Structural properties and stellar populations of cluster and field early-type galaxies at z~1.3

Paolo Saracco

INAF- Osservatorio Astronomico di Brera
Milano

In collaboration with
A. Gargiulo[1], F. La Barbera[2], D. Marchesini[3]

[1]INAF – IASF, Milano
[2]INAF – OA Capodimonte, Napoli
[3]Tufts University, MA, USA

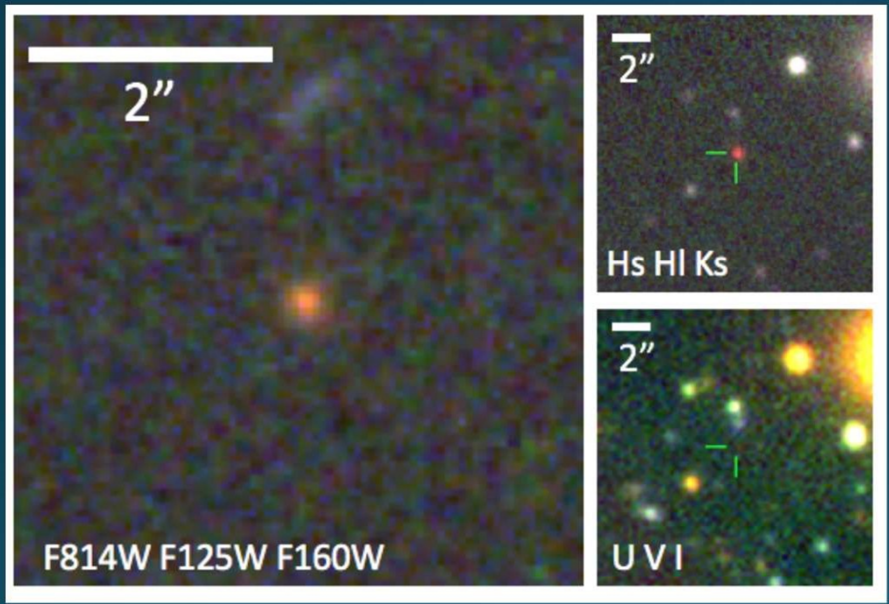
- Introduction: aim of the work
  - Why early-type (spheroidal) galaxies?
  - Why cluster vs field?
  - Why z>1?

- Cluster vs field ETGs at z~1.3
  - Results from imaging data: structural parameters, scaling relations
  - On going work on spectroscopic data: star formation history of cluster EGs and field dense EGs

- Conclusions

How have spheroidal galaxies been assembled? Who are their progenitors?

- The buildup of their stellar mass and their quenching are still matter of debate.
- Even recent models of galaxy formation come short in reproducing them at high-z.



Massive spheroid
$M \sim 10^{11}$ Msun
R_e=0.5 kpc
Mass density $\Sigma = 6 \times 10^4$ Msun/pc^2
z=3.7
age of the Universe 1.5 Gyr

Glazebrook et al. 2017, Nature

Aim: reconstructing the mass growth of spheroids studying their structure and star formation history at z~1.3

- Why clusters: high density of galaxies, large number of spheroidal galaxies → best suited for observations;
- Why cluster vs field: differences or *lack* of differences give insight on the mechanisms of mass assembly;
- Why z~1.3: to cut away a large fraction (~9 Gyr) of evolution; ground-based spectroscopy feasible with reasonable telescope time (~10 hrs)

Cluster and Field sample selection

Cluster sample 1.2<z<1.4

- XLSSJ0223 z=1.22 (23 EGs)
- RDCSJ0848 z=1.27 (16 EGs)
- XMMU2235 z=1.39 (17 EGs)

56 Elliptical galaxies (70% z_{spec})
(Saracco+14,17; Ciocca+17)

Field sample 1.2<z<1.4

- GOODS-South (31 EGs 1.2<z<1.4; 70% z_{spec}; Tamburri+14)
- COSMOS 1.0<z<1.2 (178 EGs; 20% z_{spec} ; Davies+15; Scarlata+07)
- CANDELS 1.2<z<1.4 (224 Egs; <5% z_{spec}; van der Wel+14; Huertas-Company+15)

Observed Spectral Energy Distribution (SED)

≥11 bands [0.38-8.0]μ VLT, LBT (UBVR), VISTA, HST(F775, F850, F160), Spitzer (3.6-8μ)

