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CORE VELOCITY DISPERSIONS AND METALLICITIES OF THREE GLOBULAR CLUSTERS BELONGING TO THE FORNAX DWARF SPHEROIDAL GALAXY[1]

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ABSTRACT

Integrated light spectra, obtained at the European Southern Observatory (ESO) at La Silla, Chile, of the three brightest globular clusters of the Fornax dwarf spheroidal galaxy, allow determination, by cross-correlation techniques, of the projected core velocity dispersions, with values $\sigma_p(\text{core}) = 8.8(+1.0, -1.1)$, $5.1(+1.0, -1.2)$, and $7.0(+1.1, -1.3)$ km s^{-1} for the clusters 3, 4, and 5, respectively. The corresponding estimates of the mass-to-light ratios, viz. $M/L_V = 3.2 \pm 0.8$, 1.7 ± 0.8, and $5.2 \pm 1.9 (M/L_V)_\odot$, are similar to the typical M/L_V values obtained for Galactic globular clusters. From the point of view of theories of cluster formation and evolution, such a similarity is worth noticing, given the fact that the present-day environments of globular clusters in the Galaxy and in the Fornax dwarf spheroidal galaxy appear so different.

From the total area of the cross-correlation function of the integrated light spectra, metallicity estimates can be derived with an accuracy of 0.15 dex. We obtain values of [Fe/H] equal to -1.93, -1.35, and -1.89 for the Fornax clusters 3, 4, and 5, respectively. These results, in excellent agreement with earlier determinations, confirm the existence of a large metallicity range among the Fornax globular clusters and strengthen the evidence that Fornax has a rather complex history of star and cluster formation, unexpected for such a low-mass galaxy.

Subject headings: celestial mechanics, stellar dynamics — galaxies: individual (Fornax) — Local Group — globular clusters: general — stars: abundances

1. INTRODUCTION

As a contribution to the current attempt at understanding the globular cluster and galaxy formation, it is of interest to investigate the extent of possible similarities between properties of globular clusters belonging to galaxies of different Hubble types, i.e., between clusters within different galactic environments. A similarity such that the mean luminosity in a globular cluster system—turnover value nearly independent of the parent galaxy size, type, and environment (Harris 1987, 1991)—has already been exploited for the extragalactic distance scale (Harris et al. 1991). Similarities may also exist between individual astrophysical parameters of the clusters themselves, like their masses and mass-to-light ratios. Reliable mass estimates can be derived from the globular cluster surface brightness profile and central value of the projected velocity dispersion σ_p. These observational constraints can be obtained for Galactic globular clusters as well as for clusters located in the most nearby galaxies of the Local Group.

Early preliminary studies of old Magellanic globular clusters suggested mass-to-light ratios about 10 times smaller than the typical value for Galactic clusters, for which $M/L_V \sim 2$–3. Such a systematic difference was already discussed, in the case of NGC 1835, by Meylan (1988), who showed that the methods used to obtain the above parameters can partly explain the discrepancy. New observations of velocity dispersion (Dubath, Meylan, & Mayor 1990; Mateo et al. 1991b; and Dubath, Meylan, & Mayor 1992) confirm that when the same kind of dynamical models are constrained by the same kind of observations (surface brightness profile and central value of the projected velocity dispersion), the old globular clusters in the Magellanic Clouds appear quite similar in mass and M/L_V to the globular clusters in the Galaxy. Younger star clusters, e.g., in the Magellanic Clouds, may exhibit smaller M/L_V simply because of earlier stellar evolution stages.

