Stellar Populations as Building Blocks of Galaxies
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The Recent Star Formation Histories of Nearby Galaxies

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Abstract. Recent ($\leqslant$ 0.5 Gyr) star formation histories have a large impact on the observable properties of galaxies. Using HST/ACS observations, we have used the blue helium burning (BHeB) stars to construct spatially resolved star formation histories of M81 group dwarf galaxies with a time resolution of roughly 30 Myr over the last 500 Myr. We have designed a sample of ten galaxies spanning ranges of 6 magnitudes in luminosity, 1000 in current star formation rate, and 0.5 dex in metallicity. The ACS observations allow us to directly observe the strength and spatial relationships of all of the recent star formation in these galaxies. These observations are complemented by high-quality ancillary data (e.g., Spitzer, UV/optical/H-alpha/NIR, VLA HI). Our resolved star formation maps will be compared with star formation rates inferred from H-alpha, UV, and IR observations - allowing an independent calibration of these techniques. Given the ranges in metallicity, these observations will provide calibrations of stellar evolution tracks for young, low metallicity stars. These observations will also enable us to construct prescriptions of how star formation and feedback depend on metallicity, size, gas content, and current star formation rates in galaxies. Finally, I note that the new observations becoming available as a part of the ANGST (ACS Nearby Galaxies Survey Treasury Program) will allow a large number of dwarf galaxies to be analyzed in this way.

Keywords. galaxies: stellar content, galaxies: evolution, galaxies: dwarf

1. Using HST to Map Recent Star Formation in Dwarf Galaxies: Testing Our Knowledge of the Star Formation Process

The first HST color magnitude diagram of the stars in the nearby dwarf irregular galaxy Sextans A Dohm-Palmer, *et al.* (1997) revealed for the first time a clear separation between the brightest main sequence stars and the blue helium burning (BHeB) stars - intermediate and high mass stars that have evolved beyond the main sequence, ignited helium burning in their cores, and have migrated back to the blue side of the color magnitude diagram. The separation of the main sequence stars and the BHeB was made possible by the high angular resolution of the HST (reducing photometric errors due to blends) and the low metallicity of Sextans A which leads to low differential reddening.

These BHeB stars afford a special opportunity to study the recent star formation histories of nearby galaxies. Because the position of a BHeB star in the CMD represents a unique age (as opposed to, for example, the main sequence or the red giant branch where a single position can correspond to a large range of ages), one can convert the BHeB luminosity function directly into a star formation history (SFH) (with the assumption of a universal initial mass function). The main limiting factor of this technique is that the position of the BHeB stars blends into the red clump at an age between 0.5 and 1 Gyr. Because one knows the positions of the BHeB stars in the galaxy, then one can produce a spatially resolved SFH (i.e., it is possible to produce "movies" of the recent star formation).

Translating the BHeB star luminosity function into a SFH depends on the accuracy of the stellar evolution models. We have different lines of evidence that the stellar evolution models provide an excellent guide to this stage of evolution. The first line came from the early HST observations themselves. Although the position of the blueward extension of the stellar evolution tracks is a strong function of both metallicity and stellar mass, excellent agreement between observations and models was found by choosing the stellar evolution tracks for the metallicity determined from the HII region abundances for Sextans A. In a more recent study, Dohm-Palmer, *et al.* (2002) used deeper HST photometry of Sextans A to compare recent star formation histories recovered from both the main-sequence stars and the BHeB stars for the last 300 Myr. The excellent agreement between these independent star formation rate (SFR) calculations is a resounding confirmation for the legitimacy of using the BHeB stars to calculate the recent SFR. Dolphin, *et al.* (2003) derived the recent SFH of Sextans A from the entire CMD and found good agreement with that derived from the BHeB stars alone.

Additionally, Dohm-Palmer & Skillman (2002) used all of the HST observations of Sextans A in order to compare the ratio of blue to red supergiants. This ratio provides an observational constraint on the relative lifetimes of these two phases that is a sensitive test for convection, mass-loss, and rotation parameters. Analyzing the ratio as a function of age, or, equivalently, mass eliminates the confusion of unknown star formation histories (as in previous studies of this ratio). The functional form of the observed ratio matches the model extremely well with an offset of roughly a factor of 2 (and the offset is seen as support of the latest models which include rotation). Given these tests of reliability of the stellar models, we feel confident that using the BHeB stars to construct recent star formation histories is well justified.

