Kinematics of high redshift compact early-type galaxies : are they really denser?

Adriana Gargiulo
Paolo Saracco, Marcella Longhetti, Sonia Tamburri, Ilaria Lonoce
INAF-Osservatorio Astronomico di Brera

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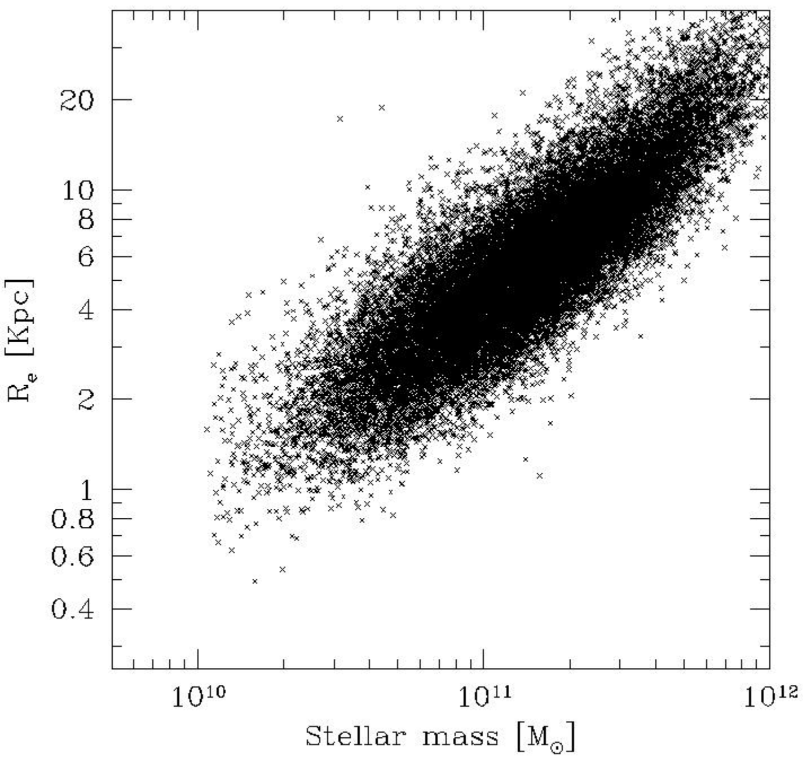
Outline

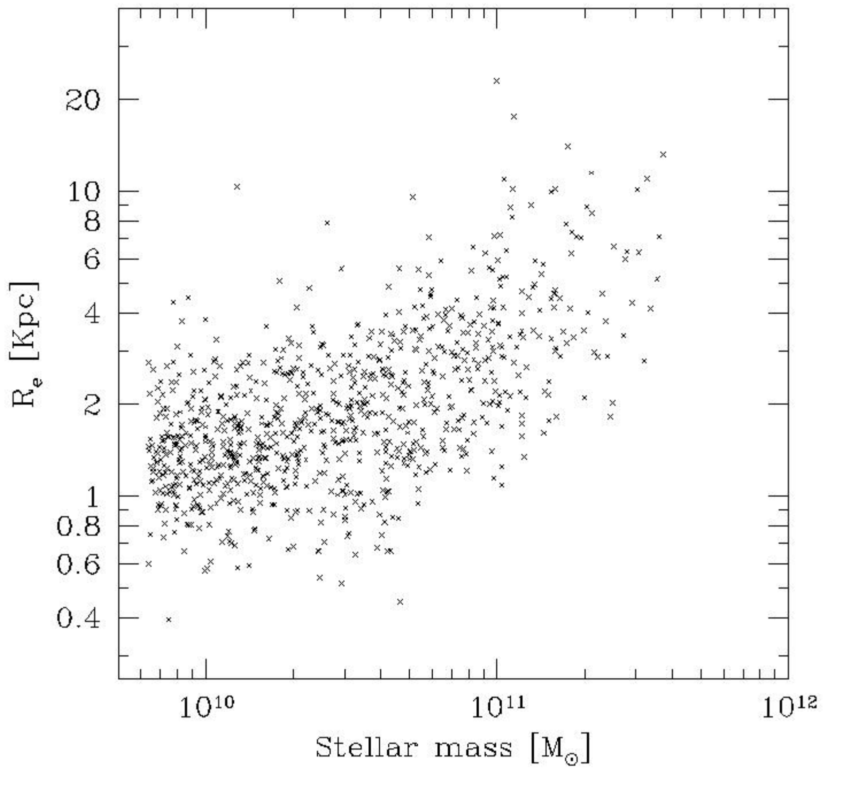
- The size of early-type galaxies at high ($1<z<2$) and low redshift
- FORS2 – VLT spectra for 4 compact ETGs at $1.3<z<1.9$
- Results
- Conclusions

The size of early-type galaxies at low redshift

- At fixed mass, local ETGs show a remarkable difference (~ an order of magnitude) in the value of their effective radii → difference in stellar mass density of a factor 100 -1000



