Color gradients in cluster Elliptical galaxies at z~1.4

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Abstract

We studied the color gradients of cluster elliptical galaxies at z~1.4. We detected in all of them radial variations of the $\sim(UV\text{-}U)_{rest}$ and $\sim(U\text{-}R)_{rest}$ color showing evidence of multiple stellar components. While we found **negative U-R color gradients**, **UV-U color gradients are always positive** with the few exceptions compatible with null gradients. We show that the observed color gradients cannot be accounted for by the radial variation of a single parameter (age or metallicity). On the contrary, **the analysis shows the presence of two main stellar components: a younger (age<1 Gyr) component with higher metallicity dominating the center (contributing less than 10% to the total stellar mass) and an older component with lower metallicity dominating the outskirts**.

1. Sample selection

The sample of cluster ellipticals (Es) has been selected in the cluster **XMM 2235-2557 at z=1.39**. according to the following criteria:

1. **z_{850}<24 (Vega) -** magnitudes brighter than 24 in the **F850LP** band. Flux limited sample 100% complete.
2. **D<1Mpc –** Galaxies (352) within one Mpc from the cluster center;
3. **$0.9<i_{775}-z_{850}<1.3$** - Galaxies (50) within this color range defining the second peak of the color distribution (**Fig. 1**)**.** This sample includes the 5 cluster member ellipticals spectroscopically identified (Rosati et al. 2009)**;**
4. **Elliptical morphology** (see **Fig. 2** for examples).

Final sample → 17 Cluster Ellipticals at z=1.39

2. Morphological classification

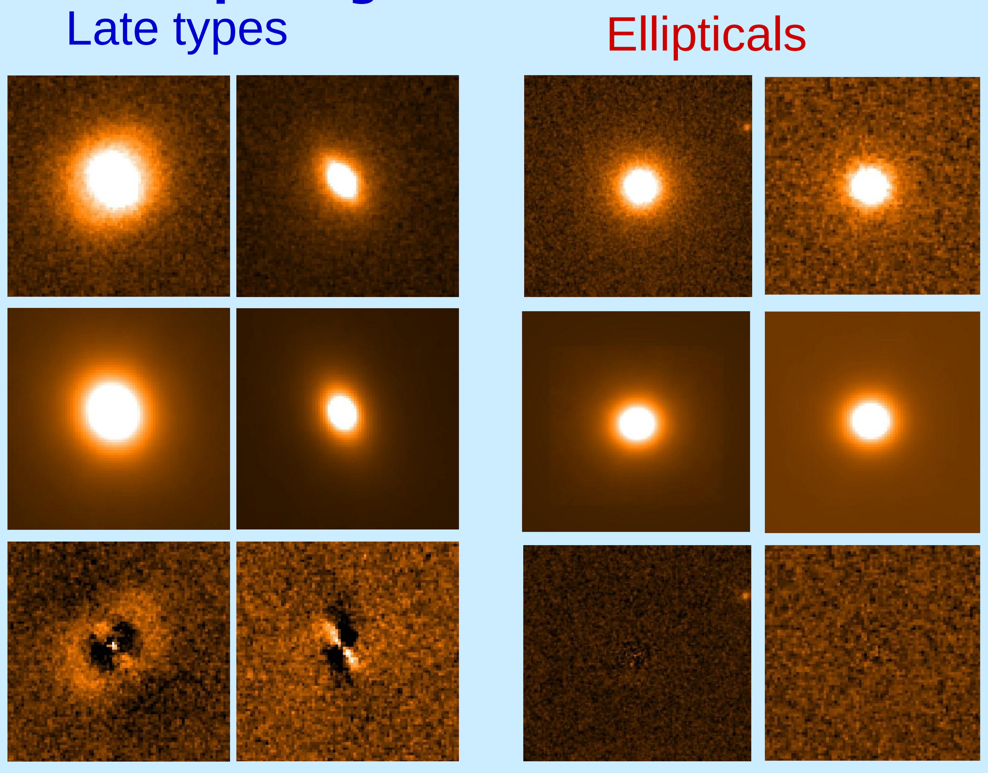
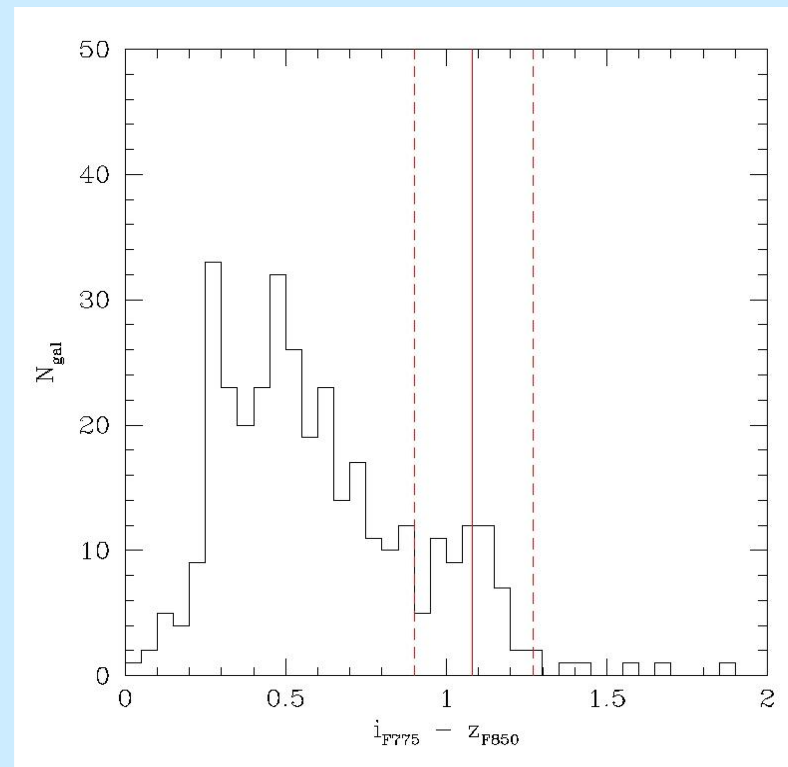


