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UBV CCD standards in two galactic directions – II

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Abstract. Using CCD observations, photometric magnitudes have been obtained in two galatic directions at intermediate latitude. A total of 7 sub-fields in one direction ($l = 3°$, $b = 47°$) have been observed leading to photometric magnitudes for 52 stars. In the second direction ($l = 278°$, $b = 47°$) a total of 10 sub-fields have been observed yielding photometric magnitudes for 139 stars. The magnitude range covered is $13 < V < 19$.

Key words : CCD photometry—calibration—star counts

1. Introduction

The general problem of the evolution of Milky Way Galaxy can be studied only through large data sets analysed rigorously. Schmidt plates, because of their large field coverage, are capable of providing such data. However, to calibrate Schmidt plates photometrically, one has to have a number of photometric standards which cover the entire range of magnitudes and colours to be studied on the plates and in addition to this, the standards should be well spread over the surface of the plate so as to minimise geometrical effects. This paper is the second in a series of papers aimed at to provide photometric standards in two galactic directions selected by us as a part of our programme to study star counts in a few galactic directions.

In this paper we present photometric magnitudes obtained through CCD observations in two galactic directions at intermediate latitude centered at $\alpha_{2000} = 15^h20.5^m$, $\delta_{2000} = 2°4'$; $l_{II} = 3°$, $b_{II} = +47°$ (hereinafter called GC filed) and $\alpha_{2000} = 11^h43^m$; $\delta_{2000} = -12°40'$; $l_{II} = 278°$, $b_{II} = +47°$ (hereinafter called Ellipsoid field). The GC field lies in the direction of galactic centre

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which happens to contain globular cluster M5. The Ellipsoid field lies in the direction of galactic antirotation. The observed stars lie in the magnitude range 13<V<19.

2. Observations

The observations were obtained in UBV passbands using CCD systems at the f/13 Cassegrain focus of the 104-cm telescope of the Uttar Pradesh State Observatory, Nainital, India. The observations of GC field and few sub-fields of the Ellipsoid field have been carried out using the older CCD system of the Observatory consisting of a coated Thomson chip having 23 micron square 384 x 576 pixels. The chip covers an area of 2' x 3' at the Cassegrain focus of the 104-cm telescope of the Observatory. The details of the UPSO CCD system and filters used have been described by Mohan *et al.* (1991). The observations of remaining sub-fields of the Ellipsoid field have been obtained using the newly acquired Photometrics CCD system consisting of a coated Tektronix chip having 24 micron square 1024 x 1024 pixels. This chip covers an area of 6' x 6' at the Cassegrain focus of the 1-metre telescope of the Observatory.

A total of 7 sub-fields have been observed in the direction of GC field. The total exposure varies from 10 minutes in V to 60 minutes in U filter. The log of observations is given in table 1a and identification charts are given in figure 1.

For the Ellipsoid field, 10 sub-fields have been observed. For this field observations in R filter have also been carried out. The total exposure time varies from 5 minutes in R to 90 minutes in U filter. The log of observations is presented in table 1b and identification charts are given in figure 2.

We have sandwiched the exposures of each sub-field in each filter with exposure of a comparison field in the same filter. The comparison field was same for all the observed sub fields in each direction and lies in the region of observations. The observations were carried out within two hours of the meridian so that air mass change within a given sandwich was only marginal. The comparison fields were standardised using Landolt's stars (1983) on two different nights. A number of bias and twilight flat-field frames were also taken on several nights during the observing runs.

Table 1a. Log of observations of sub-fields in the GC direction.

Sub-field	Date of Observations	$\alpha_{(2000)}$	$\delta_{(2000)}$	Filters	Exposures UBV (in min)
1	06-5-1992	$15^h\ 12^m\ 26^s$	+02° 04.6'	UBV	60, 30, 15
2	12-5-1991	$15^h\ 12^m\ 47^s$	–0° 12.4'	BV	30, 20, 10
3	20-4-1991	$15^h\ 13^m\ 56^s$	+02° 33.6'	UBV	45, 30, 15
4	18-4-1991	$15^h\ 17^m\ 09^s$	+01° 13.1'	UBV	30, 20, 10
5	11-3-1991	$15^h\ 18^m\ 45^s$	+01° 30.4'	BV	20, 15
6	05-5-1992	$15^h\ 20^m\ 40^s$	–0° 23.4'	UBV	60, 30, 15
7	17-4-1991	$15^h\ 22^m\ 32^s$	+01° 31.6'	UBV	30, 25, 10

Table 1b. Log of observations of sub-fields in the ellipsoid direction.