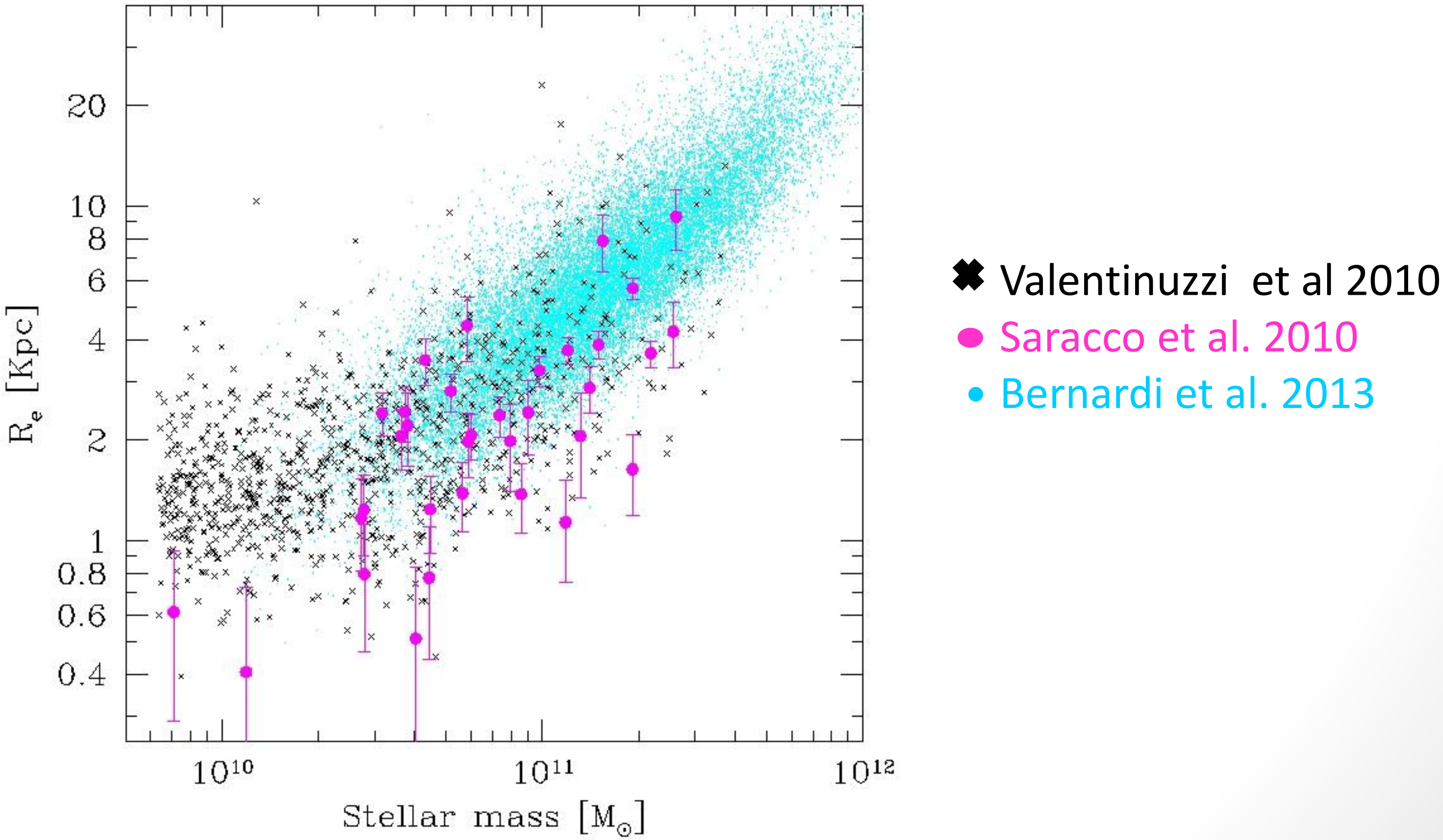
Bernardi et al. 2013 (SDSS)



Valentinuzzi et al. 2010 (WINGS)

The size of early-type galaxies at high redshift

- At fixed mass, local ETGs show a remarkable difference (~ an order of magnitude) in the value of their effective radii → difference in stellar mass density of a factor 100 -1000;
- High-z ETGs, at fixed stellar mass, show the same size dispersion of local ETGs.



Are high-z compact ETGs really denser?

When the universe was at maximum 3-4 Gyr old,

ETGs show a remarkable spread in effective radius at fixed stellar mass.

Spread in stellar mass density

Formation **OR** Evolution?

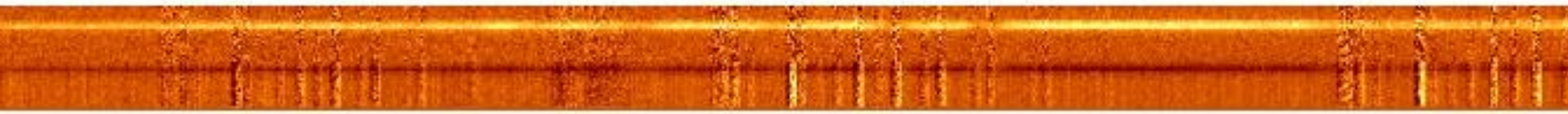
Velocity dispersions of high –z ETGs

- **To confirm the spread in stellar mass density up to z ~ 1.5 :**
  if ETGs are virialized systems (σ^2 M/Re) compact ETGs should have larger dispersion

- **To investigate the structural and the dynamical properties of compact high-z ETGs.**

FORS 2 – VLT spectroscopy for compact ETGs at z~1.4

We obtained FORS2 near-IR spectra for 4 compact ETGs at z~1.4
to measure their velocity dispersions.



8100 Å — 10000 Å

TECHNICAL INFO:

Multi Object Spectroscopy (MXU)

GRISM : 600z (7300-10700 Å) to sample the Ca H+K doublet

SLIT : 1"

MEDIUM RESOLUTION: R = 1400 (~ 7 Å at 9000 Å)

TOTAL INTEGRATION TIME : ~10 hours

S/N per pixel= 8 -10

The sample and the available data

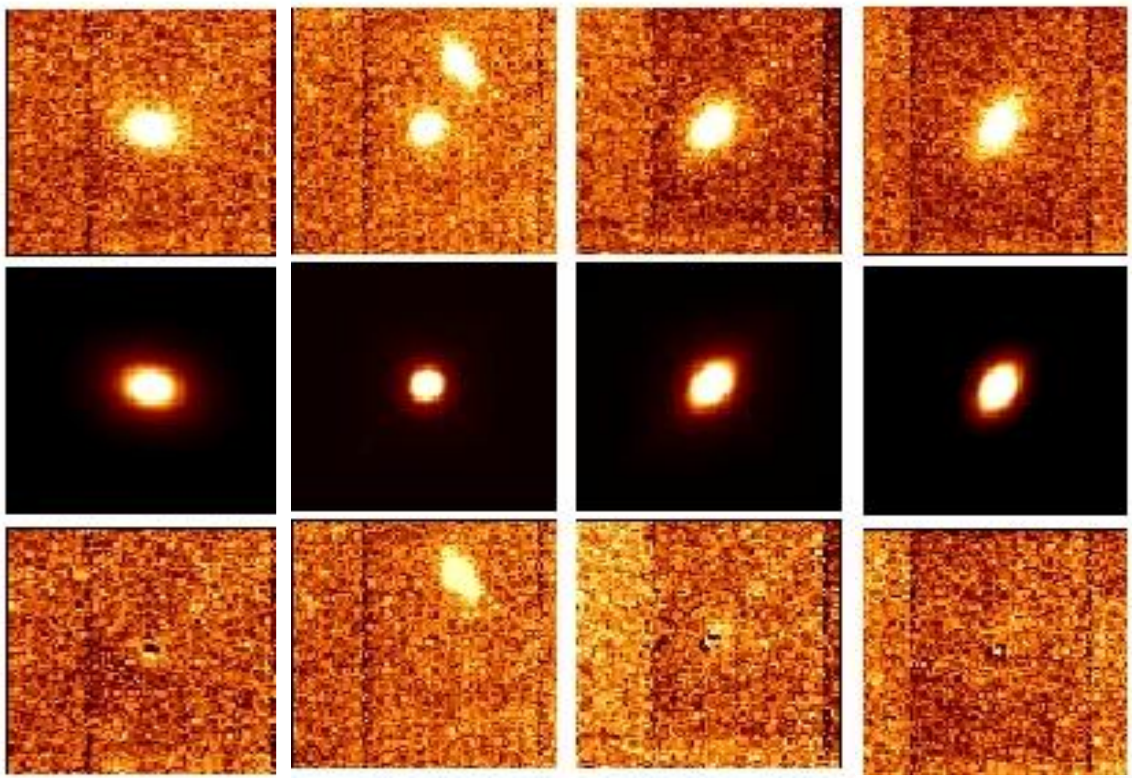
4 ETGs with:

- HST-NIC2 imaging (0.075 "/px, S/N > 3 at $3R_e$) → structural parameters (Longhetti et al. 2007)

HST image

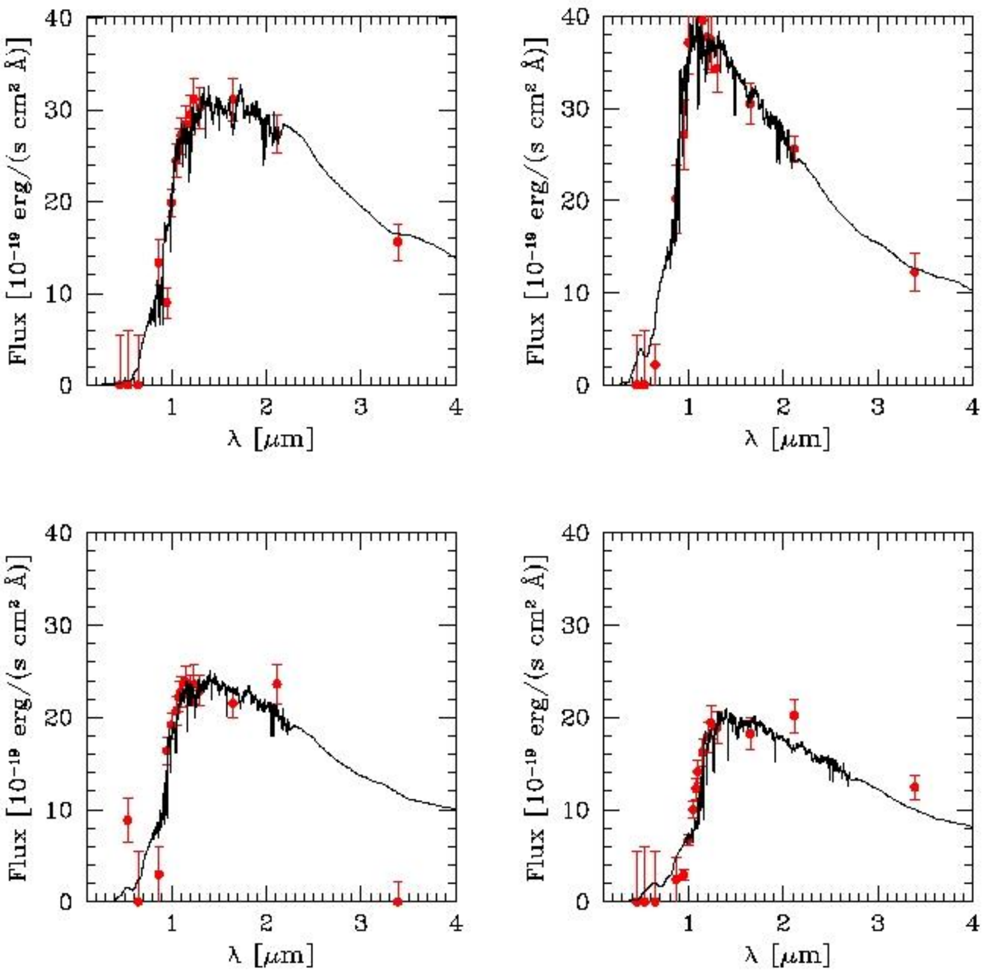
GALFIT PSF convolved model

Residual map



The sample and the available data

- Multiband photometry from λ_{obs} 0.4 to 3.5 µm (15 photometric points) → Stellar mass M*



Bruzual & Charlot (2003)

IMF = Chabrier

SFH(t) = exp (-t/τ)

