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THE COLOR-MAGNITUDE DIAGRAM OF THE METAL-RICH GLOBULAR CLUSTER NGC 6712

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ABSTRACT

The color-magnitude diagram is presented for NGC 6712 as obtained from two-color photographic photometry of 304 stars calibrated with a 25-star photoelectric sequence. The diagram differs from that of halo clusters in that (1) the giant branch at $(B - V)_0 = +1.4$ rises only 2.2 mag. above the horizontal branch instead of the usual 3.0 mag.; (2) the horizontal branch is heavily populated on the red side of the variable-star gap; and (3) the giant and subgiant sequences are displaced redward in intrinsic color from the corresponding sequences in clusters having lower metal abundance. Point 3 is shown to be a general characteristic in clusters studied to date and is correlated with metal abundance.

The reddening of the cluster is estimated to be $E(B - V) = 0.48 \pm 0.01$. The apparent visual distance modulus is $(m - M)_{app,V} = 15.6$ if $M_V = +0.5$ for the RR Lyrae stars. The true modulus is $(m - M)_0 = 14.2$ if the visual absorption is $A_V = 3\,E(B - V)$. The distance of NGC 6712 is 6750 pc from the Sun, 470 pc from the galactic plane, and 4900 pc from the galactic center, if $R_0 = 10$ kpc.

I. INTRODUCTION

Following Mayall's (1946) initial discovery of large variations in the spectral types of globular clusters, Morgan (1956, 1959) made two fundamental studies of integrated spectra in which he divided globular clusters into eight groups according to the strength of the Fraunhofer lines. By 1964, work on the color-magnitude (C-M) diagrams of Morgan's late-type clusters had clearly established that progressive, systematic differences exist in the positions and in the shapes of the sequences in the C-M diagrams as one proceeds from class I to class VIII clusters. By now, diagrams for four late-type clusters exist (NGC 6356, Sandage and Wallerstein 1960; 47 Tuc, Wildey 1961, Tifft 1963; NGC 6723, Gascoigne and Ogston 1963; and NGC 6171, Sandage and Katem 1964). All show the same differences relative to the Morgan early-type clusters as regards (1) the absolute magnitude and color of the giant branch and (2) the length of the horizontal branch.

To establish if these trends are real and systematic, we have continued the study of metal-rich clusters and present here the results on NGC 6712 ($\alpha_{1950} = 18^h50^m.3$, $\delta_{1950} = -8°47'$; $l^{II} = 25°$, $b^{II} = -4°$), classified by Morgan (1959) as a moderately strong-lined cluster of Group V. Kron and Mayall (1960) determined an integrated type of G5 for the cluster, while Kinman (1959) gives G4, based on the CH/Hγ ratio; values which show that NGC 6712 is of later type than the typical halo clusters of M3 (F7), M15 (F2), and M92 (F1).

NGC 6712 is situated in the center of the Scutum Cloud, which is one of the highest surface-brightness regions of the Milky Way. This makes precision photometry at faint levels impossible due to background problems and we have been forced to terminate the C-M diagram at $V = 17.0$ mag. to avoid the unusually severe crowding difficulties in this rich field.

II. THE OBSERVATIONS

Two-color photographic measurements of 304 stars in and near NGC 6712 were made on two yellow plates (103aD + GG11, exposure times 30 and 15 sec) and one blue plate (103aO + GG13, exposure time 15 sec) taken with the 200 inch telescope, The measure-

