A STARBURST IN THE CORE OF A GALAXY CLUSTER: THE DWARF IRREGULAR NGC 1427A IN FORNAX†

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ABSTRACT

Gas-rich galaxies in dense environments such as galaxy clusters and massive groups are affected by a number of possible types of interactions with the cluster environment, which make their evolution radically different than that of field galaxies. The dwarf irregular galaxy NGC 1427A, presently infalling toward the core of the Fornax galaxy cluster for the first time, offers a unique opportunity to study those processes at a level of detail not possible to achieve for galaxies at higher redshifts, when galaxy-scale interactions were more common. Using the spatial resolution of the Hubble Space Telescope/Advanced Camera for Surveys and auxiliary Very Large Telescope/FORS1 ground-based observations, we study the properties of the most recent episodes of star formation in this gas-rich galaxy, the only one of its type near the core of the Fornax cluster. We study the structural and photometric properties of young star cluster complexes in NGC 1427A, identifying 12 bright such complexes with exceptionally blue colors. The comparison of our broadband near-UV/optical photometry with simple stellar population models yields ages below \( \sim 4 \times 10^6 \) years and stellar masses from a few 1000 up to \( \sim 3 \times 10^4 \)\( M_\odot \), slightly dependent on the assumption of cluster metallicity and initial mass function. Their grouping is consistent with hierarchical and fractal star cluster formation. We use deep H\( \alpha \) imaging data to determine the current star formation rate in NGC 1427A and estimate the ratio, \( \Gamma \), of star formation occurring in these star cluster complexes to that in the entire galaxy. We find \( \Gamma \) to be among the largest such values available in the literature, consistent with starburst galaxies. Thus a large fraction of the current star formation in NGC 1427A is occurring in star clusters, with the peculiar spatial arrangement of such complexes strongly hinting at the possibility that the starburst is being triggered by the passage of the galaxy through the cluster environment.

Key words: galaxies: individual (NGC 1427A) – galaxies: star clusters: general

1. INTRODUCTION

Star clusters are among the most common stellar systems in the universe, present in almost all galaxies and systematically studied during the last decade thanks to the spatial resolution of the Hubble Space Telescope (HST; Lotz et al. 2004; Seth et al. 2004a; Haşegan et al. 2005; Jordán et al. 2005, 2006, 2007; Sharina et al. 2005; Mieske et al. 2006; Peng et al. 2006, 2008; Sivakoff et al. 2007; Georgiev et al. 2008, 2009a, 2009b, 2010; Masters et al. 2010; Villegas et al. 2010; Liu et al. 2011; Wang et al. 2013). Their formation occurs as part of a hierarchical process where large interstellar regions fragment into giant molecular clouds and cloud cores (e.g., Elmegreen et al. 2011). These fragments can be highly sub-structured, containing dense clumps and filaments showing a typical fractal dimension (e.g., Sánchez and Alfaro 2008; Scheepmaker et al. 2009) where cluster–cluster interactions occur and may lead to star cluster disruption or star cluster merging (Kroupa 1998; Fellhauer & Kroupa 2005). In large numbers star clusters have been detected in violent environments (e.g., Whitmore et al. 2005; Scheepmaker et al. 2009; Chandar et al. 2011; Mullan et al. 2011, etc.) and in small numbers in isolated environments like late-type galaxies (e.g., Eskridge et al. 2008) and dwarf galaxies (e.g., Billett et al. 2002) showing that the environment plays a significant role in the intensity of their formation (see Cook et al. 2012 for a typical formation rate in isolated environments for dwarf galaxies). Observational evidence has shown a clustering of young star clusters, originally described as knots, within disks in the Antennae (Whitmore et al. 1999), which are formally referred to as star cluster complexes (e.g., Adamo et al. 2012). The location of the star cluster complexes seems to be related to the spiral arms and the tidal streams between interacting galaxies, as has been observed, e.g., in M51, where a strong correlation with H\( \alpha \) and 20 cm radio-continuum emission, decreasing for older clusters, has also been reported (Scheepmaker et al. 2009). Similar results were obtained in the Milky Way: open clusters tend to cluster in groups when age, spatial distribution, and kinematics are taken into account simultaneously (de la Fuente Marcos & de la Fuente Marcos 2008) suggesting a common past in a larger hierarchical structure. The further evolution of star cluster complexes will make them disappear on certain timescales as is the case in the LMC (Gieles et al. 2008). Similar behavior was observed in several dwarf galaxies by Bastian et al. (2011). In general, the clumping of structures seems to be universal where the star cluster complexes themselves play a role in triggering star formation in isolated locations like the end of a tidal stream, as is seen in the Ruby Ring, where the central cluster triggered the formation of a ring of clusters (Adamo et al. 2012).

In this paper, we report the characterization of young star cluster complexes in NGC 1427A, a dwarf irregular (dIrr) galaxy infalling toward the center of the Fornax galaxy cluster at a mildly supersonic speed (Chanamé et al. 2000). One of the

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‡ Based on observations made with ESO Telescopes at the La Silla Paranal Observatory under programme ID 70.B-0695.
earliest ground-based photometric studies of this galaxy was performed by Cellone & Forte (1997), who already observed that the galaxy has features similar to interacting galaxies, such as a distorted ring-like structure mainly composed of young blue objects. They also noted that a bright star cluster complex in the northern part of the galaxy may be a distinct Fornax object in the vicinity of NGC 1427 and a consequence of a past interaction. Chanamé et al. (2000) showed, based on long-slit spectroscopic observations, that the northern object has the same velocity pattern as the rest of the galaxy, discarding the hypothesis of a separate entity.

Based on multi-passband ground-based imaging data, Hilker et al. (1997) pointed out that a majority of bright OB associations and H α regions in NGC 1427A were aligned along its southwest edge and reported the detection of about 34 cluster-type objects uniformly distributed over the entire galaxy. Finally, using near-UV to near-IR Very Large Telescope (VLT) imaging, Georgiev et al. (2006) reported the detection of 38 ± 8 globular cluster candidates with colors compatible with an old metal-poor population (∼10 Gyr and 0.4 Z⊙ < Z < Z⊙) and a specific frequency S⊙ = 1.6, placing NGC 1427A among the mean LMC-type galaxies in terms of their old star cluster content (Georgiev et al. 2010).

The above previous works all hypothesize that NGC 1427A is experiencing enhanced star formation and morphological distortions induced by its interaction with the galaxy cluster environment. Although the details of such interaction need to be elucidated, it most likely leads to the cessation of star formation within the galaxy before a few cluster crossing times. Such events seem to be more common at higher redshifts, as demonstrated by Mahajan et al. (2012) in their study of star cluster formation in the outskirts of galaxy clusters. Given the proximity of the Fornax cluster, NGC 1427A thus provides a unique opportunity to study the last star cluster formation episode(s) in a gas-rich galaxy before the residual star formation fuel is removed and star cluster formation is altogether quenched.

Our paper is structured as follows. In Section 2, we describe the data, the reduction procedure, and photometry and we test the limit of our sample through completeness tests. In Section 3, we describe our results, and in Section 4 we discuss our findings and draw conclusions.

