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NTT CCD photometry of the globular cluster M 79 = NGC 1904 in $UBV^{\star}$

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Abstract. We have obtained new CCD photometry (with short exposures) of the Milky Way globular cluster M 79 using the NTT under excellent seeing[1]. The main-sequence turnoff point is at $V = 19.70 \pm 0.05$, $B - V = 0.415 \pm 0.010$; the horizontal-branch level at the blue edge of the instability strip is $V = 16.25 \pm 0.10$. The cluster metallicity, estimated from the positions of the "bump" on the red giant branch, is [Fe/H] $= -1.76 \pm 0.20$. We discuss the luminosity functions of the horizontal branch and the asymptotic giant branch, in particular, the fragmentary structure of the horizontal branch in M 79 and in other clusters. Our isochrone analysis shows that M 79 belongs to the oldest Milky Way globular clusters. Its age, in the scale of Bergbusch & VandenBerg (1992) oxygen-enhanced isochrones, is 16 ± 1 Gyr, and in the scale of VandenBerg & Bell (1985) isochrones it is 18 ± 1 Gyr. The cluster has an extremely blue horizontal branch at intermediate metallicity and may be considered a good example of the "second parameter" interpreted as age. The apparent distance modulus of the cluster from Bergbusch and VandenBerg isochrones is in good agreement with the value derived from the position of the horizontal branch ($15\overset{\mathrm{m}}{.}6$).

Key words: globular clusters: individual: M 79 — HR diagram

1. Introduction

The globular cluster NGC 1904 (M 79, $\alpha = 5^{\mathrm{h}}22\overset{\mathrm{m}}{.}2$, $\delta = -24°34'$, 1950.0; $l = 228°$, $b = -29°$) belongs to comparatively well-studied Milky Way globulars. It was photometrically studied several times during the recent two decades, after the first studies by Goranskij (1976) and Alcaíno (1976). The list of corresponding papers may be found in Alcaíno et al. (1994). The latter paper contains the results of the deepest multicolor ($BVRI$) CCD photometry and of its isochrone analysis. Comparison is made with photometric data by other authors who reduced observations of M 79 using different reduction software, among them, with most extensive CCD BV photometry by Ferraro et al. (1992). The photometry of Ferraro et al. covers a wide field in M 79; they obtained and analysed a deep $V - (B - V)$ diagram, also well represented in the region of red giant branch (RGB) and horizontal branch (HB) stars.

This paper continues the deep photometric studies of M 79. Our observations were obtained for calibration purposes in the frame of our study of NGC 1841 (Alcaíno et al. 1996), but, thanks to the large telescope and high-quality, wide-format CCD detector used under excellent seeing, the results deserve special evaluation. We have achieved improved photometric accuracy, especially around the main-sequence turnoff point, along the subgiant branch and lower RGB, with a reasonably rich sample of stars belonging to the upper main sequence. Moreover, we have been able, for the first time, to add sufficiently deep U photometry.

2. Observations and reductions

The observations were acquired on two nights, December 20/21 and 21/22, 1993, using the 3.5 m NTT telescope at the ESO, La Silla, with the EMMI camera. The detector in the blue arm was a TEK 1024AB CCD #31 (1024×1024

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* Based on observations collected at the European Southern Observatory.

[1] Table 2, with the results of our photometry, is completely available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

