Colour gradients of early-type galaxies at 1<z<2: constraining their assembly history

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OUTLINE

- ***Why studying colour gradients and light profiles of high-z early-type galaxies;***
- ***Multiband light profiles of high-z ETGs;***
- ***UV–U and U-R colour gradients of high-z ETGs;***
- ***Stellar populations analysis;***
- ***Conclusions.***

AIM OF THE PROJECT

To tackle the central point of the formation of early-type galaxies (E+S0; ETGs) discriminating the scenarios of their mass assembly.

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MEANS: COLOUR GRADIENTS OF HIGH-Z ETGs

The *only* measurements that can provide us with information on the distribution of stellar populations in high-z ETGs.

Hubble Space Telescope (HST) deep images have allowed us to push the study of colour gradients up to z ~ 2, when the Universe was only 3-4 Gyr old.

COLOUR GRADIENTS: THE DEFINITION

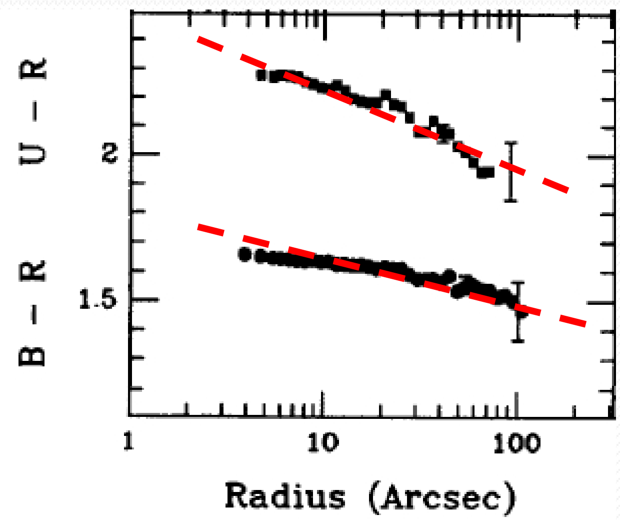
The gradient of the colour X-Y is classically defined as the logarithmic slope of the color profile

$$(X\text{-}Y)(r) = \mu_X(r)-\mu_Y(r)$$

$\mu_X(r)$, $\mu_Y(r)$: light profiles in X and Y band, respectively

↓

gives quantitative information on the radial colour variation in galaxies.



(Peletier et al. 1990)

NEGATIVE COLOUR GRADIENT: galaxy redder toward the centre

POSITIVE COLOUR GRADIENT: galaxy bluer toward the centre

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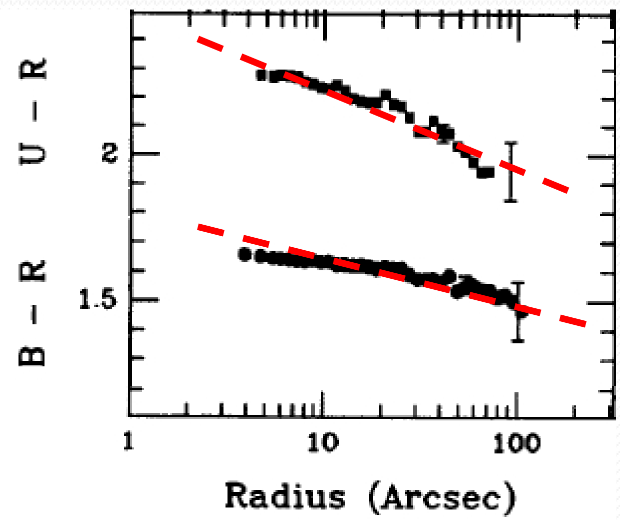

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COLOUR GRADIENTS: WHAT INFORMATION CAN WE DERIVE FROM?

