THE INTERMEDIATE-AGE GLOBULAR CLUSTER NGC 1783 IN THE LARGE MAGELLANIC CLOUD

ALESSIO MUCCIARELLI
Dipartimento di Astronomia, Università degli Studi di Bologna, Via Ranzani 1, I-40127 Bologna, Italy; alessio.mucciarelli@studio.unibo.it

LIVIA ORIGLIA
INAF-Osservatorio Astronomico di Bologna, Via Ranzani 1, I-40127 Bologna, Italy; livia.origlia@oabo.inaf.it

AND

FRANCESCO R. FERRARO
Dipartimento di Astronomia, Università degli Studi di Bologna, Via Ranzani 1, I-40127 Bologna, Italy; francesco.ferraro3@unibo.it

ABSTRACT

We present Hubble Space Telescope ACS deep photometry of the intermediate-age globular cluster NGC 1783 in the Large Magellanic Cloud. By using this photometric data set, we have determined the degree of ellipticity of the cluster ($\epsilon = 0.14 \pm 0.03$) and the radial density profile. This profile is well reproduced by a standard King model with an extended core ($r_c = 24.5''$) and a low concentration ($c = 1.16$), indicating that the cluster has not experienced the collapse of the core. We also derived the cluster age using the Pisa Evolutionary Library isochrones, with three different amounts of overshooting (namely, $\Lambda_{ov} = 0.0, 0.10,$ and 0.25). From a comparison of the observed color-magnitude diagram and main-sequence luminosity function (LF) with the theoretical isochrones and LFs, we find that only models with the inclusion of some overshooting ($\Lambda_{ov} = 0.10–0.25$) are able to reproduce the observables. By using the magnitude difference $\delta^*_{SGB} = 0.90$ between the mean level of the He clump and the flat region of the SGB, we derive an age $\tau = 1.4 \pm 0.2$ Gyr.

Key words: globular clusters: individual (NGC 1783) — Magellanic Clouds — techniques: photometric

1. INTRODUCTION

Stellar clusters are key tracers of stellar populations in different galactic environments. In particular, populous clusters in the Large Magellanic Cloud (LMC) cover a wide range of ages (from a few megayears up to 13 Gyr) which has no counterpart in our Galaxy. Hence, the study of this system allows us to extend our empirical knowledge of stellar populations in a mass regime which can be only poorly explored in our Galaxy.

The LMC clusters can be grouped into three main age families, namely, the young population with ages $\lesssim 200$ Myr (Vallenari et al. 1994; Testa et al. 1999), the intermediate population in the 200 Myr $< \text{age} < 3–4$ Gyr range (Ferraro et al. 1995, 2004b; Brocato et al. 2001; Gallart et al. 2003), and the old population, with stellar clusters coeval to the Galactic halo ones (Testa et al. 1995; Brocato et al. 1996; Olsen et al. 1998; Mackey & Gilmore 2004).

A few decades ago, the main integrated properties of the LMC cluster system were investigated, both in the infrared (Persson et al. 1983) and in the optical spectral ranges (Mould & Aaronson 1979, 1982; Searle et al. 1980; van den Bergh 1981). These studies also provided the only existent homogeneous age scale, based on the so-called s-parameter, as defined by Elson & Fall (1985). This parameter is an empirical quantity related to the position of the clusters in the $(U - B, B - V)$ color-color diagram. Clearly, this method presents many uncertainties, namely, the foreground/background contamination and the possible statistical fluctuations due to bright stars.

The advent of 8 m class ground-based telescopes and the superior performance of the Hubble Space Telescope (HST) provide sufficient resolution to properly study these clusters even in their innermost crowded regions. Accurate ages can be determined from the main-sequence (MS) turnoff (TO) measurements (see, e.g., the recent works by Mackey et al. 2006; Kerber et al. 2007; Mucciarelli et al. 2007, hereafter Paper I), once updated theoretical evolutionary models are adopted and precise estimates of the global metallicity (Salaris et al. 1993) are available. Indeed, the stellar clock is extremely sensitive to the chemical composition, and detailed abundances of iron and $\alpha$-elements from high-resolution spectroscopy are mandatory for this purpose.

