UBVRI PHOTOMETRY OF STARS USEFUL FOR CHECKING EQUIPMENT ORIENTATION STABILITY[a)]

ARLO U. LANDOLT
Louisiana State University Observatory,[b)] Baton Rouge, Louisiana 70803
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ABSTRACT

Several sets of stars have been measured, equally spaced around the sky in right ascension, over a range in declination from $-75°$ to $+30°$. The goal was to obtain a number of well-observed stars with quality internally consistent magnitudes and color indices. The stars were needed to check orientation effects of photometric equipment.

I. INTRODUCTION

The last five years have been spent observing a series of stars around the celestial equator, with the goal of establishing new *UBVRI* photoelectric standard stars (Landolt 1983). The observations were made at the Cerro Tololo Inter-American Observatory (CTIO). The *RI* standard stars were in the *E*-regions at $-45°$ declination. The telescope, and therefore the RCA 31034A photomultiplier, was swung through a 45 degree change in orientation between the program and the standard stars. Different photocells were used, as available to guest observers at CTIO. It became apparent that, on occasion, there occurred an error in the final *V* magnitudes as a function of declination. Eventually the observed effect was ascribed to an insecure photomultiplier mounting.

In the meantime, it was necessary to compare the observational data with "check" stars over a large range in declination, thereby ensuring some knowledge of photomultiplier behavior. Corrections to the *V* magnitude, if needed, could be made as a function of position.

The declination check stars were observed with an RCA 1*P*21 or 931 photomultiplier. The observations were placed on the *UBV* photometric system as defined by Landolt (1973). About ten stars were observed at each 0^h, 6^h, 12^h, and 18^h right ascension between $-75°$ and $+30°$ declination at the 0.4-m telescope. All stars were chosen from the literature, and were selected to be about 7th magnitude so that they could be identified easily without the need for finding charts. These stars were too bright for safe use of the detectors used at large telescopes. Similarly, then, a set of declination check stars was established at the 0.9-m telescope at 0^h, 8^h, and 16^h right ascension, again in the declination range $-75°$ to $+30°$. There were 48 stars in the latter group. They were selected at an appropriate magnitude level from stars in the *Atlas of Harvard-Groningen Selected Areas* charts by A. Brun and H. Vehrenberg. Since these stars are about 12th magnitude, they are accessible with care to all but the largest telescopes.

An assumption was made that the photometric system which included the 1*P*21 type photomultiplier was stable. Nearly 40 years of use by the astronomical community has indicated such to be the case. The declination check stars at the 0.4-m and 0.9-m CTIO telescopes were observed over a two year time span. The result is an internally consistent set of declination check stars along several hour circles over large angular arcs which can in the future be used to check photomuliplier/coldbox orientation stability.

II. THE 0.4-m *UBV* DATA

Almost all *UBV* observations made at the CTIO 0.4-m telescope were obtained with a RCA 931*B*-14 (serial no. A-05262) photomultiplier mounted in coldbox no. 64. A few measures were made with 1*P*21 no. 3882 which was mounted in coldbox no. 61. All of the *UBV* data were tied into Cousins' (1973) *E*-region standards. The filter information for CTIO *UBV* set no. 4 is given in Table I.

The primary goal of this effort was to establish check stars with reasonably reliable magnitudes and color indices along several hour circles over a range of declination. The assumption was made that the RCA 1*P*21 or its cousin, the RCA 931*B*, was invariant against position changes on the sky. A secondary check would result from observations of Landolt's (1973) celestial equatorial *UBV* standard stars. By calibrating against Cousins' (1973) *E*-region *UBV* standard stars, one ought to be able to recover Landolt's *UBV* standard star values.

[a)] Contribution of the Louisiana State University Observatory No. 178.

[b)] Visiting Astronomer, 1979–1981, at Cerro Tololo Inter-American Observatory which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

TABLE I. *UBV* filter set no. 4.

	Identification number	Thickness	Filter
V	291	2.55 mm	Corning 3384 = GG 495
B	280	6.74 mm[a]	Corning 5030 + (GG 13 = GG 385)
U	289	3.00 mm	Corning 9863
		5.5 mm	$CuSO_4$ solid

[a] Combined thickness.

The data reduction steps followed the precepts of Schulte and Crawford (1961). Extinction coefficients were calculated every night, if possible. Typical values are tabulated in Landolt (1983), Table I. An average of 15 standard stars was observed each night. A total of 46 of Landolt's (1973) equatorial stars was observed along with the declination check program stars, to ensure as much cross checking as possible.

A comparison of the results generated herein to this point for 46 Landolt (1973) stars tied into Cousins' (1973) stars showed, in the sense values derived herein *minus* Landolt (1973): $\Delta V = -0.0001 \pm 0.0141$, $\Delta(B-V) = +0.0014 \pm 0.0108$, and $\Delta(U-B) = +0.0089 \pm 0.0167$. If one considers a 29 member subset of these 46 stars, the 29 stars having 5 or more observations each in Landolt (1973), then one finds, in the same sense: $\Delta V = -0.0016 \pm 0.0120$, $\Delta(B-V) = +0.0001 \pm 0.0091$, and $\Delta(U-B) = +0.0070 \pm 0.0137$. One may calculate that the zero points of the Cousins and Landolt stars agree to better than 0.002 magnitude for V and $(B-V)$, and to within 0.008 magnitude or so for $(U\text{–}B)$. And, one can conclude that on these nights, at least, the RCA 1*P*21 or 931 was stable in its coldbox.

If one looks in more detail at the comparisons of the new *UBV* results generated herein, which were tied into Cousins' (1973) paper, and compare them to Landolt's (1973) work, one finds:

$$(B-V) = +0.00867 + 0.98820\ (B-V)_{\text{Cousins}}$$
$$\pm 0.00232 \pm 0.00271$$
$$(U-B) = -0.01305 + 1.01190\ (U-B)_{\text{Cousins}}$$
$$\pm 0.00248 \pm 0.00297$$
$$V = V_{\text{Cousins}} + 0.00349 - 0.00256\ (B-V)$$
$$\pm 0.00416 \pm 0.00486$$

It appears that small amounts of color equation exist. These relations were applied to all 0.4-m *UBV* results. Once done, a comparison of final magnitudes and colors for the 29 stars in common herein, tied into Cousins (1973), corrected by the three relations above, and when compared to Landolt (1973), show $\Delta V = +0.0008 \pm 0.0123$, $\Delta(B-V) = +0.0006 \pm 0.0074$, and $\Delta(U-B) = +0.0005 \pm 0.0114$. And, the correlation coefficient for the regression lines has dropped to under 4 percent from nearly 60 percent. Therefore, all 0.4-m *UBV* results from these several observing sessions are on the *UBV* system defined by Landolt (1973).

III. THE 0.9-m *UBV* DATA

The *UBV* observations obtained at the CTIO 0.9-m telescope were made with the same equipment used at the 0.4-m telescope. Again, extinction and standard stars were observed each night. The standard stars were chosen from Landolt (1973).

Sixteen of the Landolt (1973) stars were treated as program stars. Comparing their *UBV* values derived herein with the published values (Landolt 1973), shows, in the sense values in this paper *minus* Landolt (1973): $\Delta V = -0.0025 \pm 0.0070$, $\Delta(B-V) = -0.0109 \pm 0.0166$, and $\Delta(U-B) = +0.0019 \pm 0.0145$. The intercomparison does not have too much weight, however, since most stars were observed only once.

An attempt has been made recently to expand the color range of an *UBVRI* photoelectric celestial equatorial set of standard stars (Landolt 1983). Twenty two of these stars were observed in the *UBV* photometric system at the 0.9-m telescope an average 4.5 times each. An intercomparison of the data obtained herein for these 22 stars with Landolt (1983) values for the same stars shows, in the sense present data minus Landolt (1983): $\Delta V = -0.0044 \pm 0.0095$, $\Delta(B-V) = -0.0057 \pm 0.0068$, and $\Delta(U-B) = +0.0114 \pm 0.0315$. The tie-in to Landolt (1973) is, for the purposes of this paper, therefore, quite acceptable, although the $(U-B)$ intercomparisons are not as good as one would like.