Sub-field	Date of Observations	$\alpha_{(2000)}$	$\delta_{(2000)}$	Filters	Exposures UBVR (in min)
1	30-03-1993	$11^m\ 34^m\ 23^s$	−12°. 37.7'	UBVR	90,45,30,9
2	19-01-1994	$11^m\ 34^m\ 35^s$	−10 48.5	UBVR	90, 30, 25, 13
3	1-03-1992	$11^m\ 34^m\ 24^s$	−14 37.2	UBV	30, 45, 90
4	6-05-1992	$11^m\ 40^m\ 37^s$	−12 15.1	UBV	45, 30, 15
5	26-01-1993	$11^m\ 43^m\ 58^s$	−14 26.8	UBV	60, 35, 15
6	27-03-1993	$11^m\ 44^m\ 46^s$	−10 43.3	UBVR	30, 45, 20, 5
7	2-02-1992	$11^m\ 47^m\ 27^s$	−11 53.3	UBV	60, 40, 10
8	20-03-1993	$11^m\ 49^m\ 19^s$	−11 29.3	UBVR	55, 30, 12, 7
9	12-02-1994	$11^m\ 51^m\ 58^s$	−10 52.0	BVR	22, 11. 5, 10
10	29-03-1993	$11^m\ 52^m\ 33^s$	−12 37.3	UBVR	60, 40, 15, 9

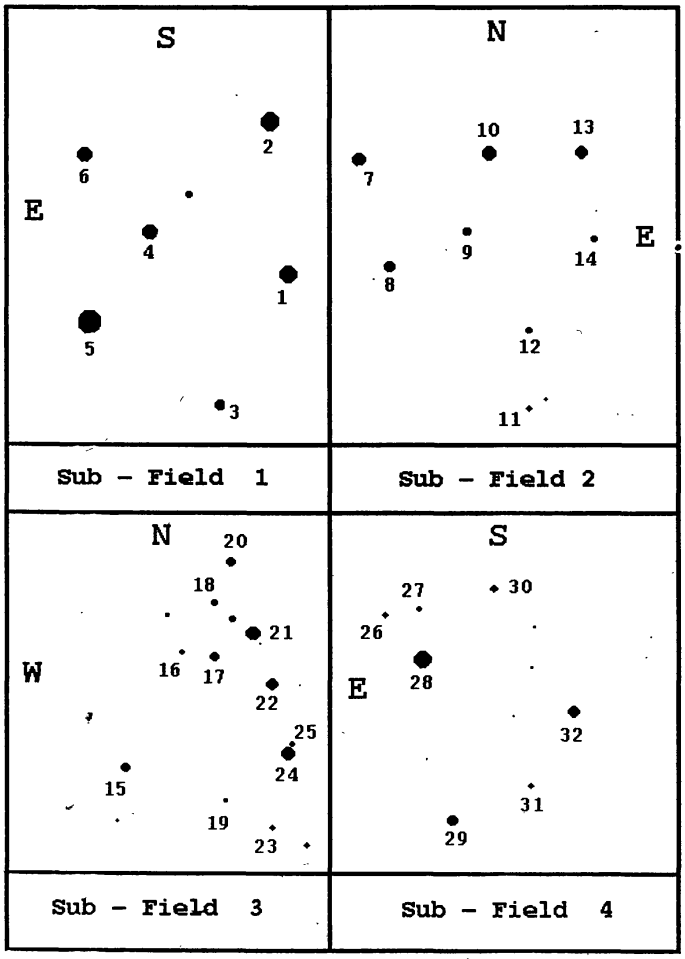


Figure 1 (a). Identification charts of the observed sub-fields in the GC field.

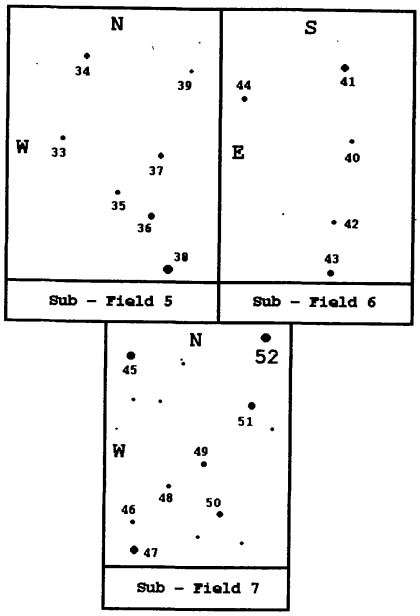


Figure 1 (b)