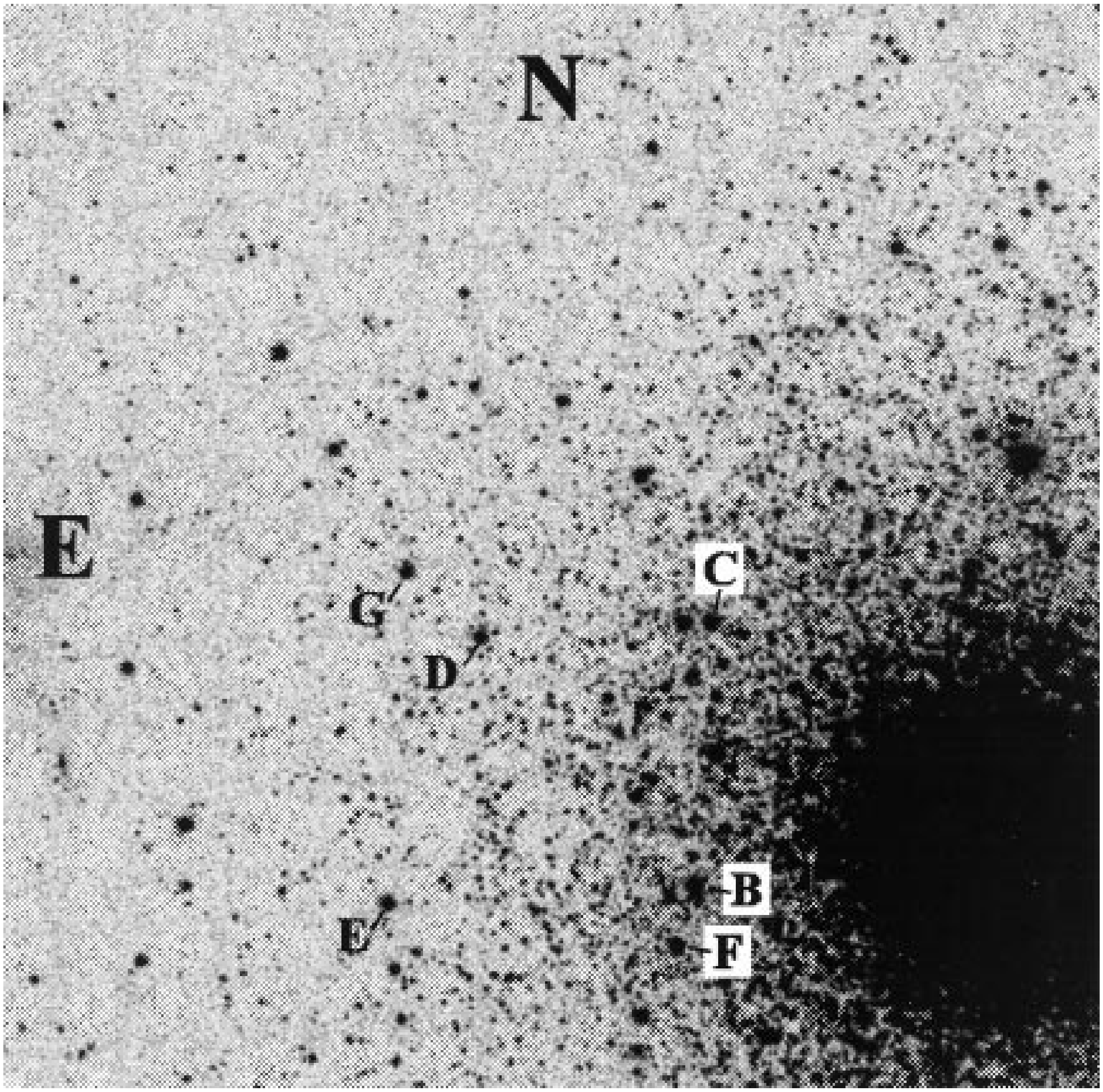

Fig. 1. A V frame of M 79, with photoelectric standards marked

pixels) with a readout noise of 8e$^-$ rms; in the red arm, a LORAL 2048 CCD #34 (2048 × 2048 pixels, binned) with a readout noise of 7e$^-$. The field covered was 6.2 × 6.2 arcmin (the central region of the cluster is heavily crowded, and it retains very few stars in our photometry). The monitored seeing was from 0.″6 to 0.″9. Seven frames in V light (exposure time: 15 s and 20 s), seven frames in B (20 s and 60 s) and seven frames in U light (60 s) were secured. These observations were originally intended for calibration of CCD photometry in NGC 1841.

The reductions of CCD photometry were performed at the Institute of Astronomy (Moscow) using the software described by us earlier (Samus et al. 1995a) and based upon the DAOPHOT II ALLSTAR application. The formulae taking into account the color terms of photometric reductions were derived by us using observations of the standard sequences in the main-programme cluster NGC 1841 (Alcaíno & Alvarado 1988), in M 79 itself (Alcaíno et al. 1987) and in NGC 2298 (Alcaíno et al. 1990). The total number of stars used for deriving the calibration formulae for this paper was 20, covering a wide range in color (photoelectric $B-V$ values from 0.38 to 1.42). The formulae used in this study are:

$$V = v - 0.0255(\pm0.0263)(b-v) + 0.0236(\pm0.0300),$$

$$B-V = 0.8105(\pm0.0470)(b-v) + 0.1721(\pm0.0537),$$

$$U-B = 1.0088(\pm0.0812)(u-b) - 0.0630(\pm0.0671).$$

Figure 1 presents a frame of the M 79 field, with photoelectric standards marked. Table 1 lists the standards in M 79 with CCD magnitudes and their deviations from photoelectric magnitudes (in the sense CCD minus photoelectric). Note that our calibration of $U-B$ is somewhat uncertain and needs improvement.

Table 1. Data for photoelectric standards

Star	V	$B-V$	$U-B$
B	13.20	1.46	1.34
	−0.04	+0.04	–
C	13.68	1.20	0.91
	+0.03	+0.03	+0.07
D	14.16	1.08	0.73
	+0.02	−0.03	–
E	14.29	1.06	0.60
	−0.03	−0.04	−0.11
F	15.09	0.40	+0.00
	+0.03	+0.02	+0.03
G	15.09	0.80	0.25
	−0.01	−0.00	–

Table 2. CCD photometry in M 79

No.	x	y	V	$U-B$	$B-V$
1	56.750	359.105	20.711	−0.514	0.440
2	58.123	779.331	16.231	0.099	0.585
3	58.312	523.236	19.997	−0.105	0.346
4	59.260	622.145	19.055	−0.105	0.427
5	60.017	719.262	17.739	0.163	0.695
6	60.212	649.719	19.671	−0.002	0.267
7	60.527	784.498	14.194	0.556	0.975
8	60.553	266.222	19.099	−0.042	0.497
9	60.947	688.113	17.043	0.130	0.731
10	60.954	792.412	17.417	0.196	0.601
11	61.438	761.222	16.622	0.124	0.599
12	61.578	700.513	16.152	0.103	0.401
13	61.588	566.864	16.075	0.193	0.806
14	61.599	574.358	17.983	−0.422	−0.146
15	62.149	642.385	20.249	−0.007	0.389
16	62.596	323.642	20.343	−0.195	0.406
17	62.831	310.906	19.883	−0.117	0.397
18	63.042	854.201	17.448	0.086	0.650
19	63.217	655.188	18.006	0.057	0.578
20	63.499	671.331	20.209	−0.268	0.401
21	63.679	285.517	19.794	−0.133	0.339
22	63.700	694.962	16.636	0.073	0.089
23	63.867	838.853	19.245	0.100	0.267
24	64.043	848.539	19.242	−0.026	0.407
25	64.154	561.045	19.429	−0.080	0.432
26	64.181	374.136	19.270	−0.137	0.455
27	64.801	885.512	20.493	0.315	0.459
28	65.090	661.713	18.990	0.072	0.479
29	65.365	613.600	16.605	0.171	0.072
30	65.579	405.031	20.608	−0.185	0.439