IV. DISCUSSION

The final *UBV* magnitude and color indices for the stars observed at the 0.4-m and 0.9-m CTIO telescopes are given in Tables II and III, respectively. Star identifications are listed in the first column: Henry Draper (HD) catalogue numbers for Table II and Selected Area (SA) numbers for Table III. The remaining columns present the same kinds of data in both tables. The coordinates in the second and third columns in both tables have been precessed to a 1985.0 equinox for ease of use. The original coordinates came from the Bonner Durchmusterung (BD) for the HD stars, and from *Harvard Annals* Vols. 101, 102, and 103 for the SA stars. Columns 4–9 give the magnitude and color indices. The V, $(B-V)$, and $(U-B)$ values result from a combination of *UBV* data from this paper and from *UBVRI* data taken with an RCA 31034*A* and tied into the *UBVRI* standards developed by Landolt (1983). The total number of combined *UBV* measures are given in the tenth and eleventh columns. The letter n indicates the number of *UBV* observations on m nights. The *RI* indices tabulated in columns 7–9 result from a tie-in to Landolt (1983). The twelfth and thirteenth columns list the number of *RI* measures, where N is the number of *RI* observations in M nights.

TABLE II. 0.4-m declination check stars.

Star	α (1985)	δ	V	B-V	U-B	V-R	R-I	V-I	n	m	N	M	Mean Errors of the Mean V	B-V	U-B	V-R	R-I	V-I	Notes
222237	23:38:41	-72 46 52	7.092	+0.995	+0.801	+0.603	+0.512	+1.117	9	7	3	3	0.0027	0.0030	0.0037	0.0052	0.0046	0.0029	
222076	23:37:17	-70 59 11	7.469	+1.030	+0.915	+0.543	+0.469	+1.014	9	7	3	3	0.0033	0.0033	0.0050	0.0023	0.0023	0.0017	
220896AB	23:27:02	-50 25 48	7.209	+0.903	+0.579	+0.467	+0.435	+0.903	4	3	1	1	0.0045	0.0015	0.0015	---	---	---	
221943	23:35:45	-44 58 30	6.923	+0.201	+0.095	+0.096	+0.106	+0.202	8	6	2	2	0.0021	0.0018	0.0018	0.0021	0.0014	0.0028	
219339	23:14:32	-24 56 10	7.283	+0.181	+0.100	+0.086	+0.096	+0.181	8	6	2	2	0.0042	0.0007	0.0007	0.0028	0.0028	0.0007	
223963	23:53:16	- 9 22 24	7.200	+1.581	+2.003	+0.906	+0.947	+1.854	8	6	2	2	0.0057	0.0032	0.0007	0.0014	0.0092	0.0106	
219018	23:11:50	+ 2 36 27	7.708	+0.620	+0.116	+0.355	+0.339	+0.694	10	6	2	2	0.0025	0.0013	0.0035	0.0021	0.0127	0.0148	
218155	23:04:49	+14 52 20	6.783	+0.004	-0.043	-0.014	-0.009	-0.024	8	6	2	2	0.0039	0.0057	0.0032	0.0099	0.0028	0.0071	
7615	1:15:42	+23 29 42	6.693	+0.047	+0.041	+0.058	-0.005	+0.052	5	4	1	1	0.0040	0.0045	0.0040	---	---	---	
44447	6:15:20	-71 42 00	6.641	+0.559	+0.019	+0.328	+0.313	+0.640	11	9	4	4	0.0057	0.0012	0.0021	0.0010	0.0020	0.0030	
38616	5:41:45	-67 24 41	7.067	-0.012	-0.054	+0.001	-0.022	-0.021	11	9	4	4	0.0045	0.0018	0.0060	0.0015	0.0020	0.0010	
39062	5:45:52	-61 14 02	7.409	+1.276	+1.387	+0.635	+0.563	+1.200	11	9	4	4	0.0030	0.0024	0.0033	0.0030	0.0020	0.0035	
38940	5:46:32	-45 39 17	7.417	+0.494	+0.049	+0.281	+0.277	+0.558	10	8	3	3	0.0025	0.0013	0.0022	0.0023	0.0017	0.0006	
37655	5:37:33	-42 58 50	7.436	+0.595	+0.071	+0.343	+0.338	+0.681	11	9	4	4	0.0021	0.0012	0.0024	0.0030	0.0015	0.0030	
39039	5:47:49	-34 55 38	7.296	+0.934	+0.662	+0.481	+0.443	+0.925	11	9	4	4	0.0018	0.0015	0.0021	0.0020	0.0040	0.0035	
37334	5:36:52	- 4 56 55	7.150	-0.160	-0.776	-0.066	-0.085	-0.151	11	9	4	4	0.0063	0.0024	0.0039	0.0040	0.0020	0.0045	
36898	5:34:11	- 0 07 23	7.169	-0.085	-0.449	-0.031	-0.054	-0.085	10	8	4	4	0.0044	0.0025	0.0028	0.0015	0.0035	0.0040	1
37981	5:42:08	+14 09 59	6.731	+1.096	+1.013	+0.579	+0.511	+1.090	11	9	4	4	0.0036	0.0030	0.0042	0.0050	0.0030	0.0070	
37557	5:39:38	+28 58 26	7.033	+1.154	+0.959	+0.609	+0.534	+1.143	11	9	4	4	0.0063	0.0033	0.0054	0.0050	0.0090	0.0100	2
37352	5:38:17	+30 08 24	7.709	+0.115	-0.147	+0.117	+0.086	+0.200	8	7	3	3	0.0110	0.0042	0.0067	0.0058	0.0012	0.0075	2
101727	11:40:52	-76 58 05	6.938	+0.394	-0.055	+0.241	+0.234	+0.475	9	5	1	1	0.0037	0.0023	0.0040	---	---	---	
102155	11:44:12	-73 03 54	6.943	+1.387	+1.253	+0.710	+0.651	+1.361	9	5	1	1	0.0023	0.0027	0.0043	---	---	---	
101105AB	11:36:50	-61 24 01	7.161	+0.002	-0.629	+0.038	+0.024	+0.062	9	5	1	1	0.0027	0.0017	0.0033	---	---	---	
101408	11:39:10	-45 43 21	7.247	+1.027	+0.787	+0.536	+0.491	+1.027	7	4	1	1	0.0034	0.0008	0.0011	---	---	---	
102540	11:47:21	-35 07 58	7.101	+0.752	+0.227	+0.421	+0.398	+0.819	9	5	1	1	0.0030	0.0020	0.0020	---	---	---	
106515AB	12:14:22	- 7 10 23	7.354	+0.814	+0.451	+0.437	+0.389	+0.826	9	5	1	1	0.0030	0.0023	0.0010	---	---	---	
106542	12:14:29	+17 00 13	6.819	+1.184	+1.165	+0.591	+0.528	+1.120	9	5	1	1	0.0037	0.0017	0.0023	---	---	---	
107146	12:18:22	+16 38 57	7.028	+0.602	+0.073	+0.330	+0.313	+0.642	9	5	1	1	0.0023	0.0020	0.0023	---	---	---	
101906	11:43:02	+24 05 14	7.411	+0.858	+0.450	+0.475	+0.438	+0.914	9	5	1	1	0.0043	0.0040	0.0030	---	---	---	2
102056	11:43:58	+28 44 37	7.024	-0.002	+0.027	-0.004	-0.004	-0.009	9	5	1	1	0.0047	0.0037	0.0037	---	---	---	2
165861	18:12:40	-70 45 17	6.718	-0.029	-0.350	+0.002	+0.005	+0.006	8	5	2	2	0.0042	0.0018	0.0028	0.0049	0.0021	0.0035	
162702	17:55:36	-65 06 40	7.299	+1.214	+1.278	+0.618	+0.543	+1.163	8	5	2	2	0.0014	0.0007	0.0025	0.0007	0.0035	0.0021	
164427	18:03:26	-59 12 32	6.887	+0.607	+0.112	+0.339	+0.319	+0.659	8	5	2	2	0.0028	0.0042	0.0007	0.0035	0.0014	0.0028	
159868	17:37:57	-43 07 46	7.257	+0.710	+0.222	+0.399	+0.372	+0.771	8	5	2	2	0.0042	0.0018	0.0007	0.0028	0.0057	0.0035	
159656	17:36:48	-42 33 02	7.168	+0.641	+0.130	+0.357	+0.332	+0.685	20	12	13	9	0.0018	0.0018	0.0025	0.0017	0.0017	0.0014	
163800	17:56:50	-22 30 44	6.991	+0.263	-0.754	+0.206	+0.221	+0.427	6	4	2	2	0.0049	0.0012	0.0016	0.0007	0.0071	0.0071	
163801	17:58:14	-27 07 14	9.312	+0.455	+0.228	+0.281	+0.285	+0.566	7	4	1	1	0.0049	0.0030	0.0034	---	---	---	
163153	17:54:09	- 7 43 53	6.926	+0.759	+0.415	+0.405	+0.354	+0.759	9	5	2	2	0.0040	0.0007	0.0027	0.0021	0.0042	0.0014	
161223	17:43:20	+ 6 04 02	7.435	+0.326	+0.180	+0.216	+0.236	+0.451	8	5	2	2	0.0060	0.0025	0.0028	0.0099	0.0071	0.0028	
161198	17:42:40	+21 38 24	7.521	+0.745	+0.284	+0.451	+0.415	+0.867	8	5	2	2	0.0007	0.0039	0.0035	0.0212	0.0198	0.0014	
161817	17:46:05	+25 46 16	6.982	+0.147	+0.138	+0.123	+0.143	+0.266	8	5	2	2	0.0028	0.0064	0.0035	0.0247	0.0276	0.0028	

1. HD 36898 has a companion estimated at $\theta \sim 278°$, $\rho \sim 10''$, $\Delta m \sim 1$ magn.; for the companion, V = 9.884, (B-V) = +0.193, and (U-B) = +0.032.
2. All observations were obtained at an air mass near to or greater than 2.0.

