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STRENGTHS OF SPECTRAL FEATURES OF GIANT STARS IN OUTLYING HALO CLUSTERS

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ABSTRACT

IIDS spectral scans with ~9 Å resolution have been obtained for giant stars in three outlying halo globular clusters, as well as in six inner halo clusters. Within the respective groups the observations were concentrated on NGC 7006, a cluster whose horizontal branch (HB) is unusually red for its metal abundance, and M2. We find that:

1. Significant λ3883 CN band strength variations occur among giant stars in all globular clusters regardless of metal abundance.

2. DDO indices constructed from the spectral data for NGC 7006 stars confirm and extend the anomalous behavior discovered in filter photometry of the cluster's giants. Similar behavior in earlier DDO filter photometry for four stars in another outlying globular, Pal 5, is confirmed by the new, higher resolution spectral data for one star and seen for the first time in data for a Pal 13 star. That this same behavior has also been found in DDO filter photometry for giant stars in the Draco dwarf spheroidal galaxy, and is inferred from 80 Å resolution spectral scanner data, leads us to suggest that the anomalous behavior in stars of metal-poor, red HB systems may be due to excess CH absorption in the 4200 Å region.

3. In our IIDS spectra, giants in the outlying clusters appear to have have unusally strong G bands relative to giants in inner halo clusters of equivalent ultraviolet excess and Ca II strengths. The combined evidence points to the abundances of CNO elements acting as *a* "second parameter" affecting the HB morphology of globular clusters.

4. Our spectra of five NGC 288 stars indicate that this globular cluster is intermediate in overall metal abundance between M5 and 47 Tuc, and that its HB is, therefore, anomalously blue, as previously suggested by Cannon. We see in this case, however, no implication of CH in the HB anomaly.

5. From the fact that three of the five Pal 13 stars observed had DDO indices and Mg "b" features of dwarf stars, we note that the cluster seems to have few giant stars.

Subject headings: clusters: globular — galaxies: stellar content — stars: abundances — stars: late-type

I. INTRODUCTION

Since the publication of papers by van den Bergh (1965, 1967) and Sandage and Wildey (1967), which pointed out the anomalous red horizontal branches (HB) in some globular clusters and dwarf spheroidal galaxies, extensive debate has occurred in the literature regarding the "second parameter" that is the presumed cause of this effect (see review by Kraft 1979). van den Bergh (1965, 1967) noted that this anomaly occurs predominately for systems on the outer fringes of the Galaxy and suggested that age or, preferably, helium abundance was the cause. Subsequently, a third possibility, CNO element abundance, has often been considered, but there is still no general consensus about which is the second parameter or whether more than one is operative.

Of the three likely possibilities, only CNO element abundance can be measured relatively easily. It was a purpose of the present project to confirm or eliminate CNO element abundance as a second parameter causing the red HBs in outlying halo systems.

A second purpose of the project was to study inhomogeneities in spectral features among stars in globular clusters (see McClure 1979; Kraft 1979). Hesser, Hartwick, and McClure (1976, 1977; hereafter HHM 76 and HHM 77) pointed out that all globular clusters that are at least as metal-rich as M5[2] exhibit significant λ4216 CN band variations from star to star on the giant

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[2]For clusters we observed, alternate designations are given in Table 1; otherwise the NGC number and the new IAU Commission 37 "C" number is given the first time a cluster is mentioned.

