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Further observations of *Hipparcos* red stars and standards for $UBV(RI)_C$ photometry

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ABSTRACT

We present homogeneous and standardized $UBV(RI)_C$ *JHK* photometry for over 100 M stars selected from an earlier paper on the basis of apparent photometric constancy. *L* photometry has been obtained for stars brighter than about $L = 6$. Most of the stars have a substantial number of $UBV(RI)_C$ observations and, it is hoped, will prove useful as red supplementary standards. Additionally, we list *JHK* photometry for nearly 300 *Hipparcos* red stars not selected as standards, as well as *L* photometry for the brightest stars.

Key words: stars: late-type.

1 INTRODUCTION

In a previous paper, Koen et al. (2002; hereafter Paper I) lamented the lack of red standards for $UBV(RI)_C$ photometry and presented observations of nearly 550 red stars extracted from the *Hipparcos* data base using the following criteria: no *Hipparcos* variability flag; colour $(V - I) > 1.7$; declination further south than $\delta = +10°$; and brightness fainter than $V = 7.6$ mag. A problem in establishing red standards is that many (if not all) M stars are variable at some level – use of the extensive *Hipparcos* data base at least helps to eliminate the overtly variable objects. Selecting $(V - I) > 1.7$ essentially ensures that we are observing M-type stars and the other criteria select the reddest stars easily accessible at the South African Astronomical Observatory (SAAO) with a small telescope without saturating the detector.

The Paper I photometry was standardized using the supplementary red stars measured by Kilkenny et al. (1998) and was shown to be in good agreement with the results of Bessell (1990), for example. The programme was carried out partly because it was felt that the homogeneous, standardized photometry would be useful for the redder stars and partly so that selected stars could be further observed to provide additional red secondary standards. For the latter purpose, we chose about a hundred of the Paper I *Hipparcos* stars which seemed to have constant brightness and re-observed them over about three years. We also obtained *JHK* (and for the brightest stars, *L*) photometry for 389 of the original (Paper I) stars. The results are presented below.

(Note that, as in Paper I, we refer to $(V - R)$ and $(V - I)$ colours without a 'C' subscript; in all cases it should be understood that we refer to the $UBV(RI)_C$ system, that is to say the *RI* photometry is on the Kron–Cousins system.)

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2 *UBVRI* PHOTOMETRY

All *UBVRI* observations were made using the 0.5-m telescope and photomultiplier-based modular photometer (Kilkenny et al. 1988) at the Sutherland site of the SAAO between 2002 January and 2004 September. The usual SAAO reduction procedures were followed; these are briefly described in the appendix to Kilkenny et al. (1998) in the context of the determination of colour equations, and extensive comments on the reduction and standardization of red star photometry were made in Paper I and will not be repeated here. Suffice it to say that careful determinations of the colour equations for the system were made three times during the observation period and no significant differences were found, so the same colour equations were used for all observations. We believe that we have assembled a homogeneous set of photometric measurements.

Along with the *Hipparcos* stars, we observed a sample of the Gliese & Jahreiss (1979) stars proposed as supplementary red standards by Kilkenny et al. (1998). In fact, some of these observations were used to establish the colour equations, but mainly the Gliese–Jahreiss (GJ) stars were observed routinely mixed amongst the general programme stars. Fig. 1 shows a comparison between the GJ star photometry from this work and the 'standard' photometry in table 3 of Kilkenny et al. (1998). Even though we have taken care with colour equations, there appear to be significant systematic deviations from exact agreement between the current (uncorrected) results and what we regard as standard. There seem to be linear systematics in Fig. 1 – at least in $(B - V)$ and $(U - B)$. Because some of the reddest GJ stars in Table 1 have only a small number of observations, we have also compared our current photometry for the *Hipparcos* stars to the table 2 results in Paper I – which were considered to be very close to the standard system. The comparison is shown in Fig. 2. From the much larger number of stars, we derive linear corrections (to our current results) in $(U - B)$ and $(V - R)$ and non-linear (piecewise linear) corrections for $(B - V)$ and $(V - I)$. These corrections are in essential agreement with the

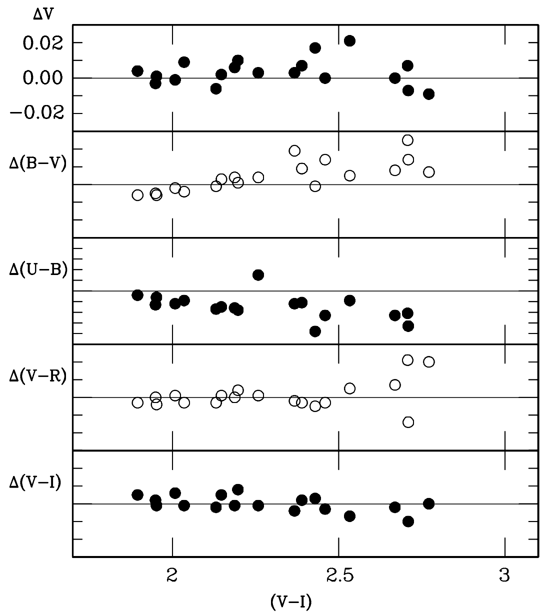

Figure 1. A comparison of photometry of GJ stars from Kilkenny et al. (1998) with data from this paper. The differences, Δ, are in the sense (table 3 of Kilkenny et al. 1998) *minus* (this paper). Ordinate carets are separated by 0.01 mag (note that the scale for Δ $(U - B)$ is different from the other ordinates).

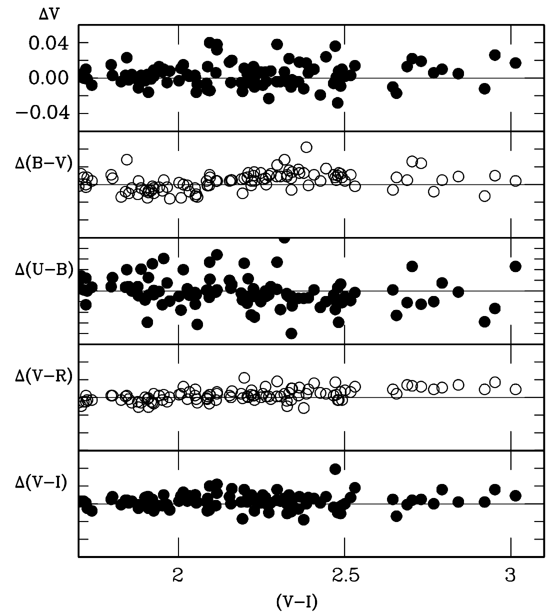

Figure 2. A comparison of photometry of *Hipparcos* stars from Paper I with data from this paper. The differences, Δ, are in the sense (table 2 of Paper I) *minus* (this paper). Ordinate carets are separated by 0.02 mag (note that the ordinate scale for Δ $(U - B)$ is different from the other panels). Three stars with large residuals in $(U - B)$ are not included in the central panel.

differences in Fig. 1 but are better defined because of the greater numbers of well-observed stars. Any corrections applied are not more than 0.011, 0.030, 0.012 and 0.006 mag in $(B - V)$, $(U - B)$, $(V - R)$ and $(V - I)$, respectively. Similar plots to Fig. 2 were made with the data separated into dwarf and giant groups but no significant differences between the two groups were detected, so the corrections were applied irrespective of luminosity class.

After application of the correcting terms, we believe that the current data are very close to the system of Paper I and thus 'standard' values. The corrected results are listed in Table 1 for the GJ stars (means and standard deviations); the standard deviations of a single observation are 0.010, 0.007, 0.015, 0.005 and 0.008 in V, $(B - V)$, $(U - B)$, $(V - R)$ and $(V - I)$, respectively, determined from 292 observations of the 16 stars with more than one observation.

The corrected results for the *Hipparcos* red stars are given in Table 2, which includes mean photometry and standard deviations for each star, number of observations (n) in the mean and spectral types taken from table 2 of Paper I. Where a luminosity class is given in parenthesis that class is *not* derived spectroscopically, but is determined from the $(U - B)/(B - V)$ colours. (Good separation for classes III and V is achieved – see, e.g. fig. 8 of Paper I – though

Table 1. Mean corrected *UBVRI* photometry and standard deviations for GJ stars.

