Age of passively evolving galaxies at high-redshift

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EMIR@GTC: Aprendiendo a Usarlo

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Objetives with GTC/EMIR:

- Faint galaxies $m_H < 21$
- ¿Massive and old galaxies (OGs) when the Universe was relatively young?
- Extremely red galaxies in XMM-LSS field
- COSMOS, CDFS and UDS
- Photometrical data
- Average variation of the intrinsic color with z using synthesis models
- Obtain with EMIR a spectroscopic confirmation

Previous works

- High redshift galaxies are typically bluer
- There is a lack of red objects in $2< z < 3$ with $(m_{1700\,Å} - m_B)_{AB,rest} > 3$
- Find old elliptical galaxies without extintion (*Miyazaki et al. 2003*)
- This OGs at odds with ΛCDM (Guo et al. 2011)
- Uncertanties in the photometric z at these redshifts (*Vazdekis et al. 2001*)
- More massive halos than predicted at high z (*Steinhardt et al. 2016*)
- Downsizing scenario (*Pérez-González et al. 2008*)

Reference	z
di Serego Alighieri et al. 2006, 2007	1.
Spinrad et al. 1997	1.0-2.0
Daddi et al. 2005	
Longhetti et al. 2005	
Toft et al. 2005	
Trujillo et al. 2006	
Daddi et al. 2005	
Labbé et al. 2005	2-0-3.0
Cassata et al. 2008,	
Kriek et al. 2008, 2009	
Hempel et al. 2011	
Toft et al. 2005	3.0-4.0
Chen & Marzke 2004	
Rodighiero et al. 2007	> 5.0
Wiklind et al. 2008	

Age (Gyr)	z	Univ (Gy)
5.5	1.2	5.4
3.5	1.9	3.6
1.7	3.4	2.0

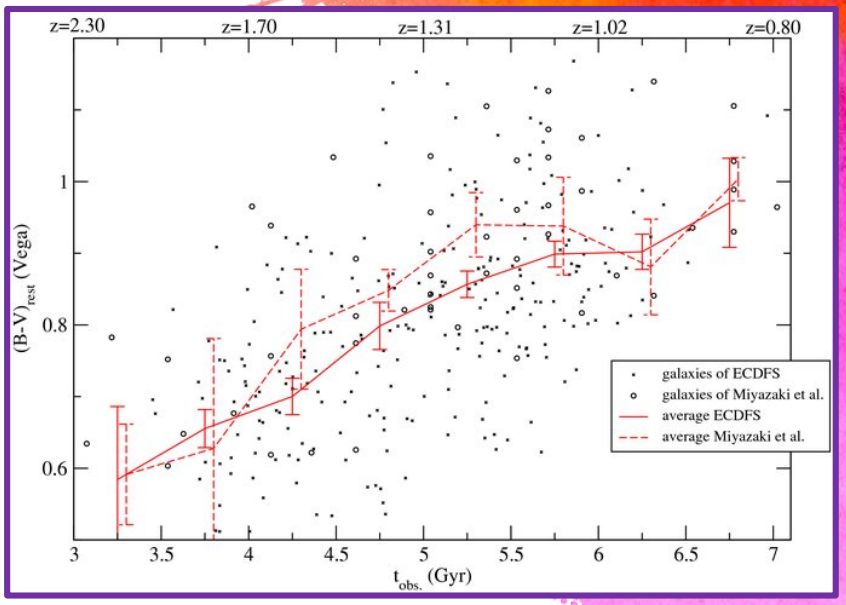
0.8 < z < 2.3:

Extremely Red Objects (EROs)

Selection criteria:

- Fluxs in JHK + Filters in the optical (S/N > 3)
- **ECDFS catalog** (*Taylor et al. 2009*)
- $(i_{775} - K)_{AB} > 2.42$
- $(J - K)_{AB} < 0.20(i_{775} - K)_{AB} + 0.39$
- ***Miyazaki et al. 2003* catalog**
- $(R - K)_{AB} > 3.35$
- ERO have different ranges of stellar masses, M/L ratios, and intrinsic colors at different redshifts
- **Photometric redshifts**
- Rest luminosities in B, V using SEDs