The sample and the data available

4 ETGs with:

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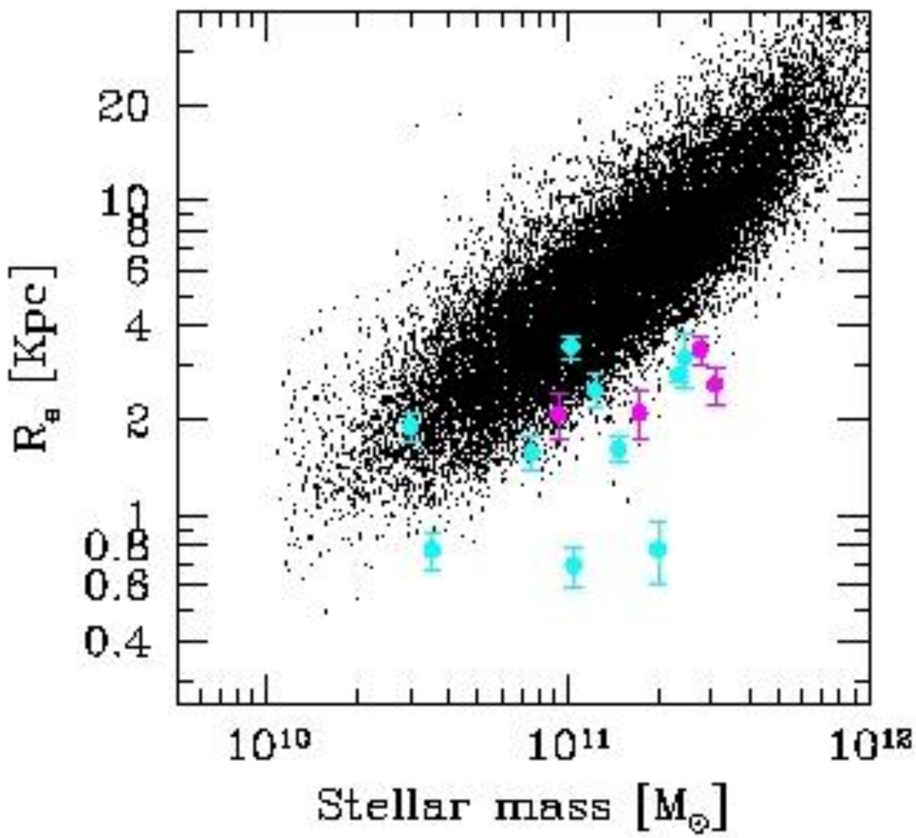
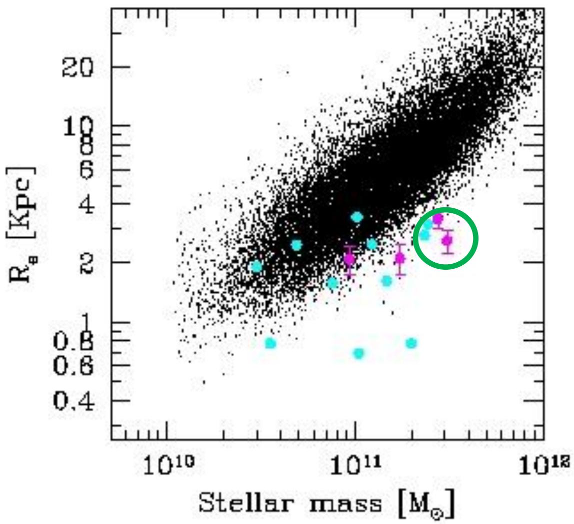
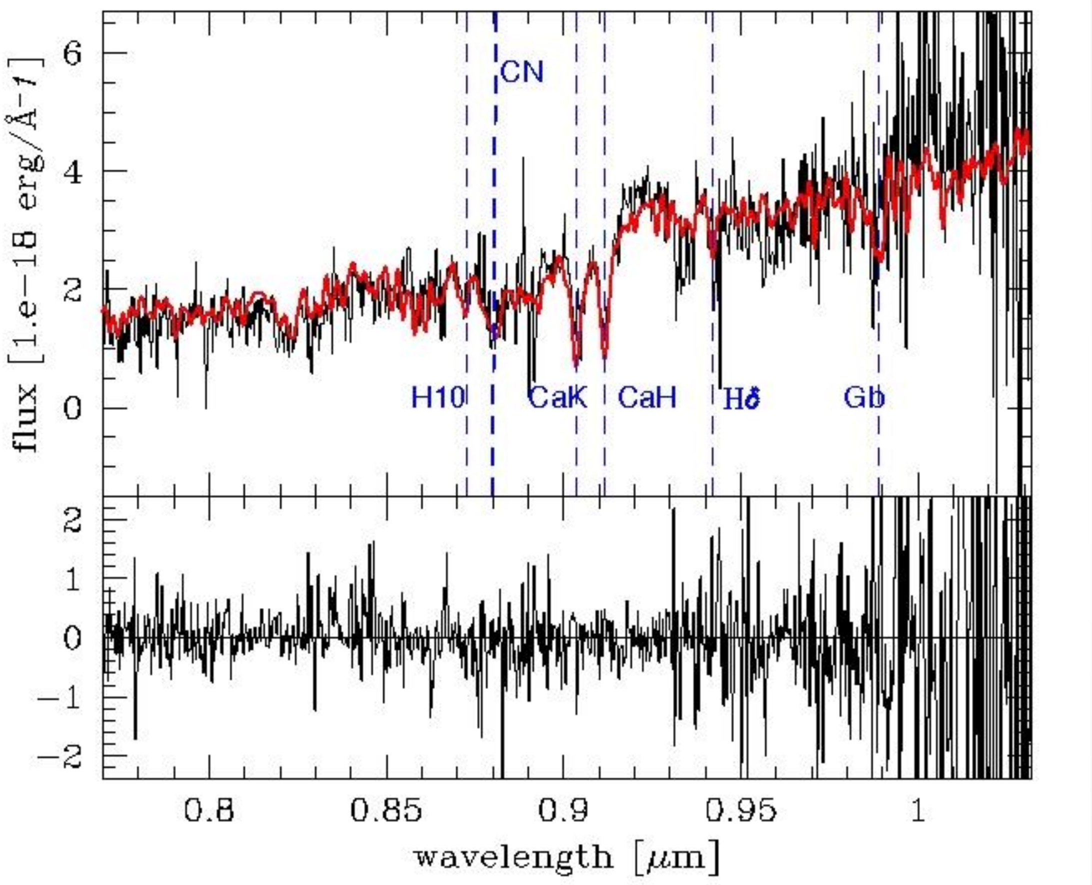


- Our ETGs
- van Dokkum et al.2008, Toft et al. 2010, Van de Sande et al. 2011 Cappellari et al. 2009, Newman 2010.