GJ	V	$(B - V)$	$(U - B)$	$(V - R)$	$(V - I)$	n	σ_V	σ_{BV}	σ_{UB}	σ_{VR}	σ_{VI}
1	8.566	1.468	1.064	0.975	2.136	44	11	5	8	3	5
54	9.818	1.544	1.150	1.088	2.457	19	5	4	15	5	6
114.1	10.688	1.464	1.007	0.973	2.158	1					
191	8.844	1.570	1.200	0.954	1.951	35	9	7	11	3	7
229	8.131	1.486	1.207	0.959	2.011	29	9	6	9	4	6
240	9.592	1.444	1.219	0.925	1.897	4	9	4	4	1	5
273	9.856	1.566	1.133	1.179	2.710	2	9	6	14	16	19
341	9.464	1.491	1.213	0.947	1.954	14	5	3	10	4	6
352	10.067	1.537	1.153	1.062	2.389	3	0	7	2	4	1
433	9.806	1.513	1.195	0.997	2.152	22	11	6	15	3	6
479	10.654	1.549	1.198	1.081	2.428	2	17	4	11	2	3
588	9.318	1.512	1.138	1.053	2.367	33	8	6	8	4	7
628	10.087	1.578	1.164	1.159	2.669	3	17	1	22	3	8
680	10.132	1.552	1.189	1.029	2.262	2	5	0	2	0	6
693	10.746	1.642	1.232	1.121	2.532	1					
729	10.493	1.733	1.293	1.212	2.773	1					
832	8.671	1.506	1.191	1.004	2.193	31	8	5	10	4	5
867A	9.083	1.513	1.087	1.011	2.203	18	17	11	38	8	20
876	10.191	1.558	1.153	1.172	2.708	1					
908	8.971	1.468	1.093	0.954	2.039	31	11	6	13	4	10

Table 2. Mean corrected *UBVRI* photometry, standard deviations and spectral types for *Hipparcos* red stars. 'Var' and 'Var?' indicate definite and possible variable stars, respectively. 'Var*' flags stars which appear constant here but show discrepancies between any or all of: this paper, Laing (1989) and Bessell (1990), and 'C' indicates stars which show very good agreement between all three sources.

HIP	V	$(B-V)$	$(U-B)$	$(V-R)$	$(V-I)$	n	σ_V	σ_{BV}	σ_{UB}	σ_{VR}	σ_{VI}	Note	Type
112	10.748	1.413	1.310	0.879	1.721	16	5	9	23	4	6		M1.5 V:
1242	11.483	1.704	1.303	1.210	2.772	14	10	12	31	4	8		M: (V)
1276	11.546	1.509	1.162	1.040	2.311	15	10	16	41	4	6		M5 (V)
1734	11.130	1.505	1.185	1.009	2.211	11	4	6	20	3	4		M2 V:
1842	11.887	1.518	1.175	1.045	2.327	12	8	10	34	6	7		M: (V)
2022	9.200	1.575	1.905	0.947	2.055	10	6	4	29	4	5		M1 (III)
3813	10.734	1.458	1.235	0.930	1.878	10	5	5	10	4	6		M2 (V)
5812	11.077	1.514	1.200	0.983	2.092	15	9	7	28	7	10		M4 (V)
6008	10.786	1.474	1.248	0.942	1.930	13	8	9	31	9	6		M1 (V)
6097	11.796	1.467	1.108	1.008	2.230	10	8	8	20	5	12		M (V)
6365	11.403	1.490	1.210	0.977	2.093	12	14	9	36	7	8		M3 (V)
8051	10.915	1.535	1.190	1.036	2.301	10	15	13	44	5	9	C	M2 V:
8691	11.791	1.483	1.075	1.005	2.206	11	11	11	32	19	8	C	M4 (V)
9724	10.189	1.516	1.155	1.048	2.338	11	20	7	21	5	10	C	M3 (V)
10464	8.827	1.579	1.960	0.872	1.738	14	8	4	14	3	6		M0 III
11301	9.010	1.573	1.902	0.904	1.878	13	19	11	17	6	12		M0 (III)
11551	8.686	1.589	1.955	0.930	1.963	12	13	9	22	5	8		M1/2 III
12810	9.457	1.577	1.889	0.961	2.112	9	24	7	47	4	10		M1 III:
14139	9.231	1.515	1.856	0.866	1.807	13	8	9	21	8	9		M0/1 III:
15782	8.455	1.697	2.011	0.981	2.040	14	10	7	22	5	7		M1 III
17339	8.840	1.616	1.924	0.964	2.060	15	16	6	42	6	10		M0 (III)
18418	10.236	1.593	1.937	0.914	1.908	10	17	6	38	6	8		M (III)
19019	8.606	1.532	1.715	0.851	1.724	10	8	4	8	3	5		M0 III
21556	10.331	1.507	1.203	1.004	2.194	7	7	3	16	2	5	C	M1 (V)
23418	11.490	1.524	0.935	1.171	2.732	6	27	16	34	7	11		M3 V:
26081	11.456	1.566	0.934	1.074	2.384	6	11	27	137	6	4	Var*	M2.5 Ve
27606	8.822	1.665	1.925	1.002	2.162	10	15	7	35	5	10		M1 III:
28226	8.492	1.642	2.024	0.938	1.952	10	12	5	22	4	6		M2 III
30016	8.535	1.670	1.976	1.006	2.170	9	14	7	29	4	11		M1 III
30920	11.071	1.693	1.178	1.301	3.021	6	12	5	35	5	10	Var*	M4.5 Ve
31814	9.053	1.630	1.996	0.919	1.887	8	9	8	40	5	11		M3 (III)
32060	8.641	1.666	2.033	0.958	2.013	9	12	5	30	4	7		M1 III
33327	8.189	1.622	1.912	1.011	2.237	9	12	8	22	3	7		M1/2 III+
34712	11.145	1.466	1.244	0.917	1.843	4	7	19	52	4	1		M: (V)
36639	8.796	1.645	2.035	0.934	1.913	8	7	3	21	3	4		M0 III
37217	11.712	1.582	1.222	1.096	2.483	4	5	10	31	4	4		M2 (V)
37433	9.139	2.154	2.076	1.340	2.840	6	14	4	27	9	20	Var	M3 Ia0-Ia
37433	8.779	2.229	2.201	1.277	2.655	3	19	17	42	5	18		
40239	9.374	1.411	1.214	0.874	1.716	9	5	4	15	3	4		M0 V
42881	10.608	1.406	0.921	0.984	2.186	4	3	8	21	2	11		M2 V:
44005	9.469	1.641	1.995	0.884	1.721	7	6	3	34	3	5		M0 (III)
47425	10.694	1.521	1.180	1.077	2.450	10	21	5	29	5	14	Var*	M: (V)
48190	10.278	1.472	1.234	0.939	1.944	10	7	6	14	2	6		M2 V:
49091	11.440	1.478	1.108	1.077	2.465	10	12	6	21	3	6		M4 (V)
49969	10.629	1.576	1.210	1.048	2.326	11	10	7	25	7	8		M0 (V)
50341	10.998	1.466	1.095	1.045	2.374	8	15	4	14	7	8	Var*	M0 (V)
51007	10.139	1.492	1.203	0.978	2.088	9	9	5	14	3	7		M0 (V)
52186	11.281	1.509	1.149	1.037	2.320	7	5	10	26	5	7		M (V)
53544	8.366	1.580	1.922	0.945	2.032	10	8	3	20	3	6		M2 III
54532	10.446	1.528	1.199	1.021	2.252	10	6	4	13	2	3		M: (V)
55042	11.516	1.332	0.818	1.019	2.384	7	11	8	28	4	6	Var*	M (V)
56244	11.535	1.547	1.047	1.151	2.655	10	19	14	54	5	9		M (V)
57056	8.281	1.567	1.902	0.900	1.861	10	8	4	6	5	3		M0/1 III
57548	11.095	1.736	1.339	1.282	2.957	7	11	7	19	6	7	Var*	M4.5 V
59204	8.625	1.633	1.920	1.008	2.216	13	25	4	24	6	16	Var?	M2 III
62452	11.395	1.563	1.130	1.160	2.688	7	16	9	32	5	9		M4 (V)
64339	8.704	1.584	1.861	1.001	2.233	13	23	5	24	6	15	Var?	M2 III
65408	8.699	1.562	1.832	0.958	2.094	15	9	4	17	2	5		M1/2 III
65714	11.223	1.527	1.141	1.105	2.534	10	13	10	27	4	11	Var*	M4+ (V)
66675	9.589	1.419	1.204	0.879	1.700	11	6	7	12	7	10		M0 V
67164	11.872	1.551	1.158	1.147	2.646	9	8	6	51	7	10		M: (V)

