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Colour Transformations between BVR_c and $g'r'i'$ Photometric Systems for Giant Stars

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Abstract

The transformation equations from BVR_c to $g'r'i'$ magnitudes and vice versa for the giants were established from a sample of 80 stars collected from Soubiran et al. (2010) with confirmed surface gravity ($2 \leq \log g$ (cm s^{-2}) ≤ 3) at effective temperatures $4000 < T_{eff}(K) < 16000$. The photometric observations, all sample stars at $g'r'i'$ and 65 of them at BVR_c, were obtained at TÜBİTAK National Observatory (TUG) 1m (T100) telescope, on the Taurus Mountains in Turkey. The M_V absolute magnitudes of the giant stars were estimated from the absolute magnitude-temperature data for the giant stars by Sung et al. (2013) using the T_{eff} from the intrinsic colours considered in this study. The transformation equations could be considered to be valid through the ranges of the following magnitudes and colours involved: $7.10 < V_0 < 14.50$, $7.30 < g'_0 < 14.85$, $-0.20 < (B-V)_0 < 1.41$, $-0.11 < (V-R_c)_0 < 0.73$, $-0.42 < (g'-r')_0 < 1.15$, and $-0.37 < (r'-i')_0 < 0.47$ mag. The transformations were successfully applied to the synthetic BVR_c data of 427 field giants in order to obtain the $g'r'i'$ magnitudes and colours. Comparisons of these data with the $g'r'i'$ observations of giants in this study show that the mean residuals and standard deviations lie within [−0.010, 0.042] and [0.028, 0.068] mag, respectively.

Keywords: catalogue – surveys – techniques: photometric

1 INTRODUCTION

All sky surveys have a great impact on our understanding of the Galactic structure. The optical and longer wavelength surveys give detailed information about the Galactic halo, and Galactic disc and bulge, respectively. The Sloan Digital Sky Survey (SDSS; York et al. 2000) is one of the most widely used sky surveys. Also, it is the largest photometric and spectroscopic survey in the optical wavelengths. Another widely used sky survey is the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006), which imaged the sky across near-infrared wavelengths. The third sky survey, which is an astrometrically and photometrically important survey, is *Hipparcos* (Perryman et al. 1997), re-reduced by van Leeuwen (2007).

SDSS is based on two sets of passbands, i.e. $u'g'r'i'z'$ and $ugriz$. For the first set, the standard Sloan photometric system was defined on the 1m telescope of the USNO Flagstaff Station (Smith et al. 2002), while a 2.5 m telescope was used for the second passband set (Fukugita et al. 1996; Gunn et al. 1998; Hogg et al. 2001). The two sets of passbands are very similar, but not quite identical. However, one can use the transformation equations in the literature to make necessary transformations between two systems (cf. Rider et al. 2004).

It has been customary to derive transformation equations between a newly defined photometric system and the traditional ones, such as the Johnson-Cousins $UBVR_cI_c$ system. Several transformations can be found in the literature related SDSS photometric system (Smith et al. 2002; Karaali, Bilir, & Tunçel 2005; Bilir, Karaali, & Tunçel 2005; Rodgers et al. 2006; Jordi, Grebel, & Ammon 2006; Chonis & Gaskell 2008; Bilir et al. 2008). All these transformations are devoted to dwarfs, the most populated luminosity class in our Galaxy. The two transformations which are carried out for red giants are those of Yaz et al. (2010) and Karaali & Yaz Gökçe (2013).

Yaz et al. (2010) used the JHK_s, BVI, and gri magnitudes in the 2MASS (Cutri et al. 2003), reduced *Hipparcos'* (van Leeuwen 2007) and Ofek's (2008) catalogues and identified two samples of red giants by matching them with the

Cayrel de Strobel, Soubiran, & Ralite's (2001) spectroscopic catalogue which contains the surface gravity $\log g$, a parameter available for dwarf-giant separation. The first sample of stars (91 giants) was used for the transformations between JHK_s and BVI, while the second one (82 giants) was devoted to transformations between JHK_s and gri. The transformations of Karaali & Yaz Gökçe (2013) are based on synthetic UBV colours of Buser & Kurucz (1992) and synthetic ugr colours of Lenz et al. (1998). They are metallicity and two colours dependent. Three sets of transformation equations are obtained, i.e. for $[M/H] = 0, -1, -2$ dex, which can be interpolated/extrapolated to different metallicities. The advantage of these transformations is that they can be used to extend the colour ranges of the observed $u - g$ and $g - r$ colours which are restricted due to the saturation of the SDSS magnitudes.

In this study, we present transformation equations between either of the most widely used sky surveys, SDSS $g'r'i'$, and BVR_c for giants. The equations are based on the data which were observed and reduced by a team who are included as co-authors in this paper. The sections are organised as follows. Data are presented in Section 2. Section 3 is devoted to the transformation equations and their application and a summary and discussions are given in Section 4.

2 THE DATA

2.1 Observations

The sample consists of fairly bright 80 giants identified and collected by their surface gravities and effective temperatures in the Pastel catalogue (Soubiran et al. 2010): (i) $2 \leq \log g$ (cm s^{-2}) ≤ 3, (ii) $4000 < T_{eff}(K) < 16000$. The sample stars cover a large range of metallicities, i.e. $-4 \leq [Fe/H] \leq 0.5$ dex. The sample stars were observed at least three exposures in each filter used. The observations were carried out at 1m RC telescope (T100) at TÜBİTAK National Observatory (TUG)[1] at Bakırlıtepe, Antalya, in Turkey from 2011 July through 2012 September. Table 1 summarises the journal of observations. The columns indicate the dates, the number of nights, and the number of observing sets at $g'r'i'$ and BVR_c filters both for the sample and standard stars.

Table 1. Observing runs at the TUG T100 telescope. Number of frames for giants and standard stars are given in the last four columns according to the filter sets used.

		Giants		Std. stars	
Date	Nights	$g'r'i'$	BVR_c	$g'r'i'$	BVR_c
July 21–23, 2011	3	137	139	187	185
Sept. 9–11, 2011	3	210	187	207	172
Oct. 31–Nov. 01, 2011	2	74	62	91	43
Nov. 21–22, 2011	2	60	45	74	39
Dec. 29, 2011	1	68	—	110	—
Feb. 19, 2012	1	162	—	79	—
Mar. 29, 2012	1	137	—	169	—
Apr. 01, 2012	1	—	57	—	60
Apr. 12, 2012	1	—	56	—	37
Apr. 16–17, 2012	2	88	87	63	56
July 28–29, 2012	2	99	66	203	141
Aug. 18–19, 2012	2	126	121	177	111
Sep. 16–18, 2012	3	248	368	203	203
Total	24	1409	1188	1563	1047

Standard reduction techniques were performed with Image Reduction and Analysis Facility (IRAF)[2]. Sky observations during the twilight were used in the flat field corrections. As the dark current level of the CCD camera is very low (0.0002 e$^-$ pixel^{-1} s^{-1}) and the exposure times during observing runs are not long, dark current corrections were not applied. Instrumental magnitudes were obtained through aperture photometry using standard IRAF software packages. The instrumental magnitudes and colours were transformed to the standard photometric systems following the procedures described below. The following equations were used for the transformation of the instrumental magnitudes and colours of giant stars to the standard magnitudes and colours:

$$V = v - k_V \times X_v + \epsilon_V \times (B - V) + \zeta_V, \tag{1}$$

$$B - V = \mu \times [(b - v) - (k_{BV} \times X_{BV})] + \zeta_{BV}, \tag{2}$$

$$V - R_c = \rho \times [(v - r_c) - (k_{VR_c} \times X_{VR_c})] + \zeta_{VR_c}, \tag{3}$$

$$g' = g - k_g \times X_g + \epsilon_g \times (g - r) + \zeta_g, \tag{4}$$

$$g' - r' = \kappa \times [(g - r) - (k_{gr} \times X_{gr})] + \zeta_{gr}, \tag{5}$$

$$r' - i' = \tau \times [(r - i) - (k_{ri} \times X_{ri})] + \zeta_{ri}, \tag{6}$$

where, b, v, r_c and B, V, R_c are the instrumental and the standard magnitudes, respectively. Similarly, g, r, i and g', r', i' denote the instrumental and standard magnitudes for SDSS $u'g'r'i'z'$ photometric system. k and X are photometric extinction coefficient and air mass, respectively, with a subscript denoting the filter or the colour. ϵ, μ, ρ, κ and τ are the transformation coefficients from the instrumental to the standard, where ζ denotes nightly photometric zeropoint with a subscript indicating the filter or the colour. Using the instrumental magnitudes of the standard stars (Landolt 2009) measured through observations and applying multiple linear least square fits to the equations above, the photometric extinction coefficients, the transformation coefficients and the zeropoint constants were estimated on each night. The averages of them are listed in Table 2. The final standardised photometric data of the sample stars are listed in Table 3. The B, V, R_c observations exist only for 65 sample stars. Therefore, we had to use the synthetic B, V, R_c magnitudes in Pickles & Depagne (2010) to estimate intrinsic $B - V$ and $V - R_c$ colours for the 15 stars which are not observed at BVR_c but observed at $g'r'i'$.

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[1] www.tug.tubitak.gov.tr

[2] IRAF is distributed by the National Optical Astronomy Observatories

Table 2. Derived average photometric extinction coefficients (k), transformation coefficients (C, see the text), zeropoints (ζ) and average standard deviation (σ) of fits for observing runs. Error values show standard deviation of the measurements.