TABLE III. 0.9-m declination check stars.

Star	α (1985)	δ	V	B-V	U-B	V-R	R-I	V-I	n	m	N	M	Mean Errors of the Mean						Notes
													V	B-V	U-B	V-R	R-I	V-I	
200 1172	0:25:09	-74 17 08	11.981	+0.506	+0.008	+0.287	+0.315	+0.602	10	6	3	3	0.0035	0.0025	0.0016	0.0046	0.0121	0.0087	
200 1173	0:25:10	-74 13 34	12.341	+0.581	+0.089	+0.326	+0.289	+0.615	9	6	3	3	0.0027	0.0017	0.0060	0.0046	0.0370	0.0393	
199 828	22:58:17	-60 07 11	13.420	+0.732	+0.211	+0.383	+0.366	+0.750	7	5	3	3	0.0045	0.0034	0.0091	0.0035	0.0185	0.0173	
199 835	22:58:42	-60 07 29	11.922	+0.964	+0.680	+0.522	+0.495	+1.018	9	6	3	3	0.0027	0.0047	0.0047	0.0040	0.0035	0.0069	
187 460	23:48:38	-44 47 22	11.733	+0.945	+0.646	+0.500	+0.480	+0.980	9	6	3	3	0.0030	0.0023	0.0027	0.0046	0.0064	0.0035	
187 468	23:49:02	-44 50 58	11.828	+1.162	+1.164	+0.703	+0.577	+1.281	9	6	3	3	0.0040	0.0043	0.0027	0.0012	0.0075	0.0081	
140 84	0:02:51	-28 46 50	11.961	+0.668	+0.136	+0.379	+0.363	+0.741	9	6	3	3	0.0030	0.0017	0.0027	0.0012	0.0035	0.0040	
140 85	0:02:52	-28 42 31	12.223	+0.718	+0.204	+0.395	+0.368	+0.763	9	6	3	3	0.0070	0.0050	0.0053	0.0075	0.0035	0.0040	
116 99	0:16:54	-13 58 42	12.133	+0.731	+0.337	+0.382	+0.357	+0.739	9	6	3	3	0.0060	0.0053	0.0063	0.0052	0.0075	0.0115	
116 180	0:17:19	-14 02 21	12.248	+0.433	-0.027	+0.254	+0.268	+0.522	9	6	3	3	0.0027	0.0047	0.0050	0.0058	0.0040	0.0058	
115 268	23:41:44	+00 47 11	12.487	+0.637	+0.076	+0.361	+0.353	+0.714	9	6	3	3	0.0040	0.0040	0.0063	0.0035	0.0075	0.0075	
115 486	23:40:47	+ 1 11 45	12.481	+0.489	-0.041	+0.291	+0.308	+0.599	9	6	3	3	0.0040	0.0047	0.0057	0.0040	0.0052	0.0064	
68 216	0:17:31	+15 44 18	12.413	+0.576	-0.026	+0.333	+0.359	+0.692	9	6	3	3	0.0057	0.0037	0.0110	0.0058	0.0104	0.0092	
68 280	0:17:18	+15 49 20	11.259	+0.877	+0.510	+0.475	+0.422	+0.899	8	5	2	2	0.0060	0.0046	0.0064	0.0028	0.0049	0.0028	
44 28	0:28:17	+30 18 11	11.327	+0.738	+0.218	+0.393	+0.368	+0.762	9	6	3	3	0.0067	0.0027	0.0133	0.0052	0.0087	0.0040	1
44 113	0:28:50	+30 18 20	11.706	+1.206	+1.027	+0.663	+0.568	+1.234	9	6	3	3	0.0027	0.0030	0.0260	0.0035	0.0058	0.0098	1
202 724	8:30:20	-75 13 45	12.492	+1.269	+1.184	+0.710	+0.660	+1.370	9	6	3	3	0.0033	0.0043	0.0267	0.0029	0.0035	0.0017	
202 728	8:30:30	-75 13 42	13.155	+0.446	+0.171	+0.277	+0.289	+0.565	10	6	4	3	0.0047	0.0079	0.0089	0.0115	0.0225	0.0295	
192 1174	9:26:50	-60 30 28	12.254	+0.692	+0.134	+0.403	+0.398	+0.801	9	6	3	3	0.0037	0.0043	0.0043	0.0017	0.0035	0.0023	
192 2289	9:26:49	-60 32 30	12.008	+0.549	+0.158	+0.345	+0.346	+0.691	6	5	3	3	0.0041	0.0057	0.0049	0.0023	0.0046	0.0023	2
172 1500	8:43:42	-45 34 12	11.590	+1.968	+2.210	+1.347	+1.475	+2.821	9	6	3	3	0.0167	0.0037	0.0357	0.0035	0.0139	0.0167	3
172 1502	8:43:43	-45 35 32	11.893	+0.806	+0.332	+0.468	+0.441	+0.908	11	7	3	3	0.0051	0.0027	0.0066	0.0040	0.0075	0.0058	
148 1245	8:00:51	-30 31 20	12.628	+0.522	+0.174	+0.325	+0.300	+0.624	9	6	3	3	0.0037	0.0050	0.0070	0.0092	0.0087	0.0150	
148 1260	8:00:55	-30 31 31	12.268	+0.281	+0.100	+0.189	+0.201	+0.389	9	6	3	3	0.0020	0.0027	0.0040	0.0069	0.0035	0.0069	
124 970	8:18:10	-15 39 35	11.855	+0.938	+0.573	+0.526	+0.502	+1.028	11	7	3	3	0.0057	0.0033	0.0069	0.0040	0.0040	0.0081	
124 972	8:18:11	-15 38 07	12.137	+0.509	+0.031	+0.310	+0.285	+0.595	11	7	3	3	0.0039	0.0012	0.0042	0.0035	0.0052	0.0069	
100 267	8:52:32	-00 38 05	13.028	+0.486	-0.033	+0.306	+0.297	+0.603	11	7	3	3	0.0060	0.0045	0.0048	0.0092	0.0046	0.0046	
100 269	8:52:33	-00 37 44	12.350	+0.557	-0.011	+0.332	+0.329	+0.661	11	7	3	3	0.0048	0.0030	0.0060	0.0006	0.0098	0.0092	
76 280	8:20:11	+14 48 19	12.669	+0.916	+0.715	+0.536	+0.469	+1.004	11	7	3	3	0.0060	0.0042	0.0096	0.0046	0.0069	0.0104	
76 281	8:20:16	+14 47 05	12.242	+0.518	+0.041	+0.299	+0.300	+0.598	11	7	3	3	0.0060	0.0030	0.0036	0.0023	0.0023	0.0046	
52 56	8:29:56	+29 17 06	13.188	+0.640	+0.116	+0.379	+0.401	+0.779	9	6	3	3	0.0117	0.0133	0.0127	0.0087	0.0046	0.0133	1
52 193	8:29:52	+29 23 35	12.413	+0.450	-0.000	+0.274	+0.304	+0.577	13	7	3	3	0.0067	0.0042	0.0042	0.0052	0.0064	0.0092	1
204 2533	16:11:41	-75 29 12	12.012	+0.943	+0.615	+0.513	+0.480	+0.994	11	8	5	5	0.0072	0.0045	0.0066	0.0045	0.0045	0.0067	
204 2545	16:11:49	-75 31 26	12.063	+0.447	-0.011	+0.288	+0.287	+0.574	11	8	5	5	0.0060	0.0027	0.0042	0.0036	0.0085	0.0103	
196 1795	17:09:47	-60 06 12	11.998	+1.325	+1.469	+0.680	+0.579	+1.260	10	7	4	4	0.0032	0.0041	0.0187	0.0045	0.0065	0.0040	
196 1801	17:09:48	-60 05 22	12.755	+0.649	+0.105	+0.399	+0.368	+0.767	10	7	4	4	0.0038	0.0041	0.0070	0.0020	0.0085	0.0065	
180 1618	16:52:14	-45 06 18	12.050	+0.538	+0.187	+0.332	+0.337	+0.668	10	7	4	4	0.0051	0.0041	0.0060	0.0035	0.0060	0.0075	
180 1644	16:52:22	-45 06 28	11.824	+0.926	-0.134	+0.598	+0.623	+1.220	10	7	4	4	0.0038	0.0041	0.0060	0.0030	0.0075	0.0060	
156 622	16:27:28	-29 56 10	11.576	+0.806	+0.278	+0.474	+0.454	+0.929	8	6	4	4	0.0046	0.0032	0.0067	0.0080	0.0025	0.0100	
156 639	16:27:34	-29 57 48	11.603	+0.543	+0.374	+0.322	+0.325	+0.647	8	6	4	4	0.0053	0.0032	0.0092	0.0025	0.0060	0.0065	
132 801	16:17:47	-15 06 42	10.839	+1.806	+2.098	+1.256	+1.468	+2.721	10	7	4	4	0.0114	0.0044	0.0196	0.0075	0.0060	0.0120	3
132 813	16:17:54	-15 07 43	11.486	+0.817	+0.339	+0.490	+0.467	+0.957	10	7	4	4	0.0038	0.0019	0.0060	0.0045	0.0045	0.0055	
108 1848	16:36:12	+00 07 44	11.707	+0.566	+0.076	+0.328	+0.321	+0.649	10	7	4	4	0.0035	0.0035	0.0038	0.0050	0.0040	0.0080	
108 1863	16:36:27	+00 04 20	12.229	+0.814	+0.419	+0.443	+0.409	+0.852	10	7	4	4	0.0028	0.0082	0.0104	0.0075	0.0060	0.0075	
84 332	16:15:58	+14 42 18	11.031	+1.046	+0.844	+0.535	+0.489	+1.026	8	6	4	4	0.0014	0.0042	0.0095	0.0040	0.0025	0.0055	
84 334	16:16:10	+14 43 59	11.996	+0.966	+0.634	+0.508	+0.490	+1.000	8	6	4	4	0.0053	0.0021	0.0057	0.0030	0.0025	0.0040	
61 225	17:01:45	+29 47 01	11.377	+1.109	+0.978	+0.597	+0.541	+1.141	8	6	4	4	0.0078	0.0046	0.0039	0.0025	0.0115	0.0120	1
61 228	17:01:50	+29 47 10	12.565	+0.659	+0.153	+0.395	+0.346	+0.743	8	6	4	4	0.0081	0.0053	0.0138	0.0060	0.0110	0.0180	1

