Color gradients in normal and compact early – type galaxies at 1<z<2

Adriana Gargiulo[1], Paolo Saracco[1], Marcella Longhetti[1]
In collaboration with : Francesco La Barbera[2] , Reinaldo de Carvalho[3]

[1] INAF – Osservatorio Astronomico di Brera, Milano, Italy
[2] INAF – Osservatorio Astronomico di Napoli, Italy
[3] Instituto Nacional de Pesquisas Espaciais, Brazil

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Outline

- Introduction:
  why early-type galaxies (ETGs),
  why high-z $(1<z<2)$,
  why colour gradients ?

- Colour gradients: what's already on?

- Our colour gradients:
  I. (UV-U) colour gradients
  II. (U-R) colour gradients

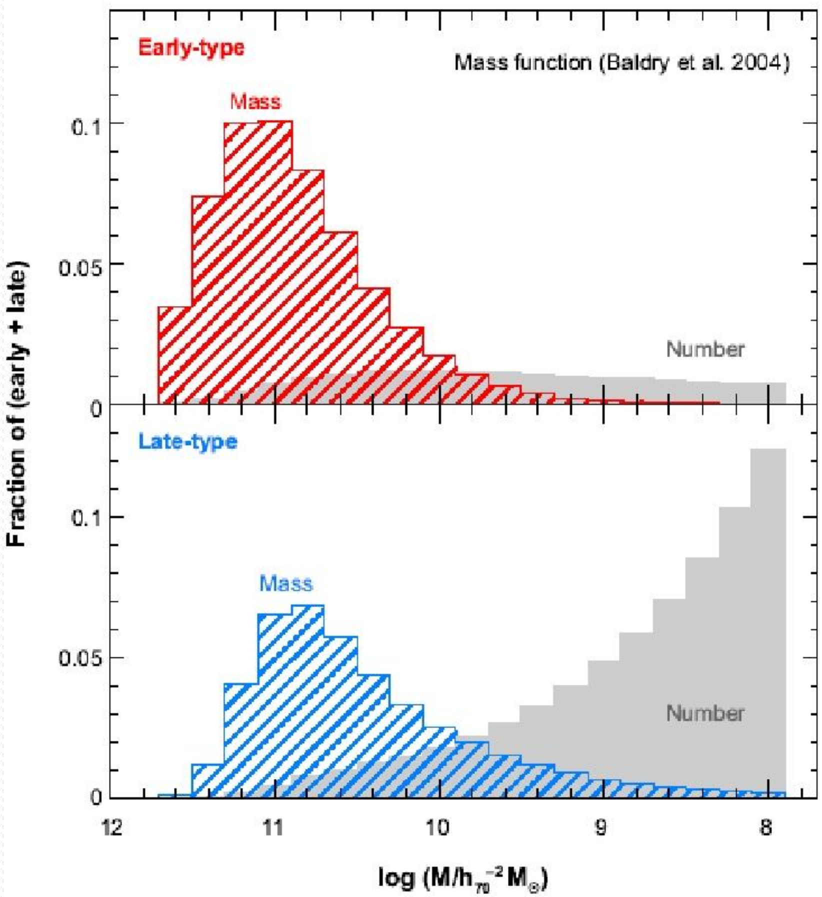
- High-z ETGs: compact and normal galaxies

- Colour gradients in compact and normal ETGs: what's going on…

- Conclusions

Why early-type galaxies, why high-z (1<z<2)?

ETGs(E+So = spheroids) are just 25-30% of the galaxies but contain 50-70% of the stars (baryons) in the local Universe



Component	Central
1. Stars in spheroids	0.0026 h_{70}^{-1}
2. Stars in disks	0.00086 h_{70}^{-1}
3. Stars in irregulars	0.000069 h_{70}^{-1}
4. Neutral atomic gas	0.00033 h_{70}^{-1}
5. Molecular gas	0.00030 h_{70}^{-1}

(Fukugita, Hogan, Peebles 1998)

Why early-type galaxies, why high-z (1<z<2)?

… hence:

Why studying ETGs ?

to reconstruct the mass assembly path of 70% of the baryons of the local Universe.

Why studying high-z ETGs ?

"Observations at high redshift are certainly the most direct way to look at the forming galaxies, and a great observational effort is currently being made in this direction."

Renzini, ARA&A, 2006

⇓

Current observational limit 1<z<2

Why colour gradients?

To probe in which way/ways the stellar mass was assembled in ETGs since their birth, a powerful tool is to gain information on the distribution of the different stellar populations within high-z ETGs

⇓

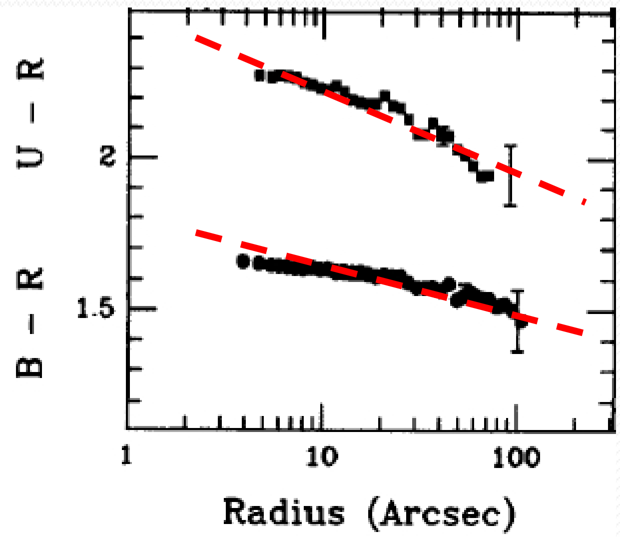
colour gradients are the only way to do this up to now

Why color gradients?

- The color gradient is defined as the slope of the radial color profile

Negative colour gradient: galaxy redder in the centre than in the outskirt

Positive colour gradient: galaxy bluer in the centre than in the outskirt



(Peletier et al. 1990)

- Carry on information about the variation of colour within a galaxy that can be due to:

  Metallicity gradient

  Age gradient

  Presence of dust

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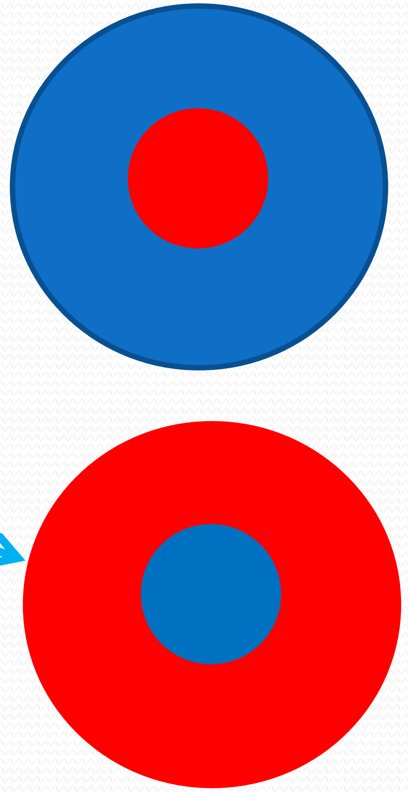

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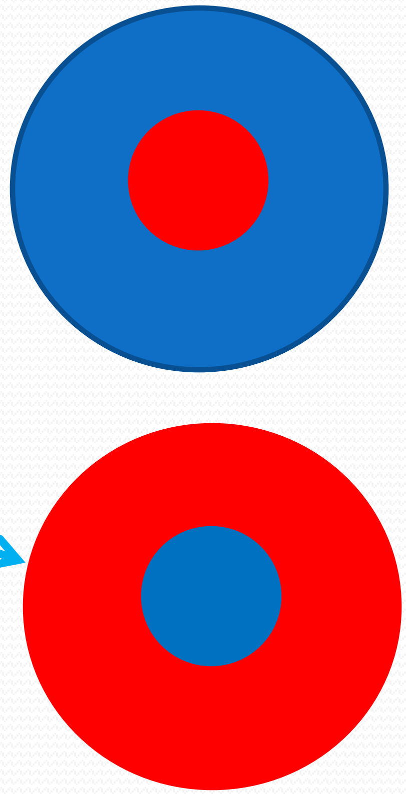


- Carry on information about the variation of of the properties of the underlying stellar population:

  Metallicity gradient

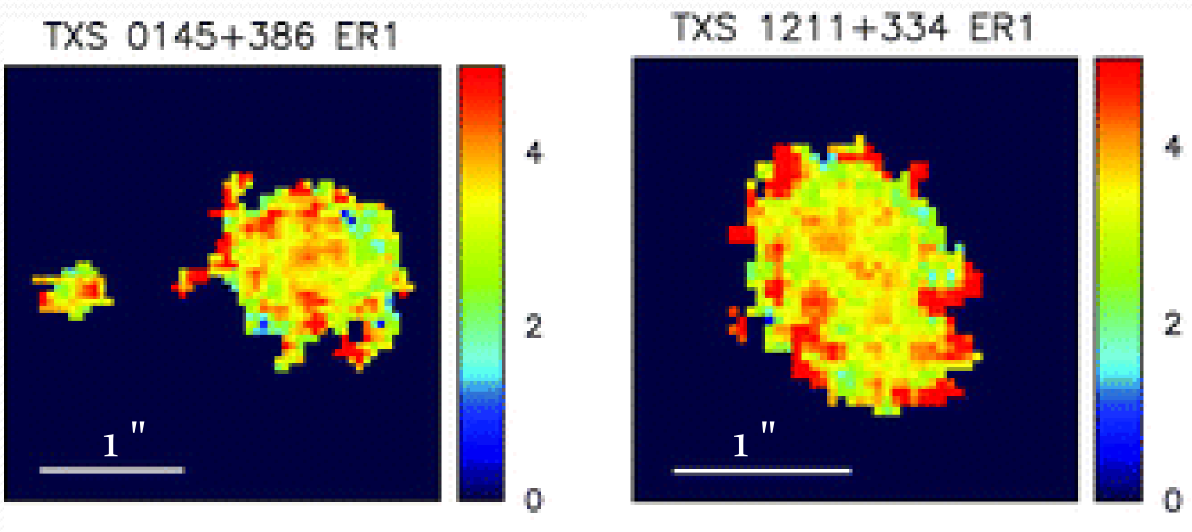
  Age gradient

  Presence of dust

The high-z ETGs: what's already on colour gradients

The lack of multiwalenght HST images has prevented an effective analysis of ETGs colour gradients in all but one case:

- Mc Grath et al. (2008)



Colour maps for two ETGs

$z_{spec} \sim 1.5$

$\sim z - H$ ($\sim B - R_{rest\_frame}$)

Nearly flat colour distribution

UV – U colour gradients: the sample

20 ETGs from the complete sample of 34 ETGs (Saracco, Longhetti, Gargiulo 2010) selected on GOODS-South field with:

- Deep ACS/HST imaging in the F435W, F606W, F775W and F850LP bands (Giavalisco et al. 2004)

  FWHM = 0.1 "

  pixel scale = 0.03 "/px

  Exposure time = 30ks – 100 ks

- spectroscopic redshifts (Vanzella et al. 2008) $(1 < z_{spec} < 2)$;

- accurate morphological classification (visual, spectral, and through surface brightness parameters in the F850LP band: $n_{850}>2$);

- $10^{10}\ M_{sun} < M_{star} < 3\times10^{11}\ M_{sun}$

UV – U colour gradients : surface photometry

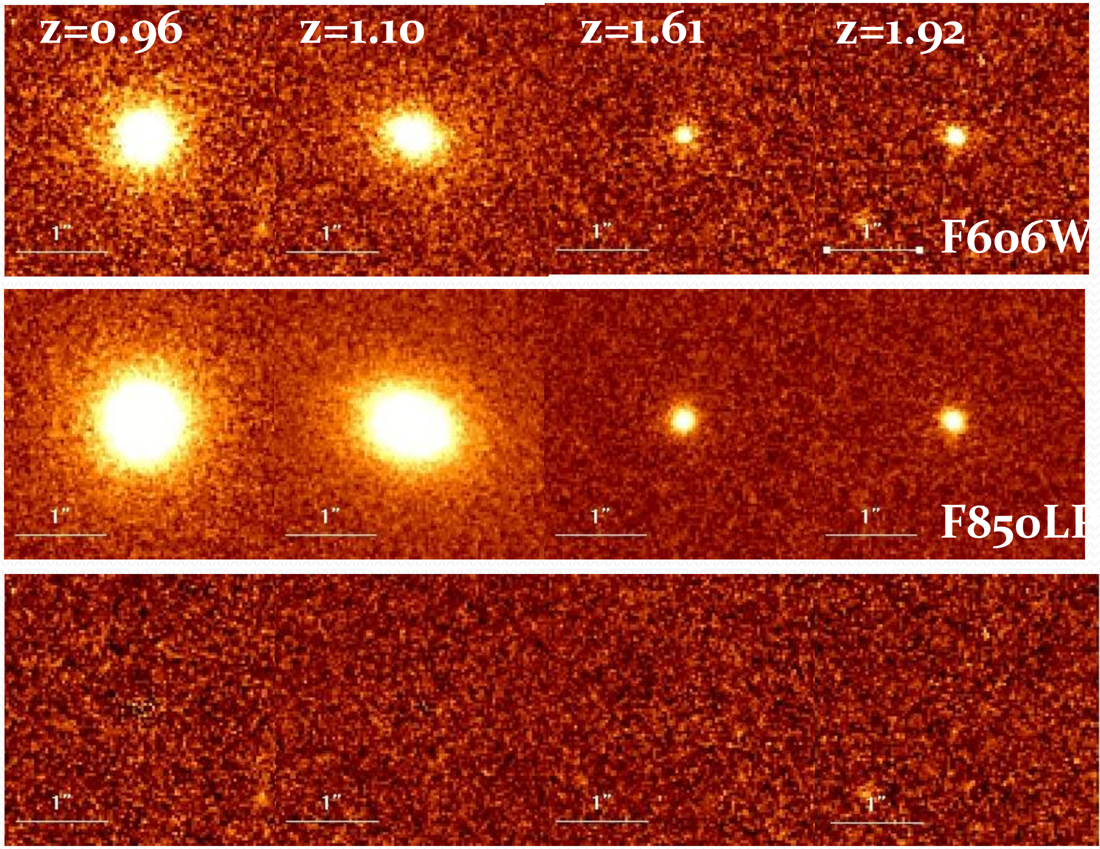
Colour gradient :

$$\nabla_{UV-U} = \frac{\Delta(\mu_{UV}(R) - \mu_U(R))}{\Delta \log R}$$

where the surface brightness (sb) profile

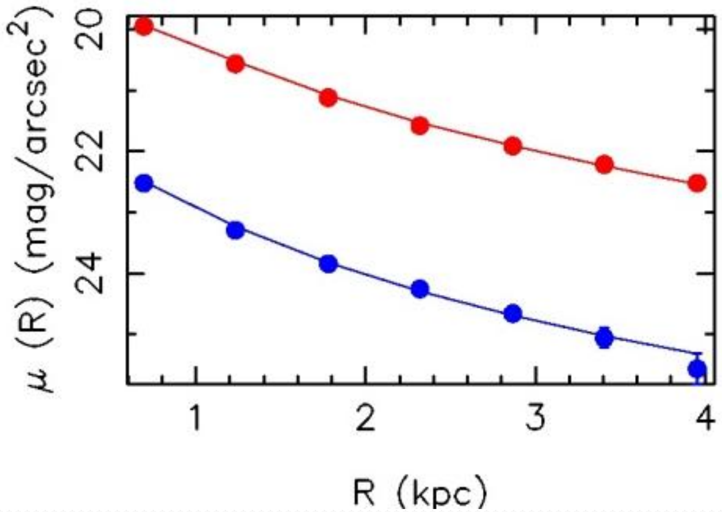
$$\mu(R) = \mu_e + \frac{2.5 b_n}{\ln(10)}[(r/r_e)^{1/n} - 1]$$

Software: GALFIT (Peng et al. 2002): 2D-PSF convolved fit of the galaxy surface brightness profiles



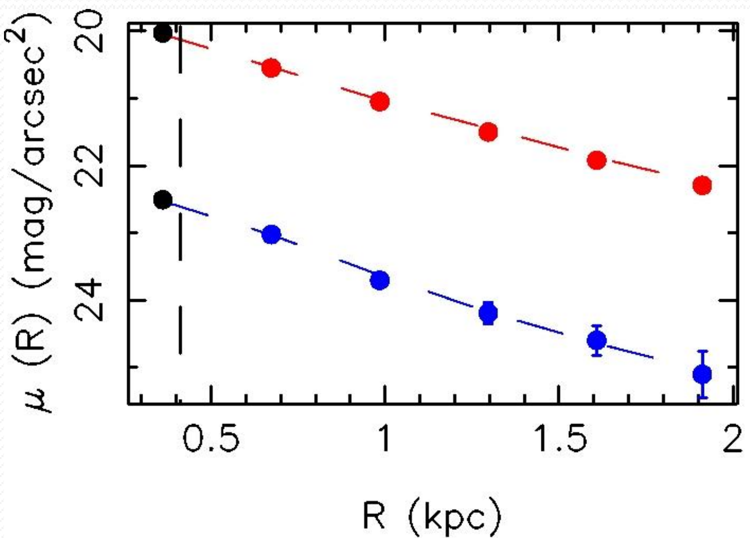
UV – U colour gradients : testing sb parameters of high-z ETGs