Fig. 2 - Ellipticals are classified those galaxies with regular shape, no signs of disks and no irregular or structured residuals resulting from the 2D fitting.



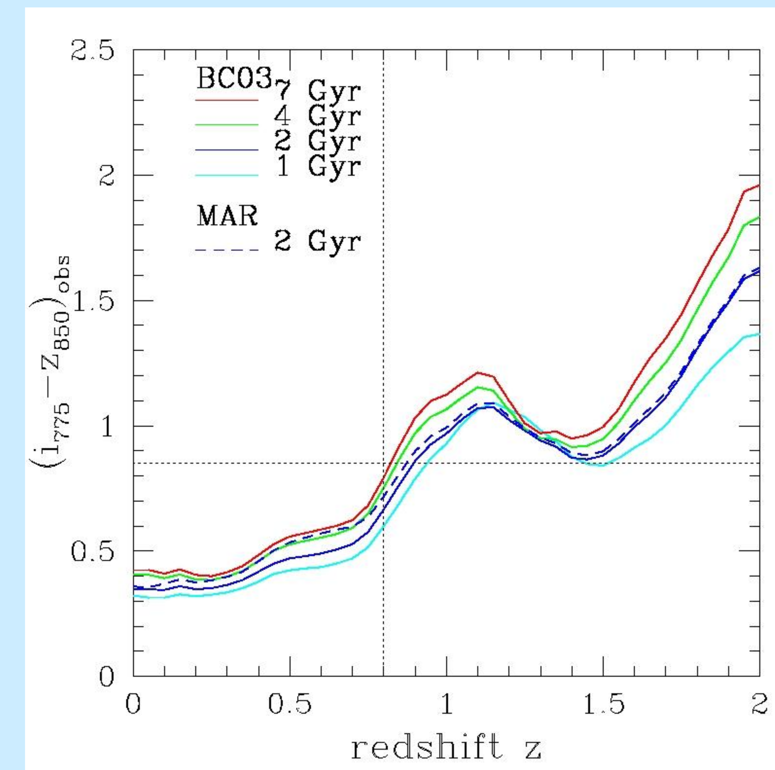


Fig. 1 – **Left**: (F775W-F850LP) color distribution of the 352 galaxies with z_{850}<24. The red solid line marks the mean color of the 5 elliptical cluster members with spectroscopic confirmation. **Right**: expected apparent (F775W-F850LP) color as a function of redshift for four different ages (BC03 models and Maraston et al. (2005) models, MAR). The color is always <0.9 mag for z<0.8-0.9 and larger than 1.3 mag for z>1.7 independently of the age.