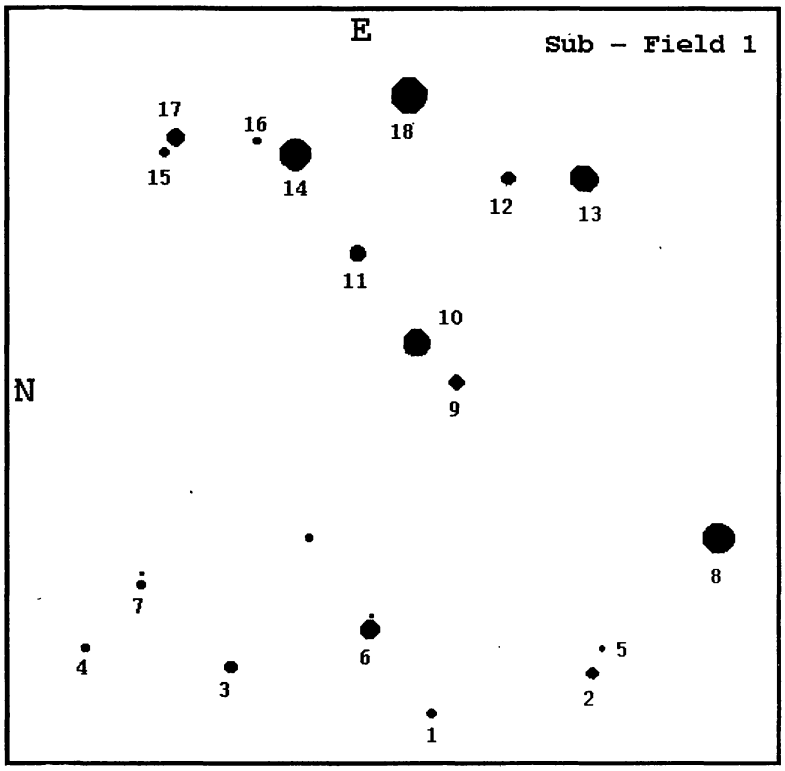


Figure 2 (a). Identification charts of the observed sub-fields in the ellipsoid direction.

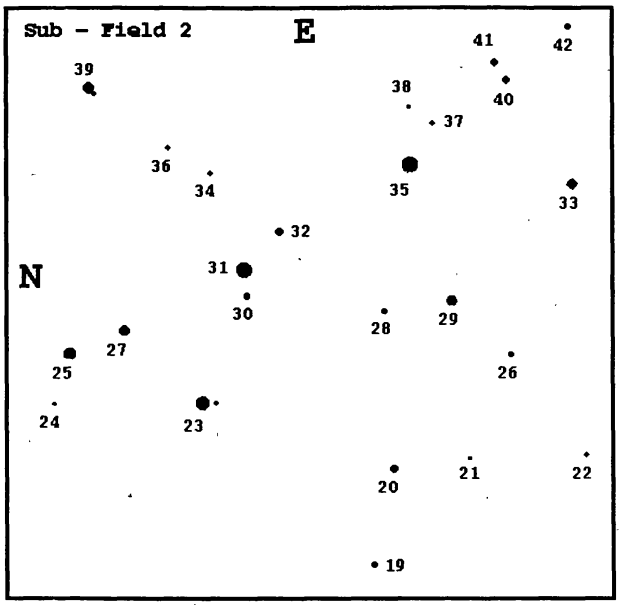


Figure 2 (b)