Table 2 – *continued*

HIP	V	$(B-V)$	$(U-B)$	$(V-R)$	$(V-I)$	n	σ_V	σ_{BV}	σ_{UB}	σ_{VR}	σ_{VI}	Note	Type
70815	9.242	1.594	1.749	1.104	2.519	13	19	6	17	6	14		M2/3 III
71253	11.317	1.598	1.126	1.224	2.844	10	6	9	26	6	9		M4 (V)
72346	9.365	1.632	2.035	0.911	1.829	10	11	4	18	3	7		M1 (III)
74995	10.567	1.602	1.234	1.106	2.500	13	7	15	33	3	7	C	M5 (V)
77498	9.419	1.684	1.935	1.059	2.338	14	18	7	15	13	10		M0 (III)
78353	10.487	1.512	1.198	0.990	2.122	12	19	4	14	6	11		M0 (V)
80018	10.586	1.559	1.169	1.091	2.470	12	11	14	27	2	6	C	M4 (V)
80229	11.783	1.464	1.050	0.979	2.130	5	9	23	48	11	24		M3 (V)
80559	10.592	1.438	1.229	0.903	1.799	11	10	9	20	5	7		M1 (V)
82181	10.100	1.741	2.037	1.047	2.226	9	13	6	23	7	15		M0 (III)
82684	9.751	2.015	2.344	1.198	2.477	5	7	4	58	3	11		M0 (III)
82809	11.748	1.672	1.248	1.179	2.704	4	8	12	40	5	15	Var*	M4 (V)
83405	10.817	1.479	1.196	0.940	1.925	10	8	9	41	5	7		M2 (V)
83557	8.285	1.666	1.952	1.033	2.260	11	11	8	14	3	9		M2 III
84141	9.053	2.150	2.039	1.184	2.341	13	8	12	31	4	5		M0 (III)
84854	9.619	1.942	2.248	1.132	2.365	9	35	8	48	6	12	Var?	M0 (III)
85658	8.988	1.913	2.029	1.274	2.797	7	15	6	30	3	13		M (III)
86933	9.119	1.652	1.975	0.959	2.005	10	27	6	33	6	14	Var?	M0/1 III
87855	8.823	1.691	1.974	1.043	2.269	11	13	8	34	3	8		M2 III:
88574	9.360	1.518	1.212	0.975	2.056	9	11	9	13	6	8	C	M2 V
88967	8.762	1.609	1.889	1.007	2.224	10	11	6	15	5	9		M1/2 III
91430	11.224	1.558	1.187	1.041	2.299	8	16	10	32	9	15		M1 V:
91644	11.194	1.413	1.303	0.878	1.709	7	10	5	23	6	6		M0 (V)
92783	9.031	1.847	1.859	1.138	2.427	10	15	8	15	4	10		M0/1 (III)
93139	8.740	1.784	2.132	0.989	2.021	10	15	8	28	6	7		M0 III:
93206	11.142	1.473	1.115	1.038	2.342	8	11	8	19	3	6		M4 (V)
95639	9.164	1.843	2.056	1.127	2.409	14	32	8	38	6	17	Var?	M1 III:
97161	8.993	1.760	2.072	1.058	2.271	15	23	8	22	4	14		M2 III
100356	10.227	1.464	1.213	0.917	1.842	13	10	5	17	3	3		M0 (V)
102141	10.343	1.566	0.844	1.245	2.924	13	19	12	61	5	13	Var*	M pe (V)
103800	11.219	1.511	1.153	1.052	2.359	12	14	9	21	5	12	C	M3 (III)
104644	11.998	1.603	1.208	1.040	2.266	12	15	12	52	6	11		M1: (V)
105474	8.516	1.691	2.052	0.984	2.057	15	17	9	17	7	10		M0/1 III
105932	11.085	1.544	1.196	0.962	1.973	12	17	11	35	4	12		M0 (V)
106836	8.521	1.614	1.921	0.989	2.160	16	15	5	22	3	9		M2 III
107711	11.510	1.623	1.250	1.100	2.481	13	12	13	42	6	7		M6 (V)
108593	8.148	1.602	1.897	0.965	2.087	15	19	4	26	4	12		M1/2 III
108657	8.518	1.590	1.956	0.918	1.920	12	14	6	29	4	9		M0 (III)
109388	10.366	1.502	1.138	1.087	2.489	14	9	7	34	7	6	C	M3 (V)
112996	9.286	1.571	1.916	0.924	1.967	16	14	6	26	4	7		M0 (III)
113520	8.192	1.537	1.676	1.075	2.474	13	24	5	19	5	10		M3 III
113602	11.554	1.535	1.215	0.993	2.114	16	13	12	21	6	8		M1 (V)
114233	10.887	1.519	1.202	0.947	1.926	12	13	8	22	3	9		M1 V:
115497	8.743	1.547	1.900	0.905	1.915	16	18	6	22	5	10		M1 III
116317	11.160	1.478	1.083	1.019	2.279	14	9	9	43	4	8	C	M3 (V)
117857	8.436	1.598	1.977	0.906	1.853	16	11	6	21	7	9		M1 III

we are not able to distinguish class IV, for example). Alternate names for the Table 2 stars have been given in table 2 of Paper I, along with other useful information.

We have flagged several stars in Table 2 as variable (‘Var’) or possibly variable (‘Var?’). The latter stars are generally brighter stars where it appears that the scatter in the data is worse than would be expected for a constant star. Of course, all Table 2 stars might well be variable at some level – many M dwarf stars exhibit occasional flares and can be constant for many observations and then show a sudden change. Some cool stars exhibit spots and could be almost continuously variable; these should have been mostly eliminated by the *Hipparcos* photometry or our own observations. The star HIP 37433, an M supergiant, appears constant in Paper I and also in our Table 2, but the two results are quite different (and we have listed both separately in Table 2). It turns out to be a known pulsator, V384 Pup, a fact we missed completely. It has been classified as LC type (Kazarovets et al. 1999) – an irregular variable of late spectral type – and has a noted range of about 8.8–9.4 mag in V, in agreement with our observations.

Overall, the Table 2 results show standard deviations of a single observation of 0.014, 0.009, 0.030, 0.006 and 0.009 in V, $(B-V)$, $(U-B)$, $(V-R)$ and $(V-I)$, respectively, determined from 1077 observations of 101 stars (excluding known and suspected variables). The largest scatter – in $(U-B)$ – is substantially attributable to the low count rates achieved for all these stars in U. The scatter in V, also rather high, might well be attributable to unrecognized variability, but that is unavoidable in dealing with M stars. None the less, it is the case that even stars which are slightly variable in brightness can still prove to be useful colour standards. It is also worth reiterating that observers should not depend on small numbers of stars to establish red colour equations or to determine zero-points; observations of significant numbers of red standards are necessary to overcome the potential variability problem.

2.1 Comparison with other sources

As in Kilkenny et al. (1998) and Paper I, we compare our results to the extensive southern observations of Laing (1989) and Bessell (1990). The intercomparisons are shown in Figs 3 and 4, where it can be seen that there are no obvious colour terms. The zero-point differences, excluding known or suspected variables, are listed in Table 3 and are overall very similar to those from our earlier contributions (Paper I and Kilkenny et al. 1998) and show little of significance – except that the large zero-point difference in $(U - B)$ between our Table 2 and Laing (1989) is of some concern. We cannot entirely explain this, although inaccuracy at U for faint, red stars – in both sources – is clearly a contributory factor. Exclusion of one or two data points substantially reduces, but does not eliminate, the discrepancy.