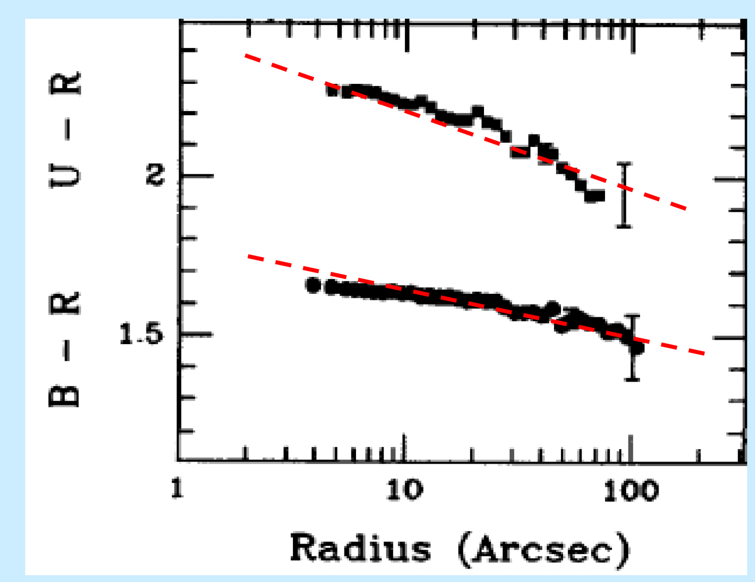
4. Color gradients: definition

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

$$\nabla_{X-Y} = \frac{\delta(\mu_X(R) - \mu_Y(R))}{\delta \log(R)}$$

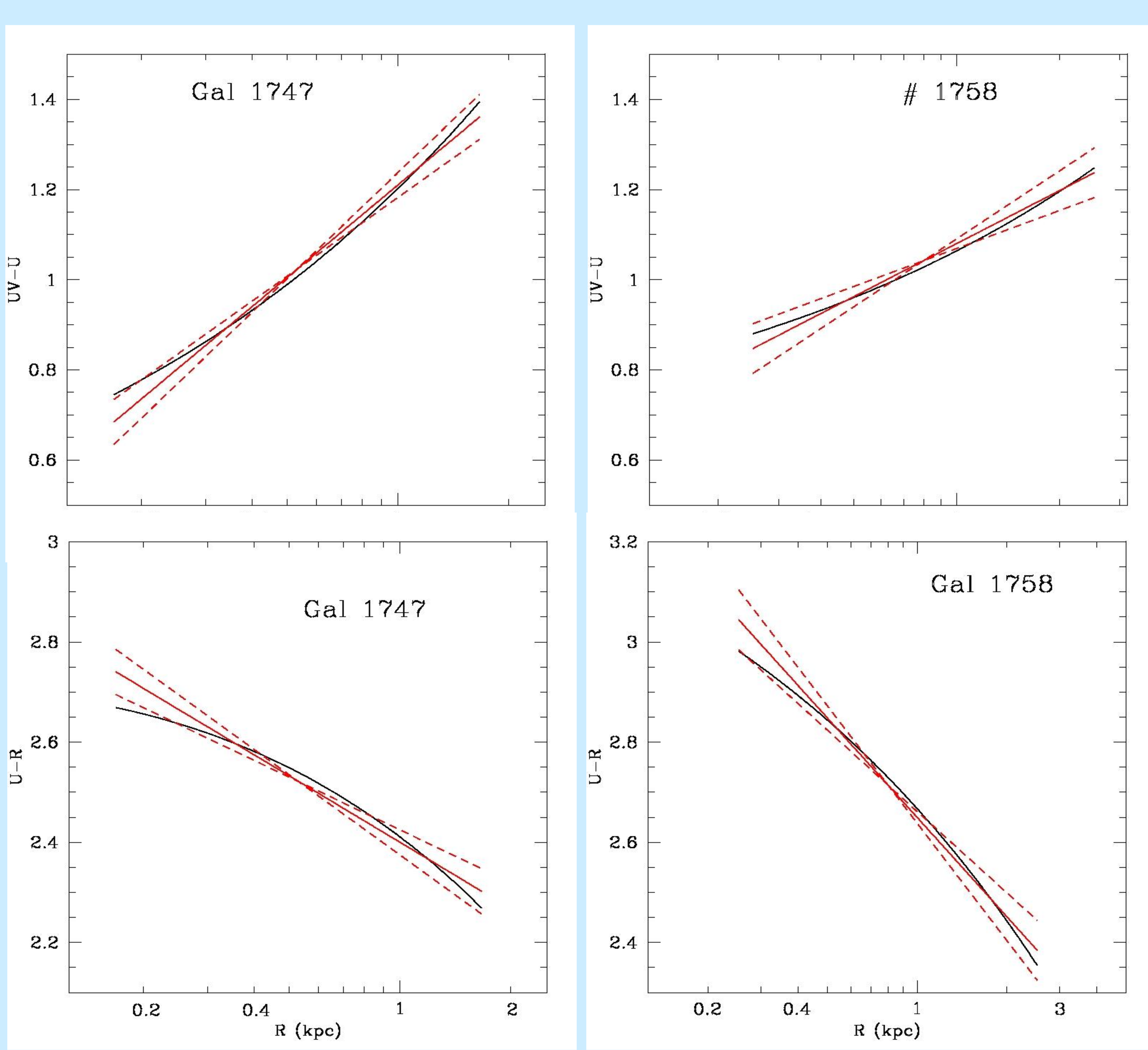
where $\mu_X(R)$, $\mu_Y(R)$ are the *surface* brightness profiles in X and Y band, respectively.

- **negative** gradient: **redder** toward the center
- **positive** gradient: **bluer** toward the center



(Peletier et al. 1990)

