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Probing the satellites of massive galaxies out to z~1

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… an unsolved problem

The formation of massive galaxies remains an important open question. Lately, it seems that the process follows two phases of evolution (e.g. Oser et al. 2010)

The **early phase** is dominated by a short-lived and intense burst of star formation at z>2, creating a massive, dense core (from an early gas-rich merger, disc instabilities, cold accretion). Typical scales would be $\Delta T \sim 1\text{-}2$ Gyr at $\sim 100\ M_\odot yr^{-1}$ (Ferreras et al. 2012, AJ)

Late phase: The massive galaxies we see today (the vast majority of them?) are not so dense, hence some mechanism is needed to grow in size from z~1-2

Gas expulsion, e.g. Fan et al. 2008
Mergers (major/minor; wet/dry) e.g. Khochfar & Silk 2006; Naab et al. 2009
Emergence, e.g. van der Wel et al. 2009

This project aims at exploring the z~0-1 range to look for the processes leading to the (*second phase*) growth of massive galaxies.

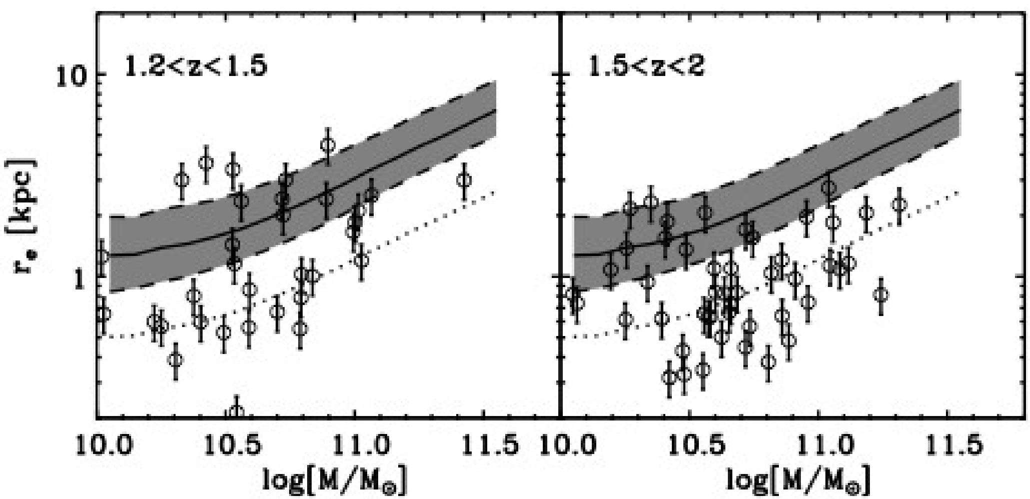
Size evolution and age

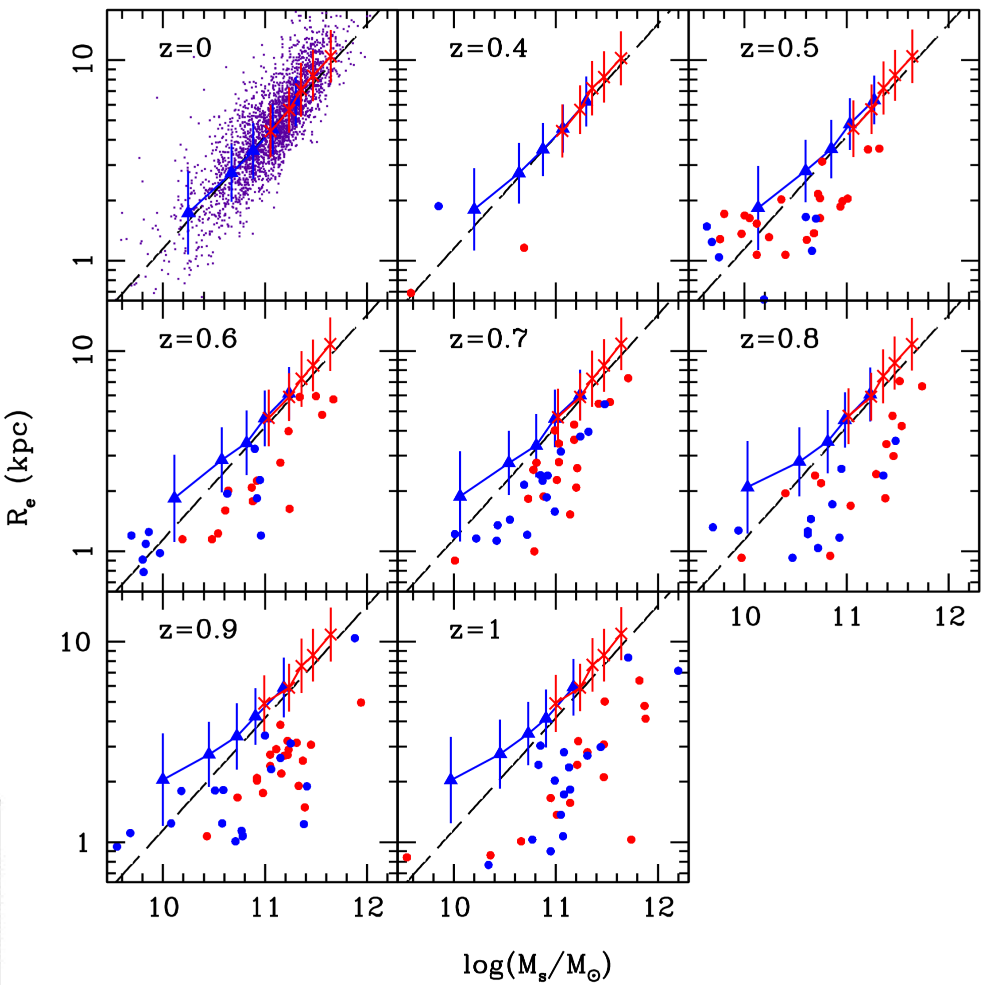
A comparison of size evolution between nearby (SDSS; triangles) and distant galaxies (PEARS; dots) shows no segregation with respect to stellar age (red/blue)

Therefore, no significant star formation should be involved in the process.

Only the downsizing trend is apparent: lower mass galaxies are younger.