The globular cluster system of the Fornax dwarf spheroidal galaxy offers a unique opportunity to extend the comparison to globular clusters in such an extreme galactic environment. The denomination dwarf spheroidal stands commonly for the dwarf elliptical galaxies, which look like loose swarms of resolved stars, with extremely low concentration and surface brightness (see Da Costa 1992 for the most recent review). They are observed only in the Local Group. Dwarf spheroidal galaxies are among the intrinsically faintest galaxies, sometimes considered as an intermediate step between globular clusters and small elliptical galaxies. Five, possibly six, globular clusters have been identified around the Fornax dwarf spheroidal galaxy (Hodge 1961, 1969), which is the only dwarf spheroidal known to contain globular clusters. On the one

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hand, Fornax is the most massive of the dwarf spheroidal galaxies detected in the vicinity of the Galaxy. On the other hand it is, by an order of magnitude, the least massive galaxy among approximately 60 galaxies for which an associated globular cluster system has been observed (Harris 1991). In addition, the specific frequency of globular clusters in Fornax—the number of clusters per unit of galaxy luminosity—is strikingly high, by far the highest known (Harris 1991). These peculiarities strengthen the importance of detailed studies of the Fornax globular clusters, made possible by their relative proximity.

Integrated light properties (e.g., Zinn & Persson 1991) and color-magnitude diagram studies (e.g., Buonanno et al. 1985) of the Fornax globular clusters confirm their similarities with old metal-poor globular clusters in the Galaxy and the Magellanic Clouds. These works suggest a large metallicity range among the Fornax globular clusters, of about 0.8 dex, rather surprising given the small size and mass of this galaxy. The field stars of Fornax exhibit a similar wide spread in metallicity. Three Fornax clusters (numbers 1, 3, and 5, following Hodge 1961) appear much more metal-poor than the mean metallicity of the field, which is comparable with the metallicity of the most metal-rich cluster (number 4). This metallicity range may well correspond to an age range among the globular clusters and the field stars of the Fornax dwarf spheroidal, pointing out a rather complex history of cluster and star formation for such a low mass galaxy (see Fusi Pecci 1987).

In order to study the globular cluster masses and mass-to-light ratios as a function of galaxy types and environments, we have undertaken a large survey dedicated to the measurement of the core velocity dispersions of Galactic, Magellanic, and Fornax globular clusters. These measurements are derived from cross-correlation techniques applied to high-resolution integrated light spectra of the cluster cores. The data about the Galactic clusters allow us to calibrate the surface of the cross-correlation function as an excellent metallicity indicator. Consequently, in addition to the core velocity dispersions, our observations provide good metallicity estimates. The results and the analysis concerning about 25 Galactic and 25 Magellanic clusters are published in Dubath et al. (1992).

We present below the results concerning the determinations of core velocity dispersions, metallicities, masses, and mass-to-light ratios for the three brightest globular clusters surrounding the Fornax dwarf spheroidal galaxy. The observations are described in § 2, radial velocities and velocity dispersions in § 3, metallicities in § 4, and the derived astrophysical parameters (mass and M/L_V) are presented and discussed in the last section, § 5.

2. OBSERVATIONS AND REDUCTION

Integrated light spectra of the three brightest globular clusters of the Fornax dwarf spheroidal galaxy, with numbers, 3, 4, and 5, following Hodge (1961), were obtained with CASPEC, the Cassegrain echelle spectrograph of the European Southern Observatory (ESO) mounted on the ESO 3.6 m telescope at La Silla, Chile. These observations, of clusters as well as standard stars, were carried out during the period 1990 December 21–27 (see Table 1 for the three clusters). The charge-coupled device (CCD) used for all these observations is the ESO CCD No. 16. It is a Tektronix TEK 512M-12, thinned, backside-illuminated device, with 512 × 512 pixels of 27 μm square each, and with a readout noise of about 10 electrons. The instrument setup is standard, with the 31.6 line mm^{-1} grating and with a wavelength domain between 4380 and 5880 Å. Spectra of thorium-argon lamps were taken before and after each exposure, with the telescope pointing toward the cluster or the standard star observed. The dimension of the entrance slit, 2".1 × 3".5, corresponds at the Fornax distance of 131 kpc (Buonanno et al. 1985) to a linear size of 1.4 pc × 2.3 pc. Thus the dimension of the sampling area is comparable to the cluster core radii (see Table 4 below). For our instrument setup and slit width, the typical full width at half-maximum (FWHM) of the emission lines of the thorium-argon comparison spectra, i.e., our typical spectral resolution, is 17–18 km s^{-1}.