The results of our photometry of 2451 stars are presented in Table 2[2]. The internal rms errors in V light, in most cases, do not exceed $0.^{\rm m}01$ for $V < 19$ and $0.^{\rm m}02$ for $V < 20^{\rm m}$; in B, they are typically below $0.^{\rm m}01$ for $B < 20^{\rm m}$ and $0.^{\rm m}02$ for $B < 21^{\rm m}$; in U, for most stars brighter than $20^{\rm m}$ the internal errors are within $0.^{\rm m}02$. Figure 2 presents the results of the comparison of our photometry with that of Alcaíno et al. (1994). We do not see any evidence for unrevealed color terms or zeropoint corrections for V magnitudes; residual corrections in $(B-V)$, if needed, do not seem linear. The large scatter of data points in Fig. 2b near $(B-V) = 0.4$ is due to stars near the photometric limit. Alcaíno et al. compare their photometry with Ferraro et al. (1992); the deviations found there apply also to our results, because the agreement of our photometry with that by Alcaíno et al. is rather good.

3. The color–magnitude diagram

Our photometric results for all measured stars are presented in Fig. 3 as a color–magnitude diagram. It covers the magnitude range from the RGB tip ($V \approx 13.15$, $B-V \approx 1.45$) to the photometric limit, by approximately $1.^{\rm m}5$ below the turnoff. The position of the turnoff point in our diagram is $V_{\rm TO} = 19.7 \pm 0.05$ and $B-V = 0.415 \pm 0.010$ (internal accuracy). This turnoff level is somewhat fainter than indicated in the earlier studies ($V_{\rm TO} = 19.6$ in Alcaíno et al. 1994).

We discuss the HB in more detail in one of the subsequent sections. Its level is found to be $V_{\rm HB} = 16.25 \pm 0.10$, somewhat fainter (by $0.^{\rm m}1$) than in Ferraro et al. (1992). Thus, we find $\Delta V({\rm TO-HB}) = 3.45 \pm 0.11$, close to the average value for Milky Way globular clusters (cf. Buonanno et al. 1989).

Comparing the positions of sequences in our CMD and in the CMD by Ferraro et al., we notice some differences, especially concerning extreme colors. Thus, the RGB tip is bluer by $0.^{\rm m}1$, and the HB at the level $V = 18.0$ is redder by $0.^{\rm m}05$ in our CMD. Nevertheless, the general similarity of the two diagrams is apparent, taking into account the somewhat poorer sample in the present study. Both diagrams show a clear asymptotic giant branch (AGB) in the magnitude range $V = 14^{\rm m}$ to $16^{\rm m}$, an extended blue HB, and a number of stars above and below the HB. Several stars are situated in the instability strip, some of them may be variables. There is no noticeable contribution of the possible blue straggler population. The presence of field stars is most apparent to the red of the subgiant and

[2] Completely available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html; data are represented here only for the first 30 stars, as a sample. For identification, note that, in the system of Table 2, the standards B and G have the coordinates $x = 403.589$, $y = 802.791$ and $x = 671.250$, $y = 509.581$, respectively.

red giant branches; their contribution is not large, as one can see from the analysis in Ferraro et al. (1992).

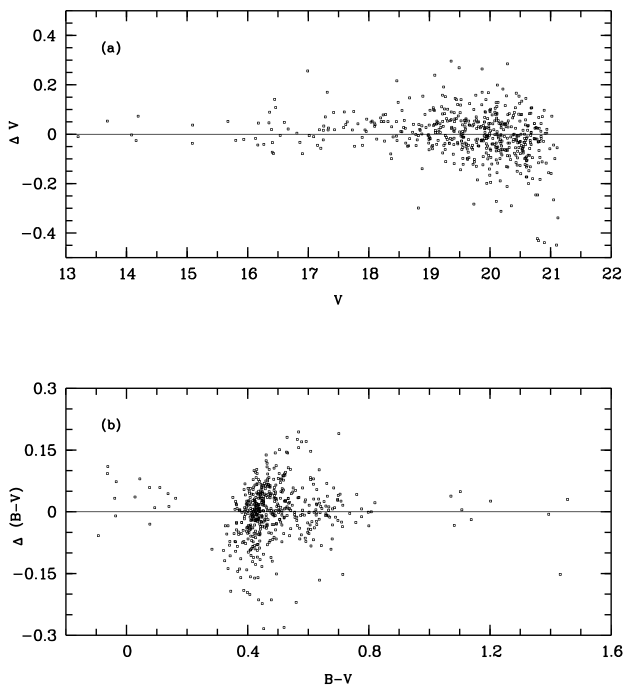

Fig. 2. Comparison of our photometry with that from Alcaíno et al. (1994). **a)**: ΔV (Kravtsov et al. minus Alcaíno et al.) versus V (Kravtsov et al.); **b)**: $\Delta(B-V)$ (Kravtsov et al. minus Alcaíno et al.) versus $(B-V)$ (Kravtsov et al.)