A few years ago, we started a long-term project aimed at determining homogeneous ages and metallicities for a representative sample of template LMC clusters, by combining high-resolution photometry and spectroscopy. The first cluster analyzed so far is NGC 1978; an accurate metallicity of $[\text{Fe/H}] = -0.37 \pm 0.07$ dex (Ferraro et al. 2006) and an age of $\tau = 1.9 \pm 0.1$ Gyr (Paper I) have been obtained. In this paper we present the results for NGC 1783, another populous intermediate-age cluster. Section 2 describes the cluster color-magnitude diagram (CMD) and its main evolutionary features. Section 3 describes its structural parameters, while § 4 discusses its age determination. In § 5 we draw our conclusions.

2. OBSERVATIONS AND DATA ANALYSIS

The results presented in this paper are based on a set of images obtained with the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC), which provides a field of view of $\approx 200'' \times 200''$ with a plate scale of 0.05'' pixel$^{-1}$. All the images have been retrieved from the ESO/ST-ECF Science Archive (proposal 9891, Cycle 12) through the F555W and F814W filters, with exposure times of 250 and 170 s, respectively. The first chip of the ACS WFC is centered on the cluster center. Figure 1 shows the F814W image of the cluster in both ACS chips.

The photometric reduction was carried out with the DAOPHOT II package (Stetson 1987) by using the point-spread function fitting method. The final photometric catalog includes almost 40,000 stars, and it has been calibrated in the Vegamag photometric system using the prescriptions of Bedin et al. (2005) and astrometrized on the Two Micron All Sky Survey photometric system, by cross-correlating...
the HST ACS catalog with the infrared catalog presented by Mucciarelli et al. (2006).

2.1. The CMD Overall Characteristics

Figure 2 shows the observed CMD using only the ACS chip sampling the cluster core. The useful magnitude range is 17.6 ≤ F555W ≤ 26. Indeed, we note that the brightest stars at F555W < 17.6 could be in the nonlinear regime of the CCD or saturated in their central pixels, making the corresponding magnitudes and colors somewhat uncertain.

The main features of the observed CMD can be summarized as follows:

1. The MS extends over more than 6 mag in the F555W band, and the TO point is located at F555W ≈ 21.2 (the identification of the TO magnitude was done by means of a parabolic fit of this region). The TO region shows a mild spread in color.

2. The slope change of the MS is at F555W ≈ 22.2 and flags the transition between radiative and convective core stellar structures.

3. The subgiant branch (SGB) is a poorly populated sequence, with a typical F555W ≈ 20.5 mag. We note that the blue edge of this sequence is not well defined.

4. The red giant branch (RGB) is well populated and extends over ≈5 mag.

5. The helium clump is located at F555W ≈ 19.25 and (F555W − F814W) ≈ 1.15.

6. The asymptotic giant branch (AGB) clump (corresponding to the base of the AGB sequence) is visible at F555W ≈ 18.4.

Figure 3 shows the radial CMDs by using the entire sample of stars detected in the ACS field of view. The bulk of the cluster population lies in the central 2′ (by radius); at r > 130″ the SGB, RGB, and He clump are barely detectable, while the brightest portion of the cluster MS is still visible.

The mild color broadening of the TO region deserves a brief discussion. Recently, Bertelli et al. (2003) found a color dispersion in the brightest portion of the MS of NGC 2173, while Mackey & Broby Nielsen (2007) found a bifurcation of the bright MS region of NGC 1846 and interpreted it as a double TO. These two pieces of observational evidence suggest the possible existence of an age dispersion in these stellar clusters. In order to check whether the broadening of the TO region in NGC 1783 can be ascribed to a possible age dispersion as well, we calculated the color distribution of the MS stars in the 20.5 mag < F555W < 21.1 mag range. The color distribution turns out to be roughly Gaussian with σ_{F555W−F814W} ≈ 0.05, which is fully consistent with observational errors (σ_{F555W} ≈ σ_{F814W} ≈ 0.03, implying a color uncertainty σ_{F555W−F814W} ≈ 0.04). Similar results are obtained by computing the color distribution in the radial CMDs of Figure 3. Thus, we can conclude that the spread in color of the TO region in NGC 1783 can be explained in terms of photometric errors, and there is not any evidence of an age dispersion.