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TABLE 1

PHOTOMETRIC INDICES

Cluster E(B-V)[a]	Star[b]	B-V	C(45-48)	C(42-45)	C(41-42)	C(38-41)	M_{HK}	M_G	M_{CH}
M2	1-47	0.98	1.256	0.822	0.158	-0.468	0.589	1.807	0.155
NGC 7089	1-40	0.93	1.176	0.661	0.104	-0.760	0.453	1.767	0.139
C2130-010	2-30	1.15	1.286	0.842	0.105	-0.455	0.646	1.871	0.212
(0.03)	2-33	1.09	1.257	0.792	0.182	-0.493	0.628	1.810	0.144
	2-59	1.44	1.350	0.914	0.195	-0.396	0.641	1.762	0.170
	2-69	1.42	1.381	0.976	0.207	-0.249	0.718	1.804	0.155
	3-19	1.18	1.322	0.866	0.166	-0.311	0.707	1.829	0.143
	3-34	1.05	1.255	0.809	0.152	-0.514	0.569	1.826	0.164
	3-45	1.18	1.258	0.802	0.140	-0.547	0.569	1.810	0.186
	3-55	1.30	1.357	0.936	0.151	-0.377	0.620	1.790	0.176
	3-81	1.12	1.286	0.819	0.132	-0.419	0.575	1.843	0.141
	4-79	1.38	1.400	0.971	0.210	-0.202	0.701	1.797	0.156
	4-83	1.17	1.277	0.828	0.112	-0.525	0.575	1.818	0.195
M5	2-50	1.04	1.287	0.881	0.106	-0.400	0.602	1.822	0.227
NGC 5904	2-51	0.97	1.183	0.729	0.195	-0.559	0.656	1.788	0.132
C1516+022	4-19	1.38	1.378	1.045	0.176	-0.191	0.773	1.775	0.207
(0.04)									
M13	A371	1.09	1.229	0.824	0.100	-0.566	0.565	1.904	0.219
NGC 6205	B786	1.58	1.470	1.075	0.299	-0.101	0.776	1.835	0.159
C1639+365									
(0.02)									
M15	2-75	1.24	1.302	0.768	0.175	-0.591	0.479	1.676	0.071
NGC 7078	S6	1.19	1.324	0.769	0.163	-0.490	0.492	1.757	0.122
C2127+119									
M92	3-13	1.33	1.394	0.847	0.161	-0.505	0.509	1.760	0.132
NGC 6341	5-45	1.03	1.241	0.692	0.091	-0.802	0.363	1.741	0.130
C1715+432	7-18	1.31	1.332	0.800	0.159	-0.557	0.491	1.746	0.132
(0.02)									
NGC 288	19	0.99	1.317	0.912	0.074	-0.383	0.595	1.905	0.246
C0050-268	20	1.36	1.512	1.106	0.305	-0.005	0.793	1.865	0.181
(0.04)	33	1.21	1.233	0.872	0.092	-0.423	0.654	1.893	0.245
	36	1.13	1.245	0.859	0.175	-0.336	0.645	1.875	0.200
	41	0.99	1.188	0.763	0.119	-0.518	0.545	1.864	0.205
NGC 7006	2-4	1.21	1.271	0.892	0.167	-0.604	0.579	1.933	0.203
C2059+160	2-16	1.01	1.258	0.788	0.065	-0.701	0.699	1.903	0.274
(0.08)	2-25	1.17	1.208	0.769	0.049	-0.781	0.368	1.868	0.200
	2-46	1.38	1.328	0.810	0.160	-0.555	0.582	1.896	0.187
	2-53	1.10	1.249	0.671	0.068	-0.533	0.368	1.929	0.174
	2-85	1.20	1.178	0.716	0.099	-0.795	0.448	1.911	0.205
	2-89	1.21	1.225	0.741	0.081	-0.749	0.394	1.893	0.191
	2-103	1.41	1.351	0.951	0.154	-0.380	0.620	1.824	0.213
	3-40	1.12	1.219	0.827	0.111	-0.736	0.475	1.911	0.203
	3-46	1.24	1.277	0.809	0.077	-0.578	0.581	1.896	0.209
Pal 5	D	1.11	1.275	0.880	0.096	-0.498	0.611	1.904	0.240
C1513+000									
(0.04)									
Pal 13	+1.3+1.0	1.26	1.176	0.731	-0.032	-0.858	0.426	1.920	0.237
C2304+124									

[a] For reddenings we have used a mean of values listed by Hesser et al. (1977) and Zinn (1980). For Pal 13 we have guessed, but a reasonable error will make no difference to our results.

[b] The star identification sources are as follows: Pal 13 - see text; NGC 288 - Cannon (1974); all others - same as those listed by Hesser et al. (1977).

branch. They note that the case is very different for open clusters where the CN strengths tend to be very homogeneous. McClure and Norris (1977) suggested that this phenomenon in metal-rich clusters could be explained by CNO mixing and is probably due to the same mechanism that produces the weak G-band strengths in some metal-poor globular cluster stars (Zinn 1973). On the other hand, Hesser (1978, 1980) and Hesser and Bell (1980) show that CN variations occur among stars on the upper main sequence of 47 Tuc (NGC 104, C0021-723). Their observations are not easily reconciled with current ideas on mixing, such as the mechanism of Sweigart and Mengel (1979). At the same time, by using the λ3883 CN band, Hesser and Harris (1979) have shown that the *metal-poor* globular cluster M22 (NGC 6656, C1833-239) has a wide range of CN strengths. Since M22 may, however, show some of the otherwise unique features of ω Cen, it is not necessarily representative of metal-poor clusters. Consequently, the question we address in the present paper is whether CN abundance variations found in metal-rich clusters are also found in clusters of low metal abundance, as is the case for Zinn's G-band effect. Our analysis relies primarily on the λ3883 CN band which is much stronger (although in a somewhat less easily observed spectral region) than the λ4216 band used by the DDO system.

