

The progenitors of mergers with massive galaxies at $z < 1$

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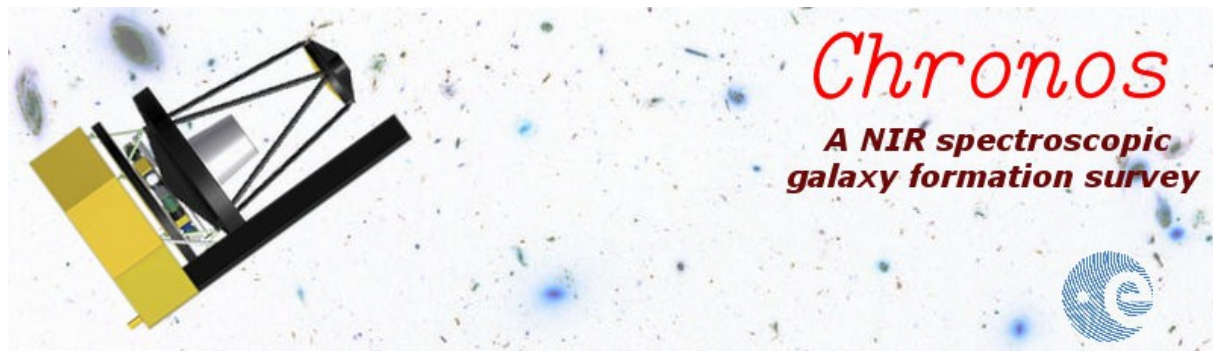
+ SHARDS team

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<http://www.chronos-mission.eu>

EWASS - S4: The mystery of ellipticals

Turku, Finland

July 8th, 2013



Chronos

*A NIR spectroscopic
galaxy formation survey*



... an unsolved problem

The formation of massive galaxies remains an important open question. The process appears to follow 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 $\Delta T \sim 1-2$ Gyr at $\sim 100 M_{\odot} \text{yr}^{-1}$ (Ferreras et al. 2012, AJ)

Late phase: Massive galaxies at $z \sim 0$ (the vast majority of them?) are not so dense. Some mechanism is needed to grow in size from $z \sim 2$

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 $z \sim 0-1$ range to look for the processes leading to the (*second phase*) growth of massive galaxies.

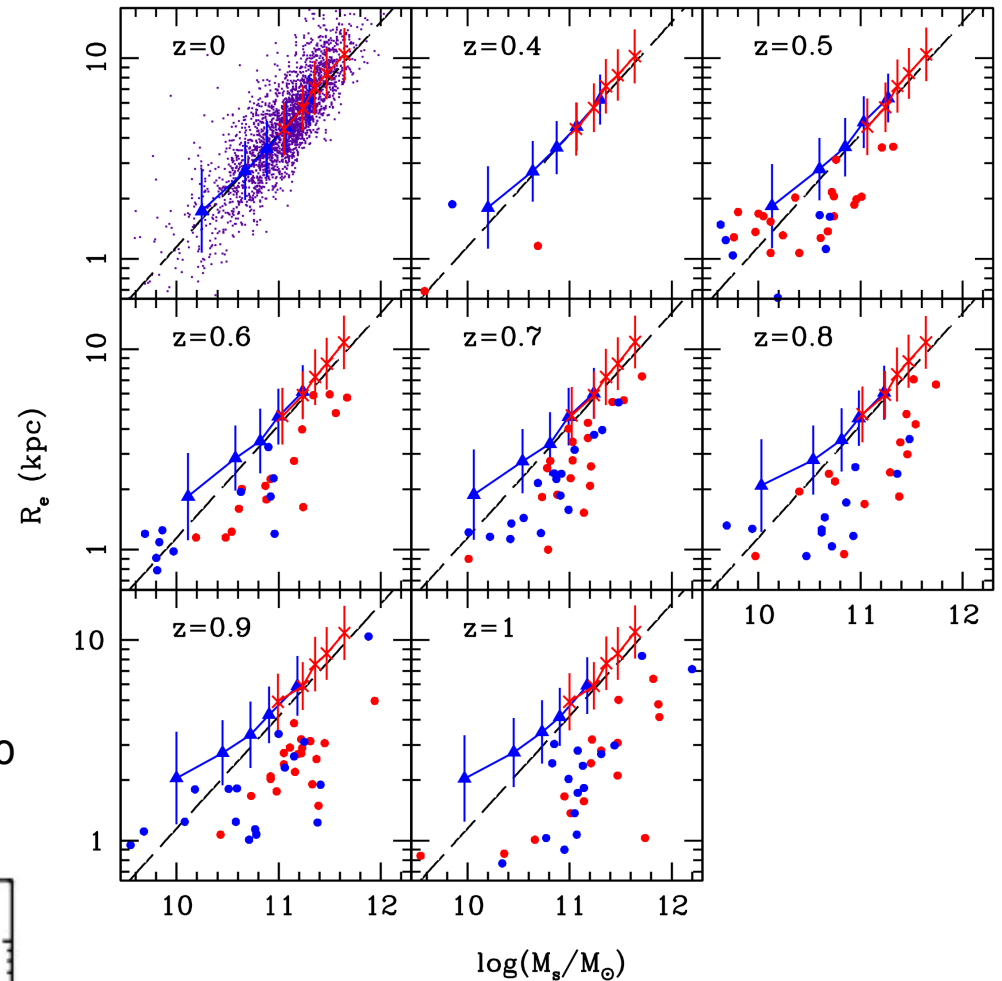
Size evolution and age

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

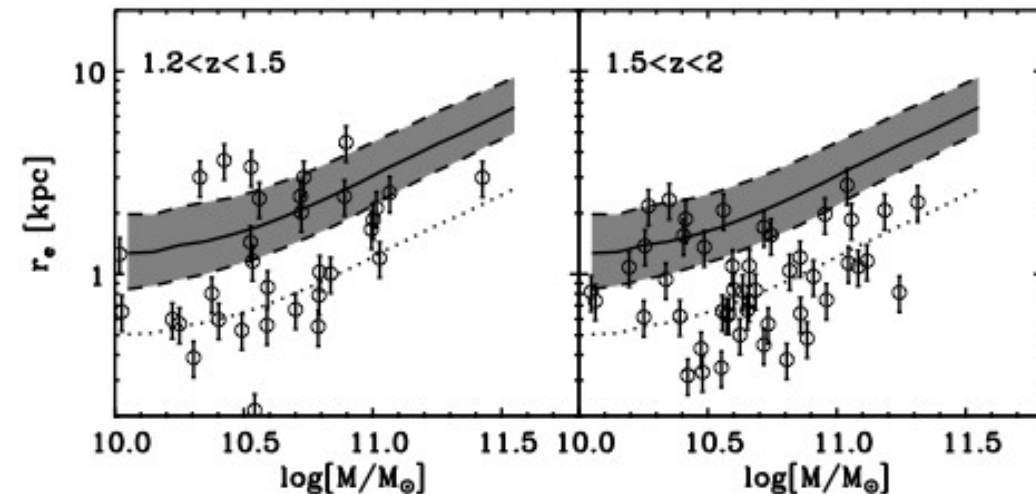
Therefore, no significant star formation should be involved in the process.