1. All observations were obtained at an air mass greater than 2.0.
2. A companion is estimated to be at $\theta \sim 270°$ and $\rho \sim 8$ arc seconds; V = 14.42, (B-V) = +0.59, (U-B) = +0.13; one measurement.
3. Suspected light variable.

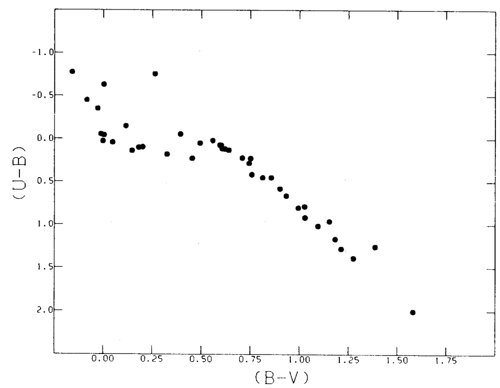


FIG. 1. The $(U-B)$,$(B-V)$ color-color plot for stars in Table II.

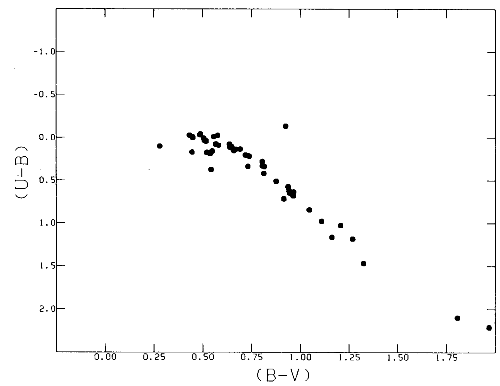


FIG. 3. The $(U-B)$,$(B-V)$ color-color plot for stars in Table III.

The magnitudes and color index numbers in columns 4–9 are mean values. Therefore, the corresponding mean errors of the mean are tabulated in columns 14–19. If the mean error for a single observation is needed for a quantity in columns 4–6, the reader need only multiply the corresponding number in columns 14–16 by the $\sqrt{n}$ from column 10. Similarly, if the mean error for a single observation is needed for any quantity in columns 7–9, multiply the corresponding number in columns 17–19 by the $\sqrt{N}$ from column 12.

The manner in which the final magnitudes and color indices were combined, yielding the values in columns 4–9, and the manner in which the errors were determined, given in columns 14–19, is stated in Landolt (1983), Section III.

Numbers in the final column indicate the presence of a footnote.

Perusal of the mean error column for the V magnitude indicates the presence of possible variable stars in Tables II and III.

Consider the 34 stars in Table II whose declination is less than 20°. The remaining seven stars in Table II always were observed at high air masses, and hence one might expect less accuracy. The average mean error of a single observation in V for these 34 stars was found to be $+0.0106 \pm 0.0038$. Hence, a two sigma error would be 0.018 magnitudes. If one then defines any star whose weighted mean error of a single observation is greater than 0.018 magnitude as being a possible variable star, then HD 37334 and HD 44447 are possible variable stars.

Similarly, consider Table III. Exclude the six stars at declinations near $+30°$, for they always were observed at air mass greater than 2.0. Also exclude SA132 801 and SA172 1500 whose mean errors in V, in comparison to other stars in the Table and with experience, show them to be variable in light. One finds for the remaining 40 stars the average mean error of a single observation to be $+0.0134 \pm 0.0046$. Therefore, a two sigma error would be 0.023 magnitudes. If one then again defines any star whose weighted mean error of a single observation is greater than 0.023 as being a star variable in light, one finds one possible candidate, SA204 2533. However, observing conditions were not always so good at $-75°$ declination; hence, it is quite possible that the star is constant in brightness.

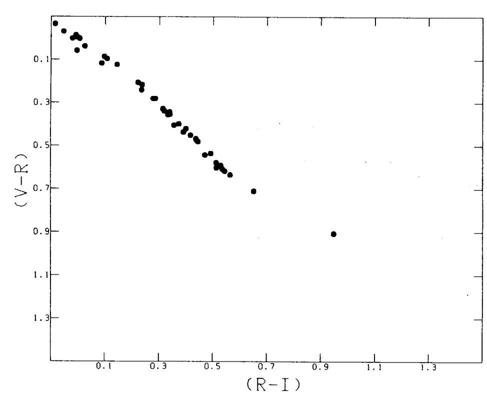


FIG. 2. The $(V-R)$,$(R-I)$ color-color plot for stars in Table II.

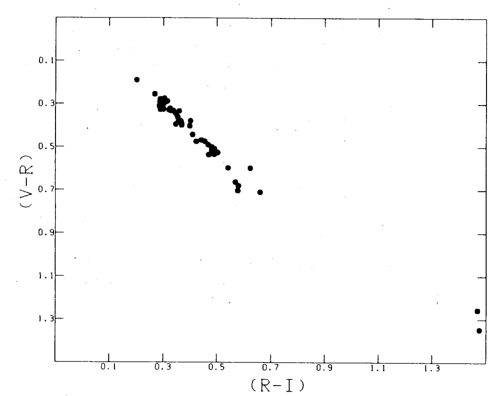


FIG. 4. The $(V-R)$,$(R-I)$ color-color plot for stars in Table III.

TABLE IV. Miscellaneous information for the 0.4-m stars.