The spectra are reduced following standard procedures described in detail in Dubath et al. (1992). The reduced spectrum is then cross-correlated with a numerical mask. The properties of this mask, as well as the details of our cross-correlation technique, are described in a previous study concerning the Magellanic globular cluster NGC 1835 (Dubath et al. 1990). The mask used so far for optical cross-correlation with the spectrophotometer CORAVEL (COrrelation RAdial VELocities, see Baranne, Mayor, & Poncet 1979) is simply extended in order to cover the complete spectral domain of our CASPEC spectra (4380–5880 Å).

Our cross-correlation technique produces a cross-correlation function (CCF)—relative intensity as a function of the radial velocity V_r—which is nearly a perfect Gaussian. A Gaussian function $g(V) = 1 - D \exp[-(V - V_r)^2/2\sigma_{\rm CCF}^2]$ is fitted to each deduced CCF in order to determine three physical quantities: (1) the abscissa of its minimum equal to the radial velocity V_r, (2) its depth D, and (3) its standard deviation $\sigma_{\rm CCF}$, related to line broadening mechanisms. Comparison of the CCF of the cluster with the CCFs of standard stars displays the broadening of the cluster CCF, produced by the Doppler line broadening present in the integrated light spectra because of the random spatial motions of the stars.

The quadratic difference,

$$\sigma_p^2 = \sigma_{\rm CCF}^2(\text{cluster}) - \sigma_{\rm ref}^2(\text{mean of 20 standard stars}) , \quad (1)$$

between (1) $\sigma_{\rm CCF}$ from the Gaussian fitted to the cluster CCF and (2) $\sigma_{\rm ref}$ which is the mean of the $\sigma_{\rm CCF}$ from the Gaussians fitted to the CCFs of a sample of about 20 giant stars of appro-

TABLE 1
RADIAL VELOCITIES AND CORE VELOCITY DISPERSIONS

Hodge Number (1)	Observation Date (2)	Exposure Time (s) (3)	S/N (4)	ϵ (km s^{-1}) (5)	V_r (km s^{-1}) (6)	σ_p(core) (km s^{-1}) (7)
Cluster 3..........	1990 Dec. 26	1800	15.0	0.6	58.3 ± 1.2	$8.8^{+1.0}_{-1.1}$
Cluster 4..........	1990 Dec. 24	2100	7.4	0.3	45.2 ± 1.0	$5.1^{+1.0}_{-1.2}$
Cluster 5..........	1990 Dec. 25	1800	7.6	0.9	61.8 ± 1.3	$7.8^{+1.6}_{-1.8}$
Cluster 5..........	1990 Dec. 26	1800	7.8	0.8	63.4 ± 1.3	$6.1^{+1.5}_{-2.0}$

priate spectral type, gives a precise estimate of the projected stellar velocity dispersion σ_p in the sampled area of the considered globular cluster (Dubath et al. 1990).

For each cluster, two independent wavelength calibrations are carried out, corresponding to the thorium-argon spectra taken before and after the cluster exposure. The two CCFs obtained never differ significantly either in terms of radial velocity V_r or in terms of projected velocity dispersion σ_p. For a given spectrum, the final results of both quantities (V_r and σ_p) are the average of the two determinations.