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

Cassata et al. (2013) (also Daddi et al. 2005; Trujillo et al. 2006; 2007; ...)



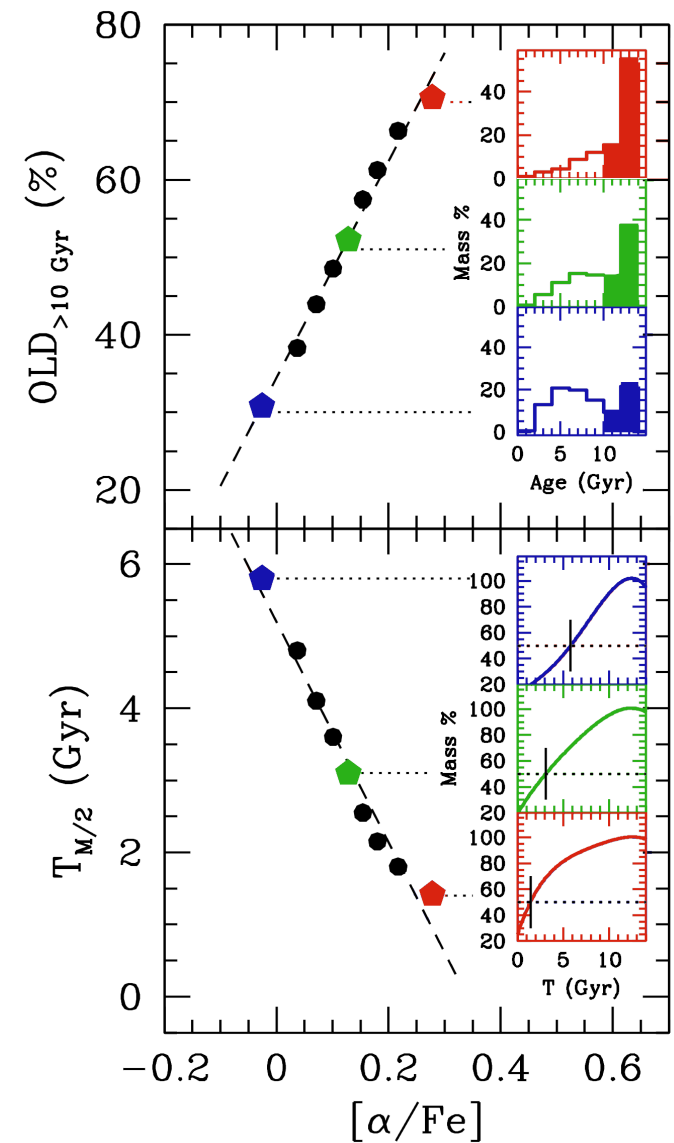
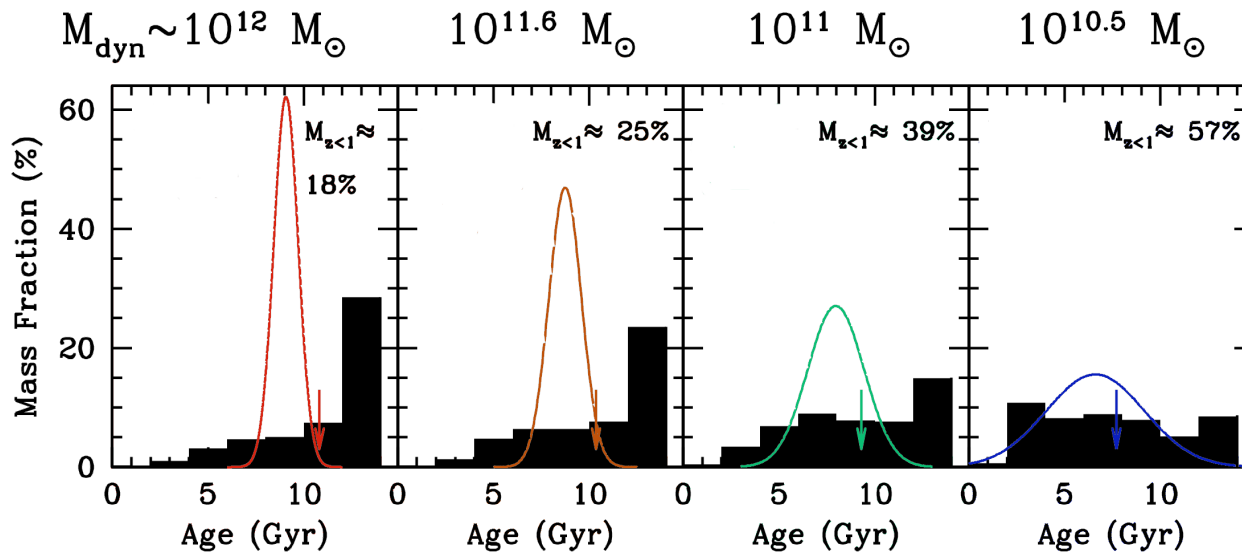
³: Trujillo et al. (2011)



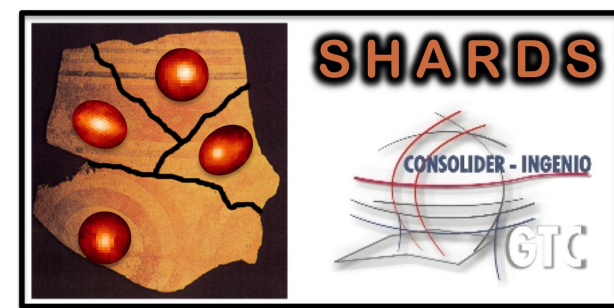
Stellar populations as tracers of the past SFH

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) (also Thomas et al. 2005; 2010)