HD	GC	BD/CoD/CPD	Spectral Type	μ_α	μ_δ	Radial Velocity	Remarks	Notes
222237	32863	-73° 2299	K4V	+0″130	-0″733	+70.2		1,2,3
222076	32838	-71° 2767	K1III	-0.073	+0.024			1
220896AB	32637	-51°13570	G6III	-0.017	-0.001		I 1059	4
221943	32819	-45°15080	A3III/IV	+0.082	-0.026	-13.3		2,4
219339	32364	-25°16354	A5V	-0.012	-0.029	-4(var.)		2,5
223963		-10° 6192	M1III			-34		2,5
219018	32312	+ 1° 4694	G5	+0.066	-0.142		ADS 16591	6
218155	32170	+14° 4929	A0V	+0.023	-0.006	+11.9		2,7
7615		+24° 204	A0					6
44447	8093	-71° 426	F8V	-0.026	+0.056		HR 2283	1
38616	7177	-67° 492	A2Ib/IIp	-0.014	0.000			1
39062	7269	-61° 517	K2IIICNII	-0.006	+0.021			1
38940	7270	-45° 2160	F5V	+0.068	+0.140	+35.5		2,4
37655	7040	-43° 1954	G0V	+0.101	+0.252	+33.5		2,4,8
39039	7302	-34° 2459	G6III	-0.015	-0.024	-4.6		2,9
37334	6996	- 5° 1342	B1.5IV	-0.001	0.000	+27.8		2,9
36898	6914	- 0° 1005	B7V	-0.015	-0.010	+10.1	ADS 4180	2,10
37981	7142	+14° 991	K1IV	-0.038	-0.012	+63.0		2,5
37557	7067	+28° 864	G5	-0.022	+0.009	-21.0		6
37352		+30° 966	B8V					11
101727	16062	-76° 686	F3V	+0.005	-0.015			1
102155	16116	-72° 1157	K1II	-0.005	-0.008			1
101105AB	15948	-60° 3195	B2III/IV	-0.027	-0.017	-18(var.)	I 421	1,2
101408	16011	-45° 7180	K0III	-0.037	-0.104	+28.1		2,4
102540	16174	-34° 7692	G5	-0.164	-0.070			6
106515AB	16729	- 6° 3532	G5V,G8V					2,10,12
106542	16732	+17° 2454	K2	-0.001	+0.005			6
107146	16796	+17° 2462	G2V	-0.172	-0.159	+5.7		2,9,13
101906	16094	+24° 2386	G2V	-0.012	-0.014	+5.3	ADS 8282	2,5
102056	16110	+29° 2206	A(m?)	-0.001	+0.023	-11.2		2,5
165861	24796	-70° 2507	B7/8II/III	-0.020	-0.021		HR 6774	1
162702		-65° 3532	K2III					1
164427	24564	-59° 7218	G0V	-0.211	-0.066	+3.3		1,2
159868	23898	-43°11901	G5V	-0.212	-0.162	-23.8		2,4,14
159656	23870	-42°12320	G2/3V	+0.176	-0.351	var.		2,4,15
163800	24456	-22° 4474	O8	-0.025	+0.010			5
163801		-27°12200	A5					6
163153	24356	- 7° 4523	G8IV	-0.057	-0.060			10
161223		+ 6° 3514	A2					6
161198	24055	+21° 3198	K0V	-0.141	-0.645			5,16
161817	24145	+25° 3344	A2VI(A2p:)	-0.063	-0.016			5

1. Houk and Cowley (1975).
2. R.v. from Abt and Biggs (1972).
3. No. 5721 in Jenkins (1963), π = +0″102.
4. Houk (1978).
5. Spectral cl., Jaschek et al. (1964).
6. Henry Draper Catalogue spectral type.
7. Spectral cl., Buscombe (1980).
8. No. 1296 in Jenkins (1963), π = +0″055.
9. Spectral cl., Kennedy and Buscombe (1974).
10. Spectral cl., Buscombe (1977).
11. Spectral cl., Bouigue et al. (1961).
12. HD 106515AB = GC 16729 (ft. = B) and GC 16730 (br. = A) = ADS 8477; for A, $\mu(\alpha)$ = -0″237, $\mu(\delta)$ = -0″061; for B: $\mu(\alpha)$ = -0″228, $\mu(\delta)$ = -0″076; No. 2819.2 in Jenkins (1963), wherein $\bar{\pi}$ = +0″036 for both components; r.v. of A is var.; r.v. of B = +18.6 km/sec (Abt and Biggs 1972).
13. No. 2836 in Jenkins (1963), π = +0″024.
14. No. 4002.1 in Jenkins (1963), π = 0″0.
15. Cape ZC 16473 = No. 4001 in Jenkins (1963), π = +0″039; No. 629 in Batten et al. (1978), sp. bin. with P = 10.09 days.
16. No. 4044 in Jenkins (1963), π = +0″047.
17. No. 4060.1 in Jenkins (1963), π = -0″003.

TABLE V. Absolute magnitudes for stars observed at 0.4-m telescope.

Star (HD) no.	Parallax catalogue no.	Absolute parallax	Standard error	V	M_V	Standard error in M_V
37655	1296.0	+ 0.0608	± 0.0180	7.436	+ 6.36	± 0.64
106515 AB	2819.2	+ 0.0409	± 0.0171	7.354	+ 5.41	± 0.91
107146	2836.0	+ 0.0235	± 0.0119	7.028	+ 3.88	± 1.10
159656	4001.0	+ 0.0460	± 0.0137	7.168	+ 5.48	± 0.65
159868	4002.1	+ 0.0064	± 0.0158	7.257	+ 1.29	± 5.36
161198	4044.0	+ 0.0455	± 0.0081	7.521	+ 5.81	± 0.39
161817	4060.1	+ 0.0071	± 0.0069	6.982	+ 1.24	± 2.11
222237	5721.0	+ 0.1107	± 0.0088	7.092	+ 7.31	± 0.17

There are more than nine *UBV* measures, on the average, for each star in Tables II and III. However, there are only about three measures in *RI* for each star. Although the magnitudes and color indices for these stars were obtained during the same observing sessions as the standard star results in Landolt (1983), these objects overall have not been measured often enough to be used as standard stars. The *UBV* portions of Tables II and III could, however, if one were desperate for standard stars, be used as such. On the other hand, if one needs standard stars at southerly declinations, there are the beautiful and highly accurate bright standards of Cousins (1973,1976) and the fainter standard stars of Graham (1982).

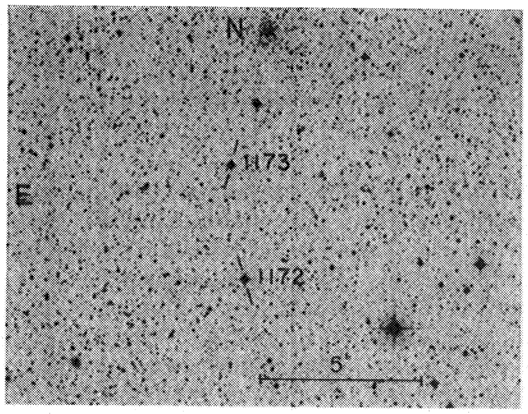
Table IV and its footnotes contain a collection of miscellaneous information for the stars observed at the 0.4-m telescope. Not listed are the many photometric measures as tabulated in Blanco *et al.* (1968). The latter compilation is a heterogeneous sample, tied into the *UBV* system, but from a variety of observing programs. Nevertheless, the *V* magnitudes in Table II were compared to the *V* magnitudes tabulated by Blanco *et al.* (1968). The stars HD 223963 and HD 36898 were excluded since a visual comparison of the numbers strongly suggests variability in light. A 0^m05 difference for HD 101906 was discounted, since it always was observed at a high air mass. A study of the remaining 37 stars showed, in the sense Blanco *et al.* *minus* Table II, $V = -0.010 \pm 0.017$.

Three stars in Table II, therefore, may be variable in light. HD 37334 and HD 44447 may be variable over the short term during which the data in Table II were gathered. HD 223963 may be variable over a longer period of the years between the Blanco *et al.* compilation and the data in Table II, not surprising since it is a late type star. On the other hand, HD 36898 probably is not variable. If one combines the *V* magnitude for HD 36898 as tabulated in Table II, $V = 7.169$, with the magnitude of its

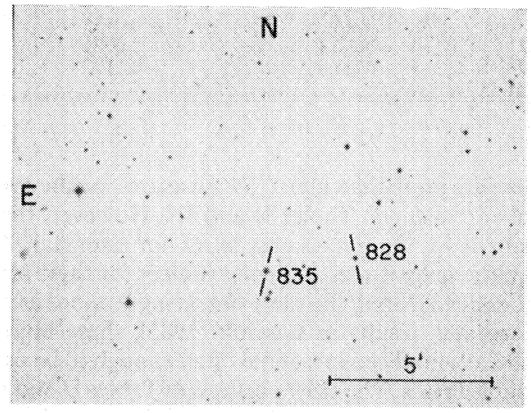
TABLE VI. Miscellaneous information for stars observed at 0.9-m telescope.