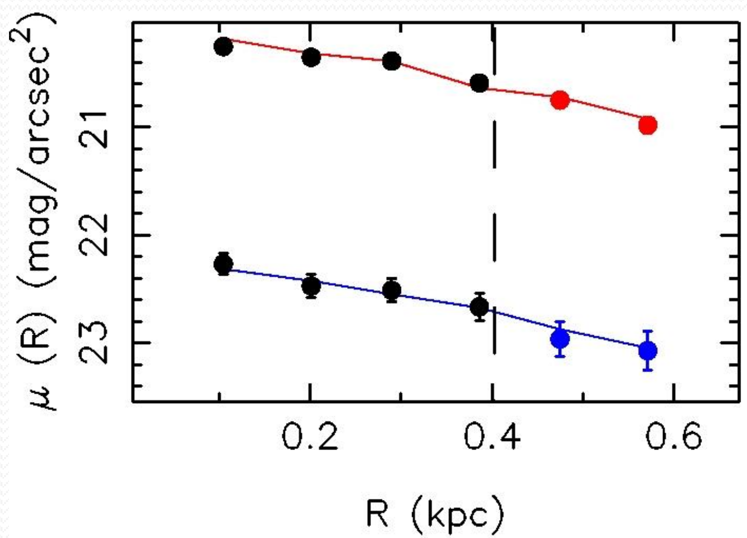
Comparison between the observed and fitted light profiles:



we measure the sb in concentric circular coronas both on the PSF-convolved images of galaxy models and on the real images.

(Gargiulo, Saracco, Longhetti 2011)



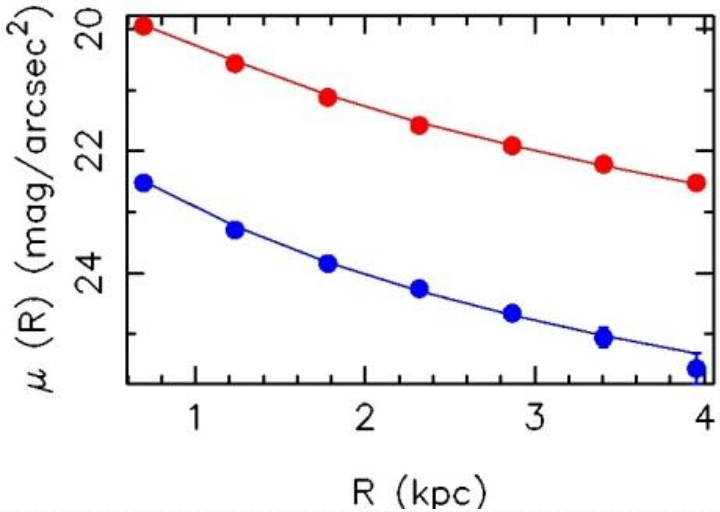


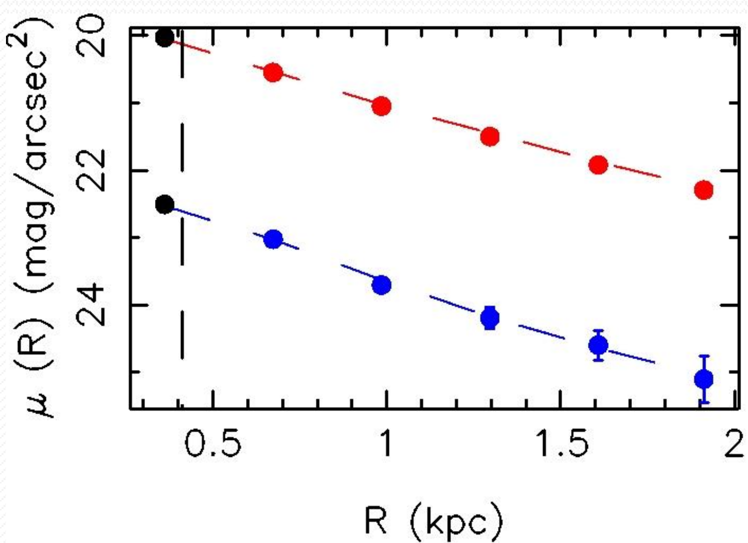
UV – U colour gradients : testing sb parameters of high-z ETGs

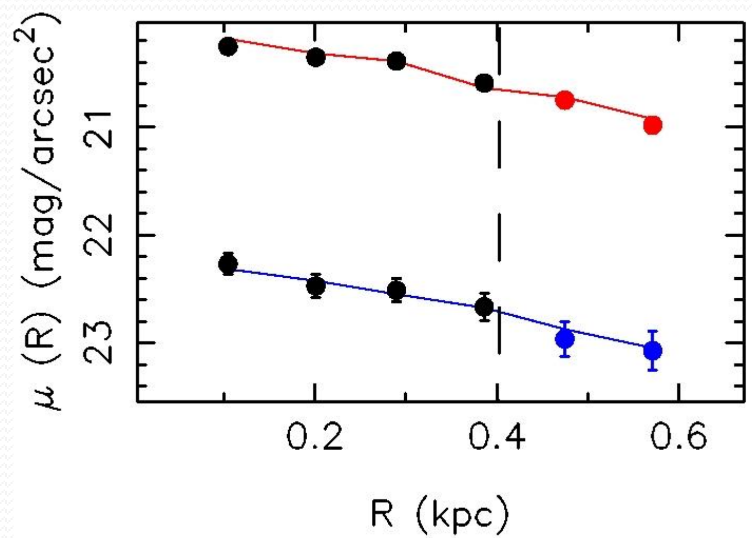
● ● Sb profile measured on the real image in F850LP and F606W filters.

● Points within half of the FWHM (~0.05“).

Sb profile measured on the PSF-convolved model image in F850LP and F606W filters.







