Discerning assembly from evolution in ellipticals at z~1.3

Paolo Saracco[1]
Marcella Longhetti[1], Adriana Gargiulo[1],
Ilaria Lonoce[1,2], Sonia Tamburri[1,2], Federica Ciocca[1,3],
Alessandra Casati[1,4]

And the contribution of

Bianca Poggianti[5], Mauro D'Onofrio[6], Gianni Fasano[5]
and the WINGS team

[1]*INAF – Osservatorio Astronomico di Brera, Milano*
[2]*Univ. Statale dell'Insubria, Como*
[3]*Univ. Bicocca, Milano*
[4]*Univ. Statale, Milano*
[5]*INAF – Osservatorio Astronomico di Padova*

Outline

- Introduction
  - Evolution of the mean effective radius of the population of ETGs/passive galaxies
  - ETGs and passive galaxies
- Scaling relations of cluster ellipticals at z~1.3
  - The size-surface brightness (Kormendy) relation
  - The size-stellar mass relation
- Cluster vs field ellipticals at z~1.3 (preliminary)
- Conclusions

Evolution of the mean effective radius (Re) of the population of ETGs/passive galaxies

Field

$$R_e \propto (1+z)^{-1}$$

Trujillo et al. 2011; Cimatti et al. 2012; Huertas-Company et al. 2013

$$R_e \propto (1+z)^{-1.9}$$

Damjianov et al. 2011

Comparison local sample: SDSS

Cluster

$$R_e \propto (1+z)^{-0.5}$$

Delaye et al. 2013; Huertas-Company et al. 2013

Two ways of understanding this evolution

Evolution of the Re of individual galaxies with time

Ellipticals continue to growth and to change across the time.

Newly quenced galaxies change the mean Re of the population with time

Ellipticals do not change their structure with time.

Evolution of the mean effective radius (Re) of ETGs "or" of passive galaxies?

ETGs = E+E/S0

Passive galaxies (z~1)= disks(30-40%) + ETGs (60-70%)

Ilbert 2010; van der Wel 2011; Cassata 2011; Tamburri in prep.

Passivity: **sSFR**=SFR/M*<(e.g.)$10^{-11}yr^{-1}$
varying with time, strongly dependent on the IMF *(See Poster Tamburri et al.)*

Disks = progenitors (hierarchical scheme)
E+E/S0 = relics of merging, descendants (hierarchical scheme)

Who is evolving?
What kind of evolution?

Aim

Assessing whether **individual Elliptical Galaxies (EGs) at z~1.3-1.4 have**

→ **completed their mass growth or**

→ **they significantly increase their mass and/or size till z=0.**

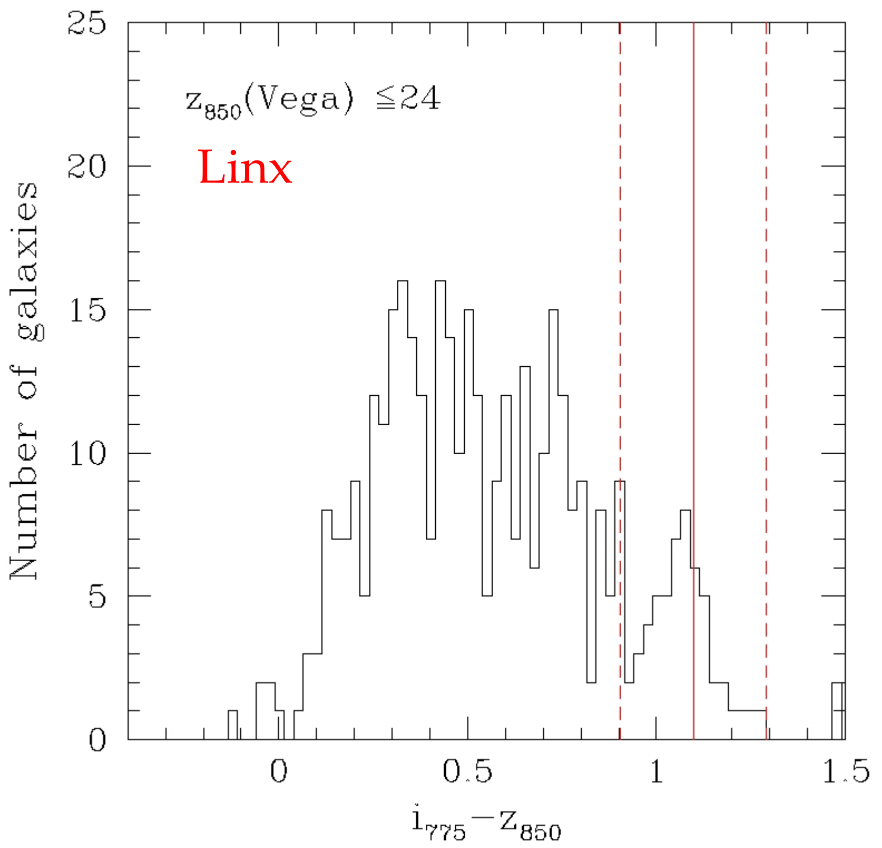
Local comparison samples of cluster ellipticals:

- Coma cluster Ellipticals (~140 EGs)
  (*Jorgensen et al. 1995*)
- Wide-field Nearby Galaxy Cluster Survey (WINGS, ~900 EGs)
  (*Valentinuzzi et al. 2010*)

RDCS 0848+4453 (Linx) z=1.27 (Stanford et al. 1997)
XMMU 2235-2557 z=1.39 (Rosati et al. 2009)

Selection criteria:

- **z_{850}<24** (ACS-F850LP)
- Dist<1Mpc **(407/350 gal)**
- 0.9<i_{775}-z_{850}<1.3 **(57/50 gal)**
  (UV-U)$_{rest}$
- Elliptical morphology **(16/17 EGs)**
  (visual analysis of
  F850LP images + 2D residuals)

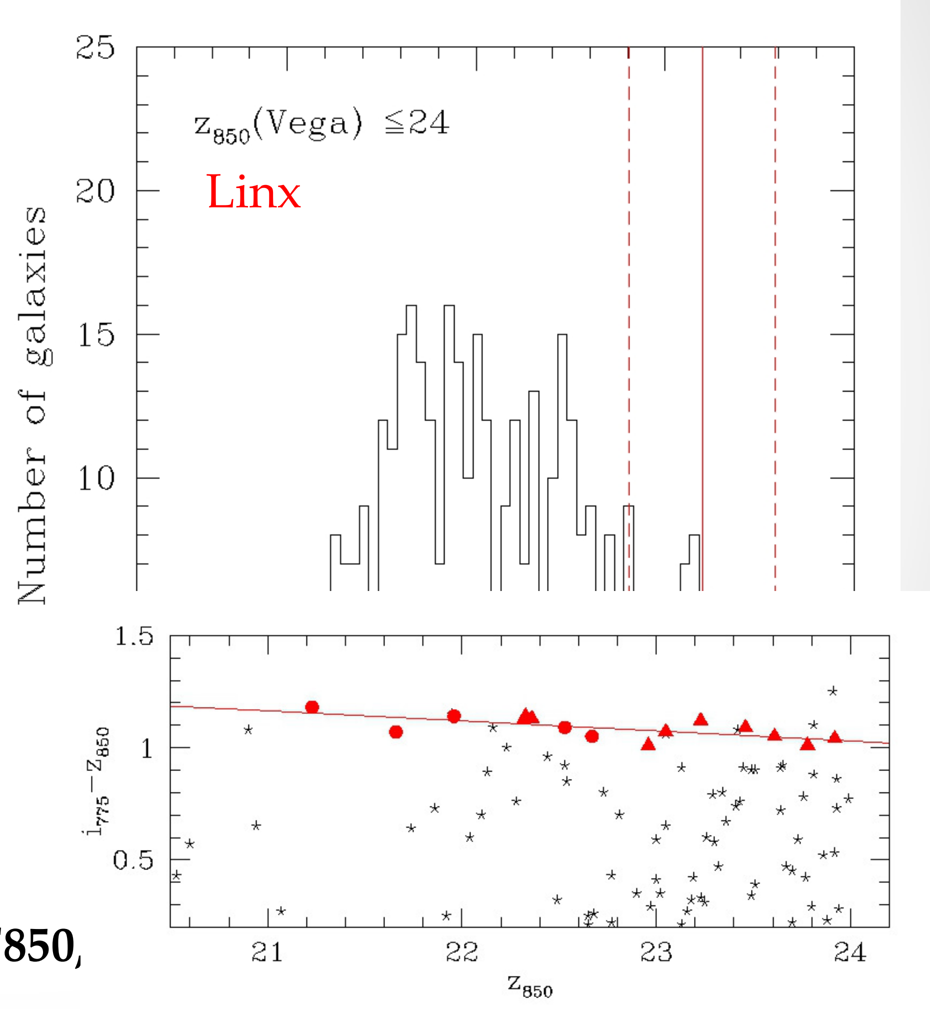


11 bands (0.3-8.0μ):
LBT (UBVR, proprietary), HST(F775, F850, F160), Spitzer (3.6-8μ)

RDCS 0848+4453 (Linx) $z=1.27$ (Stanford et al. 1997)
XMMU 2235-2557 $z=1.39$ (Rosati et al. 2009)

Selection criteria:

- **z_{850}<24** (ACS-F850LP)
- Dist<1Mpc **(407/350 gal)**
- $0.9<i_{775}-z_{850}<1.3$ **(57/50 gal)**
  $(UV-U)_{rest}$
- Elliptical morphology **(16/17 EGs)**
  (visual analysis of
  F850LP images + 2D residuals)



11 bands (0.3-8.0μ):
LBT (UBVR, proprietary), HST(F775, F850,

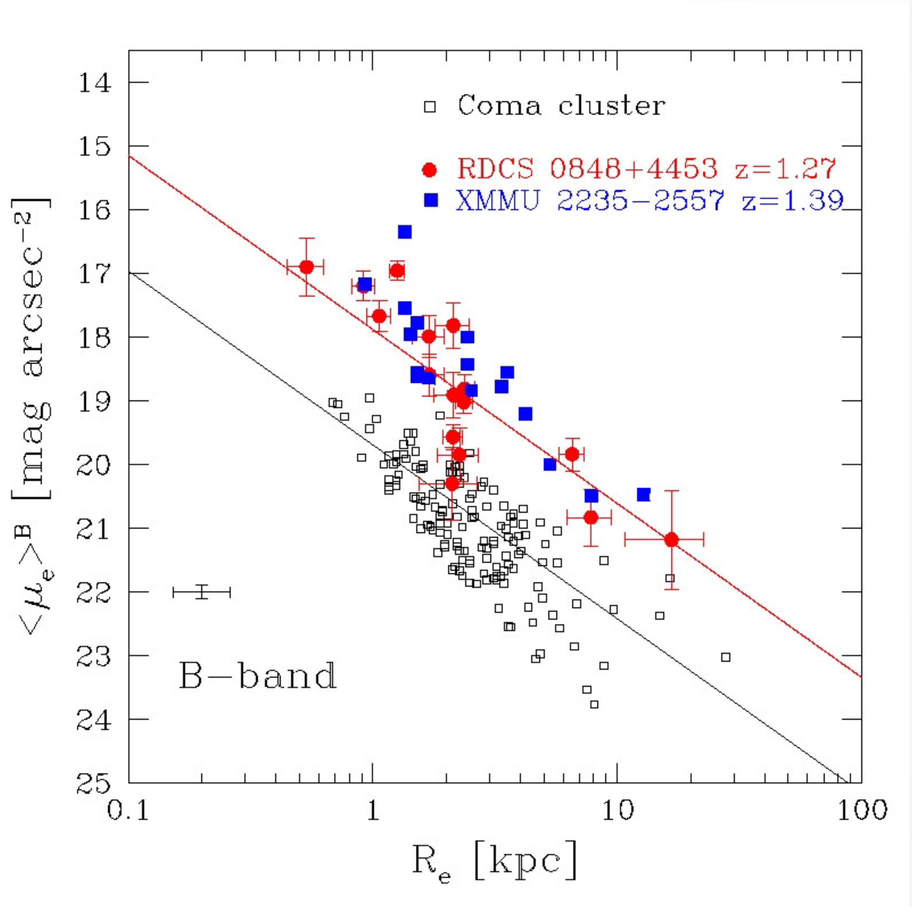
The Kormendy relation at z=1.3 (cluster ellipticals)

RDCS 0848+4453
16 Es z=1.27

XMMU 2235-2557
17 Es z=1.39

Passive luminosity evolution computed for each galaxy.