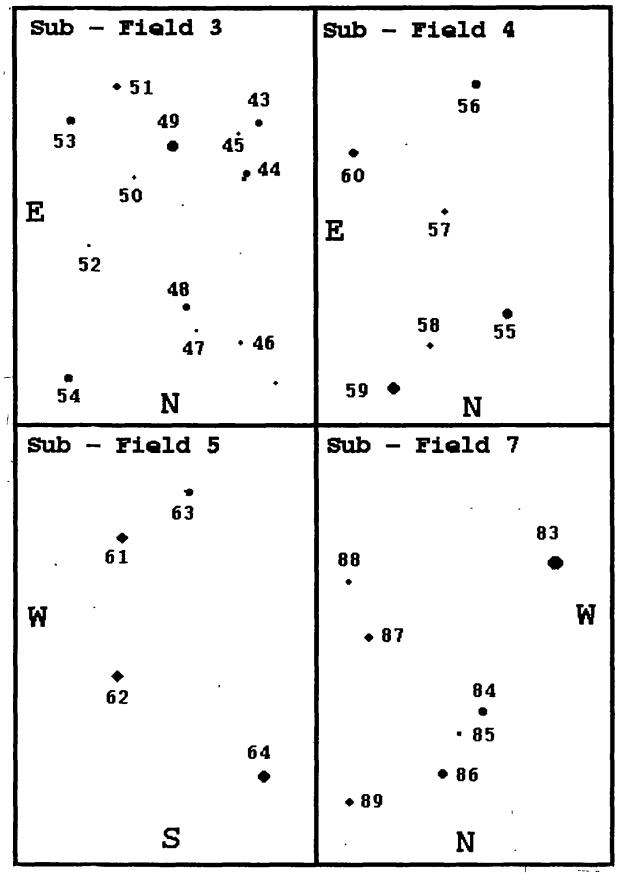
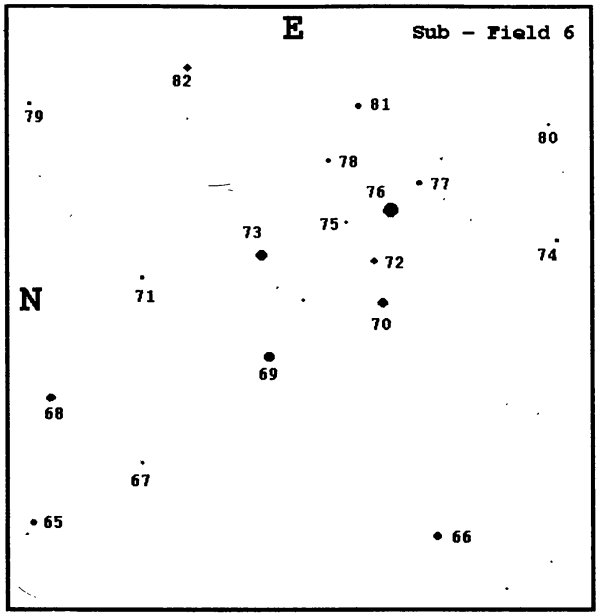


Figure 2 (c)



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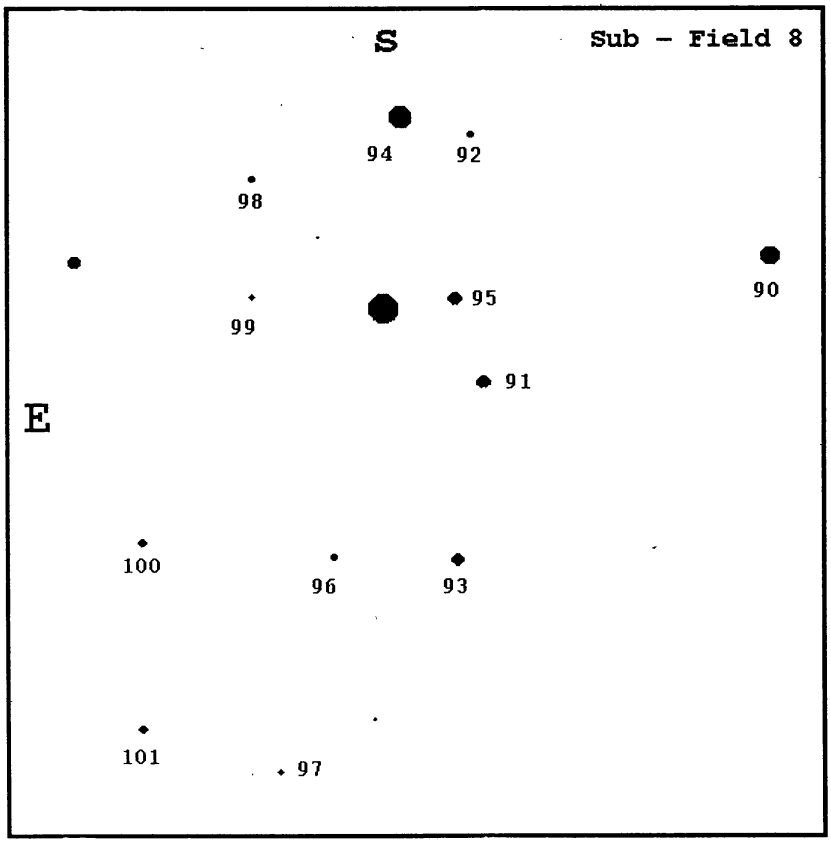

Figure 2 (e)