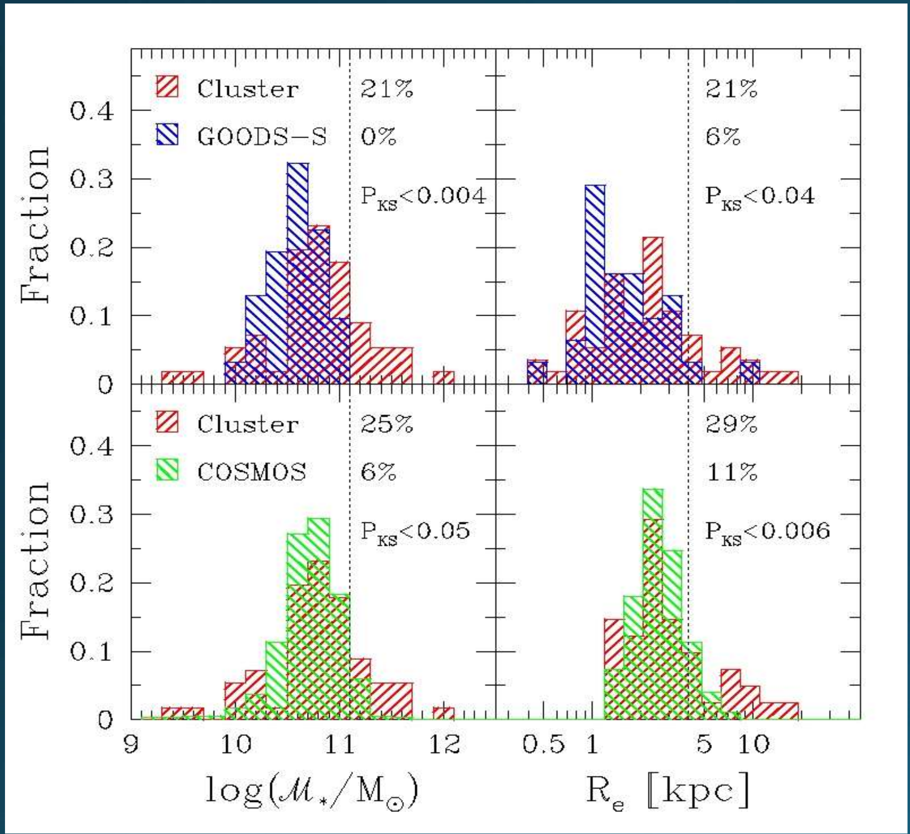
Selection criteria

z_{850}<24 ACS-F850LP

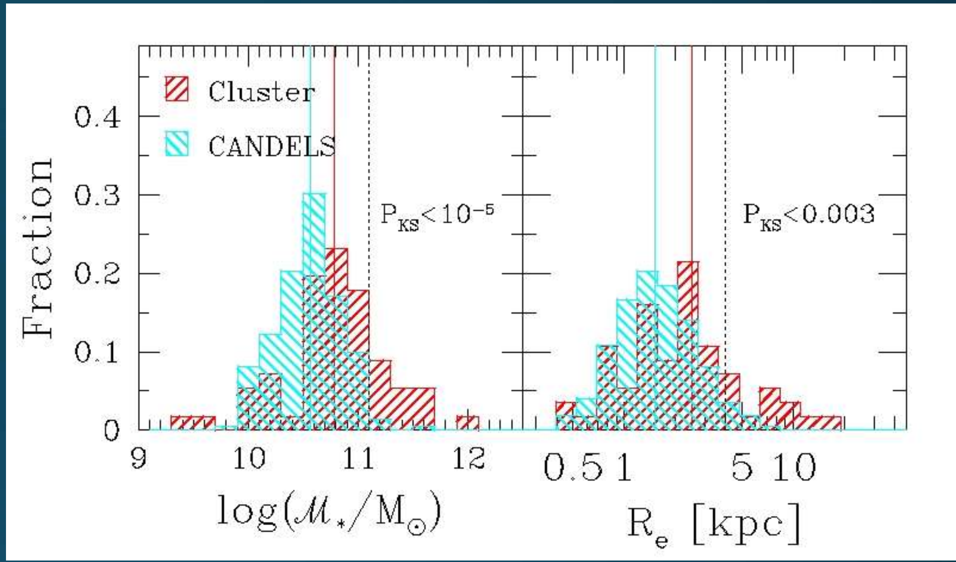
Elliptical/Spheroidal morphology

Morphology and structural parameters derived from HST-ACS images for all the galaxies (except for CANDELS)

Does the population of cluster EGs differ from the one in the field?



Saracco+17



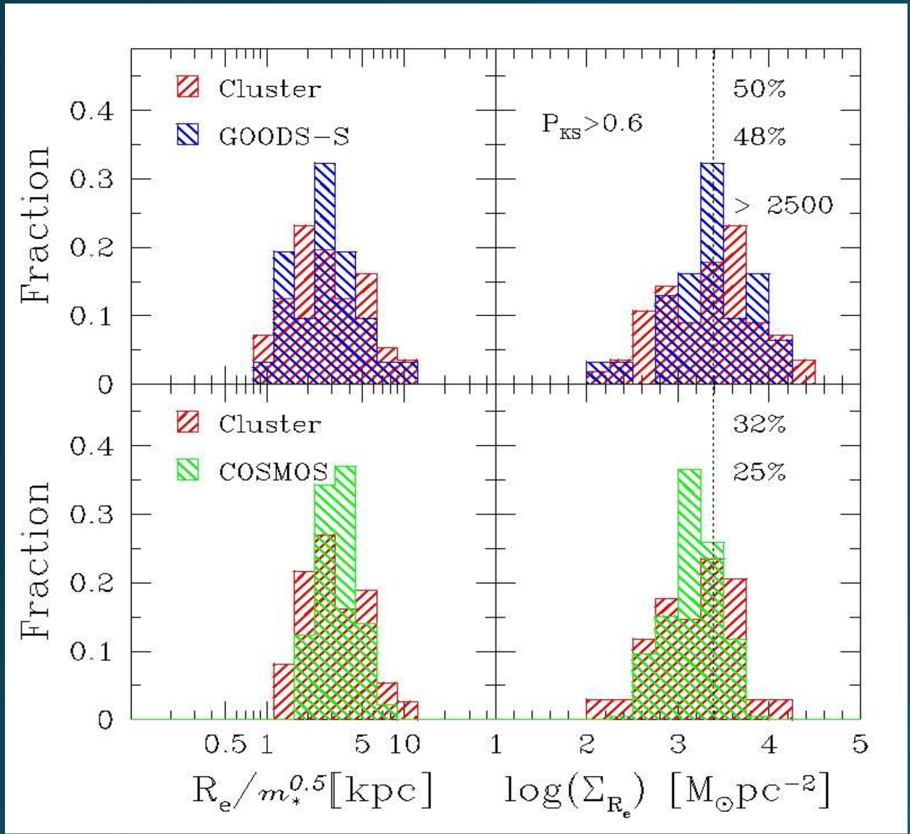
- Cluster EGs reach higher stellar masses and larger effective radius than field EGs.

Or

- There is a lack of massive and large EGs in the field with respect to cluster env.

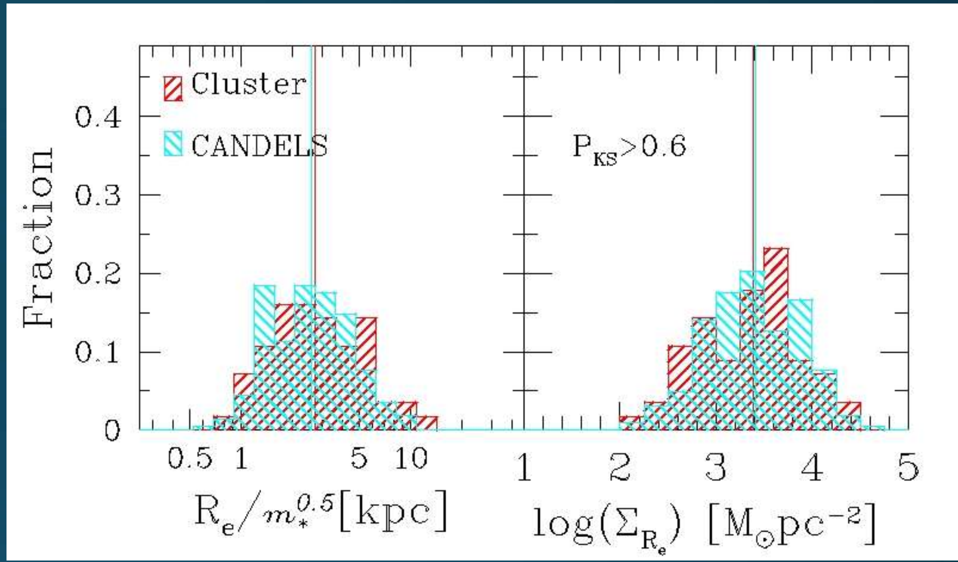
Differences significant at 3σ

Have cluster EGs different structure from field EGs?



$m = M_*/10^{11}$ Msun
Removes the dependence of R_e on mass.

$\Sigma_{Re} = \frac{1}{2} M_*/(\pi Re^2)$

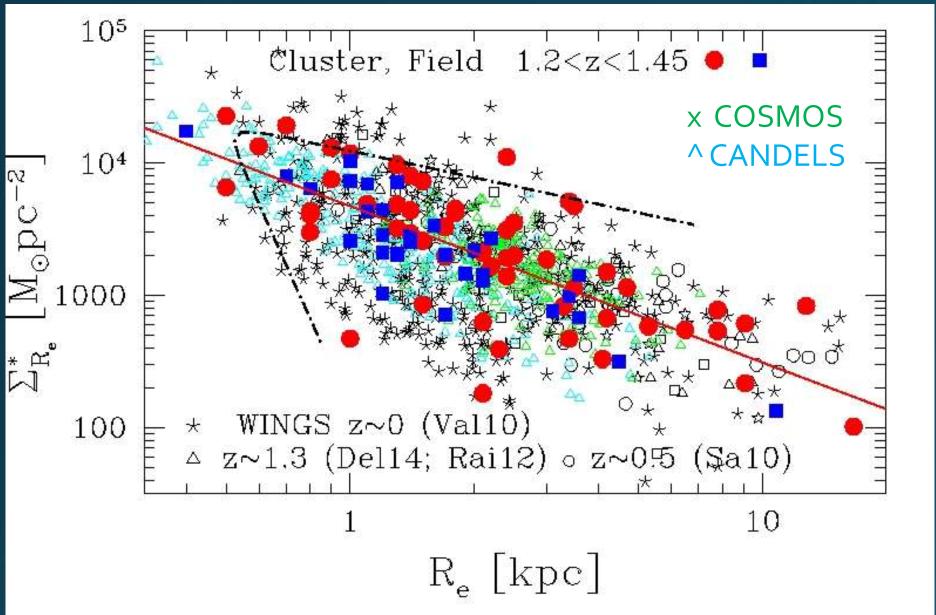


Saracco+17

- Cluster and Field EGs at z~1.3 have the same structure.