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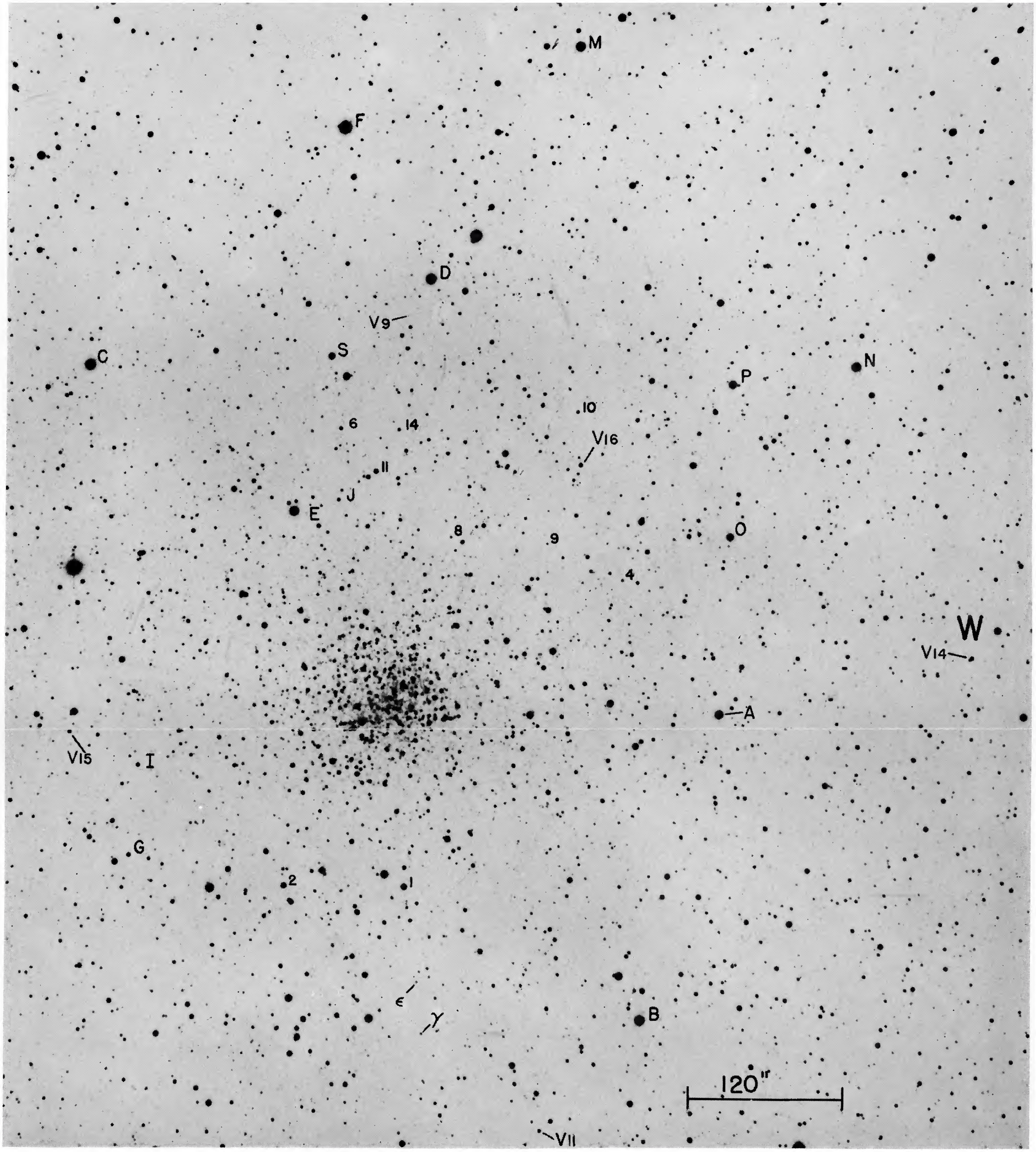

FIG. 1.—Finding chart for the 25 photoelectric standards of Table 1 and for variables V9, V11, V14, V15, and V16. The reproduction is from a 3-min blue plate taken with the 200-inch telescope