Results



Gargiulo et al. 2013 in preparation



K = 18.07

R_e = 2.6 kpc

M* = 3.1 x 10^{11} M_{sol}

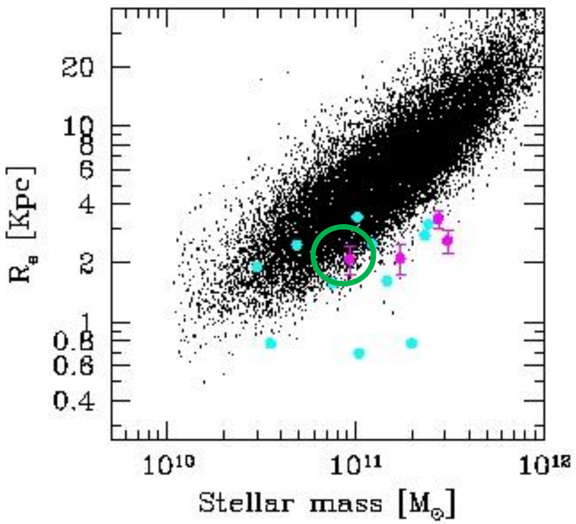
z = 1.297

σ_V = 434 ± 31 km/s

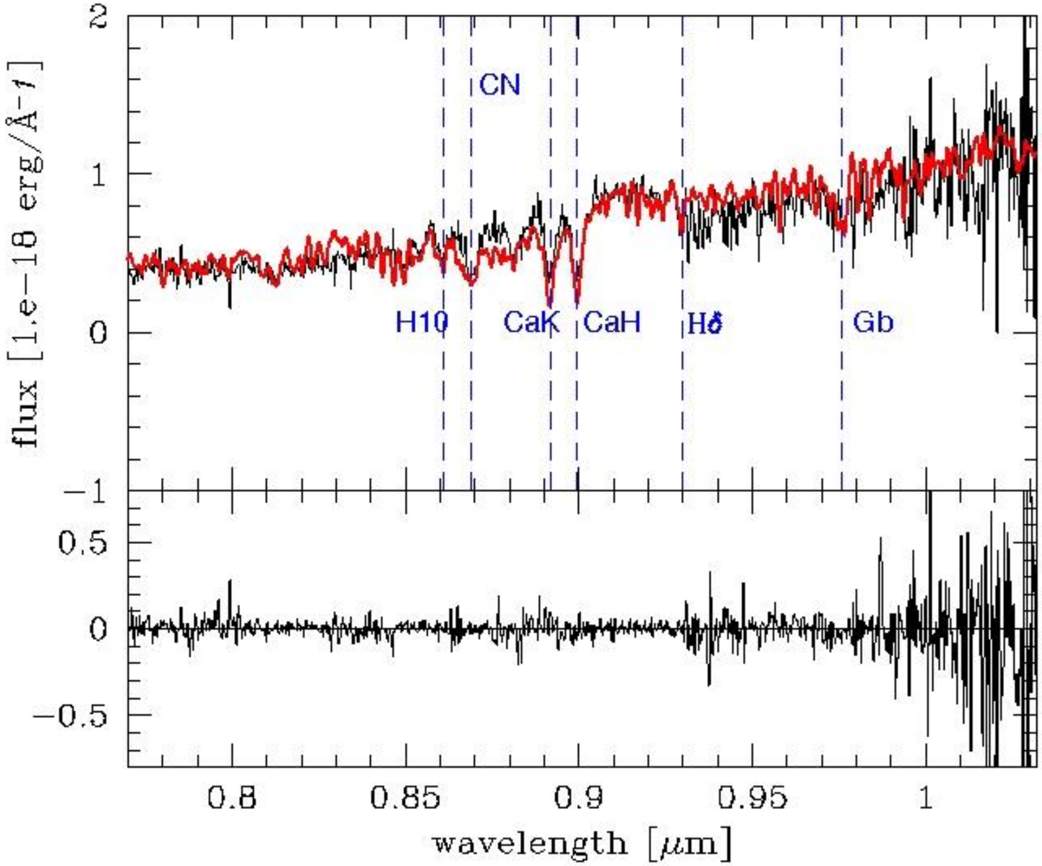
Unsmoothed and not rebinned spectrum

Best fit model

Results

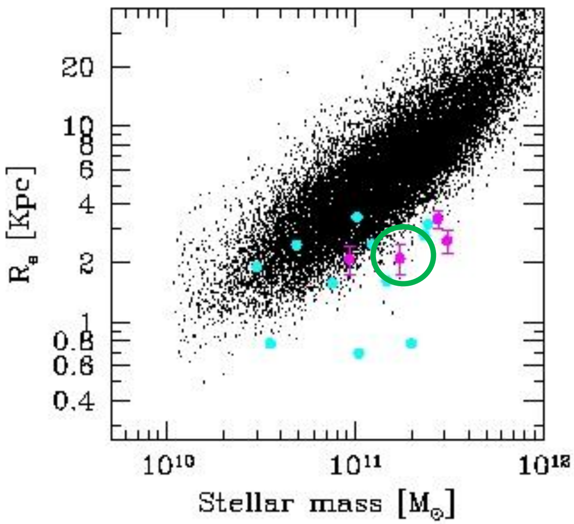


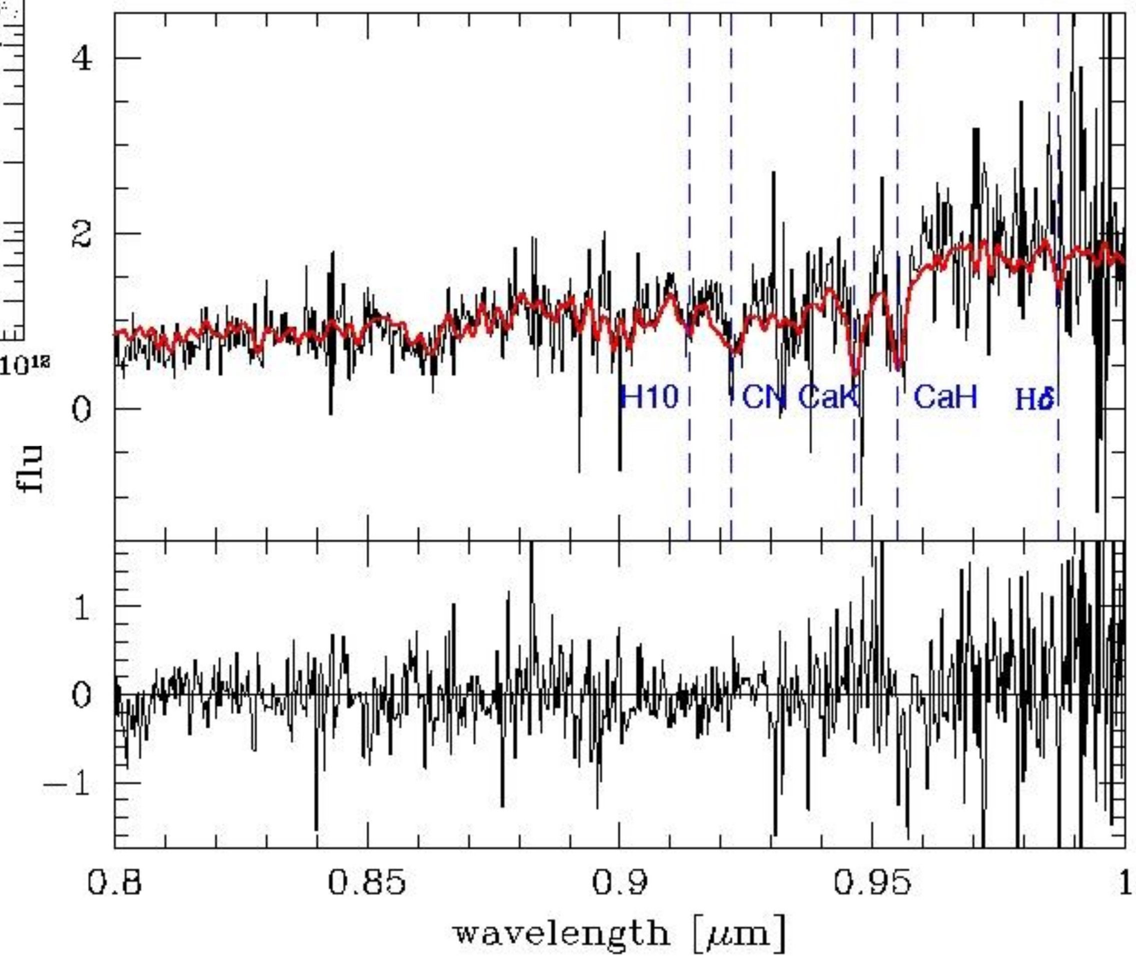
K = 18.14
R_e = 2.09 kpc
M* = 9.3 x 10^{10} M_{sol}