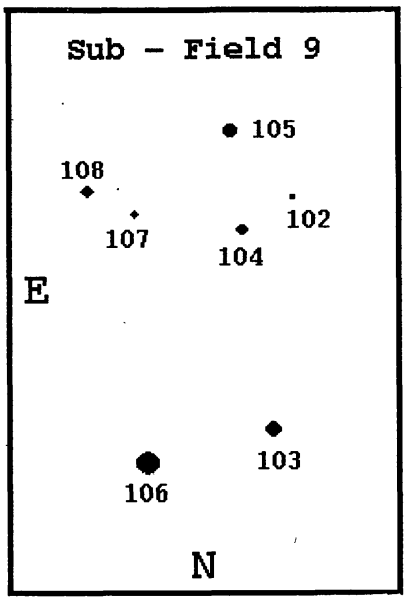

Figure 2 (f)

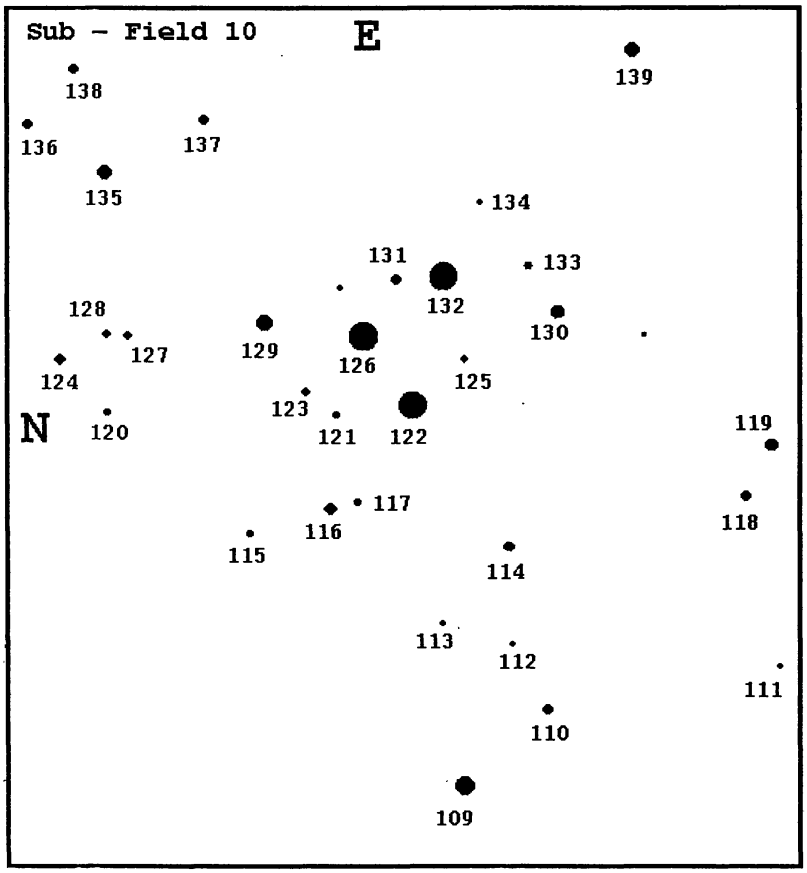

Figure 2 (g)

3. Data reduction

The data analysis was carried out using the computing facilities of the Observatory. The frames were cleaned employing the standard procedures using ESO MIDAS software running on VAX stations of the Observatory. Different clean frames of same field in same filter were co-added. Photometry was carried out on frames thus obtained using DAOPHOT photometric package by Stetson (1987). PSF was obtained for each frame and the PSF magnitudes were suitably tied to aperture photometry magnitudes. For comparison field only aperture photometry was obtained.

For each frame differential magnitudes and colours were obtained using the observed magnitudes of the comparison field. These differential magnitudes were then standardised using the transformation equations. Transformation equations used for the stars observed with the older CCD system have been obtained by Mohan *et al.* (1991)

$$\Delta (V - v) = -0.018\ \Delta (B - V) \quad (1)$$

$$\Delta (B - V) = 1.192\ \Delta (b - v) \quad (2)$$

$$\Delta (U - B) = 0.918\ \Delta (u - b) \quad (3)$$

$$\Delta (V - R) = 0.898\ \Delta (v - r) \quad (4)$$

For observations carried out with the new CCD system the transformation equations are as follows :

$$\Delta (V - v) = -0.020\ \Delta (B - V) \quad (5)$$

$$\Delta (B - V) = 1.116\ \Delta (b - v) \quad (6)$$

$$\Delta (U - B) = 0.919\ \Delta (u - b) \quad (7)$$

$$\Delta (V - R) = 0.994\ \Delta (v - r) \quad (8)$$

The precision of photometric measures varies from 0.02 mag. for $V = 13$ mag to 0.10 mag for $V = 19$ mag.

