F8 Ib-II	pAGB?
HR 7770	960	6180	1.53	0.930	0.864	2.665	0.329	−5.4	0.080	F5 Ib	D
HR 7796	562	5790	1.02	0.818	0.425	2.645	0.026	−6.6	0.234	F8 Ib	V,S
HR 7823	1010	6760	1.92	1.294	1.674	2.729	0.219	−4.7	0.000	F1 II	
HR 7834	235	6570	2.32	1.022	0.259	2.691	0.060	−3.1	−0.078	F5 II	V
HR 7847	1040	6290	1.44	1.022	1.044	2.684	0.295	−5.9	0.077	F5 Iab	
HR 8232	165	5490	1.86	0.537	0.481	2.600	0.024	−3.3	0.076	G0 Ib	D
HR 8313	283	4910	1.58	0.203	0.721	2.593	−0.032	−2.8	−0.069	G5 Ib	V
HR 8412	284	5280	2.35	0.255	0.618	2.596	0.024	−1.0	−0.066	G5 Ia	D
HR 8414	161	5210	1.76	0.386	0.562	2.596	0.002	−3.1	0.020	G2 Ib	D
HR 8692	413	4960	1.90	0.210	0.662	2.597	−0.008	−1.8	−0.087	G4 Ib	

Comments code: V-variable, D-Double, S-$uvby-\beta$ from Simbad, pAGB?- possible post-AGB star, RRL- RR Lyrae, SB-Spectroscopic Binary.

As was done for equation (1) the five A-type stars and the K1 star HR 461 were not included. The standard deviation is 152 K, the correlation coefficient $R = 0.98$.

In order to explore a possible color dependence of the above calibrations, we have selected the dereddened color $(b-y)_0$. To calculate the reddenings for the F-G supergiants we used the calibration given by equation (5) of Arellano Ferro & Parrao (1990) which provides $E(b-y)$ from $(b-y)$, c_1 and m_1 indices with an accuracy of about ± 0.03 mag. The color excesses so calculated are given in Column 8 of Table 1. Since most of these supergiants have low reddening, and given the scatter in the reddening calibration, some small negative values are expected. These negative values should be taken as indicating zero reddening. The resulting equations with the color term included have slightly smaller standard deviations and higher correlation coefficients. They are:

$$T_{\rm eff} = 501.6(\pm 255.1)[c_1] - 1980.1(\pm 467.3)(b-y)_0 + 6252.0(\pm 367.0)\,, \quad (3)$$

with the standard deviation being 129 K and the correlation coefficient $R = 0.98$, and

$$T_{\rm eff} = 2244.0(\pm 958.6)[m_1]^2 - 2350.0(\pm 1407.1)[m_1] - 2244.0(\pm 454.7)(b-y)_0 + 7375.8(\pm 236.8)\,. \quad (4)$$

with the standard deviation being 119 K and the correlation coefficient $R = 0.99$.

At this point it is important to remark that since Lyubimkov et al. (2010) used $[c_1]$, among other indices, to estimate $T_{\rm eff}$, the correlations in Figures 1 and 2 are expected. Naturally, the calibrations of equations (1) to (4) are expressed in terms of the temperature scale of Lyubimkov et al. (2010). What it is offered here are functional relations that can be comfortably used to estimate $T_{\rm eff}$ in F-G supergiants from the c_1 photometry, with comparable accuracies.

The Hβ index is also linearly correlated with the temperature. For the linear fit between Hβ and $T_{\rm eff}$, using the 47 F-G stars with Hβ in Table 1, the standard deviation is 234 K and the correlation coefficient is $R = 0.93$. Since this calibration is of less quality than the four represented by equations (1) to (4), we have not illustrated it.

4. THE log g CALIBRATION

Calibrations of the surface gravity in yellow supergiants and bright giants have been performed in the past by Gray (1991) and Arellano Ferro & Mendoza (1993). The strategy was to use the $[m_1]$-$[c_1]$ plane, on which the locus of a "standard line", determined from F-G Ib supergiants exclusively, was defined by Gray (1991). Then, a vertical parameter; $\Delta[c_1] = [c_1] - [c_1](\textit{standard line})$, can be measured. It has been shown that $\Delta[c_1]$ is correlated with log g. Arellano Ferro & Mendoza (1993) used the spectroscopic gravities for 27 F-G supergiants given by Luck & Bond (1989) to calibrate the correlation. In this work we attempt a new calibration using the new values of log g given by Lyubimkov et al. (2010). The value of $\Delta[c_1]$ for each star in the sample is given in Column 10 of Table 1. Figure 3 shows the $\Delta[c_1]$ dependence on log g. As before, the five A type and the K1 star in the sample of Lyubimkov et al. (2010) have not been included. Among the F-G stars three outliers were noted in the $\Delta[c_1]$-log g plane; HR 1242 (F0 II) and HR 3073 (F1 Ia), both of which are nonvariables, and the double star HR 6536. We have no ready explanation for their discordant position, and they were ignored. The remaining 47 stars display a clear relationship and the straight line has the form:

