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POSITIONS AND PROPER MOTIONS OF STARS IN THE REGION
OF THE GALACTIC CLUSTER IC 4665 *

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Abstract. Positions and proper motions of stars in the region of the galactic cluster IC 4665 were determined from two photographs taken with the 20-inch astrograph of the Lick Observatory in 1953, combined with data from the astrographic catalogues and from other photographic sources. All the positions were reduced to a common system by using reference stars from the AGK2. Centennial proper motions were obtained with an accuracy of $\pm 0''.4$ (p.e.). Of 125 stars measured, 26 are probable and 18 are possible members of the cluster, which has a mean centennial proper motion of approximately $0''.94$ in position angle 240° .

The present paper is the result of an attempt to separate from field stars the members of the galactic cluster IC 4665 ($17^h 43^m 7^s$, $+5^\circ 41'$; 1950.0). This cluster was observed photometrically by Hogg and Kron (1955) in 1953 and their results indicated that many non-members had been included in their observing program. Proper motions available at that time did not show any group motion to provide an independent criterion of the membership.

Since no pair of photographic plates was available for a convenient determination of relative proper motions, it was decided to determine absolute proper motions in the system of the FK3 from all the photographic positional sources suitable for this purpose. In addition, recent positions were obtained from two plates taken for the purpose with the 20-inch astrograph of the Lick Observatory on August 4, 1953. Reductions were carried out following, in general, the procedure used by Heckmann, Dieckvoss and Kox (1949).

List of stars and sources of their positions. Kopff (1943) has published the greatest number of positions of stars in the region of IC 4665. From the appearance of the cluster photographs and from Kopff's conclusions it is obvious that most of the stars in his list do not belong to the cluster. In spite of this fact all but four stars from Kopff's list have been included in the present work. The four stars were omitted because of the lack of reliable positions for them, but four

additional stars were added because, owing to their redness and faintness, they were suspected to be cluster members by the photometric observers. These additional stars were marked with *a* in the first column of Table II. The final number of stars measured is 125, and this large number was taken for the following reasons:

(a) The proper motion of the cluster was expected to be small, therefore a high accuracy was sought. To bring the heterogeneous material on positions, given below, to a common system, a large number of common stars was desirable.

(b) Kopff's results are not conclusive enough to eliminate the possibility of finding new cluster members.

Reference stars were taken from the AGK2; the corresponding positions were kindly supplied by Professor Arnold Kohlschütter of Bonn prior to their publication. Out of the total number of 56 AGK2 stars in the region, 46 stars were used for reference, regardless of whether or not they were suspected as being members of the cluster. The remaining ten stars were omitted because of their large proper motions or because they were not listed in the AGK1.

In addition to the above catalogues a list of relative positions by van de Kamp (1936) and positions in the astrographic catalogues were

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used, as shown in Table I. The positions from *Yale Observatory Transactions* 20 and 22 were not used, because their epoch is near the mean epoch of all the positions, and there are already several sources with approximately the same epochs.

TABLE I. SOURCES OF STAR POSITIONS

Source	Epoch	No. of Stars
1. Astrogr. Cat., Toulouse +7°, 17 ^h 40 ^m	1897.5	28 (9)
2. Astrogr. Cat., Toulouse +5 17 48	1899.5	19 (8)
3. Astrogr. Cat., Toulouse +5 17 40	1909.5	91 (34)
4. Astrogr. Cat., Alger +4 17 44	1910.5	10 (5)
5. Astrogr. Cat., Toulouse +6 17 36	1917.6	39 (9)
6. Astrogr. Cat., Toulouse +6 17 44	1917.6	87 (30)
7. AGK2	1930.0	56 (46)
8. van de Kamp	1934.5	30 (15)
9. Kopff	1938.1	121 (43)
10. Lick	1953.6	125 (46)

The last column in the table shows the number of our stars from each source and, in parentheses, the number of the reference stars from the AGK2. Each star appears on at least two of the astrographic plates and all but four are given in Kopff's list.

Determinations of proper motions. Preliminary proper motions of the reference stars were obtained from the comparison of the AGK2 with the AGK1, after the positions in the latter were reduced to the FK3 with the tables in *GC* Vol. 1. It was intended to use these proper motions for reductions of star positions from the epoch of the AGK2 to those of all the remaining position sources listed in the Table I.