2. OBSERVATIONS AND DATA REDUCTIONS

The present work is based on a combination of space- and ground-based observations. Space-based observations of NGC 1427A were acquired using the Advanced Camera for Surveys (ACS) on board HST (PI: Gregg, proposal ID: 9689) through the filters F475W, F660N, F625W, F775W, and F850LP. For each pointing, three exposures with a small offset were acquired. A journal of all the HST observations is given in Table 1. Ground-based observations were taken in service mode using the FORS1 instrument mounted at the VLT on Cerro Paranal in Chile (PI: Reisenegger, proposal ID: 70.B-0695). From this observing run we only use the U-band images. More details of the VLT U-band observations can be found in table N 1 of Georgiev et al. (2006).

2.1. ACS Data: Object Detections

The HST/ACS images were downloaded from the HST archive in the pre-processed _flt format. The images were charge-transfer-efficiency-corrected and each filter was combined into a single final image with the MultiDrizzle routine (Koekemoer et al. 2003) using a lanczos3 kernel function with the sky subtraction option disabled. The final color composite image is shown in Figure 1.

Figure 1. Color composite HST/ACS image of NGC 1427A. For the blue, we used the F475W channel, for the green, we used the F625W and F775W channels, and for the red we used the F850LP and the F660N channels. The image corresponds to a field of view of ~124″ × 145″. The arrow indicates the north and east.
experiment, we considered an area of three connected pixels with 4\sigma above the background noise level as our object detection setup in the original, i.e., non-convolved, F475W frame.

2.2. ACS Data: Photometry and Sizes

To account for the variable PSF across the ACS field, we used the effective point-spread function (ePSF) technique (Anderson & King 2006). Briefly, the ePSF technique uses fiducial PSFs distributed across each WFC chip (see Figure 2; Anderson & King 2006) which were added to empty flt images and later drizzled into a final single image repeating the exact procedure was done for the science images using the MULTIKING ACS/HST simulator (Paolillo et al. 2011). Therefore, our ePSFs are affected by the same distortion corrections as the science images (for a detailed discussion of the ACS/WFC resolution limitations see Puzia et al. 2014). The typical variation for a contiguous PSF FWHM was \( \lesssim 0.2 \) pixels and the largest difference was observed between each corner of the ACS at \(-0.6\) pixels. Because we are aiming to measure sizes and magnitudes, each ePSF was extracted from the drizzled image using the IRAF\(^3\) PSF task and later subsampled by a factor of 10 with the SEEPSF IRAF task. Object sizes and magnitudes were measured using ISHAPE (Larsen 1999). Briefly, ISHAPE utilizes an analytic function convolved with a PSF to model each source in an iterative routine in which the shape parameters, like the FWHM, are adjusted until the best fit is obtained. In our case, we used a King profile (King 1962) as the analytic function considering a concentration parameter \( c \), which is the ratio between the tidal and core radii, fixed to \( c = 30 \) which was later convolved with the nearest ePSF position. We chose this profile in order to make this work compatible with previous studies. From ISHAPE we obtained object sizes, fluxes, and signal-to-noise ratio (S/N) values. Since S/N correlates with the sky background, we have calculated the magnitude errors following the formula: \( 2.5 \times \log_{10}(1 + N/S) \). ACS zeropoints were adopted from the ACS webpages using the “WFC and HRC Zeropoints Calculator” considering\(^4\) the date of the image observation.

\(^3\) IRAF is distributed by the National Optical Astronomical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc, under cooperative agreement with the National Science Foundation.

\(^4\) http://www.stsci.edu/hst/acs/analysis/zeropoints/zpt.py

In Figure 2, we present the measured ACS magnitudes versus photometric errors of detected objects in four filters. The F475W photometry is the deepest compared with the other three ACS filters, justifying this filter as our detection frame. To base our analysis on the highest quality photometry, we consider only those objects with an error in magnitude less than 0.1 mag in all four ACS filters.

Because we use ISHAPE to measure star cluster sizes, we can study their size distributions in each filter. Figure 3 illustrates the distribution of FWHM values (in pixels/parsecs). Since ISHAPE takes the PSF directly into account, the histogram shows peaks at FWHM = 0 pc that correspond to unresolved, point-like objects. Due to the larger diffraction limits of redder filters, a larger number of point-like objects is expected in the redder filter compared with the bluest filter, fully consistent with our observations.

2.3. U-Based FORS1 Photometry

U-band FORS1 images were bias and flat-field corrected and later combined into a deep master U-band image. Since the object detection was performed in the ACS frame, we transformed the HST/ACS coordinates into the master U frame using the GEOMAP and GEOXYTRAN tasks in the IRAF environment. Since ISHAPE fits the central position of the objects, and due to the lower spatial resolution of FORS1, we used PSF photometry because we can deactivate the center fit option and thus directly use the positions from the ACS-FORS1 coordinate transformations. We then conduct a preliminary photometry run using the PHOT task in IRAF. Ten bright and isolated sources were used to construct an empirical PSF with a 20 pixel radius using the PSF task. This empirical PSF is later used to carry out PSF photometry with the ALLSTAR task. Finally, the photometric calibration of the U-band images was performed by means of a comparison between the calibrated photometry of the globular clusters from Georgiev et al. (2006) and the uncalibrated matched globular clusters detected by us in our master U-band frame. The reason to select them for comparison is because they are isolated objects. Therefore we minimize possible nearby object contaminations.
In Figure 4 we show the comparison between our photometry and that of Georgiev et al. (2006) as well as the U-band photometric error as a function of calibrated U-band magnitude using Georgiev et al. (2006) as a reference. Triangles and squares correspond to the same objects as the bottom panel. (Bottom panel) Photometry comparison between our work and that of Georgiev et al. (2006). Triangles and squares indicate matched globular clusters between the two studies. Because of the smaller photometric errors (i.e., $\sigma_{\text{fit}} < 0.1$ mag), we only used the brighter objects (red triangles) for the derivation of the photometry fit, and we show objects with larger photometric errors (blue squares) only for completeness purposes. The dashed line corresponds to the one-to-one relation and is plotted for guiding purposes.

In Figure 4 we show the comparison between our photometry and that of Georgiev et al. (2006) as well as the U-band photometric error as a function of magnitude. Matched globular clusters are shown with filled triangles and filled squares. However, since faint globular clusters show larger errors than the bright ones we decided to calibrate the photometry using only globular clusters with an error less than 0.1 mag. These objects are plotted as filled red triangles in Figure 4. A function of the form $y = ax + b$ was fitted to the bright globular clusters for the photometric calibration. We obtain the following values $a = 1.03 \pm 0.03$ and $b = 4.5 \pm 0.4$. For completeness purposes, we are plotting the faint globular clusters that were not used for the U-band calibration as blue squares. Despite the fact that we did not use the faint globular clusters for the photometric calibration, they follow a one-to-one line comparison and are in agreement with the photometric calibration.