Cassata et al. (2013)



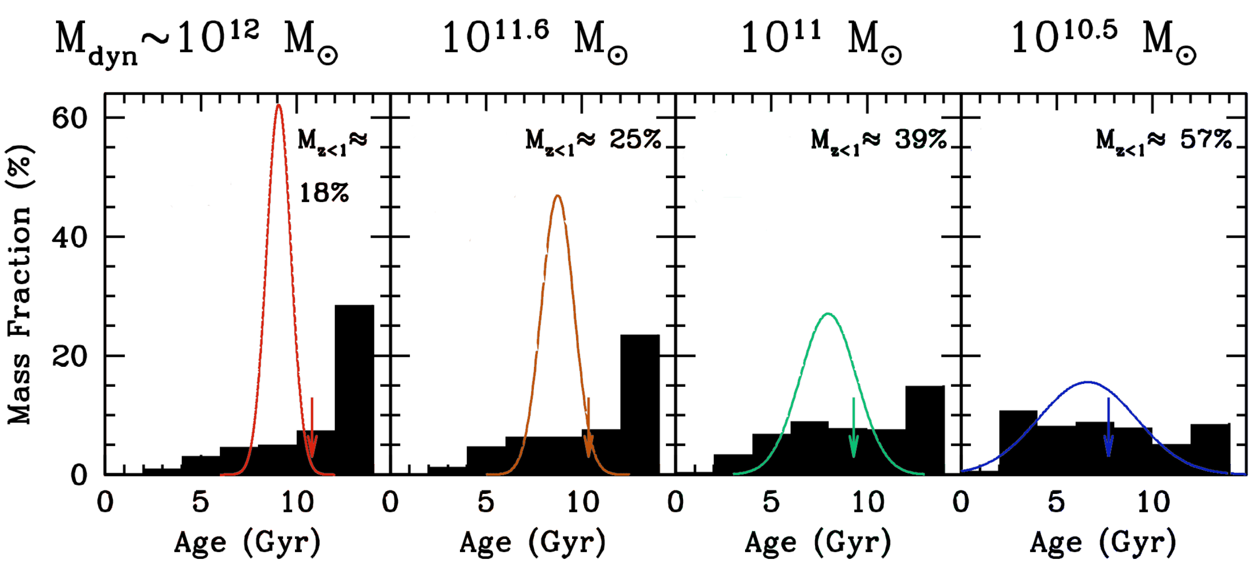


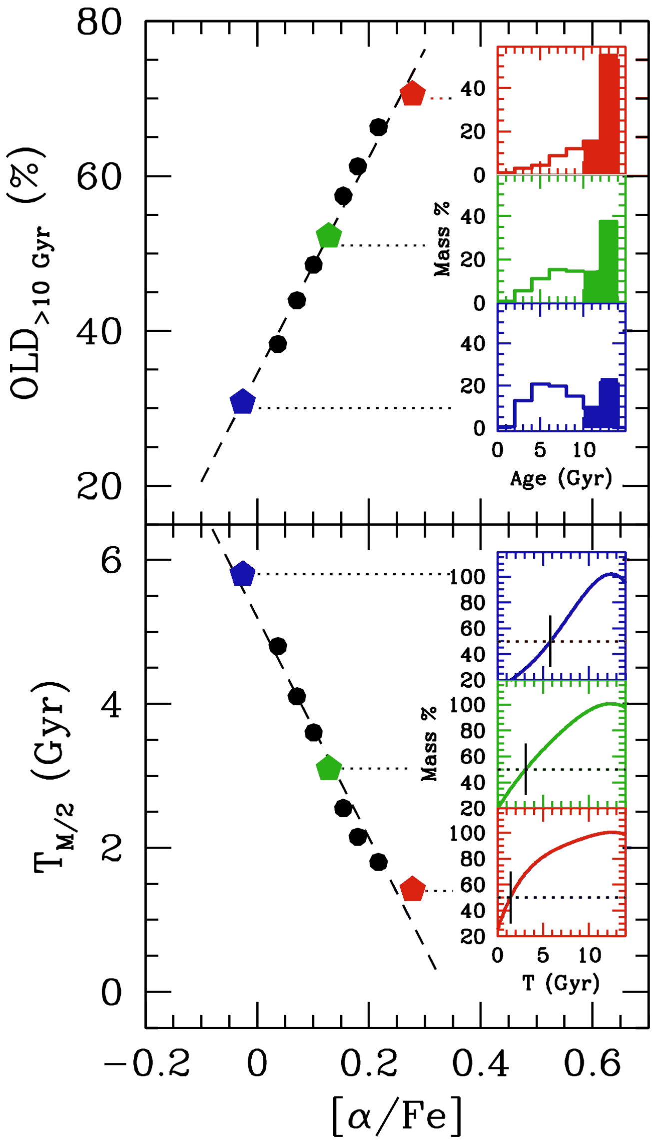
I[3]: Trujillo et al. (2011)

Stellar populations as tracers of the past SFH

Spectral fitting of early-type galaxy data (SDSS) at z<0.1 unequivocally show that the ***bulk*** of massive ETGs undergo an early & short-lived process of star formation.

de la Rosa, et al. (2011)





SHARDS: Massive Galaxies

- We use the SHARDS dataset to collect a sample of massive ($>10^{11} M_\odot$) galaxies to explore the progenitors of mergers in the z~0-1 redshift range