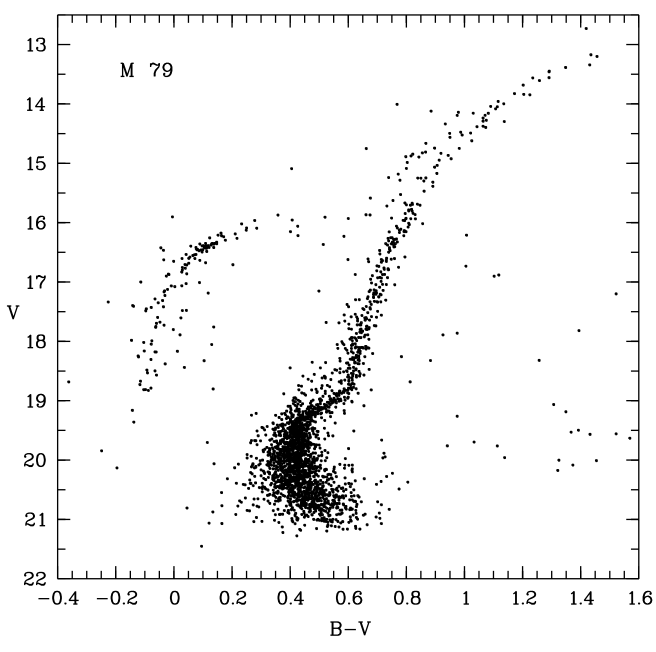

Fig. 3. The $V-(B-V)$ diagram of the globular cluster M 79 from CCD photometry of 2451 stars

4. Red giant and asymptotic giant branches

a) RGB bump and metallicity

The compilation of metallicity estimates tabulated in Alcaíno et al. (1994) shows that M 79 belongs to moderately metal deficient clusters; the scatter of metallicity values exceeds 0.3 dex. Having reliable photometry of sufficiently numerous red giants, we can apply the indirect method of metallicity estimates used in our earlier studies and by other authors. It is based upon the relation between the position of the RGB "bump" and the cluster metallicity (Kravtsov 1989; Fusi Pecci et al. 1990). The luminosity function (LF) of the RGB is shown by the solid line in Fig. 4; the bump is indicated with an arrow. The discussed detail of the LF is not as evident in our data as it is in the LF by Ferraro et al. (probably due to our smaller sample), but its position is practically identical in both LFs. The most obvious manifestation of the bump in our data is a "step" in the RGB LF at $V = 15.6$. Taking into account the LFs from both papers, we evaluate the bump position as $V = 15.95 \pm 0.10$, the error estimate reflecting some ambiguity in the location of the bump. To determine the metallicity of M 79, we used the analytic formula from Sarajedini & Forrester (1995). It relates the difference of V magnitudes between the bump and the HB to the cluster metallicity in the scale of Zinn & West (1984). For $V_{\rm HB} = 16.25 \pm 0.10$, $\Delta V(\mathrm{bump} - \mathrm{HB}) = -0.30 \pm 0.14$. Substituting this value into Eq. (1) of Sarajedini & Forrester (1995), we find for M 79 the metallicity value $[\mathrm{Fe/H}] = -1.76 \pm 0.20$. This is within the range of earlier published values based on different methods.

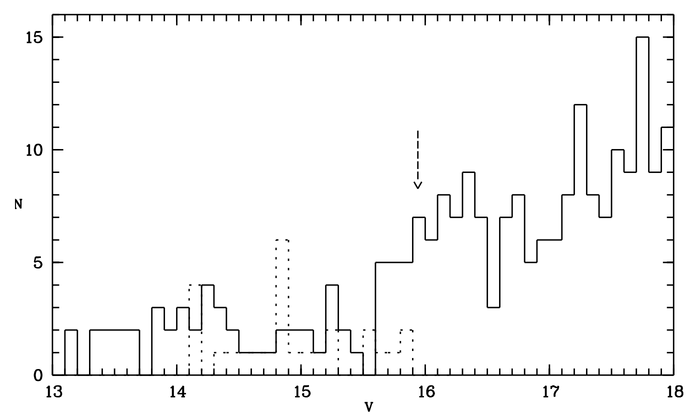

Fig. 4. The luminosity function of the RGB (solid line) and of the AGB (dashed line) for the globular cluster M 79. The arrow indicates the position of the "bump"

b) Asymptotic giant branch

The AGB is the least studied of all sequences in globular-cluster CMDs above the turnoff. Even in its lower, denser populated part, this sequence is usually represented by an insufficient number of stars. Reliable separation of AGB stars from RGB stars critically depends upon photometric accuracy.

The accuracy of our photometry makes it possible to isolate AGB stars from RGB stars with sufficient reliability, at least for V in the range from $14^{\rm m}$ to $16^{\rm m}$. The resulting LF of the AGB (dashes) is plotted in Fig. 4, together with the LF for the RGB. Note that the CMD from Ferraro et al. shows three clumps of AGB stars, corresponding to the three maxima of our LF, at $V \sim 14.2$, $V \sim 14.8$, and $V \sim 15.3$.

5. The horizontal branch and the distance modulus

Figure 5 presents the $V-(B-V)$ diagram specially for HB stars with $(B-V) \leq 0.2$. Dots are stars in the central cluster region ($r < 1\rlap{.}'4$); crosses are stars in the more peripheral regions. Some stars are plotted as circled dots, they are discussed below. The CMD shows no significant difference between the color of the reddest stars in the cluster center and in its outer regions. If we identify these stars (at $(B-V) \approx 0.18$) with the blue boundary of the instability strip, we find $V_{\rm HB} = 16.25 \pm 0.10$ as a reasonable estimate of the HB level.

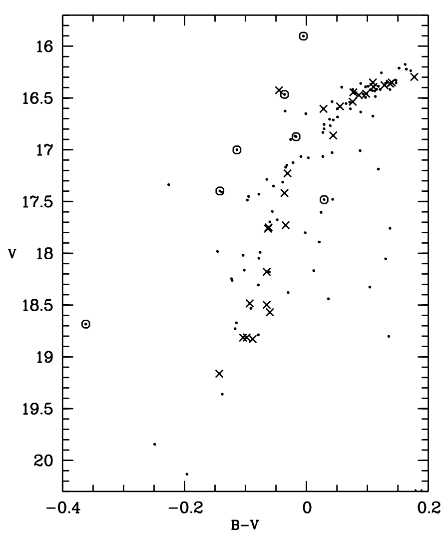

Fig. 5. The $V-(B-V)$ diagram for the horizontal branch of M 79. The designations are explained in the text

To determine the apparent distance modulus of M 79, we used the relation between the absolute magnitude of the HB and metallicity presented in the catalog by Harris (1994):

$$M({\rm HB}) = 0.2[{\rm Fe/H}] + 1.0.$$

For [Fe/H] $= -1.76$, we get $M_{\rm HB} = 0.65$. Therefore $m - M = 15.60$.

