OLD MAIN-SEQUENCE TURNOFF PHOTOMETRY IN THE SMALL MAGELLANIC CLOUD. I. CONSTRAINTS ON THE STAR FORMATION HISTORY IN DIFFERENT FIELDS

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ABSTRACT

We present ground-based B- and R-band color-magnitude diagrams (CMDs) reaching the oldest main-sequence (MS) turnoffs with good photometric accuracy for 12 fields in the Small Magellanic Cloud (SMC). Our fields, located between ~1° and ~4° from the center of the galaxy, are situated in different parts of the SMC such as the “Wing” area and toward the west and south. In this paper we perform a first analysis of the stellar content in our SMC fields through comparison with theoretical isochrones and color functions (CFs). We find that the underlying spheroidally distributed population is composed of both intermediate-age and old stars and that its age composition does not show strong galactocentric gradients. The three fields situated toward the east, in the Wing region, show very active current star formation. However, only in the eastern field closest to the center do we find an enhancement of recent star formation with respect to a constant SFR(t). The fields corresponding to the western side of the SMC present a much less populated young MS, and the CF analysis indicates that the SFR(t) greatly diminished around 2 Gyr ago in these parts. Field smc0057, the closest to the center of the galaxy and located in the southern part, shows recent star formation, while the rest of the southern fields present few bright MS stars. The structure of the red clump in all the CMDs is consistent with the large amount of intermediate-age stars inferred from the CMDs and color functions. None of the SMC fields presented here are dominated by old stellar populations, a fact that is in agreement with the lack of a conspicuous horizontal branch in all these SMC CMDs. This could indicate that a disk population is ruling over a possible old halo in all the observed fields.

Key words: galaxies: evolution — galaxies: individual (Small Magellanic Cloud) — galaxies: photometry — galaxies: stellar content — Local Group

1. INTRODUCTION

Dwarf galaxies are believed to represent the dominant population, by number, of the present-day universe and are a major constituent of groups (Côté et al. 1997) and clusters (e.g., Ferguson & Sandage 1991). Studying their star formation and chemical enrichment histories is key to understanding the evolution of galaxies on cosmological timescales (e.g., Madau et al. 1998). Local Group galaxies are ideal laboratories for detailed studies of dwarf galaxy properties: we can resolve their individual stars and thus learn about their star formation histories (SFHs) by exploring ages, metallicities, and the spatial distribution of the stellar populations they contain.

The color-magnitude diagram (CMD) is the best tool to retrieve the SFH of a stellar system. The ideal situation is when it reaches the oldest main-sequence (MS) turnoffs with good photometric accuracy. In this case, the information on the SFH can be obtained directly and with little ambiguity from the distribution of stars on the MS and its comparison with that predicted by stellar evolution models in this relatively well-known phase of stellar evolution. In particular, the range of ages and metallicities present can be determined through comparison with theoretical isochrones. To quantitatively determine the SFH, it is necessary to compare the observed density distribution of stars with that predicted by stellar evolution models (see Gallart et al. 2005). Shallower CMDs (e.g., those reaching just below the horizontal branch [HB] or a couple of magnitudes below the tip of the red giant branch [RGB]) still contain stars born throughout the galaxy’s whole lifetime, but the interpretation of the distribution of stars in terms of the SFH is progressively less detailed and uncertain as the CMD gets shallower. The reason for this is twofold: on one hand, the stellar evolution models are less accurate for more advanced stellar evolution phases such as the RGB or the HB, because the corresponding physics is more complicated or uncertain. On the other hand, in these stellar evolution phases stars of very different ages are packed together in the CMD in a small interval of color and/or magnitude, and suffer from important age-metallicity degeneracies (see Gallart [2000] and Gallart et al. [2005] for detailed discussions of all these issues).

For all the Milky Way satellites, it is possible to obtain CMDs reaching the oldest MS turnoffs using ground-based telescopes, while for the rest of the Local Group, this is possible using the ACS on board the Hubble Space Telescope (HST). The Magellanic Clouds (MCs) are particularly interesting among the Milky Way satellites since they are actively star forming, and their SFHs can shed light on the role played by interactions in galaxy evolution. But in spite of their proximity and intrinsic interest, it is remarkable that there are still important gaps in the knowledge of the SFH of the MCs. This may be explained by their huge projected size and the large number of stars to analyze.

In this paper we focus on the Small Magellanic Cloud. The SMC is a dwarf irregular satellite of our Galaxy, with a low mean metallicity and a high mass fraction remaining in gaseous form (van den Bergh 1999). These characteristics suggest that the SMC is in a more primitive evolutionary stage than its larger neighbor, the Large Magellanic Cloud. Historically, the study of this galaxy has in general been neglected in favor of the LMC. The uncertainty about its line-of-sight depth, its more complicated shape...
(elongated toward the northeast), and its larger distance from us are factors at play.

To our knowledge, only two papers have presented CMDs reaching the oldest MS turnoffs, with a small field of view in each: Dolphin et al. (2001) and McCumber et al. (2005). Dolphin et al. presented a combination of HST and ground-based F and I images of an SMC field situated 2° northeast of NGC 121 (avoiding the contamination from 47 Tucanae) in order to derive the SFH. From their ground-based images, they inferred a peak of star formation between 5 and 8 Gyr ago with a medium age of 7.5 Gyr at the 1σ level, and that 14% ± 5% of the stars were formed more than 11 Gyr ago. The SFH they derived is also consistent at the 2σ level with a continuous star formation from ancient times until ~2 Gyr ago, when the star formation rate dropped to finally stop entirely in the past 0.5 Gyr. More recently, McCumber et al. (2005) analyzed the stellar populations of an SMC field located in the “Wing” area with observations from the HST WFPC2. They compared the luminosity function from their observed CMD with those obtained from two different model CMDs, one with constant SFR(t) and another with bursts of star formation at ~2 and at ~8 Gyr. They found that the population appears to have formed largely in a quasi-continuous mode, with the main period of star formation between 4 and 12 Gyr ago and very recent star formation with bright stars as young as 100 ± 10 Myr.