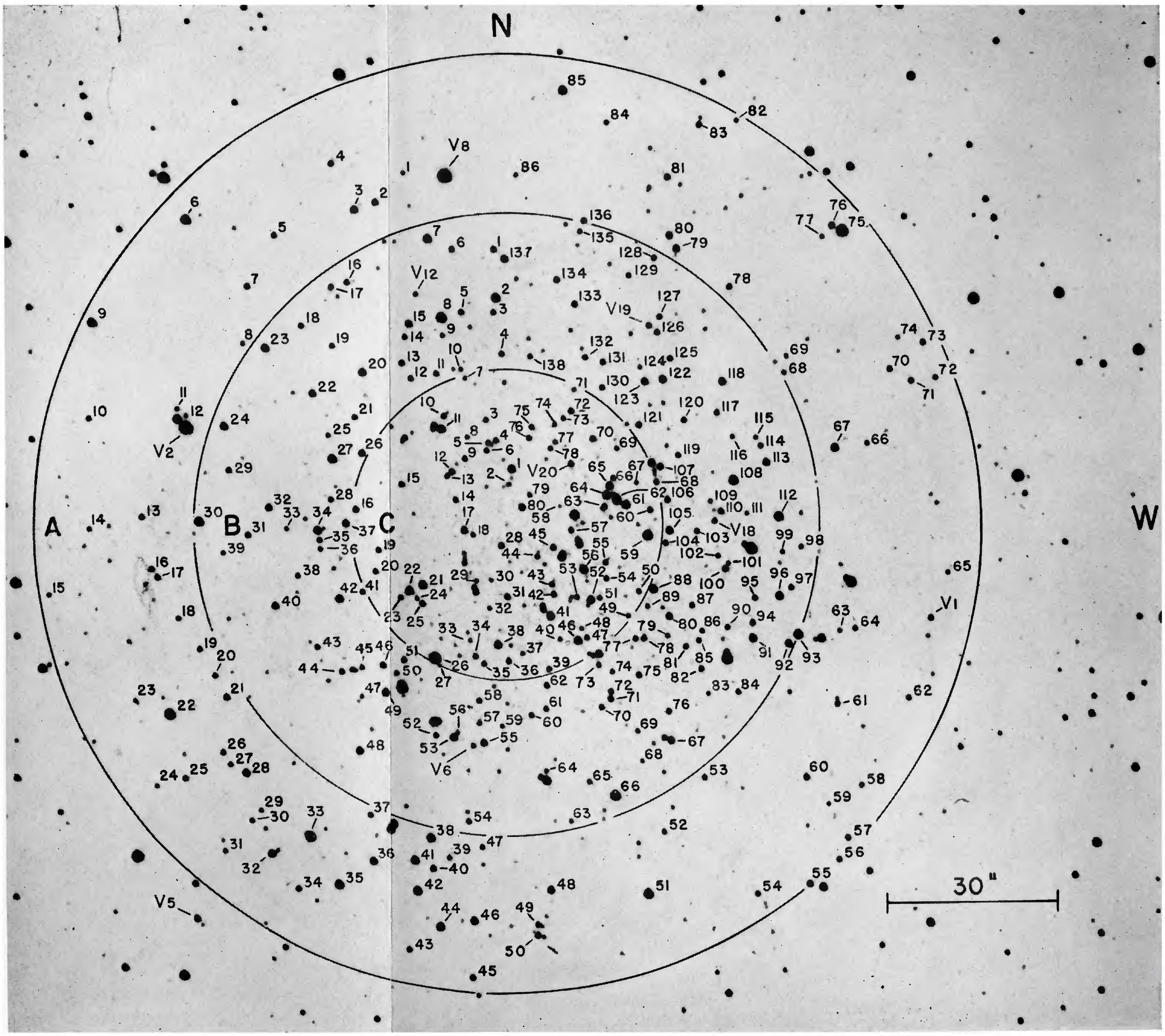

Fig. 2.—Finding chart for the 304 stars of Table 2. The reproduction is from a 30-sec yellow plate taken with the 200-inch telescope

ments were made with an iris-diaphragm photometer by reference to a photoelectric sequence of twenty-five stars established with the 100-inch and 200-inch reflectors with conventional 1P21 refrigerated photometers. The photoelectric stars are given in Table 1 together with the photographic values read back through the calibration-curves and corrected by a slight residual-color equation, also applied to the 304 program stars. The accuracy of the photoelectric values is about $\Delta V \simeq \pm 0.02$ mag. (m.e.), $\Delta(B - V) \simeq \pm 0.01$ mag. (m.e.), and $\Delta(U - B) \simeq \pm 0.02$ mag. (m.e.), as judged by internal consistency and by deviations of the standard *UBV* stars used as fundamental standards on six nights of transfer observations.

TABLE 1

PHOTOMETRIC STANDARDS IN NGC 6712

Star	Photoelectric Values					Photographic Values	
	V	$B-V$	$U-B$	n 100″	n 200″	V	$B-V$
F	10 58	0 56	0 01	1	.		
B	11 10	1 09	75		1		
C	11 24	0 64	10	.	1		
D	11 42	0 64	23	1	1		
E.	11 81	0 67	11	.	1		
M	11 92	0 44	20	1			
N	12 22	0 21	03	1	.	.. ..	....
A	12 44	0 50	11	1	5	12 41	0 42
P	12 81	0 35	21	1			
O	13 01	0 64	05	1	.	.. ..	....
S	13 14	0 78	26	.	2	13 19	0 90
11	13 65	1 36	...	1	1	13 68	1 42
1	13 85	0 46	25	4	4	13 95	0 40
2	14 00	0 58	24	1	2	14 01	0 49
I.	14 44	1 43	..	1	1	14 37	1 53
G	14 81	0 85	28	1	1	14 75	0 83
J	15 25	1 23	88	1	2	15 24	1 21
6	15 39	0 79	35	3	1	15 43	0 77
4.	15 86	1 39		2	1	15 73	1 55
10	16 13	0 70		2	1	16 05	0 69
9	16 37	1 41	..	2	2	16 27	1 49
14	16 40	0 47	{22, 35}	1	2	16 51	0 38
8	16 70	0 90	...	2	2	16 85	0 74
γ	17 09	1 13	0 75	.	2	17 12	1 16
ε	17 57	0 99		1	2	17 58	0 97

The photoelectric sequence is identified in Figure 1, which is from a 3-min blue exposure made with the 200-inch. Also shown in this figure is the identification of five variable stars discussed in the following paper (Sandage, Smith, and Norton 1966).

Identification of the 304 program stars is shown in Figure 2, which was made from a 30-sec yellow exposure, again taken with the 200-inch. Table 2 shows the results. The accuracy of the final tabulated values is estimated to be $\Delta V \simeq \pm 0.03$ (m.e.), $\Delta(B - V) \simeq \pm 0.05$ (m.e.), which is sufficient for a reconnaissance of the cluster.