Our CMDs show that there are a number of stars to both sides of the principal sequence; it is difficult to consider all these stars to be field objects. Similar stars are present in the CMD by Ferraro et al. The stars to the left of the HB are usually called UV-bright stars, they are brighter in the ultraviolet range than the majority of HB stars, and they are situated above the HB in the $U-(U-B)$ diagram. Such a diagram is shown in Fig. 6; the circled dots designate stars above the upper envelope of the main body of HB stars. The same stars are plotted as circled dots also in Fig. 5. Comparing the two diagrams, we see that all the stars above the HB in the $U-(U-B)$ diagram (with a single exception) are also outside the principle sequence in the $V-(B-V)$ diagram. The star with the lowest $U-B$ index coincides with the lowest data point in Fig. 5. The two only data points situated below the HB in Fig. 6 are the two most red-displaced points in Fig. 5 for the range of V between $18^{\rm m}$ and $19^{\rm m}$. They might be blue stragglers. The nature of stars below the HB in the $V-(B-V)$ diagram is not clear, if not all of them are field stars. Note that similar stars are present in the CMD of the globular cluster NGC 1841 (Alcaíno et al. 1996).

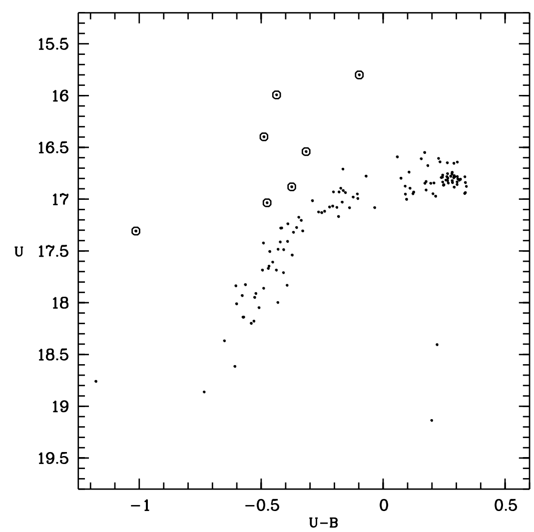

Fig. 6. The $U-(U-B)$ diagram for the horizontal branch of M 79. The designations are explained in the text

Interesting enough, the $U-(U-B)$ diagram stresses some morphological details of the HB, namely, its fragmentary structure. The most obvious are the gaps at $(U-B) \approx 0$, $(U-B) \approx -0.3$, and, possibly, at $(U-B) \approx -0.6$. The depressions in the HB LF corresponding to these gaps are marked with arrows in Fig. 7, presenting the luminosity function for the horizontal branch. This figure is discussed in more detail below.

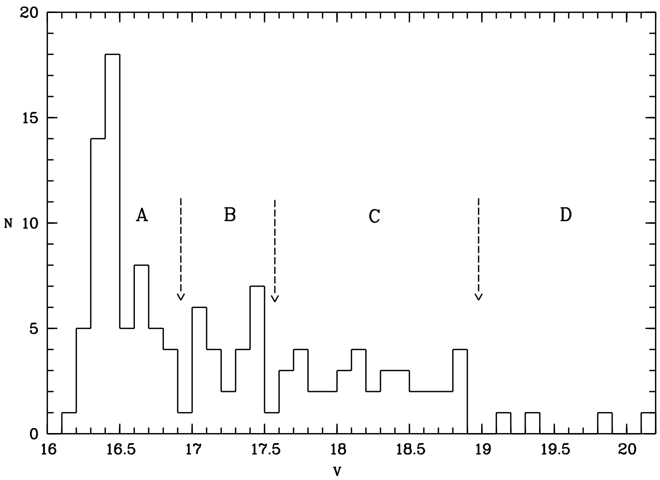

Fig. 7. The luminosity function for the horizontal-branch stars of M 79. Arrows: the positions of suspected depressions. The letters A, B, C, D designate the HB fragments discussed in the text

Here we encounter a serious problem which has been an object of numerous studies during the recent 25 years (e.g., Simoda & Tanikawa 1972; Newell 1973; Buonanno et al. 1985, 1986): the problem of the existence of any real features (gaps?) in the distribution of stars along the HB, especially along the blue HB. Many factors make it difficult to come to definite conclusions on the presence (or absence) of such details and on their persistence for different clusters. Besides difficulties connected with observations and insufficient statistics, the features may be more prominent or less prominent in different clusters, and the length of the HB (along the axis of magnitudes) may also differ.

The following considerations are also only a preliminary discussion, to be tested by further studies. We concentrate upon details (depressions) repeating themselves in several clusters.