UV – U colour gradients : testing sb parameters of high-z ETGs

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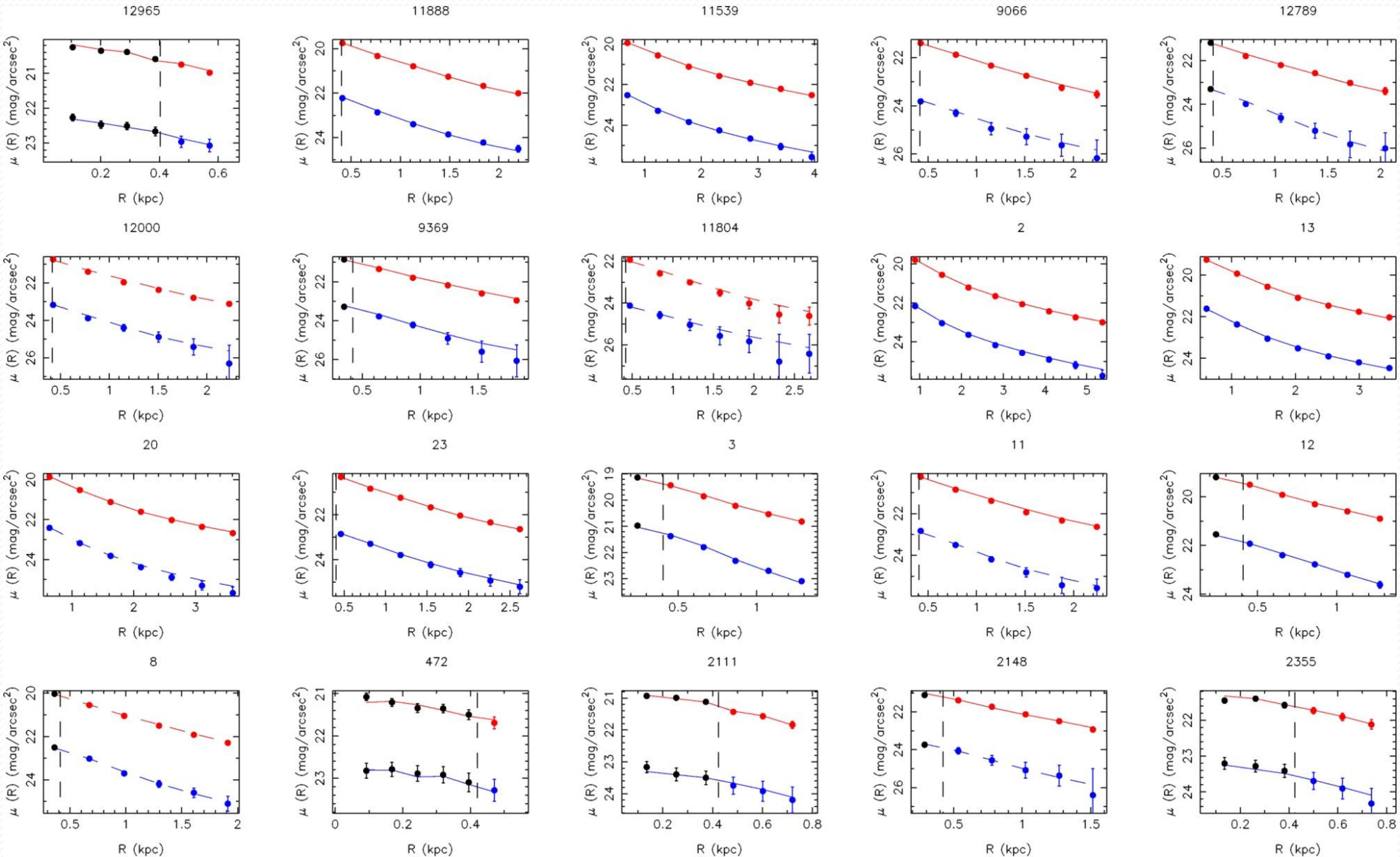
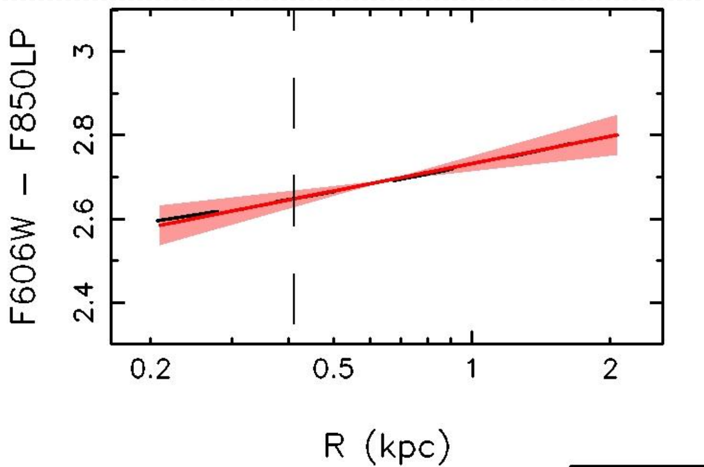
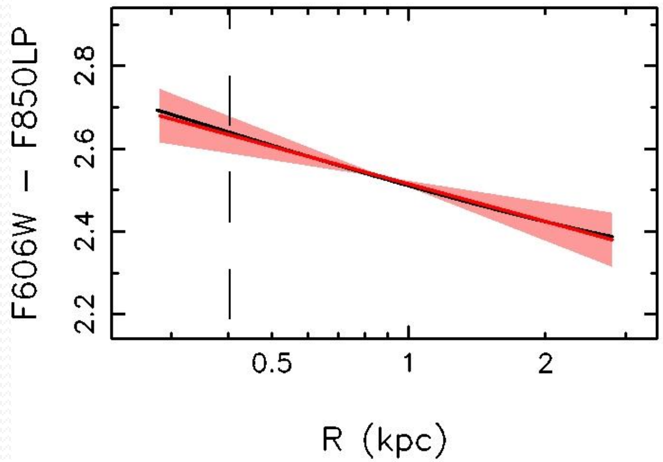
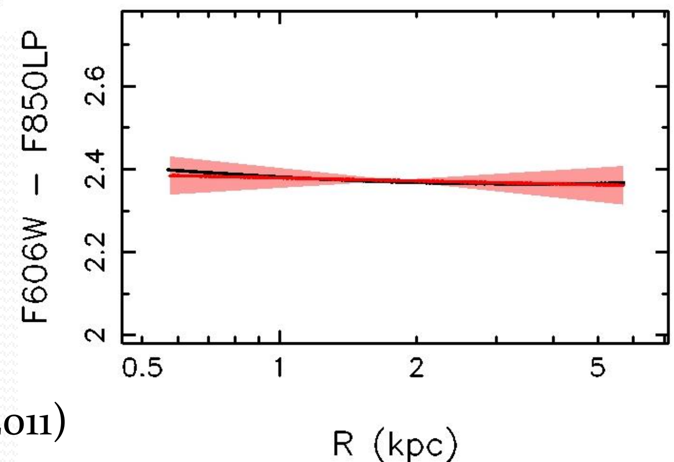


UV – U colour gradients : final product

In our high-z ETGs sample, we find significant UV –U colour gradients: positive (5 galaxies), negative (5 galaxies), null (10 galaxies).

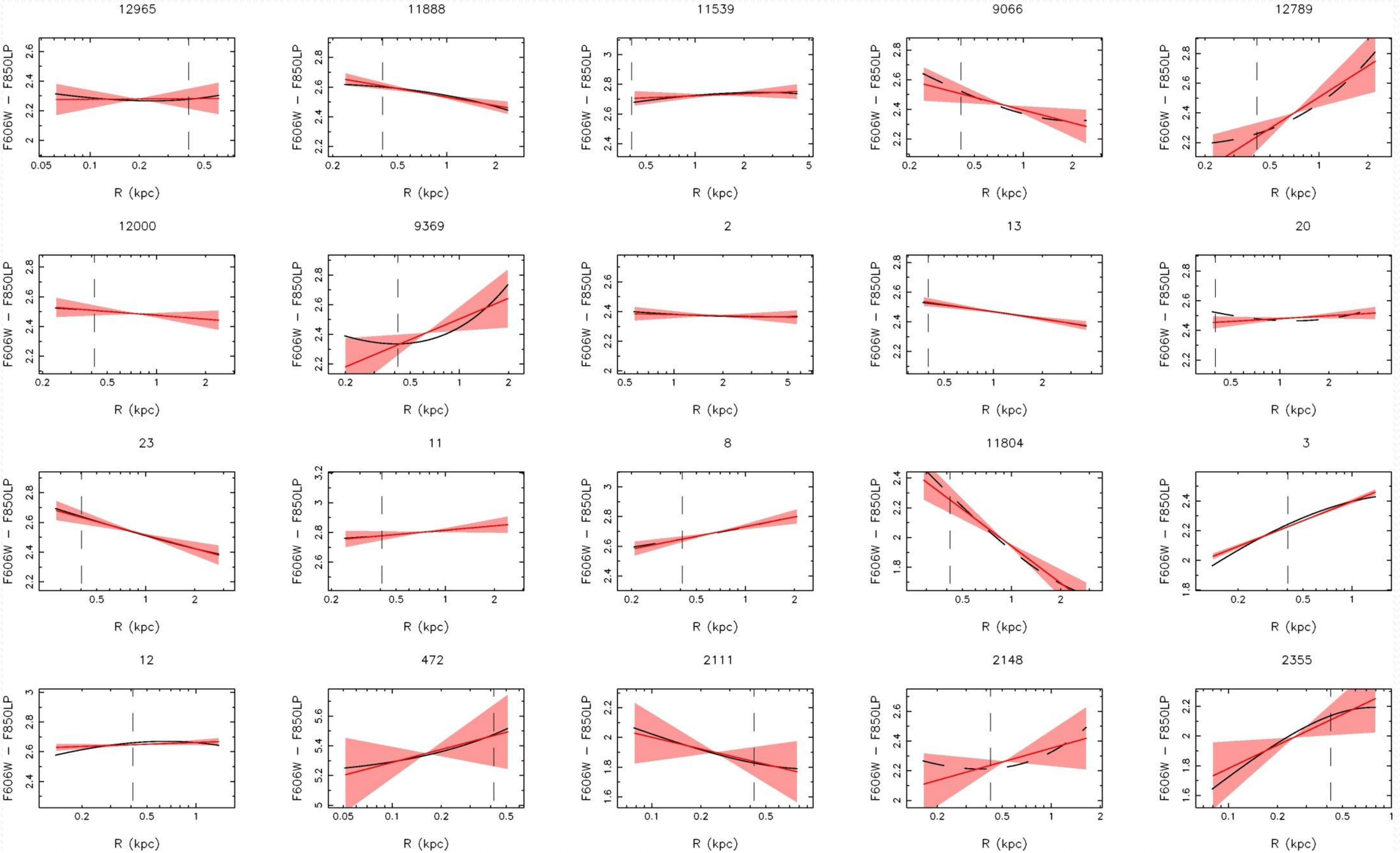






(Gargiulo, Saracco, Longhetti 2011)

UV – U colour gradients : final product



UV – U colour gradients : conclusions

In our high-z ETGs sample, we find significant UV – U colour gradients:

positive (5 galaxies), negative (5 galaxies), null (10 galaxies)

↓

Our high-z ETGs show differences in the spatial distribution of stellar light:

is this due to age and/or metallicity gradient, to the presence of localizied dust or to other factors?