Two main wide-field studies of the SMC exist: the pioneer work by Gardiner & Hatzidimitriou (1992) and a recent study from Harris & Zaritsky (2004, hereafter HZ04). Gardiner & Hatzidimitriou (1992) presented the first large-area study of the SMC, and mainly concentrated their analysis in the outer regions, beyond 2° from the SMC center. They took six photographic plates with the UK Schmidt Telescope, covering a total area of 130° × 130°. Since their photometry was rather shallow (reaching the HB level at R ~ 20 mag), they mainly gave information about the young populations (age ≤ 2 Gyr). From their CMDs and contour plots of the surface distribution of MS stars with B − R < 0.1 and R < 20, they noted the almost complete absence of bright MS stars in the northwestern part, while a considerable bright MS population was present in the eastern and southern areas. With the aid of luminosity functions they found that young populations (< 0.6 Gyr in age) are concentrated toward the center of the SMC and in the Wing region. Using an index defined as the difference between the median color [in (B − R)] of the red clump (RC) and the color of the RGB at the level of the HB, the authors inferred that the bulk of the field population has a median age around 10−12 Gyr. They were the first to note the different distribution of young and old populations in the SMC. Zaritsky et al. (2000) and Cioni et al. (2000) confirmed that the asymmetric appearance of the SMC, similar to that seen in the H I image (Stanimirović et al. 1999), is primarily caused by the distribution of young stars (upper MS stars, younger than ~0.2 Gyr), and that the older stars have a spheroidal distribution.

HZ04 presented a study of the SMC based on the Magellanic Clouds Photometric Survey (MCPS) UBVI catalog (Zaritsky et al. 1997), which covers a 4° × 4.5° area of the SMC to a depth of V ≤ 21. This work represents the most complete analysis of the spatially resolved SFH of the central part of the SMC. They divided the SMC survey into a grid of 351 cells and obtained the SFH through a χ2 minimization between the star counts in the observed CMD and those in the model CMDs based on isochrones by Girardi et al. (2002). They inferred that a significant fraction (~50%) of all stars in the SMC were formed more than 8.4 Gyr ago. Between 3 and 8.4 Gyr ago they found a quiescent period during which the SMC formed few stars. They also found a recent active time from 3 Gyr ago until now, with bursts at 2.5 Gyr, 400 Myr, and 60 Myr ago. Although deeper than the one from Gardiner & Hatzidimitriou (1992), this study is still limited by its shallowness. In fact, the oldest stars that they can observe on the MS are ~2 Gyr old, and this implies a necessarily poor temporal resolution and larger uncertainties in their SFH at ages older than that.

In spite of the increasing interest in studying the SMC, reflected by the recent works mentioned above, there are still many questions unanswered that require the information provided by CMDs reaching the oldest MS turnoffs. What is the age distribution of the old and intermediate-age population? Are there gradients in the composition of this underlying population? Shallower studies inform about the existence of a large young population in certain areas, but does this young population reflect an exceptional increase of the star formation at the present time with respect to the average SFR? To shed light on these aspects, in this article we present 12 unprecedented deep BR-based SMC CMDs with positions ranging from ~1° to ~4° from the SMC center. Our fields are distributed in different parts of the SMC, avoiding the central area, where crowding may not allow us to reach the oldest MS turnoffs from the ground. Three of our fields are located in the Wing area, near the field studied by McCumber et al. (2005); two fields are in the western part, and one is in the northwestern area, near the field from Dolphin et al. (2001) located 2° northeast of NGC 121; finally, six fields are placed toward the south at different galactocentric distances. This strategic selection of fields, in spite of their small sizes, permits us to sample several regions of the SMC with high temporal resolution in order to address the above issues. The depth of our fields, reaching the oldest MS turnoffs with very good photometric accuracy, will allow us to obtain detailed SFHs from all of them, and therefore to investigate the variation of the SFH across the SMC field. This will be the subject of a forthcoming paper. Here we focus the analysis on the inspection of the CMDs with the aid of theoretical isochrones and color functions.

This paper is organized as follows. In §2 we present the observations and data reduction. In §3 we discuss the photometry of the SMC fields, obtained using the DAOPHOT II ALLSTAR and ALLFRAME programs. In §4 the CMDs are discussed with the help of isochrones and color functions. In §§5 and 6 our results are summarized and discussed. In a future paper (N. Noël et al., in preparation) we will derive the SFH of the SMC through comparison of the observed CMDs with synthetic CMDs.

2. OBSERVATIONS AND DATA REDUCTION

The present paper is a result of a more comprehensive program to study the SMC, which also includes the determination of its absolute proper motion by observing SMC fields in which background quasars have been identified. These quasars provide a quasi-inertial reference frame with respect to which (in conjunction with existing radial velocity measurements) the absolute total space velocity vector of the SMC can be precisely determined (see, e.g., Pedros et al. 2006). The imaging strategy was therefore designed in a way that would satisfy the needs of the stellar populations program as well as the astrometry program. Given that for the latter it was mandatory to obtain R-band images, this bandpass together with B imaging was chosen to construct the CMDs.

The observations were made with a 24 µm pixel−1 Tektronic 2048 × 2048 CCD detector attached to the Cassegrain focus
of the 100 inch (2.5 m) Iréné du Pont telescope (C100) at Las Campanas Observatory in Chile. This combination gives a field size of $8.85\times8.85'$ and a scale of 0.2590 pixel$^{-1}$. The inverse gain was 3 e$^{-}$/ADU$^{-1}$ with a read noise of 7 e$^{-}$. Basic reduction of the CCD frames was done using standard IRAF$^2$ tasks. For this purpose, bias exposures, sky flats, and dome flats were taken every night.

Throughout our 4 year campaign (2001–2004), B- and R-band images of 13 fields in the SMC were obtained. The coordinates of these fields and the data obtained for each of them are detailed in Table 1, in which the first column denotes the field, the second and third columns the right ascension and the declination, respectively, the fourth and fifth columns the galactocentric distance ($r$) and the position angle ($\rho$), and the sixth and seventh columns the integration times in B and R bands.