Dohm-Palmer, *et al.* (1998) employed HST photometry of four nearby dwarf irregular galaxies (Sextans A, Leo A, Pegasus, and GR 8) and derived recent star formation histories for these galaxies. At the time, the surprising result was the lack of bursts or episodes of enhanced star formation. With time bins of only 25 Myr for the last 500 Myr, with the possible exception of enhanced star formation rates in the last 50 Myr for Sextans A and Leo A, all four galaxies are best described as nearly constant star formation rates. In retrospect, perhaps the lack of truly zero star formation rates is as surprising as the lack of periods of enhanced star formation.

2. HST ACS Observations of M81 Dwarfs

Studies of the impact of star formation ('feedback') on the properties of a galaxy are of fundamental importance to understanding galaxy evolution. One crucial aspect in these studies is a precise census of the recent star formation in a galaxy. We have recently obtained HST ACS observations of a sample of M81 dwarfs with the aim of deriving spatially resolved star formation histories with a time resolution of roughly 30 Myr over the last 500 Myr. Our sample comprises 10 galaxies in the M81 group which is host to a wide diversity of dwarf star forming galaxies. They span ranges of 6 magnitudes

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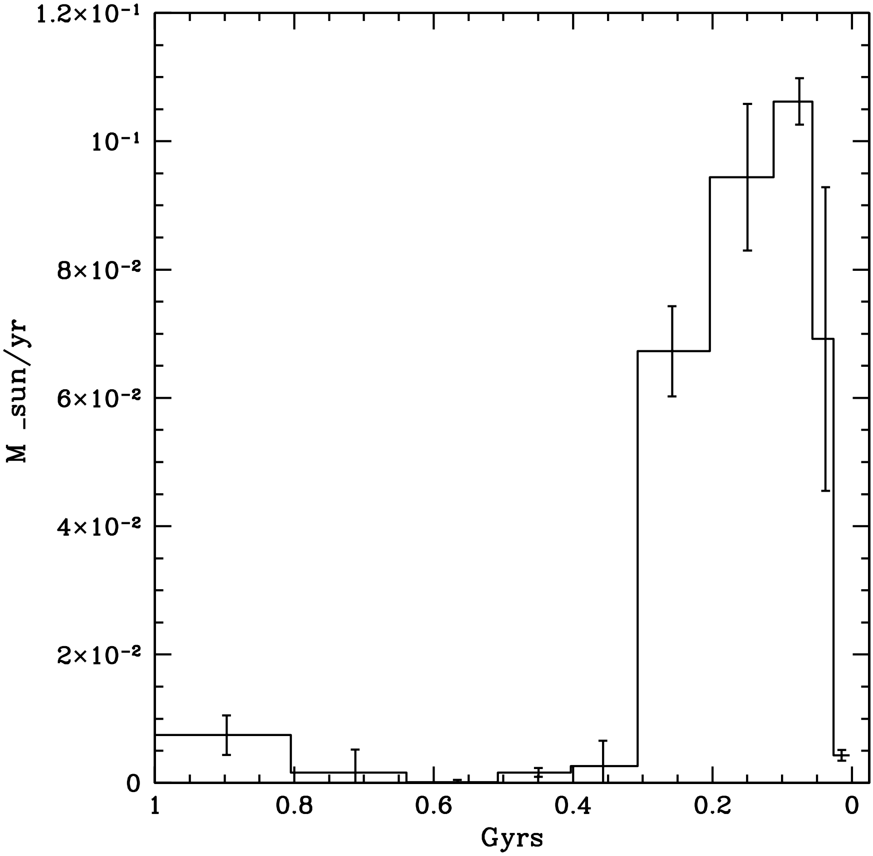

Figure 1. The recent SFH for the M81 dwarf galaxy DDO 165. Here we see an intense burst of star formation that ended just recently. The burst lasted for roughly 200 Myr.