II. THE SPECTRAL SCANS

The spectral scans used in this paper were obtained with the Intensified Image Dissector Scanner (IIDS) on the 2.1 m and 4 m telescopes at Kitt Peak, during runs in 1979 August and September. Stars were selected for observation only if star-free fields for sky measurement were identifiable on deep photographs at the fixed aperture separations imposed by the IIDS hardware. Each position was also very carefully examined with the integrating television system at the telescope to insure that the data were uncontaminated by other stars. (Because of the fixed aperture separation—99".4 and 51".7 at the 2.1 m and 4 m telescopes, respectively—observations were made on stars in the outer regions of each cluster to further minimize sky subtraction problems.) The apertures employed were 6".1 and 5".3 in diameter at the 2.1 m and 4 m telescopes. These apertures gave spectral resolutions of 8.5 Å and 10 Å, respectively, when used with the first-order blue, 600 line mm^{-1} grating. Total integration times ranged from a few minutes to about 90 minutes, during which the star and sky channels were frequently interchanged. The seeing was generally quite good and careful attention was paid to the guiding. The data were converted to relative flux units using observations of flux standard stars from the lists of Oke (1974) and Stone (1977) and using the excellent standard reduction software on the IPPS at Kitt Peak. Wavelength-dependent extinction coefficients suitable for Kitt Peak and provided in the reduction package were used.

Table 1 contains a list of stars observed. Column 1 gives the cluster name in the usual, as well as the new IAU Commission 37, designations. NGC 7006, Pal 5, and Pal 13 are outer halo globulars that exhibit unusually red HBs. NGC 288 is a globular that Cannon (1974) suggested shows the opposite effect by having an unusually blue HB. The rest are normal globulars of the inner halo. Column 2 lists the individual stars. In addition to those stars listed, we also observed a small sample of field stars from the list of DDO standards (McClure 1976), including the CH star HD 26 and samples of stars in two old disk clusters, NGC 188 and NGC 2420.

Our reduced scans for stars found to be evolved (from DDO indices and from strength of the Mg"b", MgH feature) are shown in Figure 1. These data have been smoothed from the original fluxes using a seven-point smoothing routine. Two effects are immediately apparent from examination of Figure 1:

First, the λ3883 CN band shows a wide variation of strength in all clusters in which we have observed several stars. While the statistical sample is small, these variations do not appear to be dependent on the position of the star on the giant branch and, as far as we can tell, do not correlate with G-band strengths. Norris (1978), however, has found such a correlation in the case of a larger sample of metal-rich 47 Tuc stars.

Second, there is a depression in the continuum centered on the G band in the NGC 7006 stars relative to the M2 and other metal-poor stars. This depression can be visualized by drawing two straight lines through the continuum, meeting at 4300 Å, as shown for the first NGC 7006 star. The angle subtended by these two lines is systematically greater for the NGC 7006 stars.

III. PHOTOMETRIC INDICES FOR NGC 7006

Various color and line indices were constructed by adding fluxes under rectangular bandpasses using the

FIG. 1.—Blue-violet scans of our sample of giant stars in globular clusters; outlying clusters appear in the left-hand column. The wavelength range 3630–5020 Å is plotted, and the approximate positions of the violet degraded CN bands (bandhead wavelengths of 3883 Å and 4216 Å), Ca II H(3934 Å) and K(3968 Å), Hδ(4102 Å), the extended CH "G" band (central wavelength ~4300 Å), Hγ(4340 Å), and Hβ(4861 Å) are indicated. All spectra are normalized to unit intensity at the G band; this is represented by the vertical bar. A faint star, such as NGC 7006–285, typically has 400 counts per 1.8 Å channel at ~4200 Å. Note the large variations in strength of the λ3883 CN band for stars within a given cluster. Also note the dip (represented by the two lines drawn through the continuum of the upper NGC 7006 star) centered on the G band. This broad absorption, likely due to CH, appears stronger in stars of the outlying systems observed.