3. CLUSTER RADIAL VELOCITIES AND CORE VELOCITY DISPERSIONS

The left part of Figure 1 displays, for illustration purposes, 100 Å ranges from the integrated light spectra of the three Fornax globular clusters. The spectra have been arbitrarily smoothed, by using a square filter of 0.5 Å in size, in order to reduce the noise and improve the appearance of the spectral lines (the complete digital spectra are made available through e-mail upon request). The cross-correlation functions (CCFs) obtained from the spectra at full resolution are displayed in the right part of Figure 1. The dotted curves represent the CCFs themselves, the continuous lines the fitted Gaussians. Table 1 displays for each cluster spectrum obtained in column (1) the Hodge number of the cluster observed, column (2) the observation data, column (3) the exposure time in seconds, and column (4) the signal-to-noise ratio (S/N) of the spectrum itself. The last three columns give in column (5) the uncertainty ϵ on V_r as well as on σ_{CCF}, due to the spectrum noise, column (6) the derived radial velocity V_r, and column (7) the projected velocity dispersion in the cluster core σ_p(core). Cluster 5 is the only one for which we have two spectra.

The S/N ratio is calculated as follows. For each spectrum, a mean signal S is deduced from the continuum of the (unnormalized) CCF and a noise N is computed from the photon counting noise and the CCD readout noise (see Dubath et al 1990 for more details).

In order to estimate our radial velocity uncertainty, we proceed in two steps.

1. More than 50 spectra of 23 radial velocity standard stars have been collected during the present observing run (1990 Dec. 21–27). Radial velocity V_r and σ_{CCF} are derived from these spectra with exactly the same procedure already applied to the spectra of the clusters. This allows an estimate of the accuracy of V_r as well as σ_{CCF} determinations, when dealing with high S/N spectra (S/N ~ 30–50). The standard deviation of the differences between the radial velocities from the present CASPEC spectra and from the CORAVEL reference (mean of previous numerous accurate CORAVEL measurements) is 1.0 km s^{-1}, while our internal accuracy is even slightly better (Dubath et al. 1992).

2. The additional uncertainty ϵ, which may come from the spectrum noise, is estimated by using $\epsilon = 0.2/(D \times S/N)$ km s^{-1} (from eq. [3] of Dubath et al. 1990), where S/N is the signal-to-noise ratio of the spectrum and D is the depth of the cross-correlation function. The above formula is derived from a large number of numerical simulations (about 2000). For each one, a random-noise frame is generated and added to a raw CCD frame of a bright standard star in order to reproduce the photon counting the readout noises present in a real low