### 2.4. Previous Ground-based Photometry Versus ACS Photometry

In order to double check our ACS photometry, we compared the globular clusters detected on the ACS images with their counterparts from Georgiev et al. (2006) measured by FORS1. Since the ACS passbands do not have the same wavelength coverage or the same shape as the FORS1 filters, the comparison is not exact and would require a color term. Figure 5 shows this comparison. A small shift is seen for all filters due to the difference in filter transmission. In conclusion, there are no significant deviations from a linear offset and we find that photometric errors are consistently smaller in the ACS photometry compared with the BVI FORS1 photometry. Therefore, we chose our ACS photometry results throughout the subsequent analysis.

### 2.5. Completeness Tests

Because we need to establish the photometric limits of reliability of measuring cluster magnitudes and sizes, we performed detailed completeness tests adding artificial clusters to the ACS images. However, due to the importance of the U band for the mass and age determination, we do not apply any S/N cut to objects detected in the FORS1 U band. A key point during this stage is to define the region where artificial objects are added to the images. Since we aim to study the cluster populations across the whole galaxy, we perform our tests in the area of the main galaxy body, thereby considering the worst-case scenario where objects are affected by the stellar crowding in the galaxy (see Figure 6).

Our recipe consists of the following steps. First, we generate point-like and extended sources using the ePSF library and the BAOLAB task MKCPSF (Larsen 1999). This task creates star cluster profiles by convolving the derived ePSF with a King (1962) model with a concentration parameter $r_{\text{maj}}/r_{\text{core}} = 30$ with the desired FWHM. Second, we create a zero background image with artificial extended sources on it using the convolved ePSF as input for the MKSYNTH task in BAOLAB. For each magnitude and FWHM value 100 artificial clusters are added in a $10 \times 10$ mosaic pattern with an initial distance of 200 pixels. A random shift from 0 up to 100 pixels is added in the $x$ and $y$ axis to each artificial object. Third, the zero background images are added to the science images. Finally, we run the photometry in the same way as was done for the science frames.

Completeness tests were performed for three FWHMs: 0.2, 1.0, and 2.5 pixels with the goal of studying a point-like object and two extended objects which, at the distance of NGC 1427A, correspond to 0.8, 4, and 10 pc, respectively. The results of our tests are shown in Figures 7 and 8.

The number of recovered objects as a function of magnitude decreases faster for the extended sources than for point-like sources, which are affected by crowding at fainter magnitudes, as expected. The 50% completeness limit is reached at F475W $\approx 25.6$, F625W $\approx 25.0$, F775W $\approx 24.5$, and F850LP $\approx 23.5$ mag for the extended objects (FWHM = 2.5 pixels).

Completeness tests also provide us with an estimate of the cluster size measurement error. Typically, bright and compact sources show an error in FWHM = 0.1 pixels for all passbands beyond the 50% completeness limit, while more extended ones (e.g., FWHM = 1.0) show recovered FWHMs, increasing toward fainter magnitudes. Because of the different filters resolutions and exposures, size differences between the input and the recovered sizes are expected and also increased due to crowding effects (see Figure 8). Finally we adopted the following limiting magnitudes, consistent with our 50% completeness and error selection criteria: F475W $\lesssim 25.6$, F625W $\lesssim 25.0$, F775W $\lesssim 24.3$, and F850LP $\lesssim 23.0$ mag.

### 2.6. Extinction Correction

We take into account the absorption caused by the Milky Way interstellar medium which affects the magnitudes of each object. We adopted the extinction maps of Schlafly & Finkbeiner (2011) which is a recalibration of the work by...
Values were taken from NED\(^5\) for each ACS filter considering \(R_v = 3.1\). For the U band we adopted the U CTIO bandpass.

### 3. RESULTS

#### 3.1. Color–Magnitude Diagrams (CMD)

In Figure 9 we show the Galactic foreground extinction-corrected CMD for all sources in NGC 1427A. Plotted objects have ACS photometry errors \(\leq 0.1\) mag in each filter. We do not impose a restriction in photometric errors for the U-band photometry due to its importance in mass–age determinations. In the left and center panel we find a distinctive group of luminous objects at \(F475W \leq 22.5\) mag and blue colors ((\(F475W–F775W\) \(\leq 0\)). The members of this group of star cluster candidates clearly have extended light profiles with FWHM \(\geq 2.0\) pixels and larger in at least one ACS filter. Visual inspection of the images shows that these objects correspond to extended star cluster complexes mostly located in the edges of NGC 1427A. Therefore, using the left and central panels, we adopt the following selection criteria of what will be considered blue star cluster complexes: objects with \((F475W–F775W) \leq 0\) and \((F475W–F850LP) \leq 0.2\) and \(F475W \leq 22.5\) mag. With these criteria, objects with errors larger than 0.1 mag will not appear in the CMDs. Because the observations acquired through the F475W filter are the deepest ones, the number of detected objects decreases in the reddest passbands, and therefore we have objects, like the star cluster complex seen as black open circles in the left panel of Figure 9, that are not detected in the F850LP ACS filter.

The right panel of Figure 9 shows the F475W versus U-F850LP CMD composed of the deepest photometric band and a color with the widest spectral energy distribution (SED).
coverage. In this panel, the star cluster complexes appear less clustered with a wider spread in color than in the previous panels. Part of this spread may be due to the poorer photometric quality of the FORS1 U-band images and, therefore, the star cluster complexes may appear blended or contaminated by nearby objects. We have visually checked our images for whether this is the case for all these sources and find that six sources are blended. However, due to their location in the galaxy, we cannot discard nearby object contamination, nor galaxy environment contamination. Another possibility (since object magnitudes are corrected by Galactic extinction) for the larger color spread is the internal NGC 1427A extinction, but our SED fitting analysis shows that the derived individual star cluster complex extinction values (see Section 3.3) cannot explain the spread seen in this panel. We are therefore left with the hypothesis that the color spread indeed implies a spread in the stellar population properties of these star cluster complexes.

3.2. Color–Color Diagram

Figure 10 shows the (U–F775W)₀ versus (F475W–F850LP)₀ color–color diagram which combines the most homogeneous SED coverage (i.e., objects detected in five passbands) of our photometric data into a diagnostic diagram from which we can infer rough stellar population ages and metallicities of the blue star cluster complexes. From this diagram, it is clear that the spread in colors as seen in the right panel of Figure 9 cannot be solely attributed to photometric errors and internal NGC 1427A extinction (or the line of sight) corrected by the Galactic extinction law, considering the direction of the extinction vector and the individual photometric errors. To make our analysis more comprehensive we show the position of a fiducial star cluster complex (filled red square) considering the individual magnitudes of the star cluster complexes, assuming that star cluster complexes are coeval.

We overplot SSP model predictions from GALEV (Kotulla et al. 2009) for stellar population metallicities $Z = 0.02, 0.008$, and $0.004$, and ages 3 Myr to 14 Gyr. In this diagram, our star cluster complexes lie on the left bottom side of the panel at (F475W–F850LP)₀ ≈ -0.3 mag indicating that they have relatively young ages of a few Myr. The red filled square (i.e., the fiducial star cluster complex) falls near the SSP models of solar metallicity and $Z = 0.008$ at the stellar population age of $\sim$4 Myr. Considering all objects in our cluster candidate sample and judging from the position of the bluest star cluster complexes in the color–color diagram, we conclude that we are observing the youngest star cluster complexes in NGC 1427A. Their magnitudes are listed in the last six columns of Table 1.