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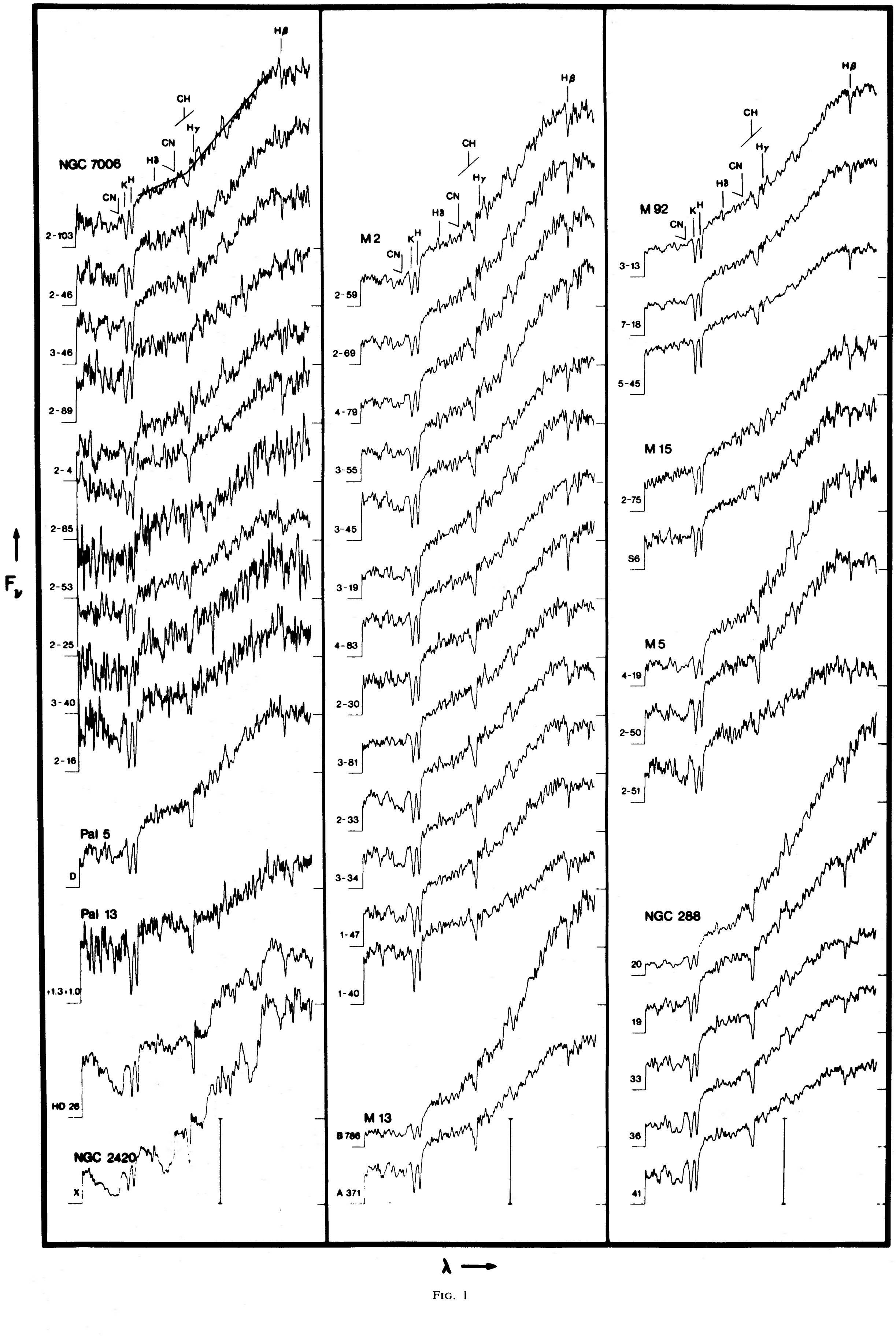