Kravtsov et al. (1997) compare the HB LFs for the clusters NGC 5986 and NGC 6139 (from photographic studies) and for M 79 (from the present study). In particular, they find that, at the level corresponding to that with $V = 16.9 - 17.0$ in Fig. 7, the HB LFs (reduced to the same HB level) have either their faint end or a depression. A similar depression occurs for NGC 1841 (Alcaíno et al. 1996) in the V range between 20.0 and 20.1 (the HB levels of NGC 1841 and M 79 differ by $\Delta V \approx 3.1$). A significant gap in the HB of M 15 (Buonanno et al. 1985) is observed for $16.1 < V < 16.5$ (here $\Delta V \approx -0.4$). We call the part of the blue HB above this depression "fragment A". In NGC 5986, there is an indication that this fragment consists of two subfragments (let us call them "Aa" and "Ab"), and the ratio of the star numbers in these subfragments may vary with the distance from the cluster center. Similar radial changes in the structure of the fragment A may be suspected for NGC 1841. Note that the blue HB in NGC 5466 (Buonanno et al. 1985) consists only of the subfragment Aa. It is also stronger populated than Ab for M 79 (Fig. 7). For M 15, the subfragment Ab is absent or greatly depressed (though the blue HB does have still fainter stars), and the above-mentioned gap seems significant.

The faint boundary of the next HB fragment ("B") is separated from that of the fragment A by $\Delta V \sim 0.5 - 0.6$ (it is located at $V \approx 17.5$ in Fig. 7). A similar depression in M 15 may be suspected at $V \approx 17.1$. According to Buonanno et al. (1986, Fig. 17), the level of this depression shows an abrupt change of the HB population density in NGC 6752 and corresponds to the faint end of the HB in NGC 288.

The next fragment, "C", is terminated in M 79 at $V \approx 18.9$, where the HB becomes much poorer populated, as it was also noted by Ferraro et al. (1992). This corresponds to the level of the faint end of the HB in M 15 found by Buonanno et al. (1985) and to a low minimum ($V \approx 16.3$) in the HB LF of NGC 6752 (Buonanno et al. 1986).

In some clusters (NGC 6752, M 13, M 79, etc.), a still fainter HB fragment ("D") is present or may be suspected. It is represented only by several stars in M 79.

We conclude that, apparently, the blue HBs of globular clusters possess a fragmentary structure. Dependent upong the length of the cluster's HB, the luminosity levels marked with arrows in Fig. 7 correspond either to the HB's faint end or to a feature in the distribution of HB stars: a gap, a depression, or an abrupt change of the HB population density. The clusters with the longest HB (like NGC 6752) may have even four macrofragments (A, B, C, D). Number ratios of stars forming different fragments (or entering different subfragments, like the above-discussed subfragments Aa and Ab) may change with the distance from the cluster center (cf., for instance, Buonanno et al. 1986; Ferraro et al. 1992; Alcaíno et al. 1996; Kravtsov et al. 1997). To confirm these results, it is necessary to observe larger samples of HB stars for each cluster.

6. The two-color diagram

The two-color diagram for M 79 is presented in Fig. 8. The solid line is the unreddened sequence of luminosity class V from Eggen (1965). On average, the deviation of the M 79 HB stars from this sequence increases with decreasing color index. To improve agreement, one needs to move Eggen's sequence at least by $0\overset{m}{.}05$ in $B - V$ along the reddening line $E(B - V)/E(U - B) = 0.72$ (dashed line). All earlier estimates of the reddening for M 79 do not reach such values, being around $E(B - V) = 0.01$. Systematic errors in $B - V$ or (more probably) $U - B$ for the bluest HB stars are not excluded. However, if we fit the HB of M 79 to the HB of NGC 1841 putting together, both in magnitude and in color, the reddest HB stars, their fiducial lines show a deviation when approaching fainter stars. This deviation reaches $0\overset{m}{.}03$ – $0\overset{m}{.}05$ in $B-V$ for stars fainter by 1^{m} than the reddest HB stars. One should notice that the color system for the reductions of both clusters is determined by the same standard stars, and the observations were gathered under absolutely similar conditions (telescope, photometer, etc.), during the same nights.

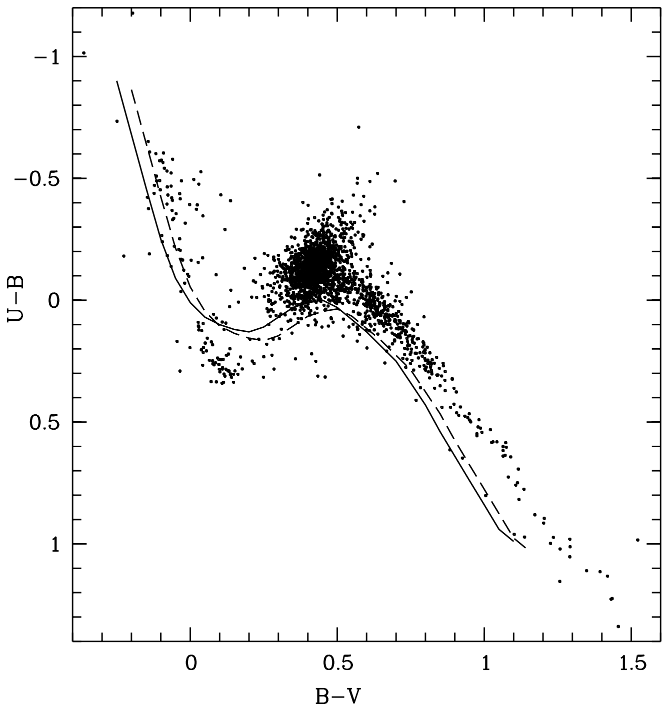

Fig. 8. The two-color diagram for M 79. The solid line and the dashed line are discussed in the text

7. The age of M 79

Alcaíno et al. (1994) fitted VandenBerg & Bell (1985; hereafter VBB) isochrones to their multicolor photometry and estimated the age of M 79 as 16 Gyr. For our analysis, we used VBB isochrones and the oxygen-enhanced isochrones of Bergbusch & VandenBerg (1992; hereafter BVB). However, we somewhat deviated from traditional, rather formal approach to isochrone fitting, with pre-fixed values of both distance modulus and reddening or of one of these two parameters. Unavoidable uncertainty of distance moduli and reddenings, possible shifts of zero points of photometry or/and of isochrones themselves, may result in considerable errors of age determinations. We attempted to make us maximally free from these uncertainties, fitting the CMD each time with a *single isochrone with fixed age and metallicity*, not imposing any restrictions on the position of this isochrone along both axes. We judge upon the fit quality taking into account agreement of the color interval of the isochrone between the turnoff and the lower RGB (age indicator) with that for the observed CMD; the isochrone to be considered must show most adequate reproduction of fiducial lines of sequences and of the RGB slope (metallicity indicator).