Colour variations → Metallicity/Age gradient; Presence of dust; Radial variationt of star-formation time scale → Variation of the properties of the underlying stellar population

SELECTION AND MAIN CHARACTERISTICS OF THE SAMPLE

The sample: 34 ETGs at $0.9 < z_{spec} < 2$ selected in the GOODS South field, 90% complete to K =20.2, morphologically selected (both visual and through the light profiles) with:

- spectroscopic redshift;
- photometry in 14 bands: **F435W, F606W, F775W e F850LP → HST/ACS**;
  3 bande U, J, H, K → ESO-VLT
  3.6, 4.5, 5.8, 8.0 μm → Spitzer;
- **recent HST/WFC3 images in the near-infrared (F160W) for 16 ETGs.**

SELECTION OF COLOURS

We have studied gradients of two colours:

~$(UV - U)_{restframe}$ (F606W-F850LP) e ~$(U-R)_{restframe}$ (F850LP-F160W)

to investigate the spatial distribution of :

UV,U emission, sensitive to dust and dominated by the light of young stellar populations;

R emission, mainly dominated by the light of old stellar populations.

MULTIBAND FITTING OF LIGHT PROFILES

We have modelled the light profiles μ(r) in the F606W, F850LP e F160W bands with a Sersic profile recovering the structural parameters (R_e, n, μ_e).

fitted profile
observed profile

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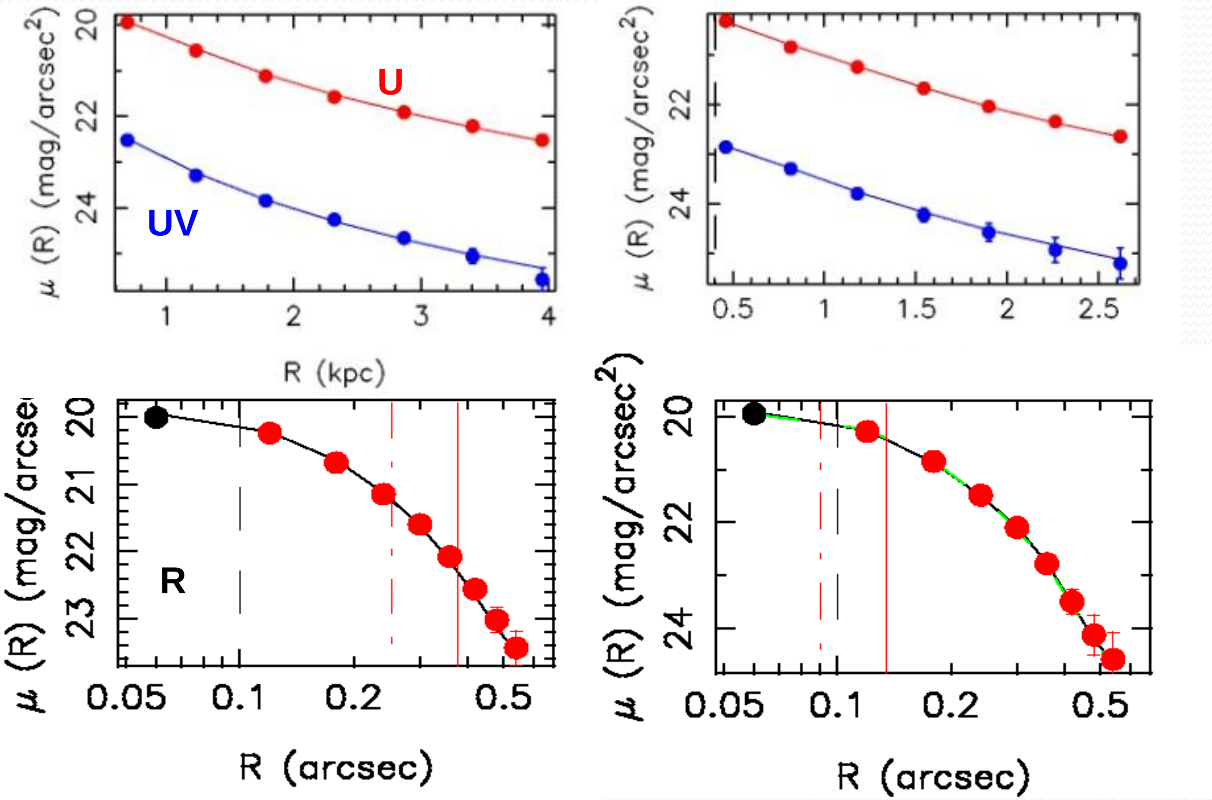