2.2. Completeness

In order to quantify the degree of completeness of the final photometric catalog, we used the well-known artificial-star technique (Mateo 1988), and we simulated a population of stars in the same magnitude range covered by the observed CMD (excluding stars brighter than F555W = 17.6, corresponding to the saturation level) and with a (F555W − F814W) ≈ 0.8 mean color. The artificial stars were added to the original images, and the entire data reduction procedure was repeated using the enriched images. The number of artificial stars simulated in each run (~2000) was always a small percentage (~5%) of the detected stars; hence, they did not alter the original crowding conditions. A total of ~250 runs were performed, and more than 500,000 stars were simulated. We have excluded from our analysis the very inner region of the cluster (r < 20″), where the crowding conditions are prohibitive. Figure 4 shows the completeness factor φ = N_{rec}/N_{sim}, defined as the fraction of recovered stars over the total simulated ones, as a function of the F555W magnitude in two different radial regions, namely, between 20″ and 50″ and at r > 50″ from the cluster center. In the inner region the sample is >90% complete down to F555W ≈ 22.5, while in the outer region it is >90% complete down to F555W ≈ 24.

3. ELIPTICITY AND STRUCTURAL PARAMETERS

The knowledge of the position of each star over the entire extent of the cluster (and in particular in the innermost region) allows
us to compute the center of gravity ($C_{\text{grav}}$) with high precision. In doing this, we applied the procedure described in Montegriffo et al. (1995), averaging the $\alpha$- and $\delta$-coordinates of the detected stars with $F555W < 22$ in order to minimize the effects of incompleteness. The $C_{\text{grav}}$ of the cluster turns out to be located at $\alpha = 4^h 59^m 09.78^s$, $\delta = -65^\circ 59' 17.82"$ (J2000.0). This finding is in good agreement with our previous determination based on near-IR photometry (Mucciarelli et al. 2006).

We also used ACS photometry of NGC 1783 to derive new estimates for the cluster ellipticity and structural parameters. The isodensity curves are computed with an adaptive kernel technique, according to the prescription of Fukunaga (1972). We used all the stars in the first chip with $F555W < 22$ in order to minimize incompleteness effects, and we fit the isodensity curves with ellipses. Figure 5 shows the cluster map with the isodensity contours (top), the corresponding best-fit ellipses (middle), and their ellipticity as a function of the semimajor axis in arcseconds (bottom). The ellipticity $\epsilon$ (defined as $\epsilon = 1 - b/a$, where $a$ and $b$ are the major and minor axis of the ellipse, respectively) turns out to be $0.14 \pm 0.03$. This value is slightly lower than the previous determination of Geisler & Hodge (1980), who found an average ellipticity of $\epsilon = 0.19$.

By following the procedure already described in previous papers (see Ferraro et al. 2004a), we also computed the projected density profile of the cluster. The area sampled by the first ACS chip was divided in 18 concentric annuli, each one centered on $C_{\text{grav}}$ and split into four subsectors. The number of stars lying in each subsector was counted, and the mean star density was obtained. The standard deviation was estimated from the variance among the subsectors. The radial density profile is plotted in Figure 6.

We used the Sigurdsson & Phinney (1995) code in order to compute the family of isotropic single-mass King models. These models are defined by three main parameters, the central potential $W_0$, the core radius $r_c$, and the concentration $c = \log (r_t/r_c)$, where $r_t$ is the tidal radius. Figure 6 also shows the single-mass King model that best fit the derived density profile. The best-fit model has been selected using a $\chi^2$ minimization (shown in Fig. 6, bottom).

We find $W_0 = 5.5$, $r_c = 24.5''$, and $c = 1.16$, corresponding to a tidal radius $r_t = 5.9''$. Our estimate of $r_c$ is consistent with the one by Elson (1992), who found $r_c = 20''$. The resulting $r_t$ lies out of the field of view of ACS. In order to properly fit the most external points of the radial profile, the best-fit King model has been combined with a constant background level (corresponding to a density of 350 stars arcmin$^{-2}$), and shown as a horizontal dashed line in Figure 6.

---

1 We emphasize that the structure of the profile and the corresponding derived parameters do not change if different magnitude limits are adopted.
4. THE AGE OF NGC 1783

Young stellar populations (with ages ≤300 Myr) are characterized by large convective cores. Theoretical studies (see, e.g., the numerical simulations computed by Freytag et al. 1996) suggest that the penetration of convective elements into a stable region (via the Schwarzschild criterion) can produce nonnegligible evolutionary effects. These predictions seem to be confirmed by several works (Becker & Mathews 1983; Barmina et al. 2002; Chiosi & Vallenari 2007), which require some amount of overshooting in the MS star convective core in order to reproduce the observed morphologies and stellar counts of young clusters, although this issue is still a matter of debate (Testa et al. 1999; Brocato et al. 2003). At variance, in older (>5–6 Gyr) stellar populations the growth of large radiative cores tends to erase the possible evolutionary effects of overshooting.