Star	Knox-Shaw Barrett no.	Potsdam DM no.	BSD no.	BSD/PD sp. type	μ_x (Units of 0″001)	μ_y (Units of 0″001)	Notes
115 268	30	—	326	dG5	− 12	+ 4	
115 486	12	—	316	G5	+ 4	+ 7	
68 216	175	—	485	G0	+ 2	+ 1	
68 280	162	—	483	d:G5	+ 10	+ 21	
44 28	106	—	427	G4	− 2	− 22	
44 113	150	—	440	d::K0	− 8	− 3	
100 267	96	—	560	—	− 14	+ 14	
100 269	99	—	562	G0:	+ 5	+ 1	
76 280	189	—	1461	G5	+ 23	− 14	
76 281	202	—	1464	G2p	− 9	− 8	1
52 26	—	—	—	—	—	—	
52 193	59	—	426	G0	+ 5	+ 5	
156 622	—	227	—	K0	—	—	
156 639	—	229	—	A5	—	—	
132 801	—	329	—	G5	—	—	
132 813	—	334	—	G1	—	—	
108 1848	—	—	864	G0	—	—	
108 1863	—	—	870	dG5	—	—	
84 332	102	—	444	K0	+ 7	− 2	
84 334	117	—	448	G7	+ 5	+ 1	
61 225	78	—	449	K0	+ 1	+ 2	
61 228	85	—	451	G7	+ 8	− 10	

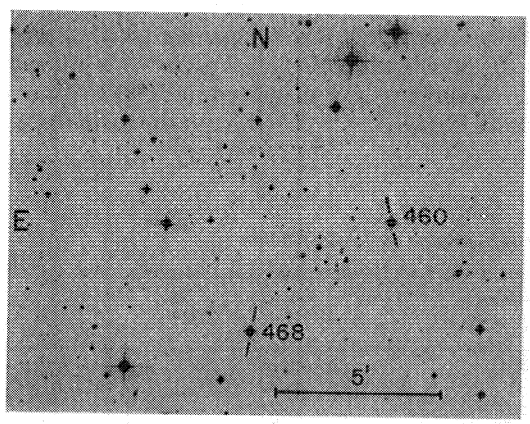
1. The BSD indicates that this star has a variable spectrum.



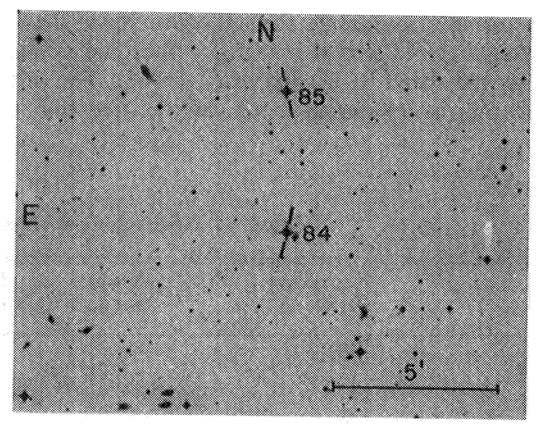
(a) SA 200 1173 and 200 1172



(b) SA 199 835 and 199 828



(c) SA 187 468 and 187 460



(d) SA 140 85 and 140 84

FIG. 5. (a) The field of SA200 1172 and 200 1173. (b) The field of SA199 835 and 199 828. (c) The field of SA187 468 and 187 460. (d) The field of SA140 85 and 140 84. Copyright *ESO/SRC Atlas of the Southern Sky*.

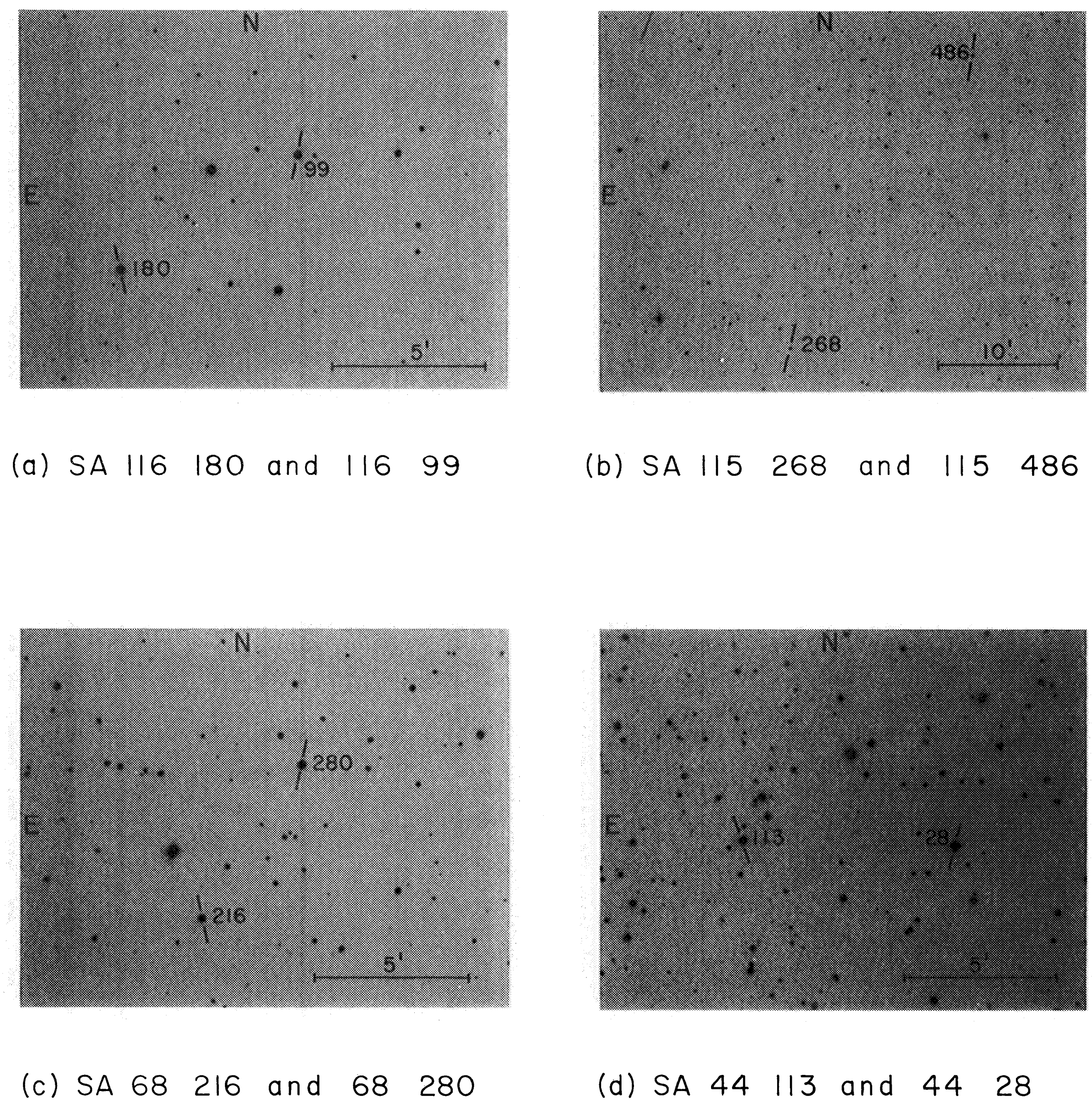


FIG. 6. (a) The field of SA116 180 and 116 99. (b) The field of SA115 268 and 115 486. (c) The field of SA68 216 and 68 280. (d) The field of SA44 113 and 44 28. Copyright *National Geographic Society-Palomar Observatory Sky Survey*.