3.3. Determination of Cluster Age, Mass, and Intrinsic Extinction

In the following we are using the photometry from all five passbands to estimate the stellar population ages, masses, and extinction values of each blue star cluster complex via SED fitting. For this we compare the star cluster complex SEDs to GALEV SSP model predictions (Kotulla et al. 2009), considering the two cases of initial mass function (IMF): a Salpeter (1955) IMF with a stellar mass range from 0.1 up to 100 $M_\odot$, and a Kroupa (2001) IMF with a range in stellar mass from 0.1 up to 100 $M_\odot$ with a broken power-law of index 1.3 for $0.1 \leq M/\odot \leq 0.5$ and a power index of 2.3 for $M/\odot > 2.5$. The GALEV model calculations include full emission line treatment for young stellar populations, i.e., the models include bound–free emission from hydrogen and helium, free–free emission, and emission from the hydrogen two-photon process as well as other less prominent line emissions. Stellar population age, mass, and extinction toward the star cluster complexes is derived through a least-square fitting technique following Bik et al. (2003) and Anders et al. (2004). In Figure 11 we show the derived stellar population ages, masses, and total extinction values for the star cluster complexes. Each measurement is plotted against mass. Derived extinctions are typically $E(B-V) \leq 0.15$ mag for all models. However, most objects do not show any significant extinction values for all model parameters, nor differences between extinctions at low and high masses, which leads us to estimate the average extinction toward the complexes as $E(B-V) = 0.03$ mag. The ages of most star cluster complexes are consistent with objects younger than 3.9 Myr, while four star cluster complexes show ages of $\sim 3$ Myr older than the others for models with solar to slightly sub-solar metallicities. Therefore, the main conclusion is that we are detecting the youngest star cluster formation sites (i.e., star cluster complexes) in the galaxy. Derived masses of the star cluster complexes show a range between $\sim$2500 $M_\odot$ up to $3.1 \times 10^4 M_\odot$, depending somewhat on metallicity. This classic mass–metallicity degeneracy is seen as a trend of increasing

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Footnote 6: GALEV models consider the continuum, which in combination with the emission lines, can account for up to 50%–60% of the emitted flux for young stellar populations at low metallicities in broad-band passbands. Ionizing photons are taken from the tabulated values from Schaerer & de Koter (1997). For $N_{LyC}$ at the youngest ages, the fractions correspond to: $N_{LyC} = 51.343$ (solar), 51.765 ($Z = -0.3$), 51.919 ($Z = -0.7$), 51.850 ($Z = -1.7$), 51.109 ($Z = +0.3$) for Kroupa and $N_{LyC} = 51.143$ (solar), 51.561 ($Z = -0.3$), 51.715 ($Z = -0.7$), 51.860 ($Z = -1.7$), 30.907 ($Z = +0.3$) for Salpeter (Anders & Alvensleben 2003).
stellar mass for higher metallicities. In order to compare how the derived masses distribute for each metallicity and IMF, a Gaussian kernel density estimator with a bandwidth of the bin size was applied to the mass histogram of Figure 11. Identical metallicities and different IMFs show histograms where mass is distributed in a similar way and the shape of the mass histograms tend to be similar for all four metallicities (except for $\text{Fe/H} = -1.7$), being somewhat consistent among themselves as a group. Nevertheless, the method used in the determination of the mass distributions of these star cluster complexes should not cover the fact that all derived masses are in the regime of significant influence of stochastic variations in the constituent stellar populations (e.g., Cerviño and Luridiana 2004; Fouesneau and Lançon 2010; Fouesneau et al. 2012). Future adaptive-optics–supported observations at near-IR wavelengths will shed more light on this particular aspect and the accuracy of our star cluster complex mass determination.

Furthermore, due to the limitations of SSP models and the accuracy of our photometry, we cannot conclude whether the star cluster complex formation started at the same time across NGC 1427A or whether there is a spatial correlation of star cluster complex ages. It will be interesting to further investigate the remaining young star cluster population using spectroscopic observations (to be presented in a forthcoming paper), to derive more accurate ages, and to address the question of spatially correlated star formation.

3.4. Determination of Star Cluster Sizes

The sizes of all sample objects were measured in all ACS passbands using ISHAPE (Larsen 1999) as described in Section 2.2. In general, object sizes should be consistent among the different passbands and reflect the wavelength-dependent resolution limits of each passband. In Figure 12 we compare the measured FWHM values in two filters against the corresponding measurements in selected filters. The sizes of the star cluster complexes are indicated as red labels listed in Table 4. To guide the eye, we add to each panel a dashed line that represents the one-to-one relation. It is clearly seen that most objects lie on or close to the one-to-one relation, fully consistent with the measurement uncertainties. The measured dispersion above 1 pixel resolution in the left panel corresponds to 0.54 and in the right panel to 0.02, a difference due to the proximity in wavelength of the selected ACS filters. The resolution limit of our data can be seen as the relatively sudden increase in scatter below a few sub-pixels. However, few resolved objects above this limit do not follow the one-to-

![Figure 9](image-url) Galactic extinction-corrected color–magnitude diagrams for sources in NGC 1427A. In each panel, the FWHM values (in pixels) of the objects are parameterized by the symbol diameter which is proportional to the size measured in the F475W frame. Error bars located in the right-hand side of each panel represent the average photometric errors of the color axis at a given luminosity. In the case of the right panel, the average error bar is affected by the relatively large U-band errors and stochastic effects at bright magnitudes and does not show the typical trend as a function of magnitude. (Left and center panels) Black dots represent objects detected in three passbands (i.e., F475W, F625W, and F775W). Red open circles show objects detected in all four ACS passbands. Filled red circles correspond to the star cluster complexes. (Right panel) Only objects that were detected in all four ACS passbands and the FORS U-band images are plotted in blue open circles. In this panel the young star cluster complexes are represented by red filled circles.

![Figure 10](image-url) Color–color diagram for sources in NGC 1427A. Blue filled dots correspond to the star cluster complexes and the red filled square corresponds to the luminosity-weighted averaged color of the star cluster complexes. Overplotted lines are SSP models from GALEV (Kotulla et al. 2009) for metallicities $Z = 0.02$ (red), $Z = 0.008$ (blue), and $Z = 0.004$ (green). Red labels indicate the stellar population age for the solar metallicity track. The arrow shows the color displacement for an object with an intrinsic extinction of $A_V = 1$ mag. Photometric errors are only visible in (U–F475W)$_b$ color because the (F475W–F850W)$_b$ error bar is smaller than the symbol size.
one line and the size differences cannot be explained as a result of the changing resolution limits of various filters. For example, two star cluster complexes (ID:6002 and ID:3070) are extended in the F475W images, but show point-source-like sizes in the F850LP filter.

