STELLAR CONTENT AND RECENT STAR FORMATION HISTORY OF THE LOCAL GROUP DWARF IRREGULAR GALAXY IC 1613

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ABSTRACT

We present resolved-star V/I photometry of the Local Group dwarf irregular galaxy IC 1613 reaching I ~ 23.5, obtained with the wide-field camera at the 2.5 m Isaac Newton Telescope. A fit to the stellar density distribution shows an exponential profile of scale length 2.9 ± 0.1′ and gives a central surface brightness µ_r = 22.7 ± 0.6. The significant number of red giant branch (RGB) stars present in the outer part of our images (r > 16.5′) indicates that the galaxy is actually more extended than previously estimated. A comparison of the color-magnitude diagrams (CMDs) as a function of galactocentric distance shows a clear gradient in the age of its population, the scale length increasing with age, while we find no evidence of a metallicity gradient from the width of the RGB. We present quantitative results of the recent star formation history from a synthetic CMD analysis using IAC-STAR. We find a mean star formation rate of (1.6 ± 0.8) × 10^{-3} M_⊙ yr^{-1} kpc^{-2} in the central r ≤ 2.5′ for the last 300 Myr.

Key words: galaxies: dwarf — galaxies: individual (IC 1613) — galaxies: irregular — galaxies: stellar content — galaxies: structure — Local Group

Online material: color figures

1. INTRODUCTION

IC 1613 is a typical dwarf irregular galaxy concerning its luminosity, metallicity, and star formation rate (SFR). In fact, it serves as the prototype for the DDO type Ir V. It is a low surface brightness galaxy with a moderate luminosity (M_V = −15.3; van den Bergh 2000) located 730 ± 20 kpc from our Sun. This distance corresponds to a distance modulus (m - M)_0 = 24.31 ± 0.06 (Dolphin et al. 2001) and a scale of 3.54 pc arcsec^{-1}. The recent calculation of Pietrzyński et al. (2006) from near-IR photometry of Cepheids gives (m - M)_0 = 24.29 ± 0.035, for which the authors claim a total uncertainty of less than 3%. While the spatial extent estimate of Ables (1972) gives an optical size of 16′ × 20′, the observation of carbon stars up to 15′ from the center by Albert et al. (2000) indicates that it is virtually twice that size. Its high Galactic latitude in the southern hemisphere confines its low extinction and color excess. Here we adopt a reddening of E(B - V) = 0.02 ± 0.02 from Cole et al. (1999).

The H II region metallicity of IC 1613 was measured by Talent (1980; see Skillman et al. 1989) to be 12 + log (O/H) = 7.86 from spectrophotometric observations of the [O ii] λ3727 line, while Lee et al. (2003) found 12 + log (O/H) = 7.62. This corresponds to [Fe/H] = −0.8 and −1.07 dex, respectively (Skillman et al. 2003, hereafter S03). The mean color (V - I) = 3.5 of the red giant branch (RGB) at M_V = −3.5 gives [Fe/H] = −1.3 for the old and intermediate-age population (Lee et al. 1993). This low overall metallicity and the high gas content (Hoffmann et al. 1996) suggest a primitive state in its evolution.

The star formation history (SFH) has been studied quite extensively by S03 for a Hubble Space Telescope (HST) WFPC2 field located 7.4′ kpc southwest of the center. Their conclusion is a relatively constant SFR over a long period, with the oldest population being more than 10 Gyr old. They also summarize the results about structure and stellar content of the whole galaxy from the literature. More recently, Borissova et al. (2004) analyzed 60 OB associations, apparently correlated with H II regions studied kinematically by Loznitskaya et al. (2003; see also Silich et al. 2006). Magrini et al. (2005) announced the detection of two candidate planetary nebulae.