The first computation of the Lick plate constants in α showed that the residuals of the least-squares solution were surprisingly large, and that they were correlated with the values of the preliminary proper motions of the reference stars. The differences between the individual proper motions and their mean, multiplied by 23.6, i.e. by the difference between the Lick and AGK2 epochs, are plotted against corresponding residuals in Figure 1. The strong correlation shown in the figure illustrates clearly that an individual value, previously called a preliminary proper motion of a star, has hardly more meaning than that of a difference of errors in the AGK2 and AGK1 divided by the interval between the epochs.

The meridian-circle positions in the AGK1 were suspected as the main source of the errors. Figure 2 is drawn from proper motions given in *Yale Transactions* 20 and 22 in the same way as the Figure 1 from the AGK2-AGK1. In spite of a systematic difference of the order of 0".01 between both sets of proper motion, and of the fact that the Yale proper motions were not used for

the reductions, the dispersion of proper motion differences about their mean has a similar correlation with the residuals. Since the source of the first epoch positions, namely the AGK1, is common for both sets of proper motions, the obvious conclusion is that the apparent scatter of proper motion differences is caused by large accidental errors in AGK1. All the reference stars are in the Leipzig zone of the AGK1, except star No. 61, which is in the Albany zone.

After the above conclusions were reached, there seemed to be no other way than to take the mean of all the preliminary proper motions, to consider this mean as a systematic motion for the whole group of the reference stars, and to use this mean for reduction of each position, under the assumption that the peculiar motions with respect to the systematic shift are small and directed at random. The mean proper motion amounted to $-0''.0073$ and $-0''.0017$ in right ascension and declination, respectively.

After the second computation of the plate constants, with the mean proper motion, the residuals improved considerably. The sum of the squares of their values in seconds of arc became 3.79 as compared with 10.48 when the individual proper motions were used. Since the field was comparatively small, less than $2^\circ \times 2^\circ$, only six linear plate constants were derived.

Since two Astrographic Catalogue plates, Nos. 3 and 6 in Table I, contain a large number of the reference stars from the AGK2, the coordinates from these plates were reduced to the chosen reference system in the same way as the Lick plates. No attention was paid to whether or not the reference stars were used for the original determination of constants in the astrographic catalogues.

Positions in Kopff's (1943) list are based on positions and proper motions in AGK2A, *Veröff. Astr. Rech. Inst. Berlin-Dahlem*, No. 55, 1943. The positions of stars in AGK2A are on the FK3 system, but their proper motions are heterogeneous and not always reliable. To bring Kopff's positions into our system, which is intended to be the FK3, the mean of differences between the Kopff positions and those of the AGK2 was formed for 43 reference stars common to both catalogues. This difference was compared with that to be expected from our adopted mean proper motion for the same set of stars. The comparison gave corrections to right ascensions and declinations of $+0''.004$ and $+0''.07$, respectively. These corrections were applied to each position in Kopff's list.

Figure 1

Figure 2

Figure 3

Figures 1 and 2. Correlation between the proper motions and the residuals of the solution for Lick plate constants.

Figure 3. Vector point diagram of proper motions in the region of IC 4665.

As a result of the foregoing reductions, at least three positions at different epochs were available for each star: on an astrographic plate, in Kopff's list, and from the Lick plates. In addition, nearly

Table II. Positions and Proper Motions.