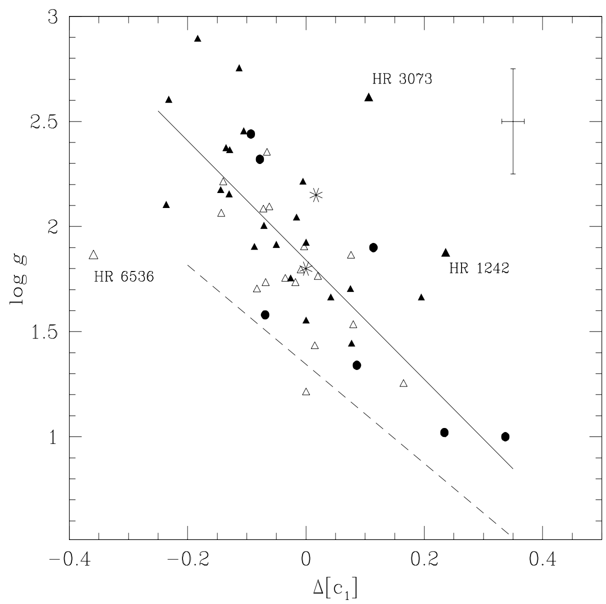

Fig. 3. Dependence of gravity on the index $\Delta[c_1]$. Symbols are as in Figure 1. The segmented line represents the calibration of Arellano Ferro & Mendoza (1993), shifted by 0.3–0.5 dex towards lower gravities. See text for discussion. The error bars correspond to typical uncertainties of ± 0.25 dex and ± 0.019 mag in log g and $\Delta[c_1]$, respectively.

$$\log g = -2.836(\pm 0.349)\Delta[c_1] + 1.841(\pm 0.040), \quad (5)$$

with the standard deviation being 0.267 dex and the correlation coefficient $R = 0.77$.

TABLE 2

PHYSICAL PARAMETERS AND PHOTOMETRIC INDICES FOR A SAMPLE OF post-AGB AND RV TAU STARS

Star	$T_{\rm eff}$ (K)	log g (dex)	$[c_1]$	$[m_1]$	$\Delta[c_1]$	Sp. T.	Comment
HD 46703	6000	0.40	1.069	0.165	−0.463	F7 IVw	pAGB
HD 56126	7167	0.67	1.375	0.393	0.700	F5 Iab:	pAGB
HD 95767	7300	1.30	1.111	0.266	0.049	F3 II	pAGB
HD 107369	7600	1.50	1.575	0.119	−0.213	A2 II/III	pAGB
HD 108015	6800	1.25	1.187	0.237	0.000	F4 Ib/II	pAGB
HD 112374	6600	0.80	1.057	0.272	0.020	F3 Ia	pAGB
HD 148743	7200	0.50	1.509	0.169	0.000	A7 Ib	pAGB
HD 161796	6850	0.37	1.447	0.251	0.312	F3 Ib	pAGB
HD 163506	6550	0.60	1.309	0.193	−0.085	F2 Ibe	pAGB
HD 172481	7250	1.50	1.297	0.164	−0.257	F2 Ia0	pAGB
HD 179821	6775	0.90	1.003	0.601	0.675	G5 Ia	pAGB
HD 190390	6600	1.60	1.071	0.190	−0.338	F1 III	pAGB
HD 170756	5900	1.13	0.679	0.534	0.281	K0 III	RV Tau
AR Pup	6300	1.50	0.879	0.328	0.025	F0 Iab	RV Tau
IW Car	6700	2.00	1.211	0.270	0.160	A4 Ib/II	RV Tau
RU Cen	6000	1.00	0.741	0.457	0.234	F7/F8;A4 Ib	RV Tau
EN TrA	6150	1.25	0.968	0.312	0.074	F2 Ib	RV Tau

Since there are evidences that log g depends on $T_{\rm eff}$ for a given luminosity class (Straizys & Kuriliene 1981) we attempted to incorporate the color term $(b-y)_0$ but found it to be insignificant.