BC03
CB07
MA05
IMFs: Salpeter/Chabrier



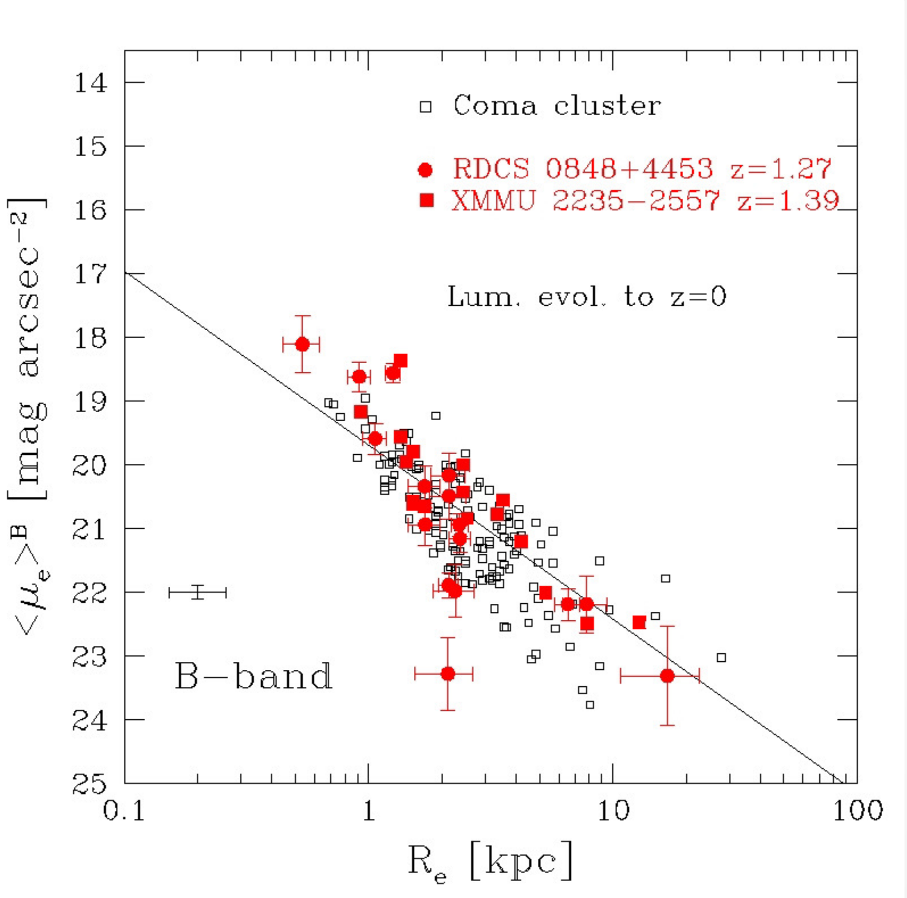
The Kormendy relation at z=1.3 (cluster ellipticals)

RDCS 0848+4453
16 Es z=1.27

XMMU 2235-2557
17 Es z=1.39

Passive luminosity evolution computed for each galaxy.

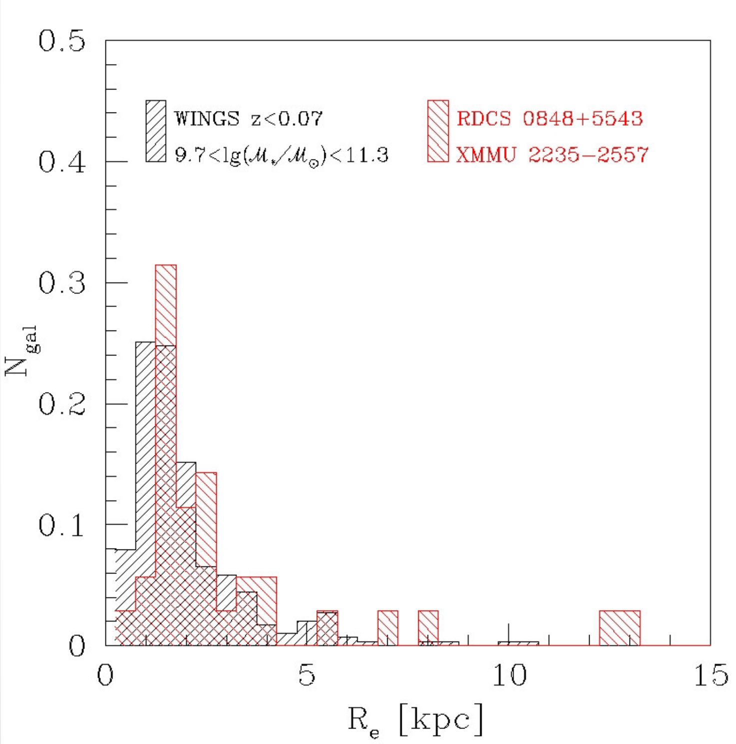
BC03
CB07
MA05
IMFs: Salpeter/Chabrier

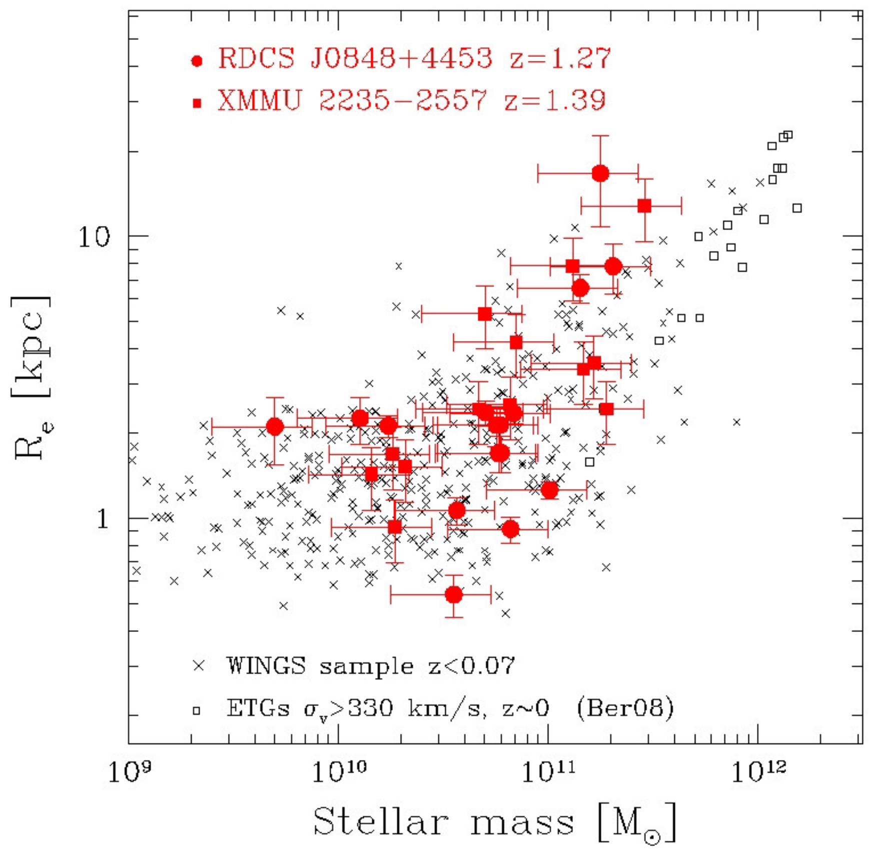


Passive luminosity evolution of the stellar mass already assembled at z=1.3 would bring EGs on the local KR.

What about the size-mass relation of cluster EGs at z=1.3?

WINGS survey (Valentinuzzi et al. 2010)
~900 cluster E+E/S0 at z=0





Same size-mass distribution in EGs at z=1.3 and at z=0

Cluster elliptical galaxies at z~1.3 follow the local scaling relations → they are similar to local cluster ellipticals of equal mass.

Which kind of evolution can they experience till z=0 to remain on the scaling relations ?

Can z~1.3 cluster EGs increase (only) their effective radius ?

Pure size evolution

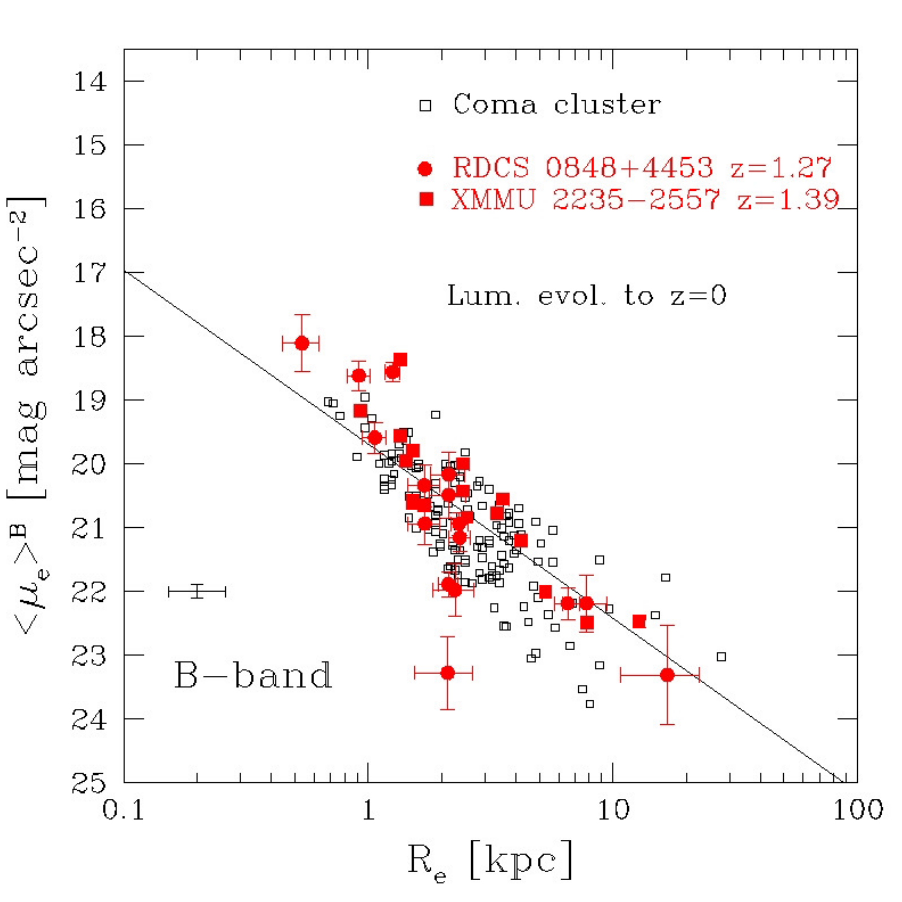
$$\langle \mu_e \rangle = M + 2.5\log(R_e^2) + 38.57$$

Size evolution cluster galaxies

$$R_e \propto (1+z)^{-0.5}$$

Delaye et al. 2013

Re(z=0) = 1.5 Re(z=1.3)
μe(z=0) 0.9 mag fainter



Can z~1.3 cluster EGs increase (only) their effective radius ?