The two bands we have at disposal sample approximately the same spectral region which are extremely sensitive to dust absorption and age variation: to partly break the degeneracy

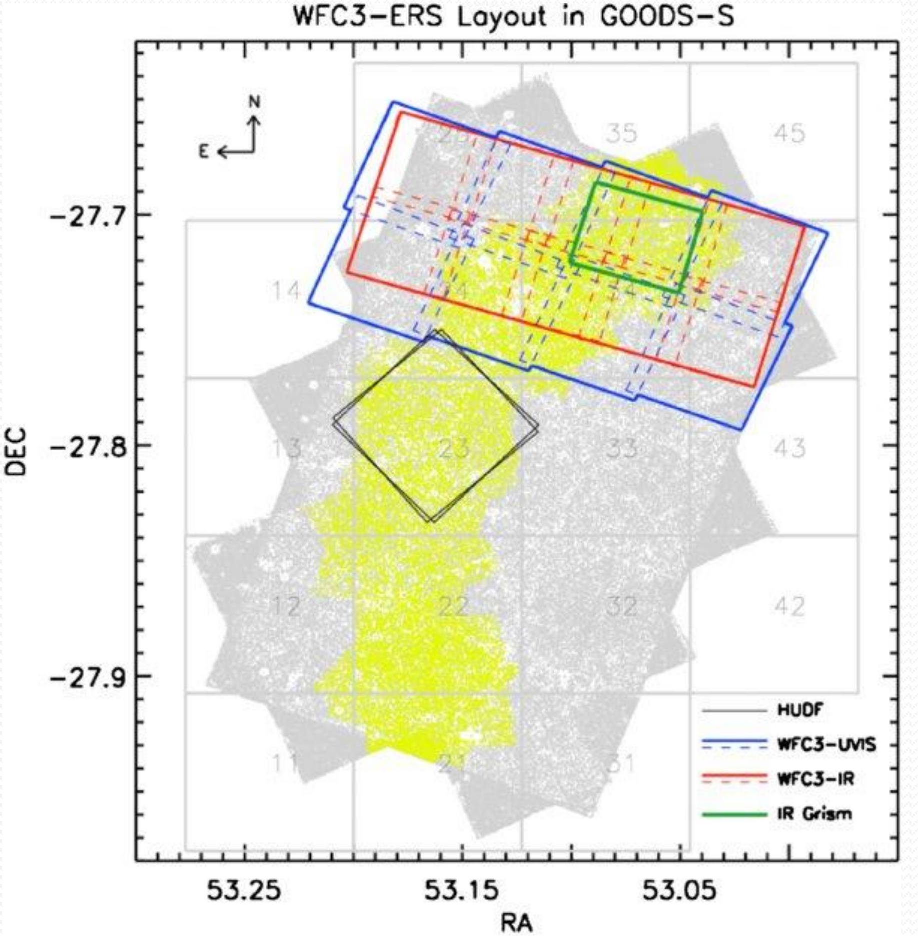
NEXT STEP: enlarge the wavelength baseline covered to map spectral region sensitive to age

U – R colour gradients : the sample

16 ETGs from the complete sample of 34 ETGs selected on GOODS-South field with:

both deep ACS/HST imaging in the F850LP bands (Giavalisco et al. 2004) and WFC3 imaging in the F160W band (P.I.s Illingworth and O'Connell)

FWHM = ~ 0.2 "
pixel scale = 0.128 "/px
Exposure time = ~ 6 ks / ~ 70 ks



Actual sample: 11 ETGs with $1 < z_{spec} < 1.6$

U – R colour gradients : exploiting the capability of WFC3

Original images values:

pixel scale = 0.128 “/px

FWHM $_{measured}$ ~ 0. 22 “

MULTIDRIZZLE →

Final images values:

pixel scale = 0.06 “/px

FWHM ~ 0. 2 “

Near the Nyquist limit

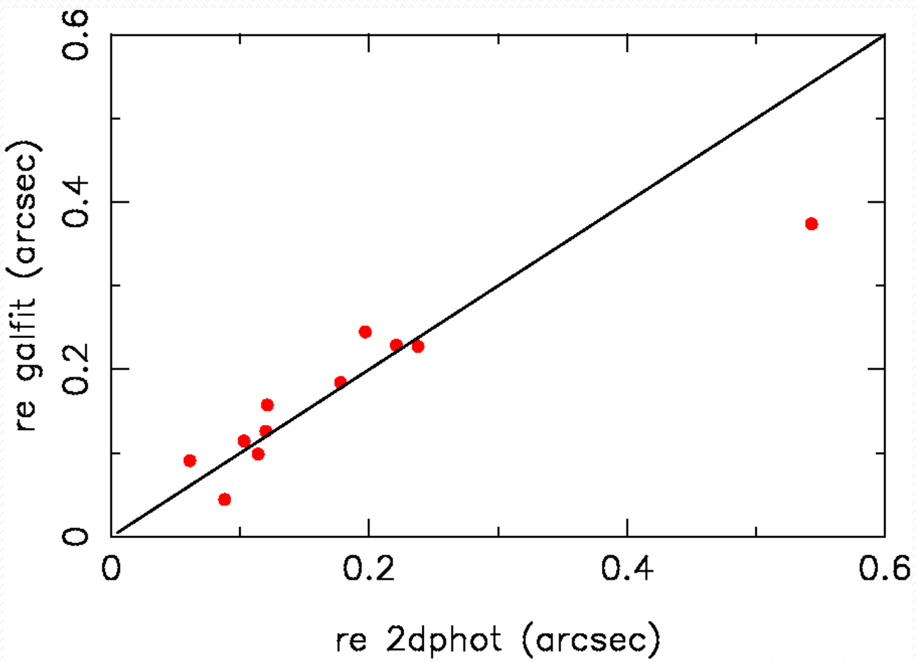
To cope with this, we adopt two different software to derive the sb parameters:

GALFIT	2DPHOT
(Peng et al. 2002)	(La Barbera et al. 2008)
galaxy convolution	galaxy deconvolution
PSF= real star	PSF= 2D moffat model

U – R colour gradients : exploiting the capability of WFC3

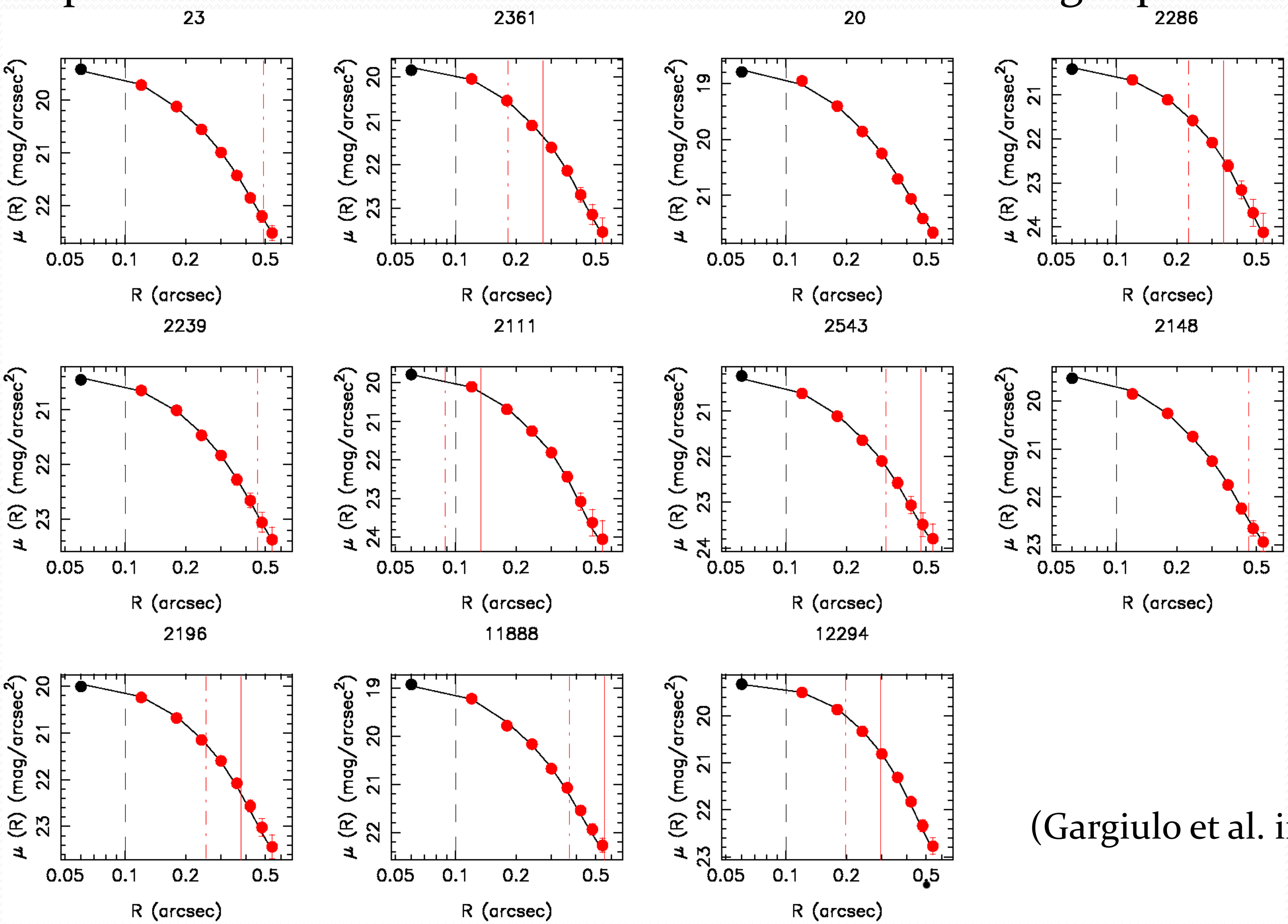
WFC3-F160W surface brightness parameters derived with the two software:

Object	z	$R_{e,gal}$ (arcsec)	$R_{e,2D}$ (arcsec)
23	1.041	0.24	0.19
20	1.022	0.37	0.54
2361	1.609	0.09	0.06
2286	1.604	0.11	0.10
2239	1.415	0.23	0.22
2111	1.610	0.04	0.08
2543	1.612	0.16	0.12
2148	1.609	0.23	0.24
2196	1.614	0.13	0.12
11888	1.039	0.18	0.18
12294	1.215	0.10	0.11



U – R colour gradients : exploiting the capability of WFC3

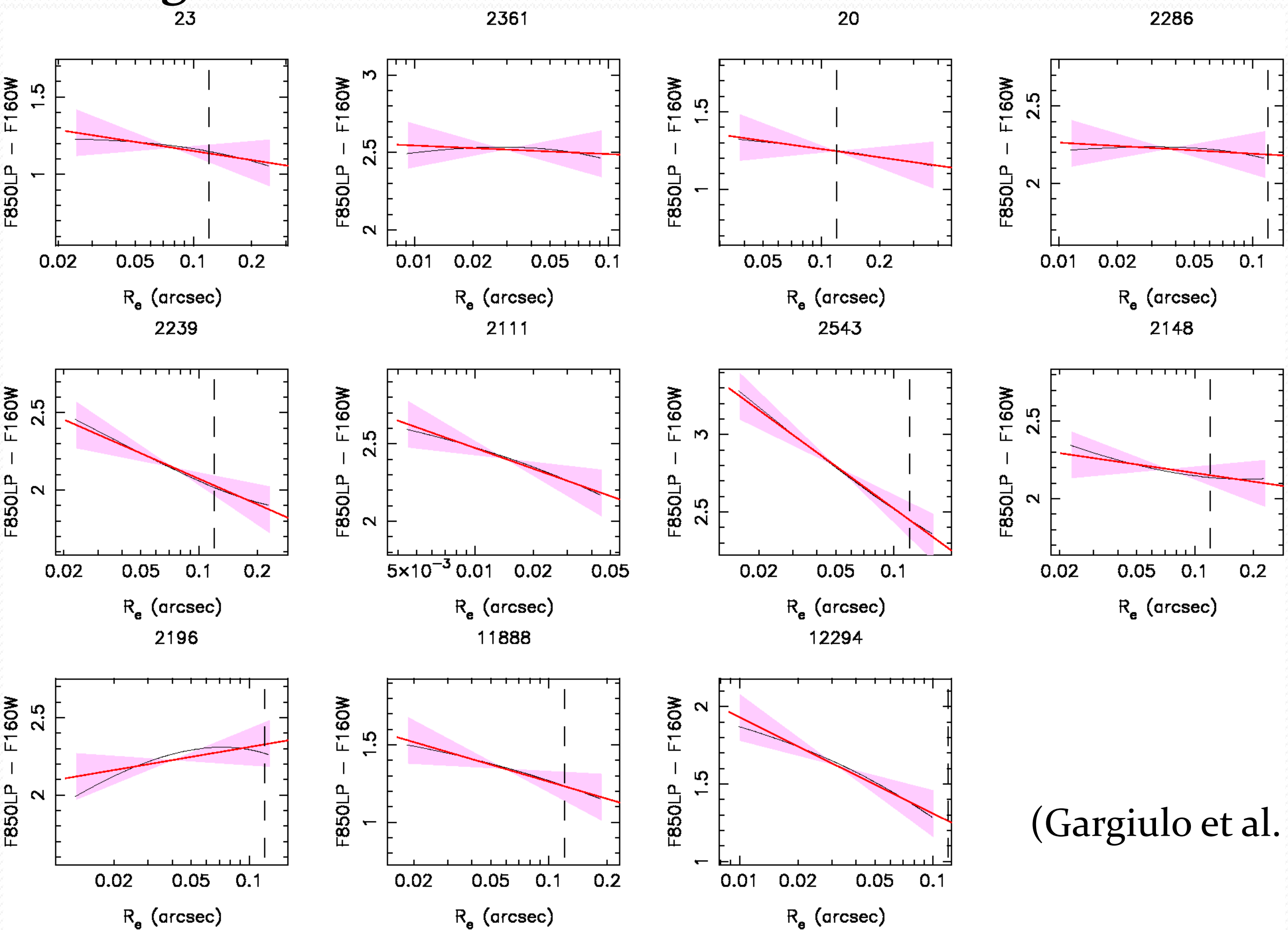
Comparison between the observed and fitted F160W-light profiles:



(Gargiulo et al. in preparation)

U – R colour gradients : final product

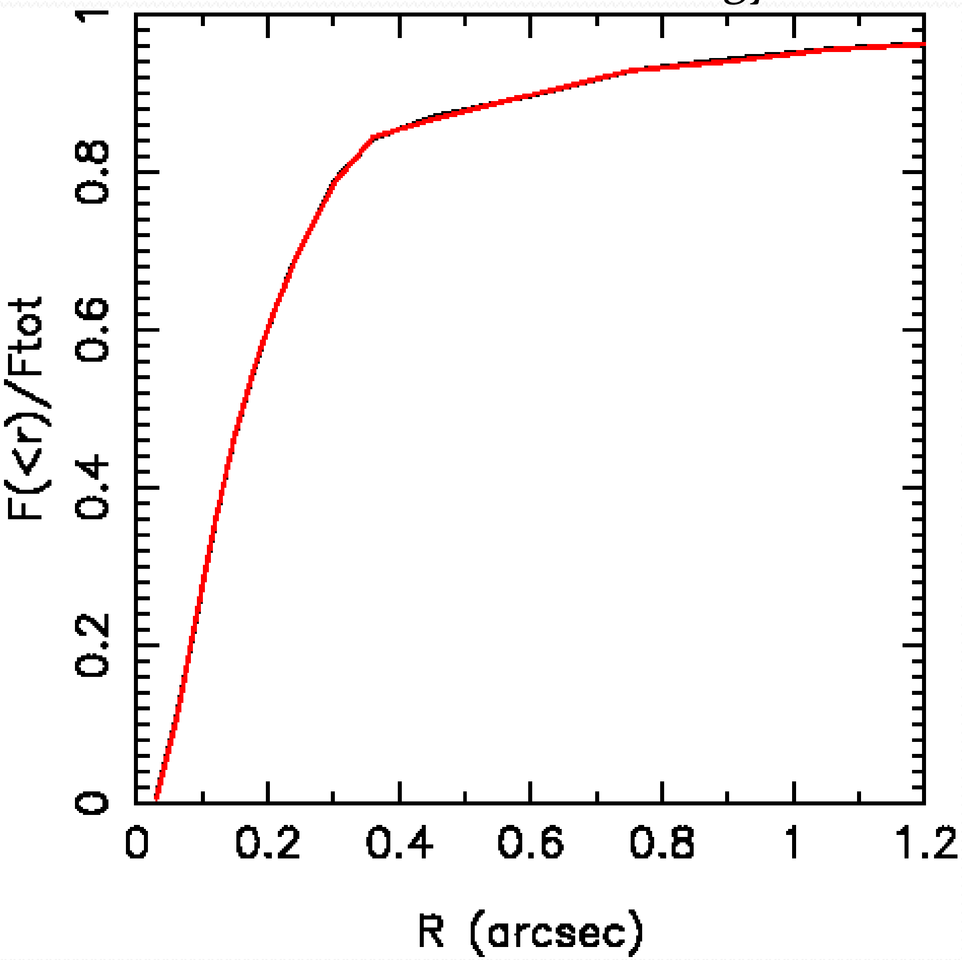
In our high-z ETGs sample, **we find principally significant negative and null U – R colour gradients.**



(Gargiulo et al. in preparation)