### Table 1

| Field         | $\alpha_{2000.0}$ | $\delta_{2000.0}$ | $r$ (arcmin) | $\rho$ (deg) | B-Band Exposure (s) | R-Band Exposure (s) |
|---------------|-------------------|-------------------|--------------|--------------|---------------------|---------------------|
| smc0057.......| 00 57             | −73 53            | 65.7         | 164.4        | 1 $\times$ 60 + 1 $\times$ 600 + 2 $\times$ 800 + 2 $\times$ 1000 + 1 $\times$ 1200 | 2 $\times$ 60 + 2 $\times$ 600 + 3 $\times$ 800 + 1 $\times$ 1200 |
| qj0037.........| 00 37             | −72 18            | 78.5         | 294          | 1 $\times$ 60 + 5 $\times$ 800 | 7 $\times$ 60 + 16 $\times$ 600 |
| qj0036.........| 00 36             | −72 25            | 79.8         | 288          | 2 $\times$ 60 + 10 $\times$ 600 + 12 $\times$ 800 | 15 $\times$ 60 + 26 $\times$ 500 + 22 $\times$ 600 |
| qj0111........| 01 11             | −72 49            | 80.9         | 89.5         | 1 $\times$ 60 + 3 $\times$ 800 | 8 $\times$ 60 + 4 $\times$ 500 + 17 $\times$ 600 + 1 $\times$ 700 + 1 $\times$ 800 |
| qj0112........| 01 12             | −72 36            | 87.4         | 81           | 1 $\times$ 60 + 1 $\times$ 600 + 6 $\times$ 800 | 9 $\times$ 60 + 7 $\times$ 500 + 15 $\times$ 600 |
| qj0035.........| 00 35             | −72 01            | 95.5         | 300.6        | 4 $\times$ 600 + 1 $\times$ 700 | 4 $\times$ 60 + 1 $\times$ 100 + 3 $\times$ 500 + 15 $\times$ 600 + 3 $\times$ 800 |
| qj0116.........| 01 16             | −72 59            | 102.5        | 95.2         | 1 $\times$ 60 + 13 $\times$ 600 + 2 $\times$ 800 | 7 $\times$ 60 + 14 $\times$ 500 + 20 $\times$ 600 |
| smc0100.......| 01 00             | −74 57            | 130.4        | 167.5        | 1 $\times$ 60 + 7 $\times$ 800 + 3 $\times$ 900 | 1 $\times$ 60 + 7 $\times$ 600 + 3 $\times$ 700 |
| qj0047.........| 00 47             | −75 30            | 161.7        | 187.7        | 1 $\times$ 800 + 3 $\times$ 1000 | 6 $\times$ 60 + 16 $\times$ 600 + 2 $\times$ 800 |
| qj0033.........| 00 33             | −70 28            | 172.9        | 325          | 1 $\times$ 60 + 5 $\times$ 600 + 1 $\times$ 700 | 6 $\times$ 60 + 3 $\times$ 500 + 20 $\times$ 600 |
| smc0049.......| 00 49             | −75 44            | 174.8        | 184.6        | 1 $\times$ 60 + 1 $\times$ 600 + 4 $\times$ 800 | 1 $\times$ 60 + 5 $\times$ 600 |
| qj0102.........| 01 02             | −75 46            | 179.5        | 169.4        | 3 $\times$ 60 + 6 $\times$ 800 | 8 $\times$ 60 + 3 $\times$ 500 + 15 $\times$ 600 + 1 $\times$ 700 + 2 $\times$ 800 |
| smc0053.......| 00 53             | −76 46            | 236.3        | 179.4        | 1 $\times$ 60 + 8 $\times$ 800 + 2 $\times$ 900 | 1 $\times$ 60 + 8 $\times$ 600 + 2 $\times$ 700 |

**Note.**—Units of right ascension are hours and minutes, and units of declination are degrees and arcminutes.

$^a$ Distance from the SMC center, $\alpha_{2000.0} = 00^h52^m42^s$, $\delta_{2000.0} = −72^\circ49'$.

3. THE PHOTOMETRY

3.1. Photometry of SMC Fields

We performed our photometry using the DAOPHOT II ALLSTAR software package (Stetson 1987 and updates: Stetson 1990, 1992) to find stars and to determine an empirical PSF for each frame and then simultaneously fit it to all detected stars. After testing various PSF models, we adopted a Moffat function with $\beta = 2.5$ (Stetson et al. 2003) as the best analytical model. The Moffat function is usually a much better representation of a star image than a Gaussian function, because it has more prominent and extended wings, like real star images. Also, unlike other functions (e.g., the Lorentz function), the Moffat function offers the option of tuning the radial falloff of the wings to match observations. Between 50 and 100 stars were used to construct the PSF of each image. Quadratic spatial variation was included because it reduced the fitting errors.

After the DAOPHOT ALLSTAR analysis of all the original frames was performed, an optimum, complete star list was achieved by cross-matching the ALLSTAR results of the individual frames with DAOMASTER (Stetson 1993). ALLFRAME (Stetson 1994) was then used to obtain simultaneous photometry of stars in all CCD images of each SMC field.

After ALLFRAME, we ran MONTAGE2 for each field. MONTAGE2 takes the images from which all the stars have been subtracted according to their final positions and brightnesses, and applies the known geometric transformations that relate their coordinate systems and the known differences in their photometric zero points to produce a median image of each field. We tested in each of the 13 SMC fields that the number of stars detected on the median of the subtracted images, and considered real stars after running DAOPHOT ALLSTAR, and ALLFRAME a second time, was less than 1%, i.e., negligible for our goal.

ALLFRAME produces an image-quality index, CHI, which is a dimensionless measure of the agreement between the brightness profile of any given object and that of the model PSF for the frame in which it is measured. Similarly, ALLFRAME gives the SHARP index, which is a first-order estimate of the intrinsic angular radius of a source. Another index provided by ALLFRAME is $\sigma$, which represents the standard error of the star’s magnitude and is representative of the internal errors of the photometry. Stars with at least one valid measurement in each band (B and R) were selected, and their final magnitudes were obtained using

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$^2$ Ver. 2.11.3, NOAO, University of Arizona.
DAOMASTER, which combines the magnitudes measured for each star in each image to provide the “mean weighted” magnitude. DAOMASTER also provides $\sigma$, CHI, and SHARP parameters for each star, which are a combination of the corresponding parameters for each image. We used the following limits for the error and shape parameters given by DAOMASTER: $\sigma_{(B-R)}^2 = \sigma_B^2 + \sigma_R^2 \leq 0.15$, $-0.6 \leq \text{SHARP} \leq 0.6$, and $|\text{CHI}| \leq 2.5$. The final number of stars we kept, measured in $(B-R)$ of each field (and consequently, in each CMD) is given in Table 2. A total of 215,121 stars down to $R \approx 24$ were measured.