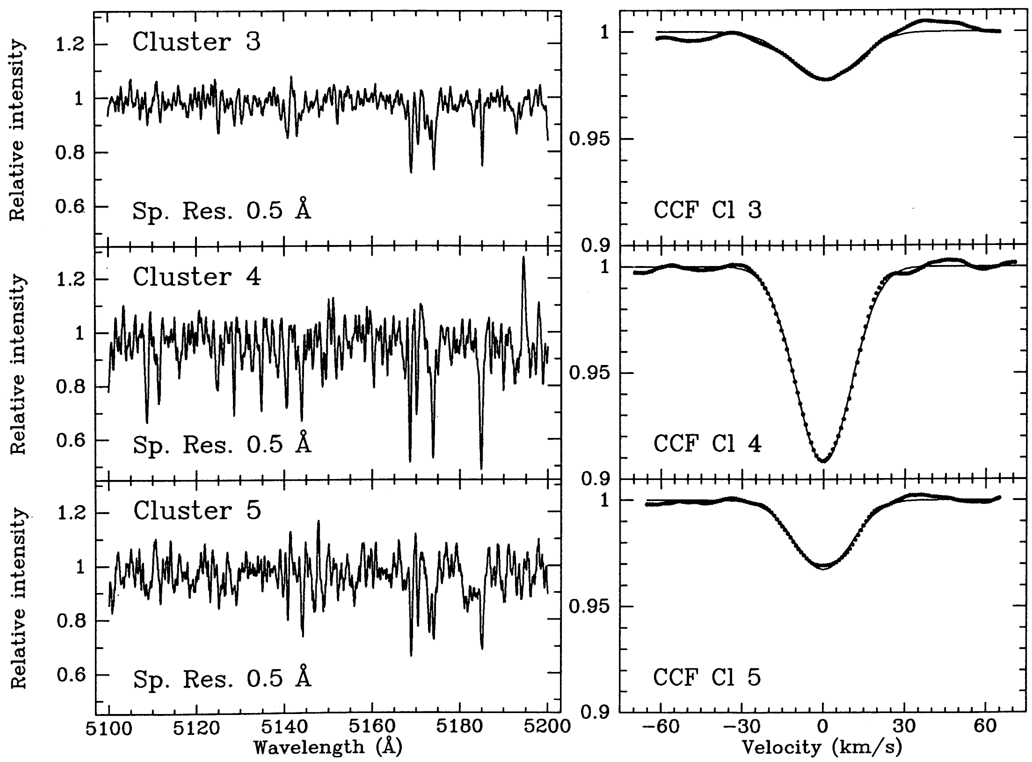

FIG. 1.—Left: for three globular clusters belonging to the Fornax dwarf spheroidal galaxy, the numbers 3, 4, and 5 following Hodge (1961), 100 Å ranges are displayed for each integrated light spectrum obtained with CASPEC (Cassegrain ESO echelle spectrograph). In this figure, and for illustration purposes only, the spectra have been smoothed by using a square filter of 0.5 Å in size. Right: the CCFs—relative intensity as a function of the radial velocity—for the same three objects. The dots represent the CCFs themselves, the continuous lines the fitted Gaussians.

TABLE 2

RECENT RADIAL VELOCITY MEASUREMENTS OF THREE FORNAX GLOBULAR CLUSTERS

Cluster 3 V_r (km s^{-1})	Cluster 4 V_r (km s^{-1})	Cluster 5 V_r (km s^{-1})	References
56.7 ± 1.4	46.1 ± 1.4	61.6 ± 1.8	Aaronson & Olszewski 1986
60.4 ± 2.5	47.4 ± 1.5	62.0 ± 2.0	Mateo et al. 1991a
58.3 ± 1.2	45.2 ± 1.0	62.6 ± 0.9	Present study
58.5	46.2	62.1	Mean values

S/N CCD frame. Each frame is then reduced, cross-correlated, and fitted to a Gaussian function. The expression giving ϵ is derived from the behavior of the scatter of the Gaussian parameters obtained (V_r and $\sigma_{\rm CCF}$) as functions of the simulation parameters (S/N and D). In all cases, the standard deviation obtained for V_r is similar to the standard deviation obtained for $\sigma_{\rm CCF}$. Consequently, the above formula provides uncertainty on V_r as well as on $\sigma_{\rm CCF}$, due to the different noises. The ϵ values are listed in column (5) of Table 1.

These two kinds of error are independent and their distributions are roughly Gaussian. The final radial velocity uncertainty, given in column (6) of Table 1, is the square root of the quadratic sum of both errors, i.e. $(1 + \epsilon^2)^{1/2}$.

Our set of standard stars is also used to derive $\sigma_{\rm ref}$, the mean $\sigma_{\rm CCF}$ of the stellar CCFs. For this purpose, only a subsample of the standard stars is considered and contains giant stars of a broad range of spectral type: G and K field giants, red giants in Galactic globular clusters, clump stars in open clusters, and metal-deficient giants of the halo population. The $\sigma_{\rm CCF}$ values obtained from their subsample are independent of the star metallicity or spectral type (Dubath et al. 1992). The scatter of the $\sigma_{\rm CCF}$ values for the individual stars is remarkably small. An averaged value $\sigma_{\rm ref} = 9.0 \pm 0.2$ km s^{-1} is used in the present study. The uncertainty on $\sigma_{\rm ref}$ is simply the standard deviation of the stellar $\sigma_{\rm CCF}$ from all the stars in the sample. This is an intrinsic uncertainty in the sense that the influence of the noise is negligible because of the high S/N (~30–50) of all the stellar spectra. As a check, the spectrum of one Fornax giant field star is used: the $\sigma_{\rm CCF}$ obtained is 9.0 ± 0.6 km s^{-1}, which match perfectly the $\sigma_{\rm ref}$ value.