U – R colour gradients : color maps

The fractional encircled energy of PSFs



F850LP

FWHM = 0.15”
Pixel size = 0.03 “/px

F160W

FWHM = 0.22”
Pixel size = 0.128 “/px

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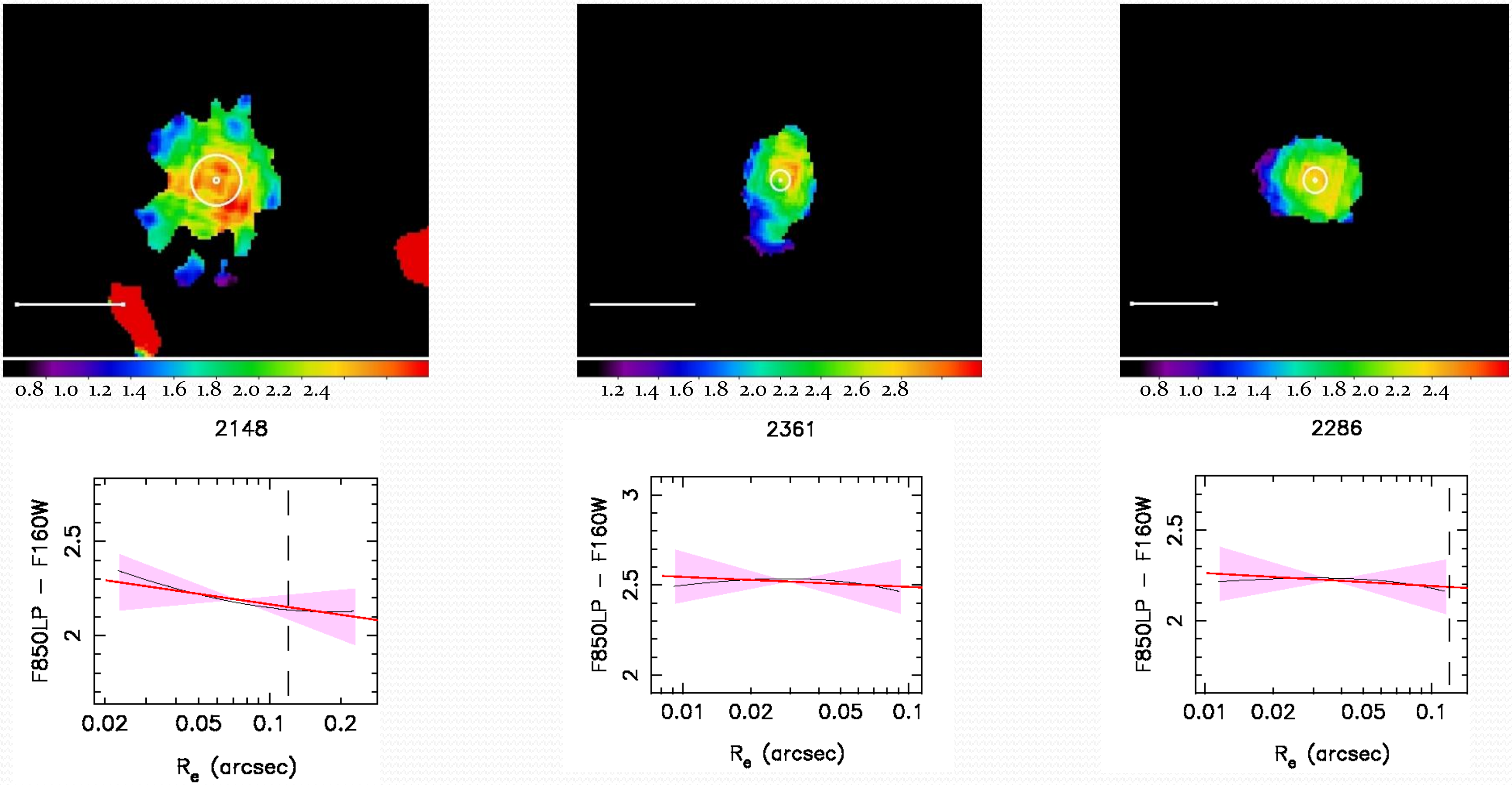
To avoid artificial colour gradients it is necessary:

- report the images to the same pixel scale → 0.03 “/px
- report the images to the same PSF → F160W PSF

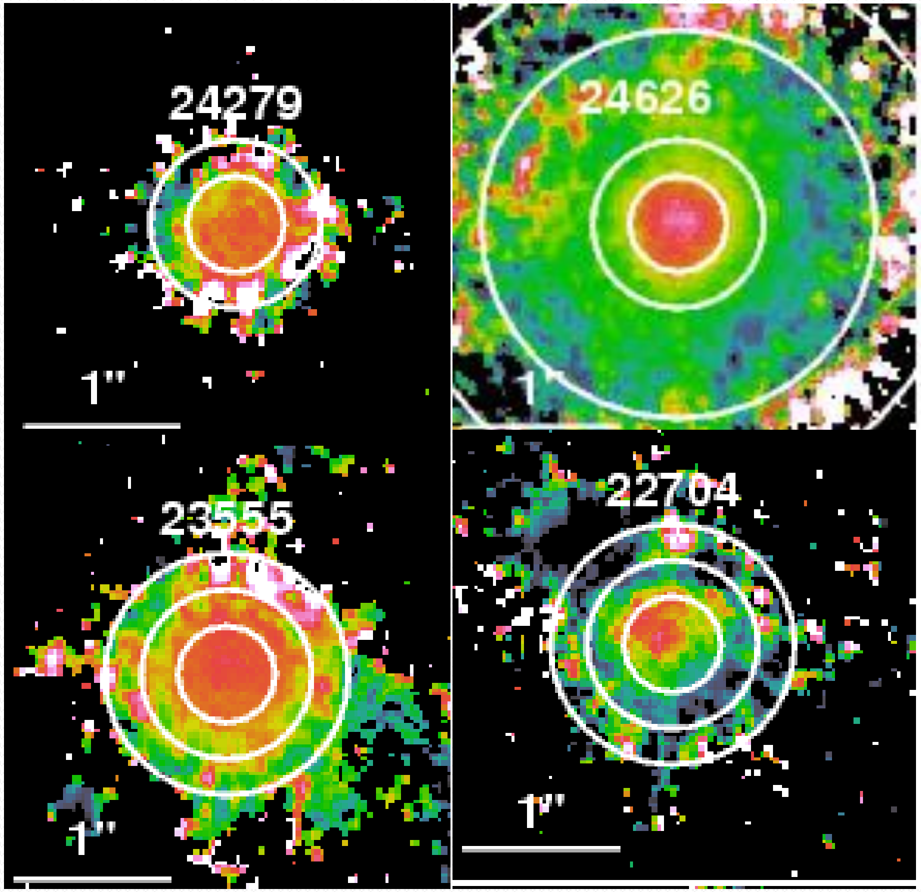
U – R colour gradients : color maps



(Gargiulo et al. in preparation)

U – R colour gradients : color maps

Guo et al. (arXiv:1101.0843) taking advantage of the recent WFC3 -F160W images of the GOODS-South



Colour maps for 4 ETGs

z_{spec} ~ 1.3 -2.0

z – H

Negative colour gradients

U – R colour gradients : partial conclusions

In our high-z ETGs sample, we find:

- significant UV – U color gradients: positive (5 galaxies), negative (5 galaxies), null (10 galaxies);

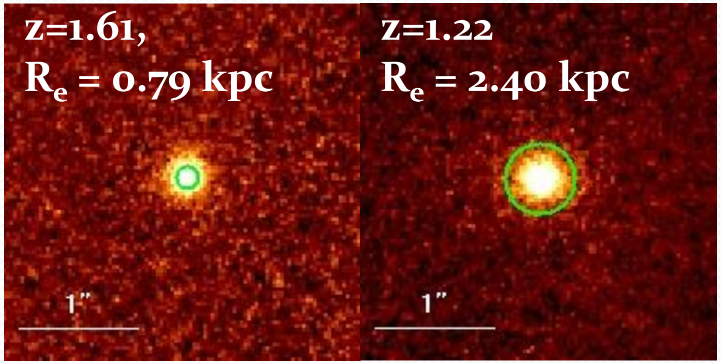
- significant U – R color gradients : predominantly negative and null;

↓

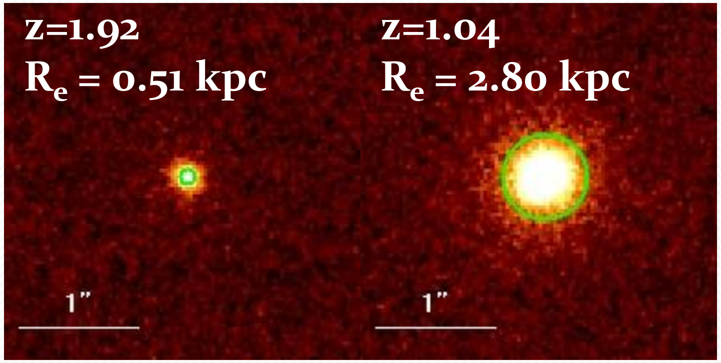
- **We resolve the spatial distribution of stellar (and dust) content**
- **The variety of UV-U and U-R colour gradients in high-z ETGs suggest that the spatial distribution of stellar (and dust) content could be not unique .**

High-z ETGs: compact and normal galaxies

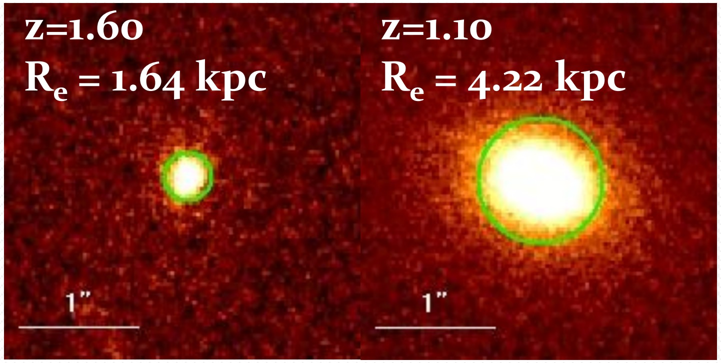
Recently, high-z ($1 \leq z \leq 2$) photometric and spectroscopic observations show that, for what concerns their sizes, ETGs are an **eterogeneous** population spanning a wide range of radius at a given stellar mass.



