Early-Type galaxies at high-z: understanding their mass assembly history

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1. INTRODUCTION

The main properties of **Early Type Galaxies** (ETGs; e.g. red colours, quiescence, old stellar population), that is elliptical (E) and spheroidal galaxies (E/S0), 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 may not overlap with a pure morphological selection. And, sometimes, morphologically and dynamically different galaxies are handled as an homogeneous population to constrain the evolution of ellipticals galaxies strictly defined.
The aim of this work is to verify how samples of **passive galaxies**, selected assuming different model parameters, differ from samples of **morphologically selected ETGs**. On the basis of these results we conduct a census of galaxy morphology over cosmic time ($0.6 \leq z \leq 2.5$) to study the morphological fraction and the number density evolution in order to put constraints on the **galaxy stellar mass assembly**.

2. DATA

- GOODS-S ACS images (Giavalisco+04);
- GOODS-MUSIC catalogue (Santini+09):
  - 15 photometric bands ($0.3 \lesssim \lambda \lesssim 24$ μm)
  - spectro/photo redshift.
- Flux limited **($Ks \leq 22$)** sample of 1302 galaxies: 76% spectroscopic coverage.

3. SAMPLES SELECTION

1) *Selection of ETGs by visual morphological classification*

- Galaxy visual inspection on ACS-F850LP images (FIG.1): regular-shaped ETGs separated from disk-irregular shaped LTGs.
- For the uncertain cases, fit of the surface brightness profile and analysis of the residual maps: galaxies having clear irregular residuals classified as Late-Type objects.

247 morphologically selected ETGs

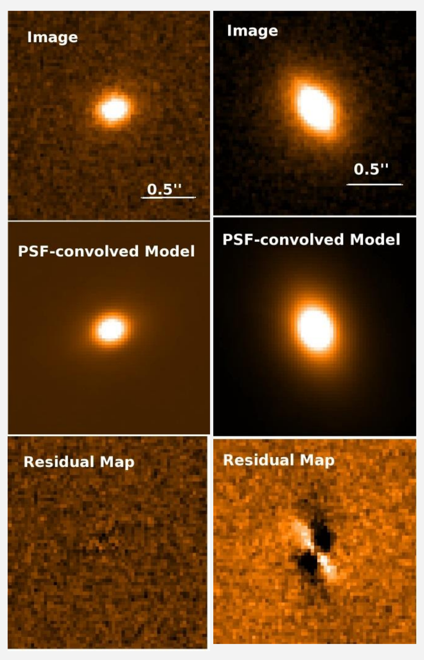

FIG.1: Each column shows the Galfit input and best-fit output for an ETG (left) and a LTG (right), fitted with a Sèrsic model profile.

2) *Selection of Passive galaxies by specific Star Formation Rate: $sSFR=(SFR/M_*) \leq 10^{-11}$ yr^{-1} with different IMFs*

- We define "***passive galaxies***" objects with **$sSFR=(SFR/M_*) \leq 10^{-11} yr^{-1}$**.
- SFR and M_* derived by SED fitting technique.
- Population synthesis models of Bruzual & Charlot 03 (BC03).
- IMF used: Salpeter IMF + 5 power-law IMFs ($\Phi(M) \propto M^{-s}$) with slope s=1.5, 2.0, 2.5, 3.0, 3.5. A steeper (e.g. s=3.5) IMF implies an higher abundance 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: Results of the passive galaxies selections performed with different IMFs. The last two columns report the morphological classification of the passive samples.

The passive selection criterion is highly depending on the IMF used in the models. Increasing the abundance of low-mass stars in the IMF (Tab.1):
- the number of classified passive galaxies decreases;
- the number of ETGs collected and the relative contamination of Late-Type objects decrease.

- **No selections of passive galaxies enables to collect all the morphological ETGs regardless of the IMF assumed in the models.**
- **All the samples of passive objects have a considerable contamination of late-type populations.**

4. CONSTRAINS ON GALAXY FORMATION AND EVOLUTION

Data: Flux limited sample classified by morphology at $0.6 \leq z \leq 2.5$: 196 ETGs + 723 LTGs

- This sample is model independent;
- Selection at $z \geq 0.6$ assures completeness at high stellar masses (see Fig.2).