In order to compute the uncertainties on the velocity dispersion σ_p (see eq. [1]), errors on the two quantities $\sigma_{\rm CCF}$ and $\sigma_{\rm ref}$ are taken into account. The uncertainty on the $\sigma_{\rm CCF}$ of a cluster CCF is also given by the combination of the intrinsic accuracy, taken equal to 0.2 km s^{-1}, i.e., similar to the uncertainty on $\sigma_{\rm ref}$, and of the error due to the noise estimated by ϵ, i.e., $(0.2^2 + \epsilon^2)^{1/2}$.

Table 2 presents a comparison of our globular cluster radial velocities with two previous similar determinations (considered are only those based on relatively high-resolution spectra, i.e., comparable to our observations). It is worth mentioning that no zero-point offset has been applied to any of the data used in the present comparison. The agreement between these three independent determinations is excellent. This proves that cross-correlation techniques applied to high-resolution spectra, even with low S/N, produce accurate radial velocities. The error estimates appear reliable, even slightly pessimistic.

4. METALLICITIES

With the present cross-correlation technique, the cross-correlation function (CCF) can be considered as the average profile of the weak spectral lines present in the spectrum of the star (see § 3.3 of Dubath et al. 1990). Mayor (1980) showed with CORAVEL measurements of a sample of F and G dwarf stars that the total area $W_{\rm CCF}$ of the dip of the CCF [$W_{\rm CCF} = D_{\rm CCF}\,\sigma_{\rm CCF}(2\pi)^{1/2}$] is essentially a function of the metal abundance and effective temperature of the star. In globular clusters, the mean effective temperature of the red giant branch correlates well with the cluster metallicity (e.g., Zinn & West 1984). Therefore, we expect the total area of the CCF of integrated light spectra of a globular cluster, noted $W_{\rm CCF(cluster)}$, to be mainly a function of the cluster metallicity.

This is confirmed by the relation between [Fe/H] and $W_{\rm CCF(cluster)}$ values for a sample of 21 Galactic globular clusters (see Dubath et al. 1992). The metallicities used for these Galactic clusters are the mean values of various recent metallicity estimates taken from the literature (Frogel, Cohen, & Persson 1983; Pilachowsky 1984; Smith 1984; Hesser & Shawl 1985; Bica & Alloin 1986; Brodie & Hanes 1986; Armandroff & Zinn 1988; Bell 1988; and Gratton & Ortolani 1989). For each cluster with independent metallicity estimates given by various authors, the typical standard deviation is of the order of 0.15 dex. In Figure 2, for each of the 21 Galactic clusters, the mean metallicity is plotted as a function of the total area of the cross-correlation function $W_{\rm CCF(cluster)}$, the latter quantity being obtained from integrated light observation (see Dubath et al. 1992). The standard deviation obtained by considering the mean metallicities (dots) and the values obtained from the defined relation (*solid line*) is 0.16 dex. This relation provides a useful tool for estimating cluster metallicities from total areas of cross-correlation functions $W_{\rm CCF(cluster)}$. As the influence of the uncertainty of $W_{\rm CCF(cluster)}$ is usually negligible, the accuracy of our metallicity estimates is $\leq \pm 0.15$ dex, i.e., $W_{\rm CCF(cluster)}$ is a metallicity estimator as good as, and possibly even better than, those found in the literature.