fitted profile
observed profile

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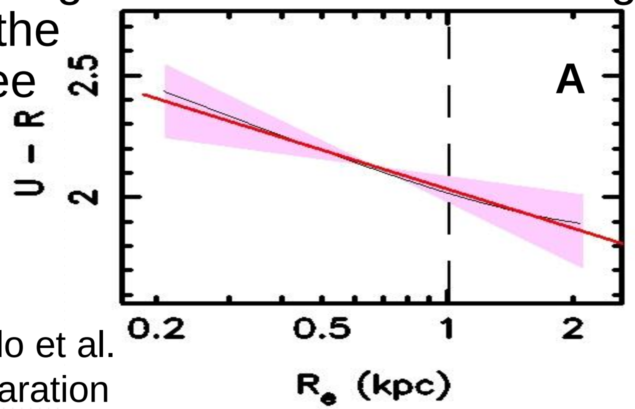
in preparation

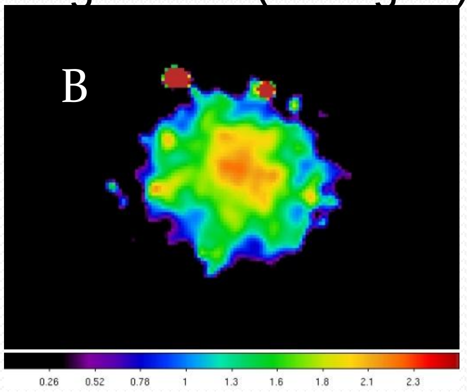
Structural parameters were fully tested both through the comparison of the fitted and real light profile, and through simulations.

COLOUR GRADIENTS: RESULTS

Known the light profiles, we estimate the colour profiles and derive :

(U-R) gradients for 14 ETGs:7 galaxies out 14 show a negative gradient (ex. fig. A) → stellar populations redder in the centre than in the outskirt (see colour map B)





— colour profile U-R(log r)
— colour profile fit.
error on gradient (1σ)

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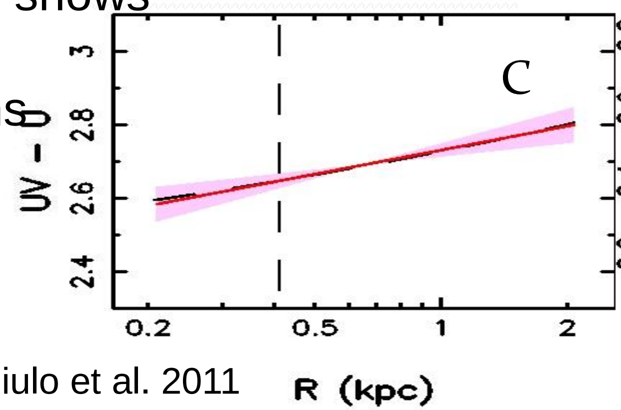
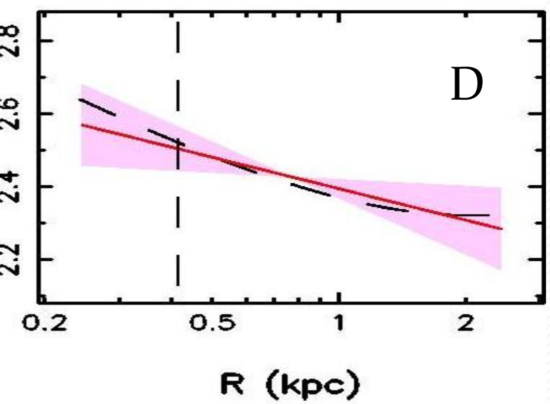
(UV-U) gradients for 20 ETGs. Despite the short wavelength baseline covered (Δλ~2000 Å), 50% of our ETGs shows significant colour gradients, both positive (stellar populations bluer in the centre than in the outskirt, 5 ETGs;ex. fig C) and negative (5 ETGs; ex. fig D).