No. Kopff	BD	m *V	Sp. Type	$\alpha-17^h$ (1950.0)	δ	Ep.	W_c	$100\mu_\alpha$	$100\mu_\delta$	W_μ	Cl. Memb.	Lick α	Position δ	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(13)	
2		10.4	G4	39 ^m 49 ^s 783	+5° 52' 54.51"	35.1	6	- 0.6	+ 2.9	1.7	-	49 ^s 773	55' 13	
3*	+6° 3503	9.0	F3	54.870	5 38 31.77	29.8	9	- 2.1	+ .2	2.9	-	54.826	31.86	
4*	5 3455	10.4	F1	6.371	5 22 24.32	33.8	8	- .2	+ .8	2.1	-	6.358	24.60	
5		10.6	A3	7.530	5 40 37.49	35.1	6	+ .3	+ .5	1.7	-	7.523	37.62	
6			G6	10.470	5 55 17.92	35.1	6	+ .3	+ 1.0	1.7	-	10.473	18.16	
7*	5 3457	9.0	A8	13.482	5 21 6.47	33.8	8	- .9	+ .6	2.1	-	13.467	6.68	
8*	5 3458	10.2	Ma	17.008	5 24 38.88	33.8	8	- .3	+ .3	2.1	-	17.014	38.96	
9		10.6	G8	17.998	5 48 49.21	35.1	6	+ .3	+ 1.3	1.7	-	17.973	49.48	
9*a	4 3485	* 9.1		20.180	4 50 34.41	35.3	5	- .6	+ .5	1.3	-	20.173	34.59	
10		10.4	K5	30.228	6 11 36.91	33.1	6	- .7	+ 1.0	2.4	-	30.205	37.15	
11	6 3507	9.4	F9	30.301	6 17 15.59	33.1	6	+ 1.8	- .5	2.4	-	30.320	15.60	
12	5 3459	9.5	F6	39.006	5 7 15.13	35.1	6	- 1.5	+ .1	1.7	-	38.991	15.16	
13	6 3508	10.1	A0	41.973	6 14 15.04	33.1	6	- 2.0	- .2	2.4	-	41.942	15.00	
14	6 3510	9.6	G5d	53.148	6 14 57.66	32.3	8	+ .6	- 2.4	2.4	-	53.155	57.30	
15*	5 3460	10.6	K0	58.747	4 58 11.95	32.4	6	+ .1	.0	1.7	-	58.755	11.99	
16	5 3461	9.8	G8	41	0.045	5 4 18.92	35.1	6	- .4	+ .4	1.7	-	0.047	19.20
17	5 3462	9.9	K3	2.982	5 47 19.95	35.1	6	- .0	- 1.0	1.7	0	2.981	20.05	
18	5 3463	10.5	G4	9.281	5 19 59.15	35.1	6	+ 1.4	- 7.0	1.7	-	9.312	57.86	
19		10.5	K0	10.490	5 46 55.12	35.1	6	- .0	- .2	1.7	0	10.480	55.12	
20	5 3464	9.3	G7d	13.341	5 24 8.84	35.1	6	- .2	- 2.9	1.7	-	13.340	8.36	
21	6 3512	9.9	G2	22.150	5 59 44.22	29.7	7	+ 3.3	+ 2.7	2.9	-	22.201	44.96	
22*	5 3465	8.8	A0	22.525	5 26 30.38	33.8	8	- .8	- .4	2.1	+	22.519	30.31	
23*	5 3466	8.1	A0	24.722	5 51 58.33	33.8	8	- .9	- .8	2.1	+	24.710	58.21	
24*	5 3467	9.0	G7g	26.602	5 34 34.74	36.1	7	- 2.4	- 2.2	1.4	-	26.572	34.42	
26*	5 3468	7.7	G6	28.252	5 28 38.83	33.8	8	+ .9	+ .5	2.1	-	28.267	38.96	
27		10.2		28.387	5 26 4.62	35.1	6	- .6	.0	1.7	0	28.376	4.66	
28*	6 3514	7.4	A2	36.937	6 4 57.43	32.3	8	- .8	+ .3	2.4	-	36.922	57.30	
29		10.7	F0	41.112	5 52 34.84	35.1	6	+ .2	- .3	1.7	-	41.107	34.74	
30*	5 3469	7.6	G7g	45.368	5 16 16.67	33.8	8	+ .6	+ .1	2.1	-	45.380	16.72	
31	5 3470	10.4	K1	46.863	5 30 45.97	34.8	11	- .6	+ .2	1.7	0	46.859	46.03	
32*	5 3471	8.4	A2	48.635	5 44 6.42	34.1	13	- 1.3	- .8	1.7	0	48.613	6.22	
33		10.9	F0	13.323	5 37 4.15	32.6	7	- 2.1	- 1.5	1.9	-	13.295	3.79	
34		11.0	F0	14.054	5 15 57.49	32.6	7	- .1	- .1	1.9	0	14.046	57.53	
35	6 3516	10.6	A1	15.507	6 15 19.19	30.9	7	- .6	+ .1	2.6	0	15.492	19.25	