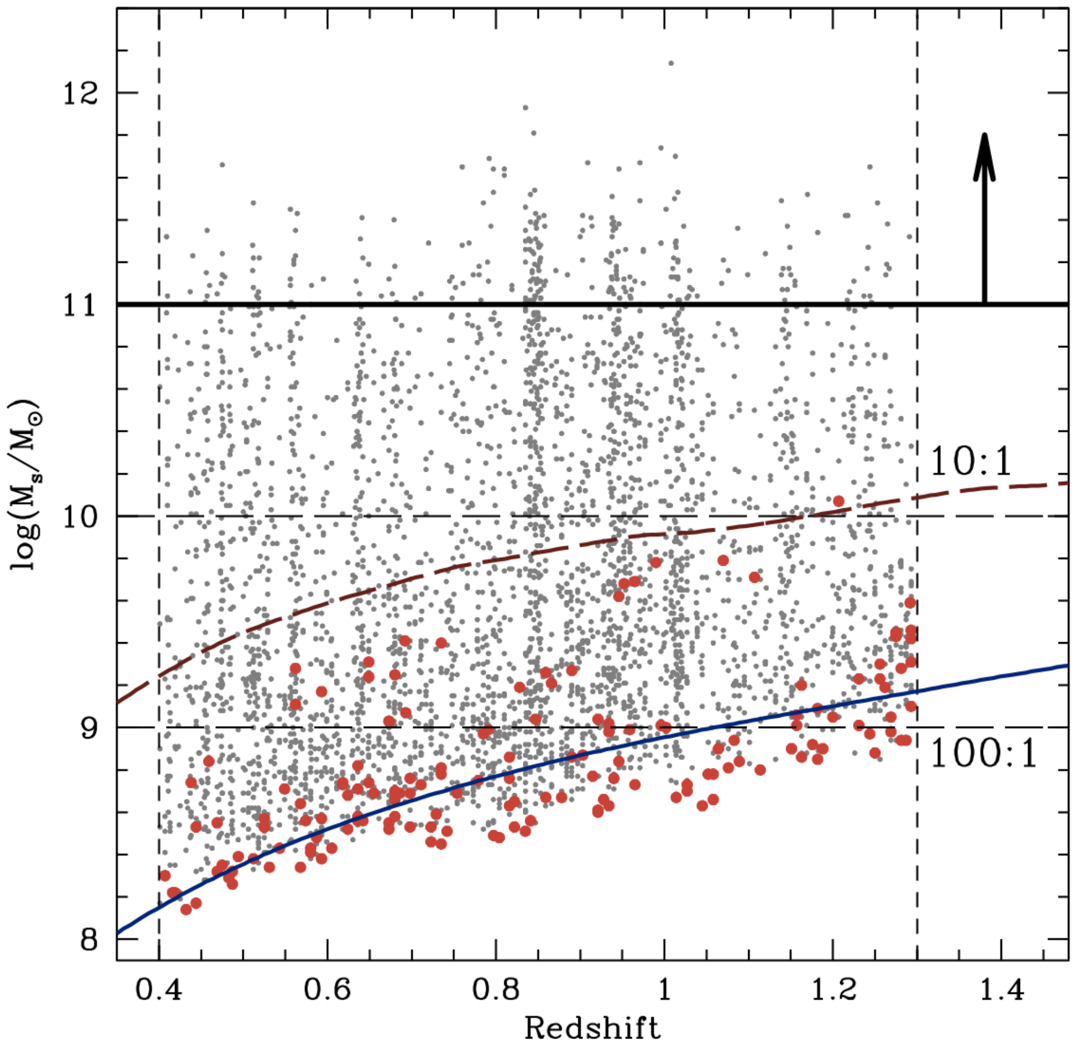
- SHARDS data allow for a more accurate characterization of the photometric redshifts

- SHARDS provide low-resolution (R~50) spectra to derive stellar ages.

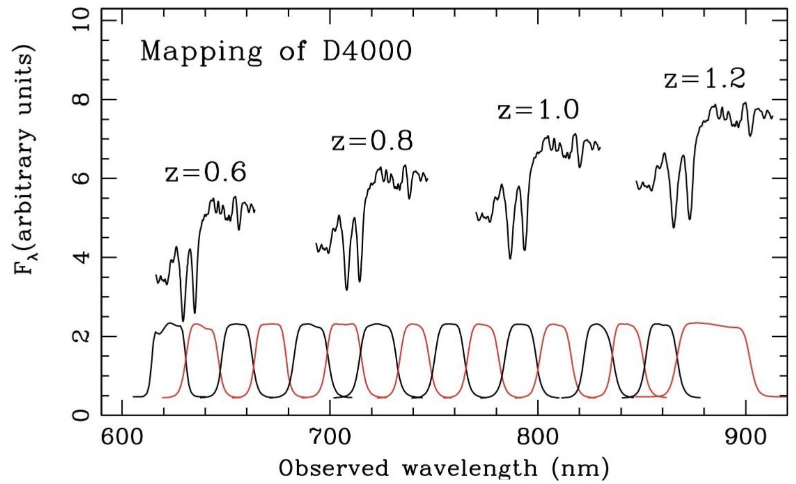
Sample selection

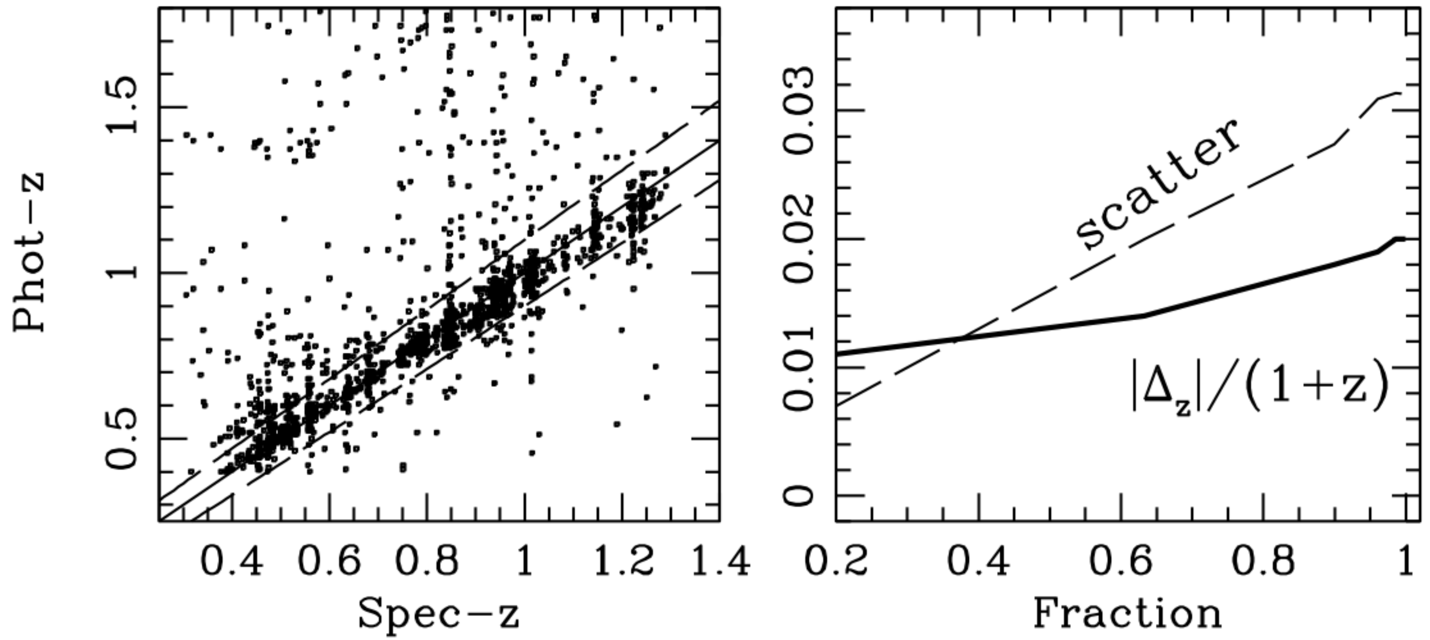
Note that in order to be complete down to a mass ratio 1:100, one needs ultra-deep surveys if we are to be unbiased against OLD stellar populations.

The blue (red) lines correspond to a K_{AB}=24 galaxy with young (old) populations. The red dots are the *observed* SHARDS galaxies at K_{AB}=24.