Magnitude/colour	k	C	ζ	σ
V	0.137±0.022	−0.076±0.008	−0.753±0.099	0.015±0.007
$B-V$	0.082±0.013	1.191±0.016	−0.012±0.035	0.010±0.003
$V-R_c$	0.044±0.023	0.942±0.009	0.068±0.021	0.008±0.002
g'	0.179±0.048	0.021±0.005	−0.229±0.092	0.016±0.007
$g'-r'$	0.072±0.025	1.035±0.009	−0.247±0.030	0.009±0.003
$r'-i'$	0.058±0.020	0.962±0.023	−0.628±0.029	0.010±0.003

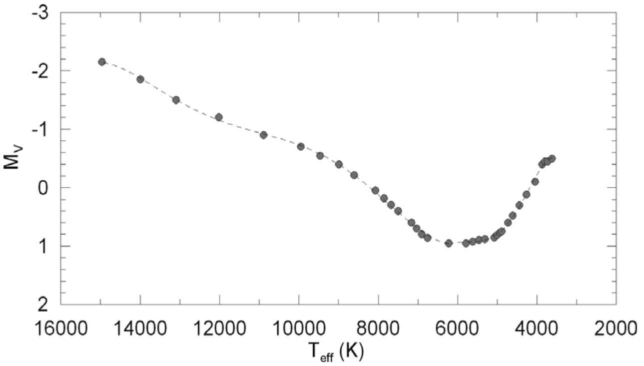

Figure 1. $M_V \times T_{eff}$ absolute magnitude-temperature diagram for the giant stars in Sung et al. (2013) which is used for absolute magnitude estimation of the sample stars.

2.2 Distances and de-reddening of the magnitudes and colours

After obtaining standardised observed magnitudes and colours of the present sample of giants (80) through Equations (1) to (6), de-reddening of them is the next step before attempting to establish the transformation equations between BVR_c and $g'r'i'$. A priory advantage for us to know calibrated absolute magnitudes of giants from the tables of Sung et al. (2013). Sung et al. (2013) have studied spectral type-M_V and spectral type-T_{eff} relation of giants in general along with other luminosity classes on the H-R diagram in the Johnson-Cousins $UBVR_cI_c$ system. Using their Table 4 and 5, we have plotted absolute magnitudes as a function of the effective temperature. The data existing on these tables in the range of $3600 < T_{eff}(K) \leq 16000$ were shown by filled circles in Figure 1. In order to increase efficient use of the data, two polynomial functions were fitted to the cooler ($3600 < T_{eff}(K) \leq 6000$) and to the hotter ($6000 < T_{eff}(K) < 16000$) regions. Dashed line in Figure 1 represents the polynomials fitted.

For a given effective temperature of our sample giants as supplied by the Pastel catalogue (Soubiran et al. 2010), the absolute magnitude (M_V) is provided by Figure 1. Nevertheless, absolute magnitude alone is not enough to estimate neither the distance nor the interstellar extinction. The total interstellar absorption in V-band could be estimated by means of the maps of Schlafly & Finkbeiner (2011) which are based on a recalibration of the Schlegel, Finkbeiner, & Davis (1998) maps, for each of the sample star, by including the Galactic coordinates of the star in question into the NED service.[3] The value A_∞ is valid for a star at infinite distance. However, we used it in the Pogson's equation and evaluated the distance to the star as a first approximation:

$$V - M_V - A_\infty = 5\log d - 5, \tag{7}$$

where V and M_V are the apparent and the absolute magnitudes from which the distance is estimated. We then reduced A_∞ to the total absorption of the star at distance d, i.e. A_d, by the procedure of Bahcall & Soneira (1980). We have replaced the numerical value of $A_d(b)$ with the one of A_∞ in Equation (7), and applied a series of iteration to obtain the final total absorption A_V by which the selective absorption (colour excess), $E_d(B-V)$ could be evaluated for distance d as follows:

$$E_d(B-V) = A_d(b)/3.1. \tag{8}$$

$E_d(B-V)$ is the standard $E(B-V)$ colour excess of the star with given V, M_V and d, from which one can compute intrinsic colour by using observed colour and de-reddened observed magnitude. The range of the colour excess of the sample stars is $0 < E(B-V) < 0.84$ mag, and their distribution in the Galactic longitude-Galactic latitude plane is plotted in Figure 2, where one may notice the $E(B-V)$ colour excess is highest on the Galactic plane and decreases towards the Galactic poles. We have made consistency check of $E(B-V)$ colour excesses of 25 giant stars by comparing the colour excesses of the clusters which they belong to. The results are given in Table 4, where the columns are explanatory to indicate the name of the cluster, the star's ID, equatorial coordinates (J2000), the colour excesses $E_d(B-V)$ of the stars estimated in this study and the colour excess $E_{cl}(B-V)$ of the cluster from the literature. The colour excesses $E_{cl}(B-V)$ of the clusters NGC 6341 and NGC 6838 are taken from Harris (1996, edition 2010), while those for the remaining five clusters are provided from Dias et al. (2002). Table 4 shows that the colour excesses evaluated in this study and taken from literature are in good agreement, in general.

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[3] http://ned.ipac.caltech.edu/forms/calculator.html

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Table 3. Photometric data of the sample stars. The columns give: (1) Current number, (2) Star name, (3), (4), (5), and (6) the Equatorial and Galactic coordinates, (7) colour excess of the star, (8)–(13) magnitudes, colours and their errors in BVR_c photometric system, (14) References for the columns (8)–(13), (15)–(20) magnitudes, colours and their errors in $g'r'i'$ photometric system, (21) effective temperature T_{eff}, (22) surface gravity log g, (23) the metallicity $[Fe/H]$ and (24) references for the columns (21)–(23).