36	5 3472	9.5	G7d	19.582	5 13 25.41	32.6	7	- .3	- 1.0	1.9	0	19.571	25.44	
37		11.0	A8	20.932	5 26 42.77	32.6	7	- .7	- .3	1.9	+	20.920	43.01	
38		10.6	F0	27.095	5 26 24.83	32.6	7	- .7	- 1.1	1.9	+	27.089	24.56	
39*	5 3473	9.4	A1	33.558	5 32 34.00	32.9	14	- .4	- .1	2.0	0	33.546	34.01	
40	5 3474	9.9	K2	35.016	5 51 12.94	33.4	12	- .3	+ 1.3	1.9	-	35.009	13.22	
41	6 3518	10.4	F0	39.673	6 23 0.08	30.7	9	- 1.2	- .1	2.6	0	39.653	0.13	
42		10.6	K5	47.389	5 27 8.41	35.1	6	- 1.6	- .6	1.7	-	47.368	8.30	
43*	5 3476	9.1	A0	50.123	5 41 14.06	34.1	13	- .1	- .7	1.7	0	50.112	13.85	
44	5 3477	10.0	A0	55.891	5 34 55.31	34.8	11	- 1.6	+ .2	1.7	-	55.864	55.26	
45*	6 3521	10.6	A0	57.692	6 38 8.94	32.3	8	- 1.3	+ .8	2.4	-	57.668	9.02	
46	4 3499	10.3	G5	58.578	4 50 17.42	33.9	6	- 6.6	- 9.6	2.0	-	58.493	15.71	
47	6 3520	9.6	F9	59.194	6 0 31.66	31.7	12	+ .9	- 6.8	2.9	-	59.201	30.16	
48		11.0	F7	2.320	6 2 55.73	29.7	7	- .4	- .7	2.9	+	2.312	55.45	
49*	5 3478	7.7	B9	6.558	5 44 5.79	34.1	13	- 1.3	- .2	1.7	0	6.538	5.65	
50*	5 3479	9.1	A0	7.406	5 26 44.57	34.1	13	- 1.0	- .4	1.7	+	7.399	44.48	
51	5 3480	9.8	A2	11.839	5 13 1.94	35.1	6	- .8	- .5	1.7	+	11.823	1.85	
52		10.8	G5	13.148	5 42 40.24	35.1	6	+ .2	- 3.8	1.7	-	13.149	39.72	
53		10.9	F0	13.961	5 34 52.98	35.1	6	- 1.1	- .5	1.7	+	13.945	52.99	
54		10.4	G7	24.705	5 44 38.44	34.8	11	+ .3	+ .2	1.7	-	24.706	38.48	
55	4 3500	9.7	G8	27.774	4 49 12.53	33.9	6	- 2.7	+ 2.6	2.0	-	27.739	13.21	
56*	5 3481	7.7	A0	28.341	5 55 34.51	31.5	14	- .6	+ .4	2.9	-	28.325	34.66	
57		10.9	A	29.505	5 49 52.19	35.1	6	- .4	- .2	1.7	+	29.494	52.13	
58*	5 3482	7.7	B8	29.946	5 42 47.52	34.1	13	- .6	- .7	1.7	+	29.942	47.43	
59		10.4	K5	31.174	5 8 12.35	35.1	6	- .5	- .9	1.7	+	31.169	12.50	
60		11.0	G1	33.278	5 37 46.19	35.1	6	- .6	+ .5	1.7	-	33.258	46.25	
61*	4 3502	9.4	F3	33.799	4 41 26.63	32.9	8	- 1.3	- .9	2.0	0	33.779	26.58	
62*	5 3483	7.0	B7	40.010	5 32 55.60	34.1	13	- .8	- 1.0	1.7	+	39.999	55.30	
63		10.5	A0	42.671	6 0 3.15	31.7	12	- .0	- .5	2.9	0	42.664	2.91	
64*	5 3484	7.4	B8	43.760	5 40 36.05	34.1	13	- .9	- .3	1.7	+	43.750	35.95	
65	5 3485	10.4	F2	52.049	5 57 13.12	31.5	14	+ .1	- .8	2.9	0	52.040	12.98	
66	5 3486	10.3	A2	56.240	5 48 41.66	34.8	11	- .4	- .6	1.7	+	56.228	41.46	
67*	5 3487	8.9	A0	59.672	5 43 6.91	34.1	13	- .8	- .8	1.7	+	59.657	6.74	
68	5 3488	7.8	F3	0.756	5 24 55.67	34.1	13	+ .7	- 3.8	1.7	-	0.760	54.81	
69*	6 3524	7.7	G7g	2.130	6 15 14.58	32.3	8	- .7	- 3.2	2.4	-	2.121	13.92	
70*	5 3489	10.0	G9	6.119	5 18 43.42	33.8	8	- .3	+ 1.0	1.7	-	6.129	43.68	
71		10.7	F5	6.306	5 54 21.14	34.8	11	+ .3	+ 3.2	1.7	-	6.307	21.72	

