THE AGE OF EXTREMELY RED AND MASSIVE ELLIPTICAL GALAXIES AT HIGH REDSHIFT

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A statistical analysis of 353 extremely red objects (EROs) classified as old galaxies (OGs) at 0.8 < z < 3.8 is carried out. We have developed a photometric method to detect the EROs at different redshifts. in our case reaching very high z.

Once we get M_V and (B-V) at rest for each galaxy, we calculate the average variation of this intrinsic colour with redshift and derive the average age through a synthesis model. The stellar masses are around ~10^{11} $M_\odot$ and formation epochs of these galaxies are within a narrow range of, on average, 2.0±0.3 Gyr for the galaxies observed at 0.8 < z < 2.5, and $0.9^{+0.4}_{-0.8}$ Gyr for galaxies at 2.5 < z < 3.8, depending significantly on the observed redshift and stellar mass: the higher the stellar mass, the lower the age of the Universe at which it was formed. This result appears to be in conflict with Λ-CDM models that claim that the most massive galaxies formed after those of lower mass.

SeLecTing EROs/OGs:

We use colours to identify EROs/OGs within a sample of galaxies. To select the red objects at different z the criteria in the **Tables** have been used with multi-wavelenghts data:

Field	0.8<z<2.5
ECDFS: *Taylor et al. (2009) Fang et al. (2009)*	$(i_{775} - K)_{AB}$>2.42 $(J - K)_{AB} < 0.20(i_{775} - K)_{AB} + 0.39$
Subaru/XMM-Newton: *Miyazaki et al. (2003)*	$(R - K)_{AB}$>3.35 And spectrum fitting

z	
2.5<z≤3.5	J-[3.6]>2.55 K-[3.6]<0.39 +0.19(J-[3.6])
3.5<z≤4.5	H-[4.5]>2.41 K-[4.5]<0.56 +0.29(H-[4.5])
4.5<z≤5.5	H-[5.8]>3.02 $[3.6]$-[5.8]<0.35 +0.14(H-[5.8])
5.5<z≤ 6.5	K-[5.8]>2.43 $[3.6]$-[5.8]<0.35 +0.18(K-[5.8])
6.5<z≤7.5	K-[8.0]>3.21 $[3.6]$-[8.0]<0.59 +0.23(K-[8.0])

- **ECDFS Field**: U, U_{38}, B, V, R, I, z′, J, H, and K_s for ECDFS from ISAAC(VLT)+Hubble (z < 2.5)
- **Subaru/XMM_Newton**: B, V, R, i′, z′, J, H, and K_s from the Subaru/XMM-Newton+UH2.2 (z < 2.5)
- **XMM_LSS:** Subaru-UDS DR3 (visible), UKIDSS (infrared) and Spitzer (mid-infrared). z > 2.5

Castro-Rodríguez & López-Corredoira (2012)
López-Corredoira (2010)

ReSt CoLouRs and AgE:

(B-V) at rest was calculated using multi-wavelength data and **SED** fits with templates of galaxies and the software package Interrest v2.0 (Taylor et al. 2009). See **Figure 2A**.

We have selected old massive elliptical galaxies with negligible internal extinction and no gas or dust. We can connect the colour and luminosity in V_{rest} of the galaxy with the average age of the stellar population and its metallicity. To estimate the average age and stellar mass corresponding to our galaxies, we use a synthesis model: Vazdekis et al. (1996), see **Figure 1**. There is an age–metallicity degeneracy, but this can be broken approximately using the mass–metallicity correlation iteratively.

$$M_* = \left(\frac{M}{L_v}\right)^* L_v \qquad \left[\frac{Fe}{H}\right] = 0.066 log_{10}\left(\frac{M_*}{1.1x10^{11}M_\odot}\right) \pm 0.11$$

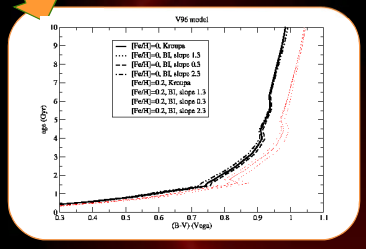

Figure 1. Variation of age with (B – V) colour stellar population synthesis model.

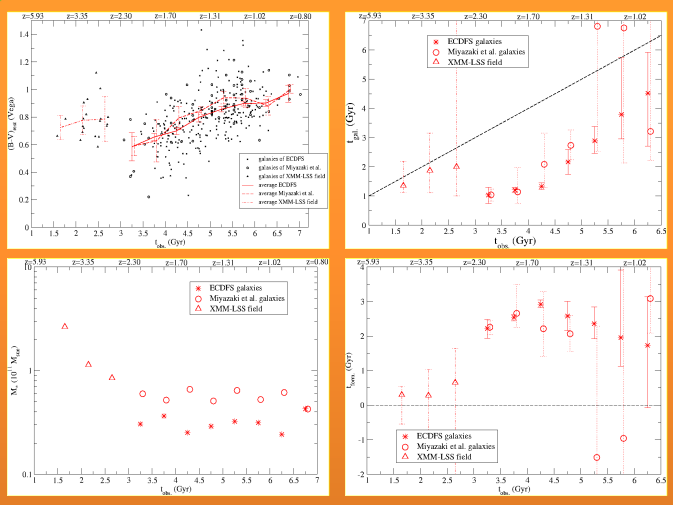

Figure 2. A) $(B - V)_{REST}$ at different ages t_{obs} (the age of the Universe corresponding to the given redshift). B) Average age (t_{gal}) of the stellar populations. C) Average stellar mass. D) Average age of the Universe at which the stellar populations of the galaxies observed at age t_{obs} were formed.

ConcLuSions

We have established a new colour criterion for identifying EROs/OGs at redshift 0.8 < z < 2.5, but at higher redshift (up to 7.5) to search for the oldest galaxies when the Universe was younger than ~3 Gyr.

We have been able to see that we still derive formation ages that are within a narrow range of, on average, 2.0 ± 0.3 Gyr ($z_{form} \approx 3–4$) for galaxies observed at 0.8 < z < 2.5, and Gyr, and ($z_{form} \gtrsim 5$, 1σ) for galaxies observed at 2.5 < z < 3.8.

The new galaxies observed at z ~3 are **massive galaxies formed at redshifts ≳ 5**

Clearly, any hierarchical Λ-CDM model concluding that very massive galaxies formed after the formation of low-mass galaxies similarly disagrees with these results.

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