SHARDS: Massive Galaxies

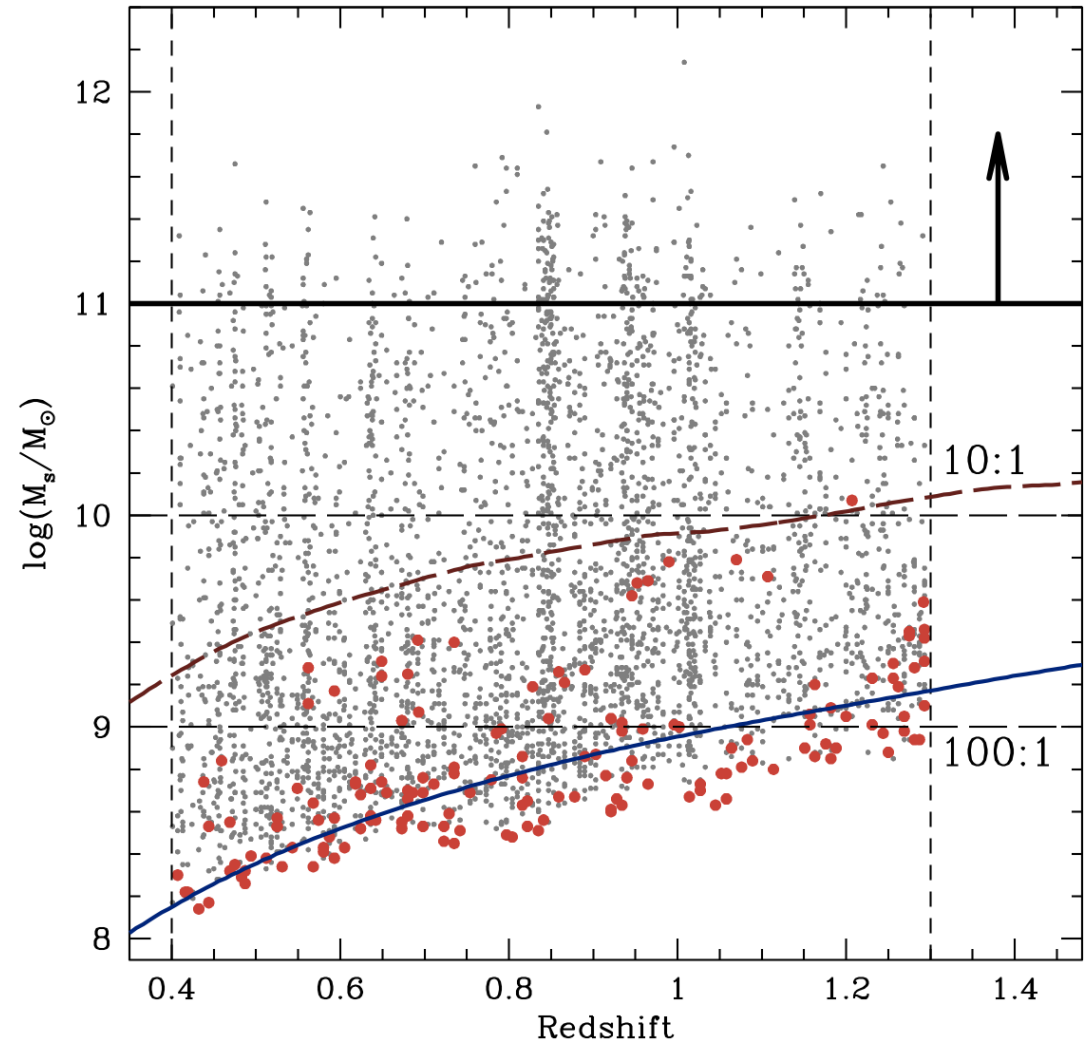


- We use the SHARDS dataset to collect a sample of massive ($\geq 10^{11} M_{\odot}$) galaxies to explore the progenitors of mergers in the $z \lesssim 1$ redshift range
- 130 arcmin² towards HDFN. Deep (26.5 AB) imaging at 10.4m GTC with 24 (16) medium-band ($\Delta\lambda \sim 170 \text{ \AA}$) filters over 5000-9500 \AA range (Talk by Pablo Pérez-González tomorrow)
- SHARDS data allow for a more accurate characterization of the photometric redshifts
- SHARDS provide low-resolution ($R \sim 50$) spectra to derive stellar ages.

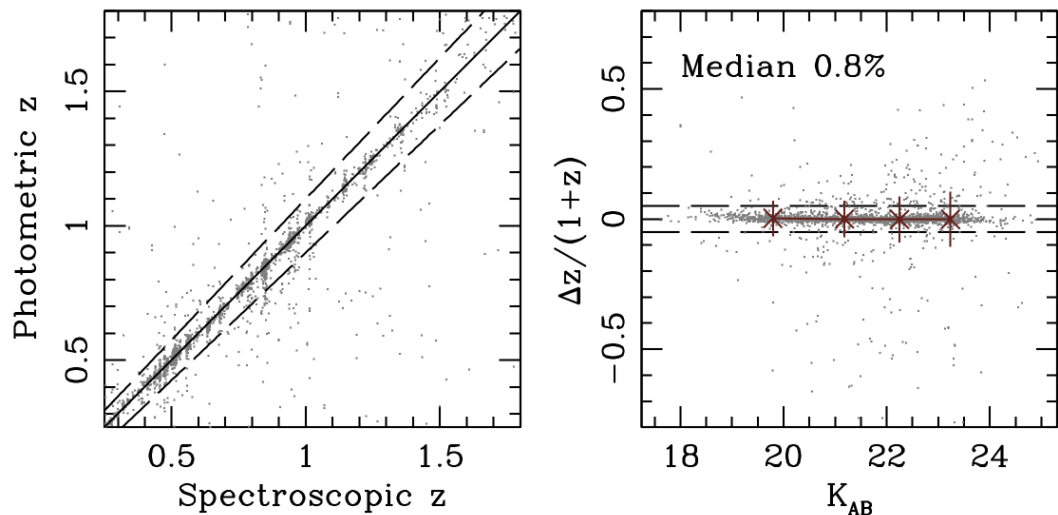
Sample selection

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 $K_{AB}=24$.