The so-called aperture corrections, i.e., the corrections that place the relative profile-fitting magnitudes into the system of the “total” instrumental magnitudes for a particular frame, were obtained from synthetic aperture photometry by measuring several isolated, bright stars through a series of increasing apertures and the construction of growth curves (Stetson 1990). We used a growth sequence that consists of 12 apertures from $r_1$ to $r_{12}$ in such a way that we considered the first radius $r_1$ about half of the one we used for the aperture photometry of our objects and $r_{12} = 30''$. The sequence is $r_k = \left(\frac{r_{12}}{r_1}\right)^{1/11}r_{k-1}$, $k = 2, \ldots, 12$. The aperture corrections were derived using the program DAOGROW (Stetson 1990). In each image we selected the brightest and most

![Spatial distribution of our SMC fields (squares) superposed on an H\textsc{i} column density image of the SMC from Stanimirovi\'c et al. (1999). The big rectangle denotes the area covered by the MCPS (Zaritsky et al. 1997). The positions of the fields studied by Dolphin et al. (2001) and McCumber et al. (2005) are also shown. The actual figure from Stanimirovi\'c et al. (1999) is delimited by the labeled box and includes the range in declination from approximately $-75$ to approximately $-70$. The gray-scale intensity range is 0 to $1.03 \times 10^{22}$ atoms cm$^{-2}$ with a linear transfer function. The maximum H\textsc{i} column density is $1.43 \times 10^{22}$ atoms cm$^{-2}$. (b, c) Distribution of young and RGB stars in the SMC, respectively (Cioni et al. 2000). The positions of our fields have also been shown. The fields superposed are the same in the three figures, but the names of each field in (b) and (c) have been omitted for clarity.](image)

**TABLE 2**

| Field       | N$^*$ |
|-------------|-------|
| smc0057     | 21246 |
| qj0037      | 21579 |
| qj0036      | 23756 |
| qj0111      | 25845 |
| qj0112      | 47548 |
| q0035       | 24114 |
| qj0116      | 19875 |
| smc0100     | 7801  |
| qj0047      | 9762  |
| qj0033      | 3797  |
| smc0049     | 3580  |
| qj0102      | 4030  |
| smc0053     | 2188  |

$^*$ Selected stars with $\sigma \leq 0.15$, CHI $\leq 2.5$, and $-0.6 \leq \text{SHARP} \leq 0.6$. 
isolated 30–80 stars among those used in the derivation of the PSF for that frame. The aperture photometry results were then provided to DAOGROW, which returns the “total” instrumental magnitude and its standard error for each of the selected stars. The aperture correction for a particular frame was obtained as the median of the differences between the “total” magnitude and the profile-fitting ALLFRAME magnitude for all selected stars on that frame. Errors in the aperture corrections were calculated as the standard error of the mean of these differences, and were typically between ±0.001 and ±0.003.

3.2. Standard Star Photometry

Our instrumental photometric system was defined by the use of the Harris BVRI filter set, which constitutes the default option on the C100 for broadband photometry in the standard Johnson-Kron-Cousins system. On photometric nights, typically six BVRI standard star areas from the catalog of Landolt (1992) were observed several times to determine the transformation of our instrumental magnitudes to the standard BR system. Thirty-one different standard stars with colors −0.49 < (B−R) < 5.00 were observed, and a total of 272 observations were made: 178 in 2001 and 94 in 2002. Most of these areas include stars of a wide variety of colors. A few of them were followed up to about 2.0 air masses to optimally determine atmospheric extinction. During these nights we also obtained short-exposure BR frames of all our fields of interest, which served the purpose of calibrating all frames taken with nonphotometric sky. Field qj0035 is not considered in this paper because we do not yet have a secure calibration for it.

The Landolt standard images are uncrowded fields; thus, no profile-fitting photometry was necessary for them. Instead, DAOGROW was used in a way identical to that for the program stars to directly derive the total instrumental magnitudes for the standard stars from their aperture photometry.

To put our observations into the standard system, we used the following transformation equations:

\[
B = b + \alpha_b (B-R) + \beta_b X_b, \\
R = r + \alpha_r (B-R) + \gamma_r X_r,
\]

where \((b, r)\) and \((B, R)\) are the instrumental and standard magnitudes, respectively, and \((X_b, X_r)\) are the air masses. No time-dependence terms were added, since a preliminary fit showed no trends in the residuals of either \(B\) or \(R\) with time.

The color terms \((\beta_b, \beta_r)\) and extinction coefficients \((\gamma_b, \gamma_r)\), as well as the zero points \((\alpha_b, \alpha_r)\), are unknown, presumably constant transformation coefficients and need to be calculated. Both the color-dependent term and the zero point in the transformation are expected to be reasonably constant properties of the telescope/filter/detector combination, and, in fact, the night-to-night differences for a given year in their computed values were found to be consistent with the uncertainty of the individual determinations. The above equations were applied to the Landolt standard star magnitudes and solved for \((\alpha_b, \alpha_r, \beta_b, \beta_r, \gamma_b, and \gamma_r)\) for each night using a custom program.

Then we followed an iterative procedure to refine our photometric transformation. First, a new set of unique \((\alpha_b, \alpha_r)\) and \((\beta_b, \beta_r)\) values for each campaign was obtained by imposing the extinction coefficients \((\gamma_b, \gamma_r)\) corresponding to each night. Then, we applied the resulting zero points and color terms to each night of each year, and new extinction coefficients were derived for each night. In this way we had a set of \((\alpha_b, \alpha_r)\) and \((\beta_b, \beta_r)\) values for each year and \((\gamma_b, \gamma_r)\) values for each night of each year. In Table 3 we present the zero points and the color coefficients. The first column denotes the year, the second and third columns indicate the \((\alpha_b, \alpha_r)\) coefficients, and the fourth and fifth columns the \((\beta_b, \beta_r)\) coefficients. The final values for the extinction coefficients are shown in the second and third columns of Table 4, in which the first column shows the night to which the coefficients correspond. Figure 2 shows the standard distributions for each filter and each year; the slope represents the extinction coefficient. Fitting errors in the zero points correspond to \(\sigma/(N-2)^{1/2}\), where \(N\) is the number of measurements we have. They turned out to be between ±0.001 and ±0.002.

The total zero-point errors of the photometry, including the error in the extinction and in the aperture corrections, and the uncertainties in the calibrations, are ~0.02 mag in both \(B\) and \(R\). These values are consistent with the systematic errors derived comparing photometry of different epochs. Using those SMC fields for which we have standard star observations from more than one night, we tested the photometric differences resulting from the use of different standard sets corresponding to different nights. We found that these differences are between ±0.001 and ±0.03 in \(B\) and between ±0.001 and ±0.04 in \(R\) (standard errors of the mean).

4. THE SMC STELLAR CONTENT

We present unprecedented deep SMC CMDs obtained using a medium-aperture telescope (100 inch). The quality of the CMDs is comparable to that of the CMDs obtained for the MCs using the HST (e.g., McCumber et al. 2005). Given the depth of our diagrams, which reach the oldest MS turnoffs, accurate information about age can be derived from the MS turnoff luminosities. As discussed by Gallart et al. (2005), reaching the oldest turnoffs will allow us to break the age-metallicity degeneracy affecting most methods for obtaining the SFH.