As expected, star cluster complexes are brighter in bluer passbands than in red passbands due to their young ages. However, at such young ages (i.e., a few Myrs) the star cluster complexes’ appearances and therefore sizes are dependent on the existence of blue and red supergiant stars. From our size comparison exercise, we conclude that few star cluster complexes in our sample show indications of simultaneously hosting blue and red supergiant stars in different locations within their star cluster complex extent, thereby producing the observed size differences. However, given the expected stochasticity of the constituent stellar populations for the observed total stellar mass, it is surprising that not more star cluster complexes show such size offsets. This, in turn, suggests that most star cluster complexes are already very well mixed in their stellar content at such young ages.

### 3.5. The Star Formation Rate

In the following we compare the star formation rate (SFR), derived from the total Hα flux, with the star cluster formation rate (SCFR) to derive a star cluster formation efficiency in NGC 1427A. The velocity of NGC 1427A shifts the Hα line emission into the F660N filter. We assume that the galaxy’s Hα flux resides inside an aperture with a radius of \( \sim 6 \) kpc. In order to measure the Hα-based SFR, we reduced the ACS F660N images following the same procedures as for the other broadband ACS images. Prior to the photometry the ACS F660N image was multiplied by the phot header value in order to obtain fluxes in units of erg cm\(^{-2}\) Å\(^{-1}\). We masked background objects and performed aperture photometry centered on the galaxy with a radius of \( \sim 5.97 \) kpc and an annulus of with a width of 300 pixels (\( \sim 1.19 \) kpc) in which the background/sky flux was measured. Since it is uncertain where the galaxy surface brightness is equivalent to the sky surface brightness, we provide a range of values derived from our data to quantify this measurement uncertainty. For this purpose, among all of the sky/background measured we adopted the highest and lowest values of \( m = 23.68 \) and \( m = 22.806 \) mag arcsec\(^{-2}\). Finally, we derived an averaged Hα flux of:

\[
F_{\text{H}\alpha} = 2.2623 \pm 1.237 \times 10^{-14} \text{ erg cm}^{-2} \text{ Å}^{-1}
\]

where the errors correspond to the Hα flux considering the maximum and minimum measured background/sky values. In view of the F660N passband including the [N\text{II}] 6548, 6583 Å
emission-line doublet, we estimate the [N\textsc{ii}] contamination by adopting the solar H/N ratio, which yields a line flux ratio of $\sim1.689 \times 10^{-4}$. The [N\textsc{ii}]-corrected $F_{\text{H} \alpha}$ value is then:

$$F_{\text{H} \alpha} = (2.2619 \pm 1.236) \times 10^{-14} \text{ erg cm}^{-2} \text{ Å}^{-1}. \quad (2)$$

The current SFR can then be derived using the relation from Hunter & Elmegreen (2004):

$$\dot{M} = 5.96 \times 10^{-42} L_{\text{H} \alpha} 10^{0.4 L_{\text{H} \alpha}} \left[ M_\odot \text{ yr}^{-1} \right] \quad (3)$$

where $L_{\text{H} \alpha}$ is the H\alpha flux in erg s$^{-1}$. We adopt the extinction coefficient value from Georgiev et al. (2006), i.e., $A_{\text{H} \alpha} = 0.811 A_V$, and a distance to NGC 1427A of 19 Mpc. Finally, we derive the current SFR as $\dot{M} = 0.05 \pm 0.03 \ M_\odot \text{ yr}^{-1}$. This value agrees with the one previously reported by Georgiev et al. (2006).

3.6. The Star Cluster Formation Rate

Since the masses of star cluster complexes are derived using models for a range of metallicities and different IMFs, we will calculate the SCFR accounting for this spectrum of possibilities.

Some caveats need to be accounted for. First, ages of the models are provided at intervals of 4 million years starting from 4 Myr; therefore ages reported to be within those intervals have been obtained by interpolation. Moreover, if a star cluster complex is assigned the youngest age from the model, it is likely that this object is younger than the age available from the model.

We compute the range of SCFR allowed by the uncertainties in our mass, age, and extinction fitted from the SSP models as described in Section 3.3 and listed in Table 5. The resulting SCFRs are listed in Table 3 for representative combinations of IMF and metallicity. Certainly, another source of uncertainty that affects any mass–age determinations is related to the ingredients of the models used for the analysis. For example, as found by Calzetti et al. (2010) and Andrews et al. (2013), a change in the upper mass limit of the IMF will change the mass estimation by a factor of 2.5. Nevertheless masses are expected to be within the order of magnitude as will be seen later in Table 2. However, we cannot ignore the fact that despite the consistency of our results for the two IMFs, we are in a lower mass regime, which has an impact on the derived masses due to the stochasticity that underestimates masses up to 0.5 dex (see Figure 3 from Fouesneau & Lançon 2010). A second possible caveat could be an age spread of 10 Myr, which is roughly the oldest age derived for the complexes, however, all star cluster complexes included in our relevant measurements show detectable flux in H\alpha and ages consistent with the time needed to form a complete population of clusters, which is similar to 10 Myr (Maschberger & Kroupa 2007). Moreover, since we are dealing with a unique episode of star formation, we have assumed that the IMF does not change during this episode. In Section 3.7 we will compute the fraction $\Gamma$ of star formation occurring in clusters to that of the entire galaxy, and it will be calculated over this 10 Myr period, thus unlikely to be highly sensitive to the SSP assumption, but not free from stochasticity. This, however, will not be the case for the IMF assumption (see Section 3.7).

Moreover, since we have a few cluster complexes with sizes larger than 50 pc, one might worry that this SCFR determination could be biased to higher values due to the contribution of individual older and smaller star clusters blending into our star cluster complexes (be it via projection effects or by being marginally resolved/unresolved) or even field contamination, thus biasing our measurements of $\Gamma$ in Section 3.7 toward higher values. Ideally one can derive the typical disruption time (e.g., Boutloukos & Lamers 2003; Lamers et al. 2005; Whitmore et al. 2007) and the corresponding “infant mortality” (Lada & Lada 2003) and then estimate the fraction of the measured mass that may be due to field stars. However, since our sample is magnitude-limited (dominated by the U-band) we cannot extrapolate any disruption scenario because we are analyzing complexes with the youngest ages provided by the models. Moreover, we also do not know the fraction of embedded versus open star clusters in NGC 1427A that can give insights into the mass fraction coming from cluster and from field stars.

In order to quantify the field and intrachannel contamination, we have simulated across our image 1296 artificial objects in a grid of 36 $\times$ 36 objects separated by 100 pixels each and centered in the galaxy and its surrounding following the same procedure as we did during the completeness tests. Our aim is that artificial objects will be affected by their local position on the image and thus affected by crowding and objects (stars, clusters, etc.) located under the artificial object, giving us an empirical approach to the contamination that affects our complexes. Because the derived complex ages correspond to the youngest age from the model, we have simulated, for each metallicity, artificial objects with magnitudes corresponding to the youngest age. In order to be consistent with the completeness tests we have considered objects with an FWHM = 2.5 pix. We would like to mention that the derived masses correspond to luminous masses and GALEV models are normalized to $10^5 M_\odot$. Therefore, we have magnitudes of the artificial objects that are escalated to the magnitudes corresponding to $10^{3.6} M_\odot$ which is the lowest mass derived for the complexes and therefore most likely to be affected by contamination.