5. Color gradients in cluster ellipticals at z~1.4



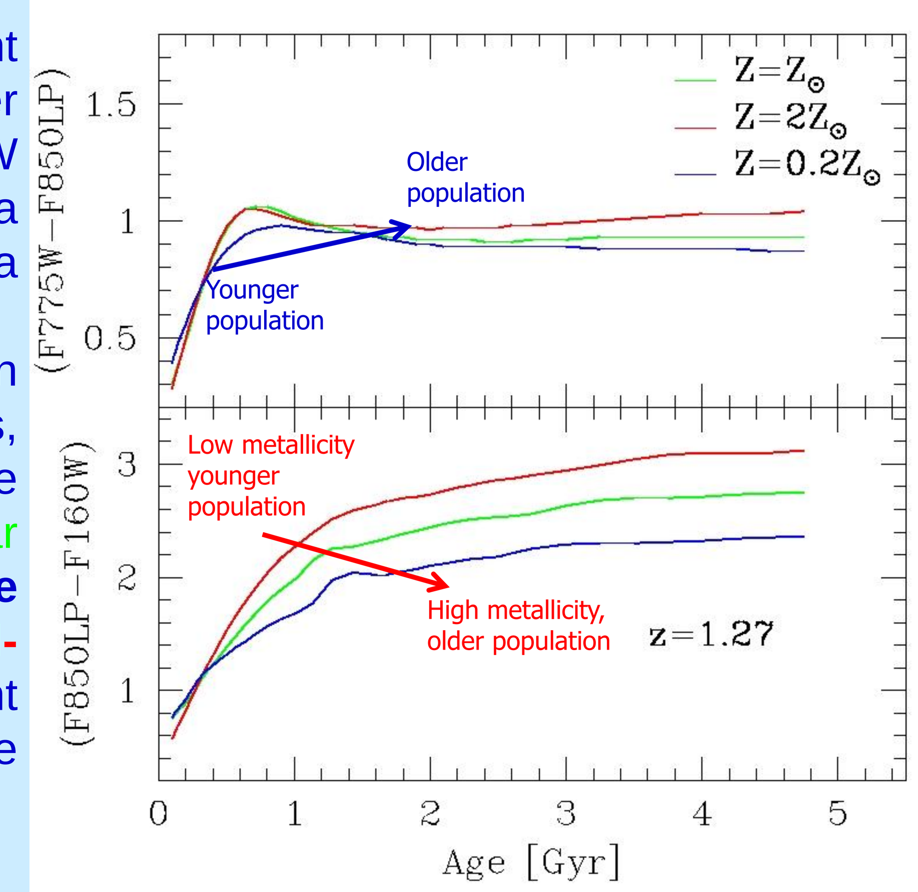
F775W-F850LP $\sim UV\text{-}U_{rest}$ gradients: **all positive**

F850LP-F160W ~U-R gradients: **all negative**

Fig. 3 UV-U (F775W-F850LP, upper panels) and **U-R** (F850LP-F160W, lower panels) color gradients for two out of the 17 ellipticals of the sample. All the galaxies show positive UV-U gradients and negative U-R gradients.

6. The nature of the observed color gradients

Fig. 4 – Expected apparent F775W-F850LP (upper panel) and F850LP-F160W (lower panel) colors for a galaxy at z=1.27 as a function of age.
The three curves have been obtained with BC03 models, Chabrier IMF and three different metallicity: solar (**green line**), sub-solar (**blue line**) and super-solar (**red-line**). The arrows represent the observed trend of the color gradients.



F775W-F850LP $\sim(UV\text{-}U)_{rest}$: sensitive only to age variations; nearly constant for age>1Gyr → UV-U positive color gradients as those in Fig. 3 imply age gradients: younger ages toward the center (age<<1Gyr), older ages dominating the outskirts.

F850LP-F160W $\sim(U\text{-}R)_{rest}$: sensitive to both age and metallicity variations. Since younger age must dominate the center, negative U-R color gradients imply metallicity gradients: metallicity higher toward the center.

Discussion and conclusions

- We find evidence of two stellar components in elliptical galaxies at z~1.4: a younger (age<<1Gyr) component with higher metallicity in the center and an older component with lower metallicity in the outskirts.
- The young age (~0.5 Gyr) of the central component rules out the possibility that it is the result of a dissipative Major merging (Mm): Mm timescale is >3 Gyr (e.g. Khockfar and Silk 2006), hence the resulting stellar population should have a comparable age. Moreover, if it was the case all the 17 ellipticals should have experienced a Mm at the same epoch, a fine tuning difficult to justify.
- Minor dry merging (mm) is ruled out as well since it cannot produce a segregation of stars based on their age and/or on their metallicity.
- The most reasonable mechanism is a very low star formation activity in the center of the galaxies acting over a long time and supplied by the inflow of interstellar and intergalactic medium.