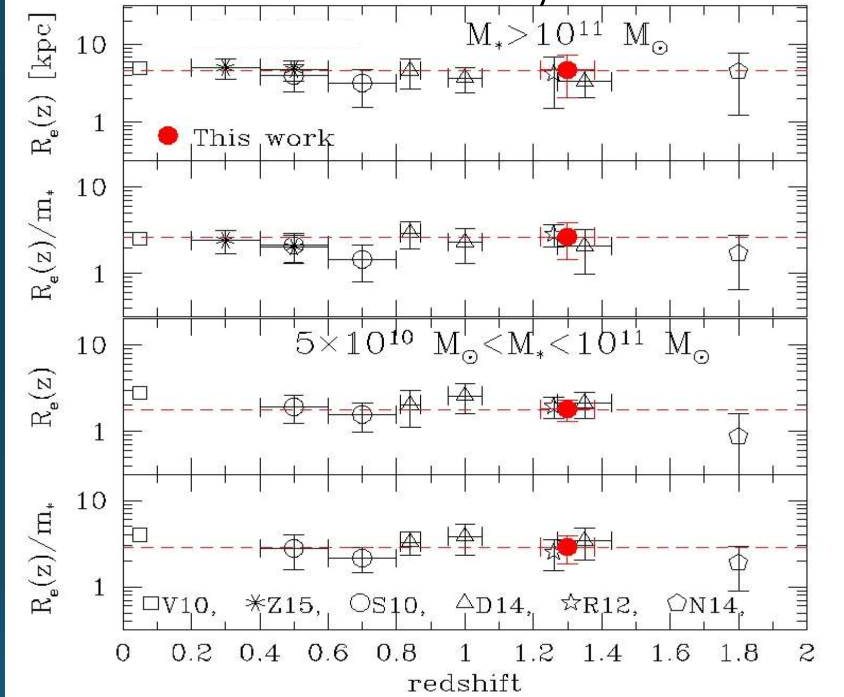
Evolution of Cluster and Field EGs since z=1.3

$$\langle \Sigma_e \rangle = \alpha' + \beta' \log(R_e)$$



Stellar mass density Σ_e=<μ_e>M/L

Clusters only



Valentinuzzi+10 (V10) - Zahid+15 (Z15) - Saglia+10 (S10)
Delaye+14 (D14) - Raichoor+12 (R12) - Newman+14 (N14)

No structural evolution of Cluster and Field EGs since z=1.3

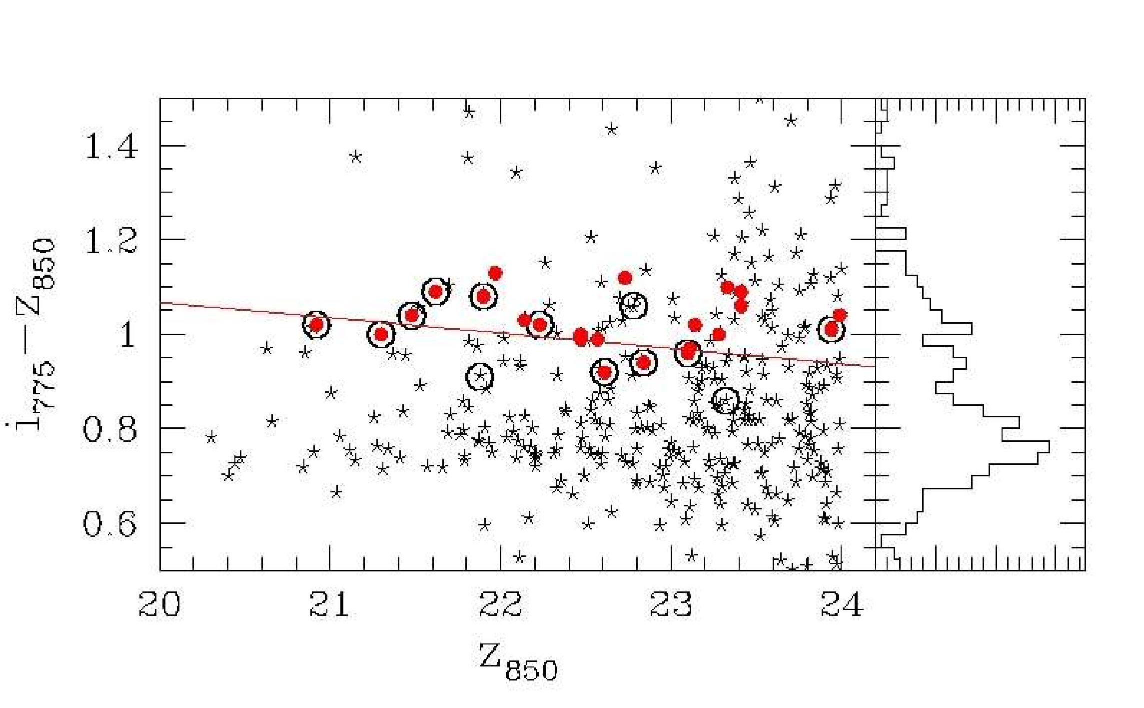
Further growth along the M-R-σ scaling relations. Dry minor merging negligible.

XLSSJ0223-0436 at z=1.22
LBT-MODS(1&2) spectroscopic observations

Slit width 1.2'', 8 hrs exposure, R~1150, FWHM~7.4 Å, σ_{inst}~113 km/s

2 masks
22 targets
(including fillers)