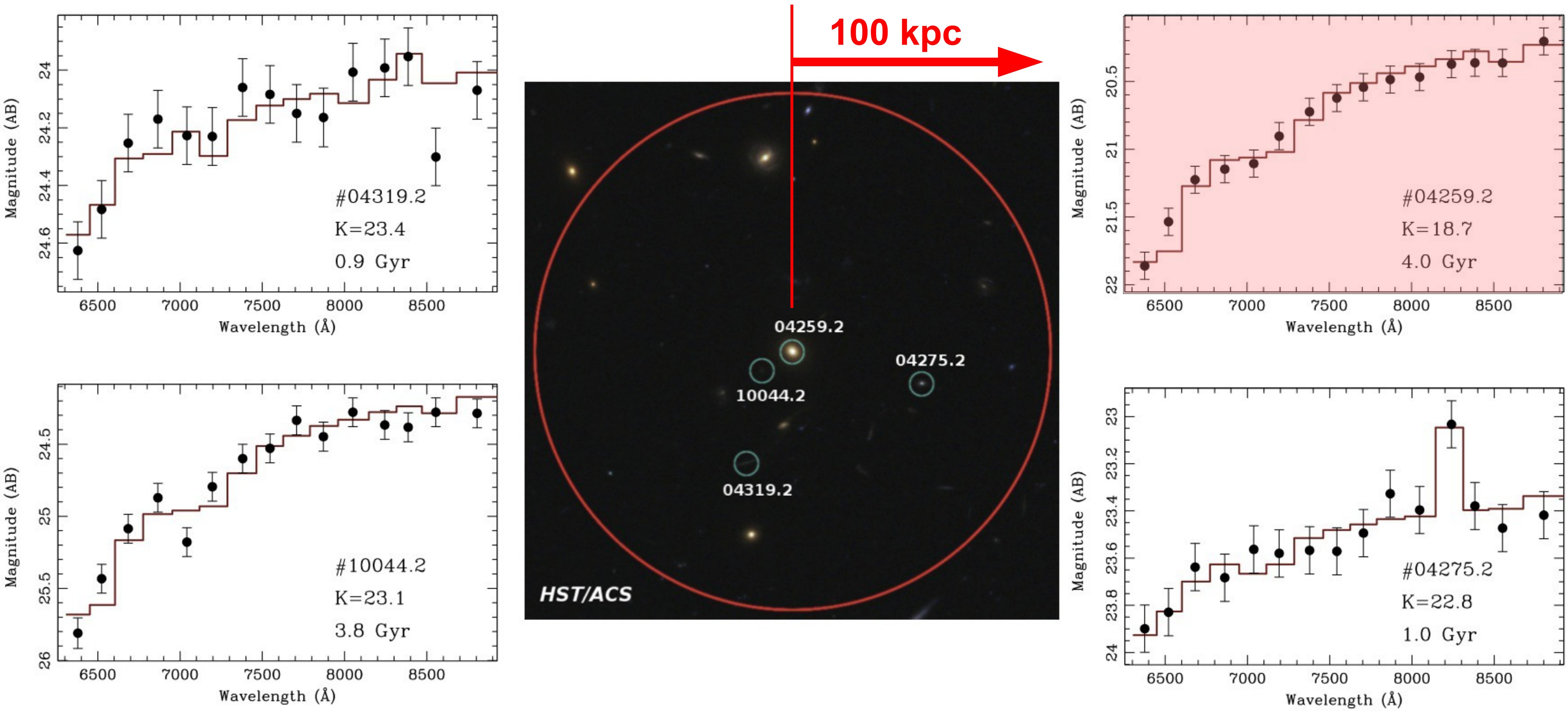
Photometric redshifts





Template fitting (2000), including emission lines.
Broadband NUV-IR + SHARDS
2% error with small scatter.
Recently updated (PPG) photo-z's improve over these estimates (1%)

An example



z=0.67

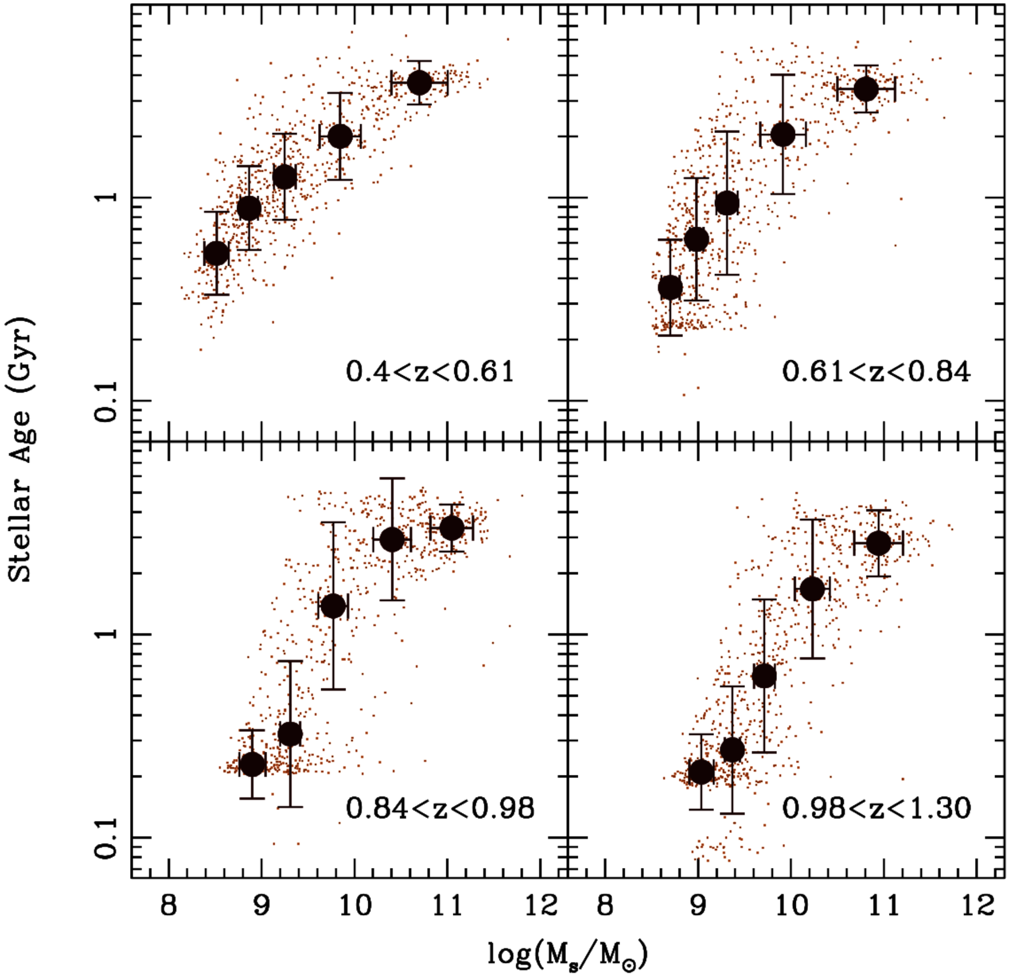
The global mass-age relation

We use a large grid of synthetic models (500k) including SSPs, τ-models and emission line spectra, to derive a mass-weighted stellar age.