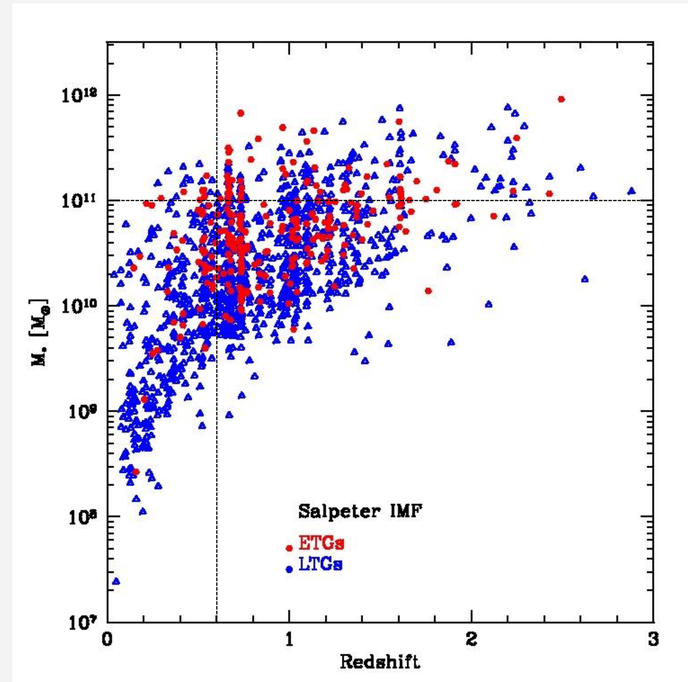

Fig.2: Stellar mass as a function of redshift. For $M_* \geq 10^{11} M_\odot$ the sample is complete in stellar mass in the entire redshift range. At z<0.6 the massive galaxies are not well sampled, due to the small field of view of the GOODS-S survey.