z = 1.267
σ_V = 269 ± 26 km/s

Results

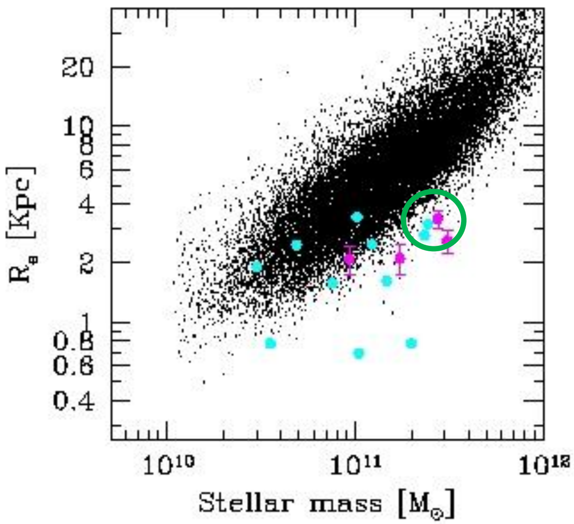




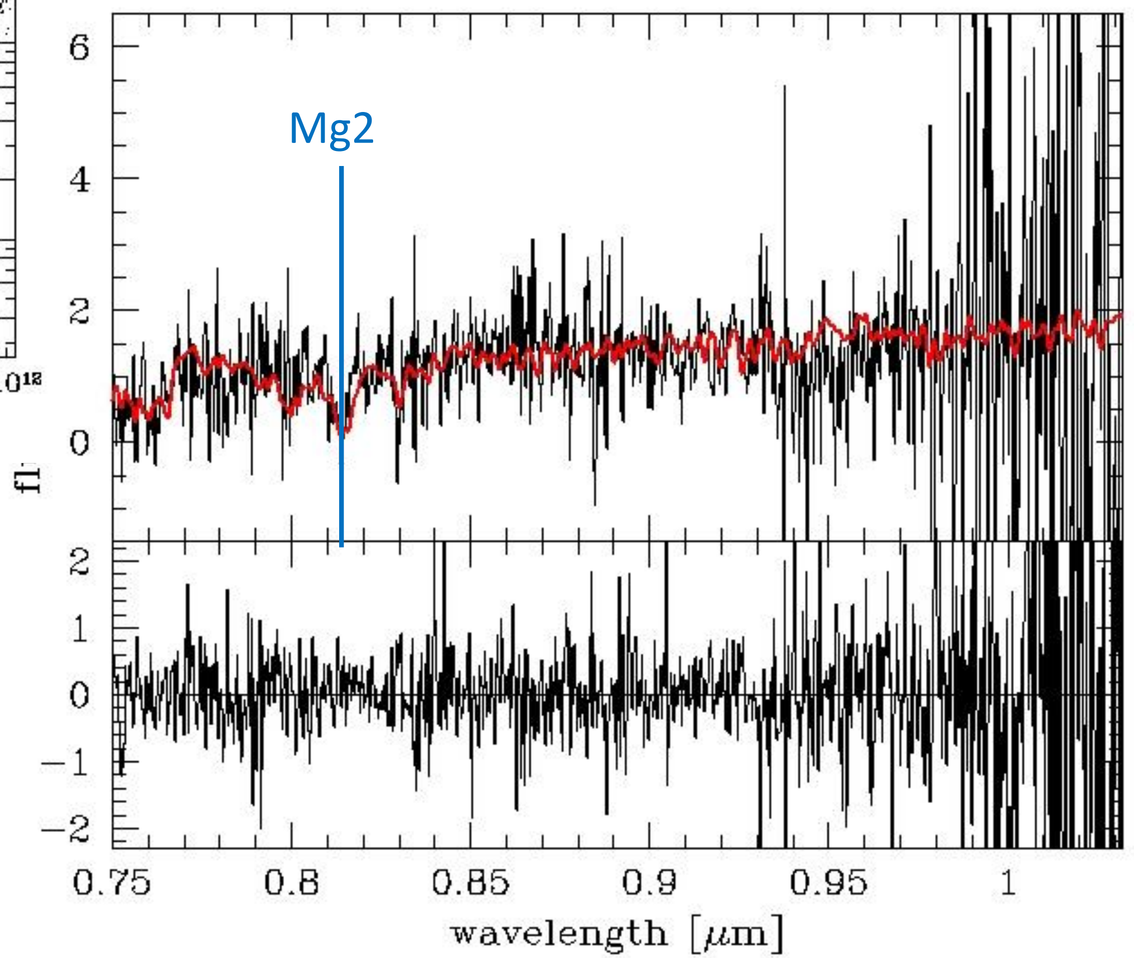
K = 18.23
R_e = 2.10 kpc
M^* = 1.7 x 10^{11} M_{sol}