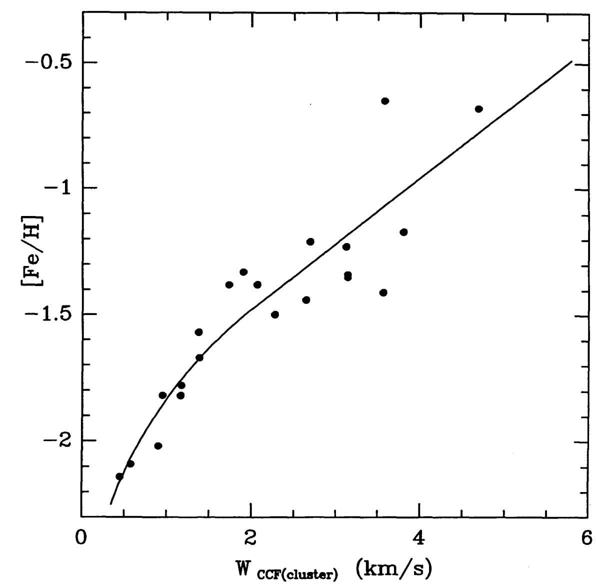

FIG. 2.—Relation between the metallicity [Fe/H] and the total area $W_{\rm CCF(cluster)}$ of the dip of the CCF for a sample of 21 Galactic globular clusters. The metallicities of the Galactic clusters are given by the mean values of various recent metallicity estimates taken from the literature (see § 4) and the $W_{\rm CCF(cluster)}$ are the total areas of the CCFs of integrated light spectra obtained with observations similar to those described in this paper (see Dubath et al. 1992).

TABLE 3

RECENT METALLICITY ESTIMATES OF THREE FORNAX GLOBULAR CLUSTERS

[Fe/H] Cluster 3	[Fe/H] Cluster 4	[Fe/H] Cluster 5	References
−2.21	−1.21	−1.81	Zinn & Persson 1981
−2.12	...	−1.99	Buonanno et al. 1985
−1.93	−1.35	−1.89	Present study

TABLE 4

ASTROPHYSICAL PARAMETERS FOR THREE FORNAX GLOBULAR CLUSTERS

Hodge Number (1)	c log (r_t/r_c) (2)	r_c (pc) (3)	μ (4)	M $(M_\odot)$ (5)	M_V (6)	M/L_V $(M/L_V)_\odot$ (7)
Cluster 3....	1.83	0.99	39.7	5.08×10^5	−8.19	3.2 ± 0.8
Cluster 4....	1.82	0.68	39.3	1.16×10^5	−7.23	1.7×0.8
Cluster 5....	1.26	2.91	17.0	4.05×10^5	−7.38	5.2 ± 1.9

It is conspicuous from a look at Figure 1 (*right*) that the total area of the CCF varies from one cluster to another. This behavior is the direct consequence of similar variations observed in Figure 1 (*left*) in the equivalent widths of the few spectral lines shown as examples. The CCF of cluster 4 is much deeper than the CCFs of clusters 3 and 5. Quantitatively, by using the relation illustrated by the solid line of Figure 2, and by knowing the total areas W_{CCF} of these CCFs, metallicity estimates of -1.93 ± 0.15, -1.35 ± 0.15, and -1.89 ± 0.15 are derived for the clusters 3, 4, and 5, respectively. These estimates are compared in Table 3 with recent metallicity estimates of lower accuracy: they appear consistent with each other, probably within 1 σ.

Our results confirm the existence of an important metallicity range among the Fornax globular clusters. They may indicate that the Fornax globular clusters are not coeval. As already suggested by Fusi Pecci (1987), cluster 4 may be younger than the other clusters, its metallicity being significantly higher. In any case, the above result strengthens the evidence that Fornax has experienced some rather complex star and cluster formations (see also Buonanno et al. 1985, and Fusi Pecci 1987). It is worth mentioning that the metallicity range of the Fornax clusters is of the same order of magnitude as the metallicity range of the clusters found in the halo of the Galaxy, despite the huge mass difference between the two galaxies.