In table 2 we have listed the identification numbers, V, (B-V) and (U-B) for each star observed in the GC field. A total of 52 stars have V and (B-V) magnitudes while for only 29 stars (U-B) magnitudes could be obtained for this field. In table 3, the identification numbers, co-ordinates (epoch 2000), V, (B-V), (U-B) and (V-R) for each star observed for the Ellipsoid field have been listed. A total of 139 stars have been observed. While all the stars have V and (B-V) magnitudes, (U-B) magnitudes could be obtained for only 71 of these. These measures have been used to calibrate Schmidt plates of the two directions.

Table 2. Magnitude and colours of observed stars in the GC field.

	Id. No.	V	(B – V)	(U – B)
Field 1	1	13.651	2.056	0.116
	2	14.217	2.018	0.944
	3	15.605	1.962	*
	4	14.191	1.725	0.229
	5	13.182	1.708	0.190
	6	14.038	1.790	0.373
Field 2	7	14.541	0.670	0.004
	8	15.442	0.700	0.107
	9	15.913	0.640	0.028
	10	13.536	0.648	0.060
	11	17.573	1.153	*
	12	17.075	0.564	*
	13	14.463	0.776	*
	14	16.947	0.759	*
Field 3	15	17.247	0.500	–0.170
	16	19.056	1.028	*
	17	17.484	0.564	–0.160
	18	18.944	1.569	*
	19	18.999	1.165	*
	20	18.723	0.540	*
	21	14.788	0.577	–0.046
	22	15.979	1.415	*
	23	19.180	0.838	*
	24	15.022	1.060	1.071
	25	19.040	0.879	*
Field 4	26	17.096	1.065	*
	27	17.873	0.592	–0.046
	28	13.056	0.487	–0.058
	29	14.512	0.782	0.297
	30	15.933	0.666	0.141
	31	17.689	1.088	*
	32	14.595	0.635	–0.011
Field 5	33	16.262	0.842	*
	34	15.544	0.668	*
	35	16.392	0.544	*
	36	15.378	0.672	*
	37	15.672	0.873	*

	Id. No.	V	(B – V)	(U – B)
	38	13.914	0.705	*
	39	17.958	0.437	
Field 6	40	16.338	0.911	0.847
	41	14.507	0.630	0.907
	42	16.430	0.751	0.640
	43	14.547	1.291	1.943
	44	15.979	0.503	0.644
Field 7	45	15.803	0.592	–0.010
	46	19.032	0.595	–0.237
	47	15.517	0.767	0.091
	48	17.900	0.725	0.160
	49	17.705	1.057	*
	50	16.820	0.814	0.347
	51	16.950	0.603	–0.039
	52	15.463	0.832	*

Table 3. Magnitudes and colours of observed stars in the ellipsoid field.

Star No.	α(2000)			δ(2000)			V	U – B	B – V	V – R
	h	m	s	°	'	"				
Field 1										
1	11	34	3	–12	37	4	18.949	–0.105	0.505	
2	11	34	4	–12	38	23	17.083	1.103	1.185	0.687
3	11	34	4	–12	35	20	16.911	0.560	0.996	0.573
4	11	34	4	–12	34	7	19.017		1.140	
5	11	34	5	–12	38	26	19.032	0.051	0.766	0.435
6	11	34	5	–12	36	29	15.393	0.388	0.796	0.427
7	11	34	6	–12	34	32	18.558		1.545	
8	11	34	9	–12	39	23	13.153	0.012	0.625	0.304
9	11	34	14	–12	37	5	15.647	0.551	0.972	0.469
10	11	34	16	–12	36	44	14.174		0.916	
11	11	34	21	–12	37	24	16.439	0.051	0.674	
12	11	34	18	–12	36	11	16.004		0.551	0.382
13	11	34	22	–12	38	2	14.200	0.602	0.893	0.441
14	11	34	22	–12	35	37	13.510	0.796	0.931	0.622
15	11	34	22	–12	34	18	18.091		1.410	0.765
16	11	34	22	–12	35	16	18.688		1.272	
17	11	34	22	–12	34	34	15.447		0.493	
18	11	34	24	–12	36	32	12.711	0.423	0.790	0.407