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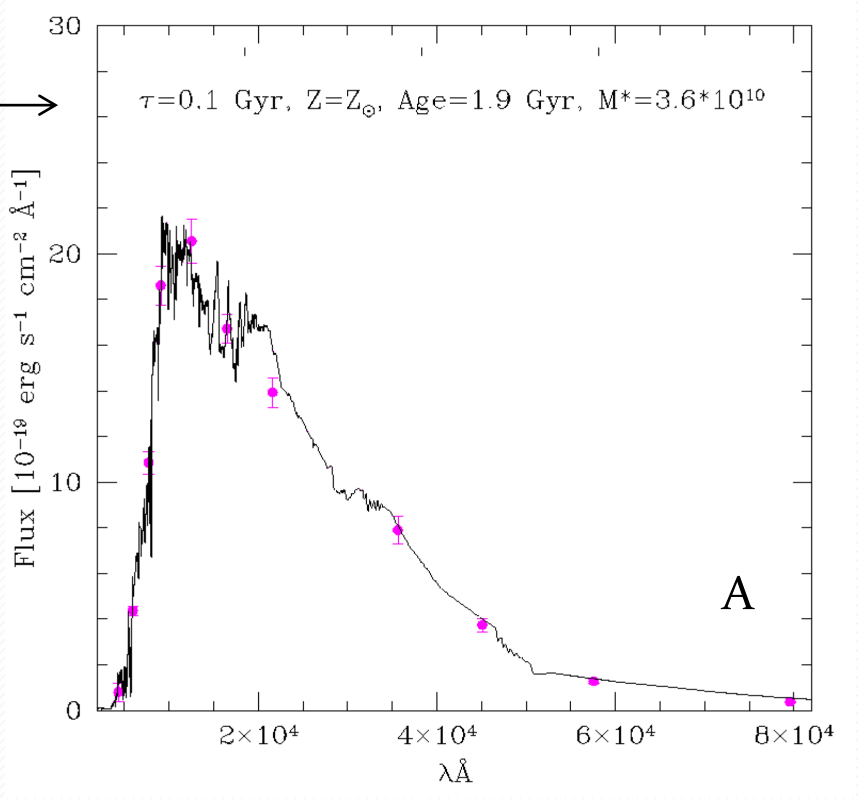
ORIGIN OF THE OBSERVED COLOUR GRADIENTS

Radial age, metallicity, star-formation time scale variation or something else?

For each galaxy:

•Spectral energy distribution fitting (SED, black line in fig A) → global properties of the underlying stellar population: age A, metallicity Z, star-formation time scale τ, dust extinction A_v;