Intermediate-age stellar populations like those in the NGC 1978 and NGC 1783 LMC stellar clusters represent the transition stage between these two regimes, and thus represent an ideal test bench to study the overshooting effects.

4.1. Basic Assumptions

In Paper I we performed a detailed comparison of the observed morphology and star counts of NGC 1978 with different sets of theoretical models and overshooting efficiencies. The best agreement between observations and theoretical predictions was reached with the Pisa Evolutionary Library (PEL).  

Hence, we have used the PEL isochrones to also determine the age of NGC 1783. We selected isochrones with $Z = 0.008$ (corresponding to $[\text{M/H}] = -0.40$ dex, as estimated by A. Mucciarelli et al. [2007, in preparation] from high-resolution spectroscopy) and with three different amounts of overshooting efficiency, namely, $\Lambda_{\text{os}} = 0.0$ for the canonical isochrones$^3$ and $\Lambda_{\text{os}} = 0.10$ and 0.25, representative of mild and strong overshooting regimes, respectively.

These theoretical isochrones were transformed into the observational plane by means of suitable conversions computed with the code described by Origlia & Leitherer (2000) and convolving the model atmospheres by Bessel et al. (1998) with the ACS filter responses. Guesses of $(m - M)_0 = 18.50$ (Alves 2004) for the distance modulus and $E(B - V) = 0.10$ (Persson et al. 1983) for reddening were adopted. However, in order to obtain the best fit of the observed sequences we allowed these parameters to vary by ≤10% and ≤40%, respectively.

Figure 7 shows the best-fit solutions for the different values of $\Lambda_{\text{os}}$, as obtained by matching the following features:

1. The magnitude of the He clump.

---

$^2$ The PEL isochrones are available at http://astro.df.unipi.it/SAA/PEL/Z0.html.
$^3$ The overshooting efficiency is parameterized using mixing length theory (Bolm-Vitense 1958) with $\Lambda_{\text{os}} = 1/H_p$ (where $H_p$ is pressure scale height), which quantifies the overshoot distance above the Schwarzschild border in units of the pressure scale height.
2. The magnitude difference between the He clump and the flat region of the SGB.

3. The difference in color between the TO and the base of the RGB.

As can be seen, the canonical model with $\Lambda_{\text{os}} = 0.0$ fits observational features 1 and 2 reasonably well with $(m - M)_0 = 18.57$, $E(B - V) = 0.13$, and $\tau = 0.9$ Gyr, but fails to reproduce feature 3.

Figure 8a shows a portion of the CMD, as zoomed into the TO region, with the best-fit ($\tau = 0.9$ Gyr) and 0.3 Gyr older ($\tau = 1.2$ Gyr) isochrones. The older isochrone better fits feature 3 but predicts a too-bright (by $\approx 0.3$ mag) He clump. Moreover, it requires a $(m - M)_0 = 18.16$ distance modulus, which is definitely too short for the LMC (Alves 2004).

Figures 8b and 8c show a similar comparison for the overshooting models. For the $\Lambda_{\text{os}} = 0.10$ model (Fig. 8b), the best-fit ($\tau = 1.2$ Gyr) and 0.2 Gyr older ($\tau = 1.4$ Gyr) isochrones are plotted. As for the canonical model, the older isochrone somewhat better fits feature 3 but predicts a too-bright (by $\approx 0.25$ mag) He clump and a too-short $(m - M)_0 = 18.25$ distance modulus.

For the $\Lambda_{\text{os}} = 0.25$ model (Fig. 8c), the best-fit ($\tau = 1.6$ Gyr) and 0.2 Gyr younger ($\tau = 1.4$ Gyr) isochrones are shown. The younger isochrone slightly better fits the SGB region but predicts a too-blue MS. In addition, it predicts a slightly too-faint (by $\approx 0.2$ mag) He clump and too-long $(m - M)_0 = 18.66$ distance modulus.