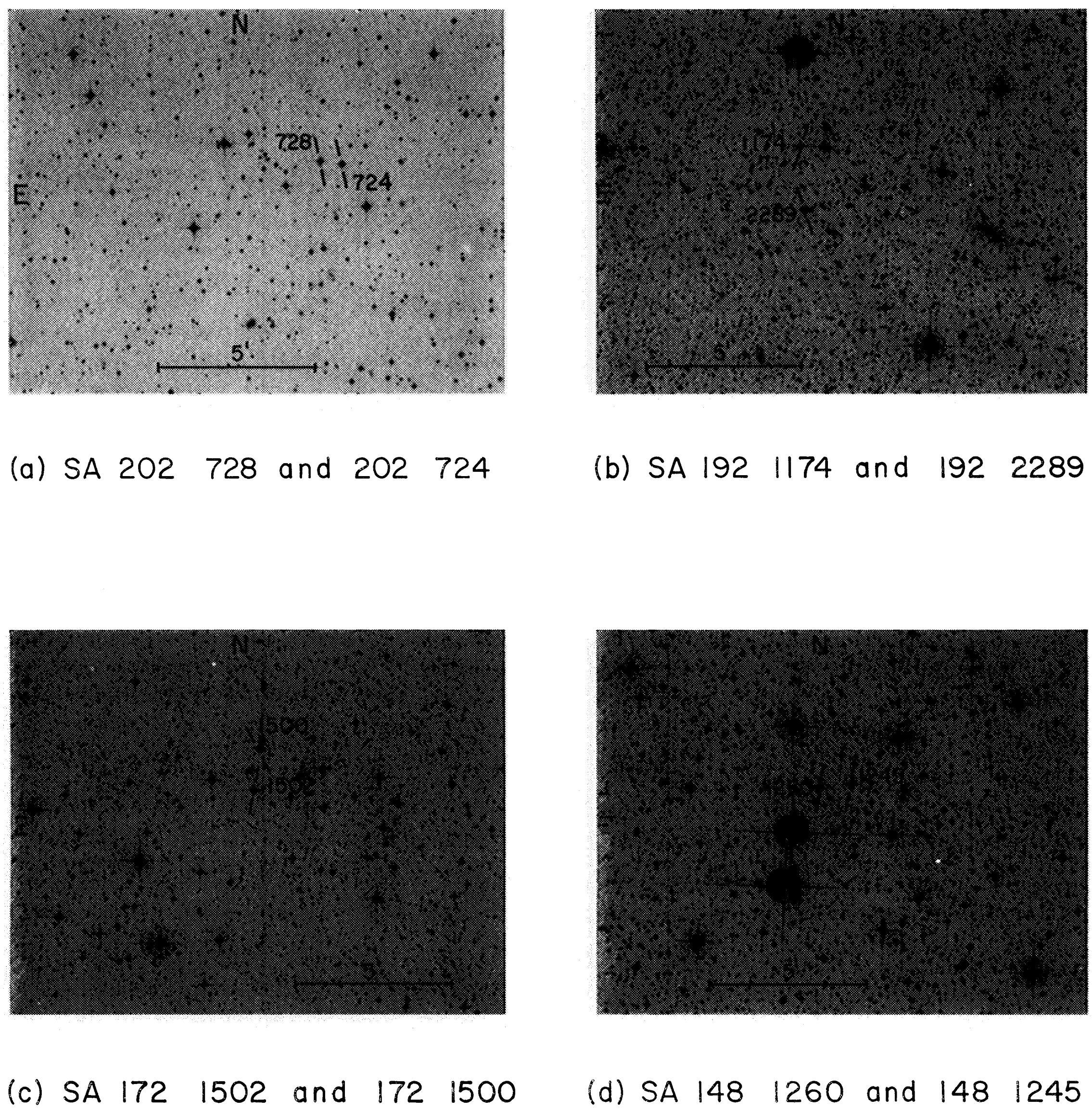
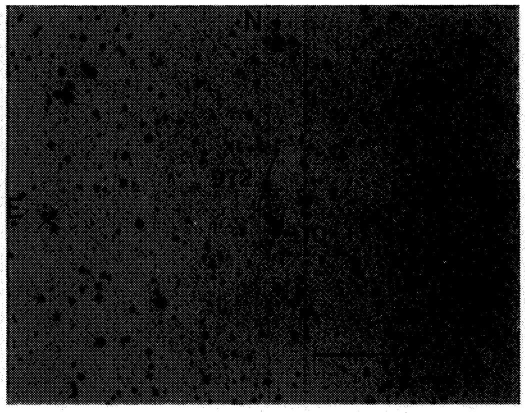
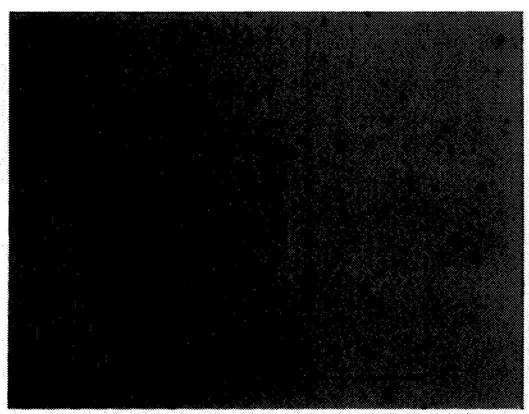


FIG. 7. (a) The field of SA202 728 and 202 724. (b) The field of SA192 1174 and 192 2289. (c) The field of SA172 1502 and 172 1500. (d) The field of SA148 1260 and 148 1245. Copyright *ESO /SRC Atlas of the Southern Sky*.



(a) SA 124 972 and 124 970

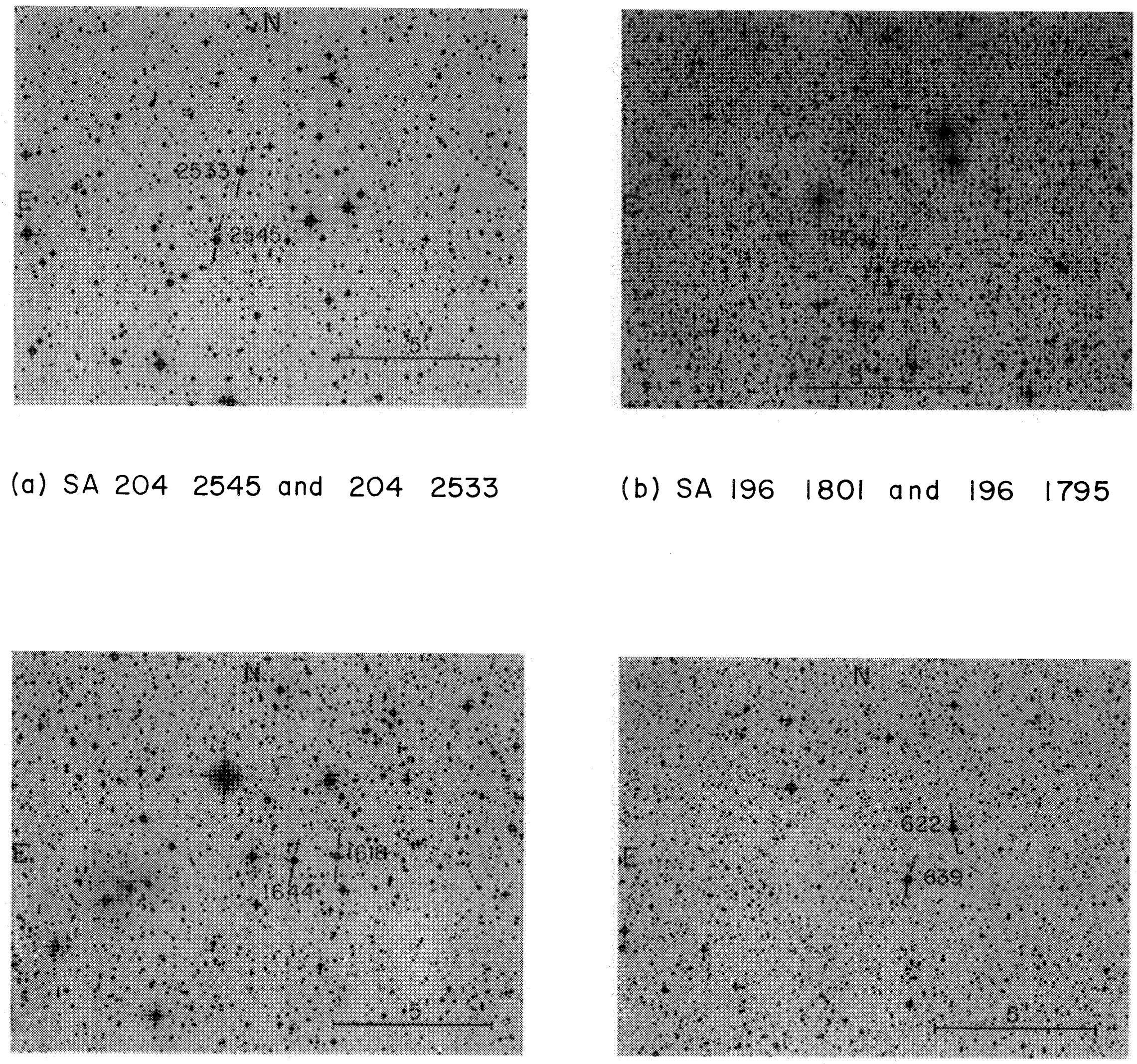
(b) SA 100 269 and 100 267



(c) SA 76 281 and 76 280

(d) SA 52 56 and 52 193

FIG. 8. (a) The field of SA 124 972 and 124 970. (b) The field of SA 100 269 and 100 267. (c) The field of SA 76 281 and 76 280. (*d*) The field of SA 52 56 and 52 193. Copyright *National Geographic Society-Palomar Observatory Sky Survey*.