The intercomparisons also reveal a few more potential variable stars – objects which appear constant in any or all of Laing (1989), Bessell (1990) and our Table 2 individually, but show large discrepancies between the data sets; these are indicated by 'Var*' in the table. Perhaps unsurprisingly, they include all three stars classified as emission line ('e'), HIP 26081, 30920 and 102141 (=GJ 207.1, 234A and 799A, respectively).

Again, we note that although stars are small-amplitude variables, still their colours may be useful. An example is HIP 50341 (=GJ 386) which appears constant in our results, but shows almost 0.5 mag difference in V with Bessell (1990); by contrast, the colour differences are all less than 0.005 mag.

A few stars have observations in all of Laing (1989), Bessell (1990) and Table 2, and some of these show very good interagreement between all three; these are noted in Table 2 with a 'C' (for 'constant' or perhaps 'more likely to be constant').

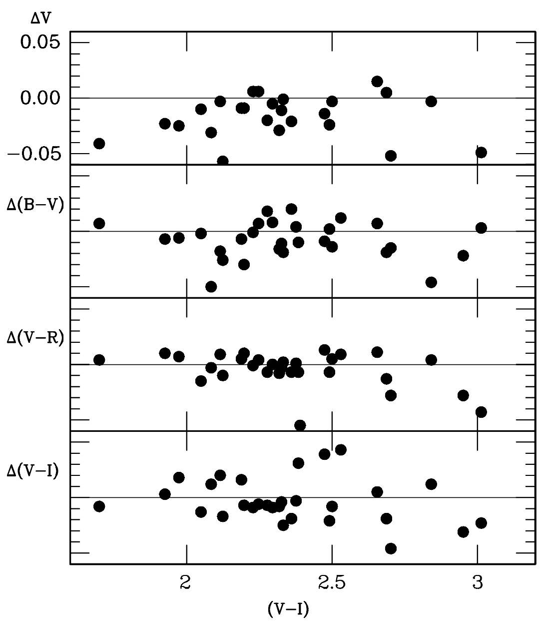

Figure 3. Comparison of the Table 2 photometry overlap (including known or suspected variables) with Bessell (1990) photometry, where the Δ differences are in the sense Table 2 *minus* Bessell.

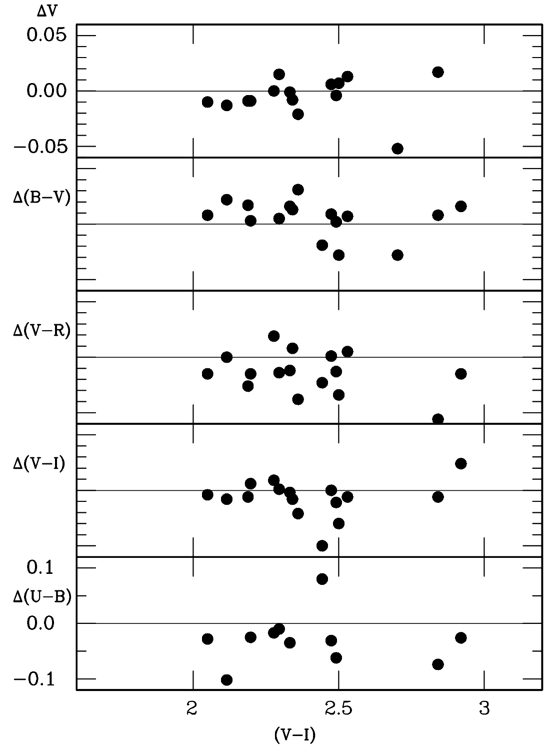

Figure 4. Comparison of the Table 2 photometry overlap (including known or suspected variables) with Laing (1989) photometry, where the Δ differences are in the sense Table 2 *minus* Laing. Note the different ordinate scale for $(U - B)$. Two stars have large V residuals and are not included in the top panel and six stars do not have $(U - B)$ in Laing (1989).

Table 3. Mean differences (in the sense Table 2 *minus* other) between Table 2 and Bessell (1990) and Laing (1989), *excluding* known or suspected variable stars.

Δ	V	$(B-V)$	$(U-B)$	$(V-R)$	$(V-I)$	n
Bessell	−0.013	−0.009		0.000	−0.002	23
(s.d.)	±0.017	±0.018		±0.008	±0.016	
Laing	−0.001	+0.009	−0.043	−0.014	−0.006	14
(s.d.)	±0.011	±0.014	±0.030	±0.020	±0.010	

3 *JHKL* PHOTOMETRY

All infrared photometric observations were made with the MkII photometer on the 0.75-m telescope at the SAAO Sutherland site. The MkII infrared instrument uses an InSb detector and is an upgrade of – but very similar to – the MkI photometer described in Glass (1973). Standard stars were observed between every three or four programme stars (equivalent to about one per hour) to track zero-point changes and all observations were reduced to the SAAO standard system (Carter 1990). *JHK* results were obtained for most of the Table 2 stars (listed in Table 4) and selected stars from table 2 of Paper I (listed in our Table 5). L could only be measured for stars brighter than about $L = 6$.

It is possible to estimate random photometric errors in the cases where repeated measurements of stars were obtained. Since at least

Table 4. *JHKL* photometry for selected Table 2 stars.