Figures 3–5 show the \([(B-R), R]\) CMDs for the 12 SMC fields in order of increasing galactocentric distance. The fields range

| Night       | \(\gamma_b\)   | \(\gamma_r\)   |
|-------------|----------------|----------------|
| 2001 Oct 16 | −0.218 ± 0.007 | −0.078 ± 0.003 |
| 2001 Oct 17 | −0.219 ± 0.007 | −0.077 ± 0.007 |
| 2001 Oct 18 | −0.219 ± 0.006 | −0.070 ± 0.009 |
| 2001 Oct 19 | −0.211 ± 0.005 | −0.065 ± 0.005 |
| 2002 Oct 10 | −0.207 ± 0.008 | −0.066 ± 0.009 |
| 2002 Oct 13 | −0.215 ± 0.008 | −0.076 ± 0.008 |

| Campaign  | \(\alpha_b\)   | \(\alpha_r\)   | \(\beta_b\)   | \(\beta_r\)   |
|------------|----------------|----------------|---------------|---------------|
| 2001........ | −0.709 ± 0.002 | −0.423 ± 0.001 | +0.040 ± 0.002 | +0.001 ± 0.001 |
| 2002........ | −0.892 ± 0.002 | −0.549 ± 0.002 | +0.045 ± 0.002 | +0.002 ± 0.002 |

| Campaign | \(\alpha_b\)   | \(\alpha_r\)   | \(\beta_b\)   | \(\beta_r\)   |
|----------|----------------|----------------|---------------|---------------|
| 2001........ | −0.709 ± 0.002 | −0.423 ± 0.001 | +0.040 ± 0.002 | +0.001 ± 0.001 |
| 2002........ | −0.892 ± 0.002 | −0.549 ± 0.002 | +0.045 ± 0.002 | +0.002 ± 0.002 |
from galactocentric radius $\sim 1^{\circ}$ to $\sim 4^{\circ}$ and sample different regions of the SMC, as shown in Figure 1, in which the fields are depicted in the context of the H i distribution (Fig. 1a) and of the young (Fig. 1b) and intermediate-age and old (RGB star) populations (Fig. 1c). All the CMDs reach a couple of magnitudes below the old MS turnoff (even the most populated), with great photometric accuracy.

Figure 3 shows the CMD of fields qj0111, qj0112, and qj0116, which have galactocentric radii ranging from 1.4$^\circ$ to 1.7$^\circ$. These fields correspond to the eastern side of the galaxy (facing the LMC) as seen in Figure 1a, from which we can see that they are located in an area of high H i concentration, inside the supergiant shell 304A with an H i mass of $5.7 \times 10^7 M_\odot$ (the total H i mass in the area observed by Stanimirović et al. [1999] is $\sim 4 \times 10^8 M_\odot$). These fields are also in the region of the bridge that connects the so-called stellar bar\(^3\) with the Wing. From Figures 1b and 1c it can be seen that these fields are located in very densely populated isopleths of the young, intermediate-age, and old populations. Indeed, the CMDs of these fields show a conspicuous MS, well populated from the oldest turnoff at $R \sim 22$ to $\sim 16$, which implies the presence of a large number of very young stars in all the CMDs. The three western fields are also shown in Figure 1a, and the corresponding CMDs are presented in order of increasing galactocentric distance from 1.3$^\circ$ to 2.9$^\circ$ in Figure 4. These fields are situated on the opposite side of the LMC, in a region with a low concentration of H i. From Figure 1b it is evident that they are located in an area of low young stellar density, but still a high

\(^3\) The SMC is not a barred Irr galaxy, for which the LMC is the prototype, but sometimes it is useful to call the brightest portion of its chaotic major axis a "bar."
density of the intermediate-age and old populations, similar to that of the eastern fields. The CMDs of these western fields show a less significant young MS, even at distances from the center similar to those of the eastern fields. This fact is in agreement with the low density of the H\textsc{i} column in this part of the galaxy (see Fig. 1a).

We would like to address whether the differences seen in the young population can be extended to the intermediate-age and old populations.

Figure 5 shows the CMDs of the six southern fields, whose galactocentric distances range from 1.1° to 4°. As seen in Figure 1a these fields are located in regions in which the H\textsc{i} column density is very low. Field smc0057, the closest to the center, presents a conspicuous young MS. Figure 1b shows that the stellar density of young stars in this field is higher than in the rest of the southern fields and similar to the eastern field qj0111. Field smc0100 still shows many bright young MS stars, but 2.7° farther on the CMDs have a less populated young MS, and present a similar distribution of stars (with less statistics going farther south). The four farthest fields are located in an area in which the stellar density is similar, as shown in Figures 1b and 1c.

Depending on their mass and metallicity, the core-He-burning stars produce the HB and the RC. The presence of a prominent blue HB points out the existence of an old, metal-poor population; the lack of such an HB and the presence of a RC may indicate that core-He burners are not as old, or are more metal-rich, or both (see Gallart et al. 2005 for details). A shared feature in all our SMC CMDs is the absence of a well-populated, blue, extended HB, pointing out that the amount of field stellar population as old and metal-poor as that of the Milky Way halo globular clusters and dwarf spheroidal galaxies is small in the SMC. The RC is
well populated and extended in luminosity, with a width of up to \( \Delta R \sim 1 \text{ mag} \), denoting the presence of a large intermediate-age population. The fields with a prominent bright MS, such as the eastern fields and smc0057, show the vertical extension of the RC feature corresponding to nondegenerate core-He burners (Gallart 1998). The older stars in the core-He-burning phase lie in the lower part of the observed RC, while younger stars are brighter.

In the following sections we discuss the main features of the SMC CMDs using isochrones (§ 4.1) and color functions (§ 4.2). This will allow us to describe the SMC stellar populations as a starting point to a study (N. Noël et al. 2007, in preparation) in which we will address the SMC SFH by comparing in detail the distributions of stars in the observed CMDs with a set of model CMDs.

### 4.1. Theoretical Isochrones

The interpretation of CMDs of composite stellar populations strongly relies on the stellar evolution models adopted (see Gallart et al. 2005). For the present work, we used the BaSTI stellar evolution models (Pietrinferni et al. 2004) as the reference. In Figures 6, 7, and 8 we have superposed BaSTI isochrones on our CMDs for three different metallicities suitable for the SMC stellar populations: \( Z = 0.001 ([\text{Fe}/\text{H}] = -1.27) \), \( Z = 0.002 ([\text{Fe}/\text{H}] = -0.96) \), and \( Z = 0.004 ([\text{Fe}/\text{H}] = -0.66) \). The final selection of the metallicities was done taking into account the RGB and MS star colors and their best matches by BaSTI isochrones of given ages and metallicities.