21/22 redshift



13 ETGs confirmed cluster members, 7 with ''high'' S/N....

XLSSJ0223-0436 LBT-MODS(1&2) spectra

Slit width 1.2’’, 8 hours exposure, R~1150, FWHM~7.4 Å, σ_{inst}~113 km/s

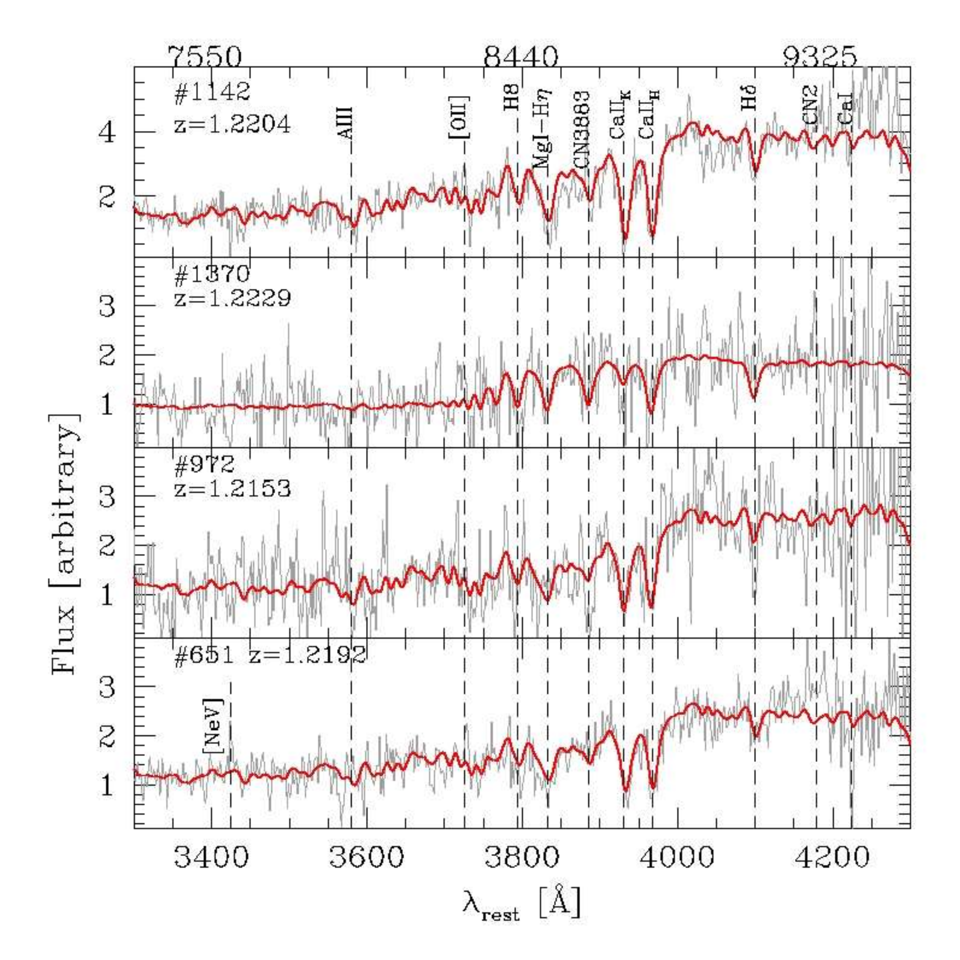
Velocity dispersion & redshift measurement

Ppxf spectral fitting (Cappellari et al. 2009)

MILES library

S/N(Å)=3-9 (~7-20 rest) at 3900-4100

Binned 3 Ang/pix



σ_e=213±38 km/s
R_e=9.2 kpc
logM*= 11.5 $M_\odot$
$\log M_{dyn}$=11.7 $M_\odot$

σ_e=230±80 km/s
R_e=0.8 kpc
logM*=10.1 $M_\odot$
$\log M_{dyn}$=10.7 $M_\odot$

σ_e=210±47 km/s
R_e=4.1 kpc
logM*=10.6 $M_\odot$
$\log M_{dyn}$=11.3 $M_\odot$

σ_e=220±38 km/s
R_e=3.5 kpc
logM*=10.9 $M_\odot$
$\log M_{dyn}$=11.3 $M_\odot$

SFR [OII] <1 $M_\odot$/yr

XLSSJ0223-0436 LBT-MODS(1&2) spectra

Slit width 1.2'', 8 hours exposure, R~1150, FWHM~7.4 Å, σ_{inst}~113 km/s

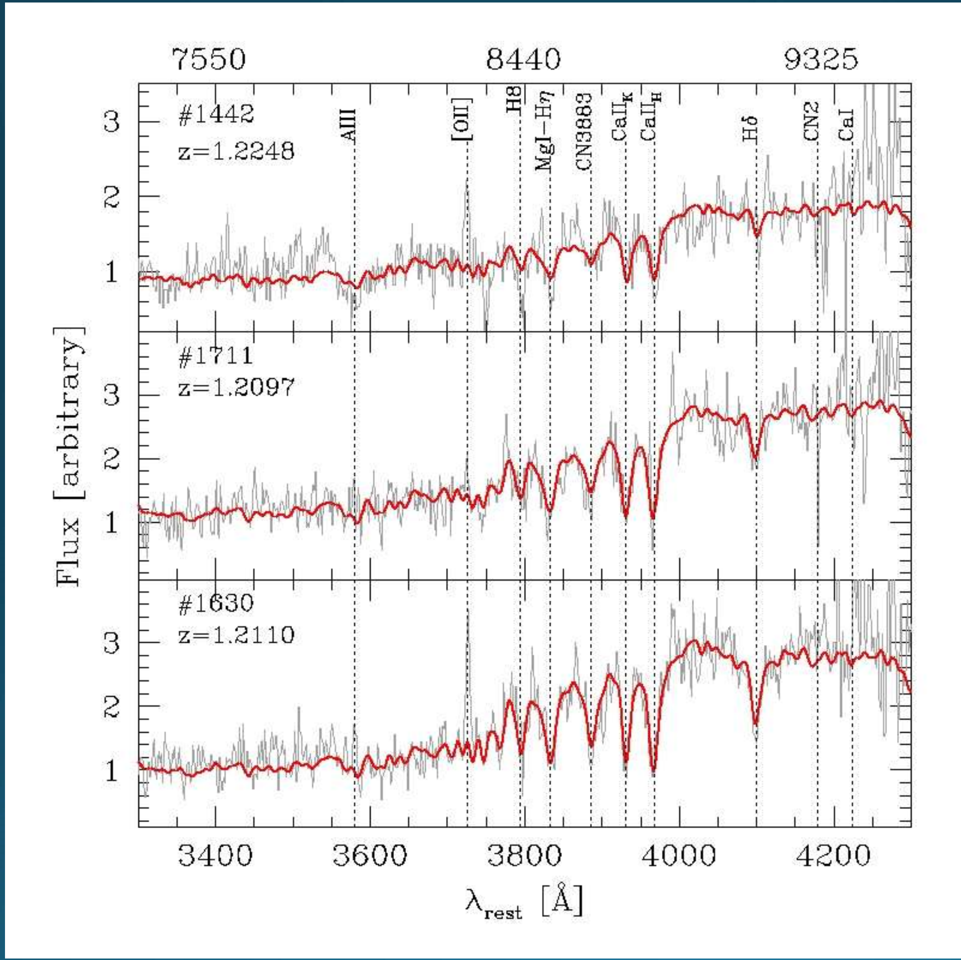
Velocity dispersion & redshift measurement

Ppxf spectral fitting (Cappellari et al. 2009)

S/N(Å)=3-9 (~7-20 rest) at 3900-4100

4/13 (30%) [OII] emission SFR<4 $M_\odot$/yr

(as in RDCSJ0848 at z=1.27; Jorgensen+14)



