Recent Star Formation in Intermediate Redshift Early-Type Galaxies: the Correlation of Age and Mass Fraction with Galaxy Morphology

M. J. Rutkowski[1,2], H. Jeong[3], S.Yi[2], S. Kaviraj[4,5,6], S. Cohen[1], R.E. Ryan[7], R. Windhorst[1], R.W. O'Connell[8], and the WFC3 SOC

[1] School of Earth & Space Exploration, Arizona State University, [2]Department of Astronomy, Yonsei University, [3]Korean Astronomical and Space Science's Institute, [4]Blackett Laboratory, Imperial College London, [5]Mullard Space Science Laboratory, [6]Department of Physics, University of Oxford, [7]Space Telescope Science Institute, [8]Department of Astronomy, University of Virginia

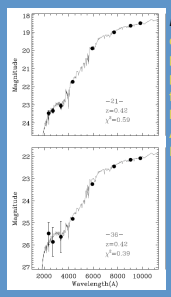
e-mail: mjrutkow@asu.edu

Abstract

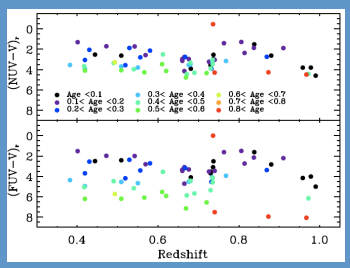
We present an analysis of the stellar populations extant in a population of 68 visually-selected early-type galaxies (ETGs) observed, in a portion of the Great Observatories Origins Deep Survey-South (GOODS-S) field, as a part of the Early Release Science (ERS) program with the Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3). We combined measured ERS and GOODS photometry to obtain panchromatic (UV-optical-near IR) spectral energy distributions (SEDs), in 10 bands, of each ETG [1]. Here, we extend the initial analysis by fitting two-component stellar population models to measure the characteristics of the young and old stellar populations. This analysis confirms a large minority (~45%) of these ETGs are best-fit with models that include a small (i.e., stellar mass fraction of ~1-4%) young (t<300Myr) stellar population (YSP). In addition, we measure the Sérsic index of each ETG, and qualitatively describe the distribution of sources near to each. Though we are limited by small number statistics, we conclude that the measured morphological parameters are not correlated with the properties (e.g., stellar mass fraction and age) of the best-fit YSP determined from the SED analysis. The lack of a morphological distinction between the environments, and two-dimensional spatial light profiles, of ETGs and their stellar characteristics can be interpreted in the context of the paradigm of ETG formation and evolution that has been developed from cosmological simulations. Specifically, our analysis suggests that the minor residual star formation (RSF) observed for these ETGs is primarily motivated by the "secular" accretion of cold gas reservoirs from the local inter-galactic medium (IGM).

Characteristics of Young Stellar Populations

We measured absolute photometry and the stellar mass of the (majority) old stellar population extant in each ETG by fitting Bruzual and Charlot (2003) spectral templates defined by a single "tau-burst" star formation history to the broadband optical-near IR SED [1]. The rest-frame UV-optical colors of the ETGs suggest [see, e.g. 4,5] the presence of a minority (by mass) YSP for many of the ETGs; this population is poorly-characterized by single component models. We confirmed the existence of a YSP by an SED analysis using a library of spectral templates defined with two ("young" [t<1Gyr] and "old" [t>~4Gyr]) stellar components (see [6,7,8]) and measure the age and mass fraction of the YSP from the best fit template.



Left: Representative results of the fitting of two-component spectral templates to the panchromatic SEDs of the ETGs. Measured photometric uncertainties are overplotted; the fitting takes into account galactic completeness limits that address large uncertainties (Δm≈0.1 AB mag) for the F225W, F275W, F336W, F435W bands (see [1]).



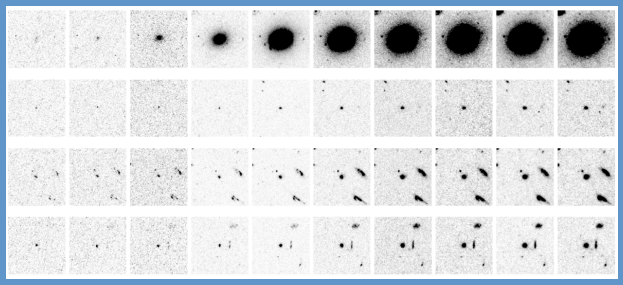
Right: Rest-frame UV-optical colors derived from the best-fit two-component stellar templates confirm the presence of YSPs (t<300Myr) in a large (>45%) minority of the ETGs.

Catalog Definition and Properties

We selected ETGs by visual inspection and require catalog ETGs to have:

- •been imaged in all UV and IR bands, to uniform depth in the ERS field
- •a spectroscopically-confirmed redshift in the range 0.35<z<1.0
- •an ETG morphology characterized by a centrally peaked light profile, which declines sharply with radius, a high degree of azimuthal symmetry, and a lack of visible internal structure.