Fig.3

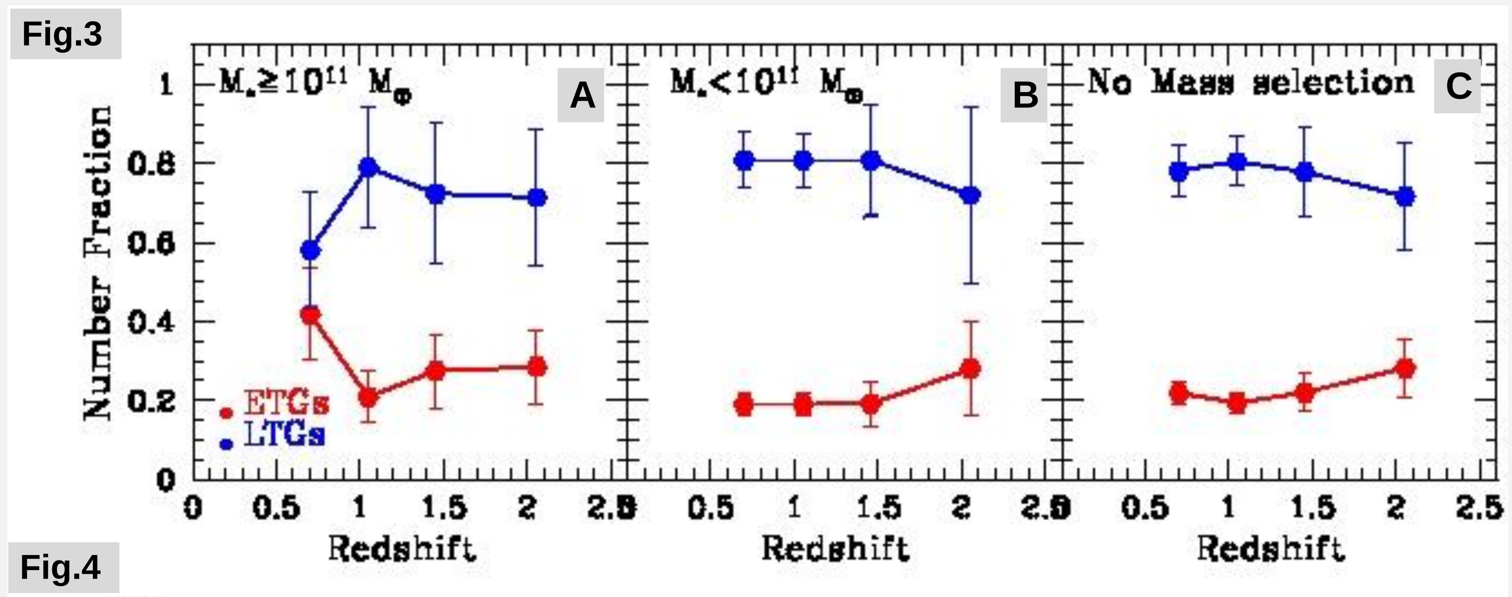

Fig.3: Fraction of ETGs and LTGs as function of redshift. **A**) $M_* \geq 10^{11} M_\odot$, **B**) $M_* < 10^{11} M_\odot$ and **C**) with no mass selection. For $M_* \geq 10^{11} M_\odot$ all types of galaxies are potentially observable in the whole redshift range (see Fig.2). The samples in B) and C) have a different degree of completeness in each redshift bin. Assuming that the mass selection affects in the same way both morphological types we perform a relative comparison of the two populations.

The **fraction** of **ETGs** and **LTGs** is **constant** over the redshift range $0.6 \leq z \leq 2.5$. At z<1 the fraction of massive ($M_* \geq 10^{11} M_\odot$) ETGs increases, while it remains constant for lower masses.