III. THE COLOR-MAGNITUDE DIAGRAM

The program stars of Table 2 are plotted in the C-M diagram of Figure 3. Also plotted are ten RR Lyrae stars and four long-period semiregular variables at their mean V and $B - V$ values as determined in the following paper. The seven RR*a* types and

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TABLE 2

PHOTOGRAPHIC PHOTOMETRY FOR STARS IDENTIFIED IN FIGURE 2

No.	V	(B−V)
Ring A		
1	16.87	1.11
2	15.73	1.27
3	15.38	0.97
4	16.21	0.95
5	16.12	1.09
6	14.42	1.30
7	16.06	1.13
8	16.68	1.46
9	14.71	1.35
10	16.37	1.18
11	16.54	1.29
12	16.75	1.34
13	16.07	1.22
14	16.73	1.27
15	16.85	0.71
16	15.96	1.23
17	15.98	1.25
18	16.45	1.10
19	16.16	1.17
20	16.14	1.29
21	15.68	0.85
22	13.78	1.44
23	16.73	0.93
24	16.80	1.22
25	16.11	1.41
26	16.20	1.37
27	16.40	1.32
28	15.16	1.03
29	16.63	0.49
30	16.37	1.29
31	16.53	1.35
32	15.10	1.52
33	13.92	0.63
34	16.07	1.42
35	14.49	1.29
36	15.22	1.43
37	16.12	1.26
38	14.76	1.57
39	16.37	1.47
40	15.77	1.23
41	14.84	1.87
42	14.67	0.79
43	16.24	1.33
44	14.85	1.59
45	15.95	1.40
46	15.10	1.34
47	16.44	1.30
48	15.23	1.49
49	16.02	1.02
50	15.62	1.34
51	14.19	1.77
52	16.37	0.52
53	16.10	1.18
54	16.20	1.10
55	15.60	1.82
56	16.08	1.23
57	15.97	1.13
58	16.38	0.55
59	16.67	1.02
60	15.77	1.15
61	16.11	1.39
62	16.20	1.19
63	16.75	1.11
64	16.22	0.57
65	16.64	1.20
66	16.50	1.23
67	15.07	1.46
68	16.52	1.34
69	16.59	0.46
70	16.00	1.36
71	16.14	1.17
72	16.30	1.41
73	16.11	1.12
74	16.81	1.06
75	13.27	1.57
76	15.70	1.45
77	16.73	0.97
78	16.08	1.52
79	15.37	0.93
80	15.63	1.45
81	15.95	0.98
82	16.91	0.77
83	16.13	1.07
84	16.63	1.17
85	14.85	1.49
86	16.85	1.17
Ring B		
1	15.98	1.22
2	14.59	1.62
3	16.21	1.37
4	16.24	1.10
5	16.13	1.10
6	16.17	1.12
7	14.98	0.58
8	14.08	1.78
9	16.57	1.25
10	16.77	1.33
11	16.19	1.24
12	16.13	0.97
13	16.04	1.16
14	16.24	1.10
15	15.43	1.44
16	16.12	0.65
17	16.22	1.28
18	16.17	1.11
19	16.25	1.04
20	15.15	1.40
21	16.18	1.16
22	15.44	1.48
23	15.17	1.32
24	15.22	1.55
25	16.67	1.24
26	15.55	1.86
27	14.69	1.85
28	16.21	0.91
29	16.14	1.02
30	14.51	1.54
31	15.98	1.10
32	15.59	1.41
33	16.87	1.18
34	15.01	1.51
35	16.08	1.18
36	16.48	1.26
37	15.41	1.43
38	16.35	0.53
39	16.65	1.44
40	15.42	1.51
41	16.17	1.11
42	15.12	1.50
43	16.18	1.12
44	16.08	1.18
45	16.42	0.91
46	15.73	1.42
47	16.98	1.07
48	15.33	1.38
49	14.94	1.49
50	16.23	1.36
51	16.00	1.20
52	16.17	0.45