(1) ID	(2) Star	(3) α (J2000) (hh:mm:ss.ss)	(4) δ (J2000) (dd:mm:ss.ss)	(5) l (deg)	(6) b (deg)	(7) $E_d(B-V)$ (mag)	(8) V (mag)	(9) V_{err} (mag)	(10) $(B-V)$ (mag)	(11) $(B-V)_{err}$ (mag)	(12) $V-R_c$ (mag)	(13) $(V-R_c)_{err}$ (mag)	(14) Ref	(15) g' (mag)	(16) g'_{err} (mag)	(17) $(g'-r')$ (mag)	(18) $(g'-r')_{err}$ (mag)	(19) $(r'-i')$ (mag)	(20) $(r'-i')_{err}$ (mag)	(21) T_{eff} (K)	(22) log g (cms^{-2})	(23) $[Fe/H]$ (dex)	(24) Ref
1	HD 26	00 05 22.20	+08 47 16.10	104.069	−52.389	0.062	8.186	0.002	1.066	0.003	0.507	0.003	1	8.646	0.002	0.740	0.003	0.255	0.003	5250	2.59	−0.29	1999ApJ...521..753T
2	BD+28 0054	00 23 43.09	+29 24 03.62	115.725	−33.083	0.036	9.890	0.002	0.535	0.003	0.304	0.003	1	10.037	0.002	0.195	0.003	−0.047	0.004	6337	2.84	−0.06	1995AJ....110.2319C
3	BD+71 0031	00 43 44.35	+72 10 43.12	122.335	9.316	0.360	10.101	—	0.469	—	0.291	—	2	10.344	0.001	0.249	0.001	0.085	0.002	6129	3.75	−1.81	2008MNRAS.391...95R
4	HD 6755	01 09 43.06	+61 32 50.19	125.108	−1.247	0.032	7.731	0.002	0.731	0.003	0.431	0.003	1	7.985	0.002	0.534	0.003	0.202	0.003	5100	2.70	−1.47	2001A&A...370..951M
5	HD 9356	01 32 08.17	+01 20 30.23	143.544	−59.891	0.021	9.823	0.001	0.413	0.001	0.265	0.002	1	10.027	0.002	0.178	0.003	−0.001	0.003	6282	2.77	−1.38	1995AJ....110.2319C
6	HD 19510	03 08 30.88	+10 26 45.22	169.083	−39.838	0.174	9.831	0.002	0.582	0.003	0.379	0.003	1	10.080	0.002	0.447	0.004	0.156	0.004	6109	2.60	−2.50	1995AJ....110.2319C
7	BD+26 0595	03 40 10.04	+26 57 37.21	163.275	−22.401	0.160	8.315	0.002	1.060	0.003	0.578	0.003	1	8.671	0.001	0.868	0.001	0.359	0.001	4383	2.10	−0.80	1984Thesis. Proust
8	HD 281679	04 09 16.98	+30 46 33.47	165.534	−15.288	0.490	9.322	0.002	0.577	0.003	0.285	0.003	1	9.582	0.002	0.335	0.002	0.152	0.002	8542	2.50	−1.43	1987SvA....31...37K
9	HD 26886	04 14 58.83	−00 59 50.82	193.602	−34.703	0.074	7.878	0.001	0.985	0.002	0.497	0.001	1	8.301	0.002	0.700	0.002	0.255	0.002	4802	2.22	−0.28	2003A&A...257..265L
10	HD 27271	04 18 33.82	+02 28 13.92	190.740	−32.035	0.075	7.471	0.001	0.969	0.002	0.474	0.001	1	7.980	0.001	0.722	0.001	0.255	0.001	4874	2.98	−0.06	2003A&A...257..265L
11	NGC 2112 204	05 53 47.54	+00 22 02.00	205.916	−12.625	0.793	11.822	0.002	1.786	0.004	1.000	0.003	1	12.937	0.003	1.571	0.004	0.749	0.003	4550	2.46	−0.17	1996AJ....112.1551B
12	NGC 2112 402	05 53 53.30	+00 24 37.90	205.889	−12.584	0.839	11.512	0.001	1.469	0.003	0.818	0.002	1	12.423	0.002	1.252	0.003	0.593	0.003	5050	2.72	−0.05	1996AJ....112.1551B
13	HD 252940	06 11 37.25	+26 27 30.11	185.021	3.752	0.133	9.110	0.002	0.206	0.003	0.148	0.004	1	9.264	0.002	0.107	0.003	−0.068	0.003	7550	2.95	−1.77	2000A&A...364..102K
14	BD+37 1458	06 16 01.52	+37 43 18.76	175.418	9.825	0.105	8.857	0.002	0.684	0.003	0.408	0.003	1	9.150	0.001	0.430	0.002	0.193	0.003	5100	2.90	−2.31	1999AJ....118..527F
15	BD+38 1456	06 20 03.84	+38 20 44.11	175.211	10.815	0.142	10.697	0.001	0.897	0.001	0.457	0.001	1	11.203	0.002	0.638	0.003	0.260	0.003	5000	2.75	−1.50	2003PASP..115...22Y
16	HD 58337	07 26 01.95	+21 54 46.00	196.614	17.118	0.033	9.700	0.001	1.323	0.002	0.605	0.001	1	10.347	0.002	0.964	0.003	0.352	0.003	4582	2.10	−0.40	1984ApJS...55...27D
17	NGC 2420 115	07 38 21.67	+21 33 51.40	198.114	19.626	0.036	11.591	0.003	1.327	0.007	0.647	0.004	1	12.068	0.002	0.849	0.003	0.273	0.003	4541	2.20	−0.60	1987AJ.....93..359S
18	NGC 2420 173	07 38 26.96	+21 33 31.30	198.128	19.643	0.036	11.807	0.003	1.095	0.007	0.528	0.004	1	12.161	0.002	0.629	0.003	0.211	0.003	4893	2.50	−0.55	1987AJ.....93..359S
19	BD-01 1792	07 39 50.11	−01 31 20.37	219.884	10.042	0.041	9.122	0.002	0.938	0.003	0.433	0.002	1	9.628	0.002	0.645	0.003	0.203	0.003	4850	2.70	−1.26	2000AJ....120.1841F
20	BD+80 0245	08 11 06.23	+79 54 29.56	133.914	30.136	0.021	9.906	—	0.634	—	0.376	—	2	10.240	0.001	0.404	0.001	0.148	0.002	5225	3.00	−2.05	2000AJ....120.1841F
21	BD+00 2245	08 16 57.77	+00 01 03.72	223.038	18.942	0.033	9.604	0.001	0.676	0.002	0.335	0.001	1	9.996	0.001	0.381	0.001	0.129	0.002	5425	3.00	−1.28	1998ApJ...500..398R
22	HD 233517	08 22 46.71	+53 04 49.19	165.382	34.891	0.044	9.675	—	1.325	—	0.665	—	2	10.335	0.002	1.049	0.002	0.411	0.001	4475	2.25	−0.37	2000ApJ...542..978B
23	NGC 2682 84	08 51 12.70	+11 52 42.40	215.601	31.909	0.030	10.560	0.003	1.058	0.005	0.512	0.004	1	11.114	0.004	0.891	0.005	0.330	0.004	4750	2.40	−0.02	2000A&A...360..499T
24	NGC 2682 105	08 51 17.10	+11 48 16.10	215.689	31.895	0.030	10.347	0.003	1.170	0.005	0.595	0.004	1	11.023	0.003	1.019	0.004	0.368	0.004	4400	2.00	0.01	2010AJ....139.1942F
25	BD+12 1924	08 51 20.10	+12 18 10.43	215.161	32.113	0.026	9.338	—	1.432	—	0.738	—	2	10.041	0.002	1.170	0.002	0.480	0.001	4131	2.30	0.00	1981A&A....99..221F
26	NGC 2682 141	08 51 22.80	+11 48 01.70	215.705	31.914	0.030	10.529	0.003	0.989	0.005	0.567	0.004	1	11.046	0.002	0.831	0.003	0.283	0.003	4650	2.80	0.06	2010A&A...511A..56P
27	NGC 2682 151	08 51 26.19	+11 53 52.00	215.608	31.968	0.031	10.555	0.003	0.958	0.005	0.601	0.004	1	11.006	0.002	0.822	0.003	0.280	0.003	4760	2.40	0.01	2000A&A...360..499T
28	NGC 2682 164	08 51 28.99	+11 50 33.10	215.673	31.955	0.031	10.603	0.003	0.969	0.006	0.579	0.004	1	11.117	0.002	0.855	0.003	0.293	0.003	4659	2.53	-0.02	2009A&A...493..309S
29	NGC 2682 224	08 51 43.55	+11 44 26.40	215.811	31.966	0.025	10.875	0.004	0.965	0.006	0.600	0.004	1	11.288	0.002	0.852	0.003	0.302	0.003	4710	2.40	−0.11	2000A&A...360..499T
30	NGC 2682 231	08 51 45.08	+11 47 45.90	215.755	31.995	0.027	11.523	0.006	0.990	0.011	0.504	0.007	1	11.979	0.003	0.778	0.004	0.281	0.004	4893	3.00	−0.35	1980ApJ...241..981C
31	NGC 2682 266	08 51 59.52	+11 55 04.90	215.653	32.099	0.032	10.451	0.003	1.105	0.005	0.483	0.004	1	11.007	0.002	0.825	0.003	0.287	0.003	4730	2.40	−0.02	2000A&A...360..499T
32	BD+23 2130	09 39 39.17	+22 52 15.42	207.548	46.593	0.028	9.716	—	1.104	—	0.686	—	2	10.212	0.002	0.858	0.002	0.284	0.002	5228	2.94	−2.42	2005MNRAS.364..712Z
33	HD 233666	09 42 19.47	+53 28 26.15	162.399	46.535	0.008	9.225	—	0.665	—	0.395	—	2	9.606	0.002	0.474	0.003	0.196	0.003	5300	2.50	−1.65	2000ApJ...544..302B
34	HD 237846	09 52 38.68	+57 54 58.59	155.634	46.250	0.009	9.844	—	0.816	—	0.474	—	2	10.267	0.001	0.541	0.002	0.231	0.003	5015	2.02	−2.81	2012ApJ...753...64I
35	BD+10 2179	10 38 55.23	+10 03 48.50	235.211	54.442	0.023	9.993	0.002	−0.160	0.002	−0.090	0.003	1	9.769	0.002	−0.390	0.003	−0.353	0.004	15750	2.80	1.40	1969ApJ...157..721H
36	BD+09 2384	10 40 25.20	+08 54 03.95	237.215	54.098	0.024	9.855	—	0.885	—	0.495	—	2	10.256	0.002	0.624	0.003	0.226	0.003	5200	3.00	−0.71	1991ApJS...77..515L
37	G146 76	10 59 57.47	+44 46 43.75	167.171	61.600	0.009	10.422	—	0.778	—	0.472	—	2	10.769	0.002	0.497	0.003	0.201	0.003	5202	2.85	−1.64	2005MNRAS.364..712Z
38	BD+32 2188	11 47 00.50	+31 50 08.65	190.506	75.227	0.019	10.708	0.003	v0.032	0.004	−0.028	0.004	1	10.620	0.002	−0.264	0.003	−0.269	0.004	10450	2.10	−1.11	2000A&A...364..102K
39	BD+27 2057	11 47 28.72	+26 24 45.56	212.163	75.716	0.019	9.550	0.001	0.872	0.001	0.431	0.001	1	9.863	0.001	0.615	0.001	0.216	0.001	4810	2.25	−0.51	2012AJ....144...20A
40	BD-01 2582	11 53 37.32	−02 00 36.74	275.101	57.703	0.019	9.538	—	0.782	—	0.478	—	2	9.899	0.001	0.498	0.001	0.206	0.001	5237	2.79	−2.14	2011ApJ...737....9R
41	BD+29 2231	11 55 52.34	+28 26 14.77	203.631	77.648	0.024	9.875	—	0.965	—	0.525	—	2	10.252	0.002	0.675	0.003	0.234	0.003	5060	2.50	−0.39	2001A&A...380..578T

Table 3. Continued.