HIP	J	H	K	L	n_{JHKL}	M_J	σ
112	8.11	7.38	7.23		2220	−2.52	0.29
1242	7.29	6.68	6.40	5.92	1111	1.41	0.20
1276	8.03	7.33	7.11		1110	−1.92	0.20
1734	7.75	7.02	6.82		2220	−1.30	0.09
1842	8.35	7.64	7.43		1120	−1.62	0.12
2022	5.92	5.05	4.85	4.72	1111	−10.20	3.44
3813	7.88	7.14	6.97		2220	−1.67	0.10
5812	7.90	7.22	7.01		1110	−1.08	0.07
6008	7.84	7.09	6.92		2220	−1.93	0.14
6097	8.43	7.73	7.51		1110	−1.72	0.18
6365	8.22	7.53	7.32		1110	−1.85	0.18
8051	7.43	6.77	6.54		2220	−0.26	0.05
8691	8.44	7.85	7.63		1110	−1.25	0.12
9724	6.62	5.93	5.71	5.49	2222	0.13	0.04
10464	5.98	5.11	4.95	4.75	1111	−9.81	1.75
11301	5.96	5.02	4.86	4.72	2222	−9.68	1.39
11551	5.53	4.64	4.46	4.28	2222	−9.64	1.75
12810	6.08	5.16	4.98	4.82	2222	−10.94	4.61
14139	6.32	5.40	5.24	5.04	1111	−8.62	1.08
15782	5.16	4.22	4.03	3.88	2222	−8.28	0.67
17339	5.53	4.62	4.42	4.26	2222	−12.10	7.71
18418	7.17	6.27	6.09	6.07	2221		
19019	5.81	4.95	4.78	4.66	3333		
21556	7.02	6.34	6.12		2220	−0.22	0.04
23418	7.31	6.62	6.39		1110	−2.53	0.60
26081	7.83	7.11	6.87		2220	−1.13	0.14
27606	5.38	4.45	4.24	4.12	2222	−9.35	1.87
28226	5.35	4.43	4.24	4.09	2222	−9.12	1.13
30016	5.03	4.13	3.91	3.71	1111	−7.03	0.69
30920	6.46	5.80	5.49	5.28	2222	1.93	0.02
31814	5.99	5.07	4.90	4.74	2222	−9.02	1.36
32060	5.39	4.48	4.27	4.12	2222	−9.53	2.14
33327	4.63	3.71	3.49	3.31	1111	−8.05	0.67.
37217	7.96	7.32	7.07		1110	−0.18	0.07
37433	4.43	3.40	3.10	2.72	1111		
40239	6.72	6.01	5.85		1110	−1.68	0.19
44005	6.58	5.69	5.51	5.55	1111	−9.41	2.14
47425	6.96	6.31	6.07		1110	0.11	0.03
49091	7.67	6.96	6.72		1110	−1.03	0.08
49969	7.10	6.46	6.21		1110	−0.45	0.06
53544	5.11	4.23	4.03	3.89	1111	−8.15	0.99
55042	7.85	7.34	7.11		1120	−0.49	0.08
56244	7.47	6.81	6.56		2220	−0.10	0.06
57056	5.26	4.42	4.24	4.09	2222	−8.14	4.22
59204	5.08	4.14	3.95	3.75	1111	−7.57	0.67
62452	7.29	6.63	6.38		1110	0.43	0.05
64339	5.13	4.24	4.03	3.87	2222	−8.11	1.02
65408	5.34	4.47	4.27	4.11	2222	−7.55	0.79
66675	6.94	6.22	6.09	5.92	1111	−0.81	0.05
67164	7.84	7.17	6.93		1110	−0.28	0.11
69503	5.34	4.43	4.23	4.11	2222	−7.49	0.88
70815	5.24	4.31	4.08	3.88	2222	−11.99	7.71
71253	6.96	6.26	5.99	5.75	2222	1.07	0.04
72346	6.33	5.44	5.26	5.13	1111	−7.64	1.36
74995	6.76	6.11	5.86	5.73	2222	1.01	0.03
77498	5.64	4.71	4.48	4.26	1111		
78353	7.28	6.56	6.34	6.23	2221	−0.72	0.06
80018	6.80	6.14	5.89	5.54	1111	0.36	0.04
80229	8.54	7.89	7.67		1120	−1.94	0.20
80559	7.81	7.09	6.91		1120	−2.21	0.13
82181	6.48	5.55	5.33	5.16	1111	−7.08	1.04
82684	5.57	4.48	4.21	4.03	1111	−6.58	0.89
83405	7.89	7.19	7.00		1110	−1.77	0.40
83557	4.65	3.72	3.49	3.31	1111	−7.87	0.88
84141	5.05	3.99	3.73	3.51	1111		
84854	5.71	4.66	4.43	4.30	1111	−8.30	2.00
85658	4.43	3.39	3.11	2.92	1111	−7.69	0.88
86933	5.82	4.86	4.67	4.53	1111	−7.45	0.98
87855	5.16	4.26	4.03	3.85	1111	−6.26	0.59
88574	6.24	5.57	5.36	5.19	1111	0.54	0.02
88967	5.19	4.30	4.10	3.93	1111	−7.92	1.20
91430	7.74	7.06	6.83		1110	−0.53	0.08
92783	5.04	4.05	3.79	3.60	1111		
93139	5.39	4.45	4.24	3.93	1111	−10.40	2.54
93206	7.61	6.91	6.70	6.56	1111	−0.71	0.08
95639	5.19	4.17	3.94	3.77	1111	−6.95	0.89
97161	5.29	4.35	4.12	3.95	1111	−10.68	3.90
100356	7.39	6.68	6.51		1110	−1.80	0.14
102141	5.85	5.16	4.91	4.70	2222	−0.05	0.10
103800	7.63	6.94	6.71	6.66	1111	−0.70	0.09
104644	8.55	7.92	7.70		1110	−0.78	0.13
105474	5.21	4.27	4.07	3.94	2222	−9.36	2.04
105932	8.08	7.42	7.21		1110	−1.05	0.09
106836	5.07	4.17	3.96	3.80	2222	−8.64	1.46
107711	7.76	7.08	6.83		1110	−0.64	1.20
108593	4.85	3.94	3.74	3.61	3332	−10.38	2.71
108657	5.44	4.57	4.37	4.27	1111	−7.04	0.68
109388	6.57	5.84	5.62	5.44	1111	0.28	0.04
112996	6.16	5.25	5.06	4.94	1111	−7.12	0.79
113520	4.31	3.40	3.18	3.00	1111	−8.16	0.86
113602	8.34	7.67	7.45		2220	−1.54	0.13
114233	7.92	7.28	7.07		1110	−0.97	0.07
115497	5.69	4.77	4.59	4.40	1111	−8.44	1.39
116317	7.70	7.07	6.86	6.66	2221	−0.73	0.14
117857	5.44	4.55	4.37	4.18	2222	−8.55	0.89

222 stars in Tables 4 and 5 were observed more than once in each of the J, H and K filters, a good measure of the photometric errors in these passbands can be formed. As the error distributions for the three filters were quite similar they were combined to give Fig. 5. Based on this diagram it is safe to say that for the bulk of the measurement the errors in *JHK* are well below 0.02 mag.

Measurements in L were obtained for 208 stars. Of these, 138 were observed more than once. A histogram of the standard deviations calculated from the repeat measurements is shown in Fig. 6: the great majority of errors is below 0.06 mag.

4 COLOUR ANALYSIS

Since the target stars were selected from the *Hipparcos* catalogue, most have parallax measurements. Of the 389 stars for which we have near-infrared photometry, 351 have positive parallaxes; 58 of these have very large errors, giving $\sigma(M_J) > 2$. Two colour–magnitude plots for the remaining 293 stars can be seen in Figs 7 and 8. The $(H - K)$ colour index is particularly useful for showing the dwarf star temperature sequence.

Colour–colour plots based on combinations of optical and near-infrared measurements are particularly interesting. We concentrate on the 293 stars for which the absolute magnitudes allow us to separate dwarfs and giants with reasonable certainty: the dividing line is taken to be at $M_J \approx 3$ (from Figs 7 and 8). Experimentation showed that plots involving $(V - R)$ – or alternatively, $(V - I)$ – and a second index made up of the difference between an optical magnitude and

Table 5. *JHKL* photometry for the Paper I programme stars not listed in Table 2.