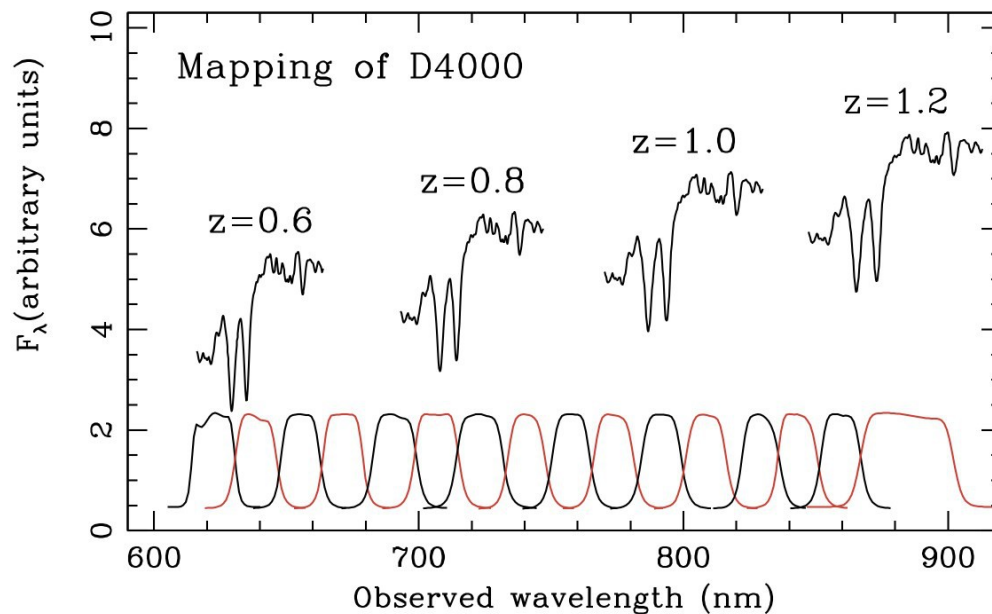


Photometric redshifts

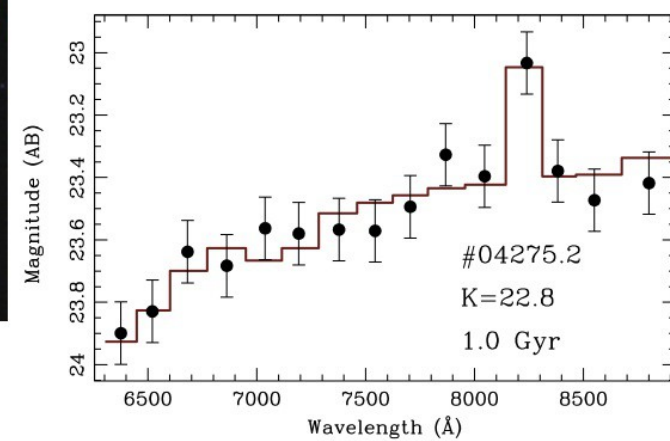
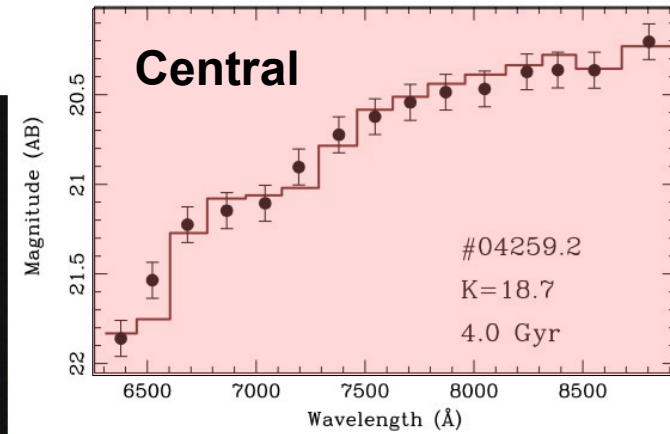
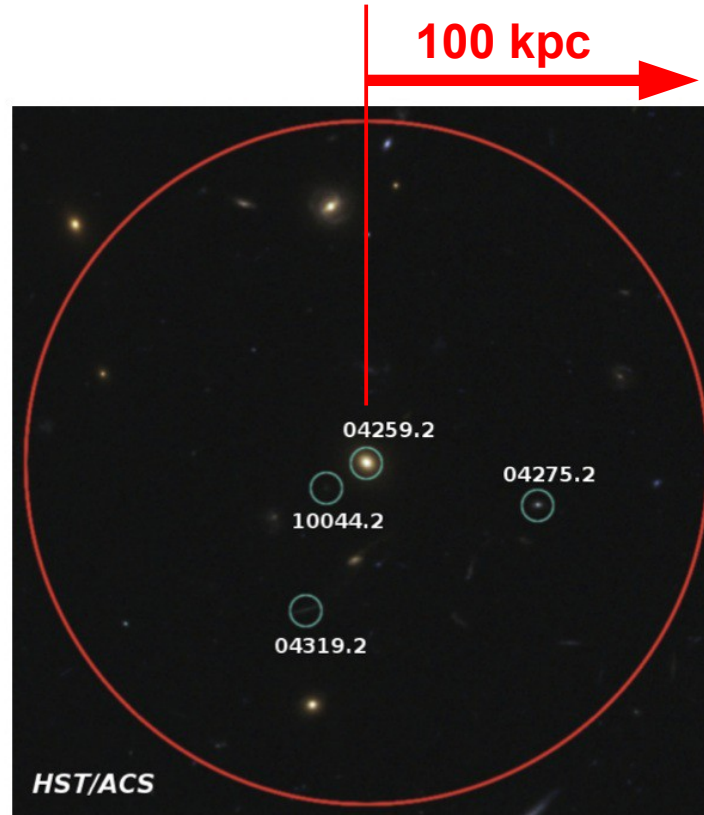
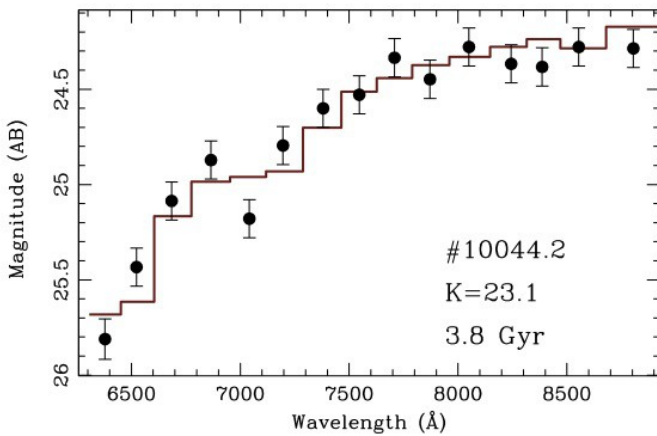
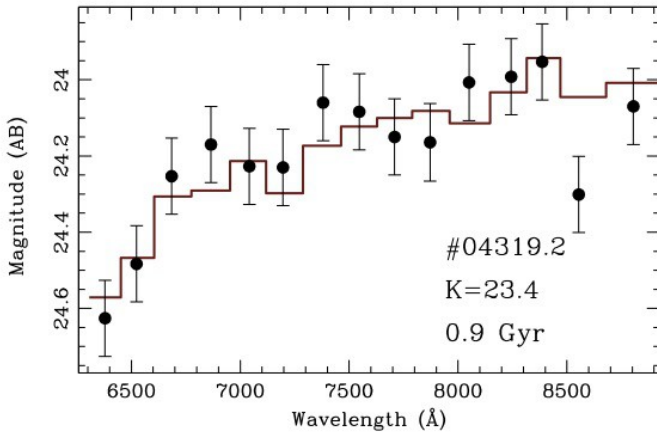


Broadband NUV-IR + SHARDS
 $\Delta z / (1+z) \sim 1\%$ with small scatter
(EAZY, Brammer et al. 2008)