The global trend is consistent with the downsizing scenario.

We select 254 massive ($>10^{11}M_\odot$) galaxies (after clean-up) and then look for satellites:

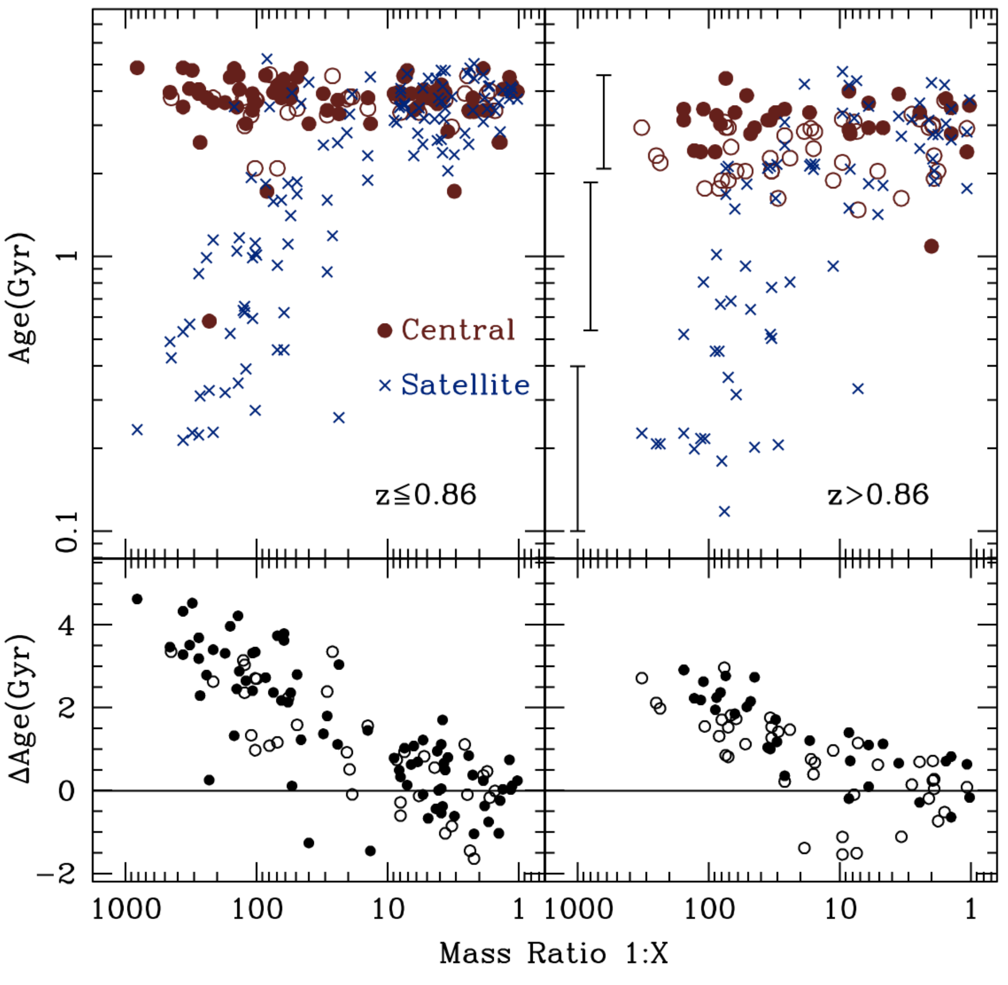
- Δz within 2% uncertainty
- Δr<100kpc (projection)

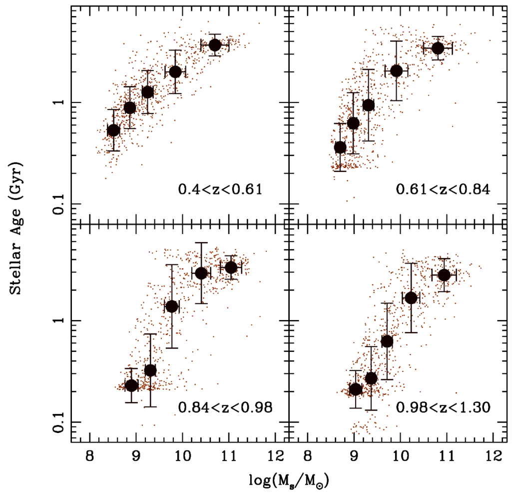


Central/Satellite age difference

Age difference between central (red) and satellite (blue) with respect to the mass ratio.

Is this difference the expected behaviour from the global mass-age trend?