σ_e=198±50 km/s
R_e=1.0 kpc
logM*= 10.8 $M_\odot$
$logM_{dyn}$=10.7 $M_\odot$

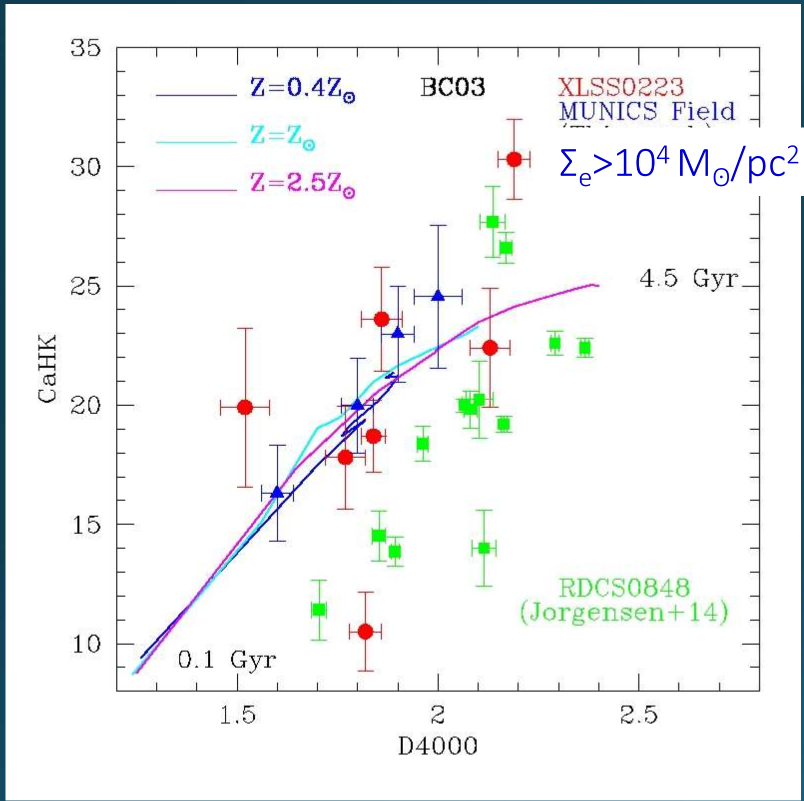
SFR [OII]
~3 $M_\odot$/yr

σ_e=247±23 km/s
R_e=4.7 kpc
logM*=11.2 $M_\odot$
$logM_{dyn}$=11.5 $M_\odot$

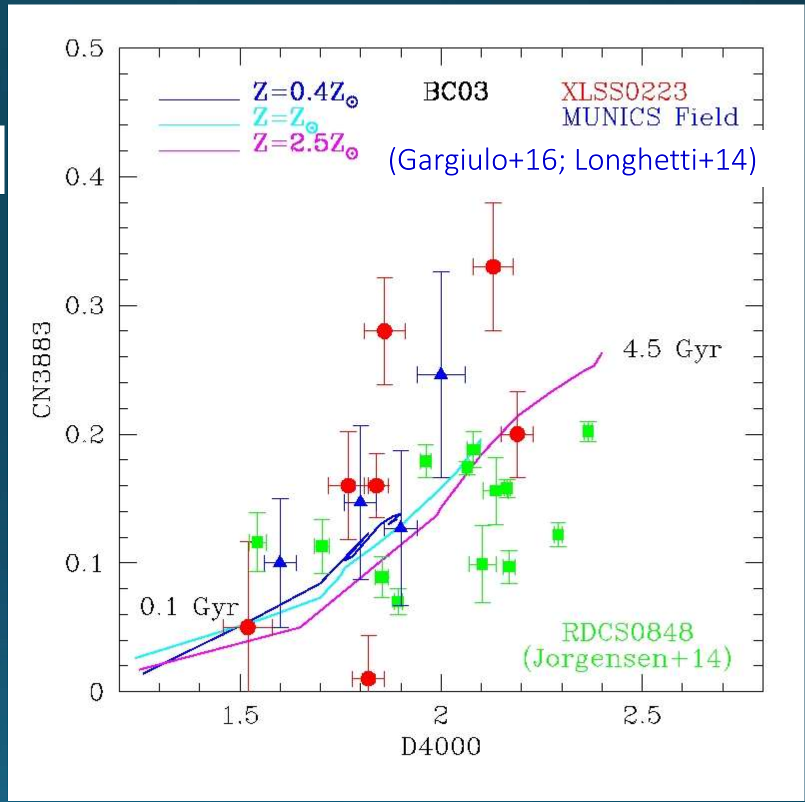
σ_e=198±42 km/s
R_e=3.3 kpc
logM*=10.8 $M_\odot$
$logM_{dyn}$=11.2 $M_\odot$

SFR [OII]
~4 $M_\odot$/yr

CLUSTER EGs vs FIELD (dense) EGs
Spectral indices



$\Sigma_e > 10^4\ M_\odot/pc^2$



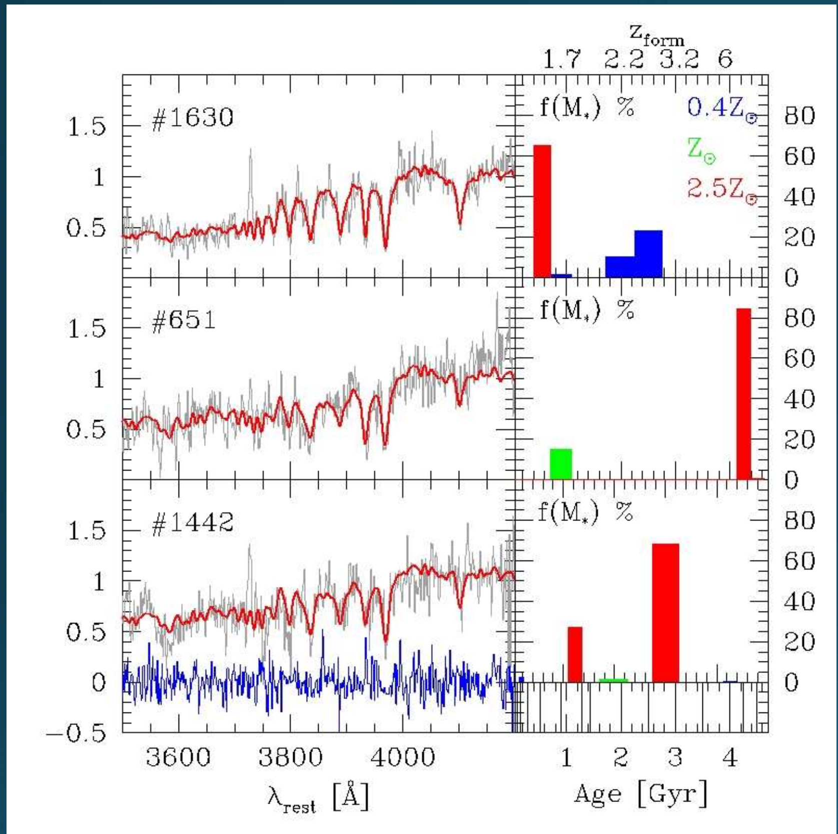
(Gargiulo+16; Longhetti+14)