Pure size evolution

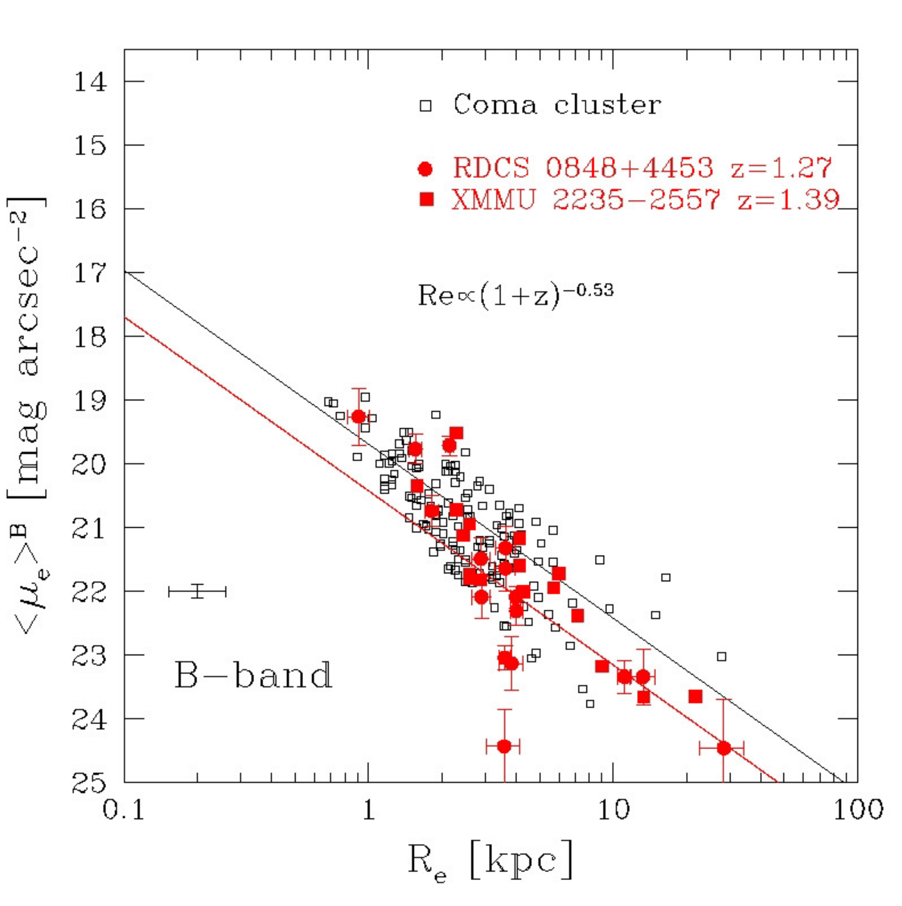
$$\langle \mu_e \rangle = M + 2.5 \log(R_e^2) + 38.57$$

Size evolution cluster galaxies

$$R_e \propto (1+z)^{-0.5}$$

Delaye et al. 2013

Re(z=0) = 1.5 Re(z=1.3)
μe(z=0) 0.9 mag fainter



Pure size evolution violates KR

Can z~1.3 cluster ellipticals increase their effective radius ?

Pure size evolution

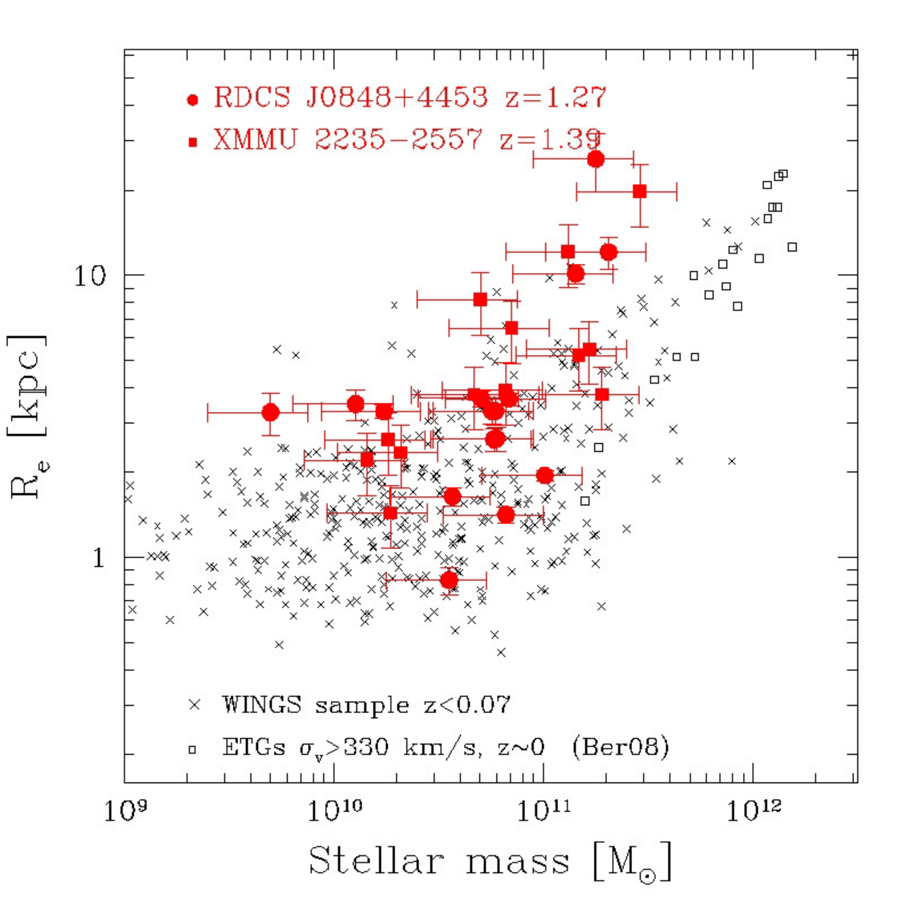
$$\langle \mu_e \rangle = M + 2.5 \log(R_e^2) + 38.57$$

Size evolution cluster galaxies

$$R_e \propto (1+z)^{-0.5}$$

Delaye et al. 2013

Re(z=0) = 1.5 Re(z=1.3)
μe(z=0) 0.9 mag fainter



Pure size evolution is ruled out: violates KR and size-mass

Can z~1.3 cluster ellipticals grow their stellar mass ?

Mass growth + size evolution

$$\begin{cases} \langle \mu_e \rangle = \mathrm{M}_B + 2.5\log(R_e^2) + 38.57 \\ \langle \mu_e \rangle = \alpha + \beta \log(R_e) \end{cases}$$

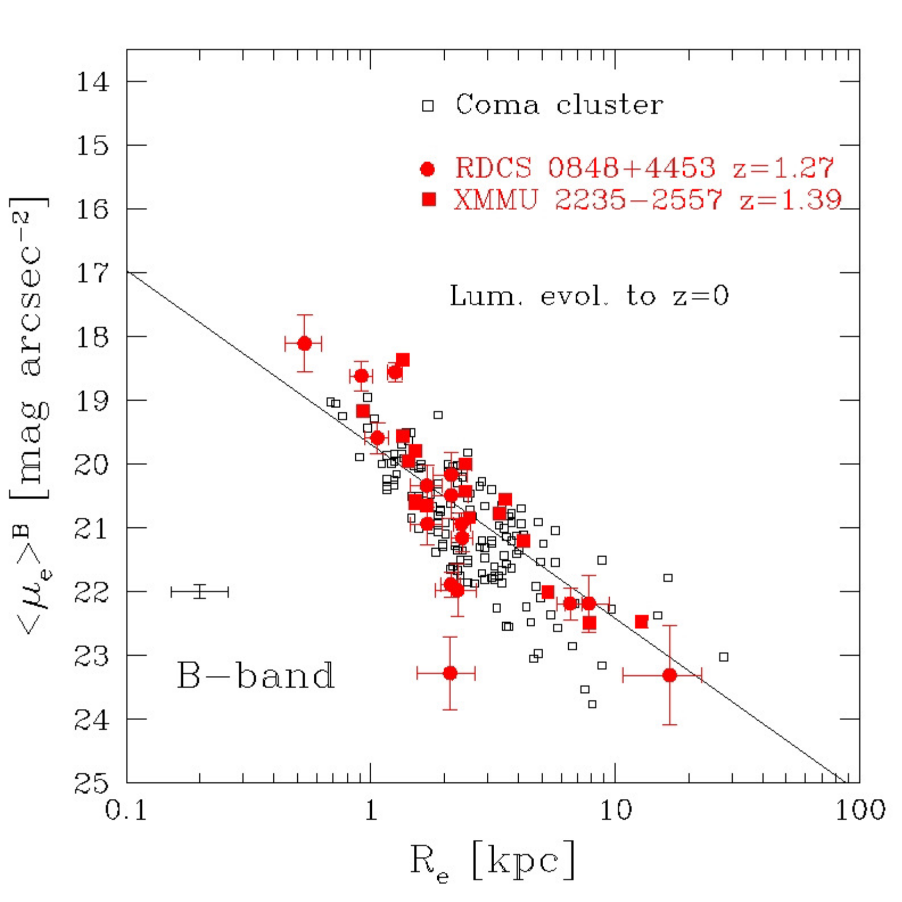
$$\Delta \mathrm{M}_B \propto -2.5\log(\delta M_*)$$

$$\delta M_* = \delta R_e^{(2-\frac{\beta}{2.5})} \qquad \beta \approx 2.7 \div 3$$

$$\delta M_* = \delta R_e^{(0.8\div 1)}$$

$$R_e \propto (1+z)^{-0.5}$$

$$M_* \propto (1+z)^{-(0.4\div 0.5)}$$



Cluster ellipticals: structural evolution

Can z~1.3 cluster ellipticals grow their stellar mass ?

Mass growth + size evolution

$$\begin{cases} \langle \mu_e \rangle = \mathrm{M}_B + 2.5\log(R_e^2) + 38.57 \\ \langle \mu_e \rangle = \alpha + \beta \log(R_e) \end{cases}$$

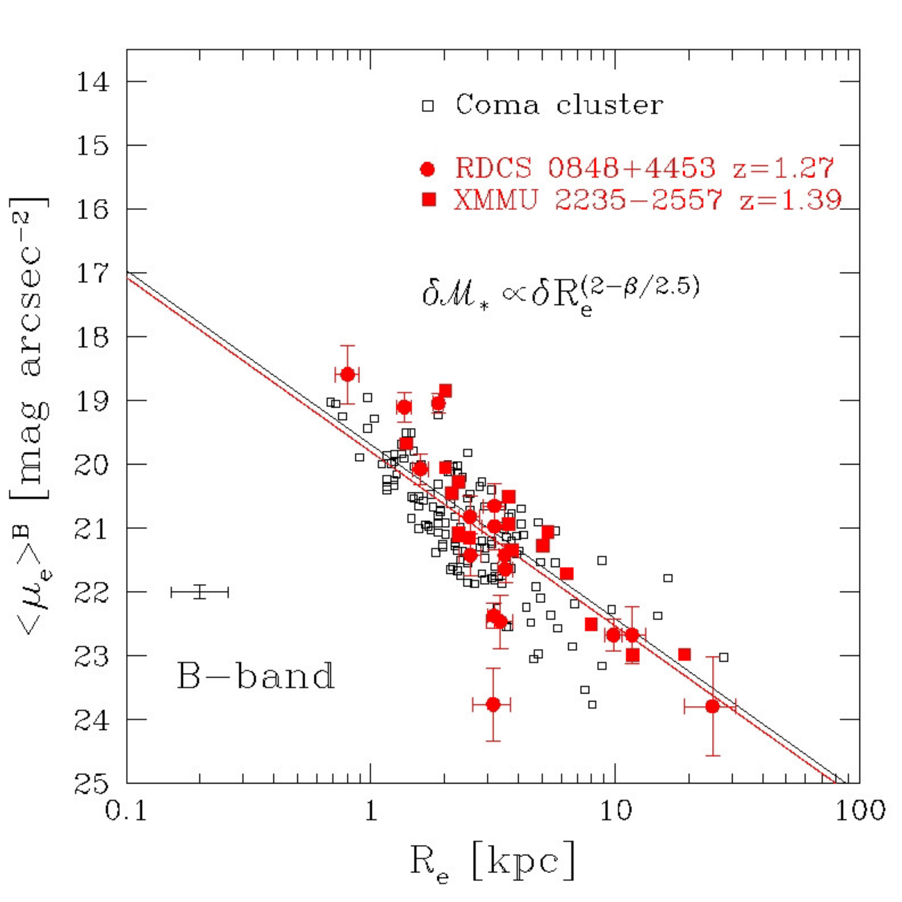
$$\Delta \mathrm{M}_B \propto -2.5\log(\delta M_*)$$