HIP	J	H	K	L	n_{JHKL}	M_J	σ
439	5.34	4.73	4.53	4.39	1111	1.80	0.01
897	8.01	7.30	7.13		2220	−2.03	0.13
1165	5.80	4.88	4.73	4.61	1111	−9.28	2.25
1412	8.16	7.43	7.26		2220	−2.73	0.18
1696	7.47	6.76	6.59		2220	−1.27	0.08
1771	8.66	7.97	7.83		1110	−3.47	0.28
3143	8.29	7.58	7.39		1110	−1.80	0.13
3493	8.04	7.32	7.14		2220	−2.65	0.16
3556	8.57	7.87	7.65		1110	−2.93	0.23
3575	6.13	5.29	5.11	4.95	1111	−12.76	8.45
3664	5.42	4.54	4.36	4.24	3333	−10.30	2.75
5018	9.01	8.29	8.18		1110	−3.75	0.32
5443	8.02	7.34	7.14		2220	−2.87	0.29
5558	6.98	6.17	6.02	5.80	4441	−7.45	0.69
5979	5.32	4.47	4.31	4.20	2222	−7.83	0.59
6069	7.92	7.24	7.04		2220	−0.93	0.49
6098	5.77	4.88	4.69	4.53	3343	−8.99	2.10
7353	5.24	4.37	4.19	4.05	2222	−8.57	0.98
7554	7.57	6.80	6.66		3330	−1.70	0.08
8114	5.70	4.80	4.61	4.45	2222	−7.15	0.75
8338	5.38	4.52	4.35	4.19	3333	−8.64	0.89
8917	6.09	5.22	5.04	4.90	3333	−8.05	0.74
9063	5.51	4.52	4.34	4.16	2232	−8.38	1.78
9205	7.26	6.41	6.24		3330	−8.76	2.21
9611	6.61	5.74	5.58	5.51	2222	−8.23	1.36
9975	5.03	4.19	3.99	3.81	2221	−8.85	1.44
10279	6.92	6.29	6.09	6.01	2222	−0.08	0.04
10500	8.74	8.08	7.87		1110	−2.34	0.21
10688	8.53	7.84	7.65		1110	−1.97	0.16
11362	6.40	5.47	5.32	5.24	2222	−8.33	1.35
12707	4.31	3.34	3.14	2.99	3333	−8.45	1.12
12749	8.75	8.15	7.94		1110	−1.87	0.18
13079	8.15	7.41	7.28		2220	−2.48	0.15
13218	7.43	6.75	6.54		3330	−0.58	0.04
13389	7.76	7.09	6.86		1110	−0.30	0.05
14444	5.60	4.68	4.50	4.34	2222	−9.81	1.43
15905	6.16	5.28	5.08	4.92	4443	−14.12	19.98
16242	7.35	6.61	6.47		3330	−1.68	0.09
16354	7.77	7.07	6.96		2330		
16397	4.85	3.92	3.74	3.61	3333	−8.11	0.64
16559	5.99	5.07	4.89	4.75	3333	−8.81	1.52
16561	5.76	4.81	4.62	4.45	3333	−9.01	1.31
16702	7.40	6.67	6.54		2220	−12.34	11.18
17335	6.24	5.33	5.16	5.08	3333		
17743	8.01	7.33	7.12		1110	−1.20	0.10
18253	9.08	8.35	8.19		1110	−3.04	0.30
18284	8.09	7.18	6.97		1110		
19275	8.77	7.90	7.78		1110	−10.57	5.61
19350	6.25	5.34	5.17	5.11	2222	−10.20	2.03
19394	8.02	7.37	7.15		1110	−0.88	0.07
19512	7.58	6.81	6.69		3330	−10.57	6.26
19848	5.87	4.97	4.80	4.67	4444	−8.99	1.16
19976	8.20	7.54	7.43		2220	−2.96	0.10
20634	5.70	4.82	4.63	4.48	3333	−6.82	0.43
20880	6.24	5.30	5.12	5.01	3333	−10.16	3.46
21361	6.69	5.84	5.70	5.60	4444	−10.43	3.81
21709	6.78	5.92	5.75	5.60	2222	−16.99	74.92
22102	5.47	4.55	4.35	4.21	2222	−12.41	5.07
22627	7.92	7.22	6.95		1110	−0.42	0.10
22762	7.51	6.86	6.63		1110	−0.46	0.05
23932	6.25	5.56	5.33	5.15	4444	0.15	0.04
24434	6.97	6.12	5.96	5.81	2222		
24472	8.42	7.75	7.55		1110	−1.89	0.18
25953	7.49	6.84	6.58		1110	−0.53	0.09
26672	5.16	4.25	4.06	3.88	3333	−9.33	1.18
26784	5.76	4.87	4.69	4.52	2222	−8.07	1.04
27359	7.49	6.84	6.63		2220	−0.88	0.05
28127	5.56	4.62	4.42	4.27	3332	−9.68	1.46
28568	4.76	3.86	3.68	3.53	3332	−7.58	0.48
29132	8.15	7.46	7.35		1110	−2.50	0.17
29295	5.06	4.36	4.16	3.99	3333	1.19	0.01
30162	3.57	2.53	2.25	2.02	1111		
30949	8.32	7.61	7.46		1110	−2.92	0.19
31638	5.70	4.76	4.58	4.45	2222	−7.77	0.65
32392	5.29	4.38	4.17	4.01	3333	−8.36	0.81
33071	6.46	5.58	5.38	5.31	2222	−7.83	2.12
33213	5.28	4.38	4.16	4.02	3333	−8.18	0.75
33499	6.95	6.34	6.08		2220	0.48	0.05
33762	9.14	8.42	8.26		1110	−2.74	0.44
34104	7.39	6.67	6.43		1110	−0.94	0.09
34361	7.71	7.02	6.82		1110	−1.18	0.09
34905	4.91	4.02	3.83	3.69	1111	−7.72	0.49
34945	4.58	3.63	3.45	3.30	2222	−8.40	0.73
35325	5.76	4.85	4.66	4.54	1111	−10.02	2.02
36208	5.75	5.13	4.88	4.67	2222	2.10	0.01
36546	8.30	7.64	7.42		1110	−2.47	0.60
37186	4.73	3.82	3.62	3.45	2222	−8.24	0.68
37288	6.85	6.09	5.92		1110	−0.86	0.05
37547	5.54	4.66	4.48	4.31	2222	−8.36	0.76
37972	9.46	8.77	8.66		1110	−4.48	0.56
39470	8.65	7.99	7.88		1110	−3.19	0.14
40172	4.93	4.03	3.85	3.72	2222	−11.64	3.10
40670	9.04	8.35	8.19		1110	−3.69	0.24
42748	6.77	6.05	5.87	5.73	1111	−0.63	0.40
42762	8.17	7.49	7.26		1110	−0.95	0.13
43521	6.75	5.85	5.69	5.58	2222		
43582	5.48	4.61	4.43	4.30	1111	−9.35	2.11
43708	8.12	7.48	7.24		1110		
44772	5.15	4.22	4.03	3.87	1111	−7.84	0.54
45051	5.60	4.68	4.49	4.35	2222	−9.45	2.68
45908	6.49	5.78	5.59	5.52	2222	−0.10	0.02
46706	6.42	5.76	5.54	5.32	2221	−0.11	0.10
48336	7.04	6.36	6.17	6.16	1111	−0.68	0.66
48477	7.09	6.37	6.16		1110	−0.98	0.06
48904	7.22	6.54	6.29		3330	−1.01	0.06
49211	7.33	6.52	6.37		1110		
49754	6.03	5.13	4.94	4.79	3333	−10.74	3.58
49986	5.96	5.25	5.03	4.88	2222	0.54	0.03
50624	5.48	4.59	4.39	4.24	3333	−7.62	0.79
50908	8.65	7.97	7.84		2220	−3.38	0.15
51317	6.23	5.58	5.35	5.14	1111	0.70	0.03
51764	7.00	6.24	6.10		1110	−9.81	2.81
52296	6.92	6.22	6.02	5.84	3333	−1.06	0.09
52621	8.13	7.48	7.30		2220		
53140	5.97	5.05	4.85	4.67	3333	−5.94	0.52
54600	5.30	4.40	4.21	4.08	3333	−7.38	0.72
54803	7.52	6.83	6.65		1110	−1.91	0.11
55456	5.20	4.31	4.13	3.98	3333	−9.35	1.79
55625	8.04	7.35	7.15		1110	−1.63	0.11
56208	5.39	4.49	4.31	4.14	3333	−9.36	1.75
56493	4.76	3.85	3.66	3.53	2222	−7.91	1.08
56528	6.53	5.85	5.64	5.48	3333	0.22	0.04
56600	7.59	6.77	6.61		2220	−7.21	1.00
56660	4.84	3.93	3.72	3.51	4444	−8.77	1.23
57459	8.01	7.30	7.08		1110	−1.55	0.13

