

Resolved Stars in M83 Based on HST/WFC3 Early Release Science Observations

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Abstract. We present a multi-wavelength photometric study of individual stars in M83 based on observations taken as part of the WFC3 Early Release Science (ERS) program. The central region of M83 has been imaged in seven broad-band filters to obtain multi-wavelength coverage from the near-UV to the near-IR. We use four filters—F336W, F438W, F555W, and F814W—to measure the *UBVI* photometric colors and intrinsic luminosity for $\sim 10,000$ stars. These measurements are used to determine the recent (< 1 Gyr) star formation history of M83. We selected 50 regions in the spiral arm and the inter-arm area of M83 and categorize them based on their $H\alpha$ morphology. To determine ages of stars in each region, the color-magnitude diagrams (CMDs) and the color-color diagrams were used with the Padova isochrones at a metallicity of $Z=0.03$ ($1.5 Z_{\odot}$). We correct the foreground and internal extinction of individual stars using the reddening-free Q parameter and improve our age estimates of stars from the isochrone fitting on the CMDs. Comparisons of stellar ages and cluster ages based on both their $H\alpha$ morphology and their spectral energy distribution (SED) fitting were made and show fairly good correlations. We also find that the regions with ages determined younger than 10 Myr are located preferentially along the active star-forming regions on the spiral arm.

1. Introduction

Detailed studies of resolved stellar populations allow us to study the stellar evolution and star formation history of galaxies in detail. With the construction of large ground-based telescopes with sensitive images and the launch of the HST, the observational astronomers in the field of stellar population studies have been able to expand their observable universe from the nearby clusters in the Milky Way and Magellanic Clouds to the clusters in extragalactic space and have also started to compare stellar evolutionary theories to the observations with unprecedented depth and accuracy. Since the H-R diagram was introduced to the astronomical community in 1910, it has been one of the most frequently used plots. Understanding the correlation between the color, magnitude, and the evolutionary phase of stars is one of the most fundamental subjects in stellar astrophysics.

M83, also known as the “Southern Pinwheel” galaxy, is an interesting laboratory for studying stellar populations. It is a massive barred spiral galaxy located at a distance of 4.5 Mpc (Thim et al. 2003) with a starbursting nucleus. Along the spiral arms, $H\alpha$

regions at different scales display recently formed massive stars, while you can find red supergiants throughout the galaxy. By plotting stellar evolution models and comparing them to observed color-magnitude diagrams (CMDs), we are able to determine the ages of stars in galaxies. However, in some of the regions with recent starbursting activity, the young stellar populations are partially obscured by dust. Therefore, spatial variations in the amount of dust can cause over-estimates of stellar ages from the isochrone fitting in the CMDs if we only apply a single value of internal extinction to correct for the individual stars in an entire region. By using the additional color information, we can constrain the variations of dust extinction in the galaxy and make corrections for individual stars.

The recently installed Wide Field Camera 3 (WFC3) on the Hubble Space Telescope allows us to study individual stars in M83 in unprecedented detail, primarily because of the much higher values of discovery efficiency (quantum efficiency \times field of view) in WFC3. The HST/WFC3 observations of M83 were performed in August in 2009 as part of the WFC Science Oversight Committee (SOC) Early Release Science (ERS) program (ID:11360, PI: Robert O’Connell). The central region (3.2×3.2 kpc²) of M83 was observed during the first observing run. The second field, the adjacent NNW field, will be included in a future publication.

2. HST/WFC3 Observations and Data Analysis

The data were obtained in seven broad- and seven narrow-band filters in the UVIS and IR channel. In this study, we used four broad-band images obtained in F336W (“U”), F438W (“B”), F555W (“V”), and F814W (“I”). Details about the data are described in Dopita et al. (2010) and Chandar et al. (2010). The raw data were processed using the MultiDrizzle task (Koekemoer et al. 2002) with the effective pixel size of 0.04” which corresponds to ~ 0.8 pc per pixel at a distance of 4.5 Mpc (Thim et al. 2003). A color composite of F336W+F555W+F814W (broad bands) and F502N+F657N (narrow bands) images is shown in Figure 1. It covers the nuclear region, part of the spiral arm, and the inter-arm region. PSF photometric analysis of the WFC3 data was performed using DoPhot (Schechter et al. 1993). We selected 50 regions indicated in boxes with region numbers to study the spatial distribution of young stellar populations in M83 and compare their ages to the cluster ages in the same region.