Equation (5), when compared with equation (5) of Arellano Ferro & Mendoza (1993), has smaller dispersion and a slightly higher correlation coefficient. However, we should note that the present calibration indicates lower gravities by 0.3–0.5 dex for a given $\Delta[c_1]$. This invited a comparison of the gravities used by Arellano Ferro & Mendoza (1993), taken from Luck & Bond (1989), with the gravities used in the present work from Lyubimkov et al. (2010) which are listed in Table 1. There are ten F and early G type stars in common; Figure 4 shows that the gravities of Luck & Bond (1989) are systematically smaller. Luck & Bond (1989) found that their spectroscopic gravities, obtained mostly from the ionization equilibrium condition on Fe I and Fe II lines, are systematically smaller by 0.3 dex than gravities derived via the membership of stars in clusters and their photometry. Similar discrepancies were found by Luck & Lambert (1985) for classical cepheids when spectroscopic gravities were compared with gravities obtained via PLC relationship. These authors forward a possible explanation as due to the fact that models built under the assumption of hydrostatic equilibrium may not be a good representation for the extended atmospheres of supergiant stars. The reader is referred to the detailed discussions on this point given in the above papers, and similar arguments might be invoked to explain the discrepancies displayed in Figure 4.

5. THE CASE OF post-AGB STARS

We often have wondered if the calibrations of physical parameters that have been worked out for young yellow supergiants would be equally valid for more evolved and less massive post-AGB stars of similar temperature and gravity. We found a few well known post-AGB and RV Tau stars in the catalogue of Stasińska et al. (2006) with reported values of effective temperature and gravity estimated by spectroscopic techniques, and with Strömgren photometry available in the Simbad database. These stars are listed in Table 2 and plotted in Figure 5 with blue and red symbols on the $[c_1]$-$T_{\rm eff}$ and $[m_1]$-$T_{\rm eff}$ planes of Figures 1 and 2. The stars are rather faint, and their spectral types may be difficult to determine with high accuracy. For this reason, and to avoid too small a sample we included several late

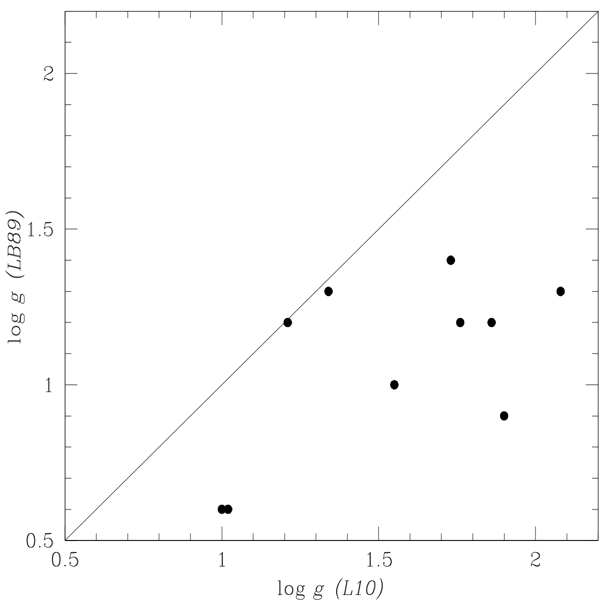

Fig. 4. Comparison of log g values for ten stars in common between Lyubimkov et al. (2010) and Luck & Bond (1989). See text for discussion.