Star No.	α(2000)			δ(2000)			V	U – B	B – V	V – R
	h	m	s	°	'	"				
Field 2										
19	11	34	25	–10	50	0	17.907		1.479	0.940
20	11	34	29	–10	50	13	17.788		1.394	0.947
21	11	34	30	–10	51	2	19.550		0.353	0.345
22	11	34	30	–10	51	43	19.092		0.888	0.852
23	11	34	32	–10	48	11	15.066	0.316	0.845	0.404
24	11	34	32	–10	46	36	19.202		0.953	0.574
25	11	34	34	–10	46	44	15.090	0.138	0.662	0.339
26	11	34	34	–10	51	28	18.018		1.020	0.523
27	11	34	35	–10	47	20	16.300	0.025	0.615	0.294
28	11	34	36	–10	50	7	18.634		1.074	0.904
29	11	34	37	–10	50	50	16.065	0.111	0.670	0.299
30	11	34	37	–10	48	38	18.344		1.339	0.787
31	11	34	38	–10	48	37	13.688	0.353	0.815	0.240
32	11	34	40	–10	48	59	17.929		1.578	0.989
33	11	34	42	–10	52	8	16.644		1.329	0.744
34	11	34	42	–10	48	15	19.250		1.134	0.738
35	11	34	43	–10	50	24	13.627	–0.140	0.548	0.239
36	11	34	43	–10	47	48	19.010		1.044	0.833
37	11	34	45	–10	50	38	19.154		0.500	0.274
38	11	34	45	–10	50	23	19.642		0.959	0.465
39	11	34	46	–10	46	58	16.405	0.239	0.794	0.399
40	11	34	46	–10	51	26	17.821		0.848	0.465
41	11	34	47	–10	51	18	18.302		1.334	1.113
42	11	34	49	–10	52	6	18.852		1.477	0.921
Field 3										
43	11	34	17	–14	37	25	15.851	0.496	0.869	
44	11	34	18	–14	36	56	17.087	0.065	0.725	
45	11	34	18	–14	37	19	18.945		0.981	
46	11	34	18	–14	35	25	17.941		0.960	
47	11	34	19	–14	35	32	19.197		0.945	
48	11	34	20	–14	35	44	16.082	0.233	0.834	
49	11	34	20	–14	37	12	15.522	0.241	0.720	
50	11	34	22	–14	36	55	18.880		0.571	
51	11	34	22	–14	37	44	17.745	0.186	0.910	
52	11	34	23	–14	36	16	19.330	–0.284	0.871	
53	11	34	24	–14	37	26	16.135	0.106	0.704	
54	11	34	24	–14	35	5	15.515	0.198	0.284	

Star No.	α(2000) h	m	s	δ(2000) °	'	"	V	U – B	B – V	V – R
Field 4										
55	11	40	32	–12	13	39	15.267	–0.007	0.716	
56	11	40	33	–12	15	43	15.681	0.648	0.919	
57	11	40	35	–12	14	35	17.667		1.452	
58	11	40	35	–12	13	23	17.708		1.395	
59	11	40	37	–12	12	59	14.686	0.286	0.856	
60	11	40	38	–12	15	9	15.854	0.040	0.702	
Field 5										
61	11	43	54	–14	24	59	16.415	0.125	0.668	
62	11	43	54	–14	26	14	15.307	–0.159	0.477	
63	11	43	57	–14	24	35	16.339		0.714	
64	11	43	59	–14	27	11	14.536	0.177	0.676	
Field 6										
65	11	44	36	–10	39	12	17.992		1.367	–0.439
66	11	44	37	–10	43	39	16.757	–0.150	0.674	0.390
67	11	44	39	–10	40	21	19.177		1.240	0.882
68	11	44	42	–10	39	18	16.031	0.066	0.696	0.296
69	11	44	44	–10	41	40	15.108	0.105	0.666	0.393
70	11	44	47	–10	42	54	15.906	–0.015	0.652	0.329
71	11	44	48	–10	40	13	18.941		0.588	0.402
72	11	44	49	–10	42	46	17.137	–0.138	0.593	0.362
73	11	44	49	–10	41	31	14.588	–0.056	0.284	0.192
74	11	44	51	–10	44	45	19.160		0.585	0.276
75	11	44	51	–10	42	25	19.740		0.407	
76	11	44	51	–10	42	54	13.787	0.588	0.939	0.505
77	11	44	53	–10	43	12	17.431	–0.092	0.507	0.319
78	11	44	54	–10	42	11	18.709		1.174	0.933
79	11	44	55	–10	38	50	18.832		0.965	
80	11	44	56	–10	44	35	19.509		0.752	0.342
81	11	44	56	–10	42	29	18.225		1.519	1.058
82	11	44	57	–10	40	35	17.623		0.962	0.804
Field 7										
83	11	43	26	–12	43	6	13.387	1.097	1.118	
84	11	43	28	–12	41	46	15.619	1.096	1.098	
85	11	43	29	–12	41	34	17.954		0.643	
86	11	43	30	–12	41	13	15.477	0.988	1.063	
87	11	43	33	–12	42	26	16.723	0.147	0.747	
88	11	43	33	–12	42	56	17.364		1.334	
89	11	43	33	–12	40	56	15.814	0.418	0.894	