In summary, we can conclude that canonical models, regardless of the adopted isochrone age, do not provide an acceptable fit to the observed CMD, while models with $\Lambda_{\text{os}} = 0.10$ and 0.25 overshooting, $E(B - V) = 0.13$, $(m - M)_0 = 18.45$, and ages between $\tau = 1.2$ and 1.6 Gyr, respectively, reproduce reasonably well all three diagnostic features.

4.2. Star Counts and Overshooting Efficiency

A quantitative check to discriminate between the different overshooting scenarios is to perform a comparison between the observed and theoretical LFs of the MS stars normalized to the number of the He clump stars, defined as

$$\Phi_{\text{norm}} = \log \frac{N_{\text{MS}}}{N_{\text{He clump}}}.$$
Such a normalized LF is a powerful indicator of the relative time-scales of the H- and He-burning phases. The observed $\Phi_{\text{norm}}$ is obtained by counting the number of MS stars ($N_{\text{MS}}$) in each 0.5 mag bin, after the correction for incompleteness and field contamination, and normalizing to the total number of He clump stars. The innermost region of the cluster ($r < 20''$; see Fig. 3) has been excluded from this analysis because of its prohibitive crowding. Formal errors for the observed $\Phi_{\text{norm}}$ in each magnitude bin are computed under the assumption that star counts follow Poisson statistics, by using the following formula:

$$\sigma_{\Phi_{\text{norm}}} = \sqrt{\frac{\Phi_{\text{norm}}^2 \sigma_{\text{He clump}}^2 + \sigma_{N_{\text{MS}}}^2}{N_{\text{He clump}}}}.$$ 

Since the ACS field of view is not large enough to properly sample the field population around NGC 1783, we used the most external region ($r > 150''$) of the decontamination field for NGC 1978 (Paper I). Indeed, these two clusters are close enough for the purpose of decontamination, and their field RGB sequences are well overlapped.

Figure 9 shows the histogram of the number of MS stars per arcmin$^2$ at $r > 150''$ from the center of NGC 1783. The number of MS and He clump stars in this field have been subtracted from the NGC 1783 cluster stellar counts, after normalization for the sampled area.

Hence, the total number of stars in each magnitude bin is given by

$$N_{\text{corr}} = \frac{N_{\text{obs}}}{\bar{\phi}} - N_{\text{field}}.$$ 

In order to compute the theoretical $\Phi_{\text{norm}}$ predicted by the PEL models, we have adopted the well-known technique of synthetic diagrams. By using the best-fit models described above, we randomly distributed the stars along the isochrone accordingly to a Salpeter initial mass function. An artificial dispersion was added in order to simulate photometric errors. For each model, 200 synthetic diagrams were computed using Monte Carlo simulations, and the corresponding $\Phi_{\text{norm}}$ values were extracted and averaged together.

Figure 10a shows the observed LF (black circles) compared with the theoretical expectations, computed using the three different overshooting models. Clearly, the $\Lambda_{\text{os}} = 0.0$ model predicts a $\Phi_{\text{norm}}$ value $\sim \text{10\%} \text{–} \text{15\%}$ lower than the observed one; the $\Lambda_{\text{os}} = 0.10$ and 0.25 models marginally ($< \text{5\%}$) underestimate the observed value of $\Phi_{\text{norm}}$. This small offset can be easily accounted for by adding a binary population to the synthetic LF. To do this, we assumed that a given fraction $f_b$ of the simulated stars were the primary star of a binary system. The mass of the primary was randomly extracted, while the mass of the secondary star was assigned by adopting the mass ratio $q$ between the secondary and primary star. The magnitude of the binary system is given by

$$M_{\text{F555W}}^{\text{bin}} = -2.5 \log 10^{-2.5(M_{\text{F555W}}^{\text{prim}} - M_{\text{F555W}}^{\text{sec}})},$$

where $M_{\text{F555W}}^{\text{prim}}$, $M_{\text{F555W}}^{\text{sec}}$, and $M_{\text{F555W}}^{\text{bin}}$ are the magnitudes of the binary and the primary and secondary star, respectively. The latter was obtained from the isochrone mass/luminosity relation. Figure 10b shows the comparison between the observed and theoretical $\Phi_{\text{norm}}$ with a binary population. The inclusion of $\sim \text{10\%}$ binaries with a flat distribution of mass ratios ($q = 0.80$) provides a good match between theoretical and observed $\Phi_{\text{norm}}$ for the models with overshooting. A residual discrepancy of $\sim \text{10\%}$ is still present between the observed and the theoretical $\Phi_{\text{norm}}$ as predicted by the $\Lambda_{\text{os}} = 0.00$ model. The adopted binary fraction is somewhat smaller than previous estimates ($\lesssim \text{30\%}$) in other LMC and SMC clusters (Testa et al. 1995; Barmina et al. 2002; Chiosi & Vallenari 2007).