FIG. 1

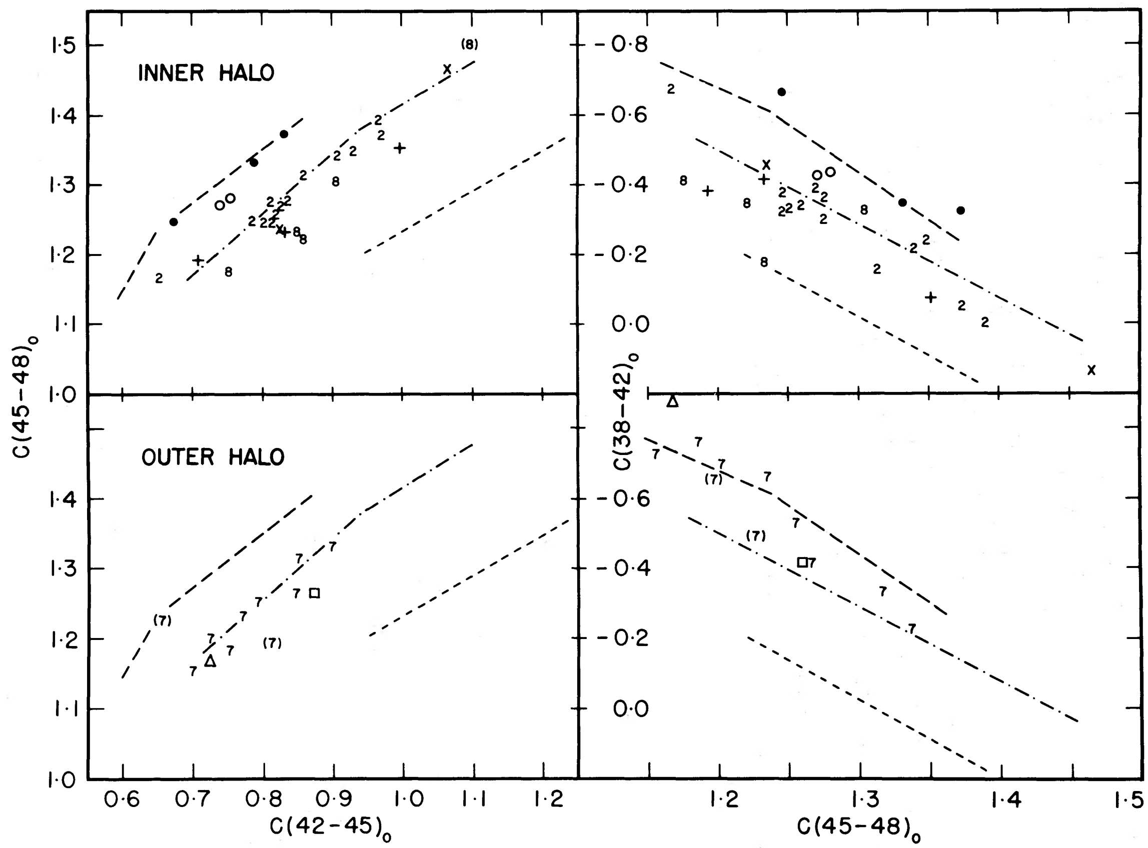

FIG. 2.—Symbols representing various clusters are M92 (*dots*), M15 (*open circles*), M13 (*crosses*), M5 (*plus signs*), M2 (*2's*), NGC 288 (*8's*), NGC 7006 (*7's*), Pal 5 (*open squares*), and Pal 13 (*open triangles*). Strength of Ca II H and K, M_{HK}, as a function of unreddened $B-V$ color for (*a*) inner clusters and (*b*) outer clusters. Cluster metallicities are from Kraft (1979); the lines (with the exception of M5, where it is based on our data) are suitably zero-point shifted from Suntzeff (1980). Note that NGC 7006 stars have significantly weaker Ca II absorption than M2 stars.

program RETICENT (Pritchet 1980). These indices are listed in Table 1. All but one of the indices discussed in this section encompass sufficient bandpass to yield uncertainties of ~0.01 mag due to count rate statistics and star-to-sky ratios. (The exception is the narrow M_G index, discussed below, for which count rate statistics suggest uncertainties of <0.03 mag for the faintest stars.) The DDO indices (columns 4–7) were transformed to the DDO system using standard stars from McClure (1976) and globular cluster stars in common with HHM 77. No difficulty in performing linear transformations to the system were experienced, and the scatter in transformed standard star DDO indices was, typically, ~0.01 mag. It is also important to note that all the calculated indices are generally formulated to be rather insensitive to extinction and/or differential refraction problems, and no evidence for any such problems was encountered.

Suntzeff (1980) has found that a Ca II line index, measuring the summed equivalent widths of the H and K lines,

$$M_{HK} = -2.5 \log \frac{\int_{3910\,\text{Å}}^{4020\,\text{Å}} F\,d\lambda / 110\,\text{Å}}{\int_{4020\,\text{Å}}^{4130\,\text{Å}} F\,d\lambda / 110\,\text{Å}},$$

is tightly correlated with [Fe/H] for globular cluster giants. Figure 2 shows the diagram of M_{HK} versus $(B-V)_0$ for our data. As shown by Suntzeff and confirmed by Figure 2, roughly parallel lines can be drawn through such data for stars in different clusters, and, when consideration is made for the abundances derived by Kraft (1979) for the clusters, it can be seen that the M_{HK} index correlates well with [Fe/H]. Examination of the NGC 7006 data relative to those for M2, the clusters on which we have concentrated our observations, shows that NGC 7006 is significantly more metal poor than M2. Based on linear interpolation in this diagram, the Ca II line strengths indicate metal abundances of $[Fe/H] = -1.4 \pm 0.1$ for M2, and -1.9 ± 0.1 for NGC