In this paper we describe a wide-field survey of IC 1613. An overview of the observations and data reduction is presented in §2, and the resulting color-magnitude diagram (CMD) is described in §3. In §4 we examine the extent and morphology of the galaxy, as well as the spatial structure of the different populations in the CMDs. An analysis of the recent SFH at different galactocentric radii is given in §5. Finally, in §6 we summarize the results and present our conclusions.

2. OBSERVATIONS AND DATA REDUCTION

Observations of IC 1613 in Harris V and Sloan Gunn i′ were conducted on five nights between 1999 November and 2000 August using the Wide Field Camera (WFC) at the 2.5 m Isaac Newton Telescope (INT) of the Observatorio del Roque de los Muchachos. The WFC is a mosaic camera made up of four 2048 × 4096 CCDs, with a pixel size of 0.33″. The total field of view is about 34′ × 34′, covering most of the galaxy. The total integration times in V and i′ were 3600 and 1830 s, respectively. A detailed observing log is presented in Table 1.

Overscan trimming, bias subtraction, and flat-field corrections were performed using the standard routines in IRAF. The i′ images have also been corrected for fringe effects. The DAOPHOT-II ALLSTAR and ALLFRAME programs (Stetson

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1 Based on observations made with the Isaac Newton Telescope, operated on the island of La Palma by the Isaac Newton Group, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.
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1987, 1994) were then used to obtain the instrumental photometry of the resolved stars from the four individual images in each band and for each chip. The ~200 stars used to model the point-spread functions (PSFs) were carefully selected to cover the whole field of view and sample the spatial variations of the PSFs. The input list of stars for ALLFRAME was created with DAOMASTER from the ALLSTAR photometry files of the individual images. This list contains all the stars that were detected on at least one image. The stars with good photometry were selected among the detected objects using ALLFRAME’s fitting parameters, and SHARP. Only those ~30,000 objects with very good photometry, i.e., with $\sigma \leq 0.15$, $\chi^2 \leq 1.1$, and $-0.3 \leq \text{SHARP} \leq 0.3$, were kept.

Our photometry of chips 1, 3, and 4 of the WFC\(^5\) was calibrated to standard magnitudes using OGLE’s photometry of the same field, kindly provided by A. Udalski (2003, private communication). Several hundred stars were used for each chip, giving dispersions of the fits at the centers of mass of the point distributions of about 0.001. Calibration of chip 2, which was outside OGLE’s field, was more laborious. In $V$, one standard star field observed during the IC 1613 INT run was used to determine the transformations between chip 2 and chips 1 and 4. The dispersion of these transformations is ~0.005. Then the transformation for the latter chips based on OGLE’s photometry was used, bringing the chip 2 $V$ photometry into the standard system. In $I$, chip 2 was calibrated differentially with respect to chip 4 using overlapping images obtained on the IAC80 telescope at Izané, Tenerife, Spain, during a photometric observing run. The dispersion at the center of mass is of the order of 0.01. Hence, the total error in our photometry is that given by Udalski et al. (2001), i.e., up to 0.02 for both $V$ and $I$ bands. Figure 1 shows our final ($V - I$, $I$) CMD.\(^6\) The spatial distribution of these stars is presented in Figure 2.

The errors given by ALLFRAME are the residuals of the PSF-fitting procedure, so they should be considered internal errors. Signal-to-noise ratio limitations, stellar crowding, blending, and star loss, which we can refer to as “observational effects,” are important error sources and significantly modify the CMD shape and stellar density distribution (Aparicio & Gallart 1995). To estimate the observational effects and the completeness of our photometry, we resorted to artificial-star tests. See Aparicio & Gallart (1995) for a detailed description of the procedure and the effects of crowding. Basically, a large number of artificial stars covering the same range in color and magnitude as the observed stars were added to the images using the corresponding PSF. These were placed on the images following a triangular grid in order to avoid crowding between artificial stars themselves and to optimally sample the chip fields. The photometry was then repeated in the exact same way as was done originally. A comparison of the input and output artificial-star list gives information about the completeness as a function of magnitude and galactocentric distance.