Global parameters derived by the SED fit (Charlot & Bruzual 2007) →



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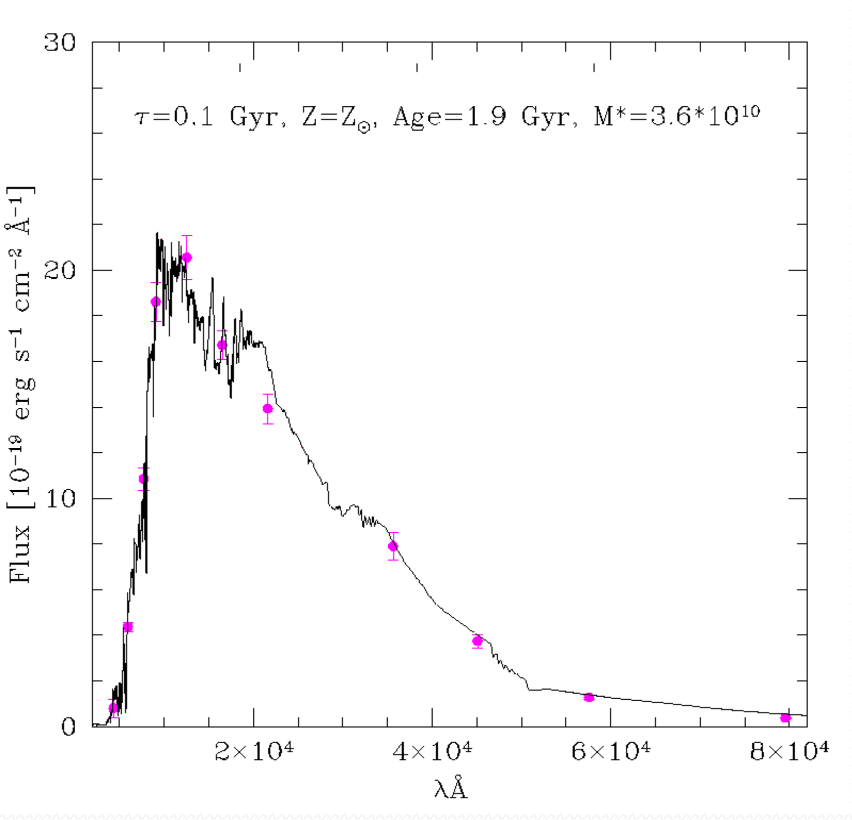
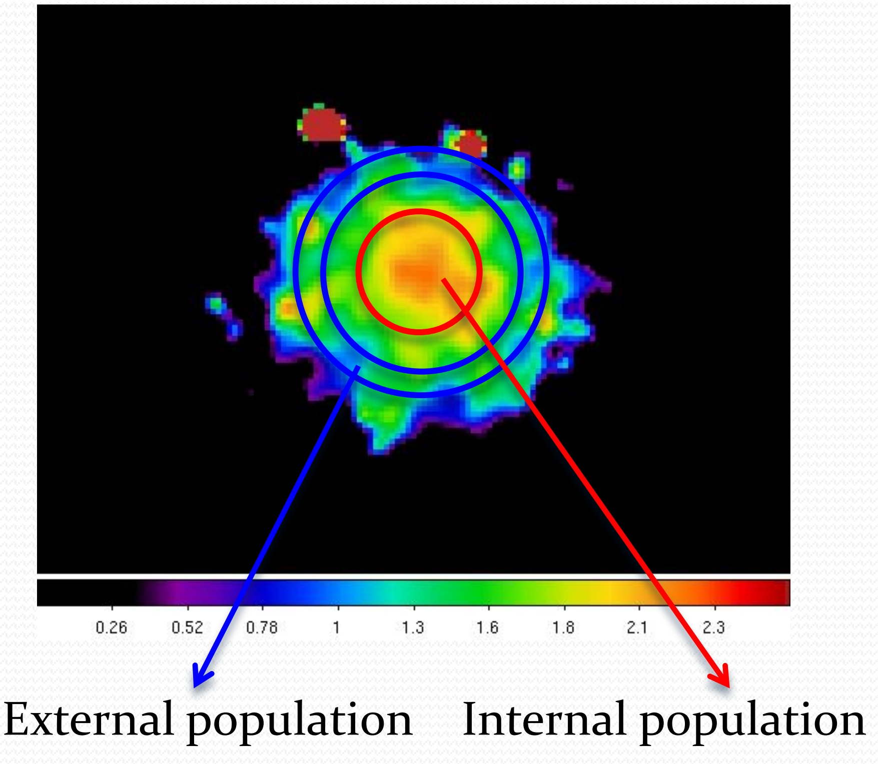
ORIGIN OF THE OBSERVED COLOUR GRADIENTS

Radial age, metallicity, star-formation time scale variation or something else?