Extinction Correction : The foreground Galactic extinctions for M83 are 0.361 (A_{F336W}), 0.290 (A_{F438W}), 0.229 (A_{F555W}), and 0.133 (A_{F814W}) mag calculated for the WFC3 UVIS filters using the extinction curve of Schlegel et al. (1998). As we mentioned earlier in this paper, since M83 has an intricate structure of dust lanes associated with active star forming regions in the spiral arms and thin layers of dust in the inter-arm area, we cannot use a single value of internal extinction and apply it to correct the extinction for all stars detected in a region of our images. Therefore, we used the traditional method of estimating intrinsic colors of individual stars from the reddening free parameter Q :

$$Q_{UBVI} = (U - B) - \frac{E(U - B)}{E(V - I)} \times (V - I). \quad (1)$$

First, we use the slope of the reddening curve for the Milky Way, 0.58 for $E(U - B)/E(V - I)$, derived from the measured $UBVI$ photometry of early type stars (Massey

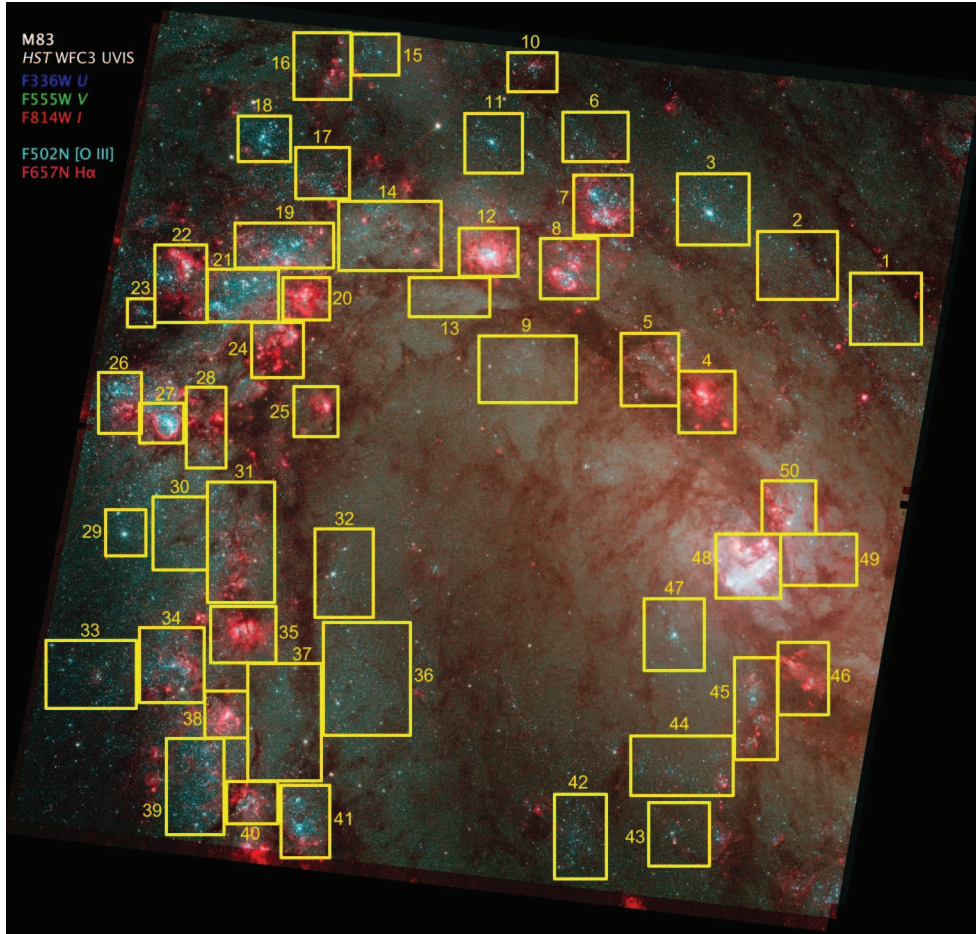


Figure 1. Color composite of F336W+F555W+F814W (broad bands) and F502N+F657N (narrow bands) images with 50 selected regions overlaid.