Mapping 4000Å break region to probe stellar populations



An example



$z=0.67$

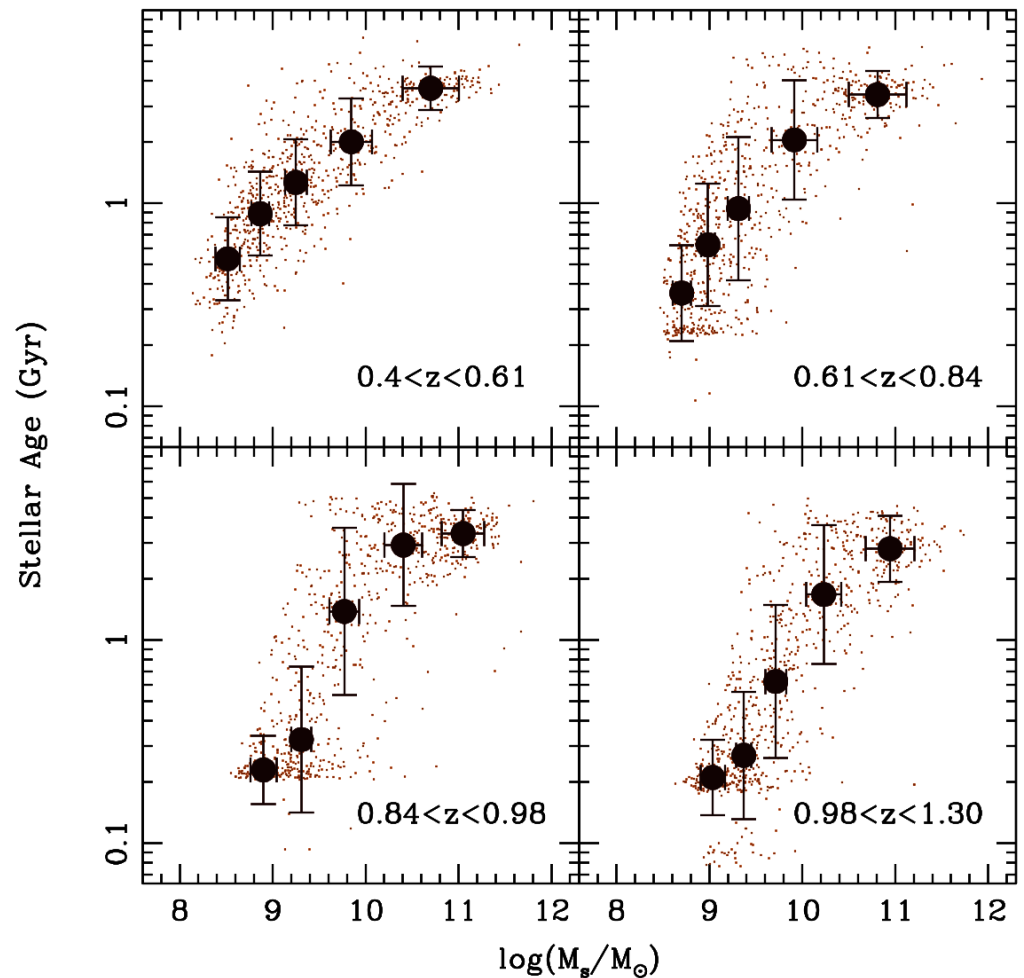
The global mass-age relation

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 ~ 250 massive ($>10^{11}M_{\odot}$) galaxies (after clean-up) and then look for satellites:

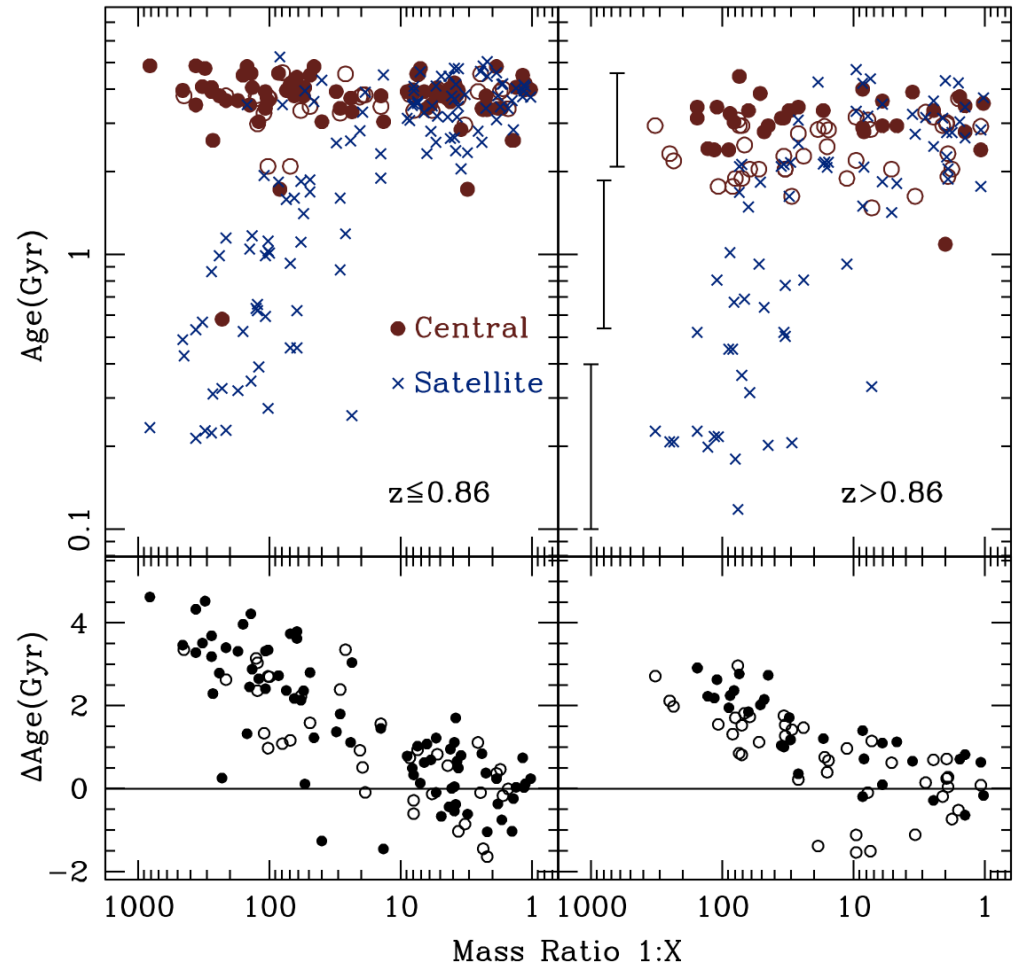
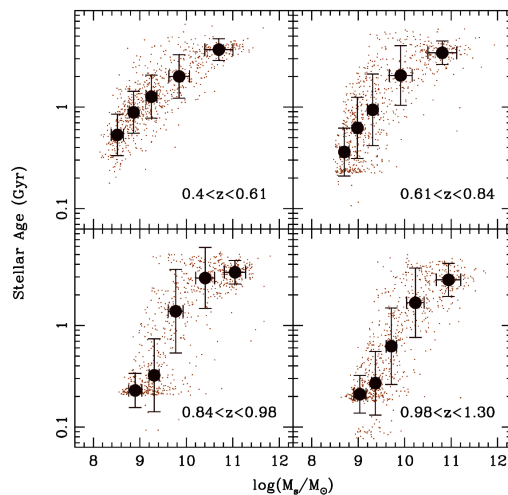
- Δz within 1% uncertainty
- $\Delta r < 100$ kpc (projection)



