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Recent star formation in high-redshift early-type galaxies: insights from the rest-frame UV

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Abstract. We combine deep $UBVRIzJK$ photometry from the MUSYC survey with redshifts from the COMBO-17 survey to study the *rest-frame* ultraviolet (UV) properties of 674 high-redshift ($0.5 < z < 1$) early-type galaxies, drawn from the Extended Chandra Deep Field South (E-CDFS). Galaxy morphologies are determined through visual inspection of Hubble Space Telescope (HST) images taken from the GEMS survey. We harness the sensitivity of the UV to young (< 1 Gyrs old) stars to quantify the *recent* star formation history of the early-type population. We find compelling evidence that early-types of all luminosities form stars over the lifetime of the Universe, although the bulk of their star formation is already complete at high redshift. Luminous ($-23 < M(V) < -20.5$) early-types form 10-15 percent of their mass after $z = 1$, while their less luminous ($M(V) > -20.5$) counterparts form 30-60 percent of their mass in the same redshift range.

Keywords. Galaxies: elliptical and lenticular, cD, galaxies: evolution, galaxies: formation, galaxies: stellar contents, ultraviolet: galaxies

1. Introduction

The vast majority of work on early-type galaxies in the past has focussed on optical spectro-photometric data. A significant drawback of optical photometry is its lack of sensitivity to moderate amounts of recent star formation (RSF). While red optical colours imply a high-redshift formation epoch for the *bulk* of the stellar population in early-type galaxies, the optical spectrum remains largely unaffected by the minority of stellar mass that forms in these systems at low and intermediate redshift. As a result it is virtually impossible to quantify early-type star formation histories (SFHs) over the last 8 billion years ($0 < z < 1$).

RSF can be efficiently traced using the rest-frame ultraviolet (UV) spectrum, which is sensitive to young, massive main sequence stars with ages less than $\sim$1 Gyr. Using a large sample of early-type galaxies detected by the GALEX UV space telescope, Kaviraj et al. (2006) have recently shown that, contrary to the expectations of traditional 'monolithic collapse' models (e.g. Bower et al. 1992), local early-types show widespread recent star formation (RSF) - at least 30 percent show blue UV-optical colours indicative of unambiguous RSF in these systems. The work presented here extends these results to high redshift by exploiting deep optical photometry to trace the rest-frame UV properties of early-type galaxies in the redshift range $0.5 < z < 1$.

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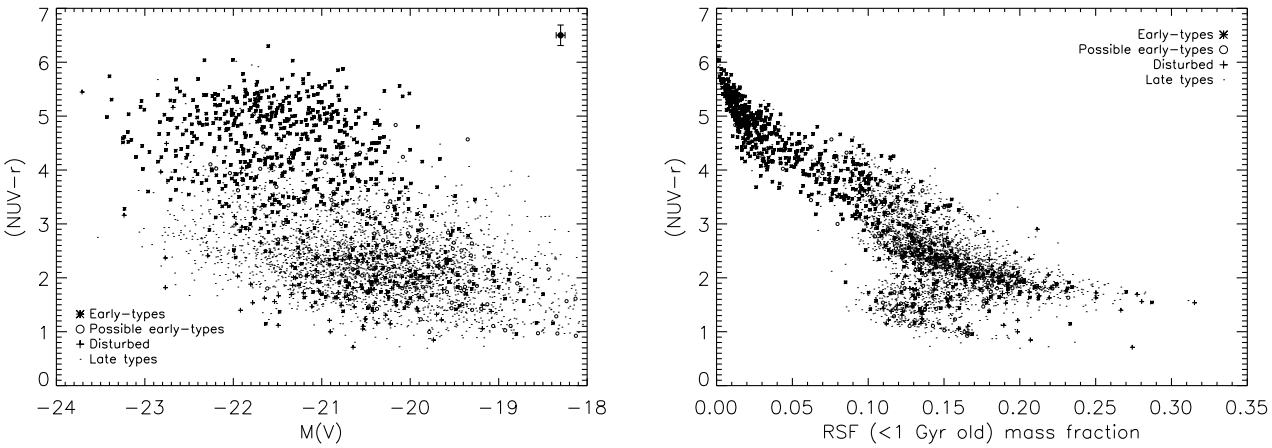

Figure 1. LEFT-HAND PANEL: Rest-frame $(NUV - r)$ colour-magniutude relation of the E-CDFS galaxy population. RIGHT-HAND PANEL: Rest-frame $(NUV - r)$ colour plotted against the RSF in the E-CDFS galaxy population. The NUV ($\sim 2300\AA$) and r band filters are taken from the GALEX and SDSS filtersets respectively.

2. Estimation of recent star formation

The RSF in individual galaxies is calculated by comparing their multi-wavelength photometry with synthetic galaxy populations, generated in the framework of the standard model. Synthetic populations are generated using the semi-analytical model of Khochfar and Burkert (2003). A library of synthetic photometry is constructed by combining each of ∼15,000 model galaxies with a single metallicity in the range $0.1Z_{\odot}$ to $2.5Z_{\odot}$, dust extinction parametrised by a value of $E(B-V)$ in the range 0 to 0.5 and convolving them with the stellar models of Yi (2003). We construct an 'average SFH' for each galaxy, by combining the SFHs of all models in the library weighted by their individual likelihoods. The RSF, defined as the *mass fraction of stars formed within the last Gyr*, is calculated from this average SFH. Figure 1 shows the derived rest-frame $(NUV - r)$ colour-magnitude relation and the values of RSF in the E-CDFS galaxy population.

3. Summary and discussion

The early-type population as a whole exhibits a typical RSF between 5 and 13 percent in the redshift range $0.5 < z < 1$, while the early-types on the broad 'red sequence', $(NUV - r > 4)$, typically show RSF values less than 5 percent. The reddest early-types (which are also the most luminous) are virtually quiescent with RSF values of ~ 1 percent. Since the timescale of this study is ~ 2.5 Gyrs, a simple extrapolation (from RSF values in Figure 1) indicates that luminous $(-23 < M(V) < -20.5)$ early-type galaxies typically form up to 10-15 percent of their mass after $z = 1$ (with a tail to higher values), while less luminous early-types $(M(V) > -20.5)$ form 30-60 percent of their mass after $z = 1$.

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