As the artificial-star sample, we took a synthetic CMD produced by IAC-STAR\(^7\) (Aparicio & Gallart 2004) using the stellar evolution library of Bertelli et al. (1994) and the bolometric corrections of Castelli & Kurucz (2003). The SFR was chosen to be constant between 13 Gyr ago and now, while the metallicity range increased from 0.0008–0.002 at $t = 0$ to 0.0008–0.006 at the present time. These ranges were chosen to be wide enough so that

\(\text{TABLE 1}\)

| UTC Date      | Time (UT) | Filter | Exp. Time (s) | Air Mass |
|---------------|-----------|--------|---------------|----------|
| 1999 Nov 6    | 22:23     | $V$    | 60            | 1.14     |
| 1999 Nov 6    | 22:32     | $V$    | 1200          | 1.13     |
| 1999 Nov 6    | 23:14     | $V$    | 1200          | 1.12     |
| 2000 Aug 10   | 04:38     | $I$    | 30            | 1.12     |
| 2000 Aug 10   | 04:41     | $I$    | 600           | 1.12     |
| 2000 Aug 10   | 04:54     | $I$    | 600           | 1.12     |
| 2000 Aug 10   | 05:05     | $I$    | 600           | 1.12     |

\(5\) See the WFC User Notes at http://www.ing.iac.es/Astronomy/instruments/wfc/wfc_notes_apr98.html.

\(6\) The photometric data are available from the first author upon request.

\(7\) The code, available for free use, can be executed at the IAC-STAR Web site, http://iac-star.iac.es/.

**Fig. 1.—** CMD of IC 1613. All the stars described in § 2 are plotted.

**Fig. 2.—** Distribution of resolved stars in IC 1613. North is up and east to the left.
they include the actual metallicity of IC 1613. In total, 76,630 artificial stars were added in five runs in each external chip, and twice as many in the central chip (chip 4), where crowding is more important. Figure 3 presents the injected and recovered CMDs for chip 4. The line in the figure indicates the 25% completeness limit, averaged over the galactocentric radius range, obtained from the ratio of recovered to injected stars as a function of magnitude. Figure 4 shows the completeness and error in recovered magnitude as a function of input magnitude for an inner and an outer field. It is important to note that, even though the recovered artificial stars were filtered using the same values of $\sigma$, $\chi^2$, and SHARP as the real stars, external errors can be as large as $\sim$1 mag at the faint limit.

3. THE COLOR-MAGNITUDE DIAGRAM

The most evident feature of our CMD (Fig. 1) is the RGB, composed of low-mass stars ($M \leq 1.8$–$2.0$ M$_{\odot}$; Chiosi et al. 1992) older than about 1 Gyr and burning hydrogen in a thin layer around an inert helium core. The age-metallicity degeneracy and the presence of the fainter extension of the asymptotic giant branch (AGB) in the same region of the CMD makes it difficult to get detailed information about the stars populating it. However, it is possible to place rough limits in time for given metallicities using theoretical isochrones. A more detailed determination of the chemical enrichment law (CEL) using this method, as well as its limitations, is presented in § 5.1.

The presence of a well-populated main sequence (MS) blueward of $V - I = 0$ and up to $I \sim 18.5$ indicates very recent star formation ($\lesssim$10 Myr). The stars with $0 \leq (V - I) \leq 0.6$ and $I \leq 22$ are most likely blue loop (BL) stars, highlighting the blue edge of the core He-burning loop, while the red edge (i.e., the red supergiant branch [RSG]), although contaminated by foreground stars, is well defined from $(V - I) \sim 1.0$ to $\sim 1.8$ and up to about $I \sim 16.5$. These are young and intermediate- to high-mass stars, so they are among the most metal-rich stars in IC 1613. However, this is a poorly understood phase in stellar evolution, and the theoretical models still contain large uncertainties owing to the importance of processes such as mass loss, overshooting, and rotation in very massive stars (see, e.g., Maeder & Meynet 2001). The BL and