z = 1.406
σ_V = 224 ± 42 km/s

Results

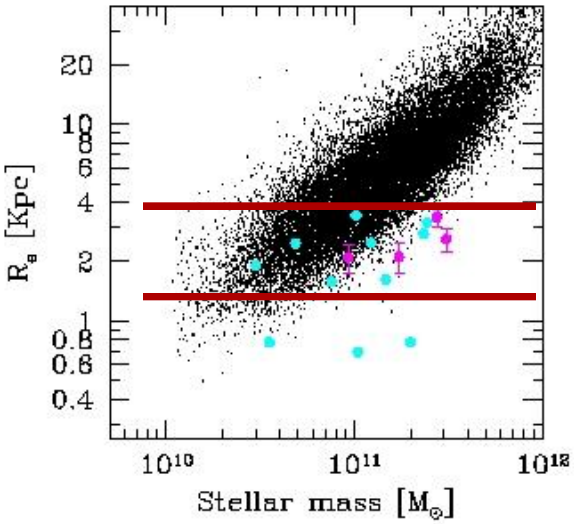


K = 18.40
R_e = 3.36 kpc
M* = 2.7 x 10^{11} M_{sol}



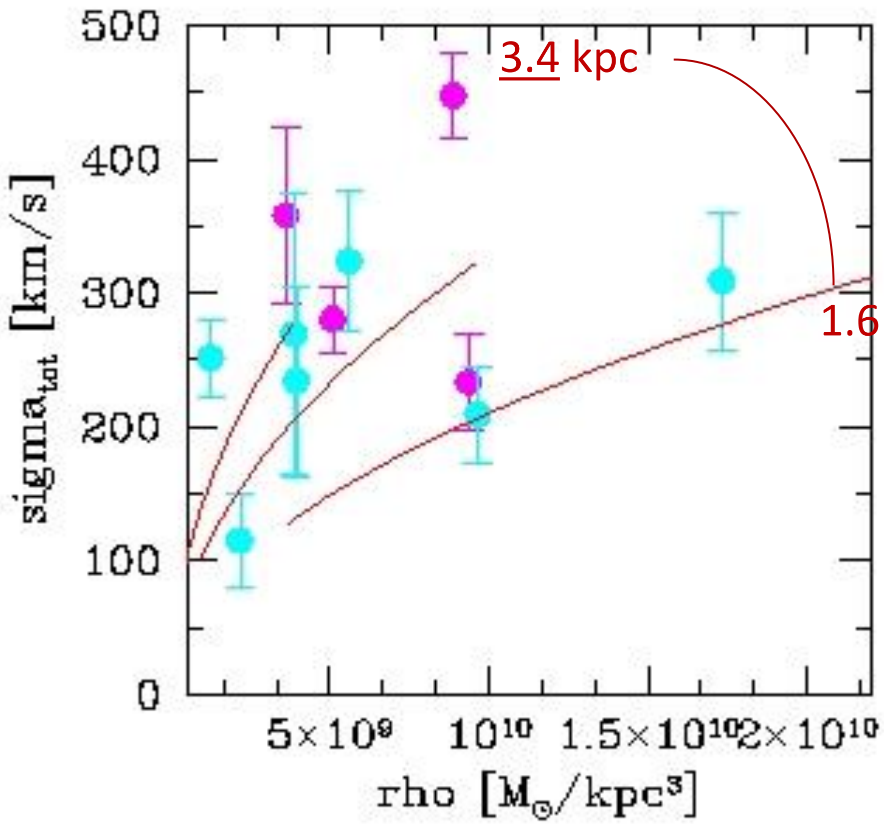
z = 1.910
σ_V = 338 ± 63 km/s

Results

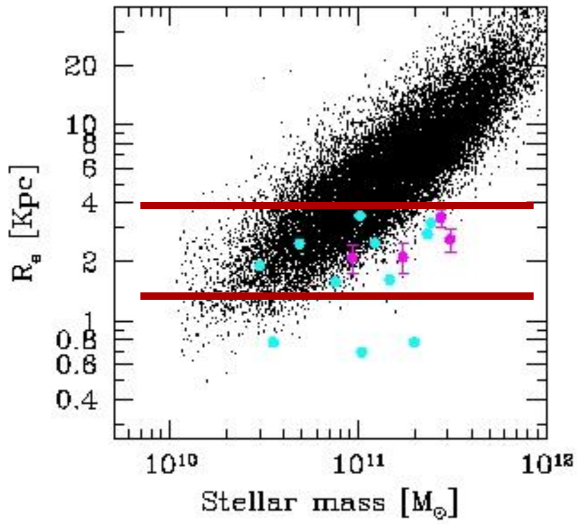


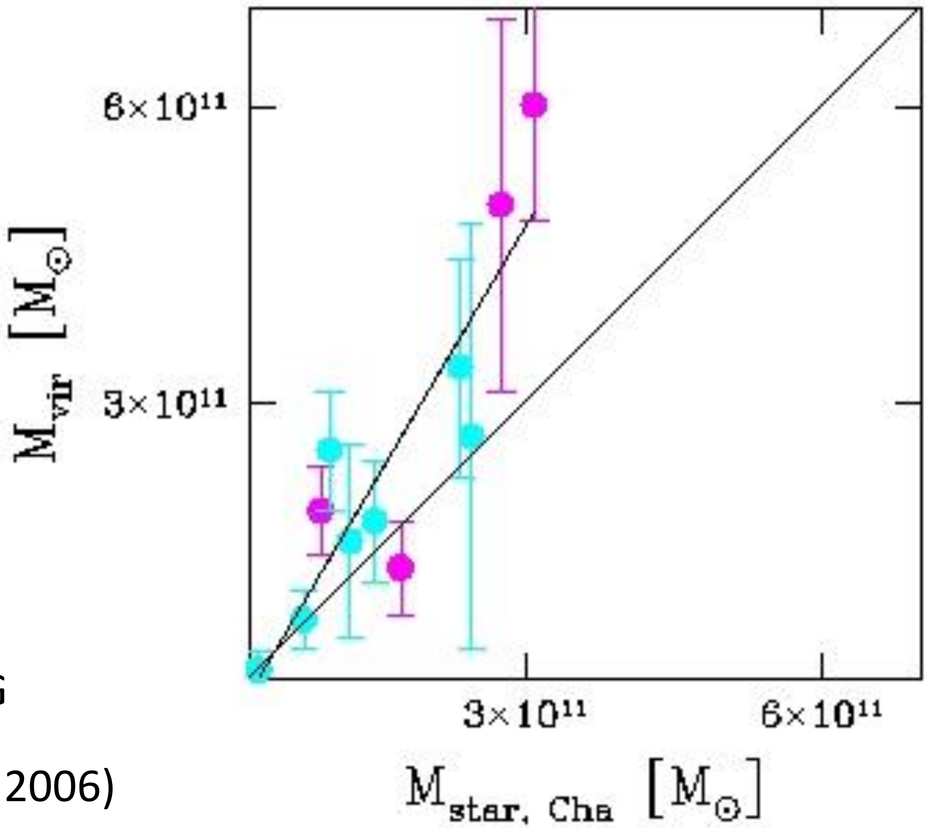
Are compact high-z ETGs really denser?

Rho = M_{star} / (2*R_e^3)