The observed CMDs have been transformed to absolute magnitudes using a distance modulus of \( (m - M)_0 = 18.9 \) (see van den Bergh 1999) and dereddened as follows. For the two outermost fields, the reddening values given by the IRAS COBE extinction maps (Schlegel et al. 1998) were used. For the innermost regions, Schlegel et al. (1998) estimated a typical reddening of \( E(B-V) = 0.037 \) from the median dust emission in surrounding annuli, since reddenings through the SMC cannot be calculated because its temperature structure is not sufficiently well resolved by DIRBE. Their quoted value, therefore, is not accurate enough, and we estimated a mean value of the reddening for each of the fields smc0057, qj0037, qj0036, and qj0111 by requiring a good fit of the CMD by isochrones that overlapped to other fields for which the IRAS COBE reddening values are reliable. This assumes the same age-metallicity relation for all fields, which is in agreement with the results found by Carrera (2006).

![Fig. 5.—CMDs corresponding to the southern side of the SMC, in order of increasing distance from the SMC center (r) with different position angles (p).](image-url)
and Carrera et al. (2007) using Ca II triplet spectroscopy. In all cases the relations $A_B = 1.316E(B-V)$ and $A_R = 0.758E(B-V)$ (Schlegel et al. 1998) have been assumed to calculate the extinction in the $B$ and $R$ bands.

Canonical isochrones of 6, 9, and 13 Gyr with $Z = 0.001$, isochrones with overshooting of 1, 3, and 4 Gyr with $Z = 0.002$, and of 0.1 Gyr with $Z = 0.004$ were superposed. In the eastern fields and in field smc0057, a 0.03 Gyr isochrone with overshooting and $Z = 0.004$ was also superposed.

Figure 6 shows the CMDs of the eastern fields with the superposition of BaSTI isochrones. In these CMDs the conspicuous MS is well populated from the oldest turnoff at $M_B = 3.5$ (13 Gyr isochrone) up to the 0.03 Gyr isochrone. All the CMDs show a large number of young stars well represented by the 0.03 and 0.1 Gyr isochrones. The areas around the 1–6 Gyr isochrones are densely populated, indicating a strong presence of intermediate-age stars. No obvious differences between the MSs of these fields can be inferred from the comparison with isochrones alone.

Figure 7 shows the CMDs of the western fields with the isochrones superposed. In these fields, the intermediate-age population (~3–4 to 9 Gyr) seems dominant. Fields qj0036 and qj0037 have a small fraction of stars born up to 0.1 Gyr ago, while qj0033, the most remote of the three, seems to have no stars younger than 1 Gyr (although this could be an effect of small-number statistics).

Figure 8 shows the CMDs of the six southern fields with the superposition of isochrones. Field smc0057, the closest to the center, presents an important MS in which the 0.1 Gyr isochrone is still quite populated. In field smc0100 there is still a substantial...
population between 1 and 3 Gyr old, but fields qj0047 to smc0053 show few stars younger than 3–4 Gyr. The population of these relatively far-off fields is not purely old but contains an important amount of intermediate-age stars that inhabit the zones of the MS and subgiant branch around the 3, 4, 6, and 9 Gyr isochrones, in addition to the several old stars around the 13 Gyr isochrones.

4.2. Color Functions

Gallart et al. (2005) have discussed the potential of MS color functions (CFs) to provide information on the stellar populations present in a galaxy. They concluded that, in fact, the CF may be a better tracer of the SFH than the LF. The reason is that in CMDs such as \[(B - R), R\] or \[(V - I), I\], the MSs of isochrones of different ages follow roughly vertical paths up to the MS turnoff, where they turn to the red, almost perpendicular to the MS, to form the subgiant branch or, in the case of more massive stars, the blue loops. This effect is clear from the CMD in Figure 9a (we return to this figure below). The fact that the turnoff of a stellar population gets redder as the population gets older implies a general dependency on age of the CF of the MS and subgiant branch stars brighter than the oldest MS turnoff. Here we discuss CFs that include the whole CMD within a region defined by \(-1 \leq M_R \leq 3.5\) and \(-0.5 \leq (B - R) \leq 1.5\). The star counts have been normalized to the total stars present in the integrated range. Most of the information belongs in any case to the MS and subgiant branch. The fraction of CF that belongs to the RGB and RC serves as a check of the metallicity assumed for the synthetic CMD, and contributes to the overall normalization of the CF.

Comparison of the stellar content of a galaxy with isochrones and CFs is complementary in terms of the information on the stellar population they provide. The isochrones give us the range of ages and metallicities present in a given CMD; the comparison between theoretical and observed CFs is a good tool to assess the relative amounts of stars of different ages present in a stellar population. This is a particular case of a comparison of the number of stars in a set of boxes in the observed and synthetic CMDs, respectively (e.g., Gallart et al. 1999). However, the CF is particularly useful for a first qualitative assessment of the SFH because it is a one-dimensional representation of the content of the CMD, in which there is a relatively direct correlation between ranges of age and color. All the models used here have been computed using the synthetic CMD algorithm iac-STAR (Aparicio & Gallart 2004).

Figure 9a shows a synthetic CMD calculated assuming a constant SFR(t) from 13 Gyr ago to the present day and metallicities...
of $Z = 0.004$ in the range $0 \text{ Gyr} \leq t \leq 1 \text{ Gyr}$, $Z = 0.002$ in the range $1 \text{ Gyr} \leq t \leq 5 \text{ Gyr}$, and $Z = 0.001$ in the range $5 \text{ Gyr} \leq t \leq 13 \text{ Gyr}$ (inset). Stars corresponding to each age interval are depicted in different colors. Thirty percent binary stars have been assumed; the feature parallel to the red of the MS for $3.5 < M_R < 5$ corresponds to binary stars. Some of these binaries between 8 and 13 Gyr old are noticeably brighter than single stars at the same age and mass (shown by the red symbols in the synthetic CMD for $2 < M_R < 3$).

