Identifying Early Type galaxies at high-z: dependence on selection criteria

S. Tamburri, P. Saracco, M. Longhetti, A. Gargiulo, I. Lonoce
(INAF- Osservatorio Astronomico di Brera, Milano)

The main properties of Early Type Galaxies (ETGs; e.g. red colours, quiescence, old stellar population) are often used to select ETGs samples at different redshift.
In particular, at z=0 ETGs are selected by means of their morphology, while at z>1 they are usually identified with the passive galaxies (low specific star formation rate).

However, samples selected on the basis of different ETGs properties, such as the lack of star formation, may not overlap. The aim of this work is to verify how samples of ETGs selected on the basis of their passivity differ from samples of morphologically selected ETGs and how these differences reflect on the statistical properties of the galaxies.

Furthermore, since the selection criterion of passive galaxies depends on the model assumptions adopted to perform their SED fitting, we tackle the important issue of the role of the stellar Initial Mass Function in such selection.
Finally, we report a preliminary result of an ongoing analysis of the evolution of the ETGs properties, exploiting the morphologically selected sample (i.e., not model dependent).

• DATA & SAMPLES SELECTION

The used samples of galaxies are selected from the GOODS-MUSIC (Santini+09), a multicolor catalog of 15 photometric bands ($0.3 \lesssim \lambda \lesssim 24$ μm, including 4 HST-ACS filters) with spectroscopic/photometric redshift measures, in the GOODS-South field (Giavalisco+04).

A complete flux limited ($K_s \leq 22$) sample of 1302 galaxies, extracted from the MUSIC catalog, is the starting point of this work.

The flux selection has been performed to assure a good spectroscopic redshift coverage (beyond 76%) and to perform an accurate morphological classification on galaxies up to z~2.

1) Selection by specific Star Formation Rate: $sSFR=(SFR/M_*) \leq 10^{-11}$ yr^{-1}

Methods:

We define "***passive galaxies***" those objects with **$sSFR=(SFR/M_*) \leq 10^{-11}$ yr^{-1}.**

Star Formation Rate (SFR) and stellar mass (M_*) are derived by SED fitting technique (FIG.1, *Hyperzmass, Bolzonella+00*), using population synthesis models of Bruzual & Charlot 03 (BC03) and assuming a Salpeter IMF.

281 passive galaxies selected

of which

182 ETGs + 99 Late Type Galaxies (LTGs)

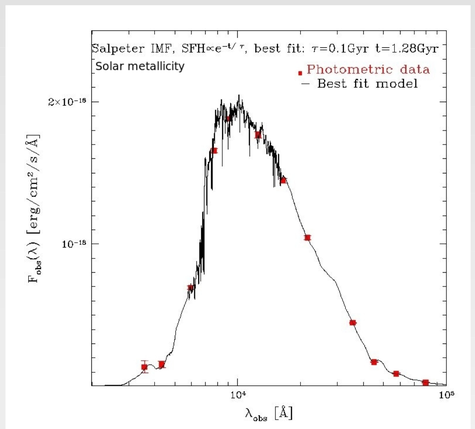

FIG.1 Observed global SED (red dots) and best fit model (black) of one ETGs of the sample.

2) Selection by visual morphological classification

Methods:

1) Galaxy visual inspection on ACS-F850LP image (FIG.2): regular-shaped ETGs separated from disk-shaped LTGs.

2) For the uncertain cases, fit of the surface brightness profile (FIG.2, *GALFIT Peng+02*) and analysis of the residual maps: galaxies having clear irregular residuals removed from the morphological ETGs sample.

247 morphological ETGs selected

of which

182 passive ETGs + 65 active ETGs

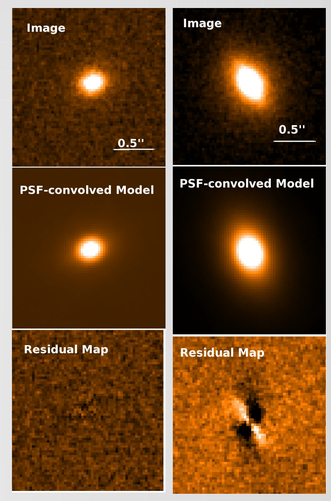

FIG.2: Each column shows the Galfit input and best-fit output for an ETG (left) and a LTG (right), fitted with a Sèrsic model profile. Through the analysis of the residual map we are able to recognize the presence of structures not directly linked to an elliptical morphology.

RESULTS: The selection criterion based on the passivity of the galaxies: ⇒ includes 35% of disc-shaped galaxies & ⇒ misses the 26% of morphological spheroids.