Table 5 – *continued*

HIP	J	H	K	L	n_{JHKL}	M_J	σ
57959	8.35	7.67	7.44		1110	−1.57	0.15
58114	8.27	7.56	7.39		1110	−2.23	0.20
58564	4.99	4.08	3.90	3.76	2222	−7.14	0.57
58688	7.60	6.87	6.70		3330	−1.88	0.15
59198	8.48	7.77	7.61		1110	−2.30	0.16
59301	8.59	7.89	7.70		1110	−3.09	0.50
59909	5.95	5.05	4.86	4.69	2222	−9.55	1.54
60064	6.02	5.10	4.91	4.79	3333	−10.40	3.32
60178	6.93	6.22	6.03		1110		
60501	8.32	7.63	7.52		1110	−3.35	0.20
60559	7.81	7.22	7.00		2230	0.26	0.05
60954	6.17	5.27	5.08	4.95	3443	−9.05	2.12
61417	7.20	6.32	6.18		1110	−13.39	17.27
61806	5.69	4.78	4.59	4.38	3333	−7.44	0.86
62351	5.94	5.01	4.83	4.68	3333	−9.64	2.36
62380	8.15	7.30	7.16		1110		
62602	6.85	5.98	5.82	5.66	2222	−12.84	11.18
63108	5.10	4.21	4.01	3.85	3333	−10.74	3.55
63707	5.38	4.48	4.28	4.12	4444	−10.51	3.49
64180	8.24	7.53	7.40		1110	−2.35	0.12
64640	5.96	5.12	4.93	4.80	3444	−9.87	2.99
65248	7.02	6.19	6.02	5.89	2221	−10.65	4.25
65520	7.75	7.11	6.86		2220	−1.06	0.08
65658	6.97	6.10	5.93	5.85	3331	−8.53	1.73
65902	6.24	5.39	5.22	5.10	2222	−8.07	0.92
67482	4.63	3.69	3.50	3.36	4444	−8.00	0.94
69454	7.00	6.32	6.11	6.23	2221	−0.35	0.05
69485	7.45	6.75	6.58		2220	−1.46	0.07
70004	7.15	6.30	6.14		2220		
70308	7.49	6.78	6.62		2220	−1.87	0.08
70974	7.64	6.66	6.46		1110		
71191	5.54	4.54	4.33	4.14	5554	−10.87	3.86
71781	6.96	6.14	5.99	5.90	4444		
72281	7.50	6.58	6.39		4440	−7.43	1.41
72511	8.48	7.87	7.62		2330	1.86	0.21
73056	8.51	7.77	7.62		1120	−2.78	0.20
73319	5.31	4.40	4.19	4.03	4444	−7.57	0.84
74190	7.79	7.10	6.87		3330	−0.81	0.08
74953	4.79	3.89	3.68	3.51	4444	−8.63	1.42
75943	8.79	8.11	8.02		1110	−6.65	0.93
76022	4.92	4.00	3.80	3.63	4444	−13.01	10.16
76111	7.00	6.18	6.02	5.89	4441	−8.63	1.91
77518	8.39	7.66	7.49		2330	−2.13	0.14
77590	4.77	3.87	3.66	3.51	4444	−7.26	0.79
77754	4.46	3.50	3.28	3.11	4444	−9.03	1.78
78190	5.84	4.88	4.66	4.49	3333		
78924	8.43	7.71	7.52		1110	−3.35	0.54
79570	3.62	2.48	2.18	1.93	5555	−7.67	0.85
80053	8.00	7.27	7.12		3330	−2.41	0.17
80213	6.20	5.32	5.16	5.03	3333	−7.61	1.19
80268	7.30	6.59	6.41		3330	−1.13	0.07
80612	7.78	7.04	6.87		2220	−1.68	0.13
80824	6.01	5.36	5.10	4.92	3443	1.85	0.02
82256	8.11	7.45	7.21		2220	−1.02	0.07
82817	5.28	4.63	4.41	4.21	4444	1.21	0.05
82926	7.39	6.71	6.48		4440	−0.81	0.16
83175	5.80	4.86	4.66	4.54	4444	−7.85	0.80
83599	6.86	6.20	6.00	5.77	3331	−0.24	0.70
84018	7.00	6.18	6.00		2220	−9.59	3.48
84165	5.78	4.82	4.61	4.44	3333	−7.58	0.97
84487	7.81	7.10	6.95		2330	−1.98	0.10
84521	8.02	7.36	7.12		1110	−0.87	0.09
84898	9.12	8.26	8.08		1110	−7.98	4.56
84901	8.21	7.24	7.02		2220	−13.10	36.10
85016	6.55	5.70	5.54	5.42	2222	−8.97	1.82
85608	6.20	5.26	5.05	4.89	2222	−8.49	1.78
85647	6.79	6.04	5.88	5.91	2222	−1.04	0.06
85665	6.37	5.68	5.49	5.42	2221	0.00	0.03
85677	5.28	4.27	4.01	3.81	3333	−8.08	1.19
86440	7.21	6.39	6.24		1110		
86707	7.54	6.84	6.65		1110	−1.47	0.14
86938	9.13	8.42	8.25		1110	−2.85	0.31
86961	7.05	6.41	6.14		1120	1.04	0.15
87322	7.45	6.71	6.56		1110	−1.70	0.10
88389	8.08	7.39	7.26		2220	−6.21	0.76
88633	8.48	7.77	7.60		2220	−4.45	2.03
89915	6.35	5.54	5.35	5.17	4444		
90085	6.04	5.10	4.88	4.76	4444		
91032	4.68	3.59	3.31	3.11	3333	−6.31	0.62
91608	7.49	6.77	6.57		3330	−1.05	0.07
92451	7.60	6.93	6.72		3330	−1.11	0.08
92871	6.38	5.67	5.44	5.24	2222	−0.32	0.05
93101	6.33	5.59	5.42	5.28	2222	−0.23	0.04
94349	7.18	6.55	6.33	6.28	1111	−0.03	0.06
94761	5.59	4.88	4.66	4.50	2222	1.16	0.02
94878	5.74	4.81	4.61	4.47	4444	−10.00	3.24
94960	7.97	7.24	7.14		1110	−3.93	0.80
96121	7.72	7.00	6.84		2220	−1.79	0.10
98884	9.15	8.44	8.31		2220	−4.01	0.41
99492	8.76	7.91	7.75		1110		
99750	7.09	6.31	6.16	6.17	3332	−7.97	1.26
99793	8.08	7.10	6.90		1110	−11.83	12.83
99819	7.92	7.05	6.86		2220	−11.51	17.07
99950	7.62	6.72	6.54		2220	−7.81	1.81
100061	6.10	5.21	5.04	4.91	3333	−12.34	10.54
100194	7.57	6.74	6.57		3330		
100490	7.85	7.17	6.99		2220	−1.49	0.08
100530	8.33	7.46	7.29		1110	−6.12	1.04
100890	6.77	5.93	5.75	5.61	3333	−7.18	1.05
100894	5.95	5.05	4.82	4.68	2222		
100923	7.77	7.10	6.88		3330	−0.94	0.52
101400	7.45	6.51	6.32		2220	−6.29	0.84
101461	9.23	8.50	8.35		1110	−3.26	0.31
101495	7.54	6.62	6.44		1110	−8.98	3.01
101573	7.66	6.77	6.58		1110	−6.37	0.93
101686	7.09	6.22	6.02		2220	−8.63	2.26
101844	8.66	7.91	7.77		3330	−2.53	0.20
101937	7.84	6.96	6.79		1110		
102235	7.64	6.93	6.76		2220	−1.50	0.57
102682	9.28	8.54	8.36		1110	−4.46	1.12
102810	6.61	5.70	5.53	5.45	2221	−7.79	1.16
103390	9.18	8.53	8.40		2220	−3.85	0.72
103393	7.89	7.31	7.07		1110	−1.24	0.15
104005	7.57	6.61	6.42		1110	−7.08	1.54
104059	8.37	7.75	7.53		2220	−1.41	0.13
104201	6.64	5.75	5.57	5.46	2222		
104432	7.74	7.15	6.93		3220	−0.42	0.06
106255	7.38	6.68	6.40	6.13	1111	0.48	0.50
106408	6.29	5.40	5.18	5.07	1111		
106415	5.02	4.09	3.89	3.73	1111	−10.87	4.12
106440	5.36	4.69	4.47	4.31	2222	1.53	0.01
106494	6.91	6.07	5.89	5.79	1111		
106525	5.93	5.05	4.86	4.73	2222	−10.16	3.39
106803	7.55	6.82	6.63		1110	−1.61	0.24
106832	8.01	7.06	6.89		1110		
107543	7.75	6.82	6.65		1110		