Results





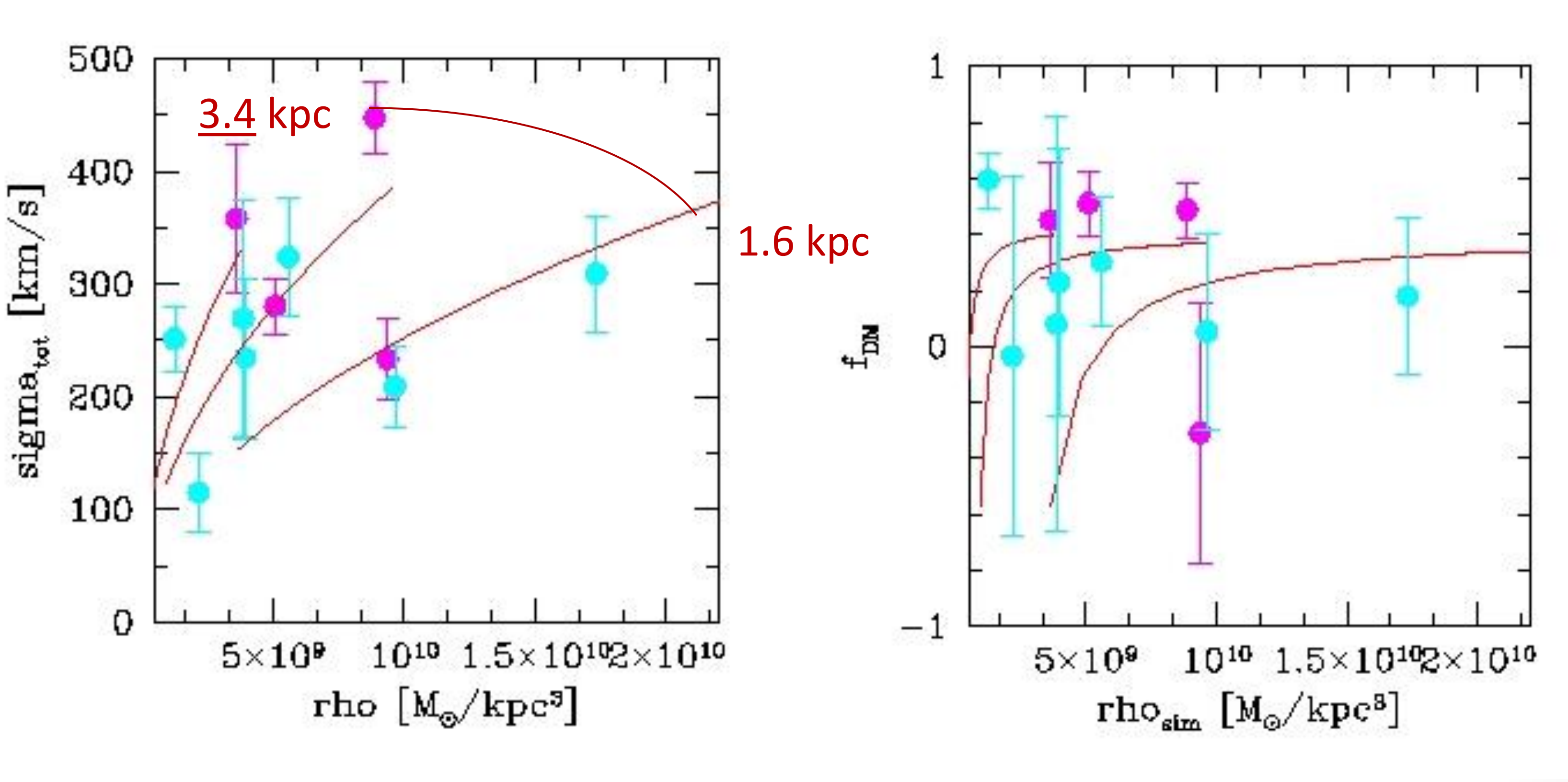
Mvir = (c * sigma^2 * R_e) / G

c = 5 (e.g. Cappellari et al. 2006)

At z ~ 1.5, for M* > $10^{10} M_{sol}$ Mvir $\propto$ K Mstar k>1
in agreement with studies at lower redshift (e.g. Rettura et al. 2006, Ferreras et al. 2005, Auger et 2010)

Under the assumption of structural homology, and of constant IMF
dark matter increases linearly with stellar mass

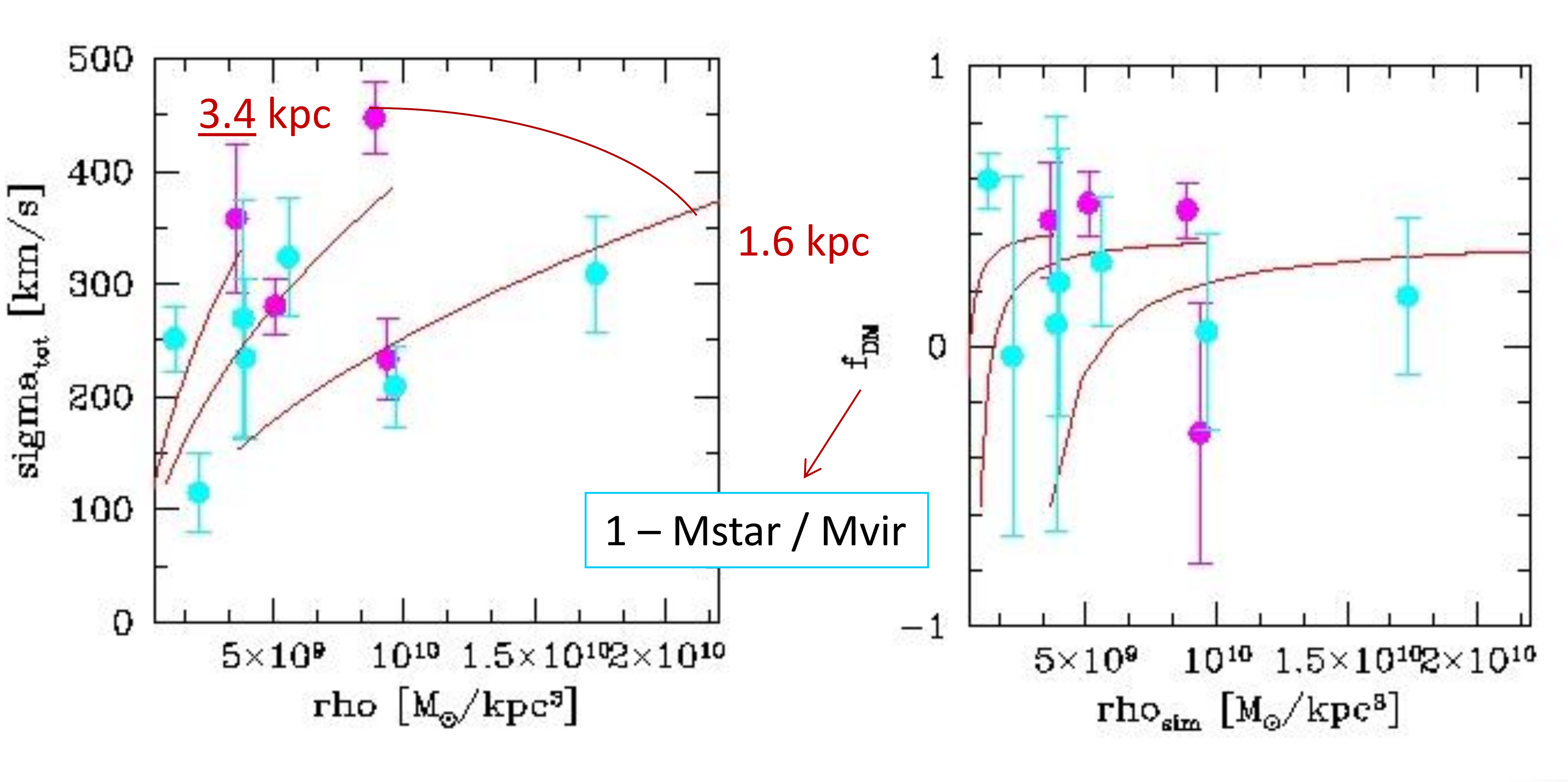
Results



In the hypothesis of structural homology, and constant IMF

- at fixed stellar mass high-z ETGs have the same dark matter fraction irrespective of compacteness;
- Dark matter fraction increases with stellar mass.

Results



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Conclusions…

- We obtained FORS2 spectra for 4 compact ETGs at redshift 1.3 < z < 1.9 to measure their velocity dispersions;
- In the hypothesis of structural homology and constant IMF our results show that:

At z ~ 1.5 the dark matter increases linearly with stellar mass

⬇

Compact ETGs are really denser both in baryonic and obscured component;
Fraction of dark matter increases with stellar mass.

Cosmological simulation of massive galaxies ($3*10_{10}M^{sol}$ - $3*10^{11}$Msol, e.g Oser et al. 2010, 2011) have shown that, at z =1.5, the mode of stellar mass accretion is mass dependent

more massive galaxies dominated by in situ star formation
less massive galaxies dominated by accretion

} higher fraction of DM with mass (e.g. Johansson 2009) but no dispersion with Re

Further investigation is needed: e.g.

- velocity dispersions for a representative sample of high-z ETGs family
- color gradients in high-z ETGs

Conclusions…

- We obtained FORS2 spectra for 4 compact ETGs at redshift $1.3 < z < 1.9$ to measure their velocity dispersions;
- In the hypothesis of structural homology and constant IMF our results show that:

At $z \sim 1.5$ the dark matter increases linearly with stellar mass

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Thank you