Star No.	α(2000) h	m	s	δ(2000) °	'	"	V	U – B	B – V	V – R
Field 8										
90	11	48	58	–11	29	41	13.240	0.833	0.902	–0.410
91	11	49	8	–11	28	43	14.358	0.108	0.535	0.318
92	11	49	8	–11	30	50	17.409		0.885	0.661
93	11	49	9	–11	27	13	14.903	–0.117	0.307	0.233
94	11	49	11	–11	31	0	12.952	0.093	0.038	–0.631
95	11	49	12	–11	29	22	14.194	0.865	0.865	0.099
96	11	49	14	–11	27	18	17.331		1.165	0.678
97	11	49	16	–11	25	27	16.890		–0.113	
98	11	49	16	–11	30	32	17.521		0.733	0.626
99	11	49	16	–11	29	32	17.939		0.782	0.627
100	11	49	20	–11	27	29	17.087	0.147	0.644	0.348
101	11	49	20	–11	25	53	16.887	0.033	0.953	–0.005
Field 9										
102	11	51	55	–10	52	9	18.083		0.980	0.714
103	11	51	56	–10	50	35	13.666		1.073	0.259
104	11	51	56	–10	51	58	16.206		0.813	0.512
105	11	51	56	–10	52	38	13.947		0.876	0.291
106	11	51	59	–10	50	25	12.417		1.060	
107	11	51	59	–10	52	6	17.775		0.756	0.558
108	11	52	0	–10	52	17	15.091		0.933	0.295
Field 10										
109	11	52	14	–12	37	12	14.748	0.389	0.806	0.431
110	11	52	17	–12	37	50	17.286	0.114	0.728	0.497
111	11	52	21	–12	39	59	19.306	–0.454	0.721	0.418
112	11	52	19	–12	37	31	19.280		0.777	0.595
113	11	52	19	–12	36	55	19.038	–0.115	0.468	0.256
114	11	52	22	–12	37	26	16.847	0.070	0.679	0.352
115	11	52	22	–12	35	15	18.073		1.165	0.674
116	11	52	7	–12	33	49	17.132	0.116	0.671	0.413
117	11	52	23	–12	36	8	18.137	0.259	1.067	0.759
118	11	52	25	–12	39	22	17.882		1.569	1.034
119	11	52	26	–12	39	34	16.724	1.136	1.193	0.758
120	11	52	26	–12	34	0	19.430		0.901	0.527
121	11	52	27	–12	35	55	18.914		1.407	1.243
122	11	52	27	–12	36	33	13.566	0.620	0.904	
123	11	52	27	–12	35	38	18.199	–0.040	0.541	0.359
124	11	52	28	–12	33	34	17.921		1.328	0.669
125	11	52	29	–12	36	57	18.868		1.449	1.013
126	11	52	29	–12	36	6	13.853	0.033	0.502	0.384

Star No.	α(2000)			δ(2000)			V	U – B	B – V	V – R
	h	m	s	°	'	"				
127	11	52	29	–12	34	7	18.312		1.401	0.770
128	11	52	29	–12	33	57	18.400		0.878	0.706
129	11	52	30	–12	35	16	15.222	0.561	0.811	0.566
130	11	52	31	–12	37	43	15.762	0.108	0.624	0.395
131	11	52	31	–12	36	21	17.334	0.026	0.563	0.444
132	11	52	32	–12	36	44	13.233	0.538	0.884	0.499
133	11	52	32	–12	37	27	19.275		1.414	1.005
134	11	52	34	–12	37	1	19.666		0.895	
135	11	52	34	–12	33	51	15.879	0.043	0.558	0.442
136	11	52	36	–12	33	10	17.104		1.868	
137	11	52	36	–12	34	39	18.149		1.172	0.971
138	11	52	38	–12	33	32	17.301	0.450	1.011	
139	11	52	40	–12	38	11	15.837	0.851	1.051	0.680

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