Table II. (continued)

No. Kopff	BD	m *V	Sp. Type	α -17 ^h (1950.0)	δ	Ep.	W _c	100 μ_{α}	100 μ_{δ}	W _{μ}	Cl. Memb.	Lick Position α	Lick Position δ
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(13)
72*	+6°3525	7.9	B9	44 ^m 9 ^s 797	+5° 8' 19".03	32.3	8	-1.0	-1.6	2.4	-	9 ^s 775	18".74
73*	5 3490	7.3	B7	14.011	5 47 31.69	34.1	13	- .7	-1.2	1.7	+	14.006	31.46
74		10.2	G8	14.141	5 30 21.76	36.5	10	-2.1	- .4	1.3	-	14.119	21.69
75	4 3505	9.7	K3	16.399	4 48 9.90	33.9	6	-1.7	+1.5	2.0	-	16.381	10.31
76*	5 3491	8.3	A0	19.424	5 34 57.57	34.1	13	- .8	- .4	1.7	+	19.414	57.41
77*	6 3526	9.6	G7	20.212	6 36 28.34	32.3	8	-1.9	- .3	2.4	-	20.188	28.21
78	5 3492	10.5	A2	20.549	5 12 56.75	35.1	6	- .1	+1.3	1.7	-	20.544	57.02
79		10.6	G7	27.019	5 6 32.84	35.1	6	-3.4	- .6	1.7	-	26.978	32.87
80*	6 3527	8.5	G3g	27.488	6 31 31.03	32.3	8	- .8	+1.8	2.4	-	27.487	31.43
81*	5 3493	8.9	A3	30.331	5 26 35.59	34.1	13	- .5	- .8	1.7	+	30.320	35.45
82*	5 3494	* 8.0	A0	35.046	5 42 33.36	34.1	13	-1.0	- .6	1.7	+	35.033	33.26
83		*10.2	A0	35.875	5 42 57.70	34.8	11	- .3	+ .1	1.7	0	35.876	57.76
84	5 3496	9.7	F7	40.303	5 31 31.19	34.8	11	-1.5	+ .4	1.7	-	40.291	31.34
85	5 3495	10.6	A0	40.945	5 14 33.40	35.1	6	-1.2	+1.0	1.7	-	40.937	33.66
86	6 3529	10.1	F8	48.280	6 11 13.46	33.1	6	- .6	-1.1	2.4	+	48.271	13.27
87		11.1	A5	48.752	5 36 10.83	35.1	6	-1.4	+ .2	1.7	-	48.734	10.90
88		10.7	A3	53.952	5 36 59.83	33.8	8	- .8	- .2	1.7	+	53.937	59.80
89	5 3497	9.9	A0	54.443	5 46 35.57	34.8	11	- .1	- .7	1.7	0	54.443	35.45
90*	5 3498	7.8	K5d	1.744	5 37 14.73	34.1	13	- .1	+ .7	1.7	-	1.753	14.90
91*	4 3508	8.7	K3	5.148	4 51 20.97	32.9	8	- .4	+ .3	2.0	-	5.143	21.11
92		10.3	Ma	5.890	6 1 56.93	34.8	11	- .8	+1.0	1.7	-	5.881	56.96
93		10.9	G5	5.986	5 38 3.56	35.1	6	-3.2	+ .5	1.7	-	5.944	3.55
94	5 3499	10.2	A0	11.376	5 7 59.08	35.1	6	-1.5	- .3	1.7	-	11.361	59.03
95	6 3531	9.7	K5	12.981	6 16 24.62	33.1	6	- .7	- .3	2.4	+	12.973	24.40
96	4 3509	8.6	G5d	16.601	4 57 36.60	31.2	9	-54.4	-20.3	2.2	-	15.781	32.19
97		10.4	A2	20.390	6 18 23.28	33.1	6	+ .1	- .3	2.4	-	20.385	23.09
98*	5 3500	9.5	G7	21.006	5 22 43.51	33.8	8	-1.6	+2.7	1.7	-	20.999	44.29
99	6 3532	9.1	K3	26.575	6 25 11.18	32.3	8	-2.9	-5.8	2.4	-	26.537	9.94
100		10.5	G2	28.064	5 17 42.92	35.1	6	- .8	+ .8	1.7	-	28.048	43.29
100a		*11.0		36.845	4 53 1.05	31.8	4	- .8	+2.5	1.9	-	36.833	1.59
101		10.4	G3	40.031	6 26 16.25	33.1	6	- .9	- .2	2.4	+	40.017	16.01
102*	6 3533	9.3	A0	43.800	6 17 15.00	32.3	8	- .6	-1.0	2.4	+	43.790	14.86
103	6 3534	9.8	G9	47.222	6 2 40.80	35.1	6	- .3	- .0	1.7	0	47.221	40.70
104*	5 3503	8.5	G6	55.331	5 19 31.74	33.8	8	- .1	+ .9	1.7	-	55.328	31.84
105*	5 3504	7.6	B9	16.278	5 42 59.82	30.0	9	+ .5	-1.6	2.7	-	16.303	59.39
106	6 3538	10.0	G5	17.049	6 0 36.13	23.9	8	+ .9	- .1	3.4	-	17.063	36.03
107	6 3539	10.3	F0	25.656	6 13 41.94	33.1	6	+ .2	+1.4	2.4	-	25.652	41.99
108		* 7.5	F5	29.237	4 58 43.70	28.0	10	- .9	-3.7	3.1	-	29.209	42.91
109*	5 3505	* 9.8	A8	29.867	4 58 59.38	28.0	10	- .2	-2.2	3.1	-	29.849	58.80
110*	6 3540	8.6	K0	35.499	6 0 18.22	26.8	10	- .0	+ .2	3.7	-	35.500	18.29
111	5 3507	10.0	A5	48.635	5 44 48.16	33.4	6	-1.0	+1.8	2.3	-	48.616	48.43
112	6 3543	9.7	F6	49.299	6 0 14.19	33.4	6	-4.0	- .6	2.3	-	49.245	13.99
113		10.0	G0	49.856	5 36 50.45	33.4	6	- .8	+1.0	2.3	-	49.845	50.56
113*a	6 3544	* 9.0		52.186	6 10 34.42	37.0	5	+ .3	+1.2	1.0	-	52.192	34.67
115*	5 3510	8.9	A5	54.728	5 34 53.60	32.6	8	+1.0	+ .1	2.3	-	54.741	53.70
116	5 3509		A6	55.466	5 21 5.40	33.4	6	-2.5	+ .9	2.3	-	55.428	5.68
117*	5 3511	* 8.7	G9	59.550	5 22 2.04	32.6	8	-1.6	- .6	2.3	-	59.541	2.02
118		10.0	A0	1.929	5 15 16.04	33.4	6	- .7	- .2	2.3	+	1.916	16.13
119	5 3513	8.7	G4	4.817	5 50 21.56	32.6	8	+6.2	-13.2	2.3	-	4.919	18.64
120	5 3514	9.9	G7	5.184	5 56 48.36	33.4	6	-1.0	- .7	2.3	+	5.178	48.13
121*	5 3512	8.4	A4	5.423	5 24 14.18	32.6	8	- .7	+2.2	2.3	-	5.409	14.54
122		10.3	A1	14.918	5 56 21.22	33.4	6	-1.8	+ .5	2.3	-	14.893	21.21
124		9.3	G8	24.900	5 22 9.46	33.4	6	-1.4	+1.8	2.3	-	24.885	9.80
124*a	4 3519	*10.8		26.853	4 46 39.68	29.5	6	-3.3	-1.4	2.4	-	26.797	39.55
125	5 3518	9.7	A2	37.819	5 42 29.48	32.6	8	-1.9	+ .1	2.3	-	37.800	29.45