53	15.05	1.32
54	16.15	1.01
55	15.47	1.40
56	16.76	0.95
57	16.39	0.52
58	16.15	1.00
59	16.74	1.19
60	16.19	1.30
61	16.14	1.34
62	16.03	1.29
63	16.88	0.34
64	16.52	1.23
65	16.34	1.32
66	13.93	1.78
67	15.22	1.23
68	16.83	1.29
69	16.50	1.34
70	16.12	1.04
71	15.76	1.22
72	15.76	1.23
73	16.22	1.01
74	16.47	0.51
75	15.98	1.37
76	16.07	1.36
77	16.13	0.61
78	15.92	1.45
79	16.48	1.30
80	15.49	1.26
81	16.13	1.14
82	16.06	1.04
83	16.80	1.21
84	16.22	1.29
85	16.26	1.34
86	16.34	0.90
87	16.20	1.08
88	14.68	1.46
89	16.56	0.47
90	16.22	0.58
91	14.96	1.33
92	15.15	0.89
93	14.25	0.77
94	15.86	1.34
95	16.10	0.92
96	14.98	1.48
97	16.09	1.23
98	16.58	1.21
99	16.64	1.34
100	15.73	1.45
101	16.66	1.31
102	16.29	1.40
103	16.12	1.13
104	15.97	1.28
105	15.07	1.30
106	15.93	1.16
107	15.50	1.52
108	14.30	1.78
109	16.62	1.28
110	15.90	1.12
111	16.85	1.16
112	14.49	1.34
113	15.37	1.47
114	16.15	1.15
115	16.63	1.20
116	16.81	0.69
117	16.25	1.21
118	15.33	1.47
119	16.12	1.16
120	16.09	1.14
121	16.02	1.18
122	15.24	1.30
123	15.41	1.25
124	16.85	1.18
125	16.07	1.01
126	16.01	1.35
127	16.20	1.26
128	16.15	1.12
129	16.52	1.22
130	16.17	1.17
131	16.17	1.06
132	16.17	1.34
133	15.84	1.40
134	15.85	1.44
135	16.40	1.27
136	16.04	1.12
137	15.38	1.48
138	16.44	1.29
Ring C		
1	15.01	1.54
2	16.83	1.27
3	16.33	1.32
4	16.08	1.01
5	16.07	1.04
6	16.15	1.18
7	16.73	1.34
8	16.87	1.16
9	16.18	1.27
10	16.00	1.31
11	14.78	1.48
12	15.73	1.54
13	16.21	1.49
14	16.20	1.21
15	16.12	1.25
16	15.73	1.26
17	15.41	1.51
18	16.49	1.18
19	16.05	1.11
20	16.18	1.14
21	14.62	1.66
22	14.52	0.92
23	16.10	1.27
24	16.63	1.29
25	15.80	1.29
26	13.14	0.42
27	17.00	1.21
28	15.76	1.21
29	16.58	1.27
30	16.85	1.26
31	15.78	1.27
32	16.60	1.19
33	16.93	1.18
34	16.08	1.42
35	16.06	1.09
36	16.01	1.29
37	16.69	1.20
38	14.98	1.29
39	16.08	1.07
40	16.68	1.18
41	14.87	1.91
42	15.80	1.00
43	16.00	1.42
44	16.10	1.29
45	15.78	1.26
46	14.79	1.45
47	16.13	1.26
48	16.72	1.45
49	16.60	....
50	16.19	1.30
51	16.33	1.44
52	14.81	1.60
53	16.15	0.63
54	16.10	1.29
55	16.13	1.34
56	14.49	1.64
57	16.01	1.14
58	14.13	1.57
59	14.07	1.70
60	16.01	1.40
61	14.66	1.56
62	14.31	1.42
63	15.76	1.36
64	14.84	1.47
65	14.98	1.48
66	16.01	1.24
67	16.86	1.18
68	15.99	1.21
69	16.43	1.31
70	15.91	1.43
71	16.76	1.31
72	16.00	1.16
73	16.39	1.26
74	16.53	0.58
75	16.17	1.22
76	16.17	1.28
77	16.57	1.33
78	16.30	1.40
79	16.70	1.46
80	15.60	1.42