$$\delta M_* = \delta R_e^{(2-\frac{\beta}{2.5})} \quad \beta \approx 2.7 \div 3$$

$$\delta M_* = \delta R_e^{(0.8\div 1)}$$

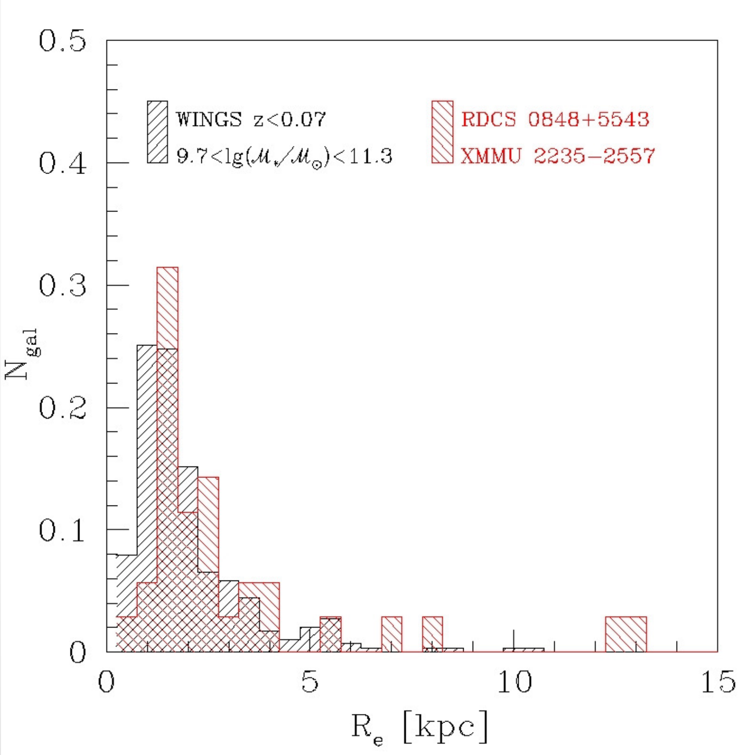
$$R_e \propto (1+z)^{-0.5}$$

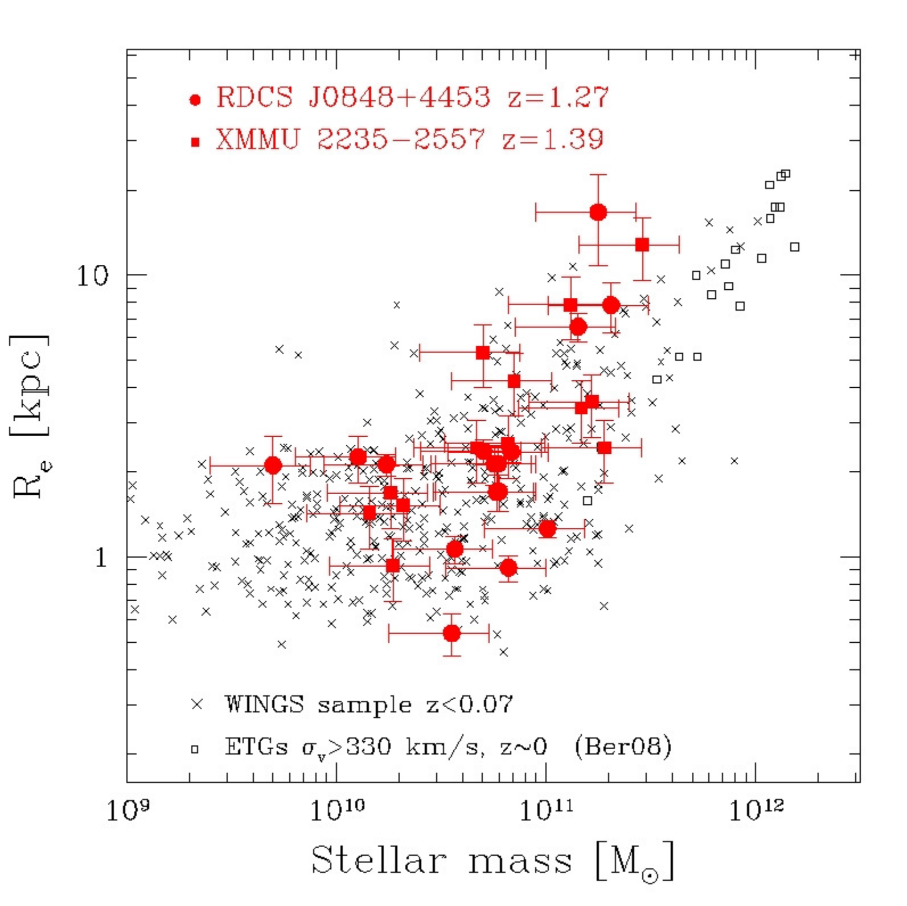
$$M_* \propto (1+z)^{-(0.4\div 0.5)}$$



Can z~1.3 cluster ellipticals grow their stellar mass ?

$$\langle \mu_e \rangle = M + 2.5\log(R_e^2) + 38.57$$

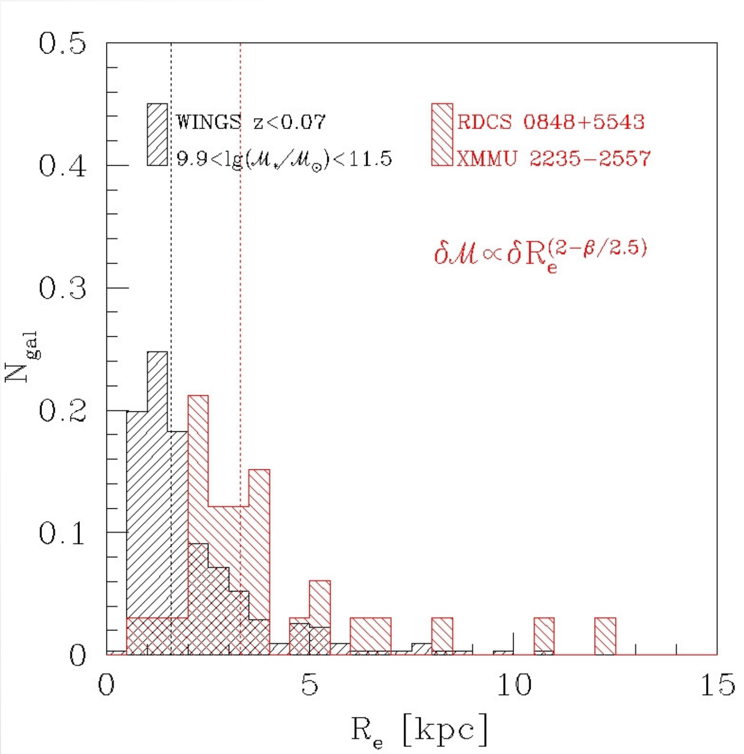


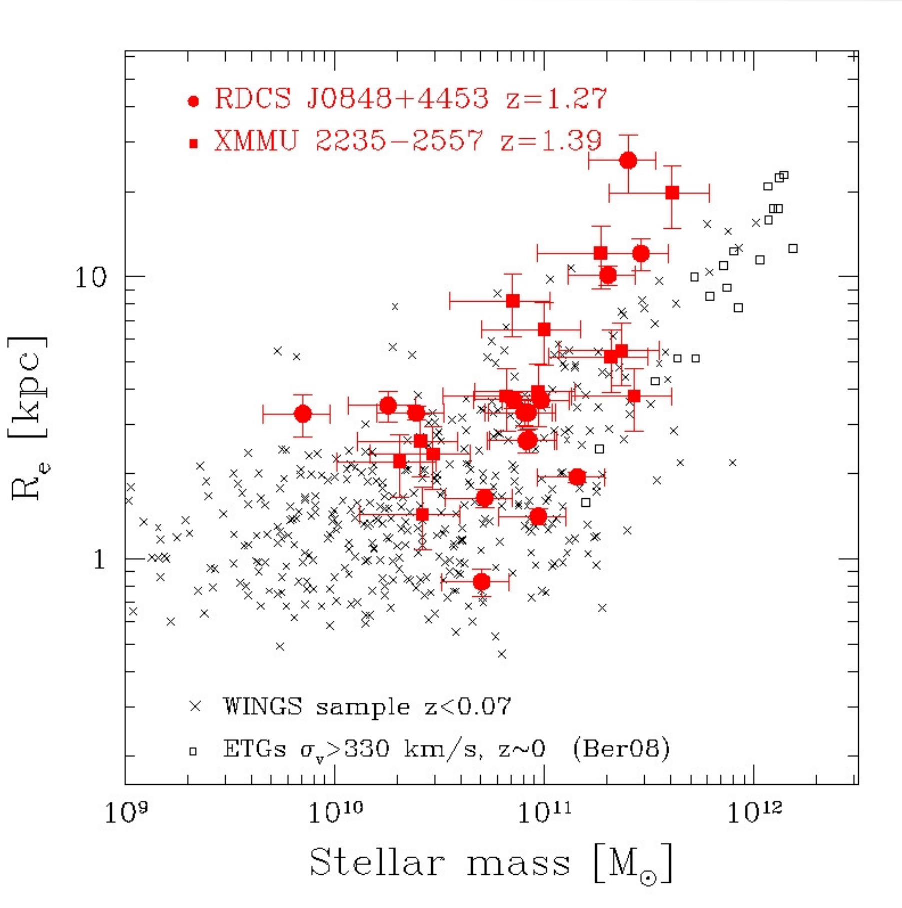


Can z~1.3 cluster ellipticals grow their stellar mass ?