Detected magnitudes from artificial objects were plugged into our fitting routine and recorded the output masses. In Figure 13 we show histograms of the recovered masses for each metallicity. Overall, input masses were recovered, but

| Table 2 |
| --- |
| Mass Variation from Artificial Tests |
| (Fe/H) | $M_{\text{low}}$ | $M_{\text{high}}$ | Low % | High % |
| Kroupa |
| -1.7 | 3.51 | 4.41 | 2.5 | 22.5 |
| -0.7 | 3.47 | 3.73 | 2.6 | 3.6 |
| -0.3 | 3.48 | 3.66 | 3.3 | 1.7 |
| 0 | 3.47 | 3.70 | 3.6 | 2.8 |
| 0.3 | 3.46 | 3.69 | 3.9 | 2.5 |
| Salpeter |
| -1.7 | 3.51 | 4.38 | 2.5 | 21.7 |
| -0.7 | 3.47 | 3.83 | 3.9 | 6.4 |
| -0.3 | 3.61 | 4.17 | 0.3 | 15.9 |
| 0 | 3.46 | 4.33 | 3.9 | 20.3 |
| 0.3 | 3.46 | 4.26 | 3.9 | 18.3 |

Note. $M_{\text{low}}$ and $M_{\text{high}}$ correspond to the lowest and highest recovered values in log $M_\odot$. Low % and High % correspond to the differences (in percentage) between the input mass and lowest/highest recovered values.
there is a spread due to the local variations (crowding, local contamination, etc.). The most extreme recovered values are shown in Table 2, allowing us to conclude that the larger source of error is due to the mass overestimation (up to 23%) rather than from mass underestimation (down to 4%).

In conclusion, we do not know the fraction of intracluster stars and field contamination, but this fraction should not bias our result to higher \( \Gamma \) values more than the uncertainties estimated to be of the order of 22.5%, as will be seen below. Finally, in the last column of Table 3, we present the final result, corrected for contamination (\( \Gamma_{\text{corr}} \)).

### 3.7. Fraction of Recent Star Formation Occurring in Clusters

The above range in SCFR then translates into a corresponding range for the fraction of star formation occurring in star clusters, introduced by Bastian (2008) as \( \Gamma = \text{SCFR}/\text{SFR} \). Our derived \( \Gamma \) values are listed in Table 3 for the representative combinations of IMF and metallicity, where we also report \( \Gamma_{\text{corr}} \), obtained by subtracting a 22.5% of the derived value in order to account for possible field contamination, as detailed in Section 3.6.

Reflecting the behavior of our mass and age SSP fits, we find \( \Gamma \) to be well constrained from below, irrespective of the assumptions of metallicity and IMF. This is illustrated in the left-hand panel of Figure 14, which shows \( \Gamma \) to be consistently around 30% or higher for any combination of metallicity and IMF slope, although with large error bars.

In order to place the \( \Gamma \) just derived for NGC 1427A within some context, in the right-hand panel of Figure 14, we plot our measurements together with similar ones determined for spiral and starburst galaxies as a function of the global star formation rate (surface) density \( \Sigma_{\text{SFR}} \) (Goddard et al. 2010; Adamo et al. 2011; Kruijssen 2012). These measurements seem to show that the cluster formation efficiency (SCFE) increases with \( \Sigma_{\text{SFR}} \), although with considerable scatter (Cook et al. 2012), and there have even been reports of no clear trend at all (Bastian 2008; Silva-Villa & Larsen 2011).

A critical aspect during the derivation of \( \Sigma_{\text{SFR}} \) \( (x\text{ axis of the right panel of Figure 14}) \) is the proper selection of the area where it is defined. The choice of this area varies from author to author. For example, Adamo et al. (2011, p. 1908) state that “To estimate a meaningful \( \Sigma_{\text{SFR}} \) it is necessary to determine the size of the region which is producing stars” and thus they assumed \( R_{80\%} \) as the normalizing area. Cook et al. (2012, p. 7) point out that “The SFR surface density \( \Sigma_{\text{SFR}} \) is calculated by normalizing the SFR over the area of the galaxy being studied: typically the whole galaxy in our sample.” Since we are resolving the stellar population in NGC 1427A, we have decided to compute its \( \Sigma_{\text{SFR}} \) for two limiting cases given by the choice of the area involved in this quantity. For the first one, we take into account the \( R_{80\%} \) of NGC 1427A as the area where the star formation occurs, and thus we assume that the galaxy light is concentrated in this radius which corresponds to \( R = 1.8 \text{kpc} \) as would be the case for an unresolved blue galaxy. However, complexes are located across the “ring shape” of NGC 1427A and therefore the star formation is more localized in this area. Hence, for the other extreme case we assume that all the star formation is occurring in the detected complexes, and therefore we have used the area covered by these complexes only (i.e., the effective radius) as the normalizing area.

In the right-hand panel of Figure 14, NGC 1427A is represented by filled black symbols with error bars (i.e., weighted means with the errors of those means). The corresponding values were obtained by simply taking the error-weighted average of the \( \Gamma \) values for the 10 different \([\text{Fe/H}]/\text{IMF}\) combinations shown in the left-hand panel.\(^7\) While such a procedure is strictly valid only for the statistical representation of a set of independent measurements (i.e., unlike the case of our \( \Gamma \) determinations, each of which represents the result of applying a model with different assumptions to the same set of observations), having the range of variation in \( \Gamma \) available on the left-hand panel allows readers to make their own judgement about what value (or range) of \( \Gamma \) best represents the situation. The gray arrow in between the NGC 1427A data points represents the vertical shift applied as

\[^{7}\text{x axis error bars represent the uncertainties coming from the propagation of the SCFR and the SFR while for the x axis the points are left without errors since this corresponds to the two extreme cases.}\]
Figure 14. Left: the variation in $\Gamma$ (corrected for contamination) at every combination of metallicity-IMF, including its corresponding uncertainty. For clarity, the corresponding points at each metallicity have been shifted by $\pm 0.5$ dex around the real value ([Fe/H] = 0.3, 0.0, −0.3, −0.7 and −1.7 dex). Blue filled squares correspond to Kroupa IMFs and red filled squares correspond to Salpeter IMF calculations. Horizontal dotted lines represent weighted means for $\Gamma$ considering a Kroupa IMF (blue), Salpeter IMF (red), and both IMF types (black). Right: $\Gamma$ vs. star formation rate (SFR) surface density. Open blue diamonds correspond to the samples from Goddard et al. (2010), green triangles to Adamo et al. (2011), and red squares to Silva-Villa & Larsen (2011). The cyan crosses correspond to the sample of Cook et al. (2012). The dotted curve represents the modeled relation for the “typical” parameters set from Table 1 of Kruijssen (2012) and the dashed line represents the fit from Goddard et al. (2010). The filled black symbols correspond to the weighted mean (corrected for contamination) for NGC 1427A considering both IMFs with different normalization areas: $R_{\text{bol}}$ represented as a black triangle and, the star complex effective radius, represented as a black circle (for further details see text). The vertical error bars correspond to the error of the mean for $\Gamma$. The gray arrow in between the filled black dots represents the 22.5% displacement of correction due to contamination of $\Gamma$ (see Section 3.6).

a correction for possible field contamination (Section 3.6). The filled triangle corresponds to the first limiting case where $\Sigma_{\text{SFR}}$ is calculated using the $R_{\text{bol}}$, and the filled circle corresponds to the second limiting case where $\Sigma_{\text{SFR}}$ is calculated considering the star complex effective radius.