half of the stars were common to both astrographic plates, and the positions of 46 reference stars were in the AGK2. Therefore most of the stars had four positions, and many of them even five sets of coordinates.

The coordinates were plotted against their epochs, and positions for each star were read from these graphs for epochs of other sources, where additional positions of these stars were given, i.e. for four remaining astrographic plates and for the list by van de Kamp (1936). All stars, except a few with too high scatter in the positions for drawing a reliable straight line, were now used as reference stars. The six plate constants were

derived in the usual way and all the positions reduced to our reference system.

Finally, the average number of positions for each star was five, with a range from three to seven. Only two stars had three positions, and four had seven. Final positions for mean epochs and proper motions were obtained from individual positions according to the formulae of the method of least squares:

$$T_0 = \frac{[wT]}{[w]} \quad \alpha_0 = \frac{[w\alpha]}{[w]} \quad \delta_0 = \frac{[w\delta]}{[w]}$$

$$\tau = T - T_0 \quad \mu_{\alpha} = \frac{[w\tau\alpha]}{[w\tau^2]} \quad \mu_{\delta} = \frac{[w\tau\delta]}{[w\tau^2]}$$

where α and δ are the coordinates of a star for the epoch T ; α_0 and δ_0 are the mean coordinates of this star for the mean epoch T_0 ; μ_α and μ_δ are proper motions in right ascension and declination, respectively. Weights w for α and δ were assigned as follows: $w = 1$ for each coordinate from an astrographic plate, $w = 2$ for positions in the AGK2, in Kopff's list and for the Lick positions, because each of these positions was obtained from two plates. Van de Kamp's positions are of the highest internal accuracy since they were obtained from 16 long-focus photographs, but their reduction to our system introduced reference errors. As a compromise the weight $w = 5$ was chosen. The epoch of van de Kamp's positions is close to the average mean epoch of all the positions; therefore, while van de Kamp's data have very little effect on the proper motions, they serve as a good check on the reliability of all the other positions.