![Fig. 3.— Left: Synthetic CMD produced by IAC-STAR showing the 153,260 stars injected in chip 4 (see text for details). Right: CMD of the $\sim$40,000 artificial stars recovered in both $V$ and $I$ and considered to have good photometry as described in § 2. The line shows the 25% completeness limit as determined from the artificial-star tests.](image1.png)

![Fig. 4.— Completeness (left panels) and errors in recovered magnitudes (right panels) for a central field (chip 4, top panels) and an outer field (chip 1, bottom panels). The error bars in the right panels show the dispersion per magnitude bin. [See the electronic edition of the Journal for a color version of this figure.]](image2.png)
RSG actually reach the red clump down to $I = 23.76$ (Cole et al. 1999), but the dispersion at the faint end of our CMD makes it impossible to distinguish them from the RGB stars below $I = 22$.

The final extension of the AGB, or red tail (Gallart et al. 1994), extends horizontally redward from the RGB tip at $I \sim 20$. AGBs are shell H- and He-burning stars of low and intermediate mass and age over about 0.1 Gyr. Their relatively large number indicates a possibly important intermediate-age population with relatively high metallicity, which would be compatible with the enhanced SFR between 3 and 6 Gyr ago found by S03.

Because of the wide field of view, the diagram also contains a relatively large number of foreground stars. Most stars with $0.5 \leq V - I \leq 1.2$ and $I \leq 20$ are probably Galactic dwarfs, since their number is the same for Figures 5b and 5c after correcting for the difference in area. More generally, the foreground contamination is rather important for $V - I \geq 0.6$.

Although old stars ($\geq 10$ Gyr) are very likely present in the RGB, our CMD is not deep enough to detail the old, low-metallicity population as it would if fainter MS stars were observed. The existence of a bona fide old population in IC 1613 is known thanks to the presence of RR Lyrae stars (Saha et al. 1992; Dolphin et al. 2001) and CMDs from HST observations showing core helium-burning, horizontal-branch stars (Cole et al. 1999; Dolphin et al. 2001; S03) and the oldest MS turnoffs (Gallart 2007).

4. MORPHOLOGY, SPATIAL EXTENT, AND DISTRIBUTION OF STELLAR POPULATIONS

To characterize the morphology of IC 1613, we plotted the RGB star distribution obtained from our photometry and convolved the resulting map with a Gaussian of $\sigma = 50''$ using IRAF’s GAUSS15 from the IMFILTER package. The result of this process is a smooth map of the stellar density highlighting the morphology of the galaxy. Fitting ellipses to the isodensity contours was done with IRAF’s ISOPHOTE routine.

From the best-fitted ellipses, where the crowding is low but the star number sufficient, we found a position angle of $80^\circ$ and an eccentricity $e = 1 - b/a = 0.15$, in good agreement with the values given by Ables (1972; P.A. = $81^\circ$, $e = 0.18$). Following the shape of the isopleths, we divided the galaxy into concentric ellipses at small radii ($\leq 10.5''$) and circles at larger radii that we used for radial star counts and stellar population gradient analysis. Their semimajor axis increases in steps of 100 pixels, corresponding to $33''$.