When we consider both limiting cases we see that NGC 1427A shows a large fraction of recent star formation occurring in a star cluster and, depending on the aperture definition discussed above, it can be interpreted as a galaxy being significantly more efficient in forming star clusters (black filled triangle in Figure 14), or in the alternative (black filled circle) case when only the small aperture is considered, it is comparable with star and star cluster formation rates found in blue compact starburst galaxies (Adamo et al. 2011). We tend to prefer the latter interpretation because we are resolving the area where star formation actually occurs. However, we point out that the larger aperture choice would be more consistent for comparisons with star formation in distant, marginally resolved, or unresolved high-z galaxies. In that case, our result hints at the tentative possibility that intermediate to high SFRs might be occurring in large fractions in star clusters in such systems. We think that regardless of the interpretation, the main result of the plots in Figure 14 is the large $\Gamma$ derived here, along with (1) the peculiar location of this gas-rich galaxy so close in projection to the center of the Fornax cluster and (2) the unusual morphology of these star-forming regions being restricted to an edge of the galaxy, both very suggestive of a starburst triggered by the interaction between NGC 1427A and the Fornax galaxy cluster environment.

4. DISCUSSION AND CONCLUSIONS

We have analyzed deep multicolor HST observations of NGC 1427A, a Magellanic-like, gas-rich dIrr galaxy near the core of the Fornax cluster and characterized the properties of its most recent episode of star formation. At the distance of the Fornax cluster, this means studying the population of resolved young star clusters and star cluster complexes, as well as the unresolved, diffuse young field stellar population traced by H$\alpha$ emission.

A set of 12 sources stands out clearly due to extreme blue colors, and we find that these sources correspond to relatively extended structures similar to star cluster complexes already seen in other galaxies. The signature of hierarchical formation processes is evident in several of the star cluster complexes where smaller star clusters are members of larger star-forming complexes. Almost all star cluster complexes seem to be associated with other young entities, as illustrated in the postage-stamp images in Figure 15 which show numerous nearby blue (i.e., young) objects. This is consistent with the fractal clustering of stars, star clusters, and star cluster complexes seen in other dwarf galaxies (e.g., LMC: Bastian et al. 2009; NGC 6822: Gouliermis et al. 2010) and numerical simulations (e.g., Allison et al. 2010 and references therein).

The sizes of the star cluster complexes are somewhat filter-dependent, probably because these structures are composed of a mix of several ingredients: a mixture of gas, OB associations, and star cluster stellar populations, the latter of which are likely to be significantly affected by stochastic fluctuations in their stellar content. Fouesneau & Lançon (2010) studied these stochastic fluctuations on the recovered cluster mass, and these show a scatter around the one-to-one line that is slightly smaller than $\approx 0.5$ dex at the mass range of the clusters we study ($\approx 10^{3.5} M_\odot$; see their Figure 3). The fact, however, that this scatter is symmetric throughout the range of cluster masses relevant for our study means that these particular stochasticity effects will more or less cancel out when the cluster masses are added up for the computation of $\Gamma$ (i.e., about half of our clusters will have their mass overestimated and half will have it underestimated). Further modeling of star cluster complexes and its dependence on the sampling of their mass function are beyond the limits of the data since we are affected by sampling effects and therefore we have no access to global information.
of the complexes but only particular information that is dominated by a few individual objects (Villaverde et al. 2009).

Seven of the detected star cluster complexes are observed relatively close in projection and two of them (ID: 3070 and ID: 3090, see Figure 15) are the pair that appear closest to one another with a projected distance of ~28 pc that can be considered the NGC 1427A counterparts of star cluster pairs (possibly bound binary systems) seen in the LMC (e.g., Dieball & Grebel 2000; Dieball et al. 2002). However, due to their location and the nature of the host galaxy, it is likely that they will be disrupted in the near future either by cluster-cluster interactions, ISM interactions (Gieles et al. 2006), and/or interactions with the Fornax galaxy cluster.

Based on the Hα flux measured over the entire galaxy, and accounting for the possibility of undetected Hα flux, we compute the global SFR in NGC 1427A and find it similar to the mean of star-forming galaxies of similar type, such as those studied by Seth et al. (2004b). Then, using our determinations of the masses and ages of the star cluster complexes, we compute the SCFR, i.e., the amount of recent star formation occurring within star clusters. We find the ratio Γ of these two SFRs to be large and consistent with observations of starburst galaxies (e.g., Adamo et al. 2011). Therefore, the star cluster complexes in NGC 1427A indicate that there is an ongoing star formation episode during which a large fraction of the star formation over the last few million years occurred in star clusters.

It would be extremely interesting to determine whether or not the recent star cluster formation in NGC 1427A has been triggered by interaction with the cluster environment. This

| ID  | $R_{\text{eff}}$ (F475W) | $R_{\text{eff}}$ (F625W) | $R_{\text{eff}}$ (F775W) | $R_{\text{eff}}$ (F850LP) | FORS U | ACS F475W | ACS F625W | ACS F775W | ACS F850LP |
|-----|-----------------|-----------------|-----------------|-----------------|-------|-------------|-------------|-------------|-------------|
| 891 | 63.04           | 72.60           | 526.8           | 346.3           | 23.412 ± 0.459 | 22.177 ± 0.006 | 22.131 ± 0.008 | 22.746 ± 0.023 | 22.447 ± 0.030 |
| 1163| 14.38           | 78.06           | 6.46            | 11.74           | 20.726 ± 0.319 | 21.962 ± 0.006 | 20.829 ± 0.003 | 22.562 ± 0.020 | 22.254 ± 0.026 |
| 1383| 54.11           | 87.28           | 11.91           | 73.25           | 20.578 ± 0.188 | 20.952 ± 0.003 | 20.541 ± 0.003 | 22.124 ± 0.016 | 20.908 ± 0.009 |
| 1776| 24.59           | 28.94           | 17.61           | 28.11           | 20.862 ± 0.125 | 20.693 ± 0.002 | 20.653 ± 0.003 | 21.614 ± 0.009 | 20.968 ± 0.009 |
| 2892| 18.37           | 24.36           | 20.89           | 15.96           | 20.703 ± 0.054 | 21.875 ± 0.005 | 21.484 ± 0.005 | 22.206 ± 0.015 | 22.206 ± 0.026 |
| 3000| 14.03           | 19.54           | 6.63            | 8.39            | 21.182 ± 0.031 | 22.419 ± 0.007 | 21.938 ± 0.008 | 22.910 ± 0.027 | 22.720 ± 0.040 |
| 3070| 6.57            | 5.63            | 0.70            | 0.12            | 20.568 ± 0.031 | 22.001 ± 0.006 | 22.186 ± 0.010 | 22.556 ± 0.020 | 22.532 ± 0.033 |
| 3090| 17.14           | 14.67           | 16.73           | 16.61           | 21.488 ± 0.048 | 22.118 ± 0.007 | 22.026 ± 0.008 | 22.545 ± 0.019 | 22.246 ± 0.025 |
| 3364| 12.09           | 11.68           | 11.39           | 8.80            | 20.966 ± 0.042 | 22.235 ± 0.007 | 22.305 ± 0.012 | 22.516 ± 0.021 | 22.679 ± 0.041 |
| 3464| 17.78           | 17.61           | 11.09           | 8.39            | 20.287 ± 0.039 | 21.481 ± 0.004 | 21.404 ± 0.006 | 21.727 ± 0.010 | 21.709 ± 0.017 |
| 5872| 3.82            | 3.82            | 2.88            | 4.05            | 21.555 ± 0.034 | 22.275 ± 0.006 | 22.245 ± 0.009 | 23.069 ± 0.026 | 22.681 ± 0.033 |
| 6002| 147.0           | 14.61           | 4.40            | 0.12            | 22.517 ± 0.269 | 21.467 ± 0.003 | 22.890 ± 0.017 | 22.577 ± 0.020 | 22.283 ± 0.027 |