5. CLUSTER MASSES AND M/L_V RATIOS

From the above velocity dispersion determinations and from the structural parameters of the three globular clusters studied, it is important to deduce the individual mass and mass-to-light ratio of every cluster. The individual masses of the clusters are computed using equation (9) from Illingworth (1976), i.e., $M = 167 r_c \, \mu \sigma_p^2$(core), where r_c is the core radius, μ is the dimensionless mass, and σ_p the projected velocity dispersion. Table 4 gives in column (1) the Hodge number of the cluster observed, column (2) the concentration $c = \log (r_t/r_c)$, column (3) the core radius r_c, column (4) the dimensionless mass μ, column (5) the mass M of the cluster, column (6) the integrated absolute visual magnitude M_V of the cluster, and column (7) the corresponding mass-to-light M/L_V. For cluster 5, the M/L_V is calculated with the mean value of the velocity dispersions from the two spectra (Table 1). The uncertainties on the M/L_V are means obtained in varying only the velocity dispersion values by their uncertainties given in Table 1. The values of the concentration parameters $c = \log (r_t/r_c)$, of the core radii r_c, and the integrated absolute visual magnitude M_V come from Webbink (1985), and derive from the fit of the observed surface brightness profiles to isotropic King (1966) models. The dimensionles masses (μ) are estimated from interpolations of Table 2 of King (1966).

For the three Fornax clusters, the corresponding estimates of the velocity dispersion [$\sigma_p = 8.8(+1.0, -1.1)$, $5.1(+1.0, -1.2)$, and $7.0(+1.1, -1.3)$ km s^{-1} for the clusters 3, 4, and 5, respectively], of the mass ($M = 5.08 \times 10^5$, 1.6×10^5, and 4.05×10^5 $M_\odot$, respectively), and of the mass-to-light ratios [$M/L_V = 3.2 \pm 0.8$, 1.7 ± 0.8, and 5.2 ± 1.9 $(M/L_V)_\odot$, respectively], are similar to the value obtained for Galactic and old Magellanic clusters (Meylan 1988; Pryor et al. 1988, 1989, and 1991; Mateo et al. 1991b; Seitzer 1991; Dubath et al. 1990, 1992). Cluster 4, potentially younger, exhibits the lowest M/L_V ratio, consistent with a brighter turnoff magnitude, although this difference is only marginally significant. From the point of view of theories of cluster formation and evolution, such a similarity in global parameters like velocity dispersion, mass, and mass-to-light ratio is worth noticing, given the fact that the present-day environments of globular clusters in the Galaxy, in the Large Magellanic Cloud, and in the Fornax dwarf spheroidal galaxy appear so different.

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Note added in proof.—The sampling uncertainty in a velocity dispersion determination may be important if the integrated light spectra are dominated by too small a number of bright stars. In order to estimate the sampling uncertainties in all our determinations of velocity dispersion, we have carried out detailed numerical simulations. The cross-correlation function (CCF) of an integrated light spectrum is simulated by adding all the CCFs corresponding to the stellar spectra of the stars present in the area of integration. This is done by using luminosity functions and color-magnitude diagrams of well-studied fiducial clusters; the dependences of stellar CCFs on temperature and metallicity are modeled and taken into account (see Dubath et al. 1992, and in preparation).

These simulations show in the case of the three Fornax globular clusters studied here that the sampling uncertainties in the velocity dispersions of Fornax 3 and Fornax 4 are small ($\lesssim 1$ km s^{-1}), while the sampling uncertainty in the velocity dispersion of Fornax 5 is somewhat larger (~ 3 km s^{-1}). Consequently, the final uncertainties in the velocity dispersion, the mass, and the mass-to-light ratio for Fornax 5 are larger than those given in this paper, and larger than those for the other two clusters. On the contrary, the influence of the sampling uncertainty on the metallicity determinations for these three Fornax globular clusters is completely negligible.