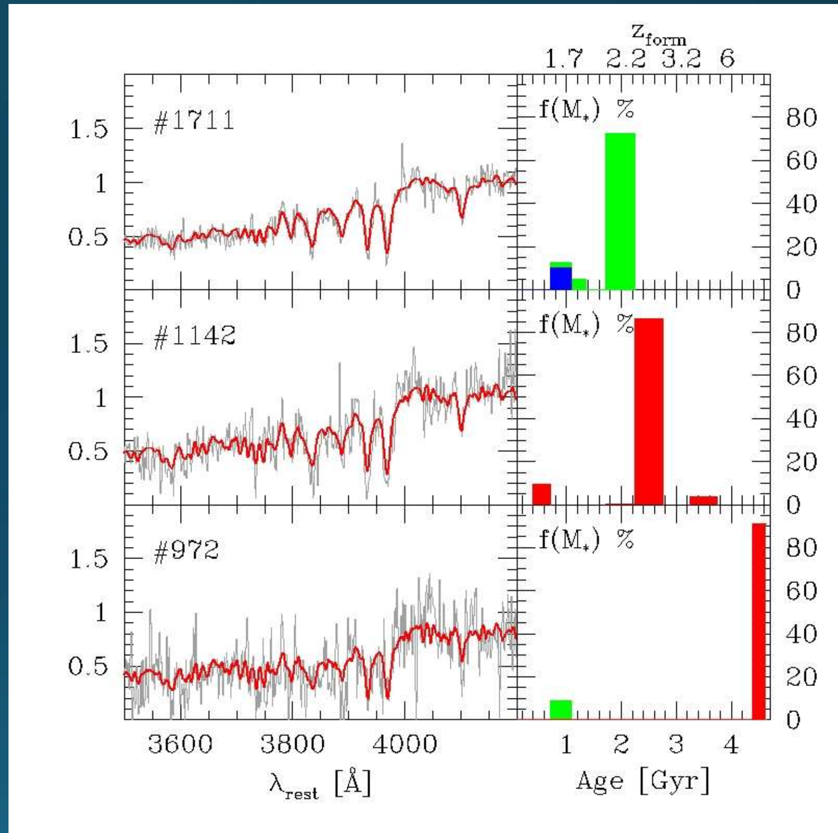
BC03
Models

Cha IMF

Large scatter, complex star formation histories, multiple stellar populations.
Sub-solar metallicity values disfavoured.

XLSSJ0223-0436 LBT-MODS(1&2) spectra
Spectral fitting





BC03 Models

Cha IMF

Main/multiple burst (not always short τ) + secondary bursts.
Z>Zsun favoured. Much different z_{form}

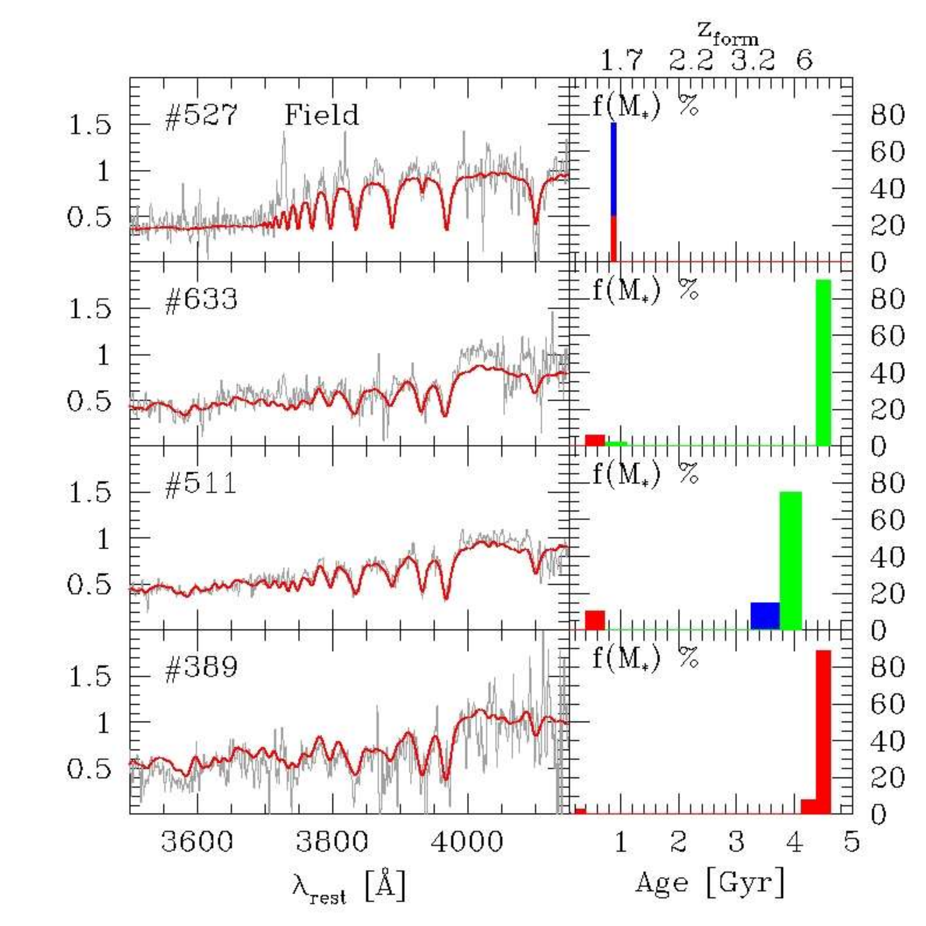
VLT-FORS2 spectra of DENSE field spheroids
MUNICS field

- Main/single burst
- short τ
- $Z \sim Z_{sun}$

Differences with cluster EGs:

- due to the different environment or to the different Σ_e?

Small statistics.



Gargiulo+16

σ_e=240±25 km/s
R_e=1.6 kpc
logM*= 11.14 $M_\odot$
logM_{dyn}=11.7 $M_\odot$
Σ_e=1.7x10^4 $M_\odot$/pc^2

σ_e=447±20 km/s
R_e=2.6 kpc
logM*=11.5 $M_\odot$
Σ_e=1.5x10^4 $M_\odot$/pc^2

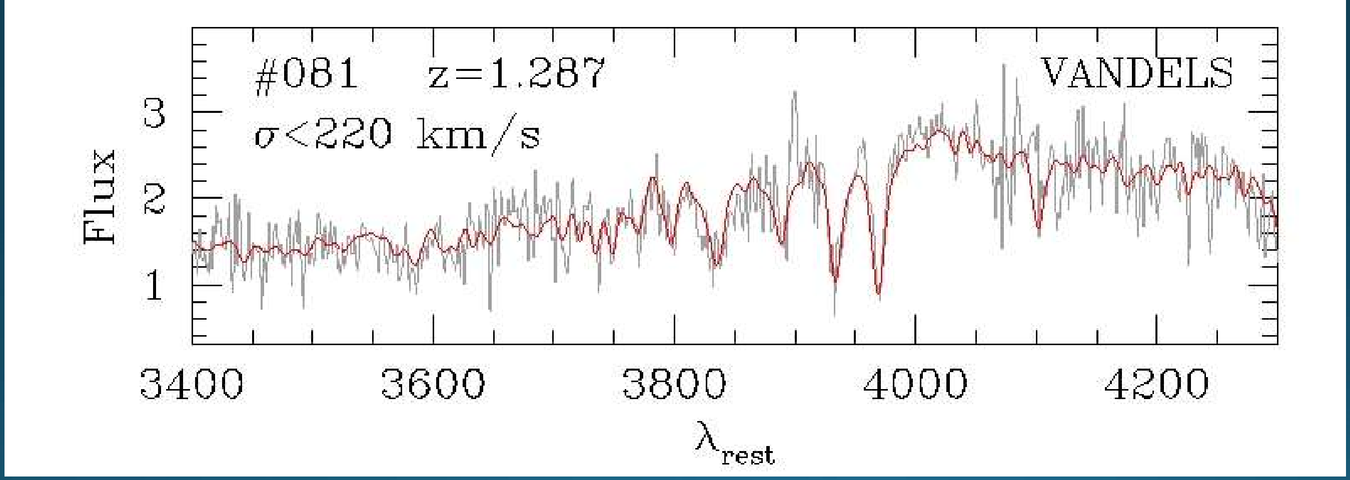
σ_e=281±30 km/s
R_e=2.1 kpc
logM*=11.1 $M_\odot$
Σ_e=1.0x10^4 $M_\odot$/pc^2