Figure 9b shows the composite CFs of populations with different SFR(t) (inset). Three main features characterize the CF: a local elevation in the blue part with $-0.3 \leq (B - R) \leq 0.2$, a central peak with $0.2 \leq (B - R) \leq 0.9$, and a second local maximum in the red part. Figure 9c shows which populations contribute to each feature in the CF for the synthetic CMD in Figure 9a. By comparing these, we find the following: the elevation in $-0.3 \leq (B - R) \leq 0.2$ in the composite CF mostly corresponds to stars in the age range $0 \leq t \leq 1.1 \text{ Gyr}$; and in the central peak $[0.3 \leq (B - R) \leq 0.9]$ there are populations of all ages, predominantly the intermediate-age and old stars ($\sim 2 - 13 \text{ Gyr}$). The second local maximum corresponds to the RC and the red part of the subgiant branch and is composed of stars with age $\geq 1 \text{ Gyr}$ as seen in Figure 9c. Going back to Figure 9b, the CF in black corresponds to a galaxy with a constant SFR(t) (i.e., the CF of the CMD in the Fig. 9a). The blue CF is from a synthetic CMD computed assuming an SFR(t) that increased by 50% between 8 and 3 Gyr ago. This CF presents a higher blue elevation due to the bigger number of young blue stars; also, the central peak is somewhat blueshifted. The green CF represents a stellar population in which the SFR(t) decreased by 50% between 8 and 3 Gyr ago. The CF in red represents a population with a gap in the SFR(t) between 8 and 3 Gyr ago.
We discuss here how the observational errors affect the CFs of artificial stars, together with the information from those that were injected and recovered magnitudes of the artificial stars, mimicking a recent enhancement of the star formation, similar to the one shown in blue in Figure 9b. Although still present, the effects of crowding are less severe in the case of field qj0111, since the CF of the corresponding model CMD (dashed line) resembles quite closely the CF for the synthetic CMD. In this field, confusion is mainly affecting the young MS. The dispersion introduced in the CMD when the observational errors are simulated produces an absolute maximum that is slightly wider, as shown by the dotted line in Figure 10. This shows how crowding could simulate a nonconstant SFH, mimicking a recent enhancement of the star formation, similar to the one shown in blue in Figure 9b. Although still present, the effects of crowding are less severe in the case of field qj0111, since the CF of the model CMD (dotted line) resembles quite closely the CF for the synthetic CMD. In this field, confusion is mainly affecting the yellow stars so the main maximum is shorter than in the synthetic CMD. In the case of smc0049, it can be seen that the CF of the model CMD (dot-long-dashed line) is similar to that of the synthetic CMD (solid line), indicating that crowding is affecting very little the CMDs of this part of the galaxy (at ~2.9°). In conclusion, only the CF of field smc0049 is substantially affected by observational errors. The effects of crowding on field qj0111 can be considered as an upper limit for fields qj0112 and qj0116. For fields smc0100, qj0047, qj0102, smc0053, qj0037, qj0036, and qj0033 the crowding level is similar to that of smc0049. Therefore, we can safely discuss the stellar content of all of our fields (except smc0057) by comparing their CFs directly with that from synthetic CMDs.

Let us concentrate now on the observed CFs of each of our fields. In Figures 11–13 the CF corresponding to the synthetic CMD (dashed lines) from Figure 9a and the CFs (solid lines) from the observed CMDs are also shown. Note that the shape of the synthetic CF depends on the selection of metallicities and stellar evolution libraries. However, small changes in the metallicity law, which result in synthetic CMDs with a color distribution compatible with the data, have very similar CFs. Comparison between the observed and synthetic CFs computed assuming constant SFR(t) lets us qualitatively analyze the SFH of each field.

Figure 11 shows the CFs of the eastern SMC fields. In Figure 11 (left), corresponding to field qj0111, synthetic CFs of synthetic populations with star formation enhanced by 50% from 1 Gyr ago to now (long-dashed line), by 30% from 1 Gyr ago to now (dotted line), and by 50% from 2 Gyr ago to now (dot-long-dashed line) were also overplotted. The CF of field qj0111 shows some differences with respect to the CF of a population with constant SFR(t). In particular, the observed CF has higher values than the synthetic one in the blue elevation \([−0.3 ≤ (B − R) ≤ 0.2; \text{age} ≤ 1.1\; \text{Gyr}]\), which indicates an SFH with enhanced star formation at young ages. This fact is also shown by comparing with the CF of synthetic populations with bursts. In fact, the blue maximum and the main peak of the CF with a burst of 30% 1 Gyr ago and the ones of the observed CF match very well, pointing out that there was an episode around 1 Gyr ago of enhanced star formation in this field that may have continued to the present time. Although a comprehensive analysis of the CMDs will be presented in a forthcoming paper, this superposition allows us to say that the observed CF is compatible with an SFH with an increase in the star formation of ~30% in the last 1 Gyr. Also note that crowding effects are not very significant in this field, as seen from the artificial star tests. The CF of field qj0112 is a remarkable case in which the CF corresponds almost exactly with that of a population with constant SFR(t) (at least on average). The CF of
qj0116 has somewhat greater values for $0 \leq (B - R) \leq 0.3$ as compared with the CF of a CMD with constant SFR(t), which may correspond to stars formed between ~1 and 2 Gyr ago, possibly indicating some enhancement in the SFR(t) at those ages in comparison with more recent ages. Note that these three fields have a very similar CMD, and that simple comparison with isochrones gives the same information for all three: the presence of stars of all ages. The differences in their CFs are a good illustration of the complementary information that the CF can provide. The presence in the observed CFs of all the features that characterize the synthetic CF is the counterpart, in this representation of the data, of the fact that the CMDs are well populated over all age ranges. The additional information brought forward by the CFs is the relative weight of the different age ranges in the population.

In Figure 12 the CFs of the western SMC fields are shown. The almost complete absence of the blue elevation in the color interval $-0.3 \leq (B - R) \leq 0.2$ reflects the fact that there are few stars younger than ~1 Gyr. This is another example of the usefulness of the CFs: while in fields qj0036 and qj0037 there are stars until around the 0.1 Gyr isochrone, the CFs indicate that the relative amount of stars between 0 and 2 Gyr is substantially less than in the case of a field with constant SFR(t). The central maximum is slightly shifted to the red, possibly indicating that the SFR(t) started to decline around 3 Gyr ago. Note that this shift is unlikely to be due to an overall shift of the observed CMD with respect to the synthetic one, since the shift does not affect the red relative maximum of the CF. In fact, this maximum is slightly shifted to the blue and is higher in the CF of the observed
CMD as compared with that of the synthetic one. This is possibly
due to field stars, which contribute more in relative numbers to
the poorly populated CMDs. Actually, the observed red maxi-
mum is particularly higher with respect to the theoretical one in
the less populated qj0033. The composition of the population in
these three western CMDs seems to be very similar, even in the
outermost field, qj0033.