the four long-period variables are plotted as crosses, while the three RR*c* variables are shown as open circles. The RR Lyrae gap is remarkably well defined with boundaries at the observed colors of $B - V = 0.65$ and $B - V = 0.90$. As expected, the long-period (LP) variables lie at the top of the giant branch. It is shown in the following paper that three of the four LP's are probably members of the cluster while No. 7 (CH Sct) is almost certainly a field star.

Even casual inspection of Figure 3 shows that the C-M diagram is strikingly similar to that of NGC 6171 (Sandage and Katem 1964) and differs considerably from diagrams of the classical halo cluster (M3, Sandage 1953; M92, Arp, Baum, and Sandage 1953;

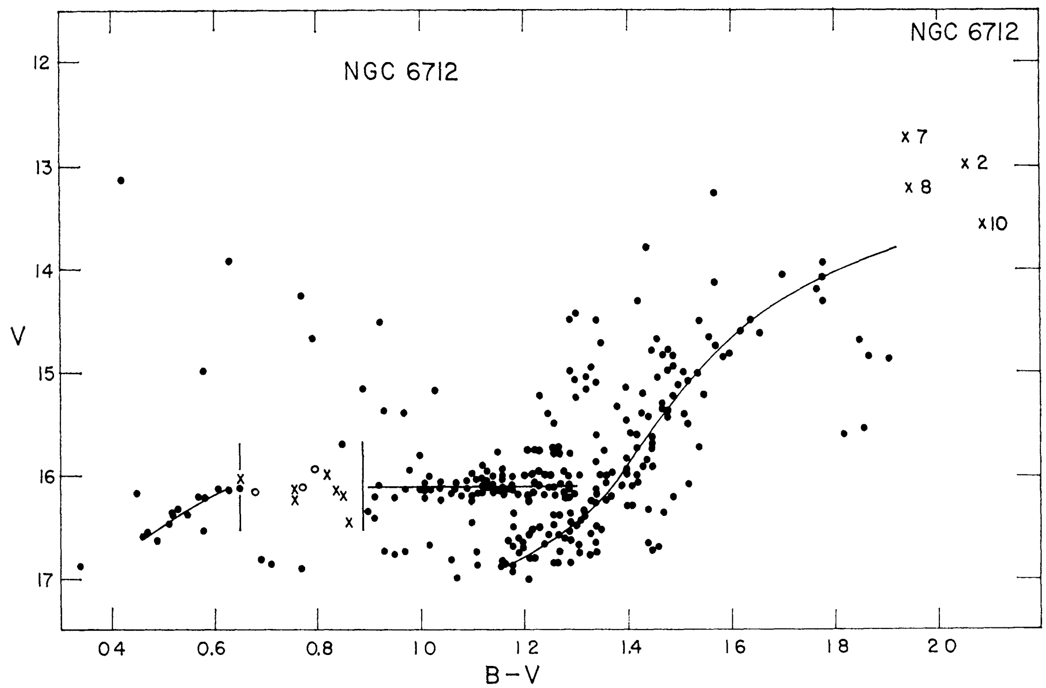

FIG. 3.—The color-magnitude diagram based on the data of Table 2 No correction for reddening has been applied Seven RR Lyrae stars of type *a,b* are shown as crosses, three of type *c* as open circles, and four long-period variables as crosses at the top of the giant branch

M13, M15, M2, M10, and M5, Arp 1955). The main differences are:

a) The giant branch in NGC 6712 does not rise steeply above the horizontal branch. The difference in magnitude between these branches read at $B - V = +1.88$ ($[B - V]_0 = +1.4$ with $E[B - V] = 0.48$, see below) is $\Delta V = +2.2$ mag. rather than the usual 3.0 mag. for low-metal-abundance halo clusters (see Sandage and Wallerstein 1960).

b) The horizontal branch is heavily populated on the red side of the variable-type gap in an almost identical way as in NGC 6171, but in sharp contrast with low-metal-abundance clusters. The difference in the population gradient between clusters as a function of metal abundance now seems well established from the many clusters studied to date.

c) The horizontal branch is of abnormal length along the color axis, abutting to the subgiant sequence at a very red intrinsic color. Again the diagram is similar to NGC 6171 in this regard. The unreddened color of the subgiant branches of various clusters at this point of juncture with the horizontal branch is a parameter which varies systematically with metal abundance. This is shown in Figure 4, which is a schematic, composite diagram that includes M92 (Morgan class I), M13 (class III), 47 Tuc (presumed to be of class VIII because of its very high metal abundance), and the open cluster NGC 188 which is of nearly solar abundance. There have been no arbitrary vertical or horizontal shifts of the cluster diagrams in Figure 4 to achieve a fit, but rather each cluster (with the exception of NGC 6712) was placed in position according to photometric distance moduli found by fitting the observed main sequences to the Hyades, using appropriate blanketing corrections (see Eggen and Sandage 1962 for the justification). The data were taken from Tifft (1963) for 47 Tuc, and from an unpublished investigation (Sandage 1964,