For each galaxy:

• U-R colour map → ETG modelled as dominated by two populations, an internal and an external one, with inizial parameters equal to $(A, Z, \tau, A_v)_{global}$;





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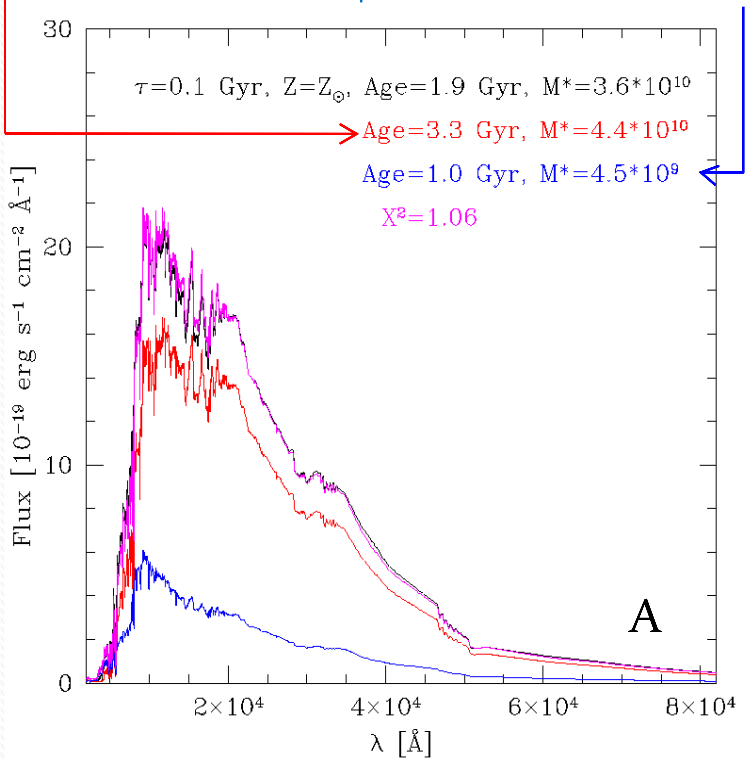
Radial age, metallicity, star-formation time scale variation or something else?

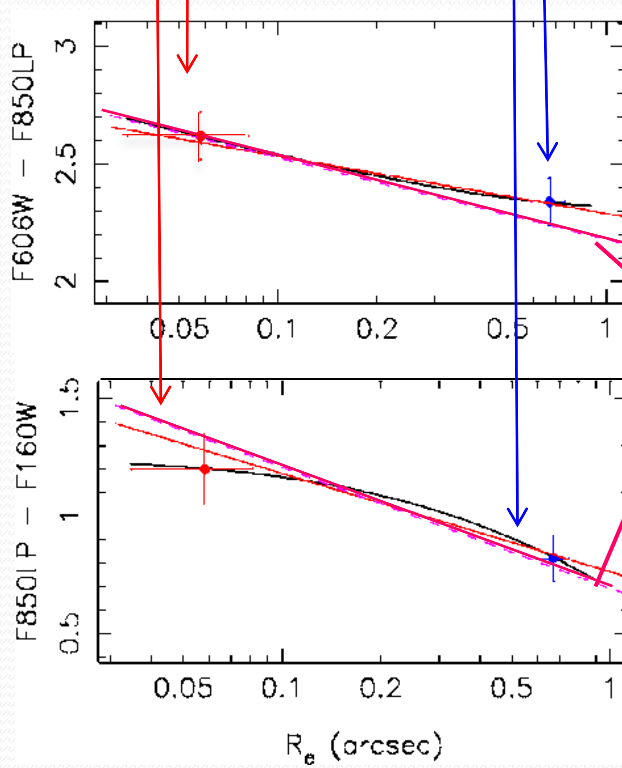
For each galaxy:

• For each population, we have fixed three initial parameters, for ex. $(Z, \tau, A_v)_{global}$, and looked for the values of age A, Ain e Aout, able to simultaneously reproduce the internal and external colour.

Age which best simultaneously reproduce internal colours, Ain

Age which best simultaneously reproduce external colours, Aout





EXAMPLE: AGE VARIATION

Gradients produced by the internal and external population with different age.