$M_{star} \sim 2.5 * 10^{10}$



$M_{star} \sim 4.0 * 10^{10}$



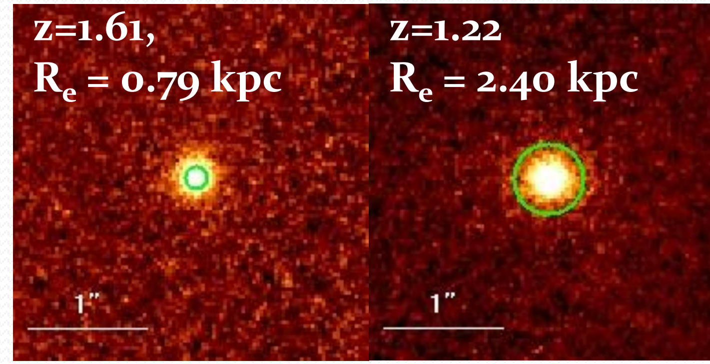
$M_{star} \sim 1.5 * 10^{11}$

Qualitative

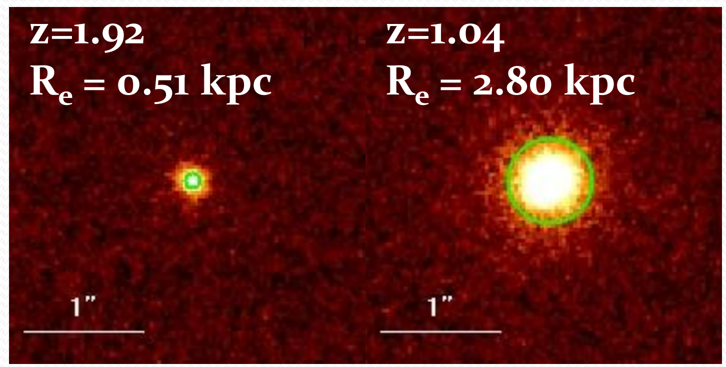
High-z ETGs: compact and normal galaxies

"we find a majority (62 per cent) of normal ETGs, similar to typical local ones, coexisting with compact early types from ~ two to ~ six times smaller in spite of the same mass and redshift."

(Saracco, Longhetti, Gargiulo 2010)



$M_{star} \sim 2.5*10^{10}$



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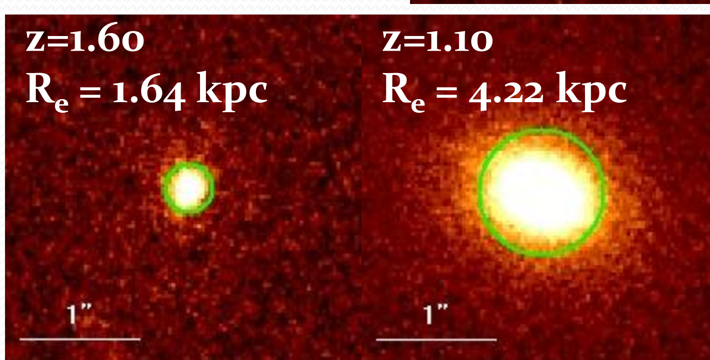

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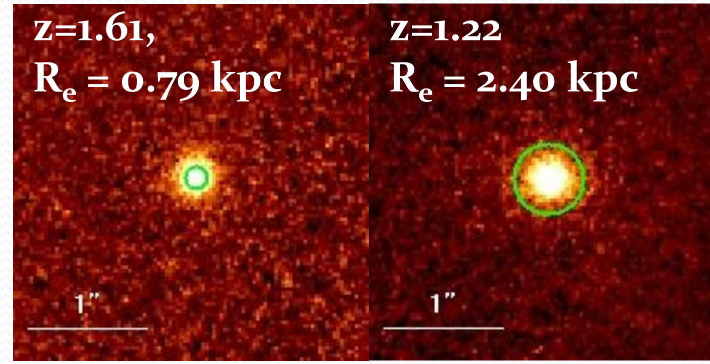
Qualitative

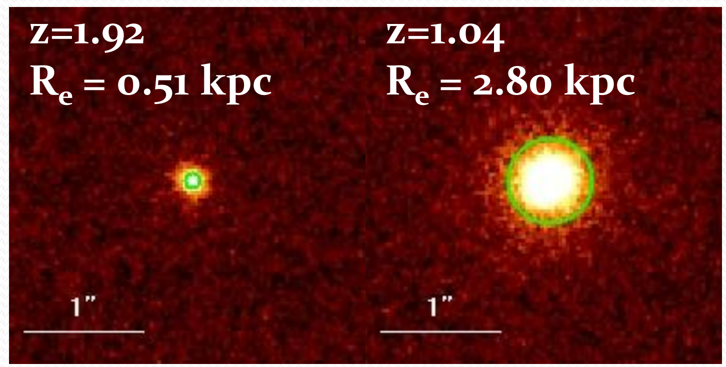
High-z ETGs: compact and normal galaxies



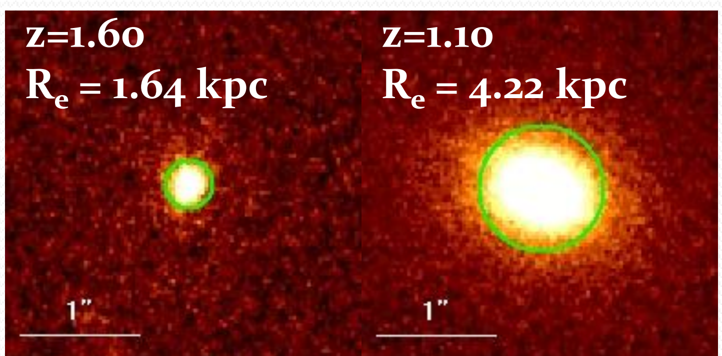
$M_{star} \sim 2.5*10^{10}$

"Furthermore, we find that the number density of compact early types at <z > 1.5 is consistent with the lower limits of the local number density of compact early types derived from local clusters of galaxies. "

(Saracco, Longhetti, Gargiulo 2010)



$M_{star} \sim 4.0*10^{10}$



$M_{star} \sim 1.5*10^{11}$

Qualitative

Colour gradient of compact and normal high-z ETGs

Early Universe:

- UV –U sample : 13 normal galaxies and 7 compact galaxies
- U –R sample: 5 normal galaxies and 6 compact galaxies

↓

Stellar population models to investigate the origin of colour gradients of both compact and normal high-z ETGs

Colour gradient of compact and normal high-z ETGs

Early Universe:

- UV –U sample : 13 normal galaxies and 7 compact galaxies
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↓

Stellar population models to investigate the origin of colour gradients of both compact and normal high-z ETGs

Local Universe:

- We have selected a sample of compact and normal ETGs from the SDSS in the same mass range and have already derived the colour gradients approximately in the same U – R bands.

↓

Stellar population models to probe an evolutionary link between high and local ETGs

Conclusions

- We ascertain the feasibility of colour gradient estimates even in high-z ($z>1$) ETGs;

- We resolve the spatial distribution of the stellar content of high-z ETGs :

  - we detect effective radial UV – U colour variations , both positive and negative, in 10 galaxies out 20 (~50 %)

  - we detect effective radial U – R negative colour variations in 5 galaxies out 11 (~50 %)

- The colours gradient we detect can be interpret as due to different factors: age, dust, metallicity…

Incoming….

- Stellar population models of our high-z ETGs to discriminate among these factors the ones responsible of the observed colour gradients in compact and normal high-z ETGs:
  - Is there any difference between compact and normal ETGs?

- Identify the evolutionary models able to explain both the high-z and local colours gradients of compact and normal ETGs:
  - Can high-z compact galaxies be the progenitors of local compact ETGs?

… Thanks