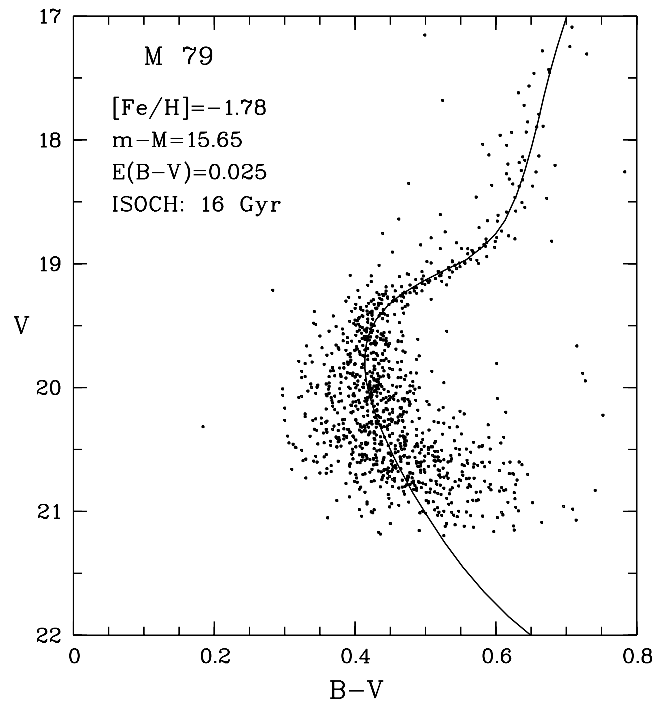

Fig. 9. The $V-(B-V)$ diagram for the turnoff region of M 79, with the superimposed Bergbusch & VandenBerg (1992) isochrone with the indicated parameters

We considered the set of BVB isochrones in the range of [Fe/H] between −2.03 and −1.26, completely covering the range of possible metallicity values for the cluster. The observed CMD included only stars in the outer cluster region, to reduce possible uncertainties due to crowding. Our criteria are best met by two isochrones for 16 Gyr age: [Fe/H] = −1.78, $m-M=15.65$, $E(B-V)=0.025$ and [Fe/H] = −1.66, $m-M=15.60$, $E(B-V)=0.01$. Figure 9 demonstrates the degree of agreement of the first of them with the $V-(B-V)$ diagram of M 79 in the turnoff region, and Fig. 10 shows how this isochrone reproduces the slope of the RGB. This age determination is practically unsensitive to metallicity in the [Fe/H] range from −2.03 to −1.48.

Figure 11 shows that the 14 Gyr isochrone (for [Fe/H] = −1.66, $m-M=15.7$) evidently does not correspond to the age of M 79, its transition from the turnoff to the RGB being considerably wider than for the observed CMD. This result is also rather unsensitive to adopted metallicity.

The 16 Gyr BVB isochrone for [Fe/H] = −1.26 also shows a poor fit to the width of the transition region. However, if we plot it for a formally negative reddening

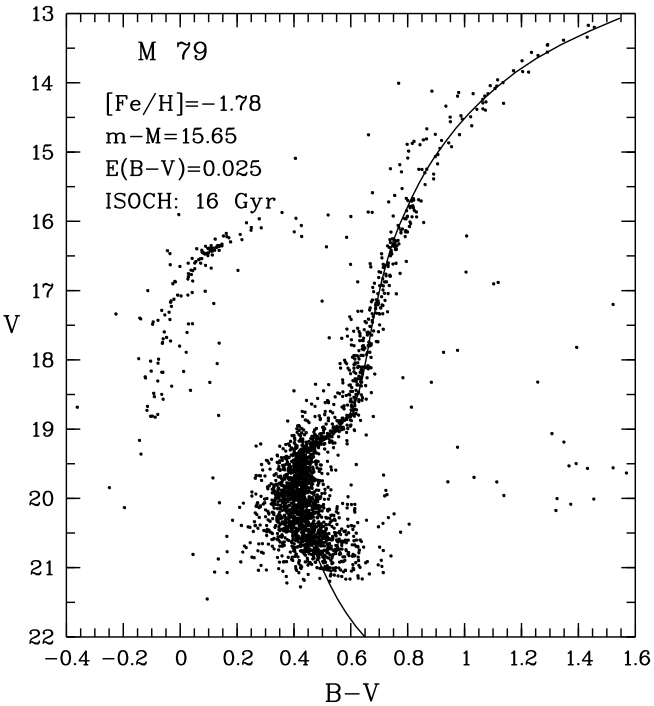

Fig. 10. The $V-(B-V)$ diagram for M 79, with the same superimposed Bergbusch & VandenBerg (1992) isochrone, showing how the isochrone reproduces the slope of the giant branch