(1) ID	(2) Star	(3) α (J2000) (hh:mm:ss.ss)	(4) δ (J2000) (dd:mm:ss.ss)	(5) l (deg)	(6) b (deg)	(7) $E_d(B-V)$ (mag)	(8) V (mag)	(9) V_{err} (mag)	(10) $(B-V)$ (mag)	(11) $(B-V)_{err}$ (mag)	(12) $V-R_c$ (mag)	(13) $(V-R_c)_{err}$ (mag)	(14) Ref	(15) g' (mag)	(16) g'_{err} (mag)	(17) $(g'-r')$ (mag)	(18) $(g'-r')_{err}$ (mag)	(19) $(r'-i')$ (mag)	(20) $(r'-i')_{err}$ (mag)	(21) T_{eff} (K)	(22) $\log g$ (cms^{-2})	(23) $[Fe/H]$ (dex)	(24) Ref
42	BD+25 2436	11 56 28.83	+24 59 16.15	219.693	77.480	0.016	9.909	0.002	0.882	0.003	0.484	0.003	1	10.323	0.002	0.678	0.003	0.237	0.003	4990	2.40	−0.48	2001A&A...380..578T
43	HD 104783	12 04 05.21	+37 59 58.95	162.411	75.271	0.015	9.094	—	0.836	—	0.474	—	2	9.533	0.002	0.605	0.002	0.236	0.001	5140	2.40	−0.55	2001A&A...380..578T
44	BD+25 2459	12 06 43.44	+24 42 59.23	223.929	79.665	0.022	9.555	—	0.955	—	0.505	—	2	10.035	0.001	0.686	0.001	0.254	0.001	4980	2.50	−0.35	2001A&A...380..578T
45	BD-04 3208	12 07 15.07	−05 44 01.61	283.291	55.444	0.042	9.991	0.003	0.412	0.004	0.254	0.004	1	10.118	0.002	0.242	0.003	0.060	0.003	5900	3.00	−2.62	2000AJ....120.1841F
46	HD 105944	12 11 29.35	+44 15 02.56	145.469	71.088	0.012	9.889	0.002	0.863	0.003	0.461	0.002	1	10.297	0.002	0.625	0.002	0.242	0.002	5090	2.10	−0.37	2001A&A...380..578T
47	BD+17 2473	12 23 31.02	+16 54 09.24	269.223	77.906	0.023	10.083	0.002	0.759	0.003	0.424	0.003	1	10.478	0.002	0.514	0.002	0.221	0.001	5050	3.00	−1.21	1998ApJ...500..398R
48	BD+25 2502	12 24 17.14	+24 19 28.31	236.060	83.274	0.018	9.922	0.003	0.786	0.004	0.438	0.004	1	10.299	0.002	0.575	0.002	0.216	0.002	5090	2.20	−0.74	2001A&A...380..578T
49	BPS BS 16076-006	12 48 22.75	+20 56 44.04	296.328	83.778	0.028	13.539	0.004	0.590	0.006	0.386	0.005	1	13.801	0.003	0.437	0.004	0.181	0.004	5199	3.00	−3.81	2009A&A...501..519B
50	BD+34 2371	12 57 49.30	+33 39 01.13	111.410	83.335	0.013	9.451	—	0.959	—	0.511	—	2	9.914	0.002	0.679	0.002	0.209	0.002	4980	2.50	−0.18	2001A&A...380..578T
51	HD 113321	13 02 46.53	+16 27 59.36	317.348	79.020	0.024	9.364	—	1.026	—	0.544	—	2	9.838	0.002	0.776	0.002	0.269	0.001	4739	2.10	−0.07	2006A&A...456.1109M
52	BPS BS 16929-005	13 03 29.47	+33 51 09.14	102.568	82.793	0.011	13.642	0.004	0.642	0.006	0.423	0.006	1	13.930	0.003	0.479	0.004	0.202	0.004	5245	2.70	−3.07	2008ApJ...681.1524L
53	BD+18 2890	14 32 13.48	+17 25 24.28	15.547	64.809	0.018	9.880	0.002	0.720	0.002	0.451	0.002	1	10.121	0.001	0.538	0.001	0.223	0.001	5000	2.20	−1.58	2000ApJ...544..302B
54	HD 128188	14 35 46.82	−11 24 12.26	339.673	43.900	0.099	10.119	0.002	0.947	0.003	0.592	0.002	1	10.451	0.002	0.744	0.002	0.360	0.001	4657	2.03	−1.35	2008A&A...484L..21M
55	BPS CS 30312-059	15 34 48.84	−01 23 37.29	3.659	41.451	0.107	13.118	0.005	0.824	0.008	0.504	0.006	1	13.529	0.003	0.653	0.004	0.313	0.004	5021	2.06	−3.14	2008ApJ...681.1524L
56	BD+11 2998	16 30 16.78	+10 59 51.74	26.608	36.278	0.043	9.086	0.001	0.688	0.001	0.414	0.001	1	9.359	0.002	0.516	0.002	0.196	0.002	5350	2.00	−1.38	1992AJ....104..645K
57	HD 156074	17 13 31.24	+42 06 22.76	66.998	35.404	0.012	7.617	0.001	1.195	0.001	0.539	0.001	1	8.115	0.001	0.815	0.001	0.168	0.002	4755	2.05	−0.10	1973A&A....22..293G
58	NGC 6341 9012	17 16 52.84	+43 03 29.50	68.238	34.894	0.020	14.541	0.008	0.565	0.013	0.385	0.010	1	14.837	0.008	0.457	0.010	0.171	0.008	5500	3.00	−2.34	2000AJ....120.1351S
59	NGC 6341 10065	17 17 11.41	+43 06 02.70	68.297	34.843	0.019	14.362	0.010	0.656	0.016	0.446	0.012	1	14.744	0.009	0.558	0.011	0.226	0.008	5260	2.40	−2.34	2000AJ....120.1351S
60	NGC 6341 11027	17 17 21.61	+43 06 15.90	68.306	34.813	0.019	14.519	0.007	0.684	0.012	0.452	0.009	1	14.917	0.010	0.574	0.012	0.226	0.010	5150	2.20	−2.34	2000AJ....120.1351S
61	NGC 6341 12018	17 17 22.38	+43 06 56.34	68.320	34.811	0.019	14.432	0.008	0.672	0.013	0.428	0.011	1	14.849	0.009	0.564	0.011	0.220	0.008	5160	2.30	−2.34	2000AJ....120.1351S
62	HD 170737	18 29 54.11	+26 39 26.24	55.019	16.213	0.043	8.117	0.011	0.804	0.011	0.462	0.011	1	8.472	0.001	0.597	0.001	0.240	0.001	5100	3.30	−0.68	2012A&A...541A.157S
63	BD+05 3839	18 37 34.21	+05 28 33.46	36.243	5.572	0.229	9.397	0.002	1.190	0.003	0.606	0.003	1	9.904	0.002	0.906	0.003	0.371	0.003	5100	2.83	−0.01	1994ApJS...91..309L
64	BD+05 3858	18 38 20.75	+05 26 02.31	36.293	5.380	0.207	9.358	0.002	1.066	0.003	0.534	0.003	1	9.804	0.002	0.788	0.003	0.329	0.003	5200	3.00	−0.03	1994ApJS...91..309L
65	HD 175305	18 47 06.44	+74 43 31.45	105.834	26.379	0.048	7.252	0.001	0.772	0.001	0.473	0.002	1	7.543	0.001	0.569	0.001	0.196	0.001	5036	2.76	−1.35	2012ApJ...753...64I
66	NGC 6705 1423	18 50 55.82	−06 18 14.80	27.259	−2.758	0.318	11.454	0.003	1.634	0.006	0.853	0.004	1	12.178	0.003	1.316	0.004	0.513	0.002	4750	2.90	0.04	2006AJ....131.2949S
67	NGC 6705 1256	18 51 00.24	−06 16 59.50	27.286	−2.764	0.372	11.626	0.004	1.699	0.009	0.909	0.004	1	12.387	0.004	1.403	0.004	0.572	0.003	4600	2.50	0.28	2006AJ....131.2949S
68	NGC 6705 1223	18 51 00.93	−06 14 56.40	27.318	−2.751	0.356	11.480	0.003	1.230	0.005	0.693	0.004	1	12.030	0.003	1.006	0.004	0.423	0.003	4750	2.50	−0.06	2006AJ....131.2949S
69	BD+05 4314	19 51 49.60	+05 36 45.84	44.989	−10.725	0.119	10.757	0.002	0.779	0.003	0.459	0.003	1	11.079	0.002	0.575	0.003	0.218	0.003	5000	3.00	−1.51	2003PASP..115...22Y
70	NGC 6838 1056	19 53 48.40	+18 48 23.50	56.773	−4.557	0.257	13.251	0.005	1.339	0.010	0.741	0.006	1	13.931	0.004	1.124	0.004	0.485	0.003	4582	2.10	−0.77	1986A&A...169..208G
71	BD-14 5890	20 56 09.13	−13 31 17.66	34.408	−33.683	0.030	10.192	0.002	0.803	0.003	0.478	0.002	1	10.517	0.001	0.653	0.002	0.230	0.003	4891	2.03	−2.16	2012ApJ...753...64I
72	BD-03 5215	21 28 01.31	−03 07 40.93	50.075	−35.866	0.048	10.123	0.005	0.613	0.005	0.368	0.006	1	10.384	0.004	0.427	0.005	0.176	0.005	5478	2.17	−1.49	2012ApJ...753...64I
73	BPS CS 22944-032	21 47 43.10	−13 40 22.00	40.906	−45.175	0.038	13.161	0.003	0.597	0.004	0.390	0.004	1	13.433	0.002	0.482	0.003	0.196	0.003	5300	2.87	−2.98	2008ApJ...681.1524L
74	HD 210295	22 09 41.44	−13 36 19.47	44.406	−49.964	0.035	9.455	0.002	0.847	0.002	0.469	0.002	1	9.937	0.001	0.719	0.001	0.254	0.002	4763	2.19	−1.25	2012ApJ...753...64I
75	HD 219715	23 18 01.19	+09 04 28.11	87.675	−47.301	0.050	9.197	0.002	0.779	0.003	0.456	0.003	1	9.733	0.004	0.566	0.005	0.213	0.004	5000	2.50	−1.10	2000A&A...353..978M
76	NGC 7789 329	23 56 55.46	+56 45 09.10	115.477	−5.328	0.313	12.307	0.003	1.433	0.007	0.774	0.004	1	12.999	0.005	1.208	0.005	0.489	0.003	4345	2.20	0.10	1985PASP...97..801P
77	NGC 7789 353	23 56 57.52	+56 45 27.30	115.483	−5.324	0.326	12.612	0.004	1.432	0.009	0.784	0.004	1	13.303	0.006	1.206	0.007	0.487	0.004	4345	2.20	0.15	1985PASP...97..801P
78	NGC 7789 637	23 57 22.43	+56 41 46.00	115.526	−5.396	0.313	12.419	0.003	1.457	0.008	0.784	0.004	1	13.118	0.006	1.222	0.007	0.513	0.004	4383	2.10	0.00	1985PASP...97..801P
79	NGC 7789 737	23 57 29.97	+56 43 19.90	115.548	−5.374	0.327	13.383	0.007	1.179	0.016	0.645	0.008	1	13.996	0.013	0.999	0.014	0.396	0.008	4990	2.80	−0.10	1985PASP...97..801P
80	NGC 7789 765	23 57 31.87	+56 41 22.12	115.546	−5.407	0.275	11.634	0.002	1.499	0.004	0.800	0.002	1	12.325	0.003	1.223	0.003	0.515	0.001	4383	2.10	−0.20	1985PASP...97..801P