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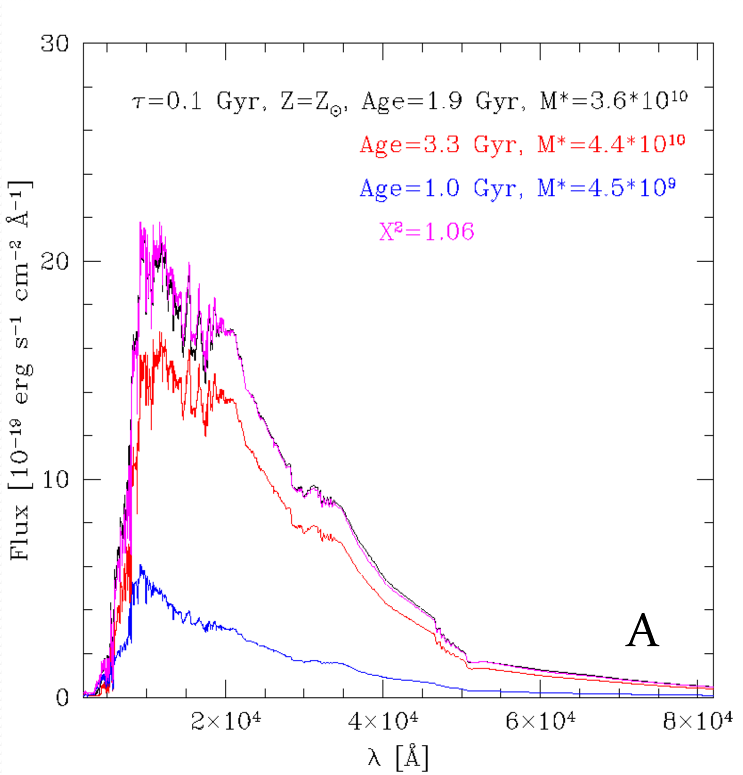

Defined the two populations able to reproduce the observed colour gradients:

$(A_{in}, Z_{global}, \tau_{global}, A_{v,\,global})$ and $(A_{out}, Z_{global}, \tau_{global}, A_{v,\,global})$

their contribution to the total mass is fixed such that their sum is the best representation (magenta line) of the observed SED.

We repeat the analysis for each parameter (A, Z, τ, and A_v) and for simultaneously variations of two stellar parameters.

RESULTS

For 50% of the galaxies of our sample:

- **Age gradients can reproduce the observed colour gradients**
- **Metallicity gradients are not able to reproduce colour gradients**

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The radial colour variations we observe can be

- ***entirely* due to radial age variation**
- **due to a combination of age and metallicity variation**
- ***not* due the variation of metallicity *alone***

SUMMARY

- Thanks to the resolution and quality of HST images, we ascertain the feasibility of colour gradient estimates in high-z (z>1) ETGs;

- We detect radial UV – U colour variations , both positive and negative, in 10 galaxies out 20 (~50 %) and negative U – R colour gradients in 7 galaxies out 14;

- **Colour gradients of 50% of our sample can be interpreted as principally due to radial age variation. A minor contribution due to dust cannot be excluded. Contrary, radial variation of metallicity and star-formation time scale are not able to reproduce the observed colour.**

- **For the remaining part of the sample, the variation of a single parameter of the stellar populations or the combined variation of two of them cannot reproduce the observed colour gradients;**

CONCLUSIONS

- We have unexpectedly found that, despite the age of our galaxies, all younger than 3-4 Gyr, they already exhibit significant differences in the properties of their stellar content.

- **The short time (3-4 Gyr) at disposal to interact with other systems, and the observed differences both in the colour gradients values and in the stellar population properties suggest differences in the formation mechanism of ETGs.**

ONGOING WORK…

Can radial change of IMF justify the observed colour gradients?

FUTURE WORK…

Direct comparison with local ETGs colour gradients

thanks