• EFFECTS OF THE SELECTION CRITERIA ON THE MAIN SAMPLE PROPERTIES

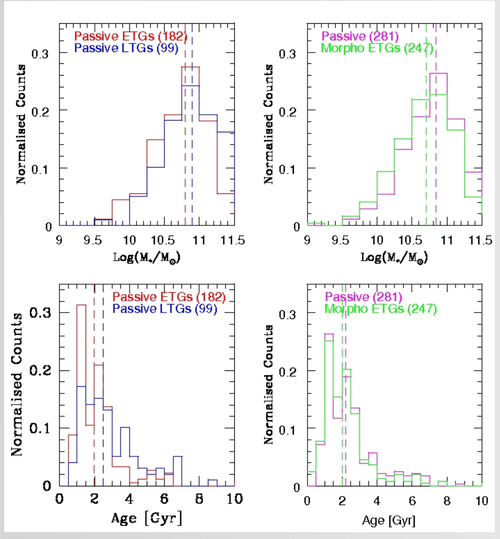

FIG.3 (*Top*): Stellar mass M_* distribution of passive ETGs (red) and passive LTGs (blue) on the left. Passive galaxies (magenta) and morphological ETGs (green) on the right. (*Bottom*): age distribution for the same sample of the top panel.
Vertical dashed lines are the median values.

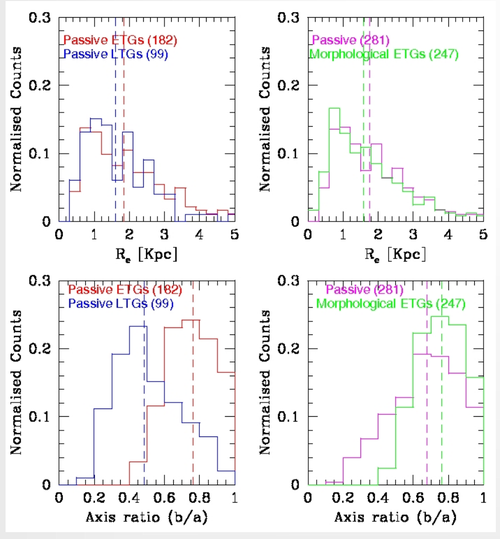

FIG.4 Effective radius (r_e) distribution (*Top*) and axis ratio distribution (*Bottom*), same samples and colors of FIG.3. The difference between the axis ratio distribution of passive ETGs (red) and passive LTGs (blue) highlights the distinct morphology of the two populations, confirming the goodness of the visual morphological classification.

RESULT: The main properties of the sample of passive galaxies do not show statistically significant differences (Kolmogorov-Smirnov Test) with those of the sample of morphologically selected ETGs.

• THE ROLE OF THE STELLAR INITIAL MASS FUNCTION ON THE SELECTION OF PASSIVE GALAXIES

The selection of passive galaxies, is based on a model dependent criterion ($sSFR \leq 10^{-11}$ yr^{-1}), since the sSFR was obtained through the SED fitting procedure.

To investigate how the selection of passive galaxies depends on the stellar IMF, we built up five different samples of passive galaxies, selected using in the SED fitting a power-law IMF, $\Phi(M) \propto M^{-s}$, with five different slope in the range s=1.5-3.5, which translates to a different proportion of low-to-high mass stars (FIG.5).

The results of the selection are shown in the second column of TAB.1: the number of selected passive galaxies, decreases with the increasing of the IMF slope, i.e. the steeper is the IMF, the higher is the low mass stars fraction.

The morphological analysis of the fraction of ETGs and LTGs includes in the different passive samples are shown in column 3 and 4 of TAB.1, respectively. It is clearly evident a systematically increase of the number of ETGs and a decrease of LTGs with steeper IMF.

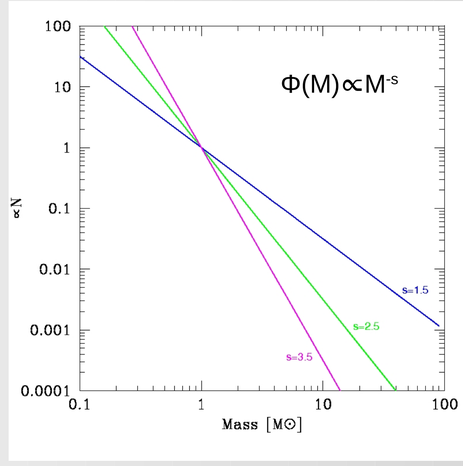

FIG.5 Stellar Initial Mass Functions with a different ratio of low-to-high mass stars. An steeper slope (e.g. s=3.5) of the power law describing the IMF, indicates an higher number of low mass stars.