Mass growth + size evolution

$$\langle \mu_e \rangle = M + 2.5\log(R_e^2) + 38.57$$

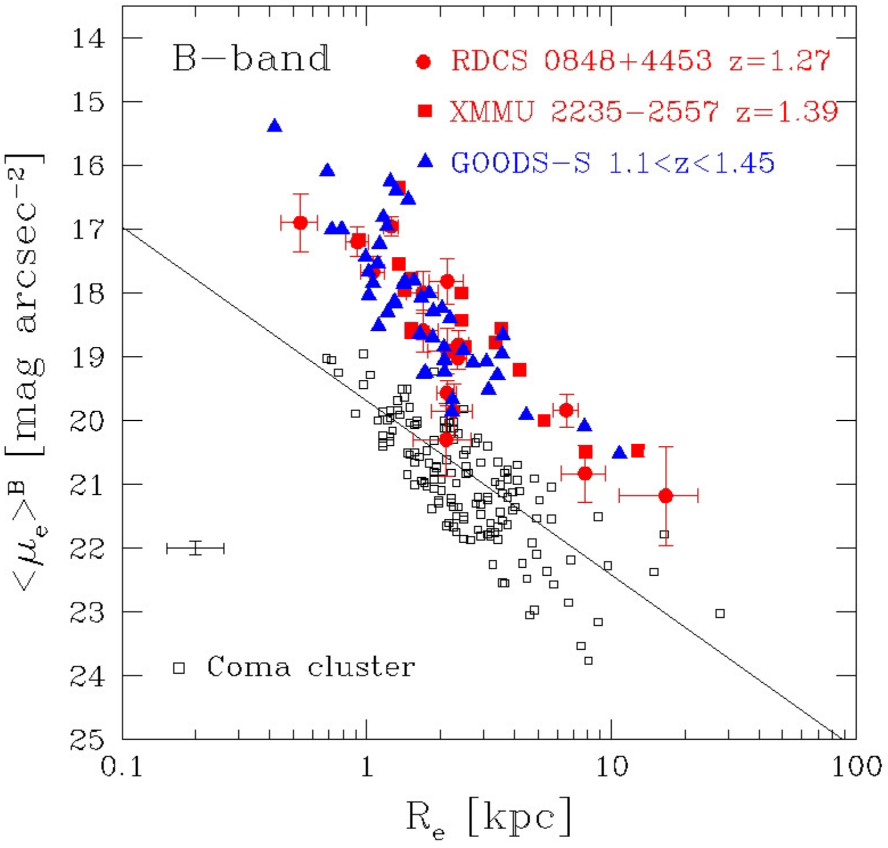


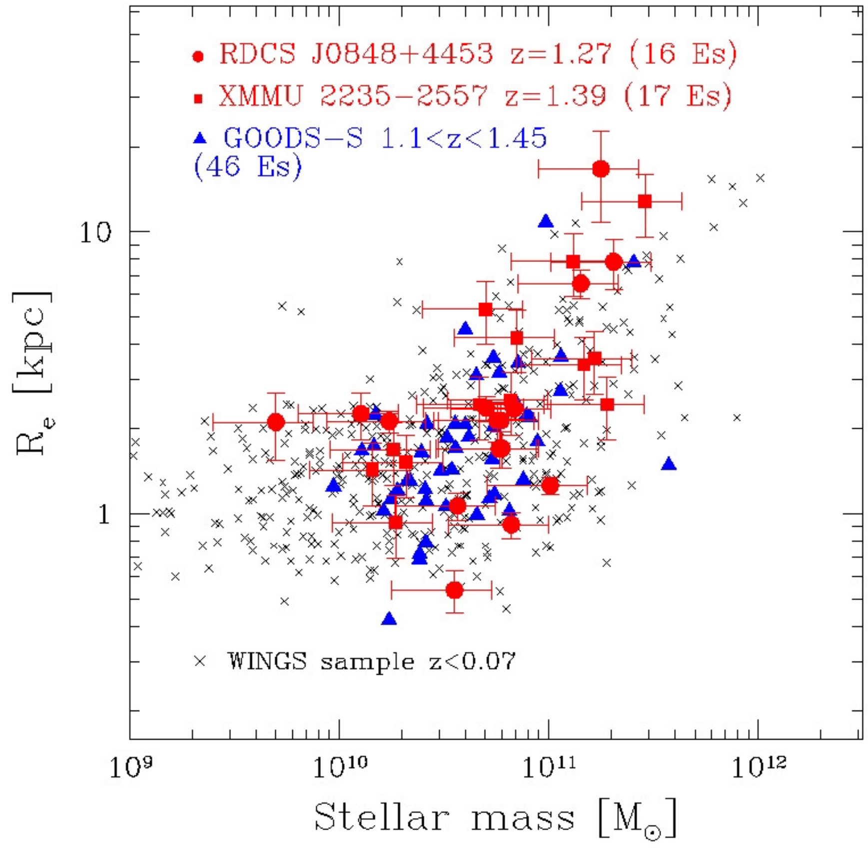


Re and M* cannot vary fulfilling at the same time the KR and the SM relation

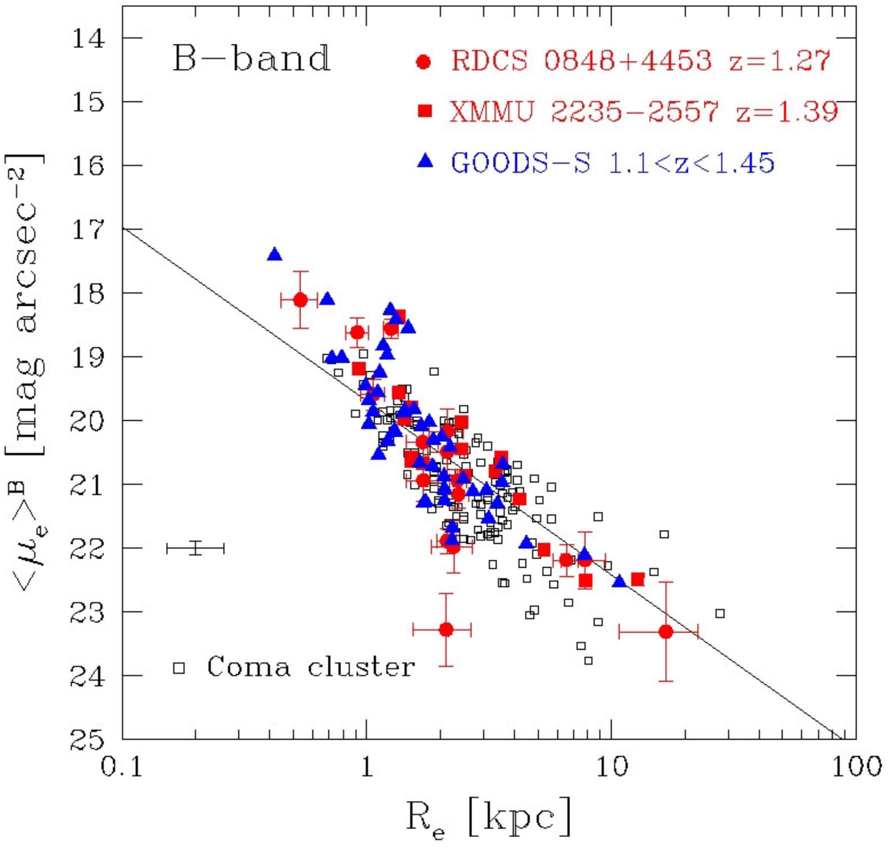
Cluster ellipticals cannot change their structure since z~1.3

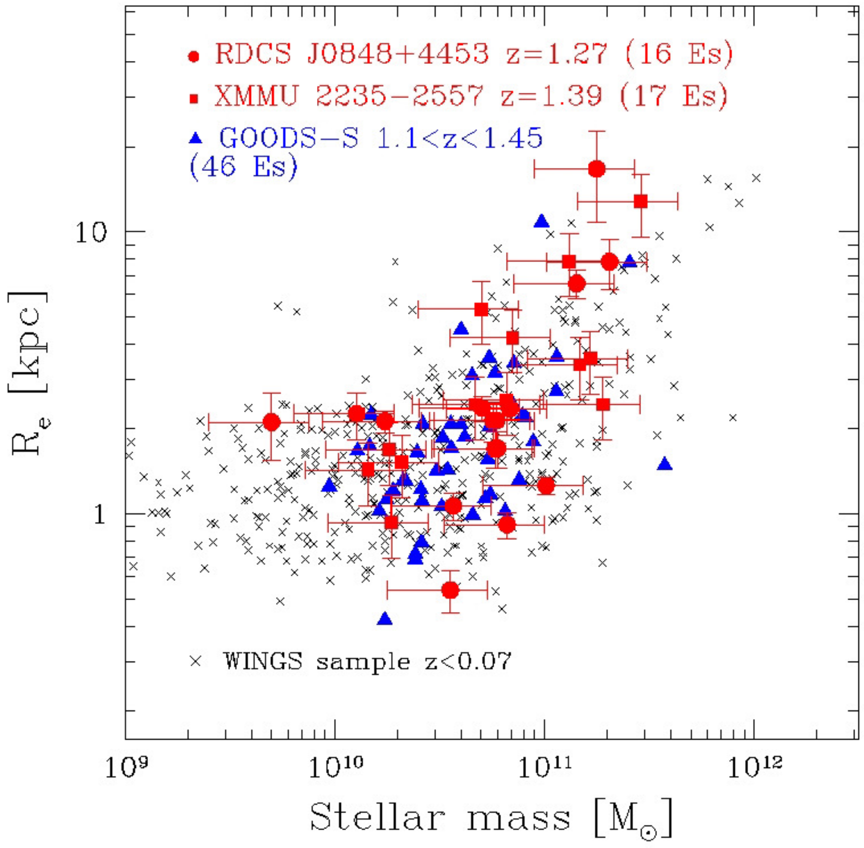
What about field ellipticals?





What about field ellipticals?





Cluster and field EGs share the same scaling relations at z~1.3

Conclusions

- Field and cluster EGs at z~1.3 share the same scaling relations;

- EGs at z~1.3 share the same scaling relations of local (cluster) EGs → their structural parameters are those of local EGs;

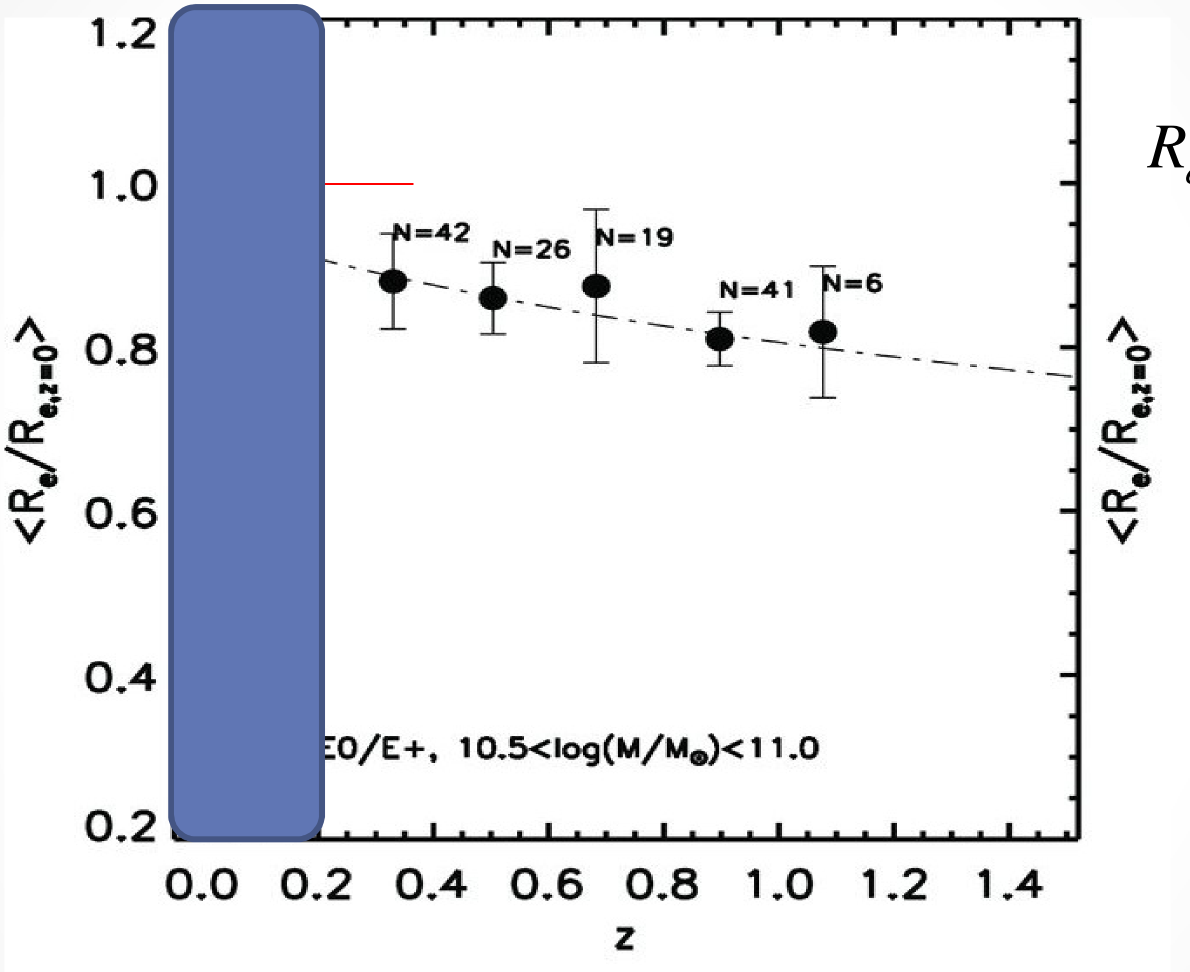
- **EGs have completed their mass grow at z~1.3 , they do not change their structure till z=0**

→ the evolution of the mean size of *passive* galaxies are not due to the evolution of individual EGs.