in luminosity, 1000 in current star formation rate, and 0.5 dex in metallicity. The ACS observations will allow us to directly observe the strength and spatial relationships of all of the star formation in these galaxies in the last 500 Myr. We can then quantify the star formation and measure (1) the fraction of star formation that is triggered by feedback, (2) the fraction of star formation that occurs in clusters and associations, and (3) to what degree star formation is governed by the feedback from star formation. The ACS observations will be complemented with high–quality ancillary data collected by our team for all galaxies (e.g., Spitzer, UV/optical/NIR, VLA HI). This will enable us to construct prescriptions of how star formation and feedback depend on metallicity, size, gas content, and current star formation rates in galaxies.

Figure 1 shows the recent SFH of DDO 165, revealing a rather dramatic burst of star formation in the recent past. At the conference I showed a movie of this, demonstrating that the burst was spread throughout the galaxy, and likely triggered by an interaction.

Acknowledgements

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References

Binney, J., & Tremaine, S. 1987, Galactic Dynamics, Princeton University Press, p. 442

Dohm-Palmer, R.C., & Skillman, E.D. 2002 *AJ* 123, 1433

Dohm-Palmer, R.C., Skillman, E.D., Saha, A., Tolstoy, E., Mateo, M., Gallagher, J.S. Hoessel, J., Chiosi, C., & Dufour, R.J. 1997, *AJ* 114, 2514

Dohm-Palmer, R.C., Skillman, E.D., Gallagher, J.S., Tolstoy, E., Mateo, M., Dufour, R.J., Saha, A., Hoessel, J., & Chiosi, C. 1998, *AJ* 116, 1227

Dohm-Palmer, R.C., Skillman, E.D., Mateo, M., Saha, A., Dolphin, A., Tolstoy, E., Gallagher, J.S. & Cole, A.A. 2002, *AJ* 123, 813

Dolphin, A. E., *et al.* 2003, *AJ*, 126, 187

Kroupa, P. 1995, *MNRAS*, 277, 1522

Terlevich, E. 1987, *MNRAS*, 224, 193

Williams, B. F. 2003, *AJ*, 126, 1312

Discussion

P. Kroupa: Could you perhaps spend a few words on how the rotation of the galaxies is dealt with? Also, stars disperse from the formation sites (inter-cluster disruption); this would affect the resulting/inferred morphology of the star-formation regions in the galaxies.

E. Skillman: Because the dwarf galaxies that we observe are dominated by solid-body rotation, the spatial relationships between features are preserved over time. This also means that there is no differential shear to stretch out and destroy features. For your second question, I refer you to the appendix of Dohm-Palmer *et al.* (1997), which deals directly with a time scale for dissipation of star forming regions. The theoretical results (Binney & Tremaine 1987, Terlevich 1987, Kroupa 1995) favor time scales for the dissolution of star clusters of order several hundred million years. Empirically, we see these stars clusters at old ages ($\sim$ 500 Myr), so it appears the the stars do not move very far from each other in this amount of time.

A. Ferguson: How exactly will you use the information you derive about the evolution of recent SF to test threshold models, since you only know the gas surface density at the present time?

E. Skillman: As you know, measuring star formation thresholds is a pretty tricky business due to interpreting a single snapshot in time. I think that using the SFH allows a more holistic approach (e.g., for propagating star formation you can see the direction that the star formation came from and the time it took to get there) so you might do a better job of estimating the surface density of the gas in the region of the most recent star formation.

R. Cid Fernandes: What is the hope of applying this or some other age-dating technique to a spiral galaxy and produce a movie of spiral arms rotating? Has this been done/tried?

E. Skillman: The real challenge is separating the the BHeB sequence from the main sequence in the presence of the differential extinction that comes with the higher metallicity environments in spiral galaxies. Within the ANGST project, we hope to be able to do exactly this in the outer parts of spiral galaxies. I do know of a similar study of M31 by Williams (2003), but this was using ground-based data, and the quality of those data are not up the standards necessary to do the type of work that I have described.

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