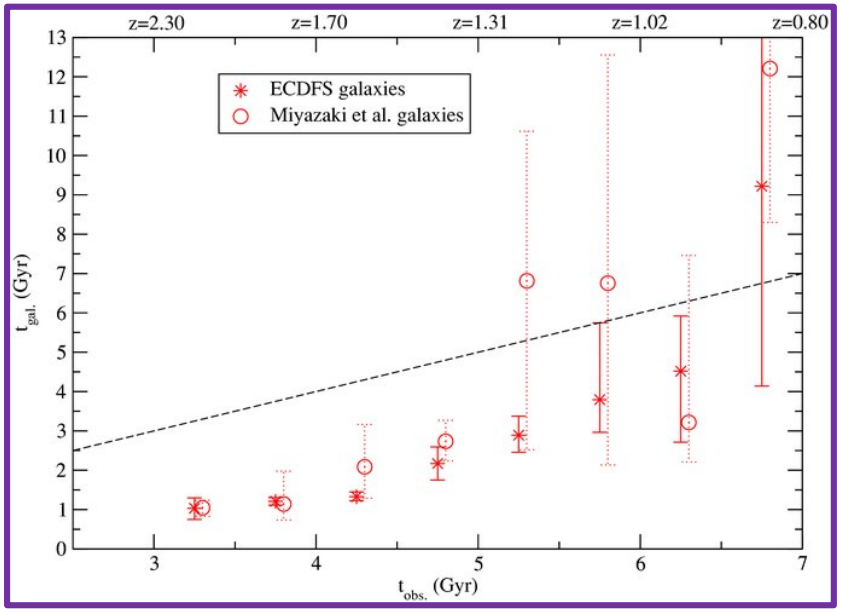
López-Corredoira et al. 2010

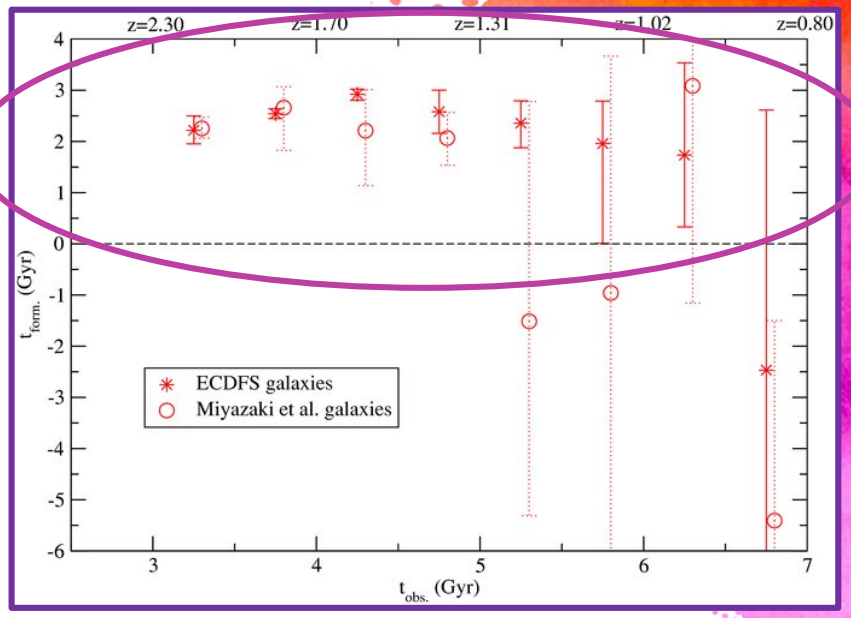
Average age with synthesis model: *Vazdekis et al. (1996; 1999)*