σ_e=234±38 km/s
R_e=2.1 kpc
logM*=11.14 $M_\odot$
Σ_e=1.1x10^4 $M_\odot$/pc^2

Larger sample of spectra of field EGs under construction

VANDELS z>1 spectra, R~600, FWHM~14 Ang, σ_{inst}~220 km/s

- kinematics for $M>10^{11}$ M_{sun}
- suited for star formation history



Summary

Structure of cluster and field spheroidal galaxies

- The structure of spheroids does not depend on the environment.
- Dense environment seems to be more efficient in assembling high-mass ellipticals.

- The structure of ellipticals does not change with time. Their growth takes place along the scaling relations: M, Re and σ change accordingly.

→ minor dry-merging negligible since z~1.3.

Stellar populations in cluster and field spheroids

- Cluster EGs: different (complex) SFHs, different τ, not single stellar population. Z>Zsun favoured. Large spread in z_{form}.
- Field dense EGs: main/single burst, short τ, Z~Z_{sun}.

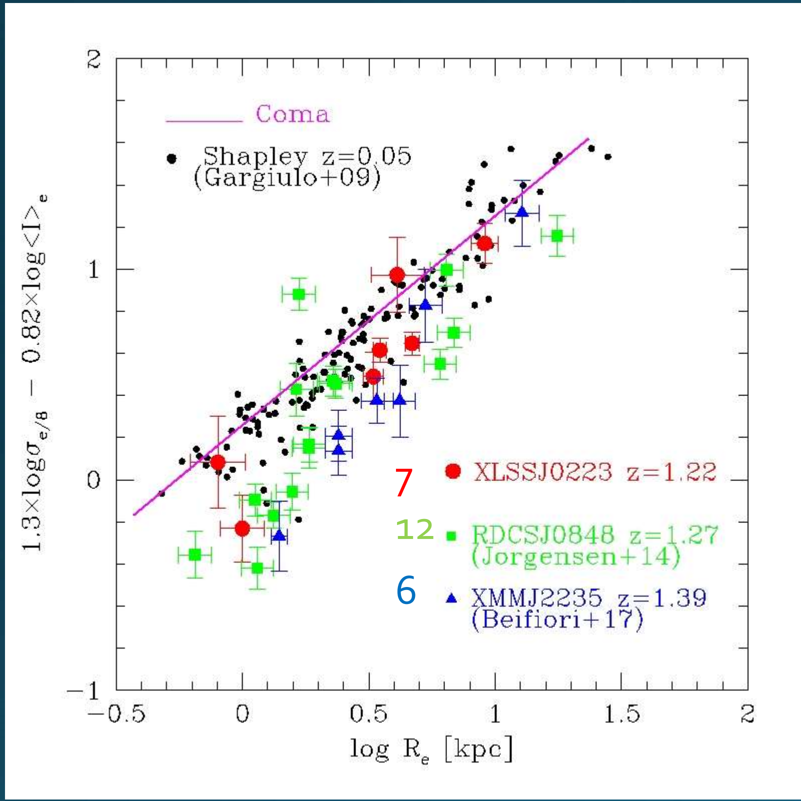
Dense (field) EGs ←→ short/single burst
Non dense (cluster) EGs ←→ longer/multiple bursts

Or Environment ?

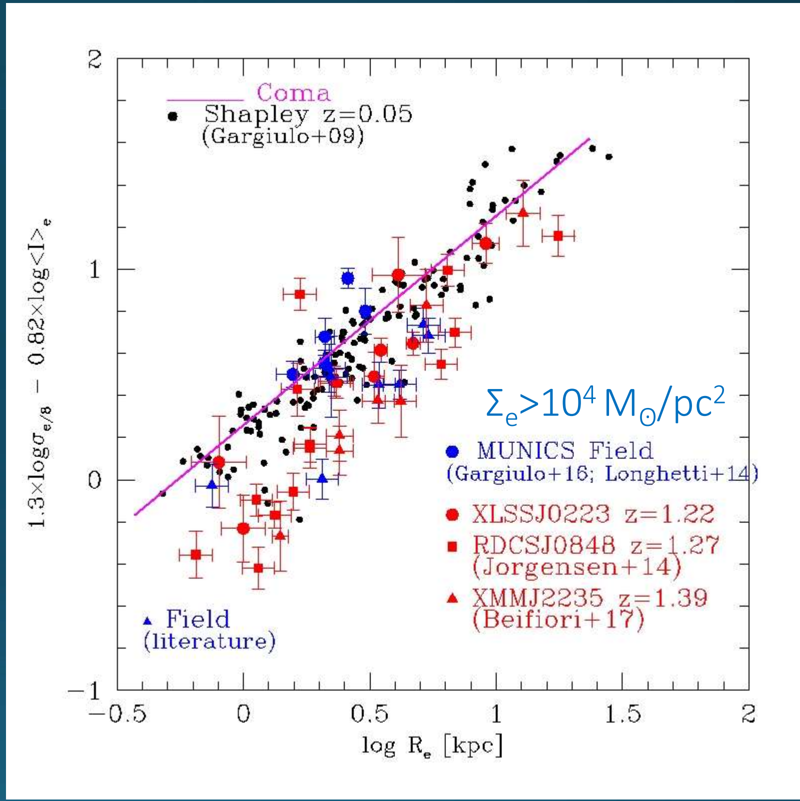
Thank you!

Fundamental plane of ETGs at z~1.3

Cluster ETGs



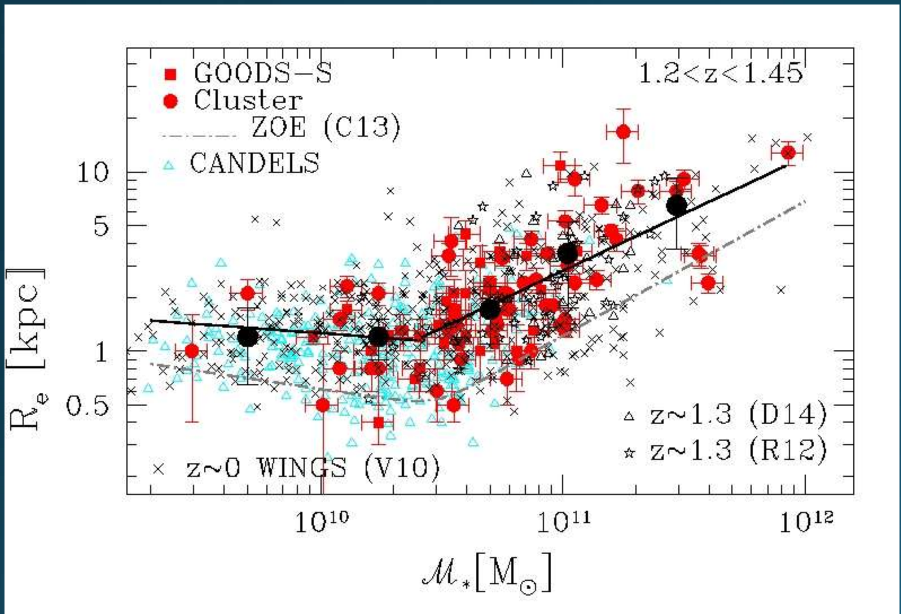
Cluster & Field ETGs



$$\mathrm{Log}(Re) = 1.1\mathrm{xLog}(\sigma_e)\text{-}0.6\mathrm{xLog}(I_e)\text{-}0.13$$