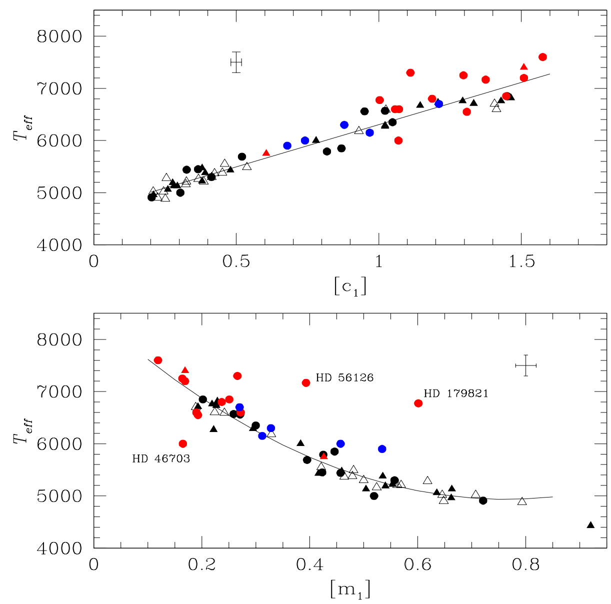

Fig. 5. Inclusion of post-AGB and RV Tau stars in the $T_{\rm eff}$ calibrations. The black symbols are as in Figure 1. The red circles are post-AGB stars and the blue circles are RV Tau stars. The red triangles are the two post-AGB candidate stars HR 6144 and HR 7542 plotted as asterisks in Figures 1, 2 and 3.

A stars and one K0 star. For the $[c_1]$ index the post-AGB and RV Tau stars follow very well the trend defined by the F-G supergiants and, therefore, it seems that the calibration is also valid for these types of stars stars. We have refrained from fitting the straight line with all points since the difference with equation (1) would be negligible. For the $[m_1]$ index the post-AGB's and RV Tau also follow the parabola of the F-G supergiants, except for three stars HD 46703 (F7 IVw), HD 56126 (F5 Iab:) and HD 179821 (G5 Ia). HD 46703 has the spectral type of a subgiant, which may explain its peculiar position. However, for HD 56126 and HD 179821 we have no explanation at hand.

Let us now explore, in a similar way, the role of post-AGB stars on the $\Delta[c_1]$-log g plane. As for the case of the young supergiants we started by plotting the stars on the $[m_1]$-$[c_1]$ diagram from which one can estimate $\Delta[c_1]$. Figure 6 illustrates both these planes. Except for the already noted outliers HD 46703, HD 56126 and HD 179821, both the post-AGB and the RV Tau stars follow the distribution on the $[m_1]$-$[c_1]$ plane. However, on the $\Delta[c_1]$-log g plane the post-AGB stars are at odds with the distribution of the supergiant stars. The five RV Tau stars (blue circles) seem to follow the supergiant trend rather well. With the available information we cannot say whether the post-AGB stars follow a completely different relationship, or if this is a result of the gravities reported by Stasińska et al. (2006) being anomalously too small. In either case it is clear that the relationship in equation (5) should be used only for the young supergiant stars.

6. COMMENTS ON THE DETERMINATION OF M_V

It would be desirable to posses a calibration that could predict the luminosity of young yellow supergiants given an observational parameter, such as for example a color index. Since these stars are luminous they could be used as distance indicators. We have attempted before to calculate such calibration (Arellano Ferro & Parrao 1990; Arellano Ferro & Mendoza 1993). However, an accurate result has been rather elusive. On the other hand a neat calibration of M_V from the intensity of the OI 7774 triplet, valid for a vast range of luminosities, was obtained by Arellano Ferro, Giridhar, & Rojo Arellano (2003), which predicts M_V with an uncertainty of 0.38 mag.

The distances provided by Lyubimkov et al. (2010) could in principle serve to explore a calibration of M_V in terms of a photometric index. The absolute magnitudes listed in Column 9 of Table 1 were calculated from the distances (Column 2) and the reddenings (Column 8). Since $\Delta[c_1]$ is correlated with log g one would expect a relationship between

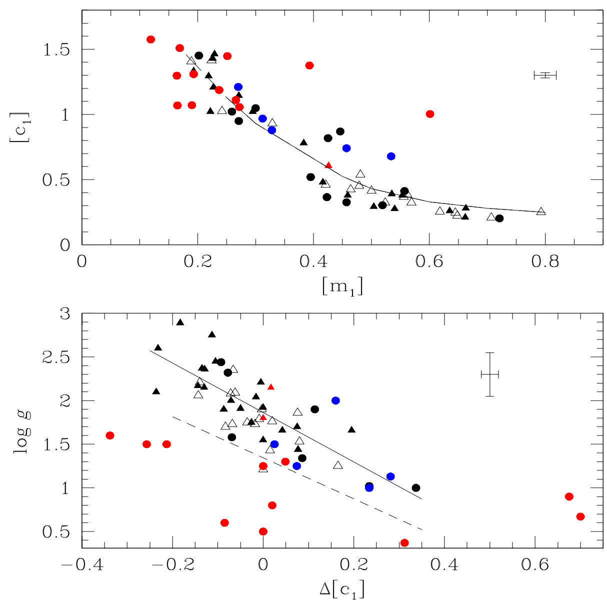

Fig. 6. Inclusion of post-AGB and RV Tau stars in the log g calibrations. The top panel shows the $[m_1]$-$[c_1]$ plane and the fiducial line definded by Gray (1991), relative to which the $\Delta[c_1]$ parameter is measured. The lower panel shows the distribution of the different groups of stars in the $\Delta[c_1]$- log g plane. Symbols are as in Figure 5. See text for discussion.