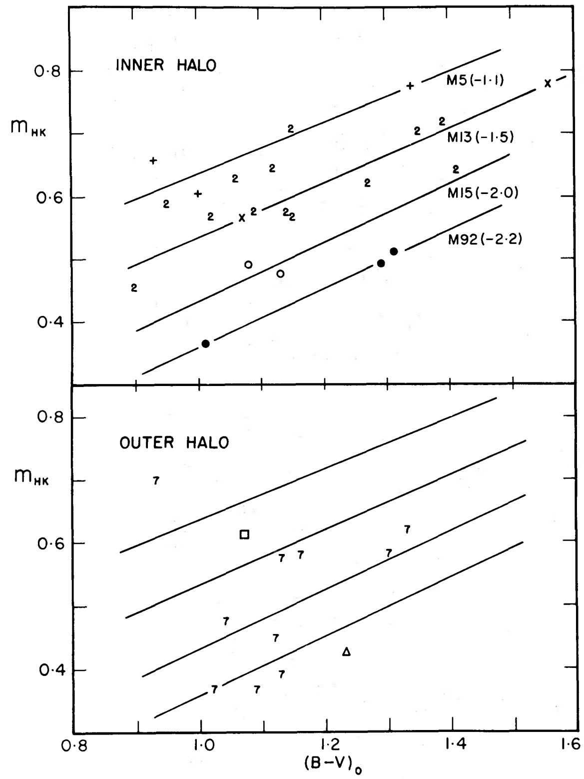

FIG. 3.—Unreddened DDO indices for (*a*) inner clusters with normal HBs, and (*b*) outer clusters with anomalously red HBs. Symbols are identical to those of Fig. 2. The lines are relations from HHM 77 for M92 (*long dashes*), M3 (*dash-dot*), and M71 (*short dashes*), representing extreme, intermediate, and least metal deficiency. Note that the outer-halo cluster stars appear to be similar to stars of lower metal abundance in the C(38−42) vs. C(45−48) diagram than in the C(45−48) vs. C(42−45) diagram.

7006. That the implied [Fe/H] for NGC 7006 is very low emphasizes the peculiar nature of the cluster's red HB.

Since we have considerably more observations of NGC 7006 stars than HHM 77, it is worthwhile to reexamine the DDO indices for this interesting cluster. The two DDO diagrams used by them to determine metal abundance are shown in Figure 3 for the new data. (Mean values have been used for globular cluster stars that are in common between this paper and that of HHM 77.) From the well-determined mean position for the cluster in each diagram, we can make relative comparisons with other well-studied clusters. In the C(45−48) versus C(42−45) diagram, the NGC 7006 stars lie, in the mean, along the M3 (and M13) sequence. In the C(38−42) versus C(45−48) diagram, however, they lie closer to the M92 sequence.[3] Clearly, there is a discrepancy here that is not present for most of the clusters observed by HHM 77. They found that in almost all cases clusters could be ordered relatively in the same way in both diagrams. The discrepancy, that the C(45−48) versus C(42−45) diagram seems to indicate higher metal abundance than the C(38−42) versus C(45−48) diagram, has been discussed by McClure (1979) in connection with observations of the Draco dwarf spheroidal galaxy. He concluded that this discrepancy was probably due to excess absorption in the "42" bandpass and perhaps due to the same effect he found in the 4200 bandpass data of Searle and Zinn (1978) and Zinn (1978) for outlying halo systems. He suggested CH and possibly CN absorption as the cause.

Since we have much higher spectral resolution data than has been heretofore applied to this problem, we can examine the cause of the anomaly in the DDO and the Searle-Zinn data in the case of NGC 7006. We have constructed two indices to measure CH absorption. The first, M_G, measures the narrow G-band feature relative to side-bands close on either side. Fluxes were summed under the various bandpasses as defined by

$$F_\lambda = \int_{\lambda_1}^{\lambda_2} F_\lambda \, d_\lambda ,$$

where the wavelengths for each bandpass are listed in Table 2. The flux ratios were converted to magnitudes to form the G-band index as follows:

$$M_G = -\frac{2.5\log F_G/F_{42} - 2.5\log F_G/F_{43}}{2} .$$

The second index M_{CH} measures a broader bandpass centered on the G band relative to broad bands on either side in regions removed from the CH absorption. It is defined as follows:

$$M_{CH} = -\frac{2.5\log F_{CH}/F_{40} - 2.5\log F_{CH}/F_{44}}{2} ,$$

where the wavelengths delimiting the bandpasses are again listed in Table 2. The latter index is intended to be a measurement similar to the angle between the two lines drawn through the continuum in the NGC 7006 star spectrum of Figure 1.

The two CH indices are shown versus $(B-V)_0$ in Figure 4. Note that the NGC 7006 stars show stronger

TABLE 2

WAVELENGTHS DEFINING CH INDICES

Index	Flux	λ_1	λ_2
M_G......	F_G	4290	4305
	F_{42}	4217	4267
	F_{43}	4310	4400
M_{CH}	F_{CH}	4216	4310
	F_{40}	4020	4120
	F_{44}	4410	4510

[3]Some scatter in the C(38−42) color can plausibly be attributed to the CN strength variations from star to star.