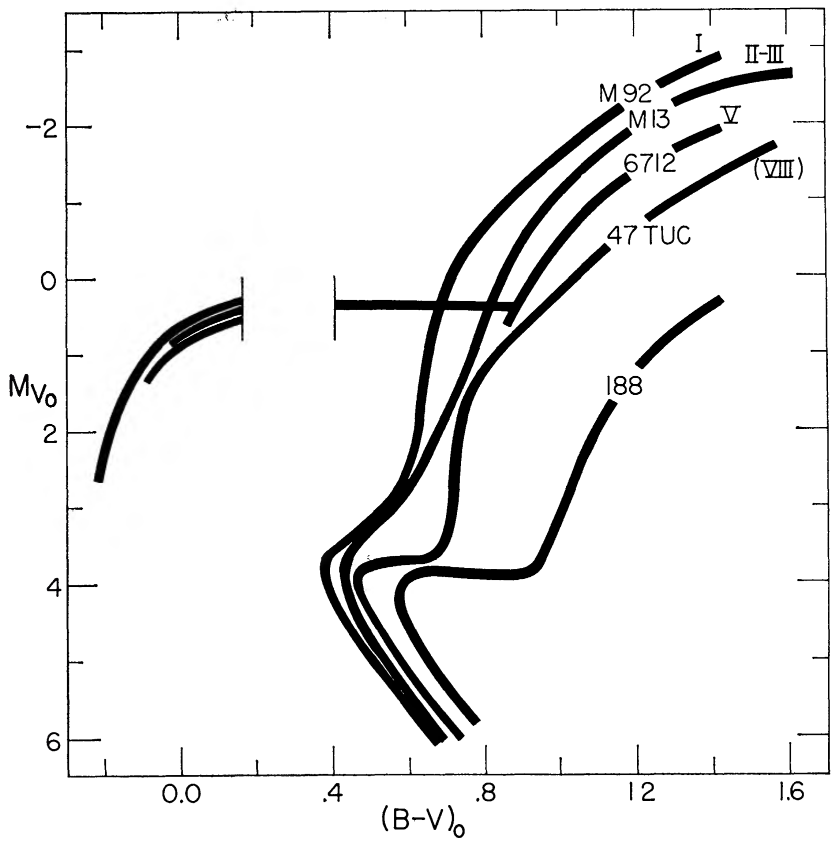

FIG. 4.—Comparison of C-M diagrams of M92, M13, NGC 6712, 47 Tuc, and NGC 188, corrected for reddening but not differential line blanketing. The clusters are labeled with Morgan's spectral groups. The systematic color shift of the giant and subgiant sequences appears to be well correlated with metal abundance.

1966) for M92, M15, M13, and M3. These data show that the horizontal branches of these four clusters coincide in M_V to within the accuracy of the method, and this justifies the fit of NGC 6712 to the composite horizontal branch in Figure 4. The abscissa of the diagram is $B - V$, corrected for reddening but not for blanketing. We have adopted $E(B - V) = 0.48$ for NGC 6712 as discussed in the next section.

Figure 4 summarizes points *a* and *c* above. The main conclusion is that clusters differ systematically in the absolute magnitude of the top of the giant branch and in the color of the subgiant branch near $M_V \simeq 0.5$, and these differences are progressive with metal abundance. Item *a* on M_V of the giant branch was first pointed out by Arp (1955), was amplified by Kinman (1959), and was later generalized to many clusters (Sandage and Wallerstein 1960). Point *c* on the color difference of subgiant branches is a generalized statement of the effect found in a comparison between M3 and M92 (Arp *et al.* 1952;

Baum 1952; Sandage and Walker 1966) and extended with the study of NGC 6356 (Sandage and Wallerstein 1960).

In Table 3 we have collected data on the colors of the subgiant branches $(B - V)_{0,g}$ read at the level of the horizontal branch for clusters with well-observed C-M diagrams and with adequately determined reddening. The purpose here is to show that all data now available are consistent with the systematics of Figure 4. The table is divided into four sections that separate the clusters into groups of roughly similar metal abundance,

TABLE 3

CORRELATION OF $(B - V)_{0,g}$ WITH METAL ABUNDANCE

Cluster	M	Spectral Group			$\delta(U - B)_g$	$(B - V)_{0,g}$*	Ref †
		Deutsch	Morgan	⟨KKM⟩			
NGC 2682	67				0 03	1 29	1
188					03	1 39	2
104.	47 Tuc			G3	13	0 92	3
6171			. .	G1 7		0 94	4
6712	.		V	G4 5		0 89	5
5904	5	A	II	F5 5	15	0 84	6
6205	13	A	III	F5 5	18	0 83	7, 13
5272	3	AB	II	F7	18	0 79	8, 13
4147		B		F0		0 80	9
5053		C				0 71	10
5897	.	C		.	. .	0 69	11
6341	92	C	I	F1 5	27	0 69	12
7078	15	C	I	F2 5	0 26	0 69	13

* Defined as the reddening-free color of the subgiant sequence read at the magnitude level of the horizontal branch when that branch exists, or at $M_V = +0$ 5 for M67 and NGC 188

† The references are:
1 O J. Eggen and A R Sandage, *Ap. J*, **140,** 130, 1964
2 A R Sandage, *Ap J*, **135,** 333, 1962.
3. R L Wildey, *Ap. J.*, **133,** 430, 1961; R G. Tifft, *M N*, **126,** 209, 1963
4. A. Sandage and B Katem, *Ap J*, **139,** 1088, 1964
5 This paper
6 H C Arp, *Ap J*, **135,** 311, 1962
7 H C Arp and H L. Johnson, *Ap J*, **122,** 171, 1955.
8 H L Johnson and A. R Sandage, *Ap J.*, **124,** 379, 1956
9 A R Sandage and M F Walker, *A J*, **60,** 230, 1955
10 A R Sandage and H. L Johnson, unpublished data
11 A R Sandage and M. Schmidt, unpublished data.
12 A Sandage and M Walker, *Ap. J*, **143,** 313, 1966
13 A Sandage, in preparation, 1966

as determined independently from (1) the spectral types of Deutsch (1955); of Morgan (1956, 1959); and of Kinman (1959), averaged with Kron and Mayall (1960) in columns labeled ⟨KKM⟩, and (2) the ultraviolet excess of the giants read at $(B - V)_0 = +1.0$, taken from the literature and from unpublished studies. Although there is some conflict of these data as to the ordering of any given cluster, the division among the four groups seems definite. The division into groups is of course arbitrary, and inspection of Figure 4 makes it likely that a continuum exists and would be found if more clusters were plotted.