Table II summarizes the results as follows:

Column 1 shows Kopff's (1943) star numbers, except for 9a, 100a, 113a and 124a, which were added to Kopff's list. Reference stars from the AGK2 are marked with asterisks.

Columns 3 and 4 give photovisual magnitudes and spectral types from Kopff's list, except for magnitudes marked by asterisks, which are V magnitudes by Hogg and Kron (1955).

Columns 5 to 8 contain positions of stars, derived from all the sources used, with their mean epochs and the weights $w_c = [w]$ of the derived coordinates.

Columns 9 to 11 give centennial proper motions with their relative weights $w_\mu = \frac{[w\tau^2]}{1000}$, where τ is expressed in years.

Column 12 indicates the cluster membership: + probable member, O possible member, - non-member. The criteria for membership are given later.

Columns 13 and 14 give positions of stars for the equinox 1950.0 and the epoch 1953.6 from the two Lick plates.

Errors. To check the Lick measurements and to determine their accuracy, differences $x_2 - x_1$ and $y_2 - y_1$ of measured coordinates on both plates were formed for all the 125 stars. The least-squares solution of $ax + bx + c = x_2 - x_1$ and $dx + ey + f = y_2 - y_1$ for the relative plate constants yielded the probable errors of a coordinate difference, and the latter errors gave $\pm 0''.06$ and $\pm 0''.08$ as probable errors for the mean x and y from both plates. These errors of internal agreement were combined with the errors of positions

and proper motions of the reference frame to give, finally, $\pm 0''.07$ and $\pm 0''.09$ as probable errors of a Lick right ascension and declination, respectively. The reference stars independently furnished errors of the same order from computation of Lick plate constants with respect to AGK2 positions.

Probable errors in the AGK2 positions used were estimated as $\pm 0''.10$ for each coordinate, under the assumption that the accuracy of the Bonn zone is the same as that of the published Bergedorf part. The scatter of preliminary motions obtained from AGK2-AGK1 was used to evaluate the probable errors of the mean proper motion used for reduction of the Lick plates.

The accuracy of Kopff's (1943) positions is the same as that of AGK2; recomputation of astrographic plate constants gave $\pm 0''.17$ as a probable error, on the average, for a position from one astrographic plate.

With consideration of the weights, introduced earlier, all the above values, on the average, give $\pm 0''.15$ as a probable error of a position of unit weight. From this value the expected probable errors of coordinates and proper motions in Table II are: $\pm 0''.048$ for α_0 or δ_0 with $w_c = 10$, and $\pm 0''.33$ for centennial proper motions $100\mu_\alpha$ and $100\mu_\delta$ with the relative weight $w_\mu = 2.0$. The probable errors found from the least-squares solutions for α_0 , δ_0 , $100\mu_\alpha$, and $100\mu_\delta$ are, on the average $\pm 0''.048$, $\pm 0''.058$, $\pm 0''.33$ and $\pm 0''.37$, respectively. These errors are in good agreement with the expected ones mentioned above. The values finally adopted for the errors are summarized in Table III.

TABLE III. ERRORS IN POSITIONS AND MOTIONS

	Probable errors	
	$\pm 0''.07$	$\pm 0''.09$
Lick positions, α_L and δ_L		
Mean positions, α_0 and δ_0 , for $w_c = 10$	± 0.05	± 0.06
Centennial p.m., $100\mu_\alpha$ and $100\mu_\delta$, for $w_\mu = 2.0$	± 0.3	± 0.4

Cluster membership. When the proper motions were obtained, it was evident that most of the stars which could be assigned to the cluster from the photograph showed a common proper motion, in spite of its small amount, of the order of only $0''.9$ per century. Fifteen of these stars, Nos. 22, 23, 53, 57, 58, 62, 64, 66, 73, 76, 81, 82, 88, 102 and 118, also satisfied the criterion for membership as defined by Hogg and Kron (1955) for their color-luminosity diagram. The mean centennial proper motion of these stars is $-0''.69$ and $-0''.63$ in right ascension and declination respectively, with probable errors of $\pm 0''.07$ and

$\pm 0''.08$. The vector point of this motion is plotted as an open circle in Figure 3. Around this point there is drawn an ellipse (the smaller of the two) with semi-axes equal to the mean errors of $100\mu_\alpha$ and $100\mu_\delta$ of a star.