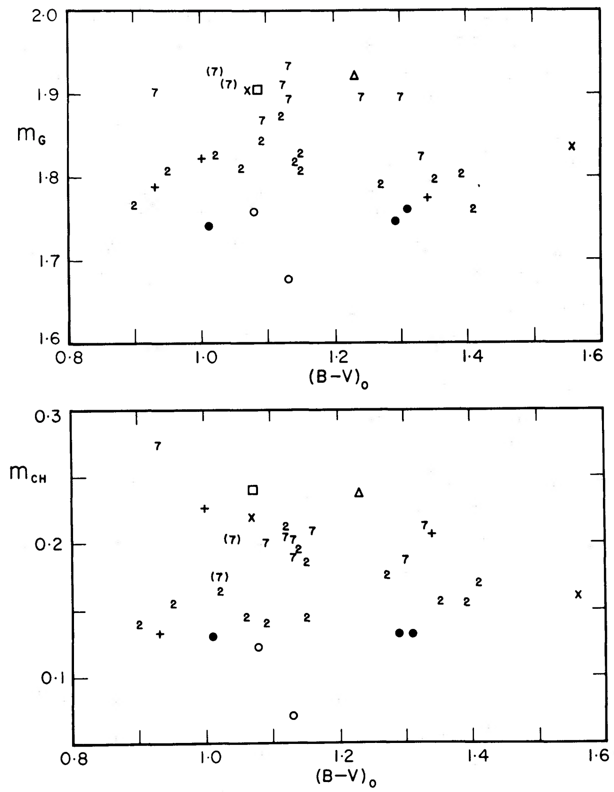

FIG. 4.—Strength of (*a*) the G band, M_G, and (*b*) broad CH absorption, M_{CH}, as a function of unreddened $B-V$ color. Note that NGC 7006 stars have considerably stronger CH absorption than M2 stars.

CH absorption in both indices relative to M2, even though the Ca II H and K lines and the DDO ultraviolet excess indicate it is more metal-poor than M2. As the CH bands are partially included within the bandpass of the DDO 42 filter, the presence in the NGC 7006 giants of CH bands that are stronger than usual for their overall metallicity leads to redder C(42−45) and bluer C(38−42) colors, thereby explaining the discrepancy noted earlier between the metallicity estimates from the two DDO color-color plots used in Figure 3.[4] The NGC 7006 spectra are very similar in this respect to Kinman and Kraft's (1980) spectrum of star 45-24 in Draco. The spectrum of NGC 7006 2-16 shows the strongest CH features and in addition, appears to have features that match the λ4077 Sr II and λ4554 Ba II lines, and possibly the C_2 bands. It may be a mild CH star; however, the spectrum is very noisy, and more data are needed to examine this possibility.

[4]We also note that uncertainties introduced by photon statistical considerations can account for most of the scatter in Figure 4, and that the *mean* loci formed by stars from each cluster are very well determined. For instance, ignoring possible color dependence of the indices, one finds $\langle M_{G,7006}\rangle = 1.896 \pm 0.010$ (m.e.) vs. $\langle M_{G,M2}\rangle = 1.810 \pm 0.008$, while $\langle M_{CH,7006}\rangle = 0.206 \pm 0.008$ vs. $\langle M_{CH,M2}\rangle = 0.164 \pm 0.006$. Consequently, the systematic differences noted in Figure 4 between NGC 7006 and M2 stars are very well established.

IV. PAL 5 AND PAL 13 OBSERVATIONS

Pal 5 and Pal 13 are two other remote clusters which exhibit anomalously red HBs. HHM 77 and McClure (1979) have pointed out that their DDO data for four Pal 5 stars show the same discrepancy in the C(45−48) and C(38−42) diagrams as discussed above for NGC 7006. We have observed one of HHM 77's Pal 5 stars with the IIDS; the data are plotted in Figure 1 and shown as open squares in Figures 2, 3, and 4. Our DDO indices derived from the spectral data for this star show the same behavior as the DDO indices from filter photometry, namely, that the star lies below the M3 sequence in the C(45−48) versus C(42−45) diagram, but midway between M3 and M92 in the C(38−42) versus C(45−48) diagram. Furthermore, our higher resolution spectral data reveal (cf. Figs. 1,4) that the star has much stronger CH absorption than most other globular cluster stars, again suggesting that the behavior of the DDO filter photometry reported by HHM 77 for four Pal 5 stars is due to stronger than usual CH features.