(1) This study, (2) Pickles & Depagne (2010)

Table 4. The colour excesses of the stars observed in various stellar clusters. Cluster names, star IDs, equatorial coordinates and evaluated colour excesses ($E_d(B-V)$) of stars are given in columns 1–5. The last two columns include colour excesses ($E_{cl}(B-V)$) of the clusters and their reference.

Cluster	Star	α (J2000) (hh:mm:ss.ss)	δ (J2000) (dd:mm:ss.ss)	$E_d(B-V)$ (mag)	$E_{cl}(B-V)$ (mag)	Reference
NGC 2112	204	05 53 47.54	+00 22 02.00	0.793	0.600	Dias et al. (2002)
	402	05 53 53.30	+00 24 37.90	0.839	0.600	Dias et al. (2002)
NGC 2420	115	07 38 21.67	+21 33 51.40	0.036	0.040	Dias et al. (2002)
	173	07 38 26.96	+21 33 31.30	0.036	0.040	Dias et al. (2002)
NGC 2682	84	08 51 12.70	+11 52 42.40	0.030	0.040	Dias et al. (2002)
	105	08 51 17.10	+11 48 16.10	0.030	0.040	Dias et al. (2002)
	141	08 51 22.80	+11 48 01.70	0.030	0.040	Dias et al. (2002)
	151	08 51 26.19	+11 53 52.00	0.031	0.040	Dias et al. (2002)
	164	08 51 28.99	+11 50 33.10	0.031	0.040	Dias et al. (2002)
	224	08 51 43.55	+11 44 26.40	0.025	0.040	Dias et al. (2002)
	231	08 51 45.08	+11 47 45.90	0.027	0.040	Dias et al. (2002)
	266	08 51 59.52	+11 55 04.90	0.032	0.040	Dias et al. (2002)
NGC 6341	9012	17 16 52.84	+43 03 29.50	0.020	0.020	Harris (1996)
	10065	17 17 11.41	+43 06 02.70	0.019	0.020	Harris (1996)
	11027	17 17 21.61	+43 06 15.90	0.019	0.020	Harris (1996)
	12018	17 17 22.38	+43 06 56.34	0.019	0.020	Harris (1996)
NGC 6705	1423	18 50 55.82	−06 18 14.80	0.318	0.428	Dias et al. (2002)
	1256	18 51 00.24	−06 16 59.50	0.372	0.428	Dias et al. (2002)
	1223	18 51 00.93	−06 14 56.40	0.356	0.428	Dias et al. (2002)
NGC 6838	1056	19 53 48.40	+18 48 23.50	0.257	0.250	Harris (1996)
NGC 7789	329	23 56 55.46	+56 45 09.10	0.313	0.280	Dias et al. (2002)
	353	23 56 57.52	+56 45 27.30	0.326	0.280	Dias et al. (2002)
	637	23 57 22.43	+56 41 46.00	0.313	0.280	Dias et al. (2002)
	737	23 57 29.97	+56 43 19.90	0.327	0.280	Dias et al. (2002)
	765	23 57 31.87	+56 41 22.12	0.275	0.280	Dias et al. (2002)

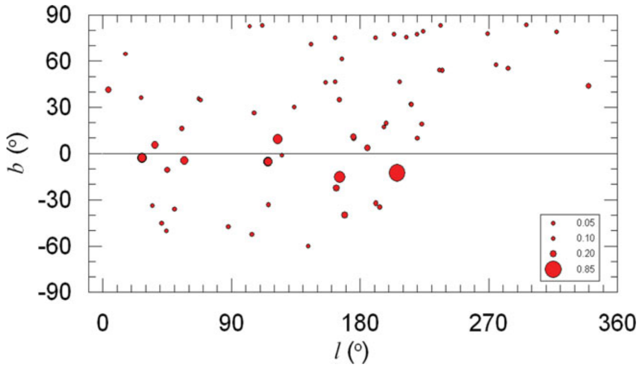

Figure 2. Galactic coordinates of the programme stars observed in TUG. The radius of the circles are proportional to the $E(B-V)$ colour excess of the star.

Table 5. Mean values of the errors for magnitude and colours in the BVR_c and $g'r'i'$ systems.

Magnitude/ Colour	Mean Error (mag)	Magnitude/ Colour	Mean Error (mag)
V	0.003	g'	0.003
$B-V$	0.005	$g'-r'$	0.003
$V-R_c$	0.004	$r'-i'$	0.003

The magnitudes and colours are de-reddened by using the corresponding $E(B-V)$ colour excess of the star and the equations in the literature, i.e. we adopted $A_V/E(B-V) = 3.1$, $E(V-R_c)/E(B-V) = 0.65$ (Cardelli, Clayton, & Mathis 1989) and $A_{g'}/A_V = 1.199$, $A_{r'}/A_V = 0.858$, $A_{i'}/A_V = 0.639$ (Fan 1999). The two colour-diagrams for the sample stars are plotted with symbols in Figures 3 and 4 for Johnson-Cousins and SDSS systems, respectively. The solid curves in Figures 3 and 4 are adopted from the synthetic data in Pickles (1998) and in Covey et al. (2007), respectively. The mean errors of the observed magnitude and colours of both systems are given in Table 5 and plotted in Figure 5.

3 TRANSFORMATIONS

The following general equations have been preferred to derive the 18 sets of transformation equations with their coefficients between BVR_c and $g'r'i'$ photometric systems using de-reddened magnitudes and colours of the sample giants in this study. Equations (9)–(17) transform BVR_c into $g'r'i'$ magnitudes and colours, while Equations (18)–(26) are their inverse transformations. The equations are:

$$(g'-V)_0 = a_i(B-V)_0^2 + b_i(B-V)_0 + c_i \tag{9}$$

$$(g'-V)_0 = a_i(V-R_c)_0^2 + b_i(V-R_c)_0 + c_i \tag{10}$$

$$(g'-V)_0 = a_i(B-V)_0 + b_i(V-R_c)_0 + c_i \tag{11}$$

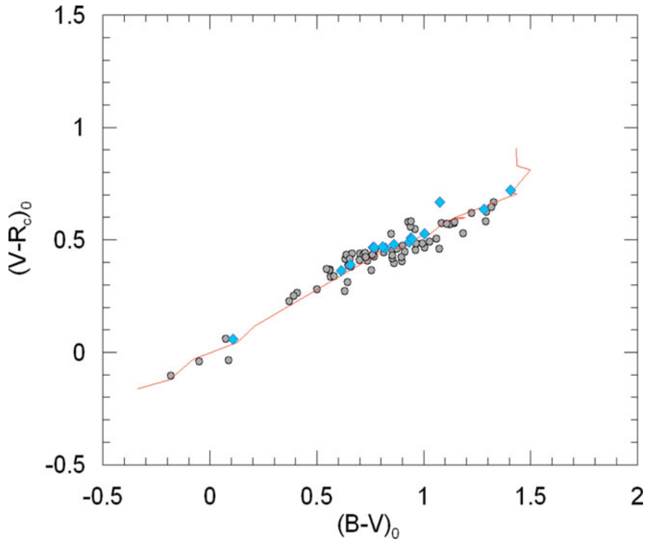

Figure 3. $(B-V)_0 \times (V-R_c)_0$ two-colour diagram of the sample stars. The positions of 15 stars with synthetic $(B-V)_0$ and $(V-R_c)_0$ colours are marked with a different symbol (◇). The solid line indicates the synthetic two-colour diagram of Pickles (1998).