Fig.4

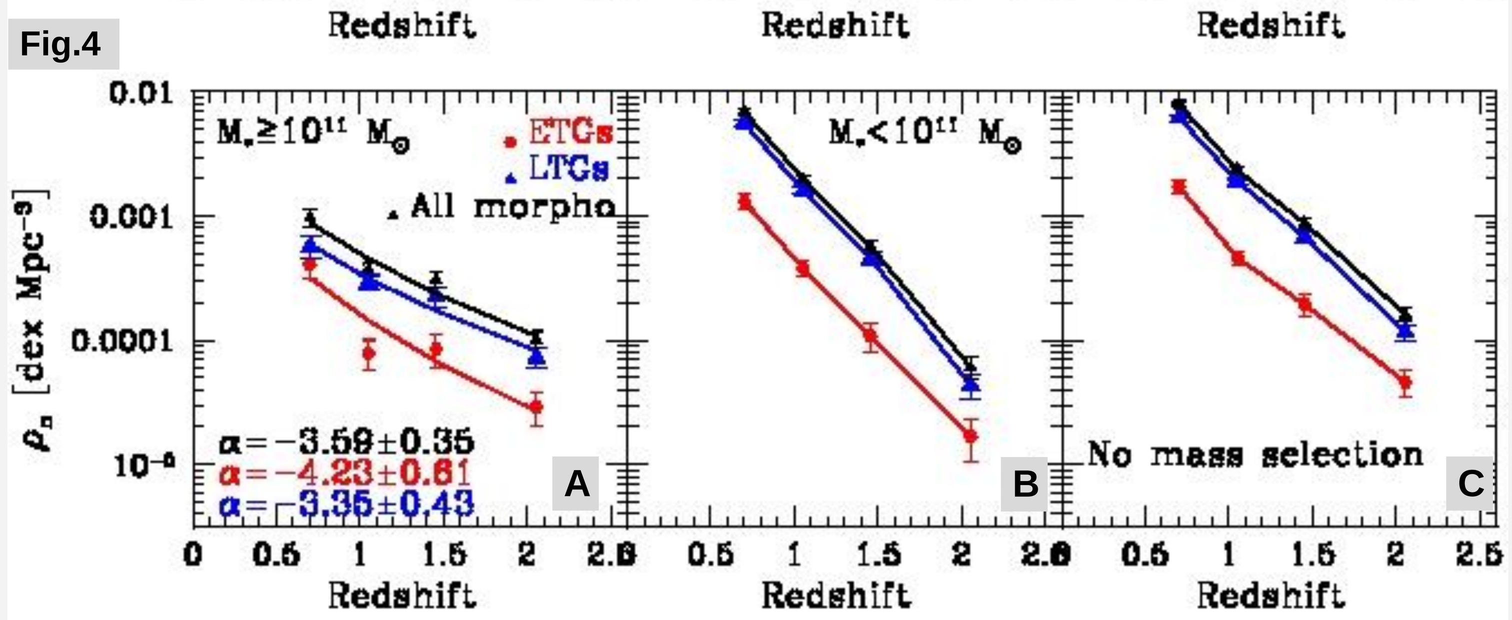

Fig.4: Number density as function of redshift. The solid lines of panel **A**) represent the rate of growth of the number density as function of the redshift: $\rho_n = \rho_0 (1+z)^\alpha$. The fit has been performed only for the larger mass ($M_* \geq 10^{11} M_\odot$) sample that is the only complete one.

The **increase** of the **number density** at decreasing redshift is common both to ETGs and to LTGs, but it has been more marked for the massive ETGs that at z~0.6 are a factor 11 more numerous than at z~2-2.5, to be compared with a factor 7 for the massive Late-Type galaxies. At $M_* < 10^{11} M_\odot$ a similar growing trend can be seen for both the two morphological classes.

Fig.5

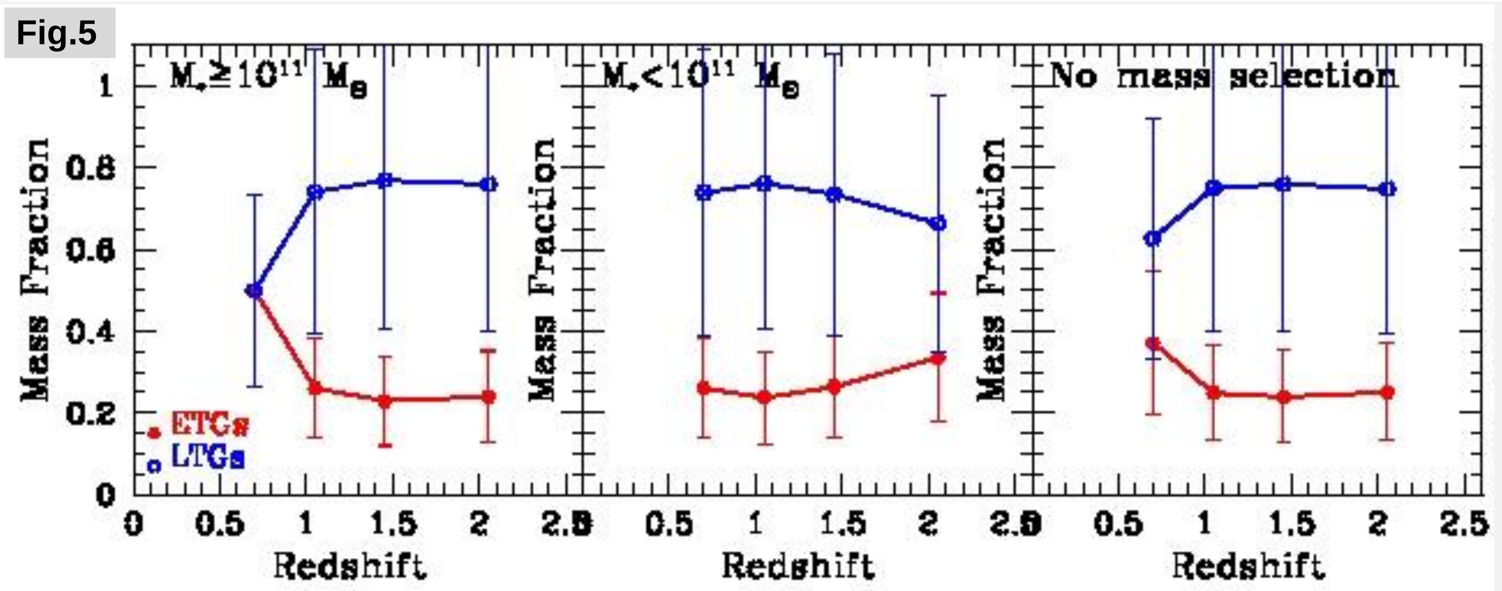

Fig.5: Stellar mass fraction as function of redshift.
As characteristic uncertainty for M_* a factor of 1.5 is assumed.