IMF Type	Passive Galaxies	ETGs fraction		LTGs fraction	
Salpeter	281	64.8 %	(182)	35.2 %	(99)
s=1.5	403	51.9 %	(209)	48.1 %	(194)
s=2.0	312	62.2 %	(194)	37.8 %	(118)
s=2.5	256	67.2 %	(172)	32.8 %	(84)
s=3.0	195	68.2%	(133)	31.8 %	(62)
s=3.5	146	70.6%	(103)	29.4 %	(43)

Tab.1: Samples of passive galaxies obtained using IMF with varying slope (s=1.5-3.5, col.1) in the model.

RESULTS:

1) The passive selection criterion is highly depending on the IMF used in the models.

2) Assuming a bottom-heavier IMF (s=3.5), the fraction of ETGs in the passive sample increases.

• CONSTRAINS ON GALAXY FORMATION AND EVOLUTION

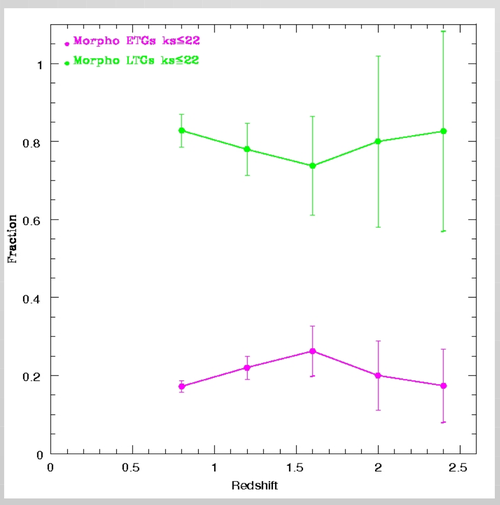

FIG.7 Evolution of the fraction of morphological ETGs (magenta, 247 galaxies) and of the remaining population of the flux selected sample (green, 1055 galaxies, Spirals+Irregulars), over a redshift range $0.7 \lesssim z \lesssim 2.5$. **The two fraction, within the error, are almost constant over the entire time spanned.**

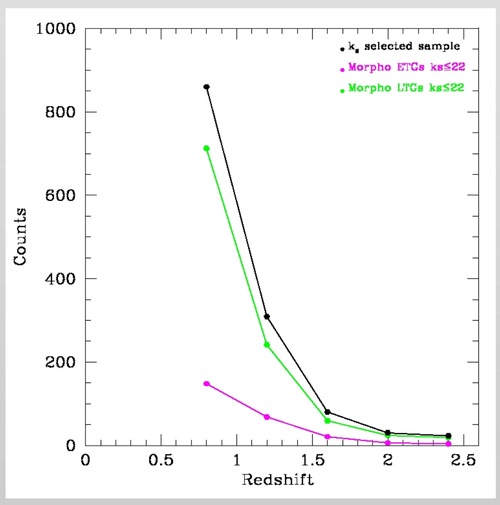

FIG.8 Total counts as function of redshift for the flux selected sample (black, 1302 galaxies) divided according the visual classifications of the galaxies (247 ETGs magenta, 1055 LTGs green). The two different population increase with decreasing redshift.

RESULT: The fraction of Early Type Galaxies and Late Type Galaxies is not evolving over a wide range of cosmic time ($0.7 \lesssim z \lesssim 2.5$). Analysis model independent.

CONCLUSIONS

Two different criteria have been adopted to select spheroidal galaxies: one based on a sSFR cut, aimed to select passive galaxies, the other on a pure morphological classification.
Our main results are:

1) The sample of passive galaxies shows a considerable presence (35%) of disc-shaped objects and does not include all the morphological ETGs.

2) The distributions of the main properties (e.g. M_*, age, SFH, SFR, r_e) of the morphological and passive samples do not show any significant differences.

3) The passive sample depends on the choice of the IMF used in the spectrophotometric models: using a bottom-heavier IMF fewer passive galaxies, with an higher fraction of morphological ETGs are selected.

4) Analyzing a flux selected sample of 1302 morphologically classified galaxies, in a redshift range $0.7 \lesssim z \lesssim 2.5$, we found that the fraction of ETGs and LTGs is constant along the cosmic time investigated.

References:
Bolzonella, M.; Miralles, J.-M.; Pelló, R. 2000, A&A,363,476
Bruzual, G.; Charlot, S. 2003, MNRAS, 344, 1000
Giavalisco, M.; et al. 2004, ApJ, 600L, 93
Peng, C. Y.; et al. 2002, AJ, 124, 266
Santini, P.; et al. 2009, A&A, 504,751

Acknowledgments:
We thank Stephan Charlot for providing the grid of stellar population models with different IMF, *ad hoc* for this analysis. This work has received financial support from Prin-INAF 1.05.01.09.05.