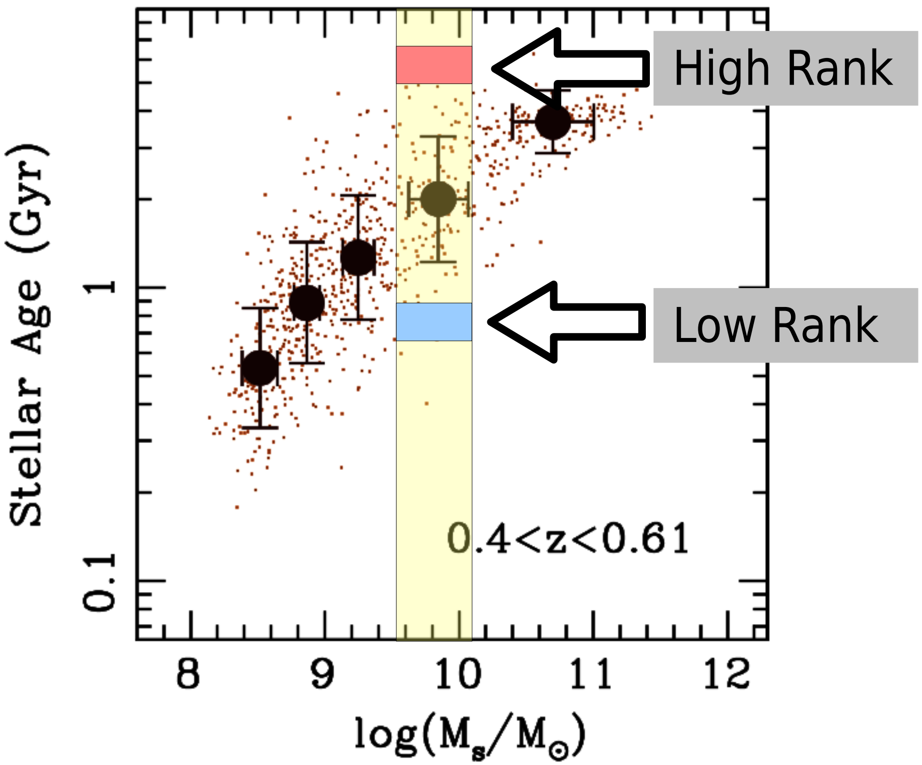


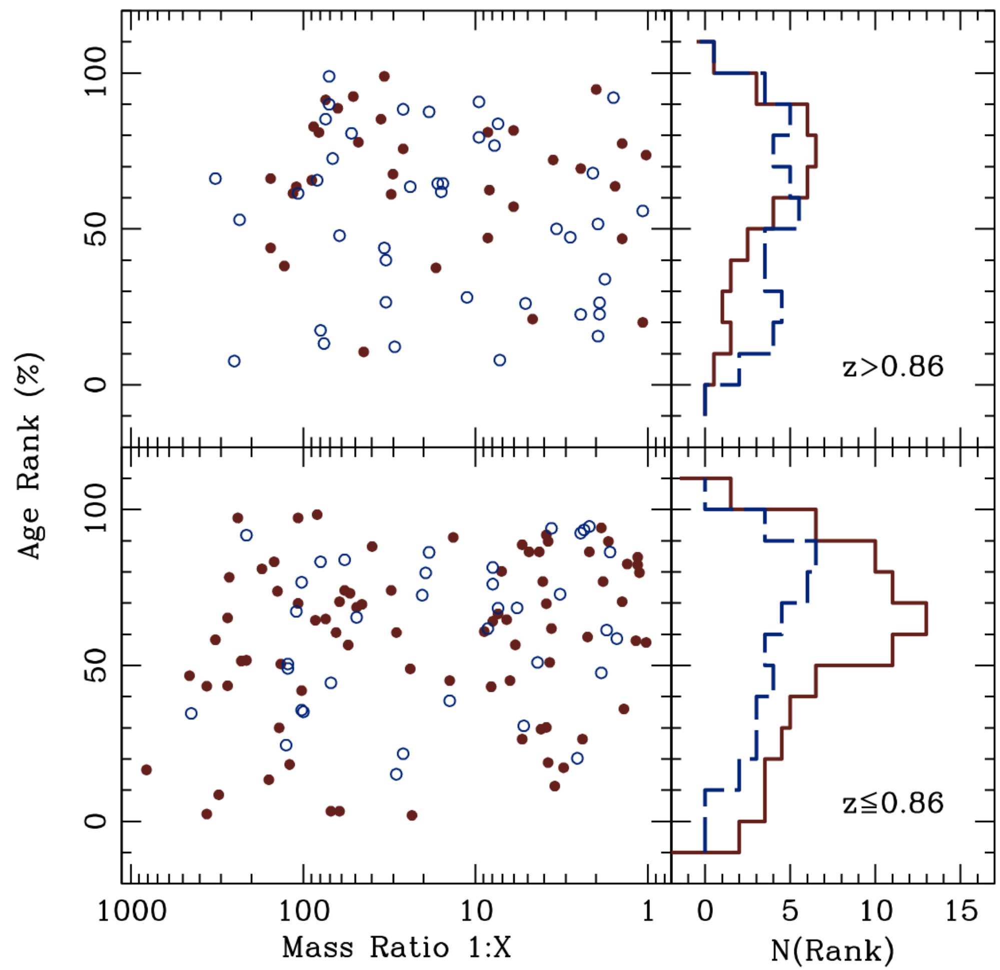


Age differences compared with global trend

In order to test whether the age difference is biased with respect to the global mass-age relation, we obtain the rank within each mass bin.

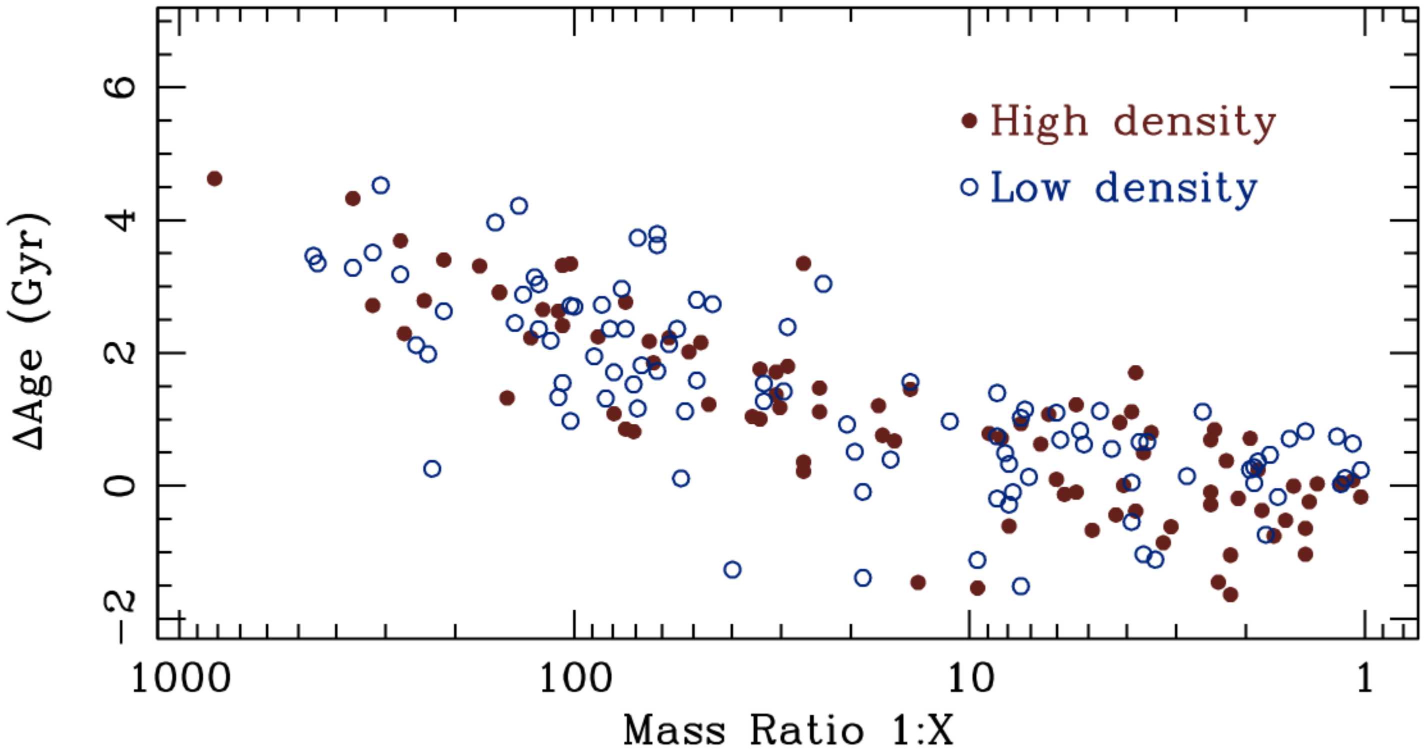
No significant difference is found





… any dependence with (large scale) environment?