The mass fraction of massive ETGs is constant up to z~1, then for z<1 it moves from ~25% to ~50%, i.e. in the lowest redshift bin the stellar mass is equally distributed between spheroids and Late-Type objects. Since the LTGs at z<1 are more abundant than ETGs, it follows that massive ETGs must be systematically more massive than massive LTGs.

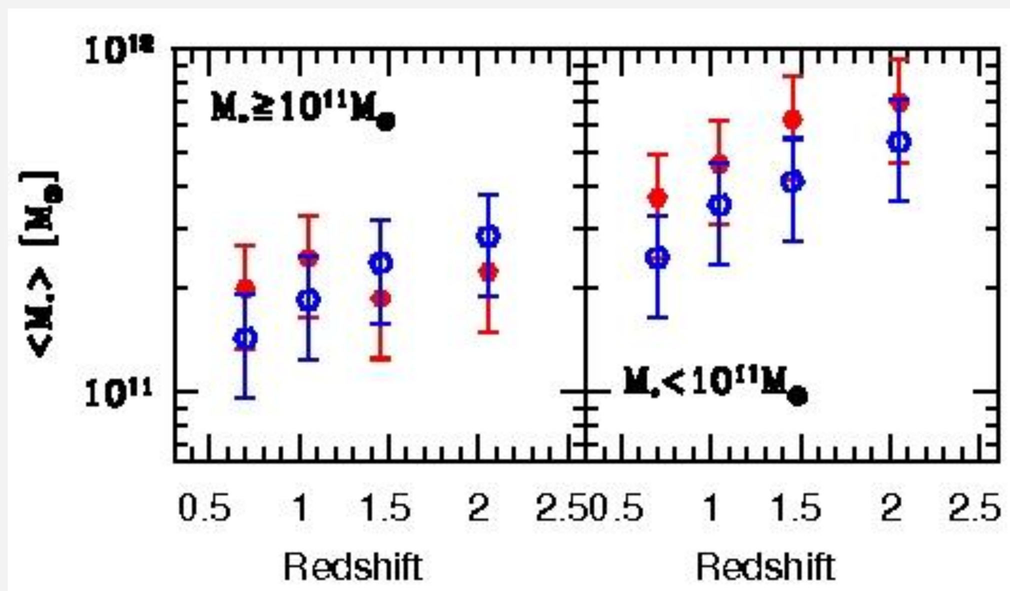

Fig.6: The average stellar mass of massive and low-intermediate mass galaxies is shown. The massive ETGs are on average more massive than massive LTGs from z<1.3, while for $M < 10^{11} M_\odot$ ETGs this happens on the entire redshift range.

CONCLUSIONS

Two different methods of classification aimed to select ETGs have been adopted: one based on a passive galaxies definition, the other on a pure morphological classification. We found that:

- The samples of **passive galaxies** show a **considerable presence** of **disc-shaped objects** and does **not include all** the morphological **ETGs**. Moreover the passive samples and their morphological composition depends on the choice of the IMF assumed in the spectrophotometric models.

We used the visually classified sample of strictly defined ETGs and LTGs to understand their mass assembly over a cosmic time crucial for the galaxy formation ($0.6 \leq z \leq 2.5$). We found that:

- The **relative fraction** of **ETGs/LTGs** is **almost constant** during the entire cosmic times analyzed, although the massive spheroids double their fraction in the lowest bin of redshift.
- The **massive ETGs** have a more **rapid increase** in their **number density** with respect to massive LTGs and at z=0.6-0.8 the two morphological classes contain the same mass fraction. Since in the same redshift bin, the massive ETGs represent less than half of the whole sample **their average stellar mass** must be **systematically higher** than the **massive Late-Type** one.

The evidences collected suggest that:

- The **massive spheroids need more time to assemble their mass**. Our results do not support that massive Late-Type objects are the direct progenitors of massive ETGs, since their number is not enough to explain the rapid increase of the number density of massive ellipticals. The massive ETGs may be the product of repeated merging events of less massive galaxies at different epochs. Furthermore, the constant trend of the relative fractions of the two morphological classes over the whole range of redshift would required a special fine tuning of many processes if the ETGs were the final product of Late-Type evolution.

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References:
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