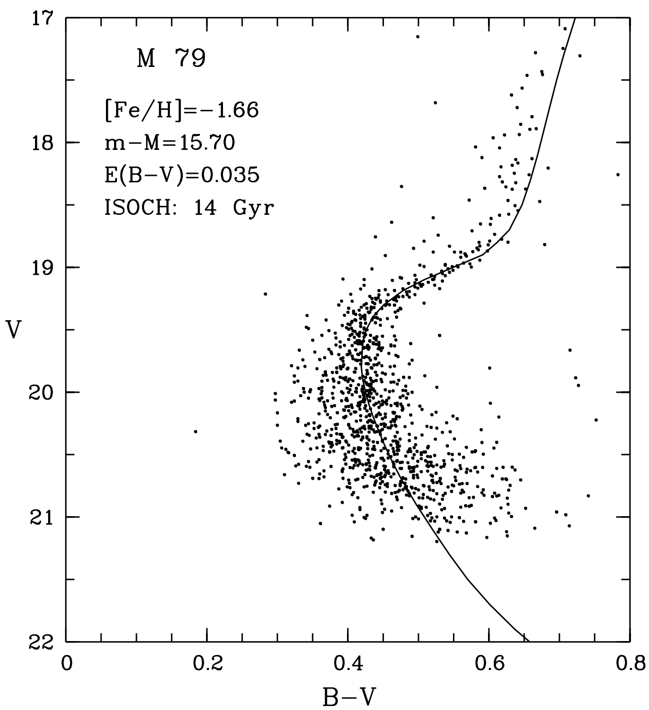

Fig. 11. The $V-(B-V)$ diagram for M 79, with the superimposed Bergbusch & VandenBerg (1992) isochrone with indicated paremeters, for the age 14 Gyr. As discussed in the text, the agreement with observations is not satisfactory

value, it gives the best presentation of the main-sequence slope among all the analyzed isochrones.

Earlier (Samus et al. 1995a,b) we demonstrated that cluster age estimates based on BVB isochrones are by approximately 2 Gyr lower than those from VBB isochrones. We have tested this conclusion once again. The 18 Gyr VBB isochrone for [Fe/H] $=-1.78$ shows the best fit for $m-M=15.75$ and $E(B-V)=0.05$. One can see from Fig. 12 that this isochrone simply coincides above the turnoff with the 16 Gyr BVB isochrone for the same metallicity, all differences occur below the turnoff point.

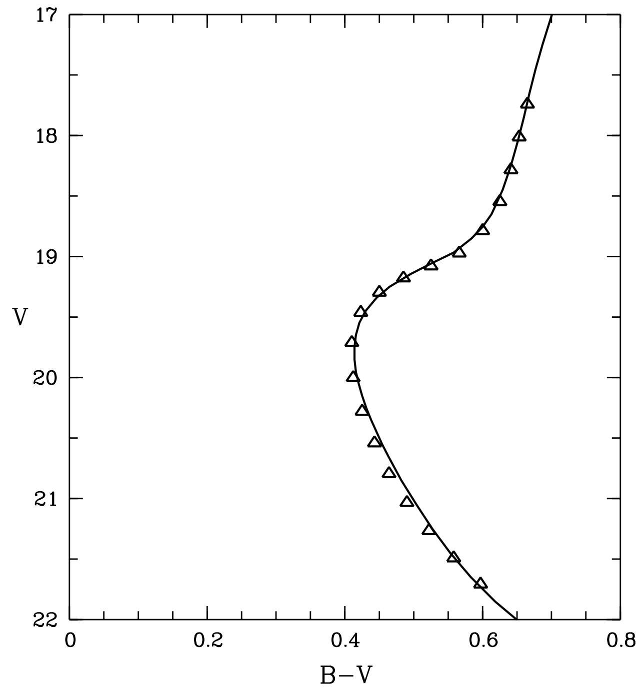

Fig. 12. Comparison between two isochrones for the same metallicity value, [Fe/H] $=-1.78$. The solid line is the Bergbusch & VandenBerg (1992) isochrone for 16 Gyr, and the triangles represent the VandenBerg & Bell (1985) isochrone for 18 Gyr

Thus, we estimate the age of M 79 as 16 ± 1 Gyr (internal accuracy) in the scale of BVB isochrones and as 18 ± 1 Gyr in the scale of VBB isochrones. So the cluster M 79 probably belongs to the oldest globulars.

8. Conclusions

We have analysed new CCD UBV photometry of the Milky Way globular cluster M 79, obtained with the NTT under excellent seeing, with short exposure times. The following results have been obtained.

1. We estimate the cluster CMD parameters: its main-sequence turnoff point is at $V=19.70\pm0.05$, $B-V=0.415\pm0.010$; the horizontal-branch level at the blue edge of the instability strip is $V=16.25\pm0.10$.

2. The cluster metallicity, estimated from the position of the "bump" on the RGB, is $[Fe/H] = -1.76 \pm 0.20$.

3. We could reliably isolate AGB stars and present the AGB luminosity function.

4. We have found evidence for the HB in several clusters consisting of a number of fragments separated with depressions (gaps). In different clusters the positions of fragments are more or less reproduced, but the presence of a given fragment in a given cluster depends of the HB morphology and the length of the HB along the axis of magnitudes.

5. The isochrone analysis shows that M 79 belongs to the oldest Milky Way globular clusters. Its age, in the scale of Bergbusch & VandenBerg (1992) oxygen-enhanced isochrones, is 16 ± 1 Gyr, and in the scale of VandenBerg & Bell (1985) isochrones it is 18 ± 1 Gyr. The cluster has an extremely blue horizontal branch at intermediate metallicity and may be considered a good example of the "second parameter" interpreted as age. The apparent distance modulus of the cluster from Bergbusch and VandenBerg isochrones is in good agreement with the value derived from the position of the horizontal branch ($15\overset{m}{.}6$).

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