et al. 1995). We also determine the empirical slope of the reddening vector in the (U-B) vs. (V-I) diagram for certain regions where the vector is well defined in our own data (e.g., color-color diagram of region 4 in Figure 2) and apply it to calculate Q values of the Padova stellar isochrones and the observational data. We then match the observed data point to its corresponding intrinsic value from the Padova model using the Q value. We do this for both the classic slope of 0.58 appropriate for the Milky Way and our own empirically determined values based on our M83 data. In general the resulting corrections are only slightly different. Corrected data points are relatively well matched with the stellar isochrones.

Stellar Ages from Isochrone Fitting : Fifty regions were selected in the spiral arm and the inter-arm area to determine the recent star formation history of M83 (see Figure 1). Each region was classified based on their $H\alpha$ morphology (see Whitmore et al. (2011) for detail). The age of the dominant stellar population in each region was determined by isochrone-fitting. Age-estimates in 50 regions range from 1 Myr to 30 Myr. Only sources detected with a signal-to-noise ratio larger than ~ 3 were used to plot the CMDs in Figures 2 and 3. In regions classified as (4a), young and blue luminous stars

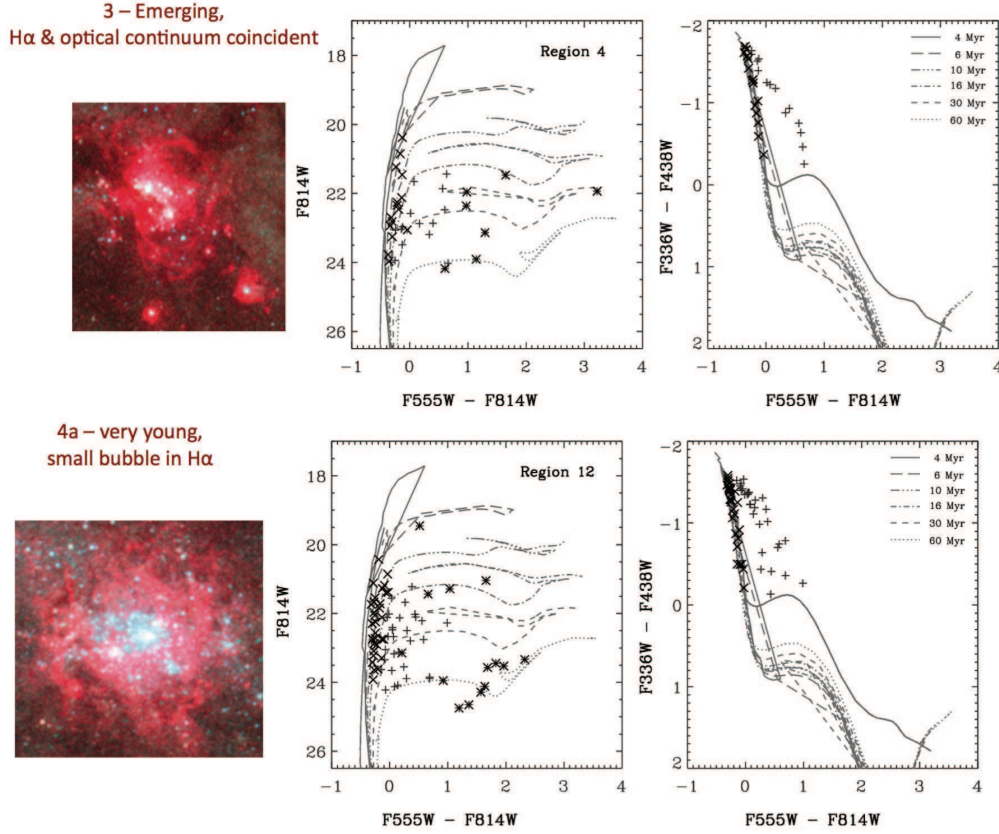


Figure 2. CMDs and color-color diagrams. The region classification for each category of H α morphology is described above the image cut-outs. Data points before and after extinction correction are plotted as crosses “+” and Xs “x”. Padova isochrones for $Z=0.03$ ($1.5 Z_{\odot}$) and ages of 4, 6, 10, 16, 30, & 60 Myr are overlaid in the CMDs and color-color diagrams.

are moderately reddened ($A_V = \sim 0.5$ - 1.0) by dust. The 39 regions that show evidence of recent star formation range in age from 1 Myr to 10 Myr. They are located in the “Pearls” in the spiral arm (Toomre 1977).