(a) SA 204 2545 and 204 2533

(b) SA 196 1801 and 196 1795

(c) SA 180 1644 and 180 1618

(d) SA 156 639 and 156 622

FIG. 9. (a) The field of SA204 2545 and 204 2533. (b) The field of SA196 1801 and 196 1795. (c) The field of SA180 1644 and 180 1618. (d) The field of SA156 639 and 156 622. Copyright *ESO/SRC Atlas of the Southern Sky.*

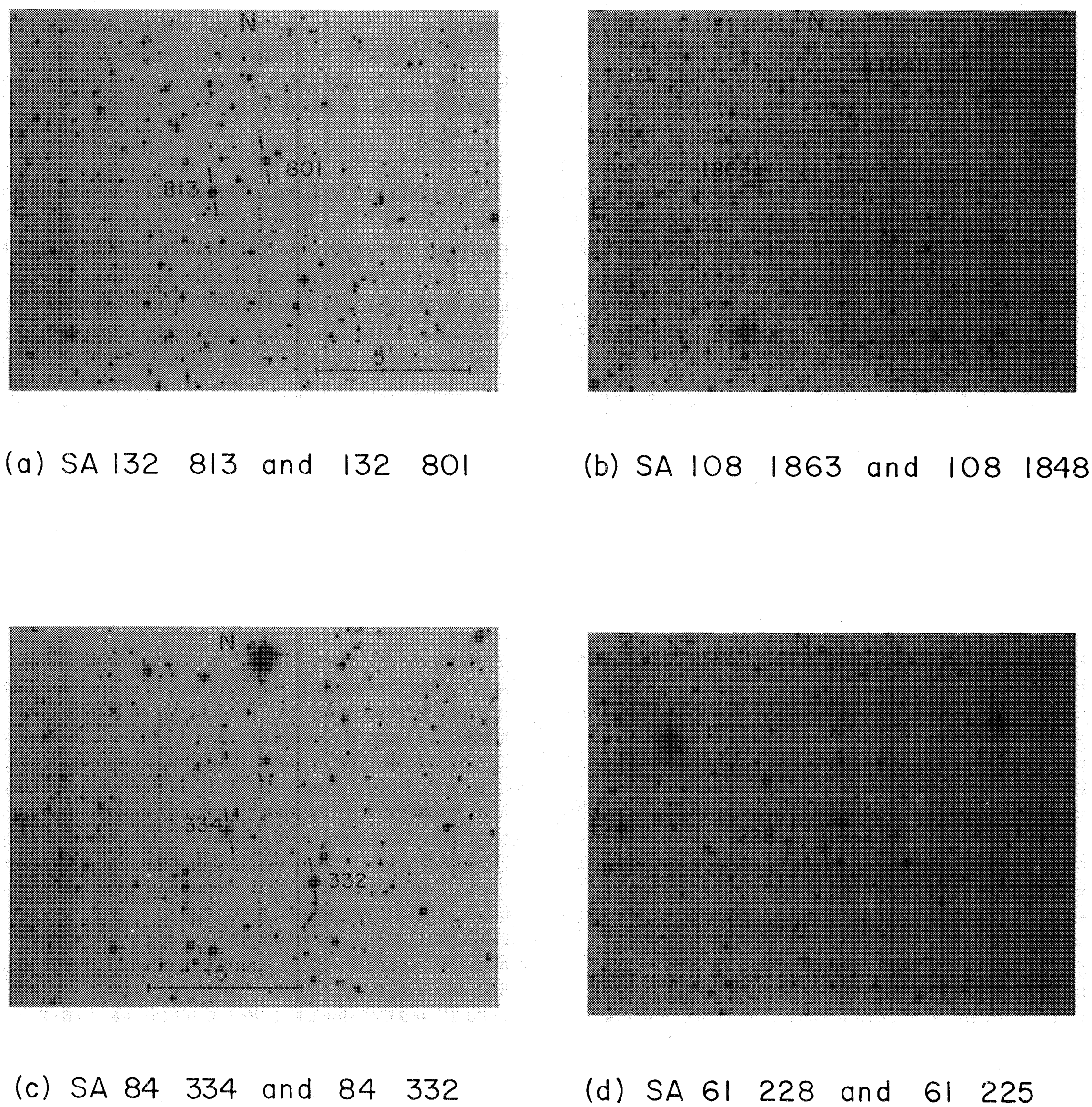


FIG. 10. (a) The field of SA132 813 and 132 801. (b) The field of SA108 1863 and 108 1848. (c) The field of SA84 334 and 84 332. (d) The field of SA61 228 and 61 225. Copyright *National Geographic Society-Palomar Observatory Sky Survey.*

companion, $V=9.884$, one finds $V=7.083$ for the combined light of the pair. This agrees well with the value of $V=7.09$ due to Hardie *et al.* (1964), whose results were quoted by Blanco *et al.* 1(968). It is highly possible, therefore, that Hardie *et al.* measured and tabulated the light of both stars. The colors agree, too, within 0.01 magnitude.

Absolute trigonometric parallaxes are known for eight stars in Table II. The parallax values have been taken from newly compiled data (van Altena 1982). The absolute magnitudes in the sixth column follow through application of the V magnitudes in the fifth column and $M_V = m_V + 5 + 5 \log p$. Differentiation of this relation gives $dM_V = 2.17\, dp/p$. Therefore, the data in the third and fourth columns provide numbers to calculate the standard error listed in the last column in Table V. As is evident, the parallaxes and hence absolute magnitudes for 2836.0, 4002.1, and 4060.1 are not reliable.

Miscellaneous information for the stars observed at the 0.9-m telescope has been collected in Table VI. Numbers in the fourth column are *Bergedorfer Spektral Durchmusterung* (BSD) identification numbers; the Selected Area digits have been omitted, as they appear in the first column. Column 5 gives the BSD spectral type. Proper motion values in units of 0\.″001 per year were taken from Knox-Shaw and Barrett (1934). A search was made for information for stars with southern declinations in the *Potsdam Spektral Durchmusterung* (PSD). Spectral types for only four stars were found; the PSD does not reach as faint magnitudes in general as the BSD. There is little correlation between the PSD spectral types and the color indices in Table III.

The original finding charts that were used at the telescope were taken from the *Atlas of Harvard-Groningen Selected Areas* by A. Brun and H. Vehrenberg. In some areas, though, these charts did not show enough faint stars to eliminate identification problems at the telescope for the fainter stars.Hence, finding charts are given herein for all stars in Table III; see Figs. 5–10.

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REFERENCES

Abt, H. A., and Biggs, E. S. (1972). *Bibliography of Stellar Radial Velocities* (Kitt Peak National Observatory, Tucson, Arizona).

Batten, A. H., Fletcher, J. M., and Mann, P. J. (1978). Publ. Dom. Astrophys. Obs. **15**.

Blanco, V. M., Demers, S., Douglass, G. G., and FitzGerald, M. P. (1968). Publ. U. S. Naval Observatory, Second Series, **21**.

Bouigue, R., Boulon, J., and Pedoussant, A. (1961). Toulouse Ann. **28**, 33.

Buscombe, W. (1977). *General Catalogue of MK Spectral Classifications*, 3rd ed.

Buscombe, W. (1980). *General Catalogue of MK Spectral Classifications*, 4th ed.

Cousins, A. W. J. (1973). Mem. R. Astron. Soc. **77**, 223.

Graham, J. A. (1982). Publ. Astron. Soc. Pac. **94**, 244.

Hardie, R. H., Heiser, A. M., and Tolbert, C. R. (1964). Astrophys. J. **140**, 1472.

Houk, N. (1978). *Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars*, **2**.

Houk, N., and Cowley, A. P. (1975). *University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars*, **1**.

Jaschek, C., Coude, H., and de Sierra, A. C. (1964). *Catalogue of Stellar Spectra Classified in the Morgan-Keeman System* (La Plata).

Kennedy, P. M., and Buscombe, W. (1974). *MK Spectral Classifications Published Since Jaschek's La Plata Catalogue* (Evanston).

Knox-Shaw, K., and Barrett, H. G. Scott (1934). *The Radcliffe Catalogue of Proper Motions in the Selected Areas 1 to 115* (Oxford University Press, London).

Landolt, A. U. (1973). Astron. J. **78**, 959.

Landolt, A. U. (1983). Astron. J. **88**, 439.

Meurers, H., van Schewick, H., and Stangenberg, B. (1962). Veroff. U. Sternwarte zu Bonn, No. 60.

Schulte, D., and Crawford, D. (1961). Kitt Peak National Observatory Cont. No. 10.

van Altena, W. F. (1982). Private communication.