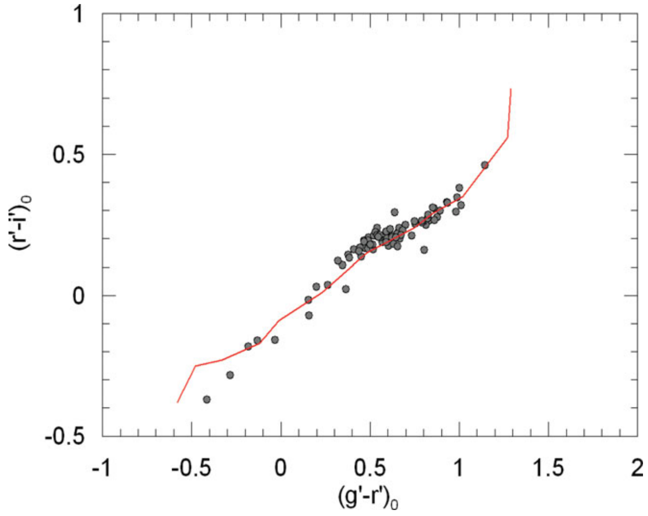

Figure 4. $(g'-r')_0 \times (r'-i')_0$ two-colour diagram of the sample stars. The solid line indicates the synthetic two-colour diagram of Covey et al. (2007).

$$(g'-r')_0 = a_i(B-V)_0^2 + b_i(B-V)_0 + c_i \tag{12}$$

$$(g'-r')_0 = a_i(V-R_c)_0^2 + b_i(V-R_c)_0 + c_i \tag{13}$$

$$(g'-r')_0 = a_i(B-V)_0 + b_i(V-R_c)_0 + c_i \tag{14}$$

$$(r'-i')_0 = a_i(B-V)_0^2 + b_i(B-V)_0 + c_i \tag{15}$$

$$(r'-i')_0 = a_i(V-R_c)_0^2 + b_i(V-R_c)_0 + c_i \tag{16}$$

$$(r'-i')_0 = a_i(B-V)_0 + b_i(V-R_c)_0 + c_i \tag{17}$$

$$(V-g')_0 = d_i(g'-r')_0^2 + e_i(g'-r')_0 + f_i \tag{18}$$

$$(V-g')_0 = d_i(r'-i')_0^2 + e_i(r'-i')_0 + f_i \tag{19}$$

$$(V-g')_0 = d_i(g'-r')_0 + e_i(r'-i')_0 + f_i \tag{20}$$

$$(B-V)_0 = d_i(g'-r')_0^2 + e_i(g'-r')_0 + f_i \tag{21}$$

$$(B-V)_0 = d_i(r'-i')_0^2 + e_i(r'-i')_0 + f_i \tag{22}$$

$$(B-V)_0 = d_i(g'-r')_0 + e_i(r'-i')_0 + f_i \tag{23}$$

$$(V-R_c)_0 = d_i(g'-r')_0^2 + e_i(g'-r')_0 + f_i \tag{24}$$

$$(V-R_c)_0 = d_i(r'-i')_0^2 + e_i(r'-i')_0 + f_i \tag{25}$$

$$(V-R_c)_0 = d_i(g'-r')_0 + e_i(r'-i')_0 + f_i. \tag{26}$$

The values of the coefficients and their errors are given in Tables 6 and 7. The distribution of the sample stars on the colour planes are plotted in Figure 6. The ranges of the magnitudes and colours in the transformations are: $7.10 < V_0 < 14.50, 7.30 < g_0 < 14.85, -0.20 < (B-V)_0 < 1.41, -0.11 < (V-R_c)_0 < 0.73, -0.42 < (g-r)_0 < 1.15$, and $-0.37 < (r-i)_0 < 0.47$ mag. The residuals of the colours from the curve fits are plotted in Figures 7 and 8, while the means and standard deviations of the residuals are included to the data in Tables 6 and 7.

The transformation equations from BVR_c to $g'r'i'$ colours derived in this study have been applied to another sample of 427 giants taken from Pickles & Depagne (2010) as explained in the following. Smith et al. (2005) have published a list of ~16000 southern SDSS standards, which includes some repetition. 6117 of them were turned out to be of luminosity class III, i.e. giants, which cover the spectral range A-M. We have selected a sample of 427 giants with uncertainties in g', r' and i' less than 0.01 mag. The $E(B-V)$ colour excesses used for de-reddening the g' magnitudes, and $g'-r'$ and $r'-i'$ colours have been evaluated in two steps, by a procedure similar to the one used for the original sample from which the Equations (7) and (8) derived as in Section 2.2. The g' magnitudes, and $g'-r'$ and $r'-i'$ colours are de-reddened according to the corresponding $E(B-V)$ colour excesses of the stars and the equations of Fan (1999). The $(g'-r')_0 \times (r'-i')_0$ two-colour diagram of the sample of 427 stars obtained from Pickles & Depagne (2010) are given in Figure 9.

To estimate intrinsic BVR_c colours of the sample of those 427 giants, we have identified them first in Pickles & Depagne (2010), and then recorded their V magnitudes and, $B-V$ and $V-R_c$ colours. Then, those V magnitudes and, $B-V$ and $V-R_c$ colours are de-reddened by the procedure explained in the Section 2.2, and transformed them to g'_0 magnitudes and, $(g'-r')_0$ and $(r'-i')_0$ colours by using the transformation equations derived from the original sample of 80 giants in this study. Then, we have compared those g'_0 magnitude and, $(g'-r')_0$ and $(r'-i')_0$ colours obtained through transformation equations to the g'_0 magnitude and, $(g'-r')_0$ and $(r'-i')_0$ colours evaluated from Pickles & Depagne (2010). The residuals, i.e. the differences between the original and evaluated colours, are plotted in Figure 10. The mean and standard deviations of the residuals for each

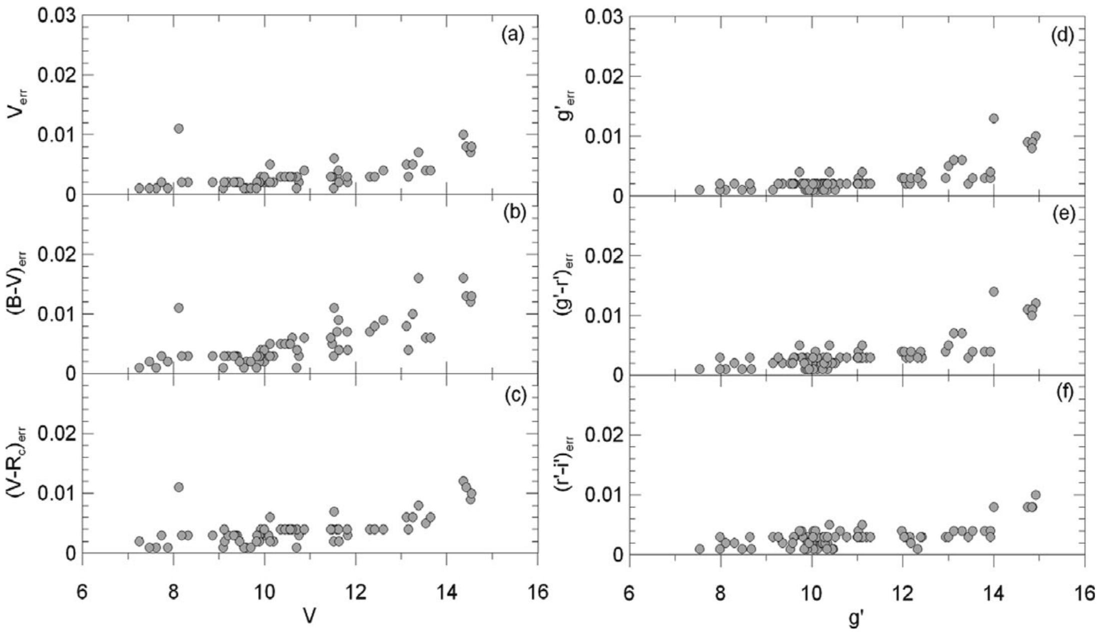

Figure 5. Distributions of the errors of the magnitudes and colours of the sample stars.

Table 6. Coefficients for the Equations (9)–(17). The figures in the first line indicate the equation number, R is the correlation coefficient and, s and $m.r.$ are the standard deviation, and mean residuals, respectively.

	(9)	(10)	(11)	(12)	(13)
Coefficient	$(g'-V)_0$	$(g'-V)_0$	$(g'-V)_0$	$(g'-r')_0$	$(g'-r')_0$
a_i	−0.122±0.051	−0.155±0.227	0.404±0.083	−0.045±0.031	0.381±0.120
b_i	0.651±0.074	1.044±0.160	0.168±0.166	1.006±0.055	1.528±0.055
c_i	−0.069±0.028	−0.056±0.032	−0.035±0.024	−0.197±0.024	−0.170±0.009
R	0.912	0.876	0.907	0.986	0.992
s	0.068	0.080	0.070	0.059	0.059
$m.r.$	0.000	0.000	0.000	−0.006	−0.002

	(14)	(15)	(16)	(17)
Coefficient	$(g'-r')_0$	$(r'-i')_0$	$(r'-i')_0$	$(r'-i')_0$
a_i	0.464±0.063	−0.243±0.035	−0.420±0.064	−0.026±0.049
b_i	0.931±0.128	0.730±0.051	1.111±0.030	0.897±0.099
c_i	−0.205±0.018	−0.224±0.019	−0.209±0.005	−0.185±0.014
R	0.982	0.940	0.993	0.953
s	0.054	0.047	0.031	0.042
$m.r.$	0.000	0.000	−0.001	0.000

colour are also indicated in the corresponding panel of the figure.