Can the elliptical shape be the final stage of a process of assembly after which the EG does not change anymore?

Thank you!

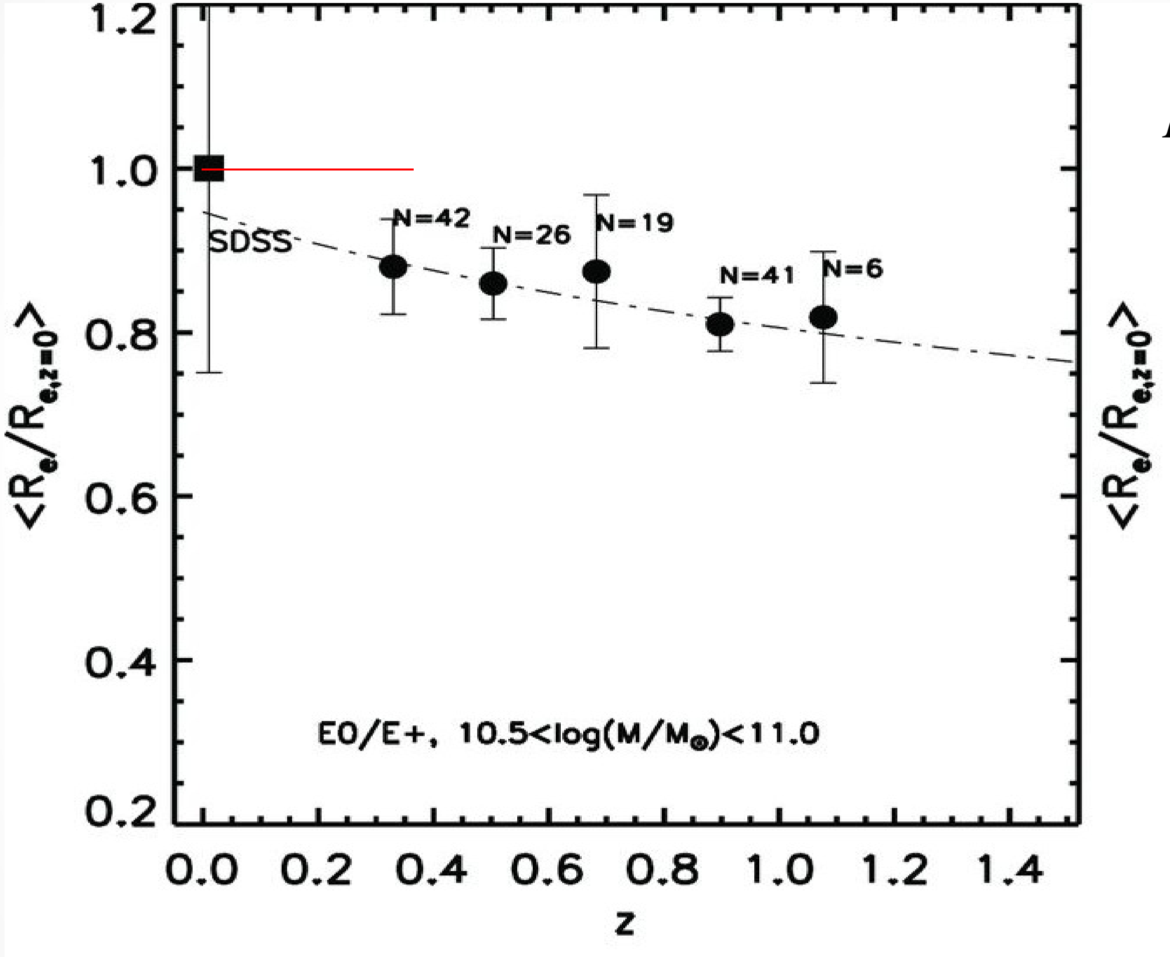
Size evolution



$$R_e \propto (1+z)^{-0.5}$$

Huertas-Company et al. (2013)

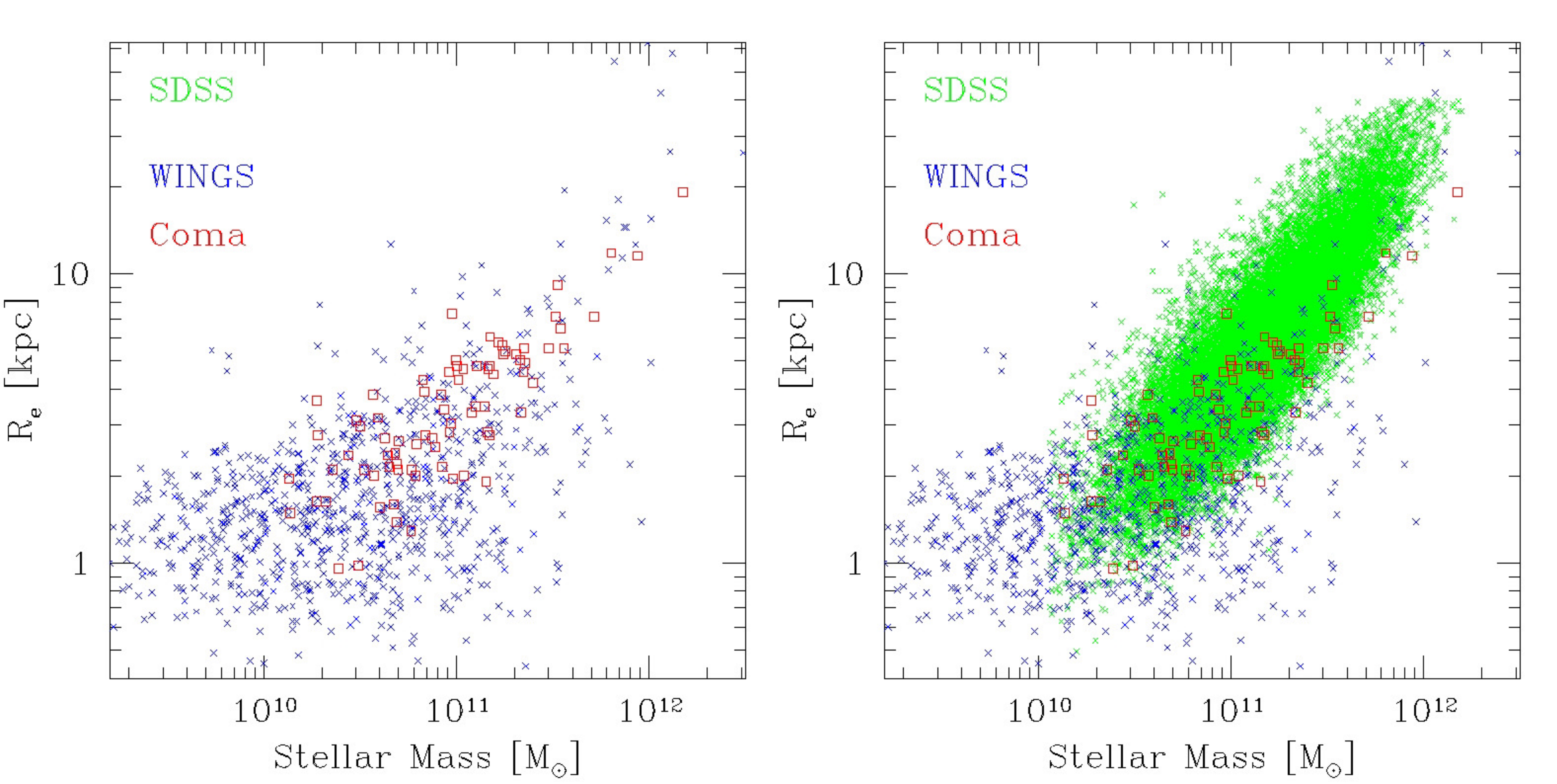
Size evolution



$$R_e \propto (1+z)^{-0.5}$$

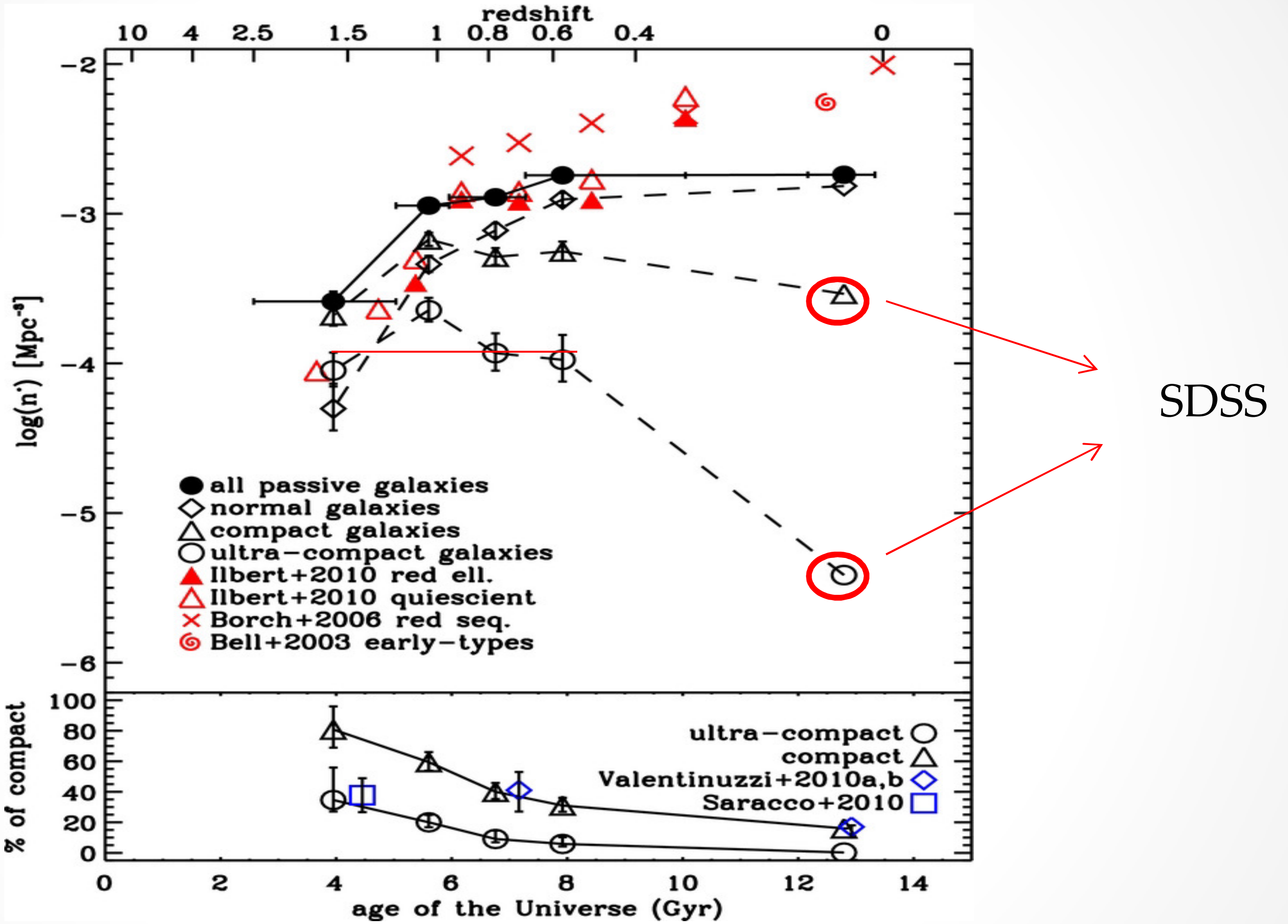
Huertas-Company et al. (2013)