Central/Satellite age difference

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

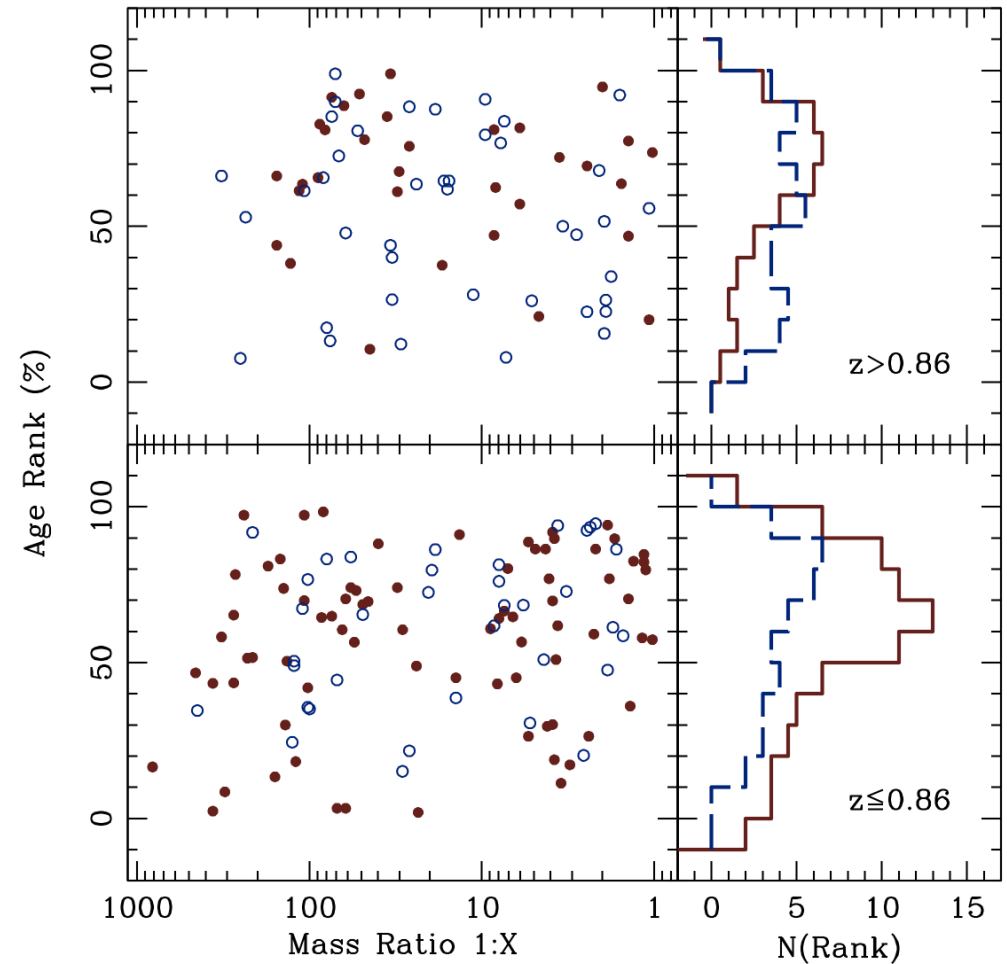
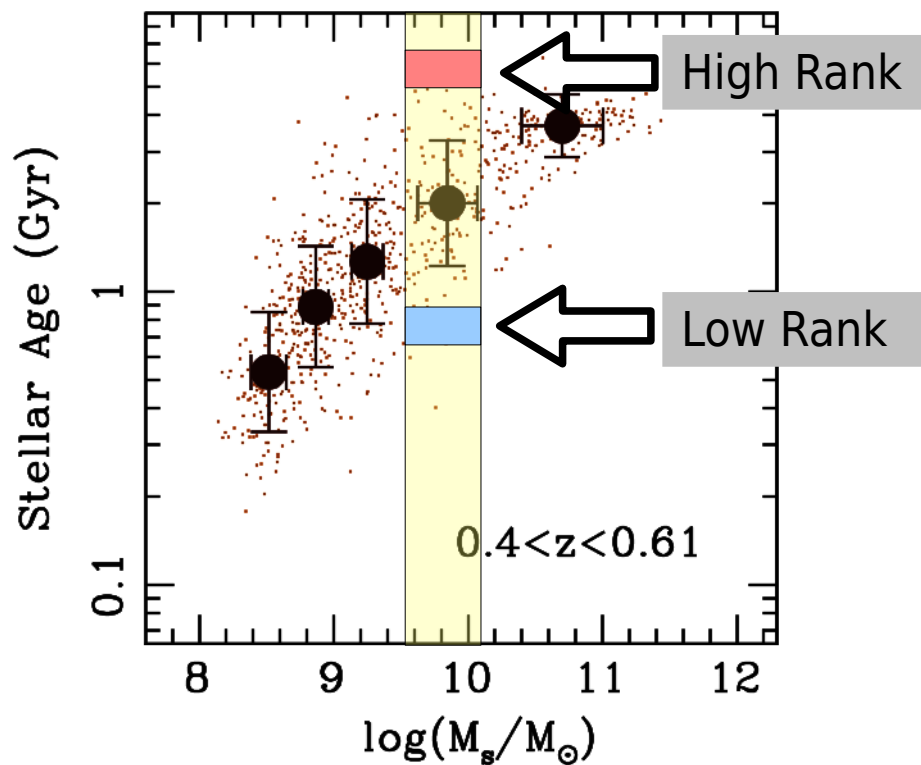
Is this difference the expected behaviour from the global mass-age trend?