4 SUMMARY AND DISCUSSION

The transformation equations from BVR_c to $g'r'i'$ colours and vice versa for giants were derived and presented. The transformation equations were obtained using the observed magnitudes and colours of a sample of 80 giants selected from the Pastel catalogue (Soubiran et al. 2010) with confirmed surface gravity ($2 \leq \log g$ (cms^{-2}) ≤ 3) at effective temperatures from 4000 to 16000 K. The $g'r'i'$ magnitudes of all sample and 65 of them at BVR_c magnitudes were obtained by observations carried out with the T100 telescope at TUG at Bakırlıtepe, Antalya, in the years 2011–2012. The BVR_c magnitudes of 15 giants were completed from the synthetic BVR_c magnitudes in Pickles & Depagne (2010). We have used the M_V absolute magnitudes and T_{eff} temperatures for giants at various spectral types presented in Sung et al. (2013) to produce Figure 1, which were used to estimated the M_V absolute magnitudes of the sample stars used in this study. We have de-reddened the magnitude and colours in

Table 7. Coefficients for the Equations (18)–(26). The symbols are as in Table 6.

	(18)	(19)	(20)	(21)	(22)
Coefficient	$(V-g')_0$	$(V-g')_0$	$(V-g')_0$	$(B-V)_0$	$(B-V)_0$
d_i	0.041±0.016	−0.104±0.165	−0.460±0.059	0.022±0.018	0.466±0.117
e_i	−0.615±0.013	−1.096±0.029	−0.243±0.111	1.028±0.014	1.947±0.028
f_i	−0.030±0.007	−0.156±0.014	−0.052±0.015	0.205±0.007	0.418±0.015
R	0.989	0.977	0.989	0.996	0.987
s	0.049	0.067	0.050	0.055	0.098
$m.r.$	0.001	−0.001	−0.005	0.002	0.005

	(23)	(24)	(25)	(26)
Coefficient	$(B-V)_0$	$(V-R_c)_0$	$(V-R_c)_0$	$(V-R_c)_0$
d_i	1.321±0.092	−0.002±0.016	0.102±0.097	0.335±0.037
e_i	−0.616±0.193	0.552±0.009	1.085±0.017	0.449±0.068
f_i	0.162±0.023	0.112±0.004	0.229±0.009	0.158±0.009
R	0.974	0.992	0.991	0.995
s	0.071	0.033	0.039	0.030
$m.r.$	0.000	0.007	0.001	0.002

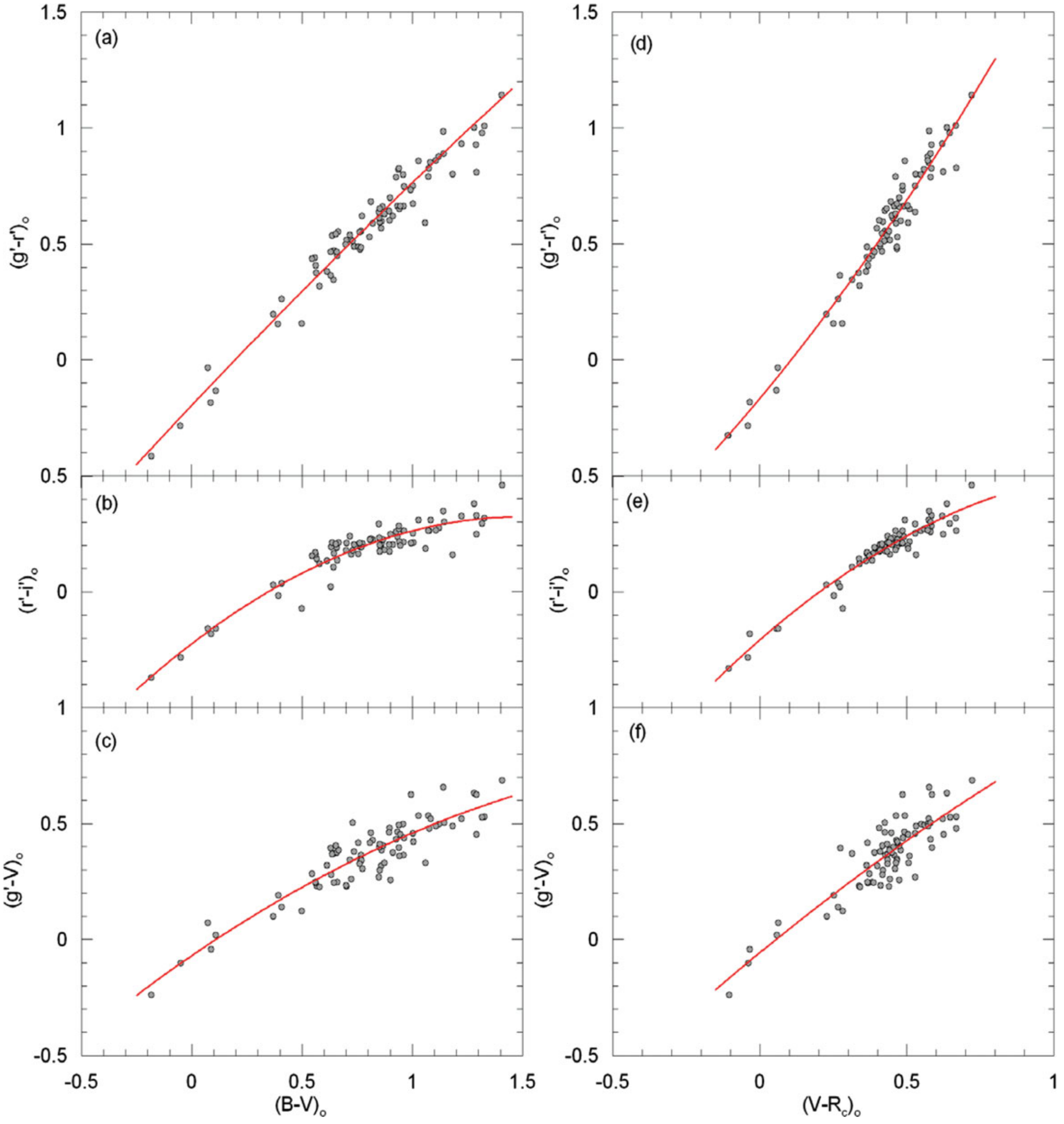

Figure 6. Distributions of the sample stars in six colour planes. The curves indicate quadratic polynomials.

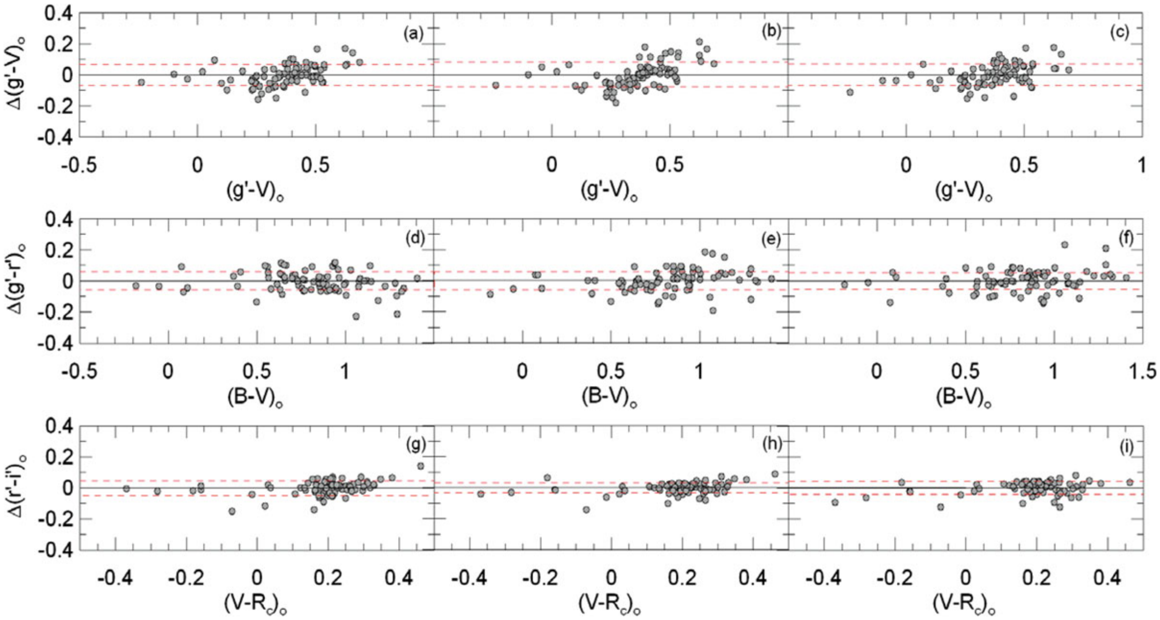

Figure 7. Distributions of the residuals of the sample stars for transformation Equations (9)–(17).