5. DISCUSSION AND CONCLUSIONS

The overall CMD characteristics of NGC 1783 are quite similar to those of NGC 1978 (Paper I), although there is evidence of an age difference. Indeed, we have shown that the best-fit solutions to the observed CMD features are obtained by selecting $\Lambda_{\text{os}} = 0.1 \text{–} 0.25$ and $\tau = 1.2 \text{–} 1.6$ Gyr for NGC 1783 (see § 4) and $\Lambda_{\text{os}} = 0.1$ and $\tau = 1.9$ Gyr for NGC 1978 (Paper I).
Further insight on the relative age of the two clusters can be obtained from a direct cluster-to-cluster comparison of the overall CMD properties. To this aim we can define the $\delta V^1_{\text{He clump}}$ parameter as the magnitude difference between the luminosity distribution peak of the He clump and the flat region of the SGB. This differential parameter can provide an independent estimate of the age, and it is formally analogous to the so-called vertical method, based on the magnitude difference between the TO and the horizontal branch magnitude level, used to infer the age for old globular clusters (see, e.g., Buonanno et al. 1989).

Figure 11 shows the two observed CMDs with the $\delta V^1_{\text{He clump}}$ parameters: we find $\delta V^1_{\text{He clump}}$ = 0.90 and 1.56 for NGC 1783 and NGC 1978, respectively. This difference is an independent, clear-cut indication that NGC 1783 is younger than NGC 1978.

Figure 12 shows the theoretical relations between the $\delta V^1_{\text{He clump}}$ observable and the age, as derived from the PEL models with different amounts of overshooting. The gray area marks the region of the $(\tau, \delta V^1_{\text{He clump}})$-plane for a mild/strong overshooting efficiency appropriate for NGC 1783. Hence, by entering the measured $\delta V^1_{\text{He clump}}$ in the above relations, an independent estimate of the age based on this differential parameter can be obtained.

By using the measured value of $\delta V^1_{\text{He clump}}$ = 0.90, we find $\tau = 1.4 \pm 0.2 \pm 0.1$ Gyr for NGC 1783, where the first error refers to the uncertainty in overshooting efficiency and the second to the uncertainties in the adopted reddening and distance modulus. This age is still consistent with the one inferred by Geisler et al. (1997; $\tau = 1.3$ Gyr), while it is significantly older than the age derived from the $s$-parameter ($\tau \sim 0.9$ Gyr) and by Mould et al. (1989; $\tau = 0.7$–1.1 Gyr). Mucciarelli et al. (2006) note that the $N_{\text{bright RGB}}/N_{\text{He clump}}$ population ratio computed for NGC 1783 is too high for the clusters undergoing the RGB phase transition, as suggested by the $s$-parameter age. Our new determination of an older age for NGC 1783 better reconciles the $N_{\text{bright RGB}}/N_{\text{He clump}}$ population ratio with the observed well-populated RGB.

Finally, we note that the structural parameters ($r_c$, $r_t$) and the age of the cluster inferred from this study allow us to constrain the dynamical state of this cluster. The resulting core radius of $r_c = 24.5''$ [corresponding to $\sim 5.9$ pc adopting the distance modulus of $(m - M)_0 = 18.45$, obtained from the best fit with the overshooting models; see § 4] is consistent with the age-core radius relationship discussed by Mackey & Gilmore (2003) based on the surface brightness radial profiles of 53 LMC rich clusters. The youngest (ages $\leq 200$ Myr) clusters of their sample exhibit core radii $< 3$ pc, while the older (both intermediate-age and old) stellar clusters show a more scattered distribution, with $r_c$ between $\sim 1$ and $\sim 8$ pc, a major peak at $r_c \sim 2.5$ pc, and the presence of several objects with $r_c \approx 5$ pc.

The inferred concentration parameter, $c = 1.16$, is consistent with a non-core-collapse cluster (Meylan & Heggie 1997), as expected given the relatively young age of NGC 1783.