3. Summary and Future Work

The CMDs and color-color diagrams of resolved stars from the multi-band HST/WFC3 observations of M83 indicate the presence of multiple stellar population features, including the recently formed MS, possible He-burning blue-loop stars, RGB, and AGB stars. The regions with ages determined younger than 10 Myr are located along the active star-forming region on the spiral arm. Ages of young stellar populations in each selected region are in fairly good agreement with the cluster age-datings from SED fitting and from H α morphology. Near-IR data (F110W and F160W) and the adjacent

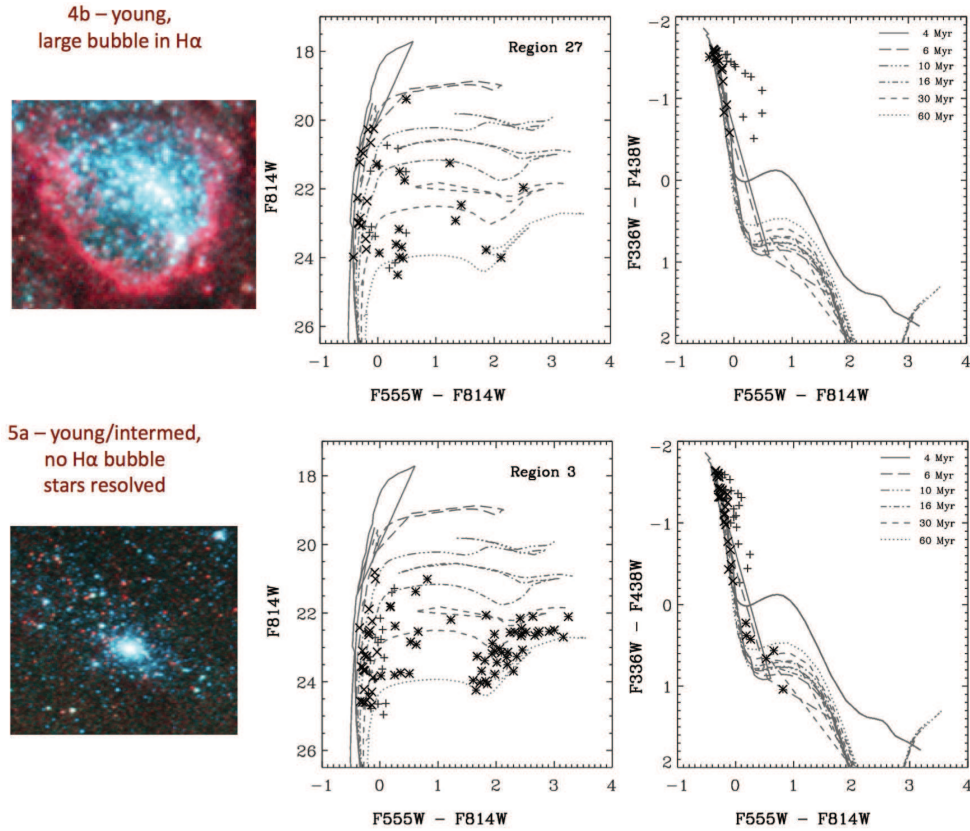


Figure 3. CMDs and color-color diagrams. The region classification for each category of H α morphology is described above the image cut-outs. Data points before and after extinction correction are plotted as crosses “+” and Xs “x”. Padova isochrones for $Z=0.03$ ($1.5 Z_{\odot}$) and ages of 4, 6, 10, 16, 30, & 60 Myr are overlaid in the CMDs and color-color diagrams.

NNW field will be added to the analysis in the future.

Acknowledgments. We are grateful to the Director of the Space Telescope Science Institute for awarding Director’s Discretionary time for this program. Support for program #11360 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

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