Size-mass: SDSS vs others



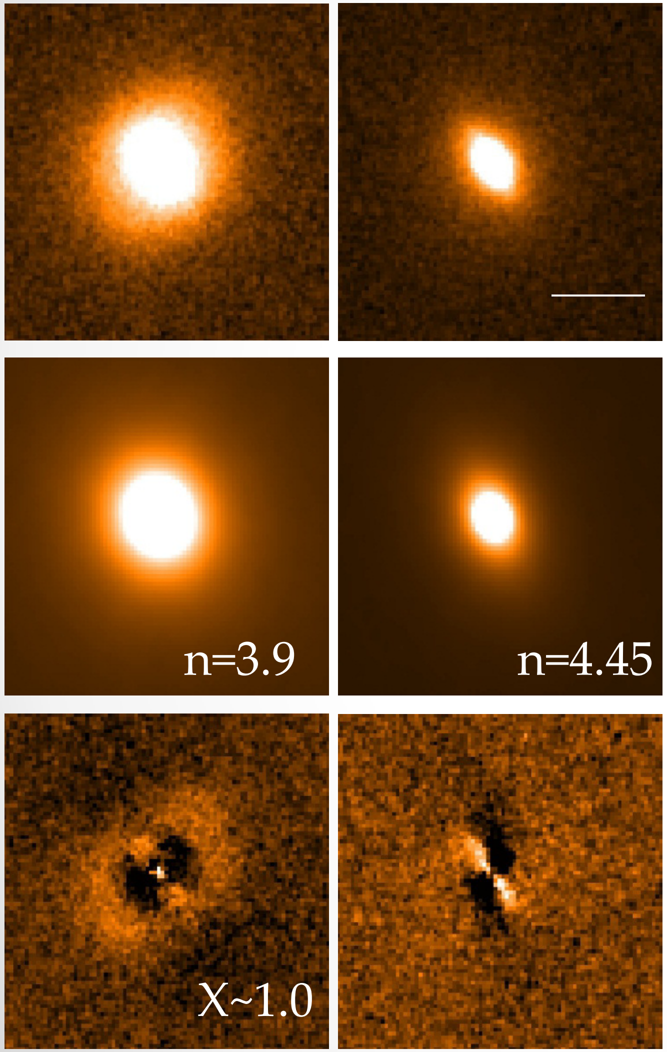
"…few galaxies at the compact end are missed by the target criteria. However, to take care of the seeing effect we used only galaxies with angular size R_{50}>Dmin where Dmin=1.6 arcsec." *(Strauss et al. 2002; Shen et al. 2003)*

Number density of compact Galaxies



Cassata et al. (2011)

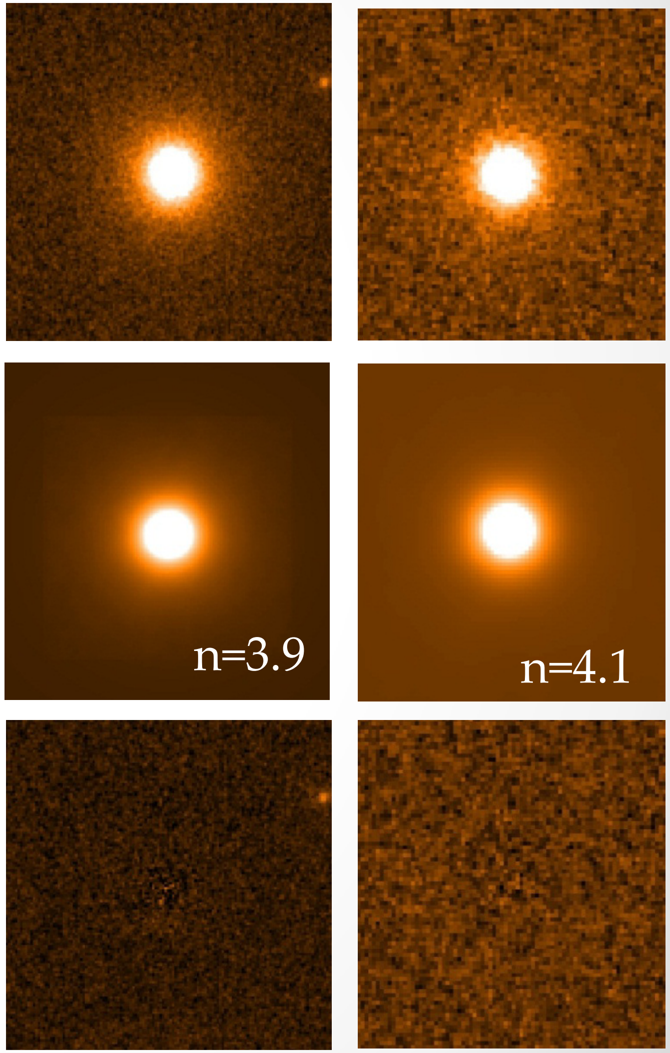
Late Types



Elliptical galaxy:

- Regular shape
- no signs of disk on the F850LP image
- No irregular or structured residuals

Ellipticals



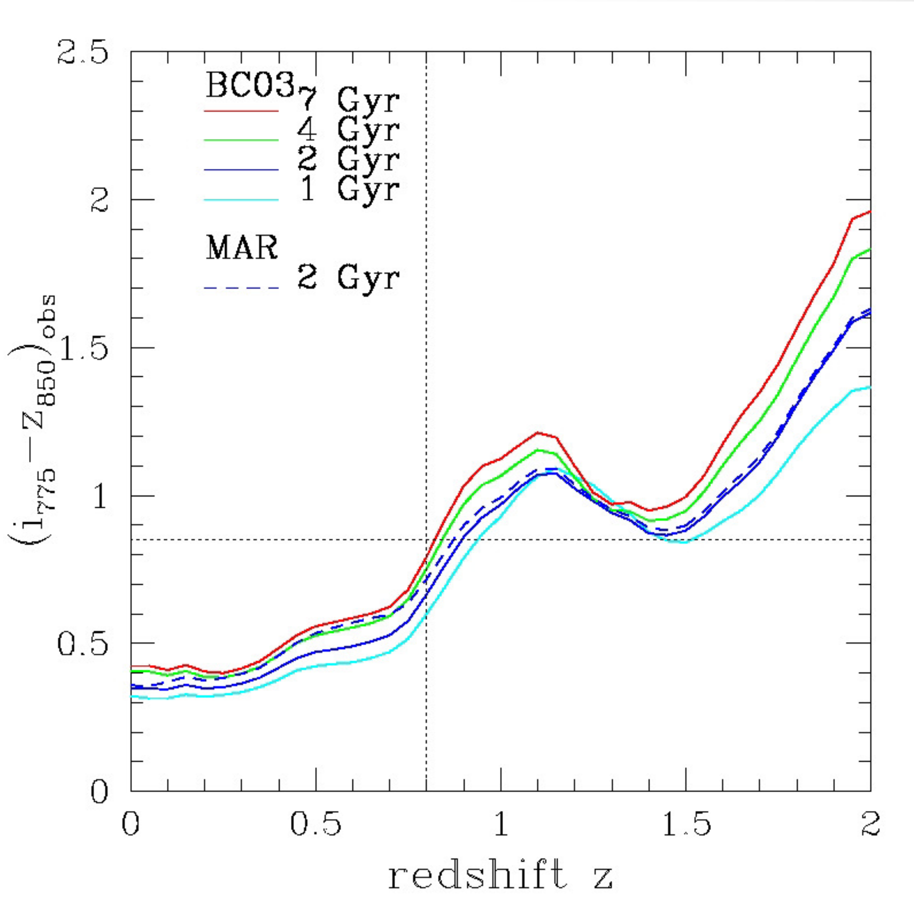
RDCS 0848+4453 (Linx) z=1.27 (Stanford et al. 1997)

16 Ellipticals (5 with z_{spec})

Selection criteria:

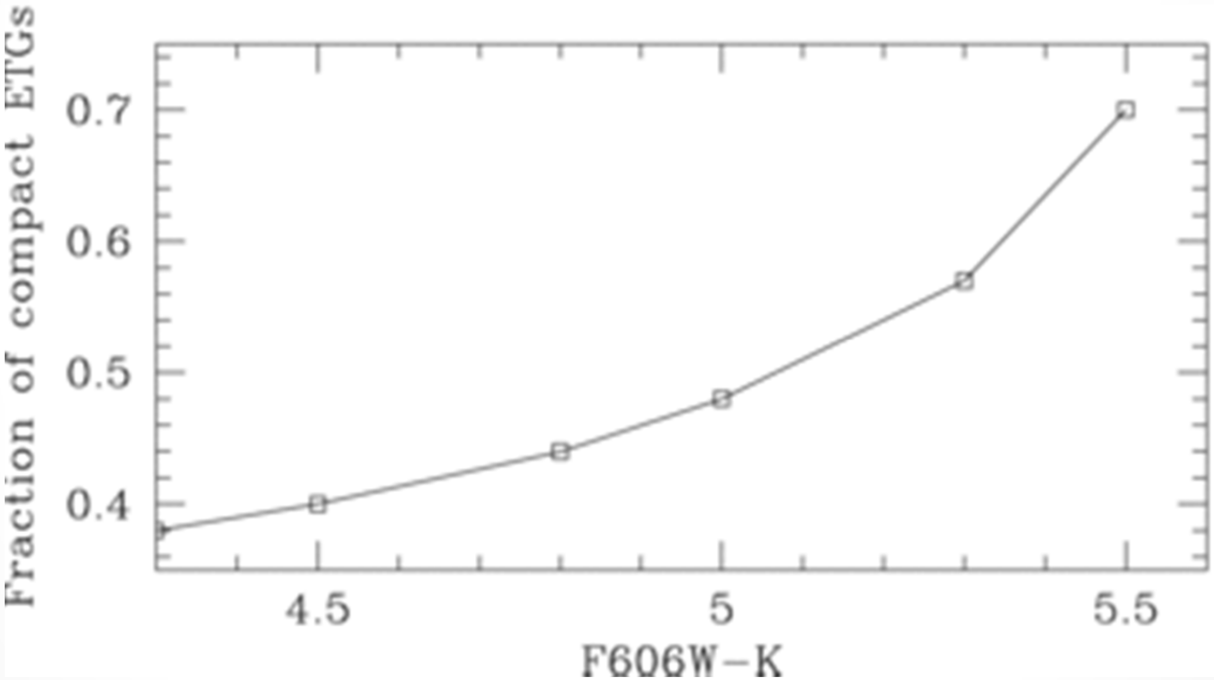
- **z_{850}<24 (ACS-F850LP)**
- Dist<1Mpc
- $0.9 < i_{775} - z_{850} < 1.3$ $(UV-U)_{rest}$
- Elliptical morphology (visual classification images + residuals)

11 bands (0.3-8.0μ)
- LBT (UBVR, proprietary)
- HST(F775, F850, F160)
- Spitzer (3.6-8μ)



Complete sample: 34 ETGs at $0.9<z_{spec}<1.9$ ($z_{med}=1.5$)

Red color selection biased toward compact ETGs



~(R-K)

(Saracco, Longhetti, Gargiulo 2010)