Table 3 shows that $(B - V)_{0,g}$ becomes progressively bluer as the metal abundance is decreased. The clusters M2 (Arp 1959) and M53 (Cuffey 1958), not given in the table, appear to violate slightly the correlation, but the color system and/or the reddening for these two clusters are not known with sufficient accuracy to tell if the violation is real.

Our conclusion then is that Table 3 and Figure 4 illustrate a general rule. The effect may be understood theoretically by a combination of (1) differential line blanketing on $B - V$ colors, and (2) an intrinsic change of stellar radius—and therefore color—for stars of the same luminosity but with different metal abundance, as predicted by Hoyle and Schwarzschild (1955, Fig. 4).

IV. THE REDDENING AND DISTANCE MODULUS OF NGC 6712

The reddening of NGC 6712 has been estimated in four ways, three of which depend on properties of the cluster stars themselves.

1. The color boundaries of the variable-star gap are sharply defined and occur at $B - V = 0.65$ and $B - V = 0.90$. In the unreddened cluster M3, the gap occurs between $(B - V)_0 = 0.17$ and $(B - V)_0 = 0.42$, giving $E(B - V) = 0.48$ for NGC 6712 if we assume that the color boundaries of the gap are independent of metal abundance. This may not be strictly true because of small differential blanketing in $B - V$ between the clusters at the temperature of the RR Lyrae stars, or because of a real difference in the boundaries in T_e as a function of metal abundance. Lack of knowledge precludes correction for these possible intrinsic differences.

2. Horizontal-branch stars blueward of the variable-star gap in the well-observed clusters M3, M13, M15, and M92 (Sandage 1964) define a single sequence that can be used as a fiducial line. The shifting of Figure 3 along the color axis to obtain coincidence with these blue branches gives $E(B - V) = 0.48 \pm 0.02$ for NGC 6712.

3. Comparison of the colors of the RR Lyrae stars in NGC 6712, given in the following paper, with the variables in M3 (Roberts and Sandage 1955; Sandage 1959) gives $E(B - V) = 0.48 \pm 0.02$ if NGC 6712 variable 13 is included, or $E(B - V) = 0.50 \pm 0.01$ if No. 13 is excluded. The method is to enter the period–mean color relation of the M3 variables and to extract that $(B - V)_0$ which applies at the given period. The observed period and color for the ten cluster variables in 6712 then provide $E(B - V)$ for each of the stars. The method assumes that (1) the period–intrinsic color relation for variables in M3 and in NGC 6712 is the same, and (2) that $E(B - V) = 0.00$ for M3. Justification for the first assumption comes by noting that both clusters have the same mean period of $\bar{P}_{a,b} = 0^{d}55$ for the *a*, *b* variables and are, therefore, of the same Oosterhoff (1939) class. Furthermore, the period-amplitude relation for the NGC 6712 variables is the same as for M3. Using an early model that accounts for the Oosterhoff mean-period effect (Sandage 1958), these facts require that the period–intrinsic color relation in the two clusters should also be the same. The assumption of zero reddening for M3 is the result of a direct determination (Sandage 1964).

4. Reddening for the individual stars of the photoelectric sequence of Table 1 can be determined in the usual way from the $U - B$, $B - V$ diagram. None of these stars is a cluster member. Assuming them to be dwarfs, and using the normal calibration of the age-zero main sequence permits the reddening to be plotted as a function of apparent modulus. Extrapolation to $(m - M)_{\text{app}} \simeq 15.6$ gives $0.44 < E(B - V) \lesssim 0.50$ for the cluster itself. The method is not accurate because the number of stars in our sample is small and the entire range of $(m - M)$ is not covered.

The four methods taken together are consistent with $E(B - V) = 0.48 \pm 0.01$, which we adopt. The value is in reasonable agreement with the two possible values obtained by Kron and Mayall (1960) of $E(B - V) = 0.34$ and $E(B - V) = 0.52$ on their two assumptions concerning the intrinsic colors of globular clusters.

The apparent distance modulus of the cluster is $(m - M)_{\text{app},V} = 16.11 - \langle M_V \rangle$ where $\langle M_V \rangle$ is the mean absolute visual magnitude of the RR Lyrae stars and where we have taken 16.11 as the average V for the cluster variables, adopted from the following paper. The best that can be done at the moment is to put $\langle M_V \rangle \simeq +0.5$, which gives $(m - M)_{\text{app},V} \simeq 15.6$. Kron and Mayall's wide-angle photometry (1960) gives $V_t = 8.13$, which gives $M_{V_0} = -7.5$ for the absolute magnitude of the entire cluster, a value that is of course independent of the absorption. Adopting a visual absorption of $A_V = 3\,E(B - V)$ gives the true modulus of $(m - M)_0 = 14.2$. This corresponds to a distance from the Sun of 6750 pc and a distance from the galactic plane of 470 pc. The distance of the cluster from the galactic center is 4900 pc if $R_0 = 10$ kpc.

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