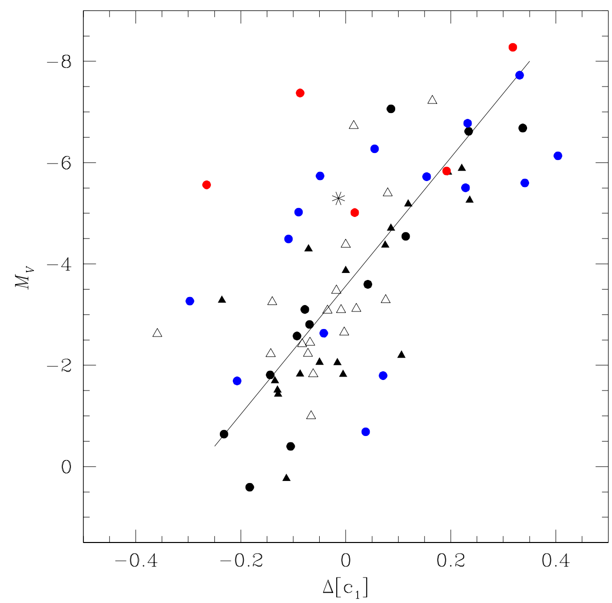

Fig. 7. Trend of M_V with $\Delta[c_1]$. The black symbols are as in Figure 1. The blue circles correspond to a sample of F-G supergiants and the red circles to a well documented post-AGB stars taken from Table 3 of Arellano Ferro et al. (2003), where values of M_V were calculated from the O I 7774 feature.

M_V and $\Delta[c_1]$. In Figure 7 the plot of $\Delta[c_1]$ vs M_V is shown. Although a trend is clearly seen, the scatter is large ($\sigma = 1.3$ mag). Inclusion of the color term, $(b-y)_0$ does not improve the relationship ($\sigma = 1.1$ mag).

We find of interest to consider a sample of F-G supergiants and 5 well documented post-AGB stars listed by Arellano Ferro et al. (2003) (their Table 3) for which values of M_V have been calculated from the O I 7774 calibration. $uvby-\beta$ photometry for all these stars is available in the *Simbad* data base and thus we can calculate their $\Delta[c_1]$ parameters. They are plotted in Figure 7 (blue and red symbols) along with the F-G supergiants of Table 1. We see that both groups of stars follow the same trend and display a similar scatter. One can conclude from this that while the distances in Lyubimkov et al. (2010) are consistent with the absolute magnitudes predicted from the strength of the O I 7774 feature in F-G supergiants, a reliable calibration of M_V in terms of a photometric index, for example $\Delta[c_1]$, is not foreseen.

7. CONCLUSIONS

New accurate values of $T_{\rm eff}$ and log g (Lyubimkov et al. 2010) lead to reliable functional relationships for the Strömgren reddening free indices $[c1]$ and $[m1]$, which allow to predict the effective temperature and gravity of F-G supergiants. The temperature calibrations are given in equations (1) and (2) which predict the effective temperature with an standard deviation of 152 K. If the reddening is available, alternative calibrations, given by equations (3) and (4) provide slightly smaller standard deviations (129 and 119 K respectively). These calibrations are valid for the more evolved post-AGB stars of similar temperature and gravity. Given the fact that RV Tau stars are variables of large amplitude, it is rewarding to see that the five RV Tau stars included follow the temperature trends very closely. Perhaps their mean temperature and photometric indices are not too different from the temperatures reported by Stasińska et al. (2006) and the mean photometric indices calculated here.

The stellar gravity can also be predicted from the $\Delta[c_1]$ index (Gray 1991) from the calibration given by equation (5), with an accuracy 0.28 dex. The color term was found to be insignificant. This equation is valid for F-G yellow supergiants and very likely for RV Tau stars. However, well known post-AGB stars of similar temperature and gravities (see Table 2) do not follow the calibration.

We have not been able to determine a reliable calibration that can predict the absolute magnitude M_V for F-G supergiant stars from photometric indices as accurately as from the strength of the OI 7774 feature.

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