Note. Star cluster sizes are given in units of parsecs. Luminosities are given in units of magnitudes. For a King30 profile $R_{\text{eff}} = 1.48 \times \text{FWHM}$. 

Figure 15. HST/ACS color composite mosaic of the star cluster complexes. The color code used for blue corresponds to the F475W, for green corresponds to the F775W, and for red corresponds to the F850LP passband. Each stamp represents a field of view of 402 × 402 pc². Each star cluster complex is indicated by two white lines. From left to right in the top row: ID:891, ID:1163, ID: 5872, and ID:6003. Bottom row left stamp: ID3364. Each one of the two bottom central panels shows two star cluster complexes: ID:2892 and ID:3000 (left and right) and ID:1383 and ID:1776. The panel at the bottom right shows three star cluster complexes (from left to right): ID:3070, ID:3090, and ID:3464.
### Table 5
Star Cluster Complexes Parameters II: Extinctions, Ages, and Masses for Kroupa and Salpeter IMFs

| ID  | \(E(B - V)_{max}\) | Age\(_{max}\) | Mass\(_{max}\) | \(E(B - V)_{max}\) | Age\(_{max}\) | Mass\(_{max}\) | \(E(B - V)_{max}\) | Age\(_{max}\) | Mass\(_{max}\) | \(E(B - V)_{max}\) | Age\(_{max}\) | Mass\(_{max}\) | \(E(B - V)_{max}\) | Age\(_{max}\) | Mass\(_{max}\) |
|-----|-----------------|-------------|--------------|----------------|-------------|--------------|----------------|-------------|--------------|----------------|-------------|--------------|----------------|-------------|--------------|
| 891 | 0.0009          | 6.6001      | 3.3102       | 0.1009         | 6.6002      | 3.6006       | 0.0000         | 6.6003      | 3.6305       | 0.0000         | 6.6004      | 3.6704       | 0.0000         | 6.6005      | 3.7005       |
| 1163| 0.0009          | 6.9001      | 4.3507       | 0.0002         | 6.6001      | 3.8707       | 0.0000         | 6.6004      | 3.8400       | 0.0000         | 6.6005      | 3.8705       | 0.0000         | 6.6006      | 3.9005       |
| 1383| 0.0002          | 6.6001      | 3.8202       | 0.0806         | 6.6000      | 4.0400       | 0.0002         | 6.6001      | 4.1400       | 0.0002         | 6.6002      | 4.2402       | 0.0002         | 6.6003      | 4.3702       |
| 1776| 0.0000          | 6.6001      | 3.8600       | 0.1004         | 6.6102      | 4.1505       | 0.0002         | 6.6202      | 4.1800       | 0.0002         | 6.6302      | 4.2202       | 0.0002         | 6.6402      | 4.3202       |
| 2892| 0.0000          | 6.9001      | 4.3505       | 0.0004         | 6.6101      | 3.6801       | 0.0002         | 6.6202      | 3.8103       | 0.0002         | 6.6302      | 3.8505       | 0.0002         | 6.6402      | 3.9005       |
| 3000| 0.0002          | 6.9001      | 4.6005       | 0.0000         | 6.6001      | 3.4601       | 0.0000         | 6.6001      | 3.6000       | 0.0000         | 6.6001      | 3.6300       | 0.0000         | 6.6001      | 3.7000       |
| 3070| 0.0000          | 6.9002      | 4.1600       | 0.0000         | 6.6001      | 3.5600       | 0.0000         | 6.6001      | 3.7000       | 0.0000         | 6.6001      | 3.7300       | 0.0000         | 6.6001      | 3.8000       |
| 3090| 0.0000          | 6.6001      | 3.7000       | 0.1404         | 6.6003      | 3.7105       | 0.0006         | 6.6004      | 3.7706       | 0.0006         | 6.6007      | 3.7305       | 0.1404         | 6.6009      | 3.9005       |
| 3364| 0.0000          | 7.0801      | 4.3500       | 0.0000         | 6.6501      | 3.5504       | 0.0000         | 6.6603      | 3.6300       | 0.0000         | 6.6601      | 3.6600       | 0.0000         | 6.6601      | 3.7000       |
| 3464| 0.0000          | 7.0802      | 4.6304       | 0.0000         | 6.6602      | 3.8802       | 0.0000         | 6.6603      | 3.9802       | 0.0000         | 6.6604      | 3.9902       | 0.0000         | 6.6605      | 4.1002       |
| 3872| 0.0000          | 6.9001      | 4.1600       | 0.0000         | 6.6002      | 3.4100       | 0.0000         | 6.6003      | 3.5500       | 0.0000         | 6.6004      | 3.5800       | 0.0000         | 6.6005      | 3.7000       |
| 6002| 0.0000          | 7.0802      | 4.3704       | 0.0000         | 6.6502      | 3.5702       | 0.0000         | 6.6602      | 3.6801       | 0.0000         | 6.6601      | 3.7000       | 0.0000         | 6.6602      | 3.8000       |

**Note.** The total extinction values are given in units of magnitudes, while star cluster ages and masses are provided in units of the decadal logarithm of years and solar masses, respectively.

**Kroupa IMF**

**Salpeter IMF**
could be achieved by a measurement of $\Gamma$, the SFR relative to the field SFR, for star formation episodes that occurred before the galaxy started its plunge into the dense core of the Fornax cluster, i.e., for stellar populations with ages comparable to and larger than a crossing time through the Fornax center. This is, however, a complex task for which not only would the star and cluster formation histories have to be derived, but also the star cluster destruction processes (e.g., infant mortality) accounted for.

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APPENDIX

APPENDIX MATERIAL

Here we present Tables 4 and 5 where our measurements are accounted for.

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