Age differences compared with global trend

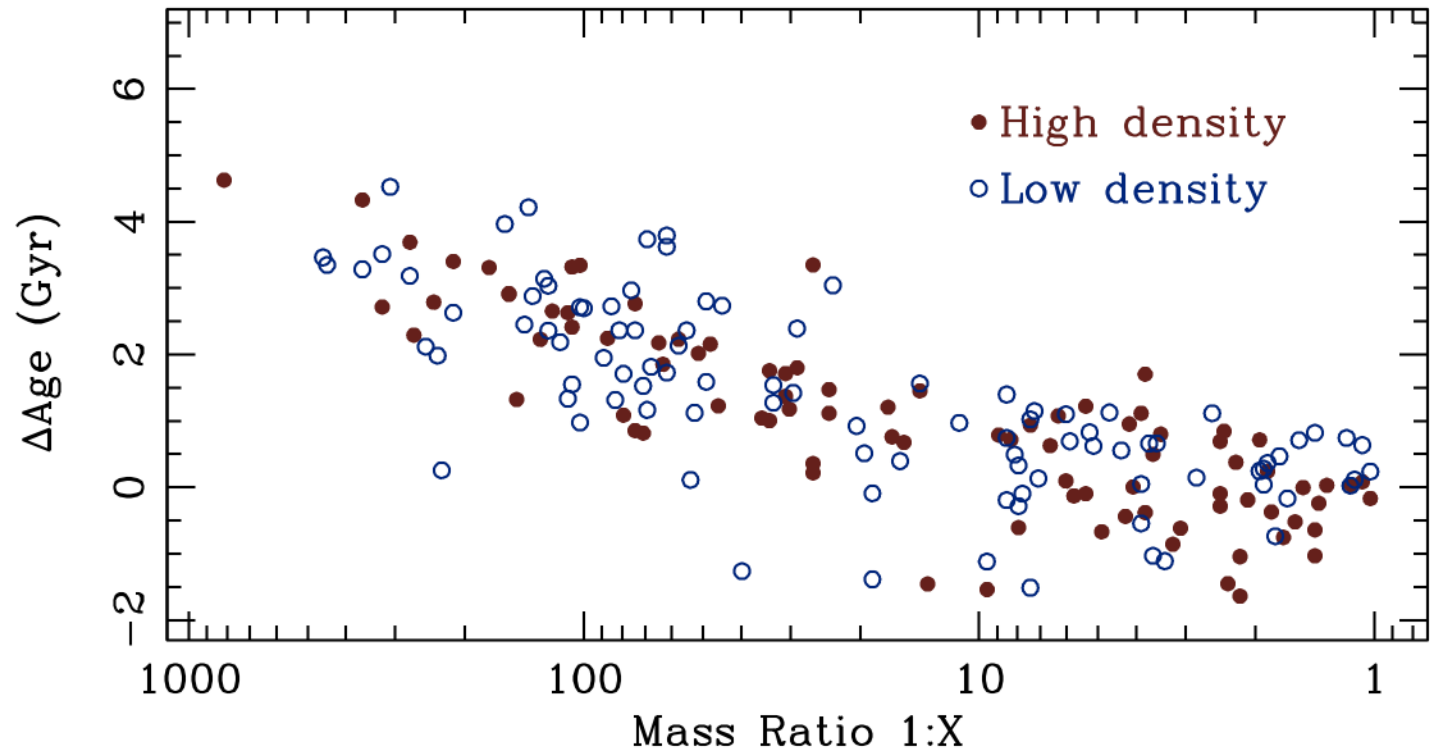
In order to test whether the age difference is biased with respect to the global mass-age relation, we obtain the rank within each mass bin.

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 ($\Delta r < 500 \text{ kpc}$), at the same redshift. No difference found either between “low” and “high” density regions.

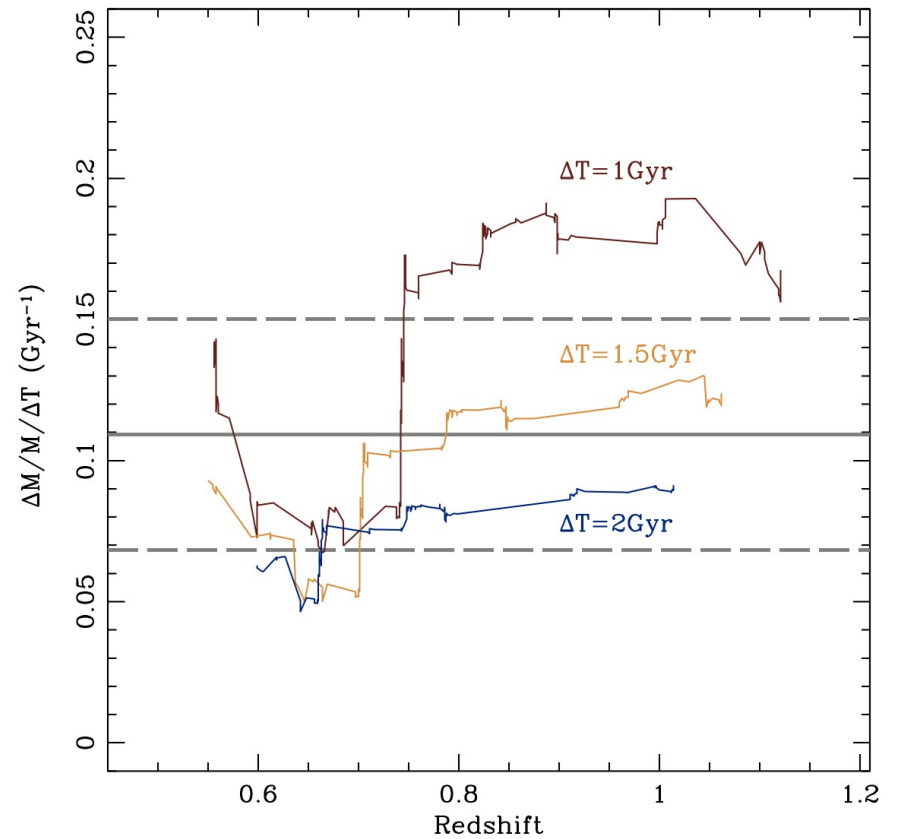
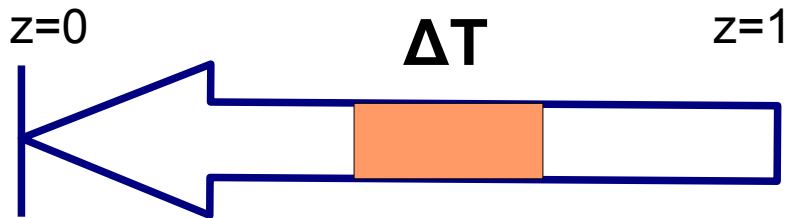


Mass growth from $z \sim 1$

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

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

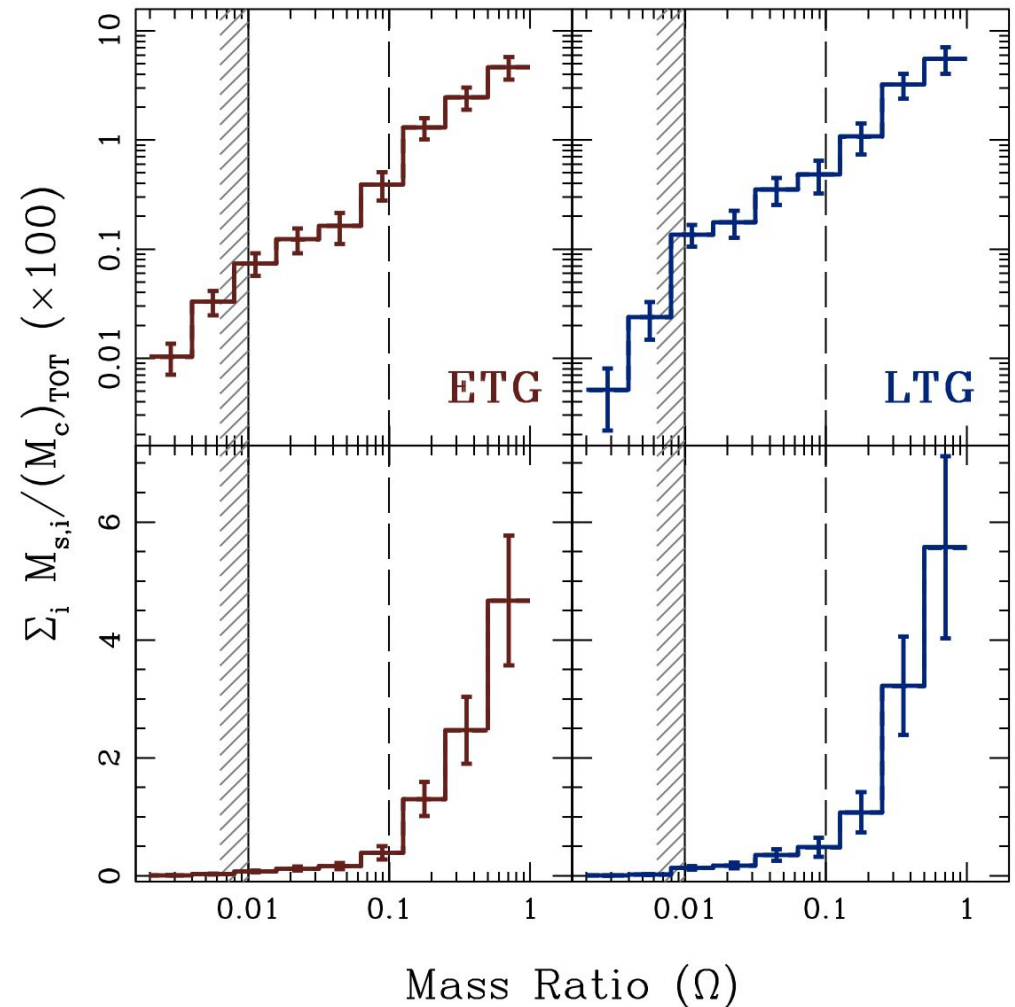
$$\frac{\Delta M_{z=1 \rightarrow 0}}{M_{z=1}} = 1.96 \pm 0.31$$