We observed five red stars in the field of Pal 13, identified in terms of position in arcmin (east and north) from star no. 1 of Hartwick and Sargent (1978) as follows: (−1.6, +0.5), (−1.3, +1.1), (+1.2, −1.4), (+1.4, −0.7), and (+1.3, +1.0). The first three stars were found to be foreground dwarfs on the basis of both DDO indices and Mg"b", MgH absorption. The fourth star is almost certainly a globular cluster star, but the signal-to-noise ratio for it was rendered too poor by clouds to allow further interpretation.

The fifth Pal 13 star is a globular cluster star and is plotted as an open triangle in the figures. It shows behavior similar to the NGC 7006 and Pal 5 stars except that it appears to be more metal poor. In the latter respect, our data confirm the findings of Cowley, Hartwick, and Sargent (1978) whose spectra for this cluster show weaker metal features than most other clusters. In our M_{HK} and C(38−42) versus C(45−48) diagrams, the Pal 13 star appears more metal weak than M92. It shows the DDO index discrepancy because it lies near the M3 sequence in the C(45−48) versus C(42−45) diagram. In addition, Figure 4 shows that it exhibits stronger CH absorption than most globular cluster stars.

V. NGC 288 OBSERVATIONS

The globular cluster NGC 288 is of special interest because it exhibits (Cannon 1974) an anomalously blue HB for the color and slope of its giant branch and for its Kinman/Deutsch type—behavior opposite to that of the outlying clusters we have discussed. The positions of our NGC 288 stars in the DDO diagrams indicate that

NGC 288 is more metal rich than M5, but, judging from HHM 77's observations, it is less metal rich than 47 Tuc. (It is worth calling attention to the widely ranging and very strong λ3883 CN band strengths in Fig. 1 and their probable effect on the C(38−42) indices in Fig. 3, combined characteristics that seem to be associated with clusters of relatively high metallicity.) We cannot judge its metal abundance from our $M_{\rm HK}$ index because we do not have observations of globular cluster stars more metal rich than M5, and our observations of the Population I cluster NGC 188 indicate that the abundance sensitivity of the index reverses at some point for metal-rich clusters. Our CH indices for NGC 288 also support the DDO result that this cluster's giants are more metal rich than M5's. Thus we conclude that the metal abundance of NGC 288 is intermediate between that of M5 and 47 Tuc, and that the blue HB is indeed anomalous. We find no peculiarities regarding CH absorption.

VI. DISCUSSION

We have determined that giant stars in the outlying cluster NGC 7006 have anomalously strong CH absorption relative to giants in inner halo globular clusters. From a comparison of spectral data for one star in Pal 5 with DDO filter photometry for it and for three others, Pal 5 giants behave similarly. Spectral data for presumed giants in Pal 13 have revealed a large percentage of field dwarfs in the cluster vicinity; good spectral data obtained for one giant again suggest that it behaves like the NGC 7006 stars—in particular, it appears to be very metal poor, but has very strong CH absorption. In this respect NGC 7006, Pal 5, and Pal 13 giants may be similar to those of other outlying systems, including the Draco dwarf spheroidal galaxy, which exhibit anomalously red HBs.

DDO indices for NGC 7006 giants were the basis of an earlier study of Hartwick and McClure (1972) who suggested that these stars have strong CN absorption. The interpretation of the indices in terms of abundances is now seen to be complicated, however, in that: (1) we have shown that CN strength variations appear to be a general feature of globular cluster giant-star spectra, regardless of the mean [Fe/H] value of the cluster; and (2) the DDO CN index is affected by CH absorption as suggested by Bell, Dickens, and Gustafsson (1978). Hartwick and McClure (1972) measured some of the brightest and reddest stars in the cluster, and from our new observations these seem to be among the strongest in CN absorption. Taking all the stars in the present study, the NGC 7006 stars appear to be approximately equal to M2 stars in CN strength but significantly stronger than M92 or M15.

In conclusion, it appears that CNO element abundance (and in particular, C) is a second parameter affecting the morphology of the HBs of outlying halo clusters. This is based on several independent lines of evidence including the following:

1. The present study shows that CH bands are anomalously strong in NGC 7006 stars and the stars we have observed in Pal 5 and Pal 13. Kinman and Kraft (1980) show that at least one star in the Draco dwarf spheroidal galaxy also shares this anomaly.
2. The DDO indices of HHM 77, Hartwick and McClure (1974), and the present paper indicate excess absorption for the outlying systems in the "42" band-pass, which includes CH bands.
3. As discussed by McClure (1979), independent support for the conclusions arrived at here can be found in the Searle and Zinn (1978) and Zinn (1978) data for outlying systems, where excess absorption in the region of CH and/or CN bands can be inferred.
4. Finally, CO band strengths measured by Cohen, Frogel, and Persson (1978) and Pilachowski (1978) show that for clusters of similar [Fe/H], HB morphology varies with CO strengths of the giant stars (see Cohen 1980).

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