We identified 68 ETGs in the ERS field matching these criteria. We excluded 34 ETGs identified in [1] at z>1.0. Excluding these galaxies better ensures that all ETGs are on similar angular size scales (which improves the qualitative inspection) and that redshifts were measured using similar spectral features (i.e., the Ca H&K absorption complex).

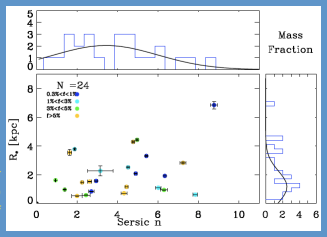


F225W F275W F336W F435W F606W F775W F850LP F098M F125W F160W

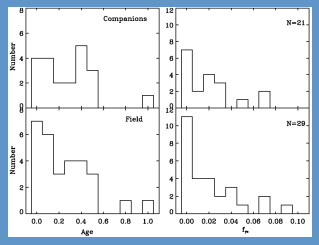
Above: Representative ten-band postage stamps of the first four catalog members [1]. Each is 11.2" on a side, and the catalog ETG is centered in each stamp. Note, photometry was measured in the original image mosaics (see [2,3]). In this study, we use stamps that were each defined to be 10 kpc on a side; this ensures that an uniform volume was considered in the environmental analysis of each ETG.

Morphology and ETG environment

Cosmological simulations of ETG minor mergers can be directly tested observationally using these high spatial resolution ERS data. To better constrain the mechanismlet(s) promoting the observed RSF, we measured quantitative and qualitative morphological parameters associated with the ETG and its local environment. First, we characterized the two-dimensional stellar light distribution in the F336W, F850LP, & F160W bands by measuring the best-fit Sérsic function using GALFIT [9].



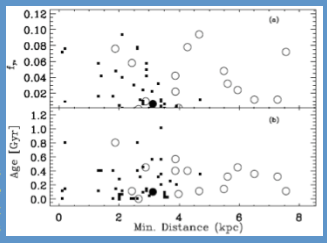
Right: Parameters derived from the Sérsic profile fitting are plotted using a color scheme indicating the YSP mass fraction derived from the two component SED analysis. These data are well-distributed in this parameter space; this measure of morphology does not distinguish "quiescent" ETGs from those with RSF (cf. [10]).



In [1], we provided a classification note for each ETG, noting probable S0 galaxies, dual-core spheroids and ETGs exhibiting dust features. Furthermore, we classified each galaxy according to four qualitative environmental parameters designed to describe and distinguish between the type and number of "companion" objects identified in proximity (in projection) to the ETG.

Left: The characteristics of YSPs extant in ETGs, differentiated by the summary of the qualitative descriptions of ETG neighborhood. The environment of each ETG does not appear to be correlated with the measured characteristics of the YSP, though this conclusion may be frustrated by small number statistics.

Lastly, we used *Source Extractor* [11], coupled with HYPERZ [12], to detect objects located in close proximity (z_{ETG}±0.1, assuming a Λ–CDM cosmology defined in [13]). We measure the number of galaxies, the distance in projection to the closest galaxy, and noted those ETGs that were identified as contiguous with the nearest object detected by *Source Extractor*.



Right: In panels (a) and (b), the distance to the ETGs's nearest neighbor is denoted by an open circle (○) and is plotted with respect to the ETG's YSP mass fraction and age, respectively. Additionally, filled circles indicate ETGs that are contiguous with detected objects. Nearest neighbors, defined by proximity *on the plane of the sky*, are overplotted as filled squares (■). The characteristics of the YSPs are not correlated with the ETG environment. The distribution of nearest neighbors agrees generally with recent cosmological simulations of ETG-minor mergers [14].

References

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Conclusion

We extend the study of residual star formation in ETGs at low redshift [15] to higher redshift and significantly higher spatial resolution. Our analysis confirms the presence of low-level (1-5% by mass) young (t < 300Myr) stellar populations in these ETGs. The relative fraction of ETGs that are host to YSPs is in broad agreement with the observations of declining star formation in galaxies from a cosmic peak at z≈2-3 [16]. We measure qualitative and quantitative morphological parameters for the ETGs and local environment but do not identify any strong correlation between these parameters and the stellar characteristics determined by the SED analysis. Our analysis does not suggest that YSPs are exclusively associated with ETGs whose morphology may imply recent minor merger activity, though we do identify ETGs with environmental morphology that is consistent with such activity [10,14]. Furthermore, the UV-optical colors and morphology of these ETGs do not imply that the observed RSF results from recent (t< ~4 Gyr) major merger activity. Thus, the dominant process governing formation of YSPs in intermediate-z ETGs is likely to be "secular", i.e., the accretion of cold gas onto the ETG from the IGM (cf. [17]). Detection and mapping of cold gas (CO, HI) with current or future (ALMA; SKA) observatories will provide a critical test of this hypothesis.