General spheroid formation scheme: the inside-out growth of ETGs

Integrating the Sersic profile

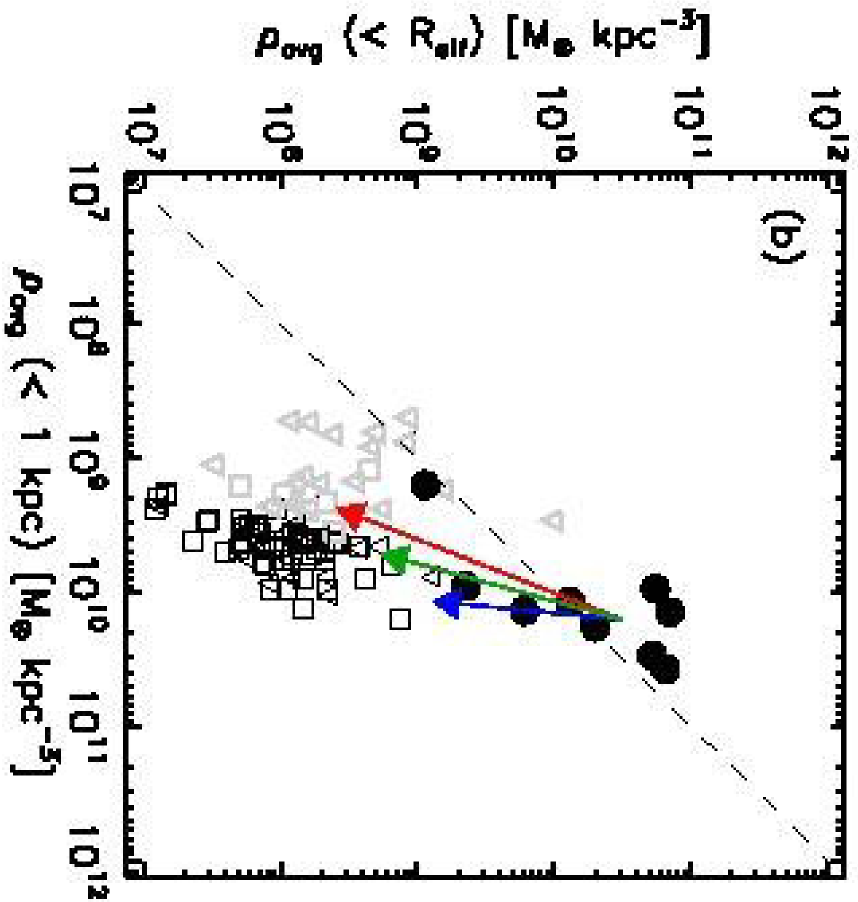
$$I(R) = I_e \left\{ -b_n \left[\left(\frac{R}{R_e} \right)^{1/n} - 1 \right] \right\}$$

$$A = \pi R_1^2 \qquad R_1 = 1kpc$$

$$\frac{L_1}{L_{tot}} = \frac{\gamma(2n, x)}{\Gamma(2n)}$$

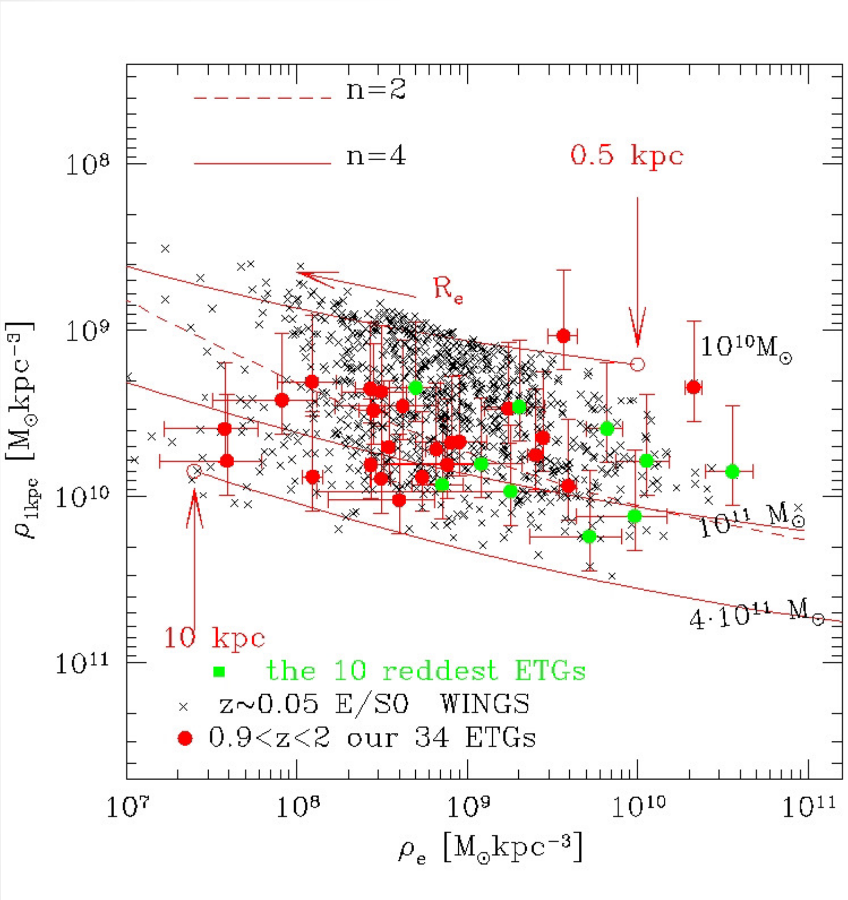
$$M_1 = \frac{L_1}{L_{tot}} \times M_*$$

$$\rho_1 = \frac{M_1}{\frac{4}{3}\pi R_1^3} \qquad \rho_e = \frac{0.5 M_*}{\frac{4}{3}\pi R_e^3}$$

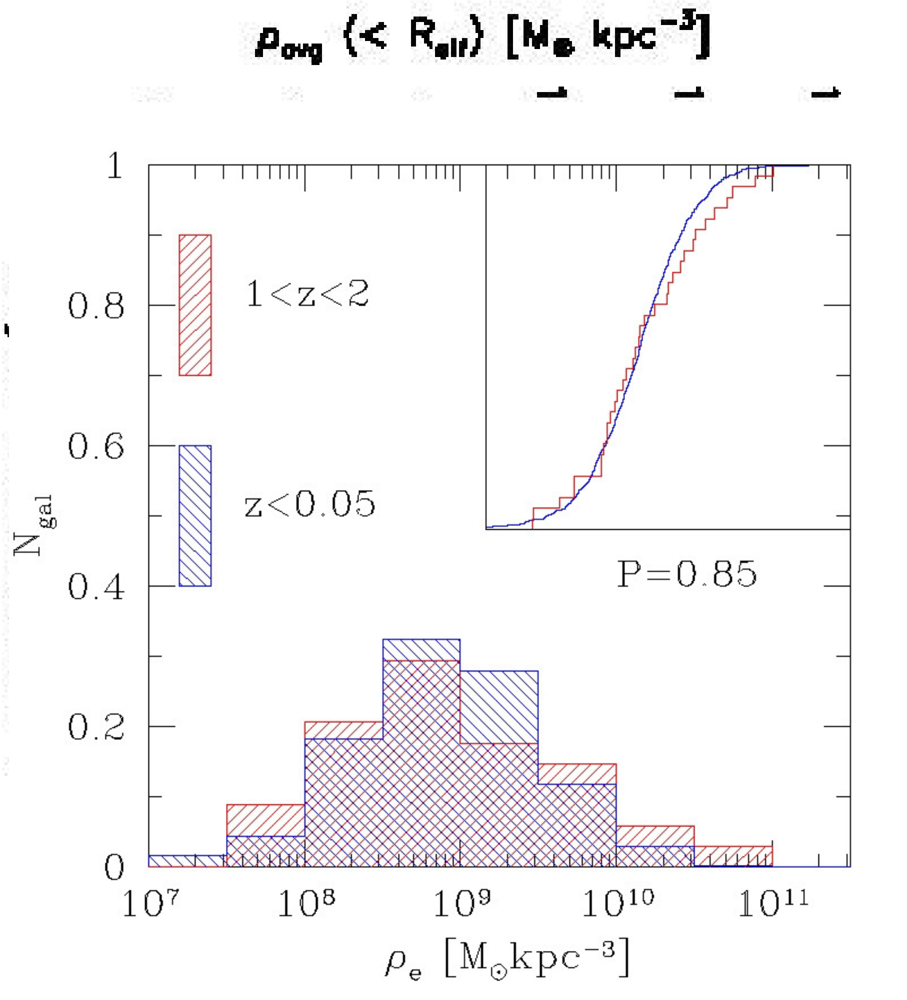


(Bezanson et al. 2009;
see also Hopkins et al. 2009; Tiret et al. 2011)

General spheroid formation scheme: the inside-out growth of ETGs



(Saracco, Gargiulo, Longhetti 2012)



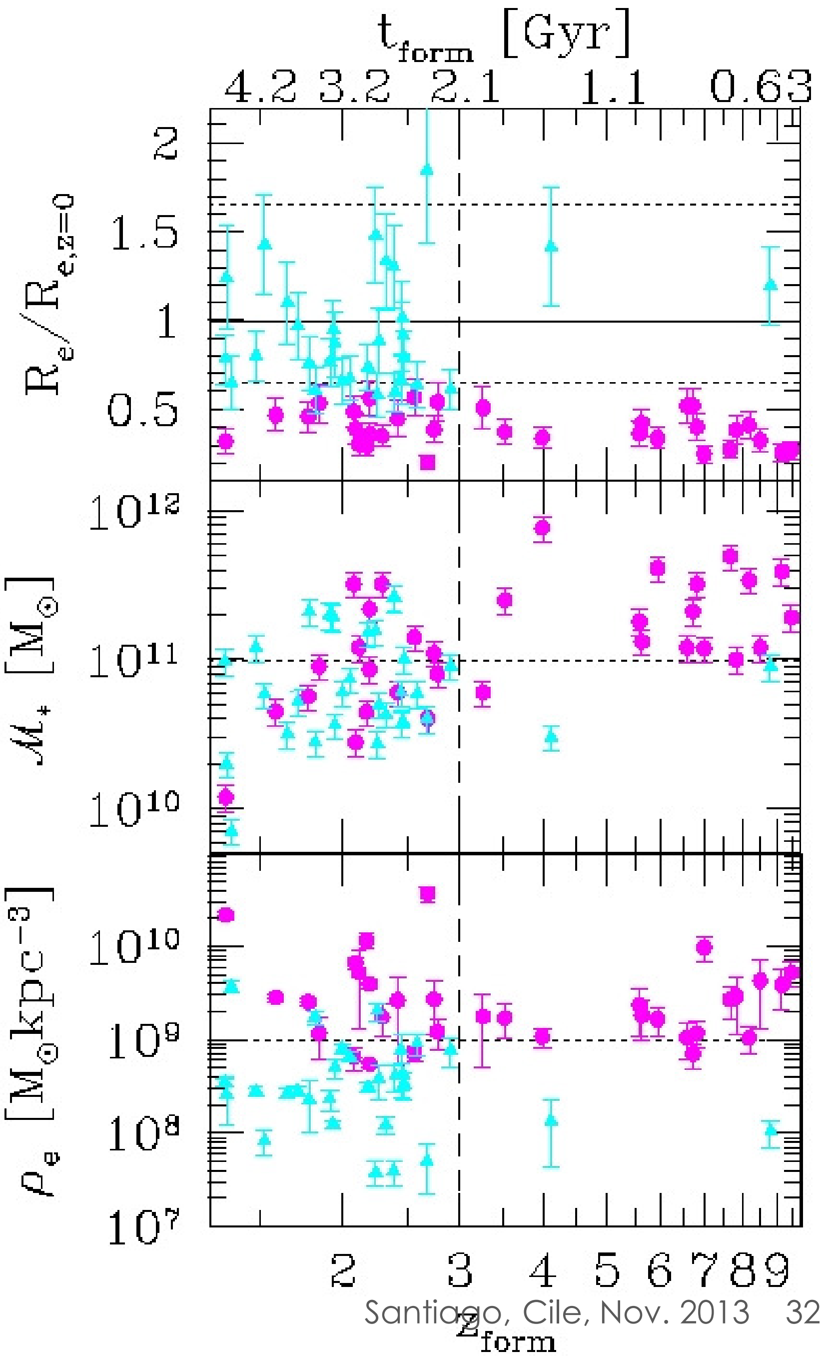
see also Hopkins et al. 2009; Tiret et al. 2011)

Constraining the first 3 Gyr

Oldest stars are assembled in compact ETGs (but not vice versa…)

Oldest stars are assembled in massive ETGs (but not vice versa…)

Oldest stars are assembled in denser ETGs (but not vice versa…)



(Saracco, Longhetti, Gargiulo 2011)