A star was considered a probable member of the cluster, and marked with a plus sign in Table II, if the vector point of its proper motion fell within the area of the ellipse. This criterion is arbitrary; it was chosen because the mean error is used as one of the measures of the accuracy, and because it is larger than the probable error. Use of the latter for an ellipse would reduce the probable members by one-half.

Next, a larger ellipse, with semi-axes equal to twice the probable error, was drawn as a limit for possible cluster members. This limit is also arbitrary, but its justification is the fact that all stars but one, considered as probable members by Hogg and Kron, fall within this ellipse. The one star, No. 105, falls far outside the proper motion criterion, but it satisfies all three photometric criteria by Hogg and Kron. This star is also outside and moving away from the main body of the cluster. Whether this fact has any significance, cannot be decided from the present data.

The stars with vector points between both ellipses were adopted as possible members, and are marked with O in Table II. All the stars outside the larger ellipse are considered field stars, and are marked with a minus sign. Proper motions of 23 stars are too large to be plotted within the area of Figure 3.

Proper motion of the cluster. Although proper motions were determined in an attempt to refer them to the FK3 system, the values obtained in the preceding section for the cluster should be considered with some reservations because of the nature of the reference system. Two factors affecting the derived cluster proper motions are:

First, the reference stars used for initial reduction of the plates contained 12 probable cluster members amongst them. Correction for this systematic motion changes the proper motion of the cluster to $100\mu_\alpha = -0''.81$ and $100\mu_\delta = -0''.47$;

Second, the reference frame was related to the FK3 by means of AGK2 and AGK1, the latter corrected by the aid of reduction tables. The magnitude equation and the accidental errors in AGK1 may be large enough to prevent a rigorous reference to FK3.

None of these stars is in the FK3, but since 13 are in GC, one may expect that the GC proper motions reduced to FK3 and compared with our proper motions could serve as an independent check on our system of reference.

Unfortunately, the GC proper motions for these 13 stars seem to be extremely unreliable; the centennial proper motions for definite cluster members differ from each other as much as $5''.1$ in right ascension and $2''.1$ in declination.

The total of the differential effect of galactic rotation, and of the corrections to the motion of the equinox and to the precession constant is represented by a vector point marked with the cross in Figure 3, if values by Morgan and Oort (1951) are used. The cross does not indicate the general trend of proper motions of the field stars, as would be expected. A correction of $-0''.5$ to centennial proper motions in declination and of $+0''.2$ to those in right ascension would bring the cross in a more probable position.

If the effect of the solar motion is added to the previous effects, the corresponding vector points are marked with squares in Figure 3. The open square is obtained if the basic solar motion by Vyssotsky and Janssen (1951) is used; the filled square corresponds to $h = 20$ km/sec, $A = 275^\circ$, $D = +29^\circ$. In both cases the distance of 430 pc to the cluster was adopted, as deduced by Hogg and Kron.

Although our reference system may deviate from the FK3, it seems that all the positions of stars used are put on a reasonably uniform basis, and that the proper motions obtained may serve better for the future investigations of the cluster than those available previously.

Discussion. After the present investigation was completed, the author learned that seven plates of the cluster were taken by R. J. Trumpler at the Allegheny Observatory around 1917. Dr. N. E. Wagman, Director, has kindly consented to repeat the photographs and to make them available for further investigations of proper motions in this cluster.

Because of this possibility of being able to improve considerably the internal accuracy of proper motions, the discussions regarding the dispersion of the proper motions are postponed until the Allegheny plates can be measured. The same consideration applies to the peculiar proper motion of the cluster. Although the new material does not promise any improvement regarding the reference to the FK3, it will permit a better separation of the proper motions of the cluster members from those of the field stars.

Unfortunately, no reliable space motion of the cluster can be obtained unless more information on its radial velocity becomes available. At present only four radial velocities, ranging from -7 to -26 km/sec are given for the cluster members in R. E. Wilson's *General Catalogue of Radial Velocities*.

There are several determinations of the distance to the cluster, ranging from 260 to 430 pc, the latter being by Hogg and Kron (1955), which places the cluster 350 pc closer to the galactic center than the sun, or possibly at the inner edge of the local spiral arm, but certainly outside the outer arm of two inner ones indicated by Kwee *et al.* (1954).

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