Any preferred growth channel?

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

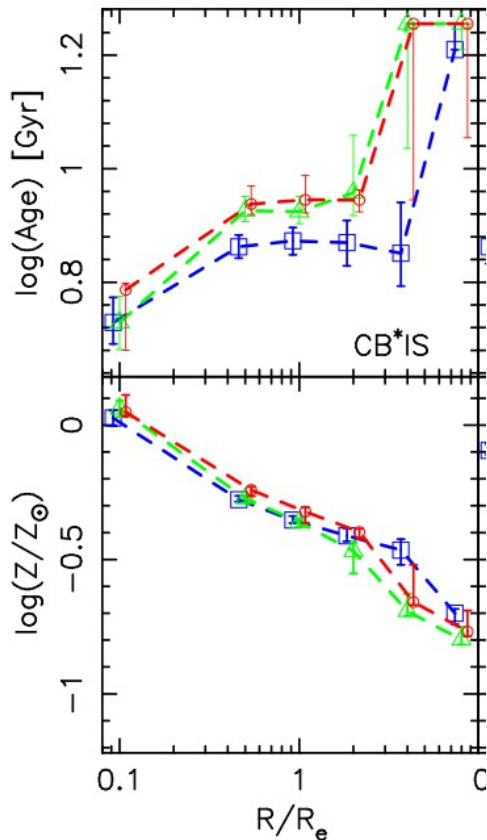
Clustering would mainly smooth out the high mass ratio peak, creating a plateau (in preparation)



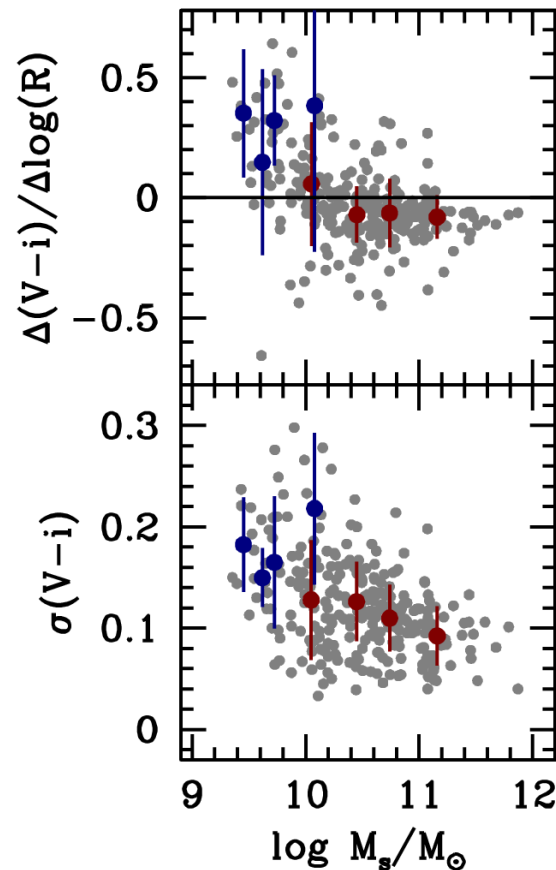
Back to major mergers?

After all, the mass growth would be compatible with a small amount of dry major mergers. Furthermore, 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 $z \sim 0.3-1.0$

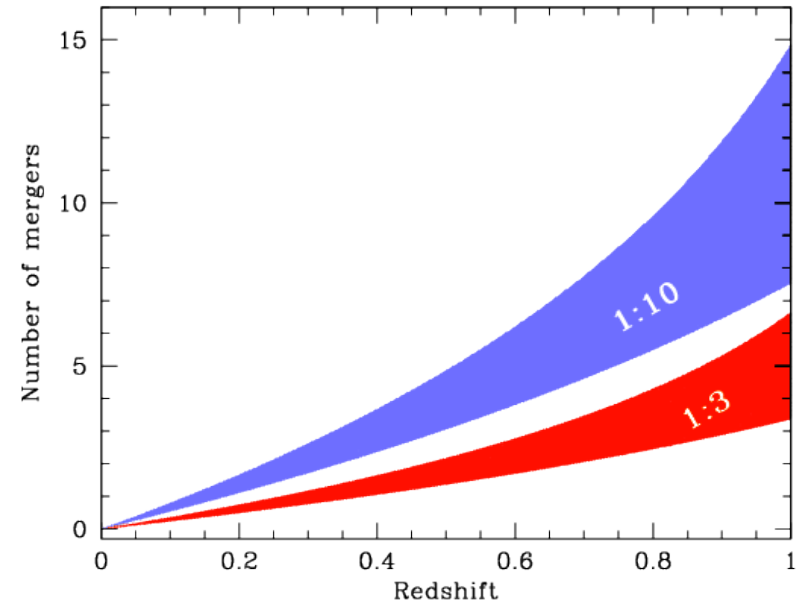
La Barbera et al. (2012)



Ferreras et al. (2009)



Trujillo et al. (2011)



Conclusions

Sample of massive galaxies ($\geq 10^{11} M_{\odot}$) from SHARDS

Selection of “pre-merger” systems (sat. with $\Delta r < 100 \text{ kpc}$, $\Delta z / (1+z) < 0.01$)

Stellar population analysis of $R \sim 50$ 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 at mass ratios $\geq 10:1$

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!