Figure 6 shows the radial profile of the galaxy constructed from the number of stars in each ellipse after correcting for completeness. The correction was obtained from the ratio of the number of recovered to injected stars in the artificial-star test for each annular region. The area of the ellipses has been calculated via Monte Carlo sampling, carefully taking into account the gaps between the chips, as well as the regions around saturated stars, when calculating the effective surface. An approximate surface brightness scale, shown on the right-hand side of Figure 6, was calculated from the stellar density in each ellipse. The calibration was calculated by comparing the star number with the total sky-subtracted flux for each ellipse and then averaged over the radius range for consistency. An exponential least-squares fit to this curve between $2'$ and $15'$ from the center gives a scale length of $2.9' \pm 0.1'$ ($620 \pm 20$ pc) and central surface brightness $\mu_V = 22.7 \pm 0.6$. The former value is slightly smaller than the $760 \pm 50$ pc ($\sim 3.5' \pm 0.2'$) given by Hodge et al. (1991). However, a similar larger length is obtained when fitting only the inner $\sim 7'$, as was done by the authors because of the limited depth of their photometry, and omitting the crowding correction. The profile seems to get steeper at $r \sim 12'$, but this change of slope could be an artifact of the background subtraction and small number statistics.

The large field of view covered by the WFC permits us to study the spatial gradients of the stellar population across the galaxy. Ideally, that would give us hints about its formation and evolution. However, in the case of shallow CMDs, the spatial variations of the morphology of the CMD only accurately reflect differences in the SFH over the last several hundred million years. Such variations have been observed in all the known dwarf irregular galaxies through CMD morphology (e.g., WLM, Minniti & Zijlstra...
To give a quantitative measure of the gradient in the age composition of the stars in IC 1613, the stellar surface density for different populations of resolved stars is presented in Figure 8. The age gradient is clearly visible: while the density of the older stars follows the expected exponential decrease from the central region, that of the young population peaks at a radius of \( r \sim 3'\) and vanishes rapidly as the radius increases. This results in the scale length of the young population being much smaller than that of the older stars; a fit to the profiles between 3.5' and 12.1' from the center of IC 1613 gives scale lengths of \( 1.19' \pm 0.04', 2.0' \pm 0.1', 3.2' \pm 0.2', \) and \( 3.8' \pm 0.1' \) for the MS, BL+RSG, AGB, and RGB, respectively. The off-center peak in the distribution of the young population, visible at \( r \sim 3'\)–3.5' in Figure 8, is due to the fact that the star-forming regions are distributed in a somewhat circular pattern at this distance from the center (Hodge et al. 1990), where Silich et al. (2006) observed a higher H\(_\alpha\) column density.

Because of the large dependence of the RGB color on metallicity, the position of the RGB in a CMD can be used to estimate the metallicity of the stellar system using empirical relations (e.g., Da Costa & Armandroff 1990). For the same reason, the width of the RGB is often considered to be an indication of the metallicity dispersion. On the CMDs presented in Figure 5, it appears that the RGB in the central region is wider than that at larger radii and suggests the existence of a metallicity gradient. However, a RGB width gradient may also reflect an observational-effects gradient. To check this possibility, the following procedure was used, including measurements of real- and artificial-star RGB width and...
error estimates. We measured the width of the RGB at $M_I = -3.5$ as a function of galactocentric distance for the real stars as follows: for each radius interval, chosen so that the RGB contains about 800 stars, a subsample of 450 RGB stars was selected at random. The resulting RGB was sliced in intervals of 0.25 mag in the range $20.5 \leq I \leq 22$, and the width of the RGB in each magnitude range was obtained from the full width at half-maximum (FWHM) of a Gaussian fit to the color function. The width at $M_I = -3.5$ was then interpolated from a linear fit to the FWHM versus magnitude plot. We repeated this operation 20 times using a different subsample of RGB stars each time, and we used the dispersion of these solutions as the error bars. The same process was followed for the synthetic CMD used in the artificial-star tests, except that the radius bins and random subsamples contained 2500 and 1500 stars, respectively. The resulting plot is presented in Figure 9 for IC 1613 (top) and the artificial stars (middle).