Finally, Figure 13 shows the CFs of the southern SMC fields.
In the case of field smc0057, the relative amount of young stars
might have been overestimated due to crowding effects if these
were not taken into account. The overplot of the observed CF
(solid line) with the synthetic (dashed line) and model (i.e., after
taking into account crowding effects; dotted line) ones shown in
Figure 13 indicate that part of the enhancement of the blue ele-
vation in field smc0057 is produced by observational errors but
that there is still a true recent enhancement (0 Gyr \(\leq t \leq 3\) Gyr)
in the star formation. The CF of field smc0100 is still almost com-
patible with a constant SFR(t) on average, with a possible truncation
of the SFR(t) at recent ages, as also hinted by the comparison
of its CMD with isochrones in Figure 8. Moving farther away
from the SMC center, the elevations corresponding to the first
structure in the CFs are less conspicuous, indicating that young
stars are less common and that intermediate-age stars dominate
the fields. The fact that the main peak is redder in the observed CF
from field qj0047 on (except, maybe, in the case of field qj0102,
which is situated more toward the east than the other southern
fields) points out that there is a larger amount of old stars and, like
in the western fields, that possibly the SFR(t) started to decline
around 3 Gyr ago. As in the case of the western field qj0033, the
second, red relative maximum in the CFs gets bigger with in-
creasing galactocentric distance. The reasons for this are twofold.
First, the amount of stars in the RC and in the RGB relative to
the total stellar content is larger at larger distances from the center
(even though no large differences among fields seem to be present
beyond \( r \approx 2.7^\circ \)), where the age of the stellar population is older
on average. Second, the contamination by foreground stars is
larger relative to the total number of stars from the galaxy. This last
factor may be the main player in the case of field smc0053.

5. SUMMARY

We obtained B- and R-band photometry of stars from 12 SMC
fields observed during four different campaigns with the C100
telescope at Las Campanas Observatory. The spatial distribution
of the fields samples different parts of the galaxy, in both areas
with large amounts of recent star formation such as the Wing and “undisturbed” regions in the west and toward the southern part of the galaxy, in which the stellar populations may be representative of the underlying population of the SMC formed prior to the events of star formation that shaped its current irregular morphology. The stellar content present in these SMC fields has been analyzed by means of a set of \([B - R, R]\) CMDs that reach the oldest MS turnoffs \((M_R \sim 3.5)\) with an excellent photometric accuracy.

In this first approach to studying the SFHs of our SMC fields, we found the following. The fields in the Wing contain very young blue stars and show a broad MS turnover/subgiant region and a wide range in luminosity of the RC, pointing out that star formation in these parts has extended from at least \(~13\) Gyr ago to the present with no substantial gaps, as the areas around all the overlapped isochrones are well populated. Field q\,j0111 (the closest to the center of the SMC in the Wing) seems to have experienced an enhancement in its recent star formation, compatible with an enhancement of 30\% in the SFR\((t)\) over the last \(~1\) Gyr. This is indicated by the height of the blue elevation in its CF \((\text{color interval in the range} -0.3 \leq (B - R) \leq 0.2)\) as compared with that of CFs corresponding to synthetic populations with different SFR\((t)\). The other two fields analyzed in this direction seem to have had an SFR\((t)\) close to constant on average.

Very little star formation has been going on from \(~1\) Gyr ago until now in the western fields, as indicated by the much lower amount of young blue stars and the lack of the blue elevation in the CFs. Considering the RCs (formed by stars older than \(~1\) Gyr) of fields q\,j0036 and q\,j0111, both located at the same galactocentric distance, we found that the number of stars is comparable, indicating that the integrated SFR\((t)\) from old ages to \(~1\) Gyr ago in both fields is similar, and that there was a mechanism in the Wing that triggered the star formation around \(~1\) Gyr ago, in particular in the location of field q\,j0111. Field q\,j0033, although located farther away from the center in the northwest, presents a distribution of stellar ages similar to that of the two other western fields, as seen from the resemblance of the three CFs and from its CMD, in which the area below the turnover of the 4 Gyr isochrone is still quite populated. In fact, the apparent differences between these CMDs are mainly due to the different numbers of stars in them rather than to fundamentally different compositions of the stellar populations. Something similar occurs in the case of the southern fields beyond \(\pm 2.2\)\,kpc. In addition, we estimated that the SFR\((t)\) at intermediate to old ages in fields located at the same distance from the SMC center and at either side (e.g., q\,j0111 and q\,j0036) is similar. With the current analysis of the data we cannot provide a detailed SFH for these fields, and therefore, we can neither confirm nor rule out periods of quiescence as found in other studies that used shallower data. This will be the subject of a forthcoming paper.

The three fields situated toward the east, in the Wing region, show very active recent star formation. In the case of the field closer to the center, q\,j0111, we estimated that the current star formation rate (from around \(~1\) Gyr ago to the present) in this field is \(~30\%) larger than the SFR\((t)\) averaged over the galaxy’s life. However, the other two northeastern fields, situated just slightly farther away from the center, have a CF that is compatible with that of a constant SFR\((t)\) over the whole galaxy’s history. Therefore, only the parts of the Wing closer to the center seem to be undergoing an exceptionally intense episode of star formation at the present time.

At the radius of the innermost field (\(~1\) kpc), we derived a crossing time of \(~10^8\) yr, obtained adopting a measured velocity dispersion of 36 km s\(^{-1}\) (Carrera 2006; using the stars below the RGB tip corresponding to our SMC fields). In the case of our outermost field (\(~4\) kpc) the crossing time is \(~2 \times 10^8\) yr. Large-scale asymmetries should disappear within a few crossing times, and the population older than \(~1\) Gyr is then expected to be well mixed at a radius of \(~1\) kpc, while the population older than \(~2\) Gyr is well mixed at \(~4\) kpc. Hence, although our fields only cover little isolated parts of the SMC (as compared with the huge area embraced by HZ04), they are representative of the SMC populations older than \(~2\) Gyr.

The larger amount of young stars present in the eastern fields may be related to a recent interaction between the SMC, the LMC, and the Milky Way, as suggested by numerical models (e.g., Yoshizawa & Noguchi 2003). Note that the presence of a
considerable young population in the eastern fields and the lack thereof in the western ones is in good correspondence with the existence or absence of large amounts of H\textsubscript{i} at the corresponding locations (Stanimirović et al. 1999). It is interesting to note that this trend is not maintained in the closest southern field, smc0057, in which there is a considerable young population but the amount of H\textsubscript{i} is small.

The presence of a substantial intermediate-age population in our outermost SMC fields could be the sign that a few gigayears ago H\textsubscript{i} gas extended as far as $r/\text{C}_{24}$ and has since gradually receded to the more central regions. Another possible explanation for this is that tidal interactions happened periodically, and then these stars dynamically mixed, resulting in old stars (those from previous passages) being symmetrically distributed and younger ones being only in the current tidal feature. None of the studied fields is dominated by an old stellar component, as one would expect for an old stellar halo similar to that of the Milky Way. This may mean that a disk population still dominates over a possible old halo, if it does exist in the SMC.

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