Table 5 – *continued*

HIP	J	H	K	L	n_{JHKL}	M_J	σ
107691	6.16	5.35	5.18	5.04	2222	−6.87	0.74
107705	6.58	5.84	5.66	5.62	1111	−1.04	0.09
108159	8.47	7.81	7.58		1110	−0.90	0.12
108320	7.77	6.97	6.80		2220	−7.30	1.64
108380	7.80	7.05	6.87		1110	−1.49	0.11
108405	6.83	6.12	5.91	5.81	2222	−1.05	0.09
108569	6.69	5.99	5.80	5.66	2222	−0.37	0.04
108782	6.26	5.53	5.36	5.22	2222	−0.07	0.03
109480	8.01	7.29	7.12		1110	−2.87	0.67
109756	8.65	7.97	7.76		1110	−2.05	0.20
110406	3.79	2.86	2.63	2.49	2222	−6.16	0.47
111313	7.26	6.59	6.37		1110	−0.54	0.07
111427	4.61	3.58	3.31	3.13	2222	−6.80	0.96
112276	6.63	5.68	5.50	5.42	1111		
112388	8.98	8.28	8.10		1110	−1.86	0.22
112652	8.49	7.74	7.58		1110	−2.60	0.17
112851	5.56	4.62	4.43	4.30	2232		
112978	8.50	7.80	7.59		1110	−1.44	0.12
113020	5.99	5.31	5.04	4.81	2222	1.64	0.02
113078	6.41	5.48	5.29	5.16	3333		
113244	8.20	7.47	7.29		1110	−1.93	0.14
113590	8.20	7.45	7.28		2220	−2.24	0.14
113850	7.74	7.03	6.85		1110	−1.59	0.09
113916	5.03	4.16	3.96	3.82	2222	−9.08	1.73
113971	5.16	4.24	4.06	3.94	1111	−10.35	2.04
114252	8.00	7.27	7.11		1110	−1.70	0.12
115099	8.23	7.51	7.34		1110	−2.56	0.30
115139	4.67	3.75	3.57	3.43	1111	−9.75	1.86
115211	8.03	7.27	7.10		1110	−2.09	0.20
115648	8.32	7.58	7.41		2220	−2.42	0.19
115707	5.91	4.97	4.80	4.71	3333		
116003	7.29	6.60	6.37		1110	−0.85	0.25
116271	5.17	4.26	4.07	3.93	3333	−7.49	0.92
116586	6.14	5.24	5.07	4.93	1111	−6.93	0.73
116645	8.44	7.74	7.49		1110	−1.33	0.14
117473	5.89	5.27	5.07	4.93	4444	1.12	0.02
117523	5.75	4.86	4.67	4.58	2222	−6.94	0.63
117828	6.52	5.78	5.58	5.49	1111	−0.03	0.03
117886	8.02	7.31	7.14		2220	−1.97	0.13
118095	8.11	7.16	6.95		1110		
118130	8.50	7.72	7.54		1110	−3.15	0.48
118200	7.96	7.31	7.06		2220	−1.16	0.11
120046	5.98	5.07	4.89	4.76	2222	−10.02	2.00

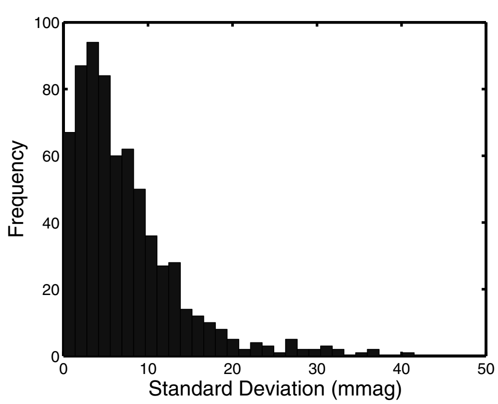

Figure 5. The relative frequencies of errors in *JHK*, based on repeated measurements for stars.

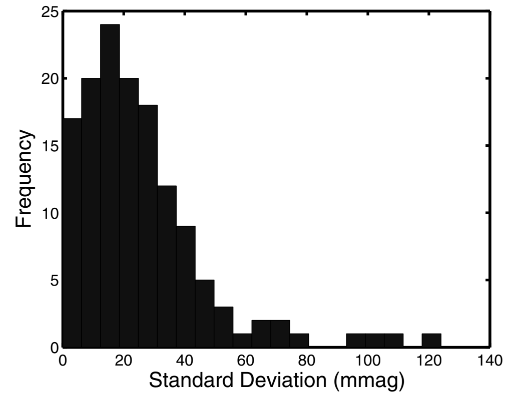

Figure 6. The relative frequencies of errors in *L*, based on repeated measurements for stars.

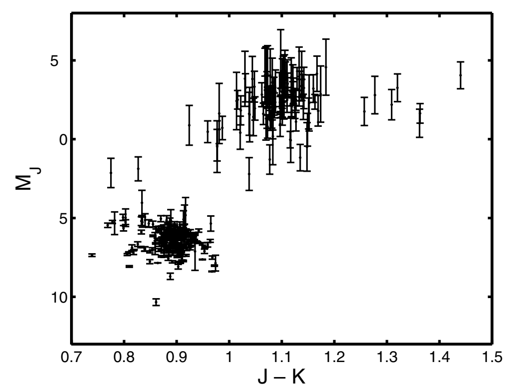

Figure 7. Near-infrared colour–magnitude plot for the stars with reasonably accurate absolute magnitude determinations. Photometric errors have not been included in the estimates shown by the error bars, as the parallax errors dominate.

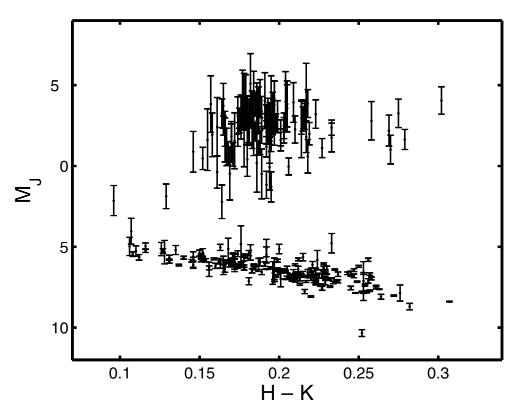

Figure 8. As for Fig. 7, but using the $(H - K)$ colour index.

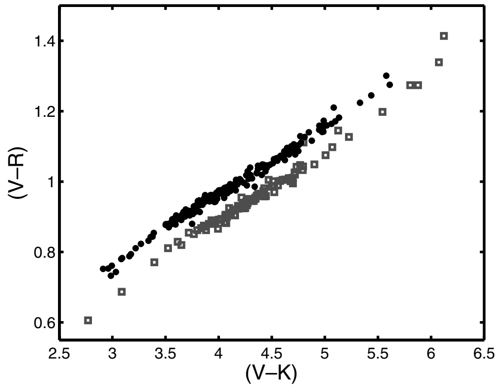

Figure 9. Colour–colour plot for the stars for which dwarfs (solid dots) and giants (open squares) could be separated with good confidence.

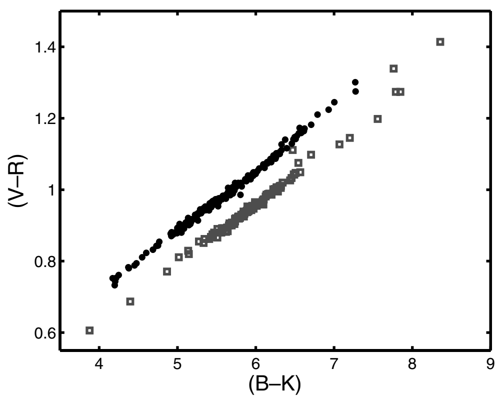

Figure 10. As for Fig. 9, but using $(B - K)$ instead of $(V - K)$.

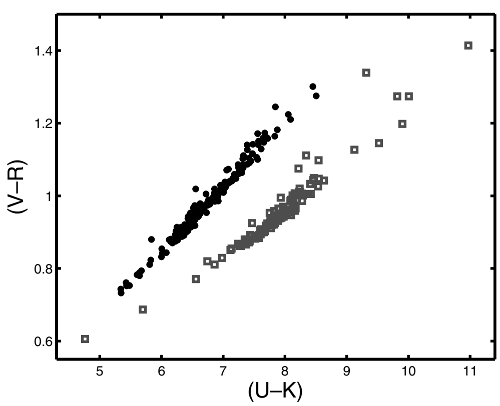

Figure 11. As for Fig. 9, but using $(U - K)$ instead of $(V - K)$.

K, were most useful. Plots of $(V - R)$ against $(V - K)$, $(B - K)$ and $(U - K)$ are therefore presented in Figs 9–11. Temperature sequences for both dwarfs and giants are well separated, particularly in the $(U - B) - (V - R)$ plot. The sequences are close to linear over most of their ranges in the $(B - K) - (V - R)$ and $(V - K) - (V - R)$ plots.

5 SUMMARY

We have given homogeneous and standardized *UBVRI* photometry for over 100 M stars which can serve as secondary standards for red colour equation determination. We have also given *JHK* (and, where possible, *L*) photometry for nearly 300 *Hipparcos* red stars for which *UBVRI* photometry was previously measured.

It is clear from Figs 9–11 that accurate fundamental properties of the stars in our programme can be derived by comparing the photometry to theoretical results. This is particularly true for those objects with accurate parallax measurements – see the recent work by Casagrande, Portinari & Flynn (2006) on G and K dwarfs.

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