Figure 9 shows that the RGB recovered in the artificial-star tests is wider in the center of the galaxy. In addition to the expected FWHM widening due to signal-to-noise ratio limitations, crowding in the central part further disperses the stars on the CMD. Crowding is important and affects the width of the RGB up to $r \sim 10'$. To correct the observed RGB for the effects of crowding, we calculated the broadening parameter as a function of radius by subtracting in quadrature the injected width from the recovered width. The corrected width was then obtained by subtracting in quadrature the broadening parameter from the observed RGB width and is shown as the thick line in the top panel of Figure 9. The FWHM of the corrected RGB still presents a significant variation across the central $\sim 6'$. A higher metallicity dispersion in the central region could be responsible for this residual width excess. However, the bottom panel of Figure 9, showing the width of artificial RGBs for which the age of the youngest stars is progressively older, indicates that this excess is consistent with the presence of stars between 1 and $3-4$ Gyr old in the center. Thus, there is no strong evidence of a metallicity gradient across the galaxy, but its presence cannot be ruled out with the present set of data.

5. RECENT STAR FORMATION HISTORY

5.1. The Method

The reconstruction of the recent SFH has been performed in a way similar to that described in S. L. Hidalgo et al. (2007, in preparation) or Gallart et al. (1999). The main difference here resides in the fact that our CMD is not sufficiently deep to contain discriminating information about intermediate-age and old stars. We limited our study to the recent SFH, i.e., the last $\sim 300$ Myr, based on the MS, BL, and RSG populations. This limited the determination of the SFH to the inner $r \leq 10'$, since these populations are absent beyond this radius.

In short, the SFH is derived from the comparison of the star distribution of the observed CMD with that of a synthetic CMD. The synthetic CMD used in the comparison must cover a range of age and metallicity at least as large as the one that can be expected in such a dwarf irregular galaxy. It was generated by IAC-STAR (Aparicio & Gallart 2004) using the stellar evolution library of Bertelli et al. (1994) and the bolometric corrections from Castelli & Kurucz (2003) with the following parameters: the SFR was chosen to be constant between 13 Gyr ago and now, the initial mass function (IMF) was that of Kroupa et al. (1993), and the fraction of binaries was set to zero. To fix the input CEL we fitted isochrones of different metallicities to the upper RGB of the outer field, where crowding is not dominant. We used the Girardi et al. (2002) isochrones for different ages (1.585, 2.239, 5.012, 10.00, and 12.59 Gyr old) and metallicities between $Z = 0.0005$ and 0.006 in steps of 0.0005. The metallicities that were not available in the original library were interpolated using IAC-STAR. A metallicity was considered valid at a given age if the corresponding isochrone was inside the FWHM of the RGB in the range $20.4 \leq I \leq 21$. Figure 10 (diamonds) shows the values obtained
made of short, violent bursts of star formation separated by periods of inactivity, regardless of the input SFH (see also Aparicio & Hidalgo 2007).

The reconstructed SFH is a linear combination of the different partial models. The best solution is obtained through $\chi^2$-minimization by a genetic code. A thorough description of the algorithm and method is presented in Aparicio & Hidalgo (2007).

In total, we used 24 models with different CMD parameterization and time resolution. The consistency of the method was checked by solving the SFH of synthetic CMDs and comparing the solutions with the input SFHs. Some of the regular grid models did not give a satisfactory solution, but the discrepancies could generally be traced to small differences in the location of evolutionary phases in the CMD, while the solutions obtained with the à la carte parameterization were found to be more stable and are the ones we present here.

5.2. The Results

Of the three metallicity ranges used for the stars younger than 300 Myr, the second one, i.e., $Z = 0.0025 - 0.0045$, gave the best solutions and is shown as a hatched region in Figure 10. This is consistent with the $H$ region metallicity of Talent (1980). Our best solutions for the SFHs at different galactocentric distances are presented in Figure 11. The radius ranges were chosen so that the CMDs contain the same number of stars. The error bars correspond to the dispersion of 20 solutions for which $\chi^2 = \chi^2_{\text{best}} + 1$ (see Aparicio & Hidalgo 2007).