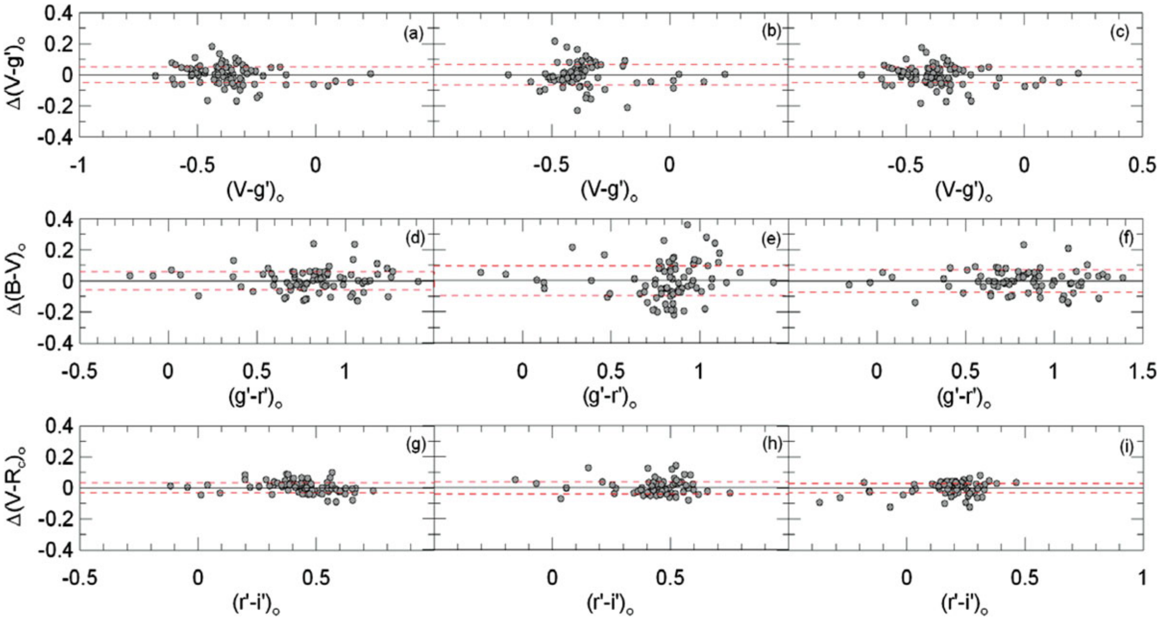

Figure 8. Distributions of the residuals of the sample stars for inverse transformation Equations (18)–(26).

both photometric systems, BVR_c and $g'r'i'$ of the sample by a procedure commonly used in the literature.

The transformation equations from BVR_c to $g'r'i'$ (Equations (9)–(17)) and inverse transformations (Equations (18)–(26)) were derived by fitting quadratic polynomials to $(g'-V)_0$, $(g'-r')_0$ and $(r'-i')_0$ which are given in terms of $(B-V)_0$ only or $(V-R_c)_0$ only, or by fitting a linear function to them if they are expressed both $(B-V)_0$ and $(V-R_c)_0$. Similarly, $(V-g')_0$, $(B-V)_0$ and $(V-R_c)_0$ expressed by a quadratic function of $(g'-r')_0$ or $(r'-i')_0$, or they are expressed by a linear function fit both $(g'-r')_0$ and $(r'-i')_0$ colours used in the equation. The correlation coefficients and the standard deviations in Table 6 show that all the transformation Equations (9)–(17) provide sufficiently accurate magnitude and colours. However, the most accurate colours $(g'-V)_0$, $(g'-r')_0$ and $(r'-i')_0$ come from the quadratic equations containing only $(B-V)_0$, or $(V-R_c)_0$. The correlation coefficients given in Table 7 for inverse

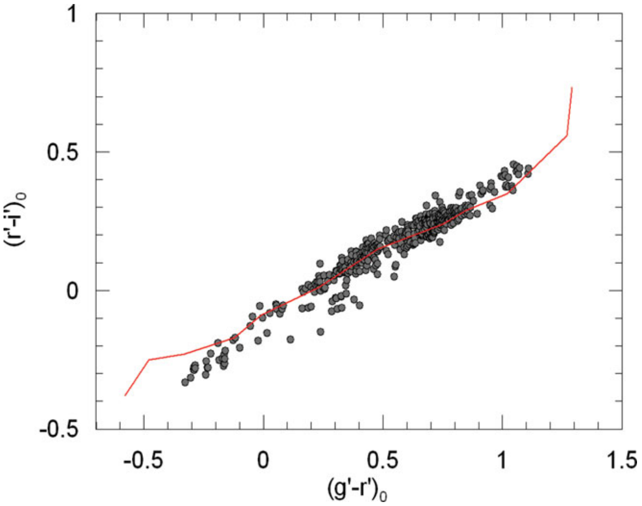

Figure 9. $(g'-r')_0 \times (r'-i')_0$ two-colour diagram of 427 stars used for the application of the transformation equations. The solid line indicates the synthetic two-colour diagram of Covey et al. (2007).

transformations are a bit larger, while the standard deviations are smaller. The most accurate colours $(V-g')_0$, $(B-V)_0$, and $(V-R_c)_0$ come from the quadratic equations containing only $(g'-r')_0$, or $(r'-i')_0$ and from the linear equation if both $(g'-r')_0$ and $(r'-i')_0$ appear in the equation.

The transformation equations could be considered valid for the ranges of the magnitudes and colours used in the transformations: $7.10 < V_0 < 14.50$, $7.30 < g'_0 < 14.85$, $-0.20 < (B-V)_0 < 1.41$, $-0.11 < (V-R_c)_0 < 0.73$, $-0.42 < (g'-r')_0 < 1.15$, and $-0.37 < (r'-i')_0 < 0.47$ mag, rather larger than the ones provided by Yaz et al. (2010), i.e. $0.25 < (B-V)_0 < 1.35$, $0.10 < (g-r)_0 < 0.95$, and $0 < (r-i)_0 < 0.35$.

We applied the transformation equations derived in this study to the synthetic BVR_c data of 427 giants taken from Pickles & Depagne (2010). The ranges of the mean residuals (*m.r.*) and standard deviations (s) are $-0.010 \leq m.r. \leq 0.042$ and $0.028 \leq s \leq 0.068$ mag, respectively. That is, the g' magnitude and, $(g'-r')_0$ and $(r'-i')_0$ colours of a giant can be estimated by our transformations with an accuracy of at least ~0.05 mag. Yaz et al. (2010) derived transformations between 2MASS, SDSS and BVI photometric systems for late type giants for two cases, i.e. metallicity dependent and free of metallicity. We have compared their residuals and the standard deviations free of metallicity. Their mean residuals are rather small, i.e. $-0.0005 \leq m.r. \leq 0.0004$ mag. However, the corresponding standard deviations are larger than the ones in our study, $0.075 \leq s \leq 0.167$ mag. That is, our study provides magnitudes and colours with an accuracy of ~1.5 times that of Yaz et al. (2010).

Sufficiently small residuals and the standard deviations confirm the quality of the observations made in TUG, and accuracy and the precision of the reductions applied to these observations. The metallicities of the sample stars used for deriving the coefficents of the transformation equations between the two photometric systems cover a large range, $-4 \leq [Fe/H] \leq 0.5$ dex. However, the number of stars with $[Fe/H] < -1$ dex are small. Hence, we did not consider the metallicity in our transformations. Though, we obtained transformation equations which provide accurate colour and magnitudes.

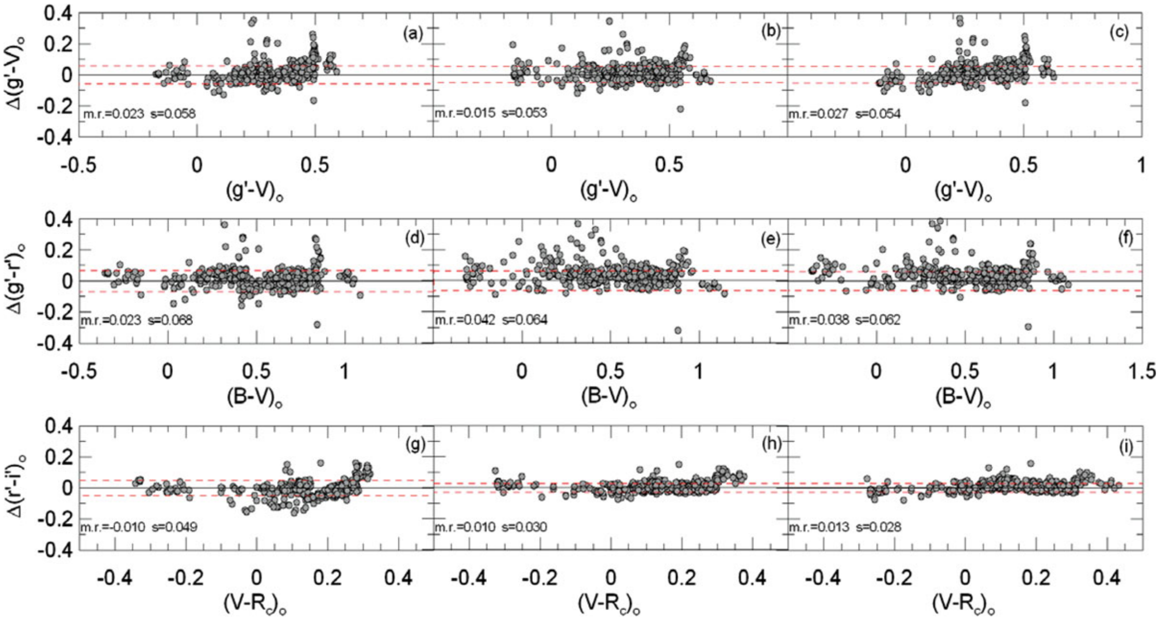

Figure 10. Distributions of the residuals of 427 stars used for the application of the transformation equations. Mean residuals (*m.r.*) and standard deviations (s) are also indicated in each panel.

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