A simple estimate of environment is the number of galaxies within some fiducial distance (Δr<500kpc), at the same redshift. No difference found either between "low" and "high" density regions.

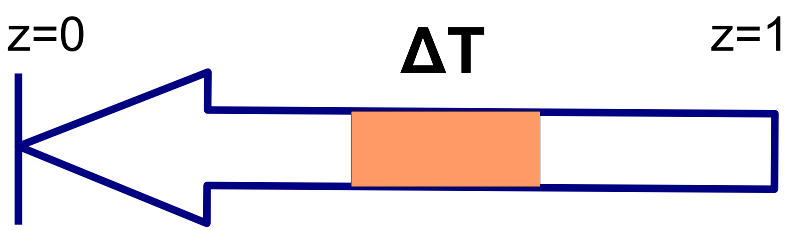


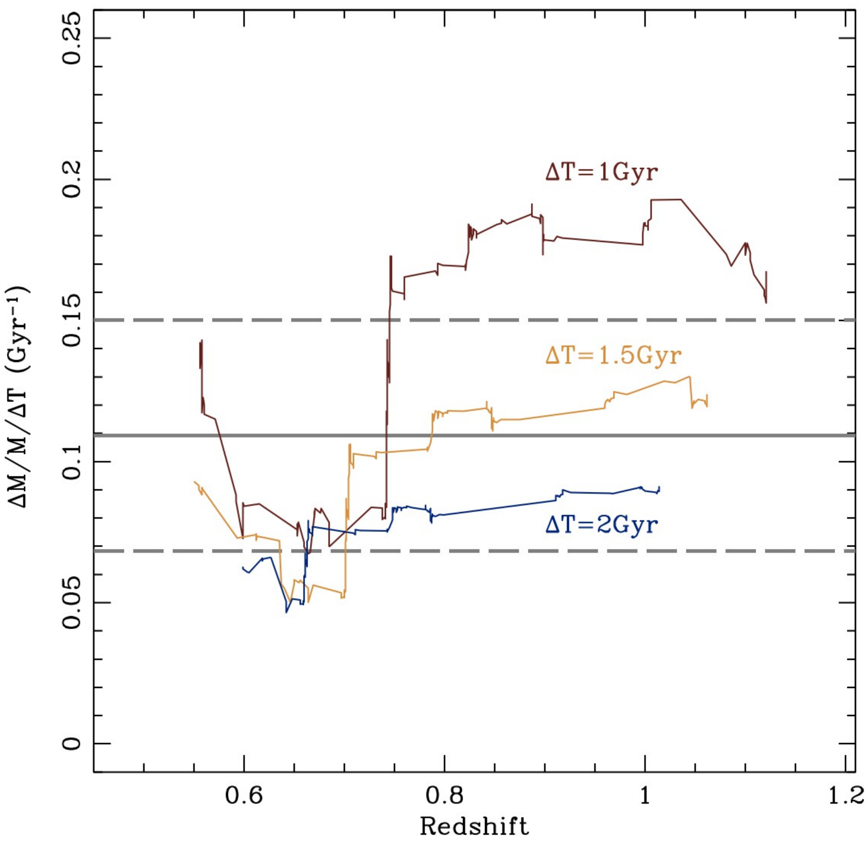
Mass growth from z~1

Over a typical merging timescale (1-2 Gyr) the mass growth rate stays roughly constant between z~1 and 0.

The cumulative effect between z~1 and z=0 corresponds to a total mass growth per massive galaxy:

$$\frac{\Delta M_{z=1\rightarrow 0}}{M_{z=1}} = 1.96 \pm 0.31$$

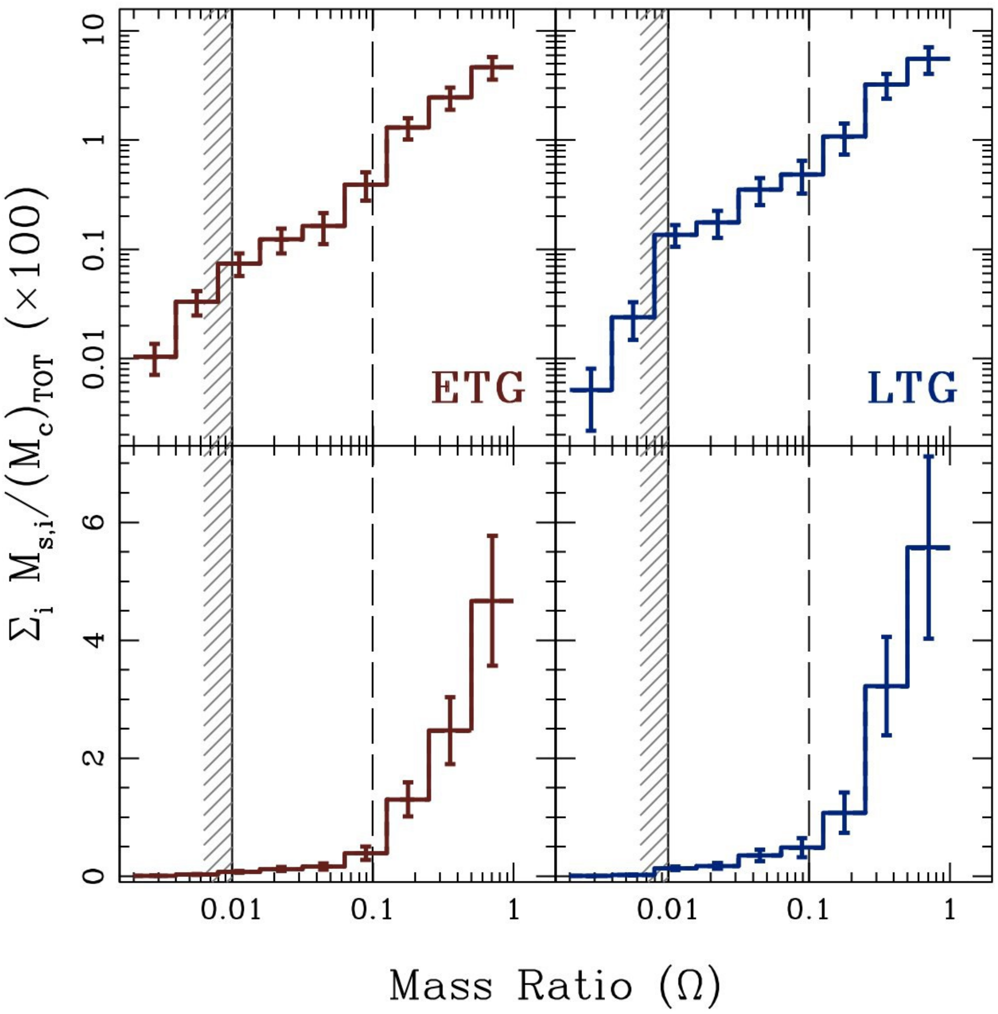




Any preferred growth channel?

Although we still need to correct for clustering in the data, it seems like **major mergers** are very relevant here !

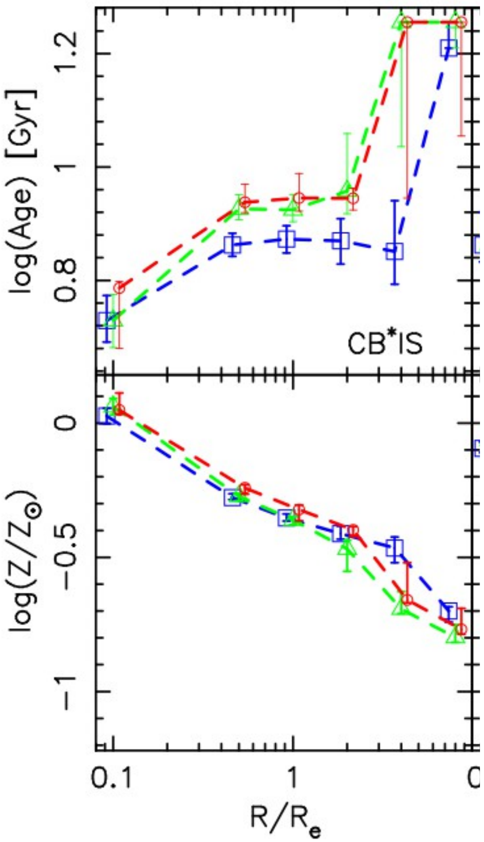
Clustering would mainly smooth out the high mass ratio peak, creating a plateau (in preparation)



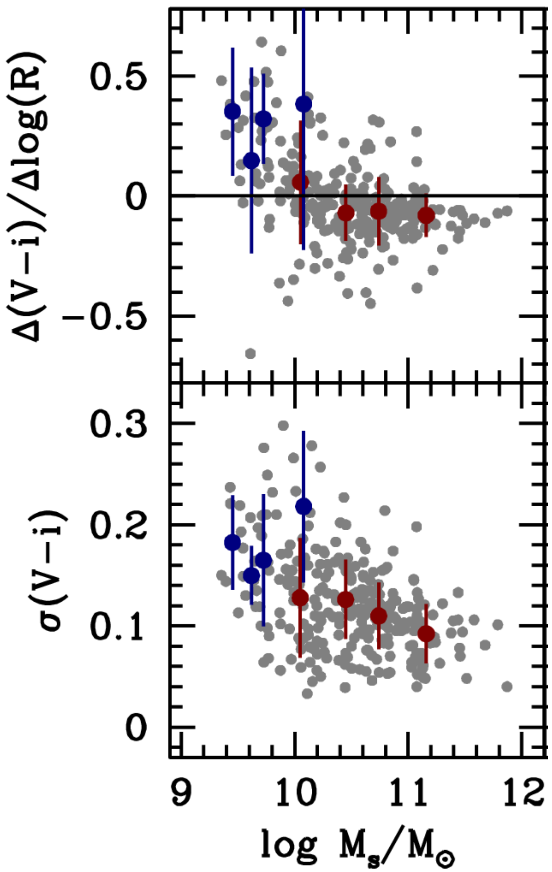
Back to major mergers?

After all, the mass growth would be compatible with a small amount of dry major mergers. Furthemore, the age difference would be compatible with the small age gradients found in z<0.1 ETGs in SDSS, and with the small colour gradients in ETGs at z~0.3-1.0

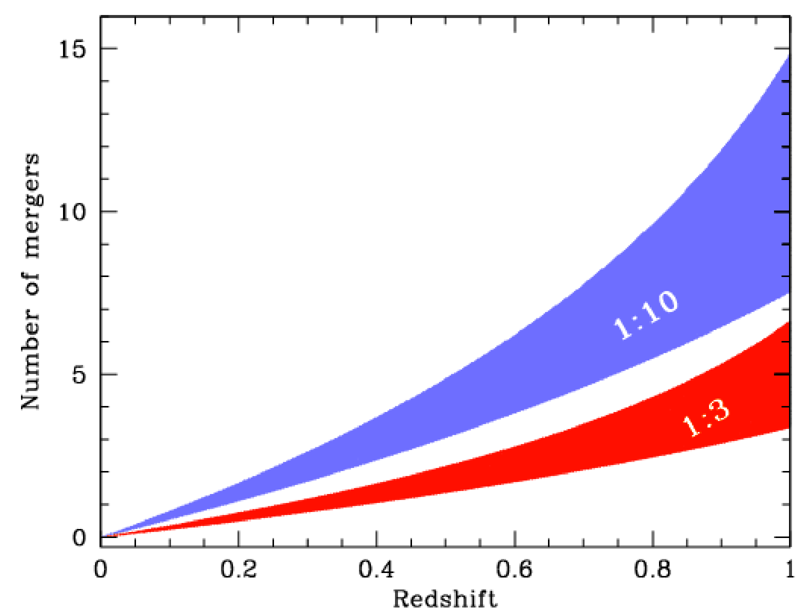
La Barbera et al. (2012)



Ferreras et al. (2009)



Trujillo et al. (2011)



Conclusions

Sample of massive galaxies from SHARDS
Selection of "pre-merger" systems (254 massive galaxies)
Stellar population analysis of R~50 SEDs
Tracking the growth of massive galaxies over the past 8 billion years

Clear trend of younger populations assembled at z<1 into massive galaxies
No significant difference with respect to global mass-age relation
Mass growth by a factor ~2 between z=1 and today, rather constant
No preference towards minor mergers!