The overall picture is a relatively constant SFR at all radii, decreasing with increasing radius, while the mean age of the stars increases with radius. The very central region, Figure 11a, shows a fairly constant SFR for the last 300 Myr of $(1.6 \pm 0.8) \times 10^{-3} M_\odot \text{yr}^{-1} \text{kpc}^{-2}$, in excellent agreement with the value found by Cole et al. (1999): $(1.6 \pm 10^{-3} M_\odot \text{yr}^{-1} \text{kpc}^{-2})$ using the $V$-band luminosity function of their WFPC2 central field and assuming a Salpeter IMF. The sharp drop in the last $\sim 25$ Myr is in agreement with the lack of very bright stars at the center of IC 1613 first noted by Hodge et al. (1991).

Between 2.5′ and $\sim 6′$ (Figs. 11b–11d) the SFR increased by a factor of $\sim 2-3$ in the last $100-150$ Myr. This corresponds to the peak in the radial distribution of young stars and $H$ regions found by Hodge et al. (1990).

The field studied by S03 is a small fraction of the region for which the SFH is represented in Figure 11e. The SFH calculated via the Cole method in S03, shown by the long-dashed lines, is very similar to the one we obtained here for the whole elliptical annulus. At larger radii, the number of stars formed more recently than about 300 Myr decreases to a negligible value when the radius reaches $\sim 10′$.

6. CONCLUSIONS

We have presented an analysis of the stellar content, morphology, and recent star formation history (SFH) of the Local Group dIrr galaxy IC 1613 based on wide-field $(V - I, I)$ photometry of resolved stars.

The distribution of resolved stars can be fitted with ellipses of position angle $80^\circ$ and eccentricity 0.15. The exponential fit of the resulting radial profile has a scale length of $2.9′ \pm 0.1′$. The relatively large number of RGB stars still present in the outer part of

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8 Three methods were used in S03 to calculate the SFH. The Dolphin method gives the SFR on a relative scale only. For the Tolstoy method, the vertical scale of their Fig. 7 gives a mean SFR $\sim 3 \times 10^{-3} M_\odot \text{yr}^{-1} \text{kpc}^{-2}$, a factor of $\sim 15-20$ higher than that of the Cole method and as high as the mean value of the SFR over the whole galaxy (Mateo 1998).
our observed field ($r > 16.5'$) indicates that the galaxy is actually more extended than previously estimated.

The well-populated young evolutionary phases of the CMD of the central region of IC 1613 indicate very recent star formation ($\leq 10$ Myr). The changing CMDs as a function of galactocentric distance show a strong gradient in the age of the younger stellar population, with the young stars lying preferentially in the central part, while the older stars are distributed more uniformly. No evidence of star formation more recent than about 300 Myr was detected beyond $r \geq 10'$. Analysis of the width of the RGB as a function of radius is consistent with no metallicity gradient. The combination of the crowding effect and the presence of younger stars in the RGB is responsible for the widening toward the center of the galaxy.

In the region where the recent SFH could be studied ($r \leq 10'$), the results indicate a decreasing SFR from the center outward as

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Fig. 11.— Best SFR obtained for each galactocentric distance. The radial ranges were chosen so that the corresponding CMDs contain the same number of stars. The error bars correspond to the dispersion of 20 solutions for which $\chi^2 = \chi^2_{\text{best}} + 1$, where $\chi^2$ is the residual of the best solution, indicated in each panel. The gap in the solutions between 300 and ~1500 Myr is due to the lack of information from either the young populations or the RGB in this age range. The solutions obtained by Cole et al. (1999) and S03 for their respective WFPC2 fields are plotted in (a) and (e). [See the electronic edition of the Journal for a color version of this figure.]
expected from the distribution of neutral gas in IC 1613, with the exception of the annular region where the star-forming regions are clustered ($r \sim 4'$), and therefore the SFR is a factor of $\sim 2-3$ higher.

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