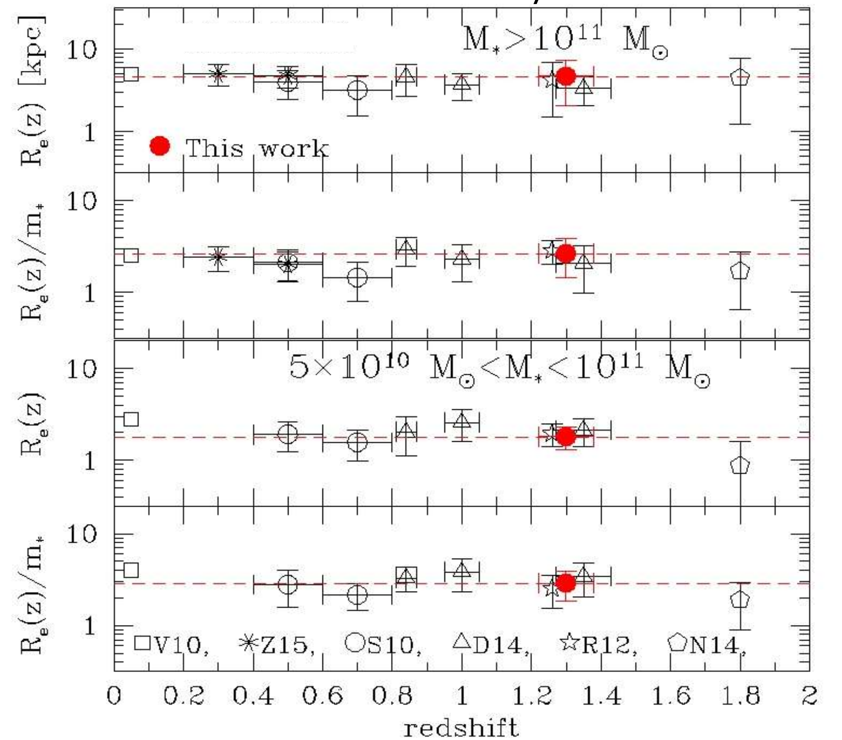
Variation of the M/L along the plane (age-mass rel)

Evolution of Cluster and Field EGs since z=1.3



Saracco+17

Clusters only



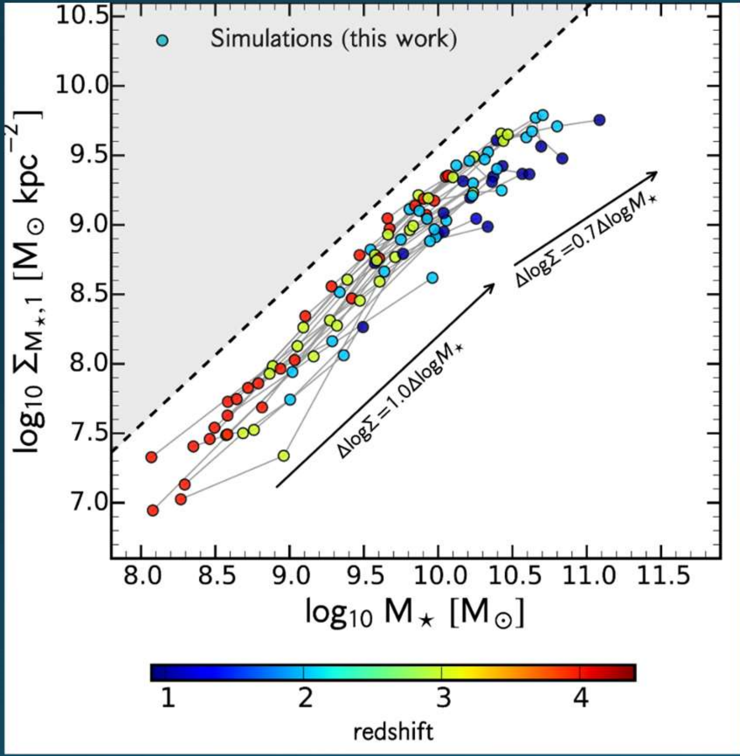
Valentinuzzi+10 (V10) - Zahid+15 (Z15) - Saglia+10 (S10)
Delaye+14 (D14) - Raichoor+12 (R12) - Newman+14 (N14)

No structural evolution of Cluster and Field EGs since z=1.3

(agreement with Jorgensen+14 and Woodrum+17; contrast with conclusions of Beifiori+17)

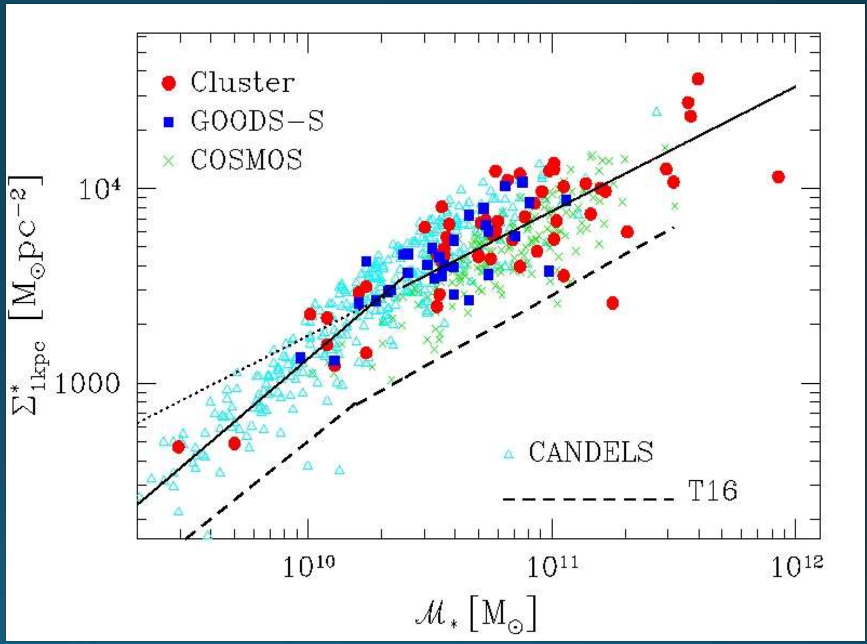
Mass growth, quenching and galaxy central regions

Central stellar mass density Σ_{1kpc} (<1kpc)



(Tacchella+16)

Early-type galaxies 1.2<z<1.5.



(Saracco+17)

Simulations suggest that quenching occurs once a specific value of central density is reached. Causal physical link or «side effect» ?