$$(B-V)_{rest} = b_1 + b_2(t_{obs} - 5) + b_3 \log_{10}(M_*)$$

$$t_{gal} = c_1 + c_2(t_{obs} - 5) + c_3 \log_{10}(M_*)$$

$$t_{form} = d_1 + d_2(t_{obs} - 5) + d_3 \log_{10}(M_*)$$





< 4 Gyr

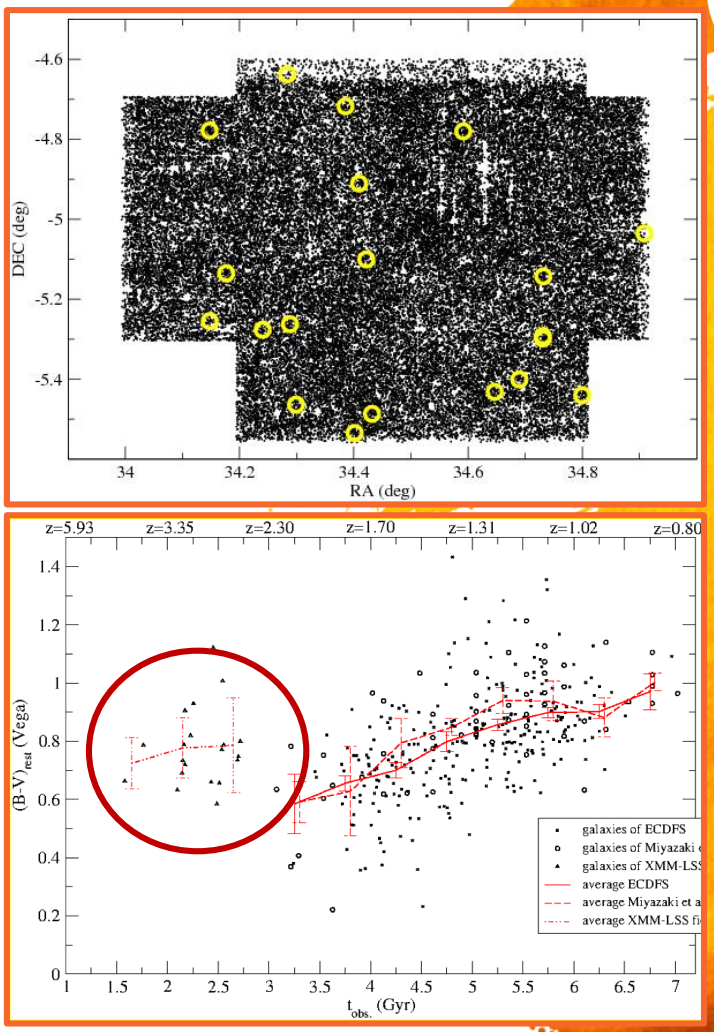
López-Corredoira et al. 2010

z > 2.5:

Z high Extremely Red Objects (Z-EROs)

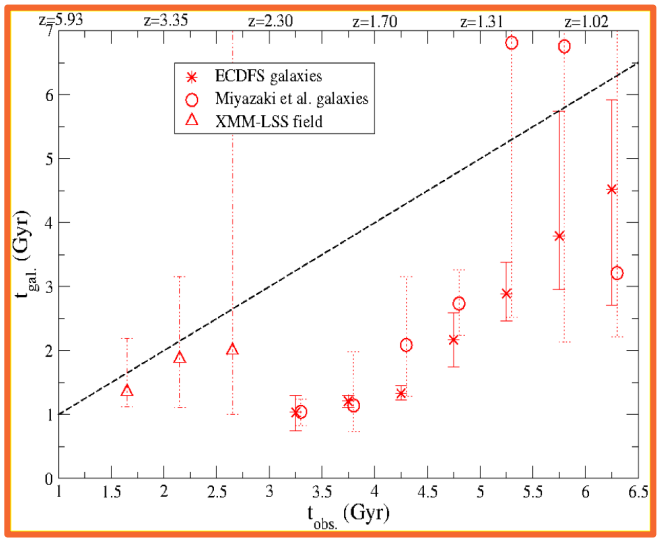
- **63550 galaxies in XMM-LSS**
- Optical-MIR data (SUBARU, UKIDSS, Spitzer)
- 20 candidates (z_{phot})

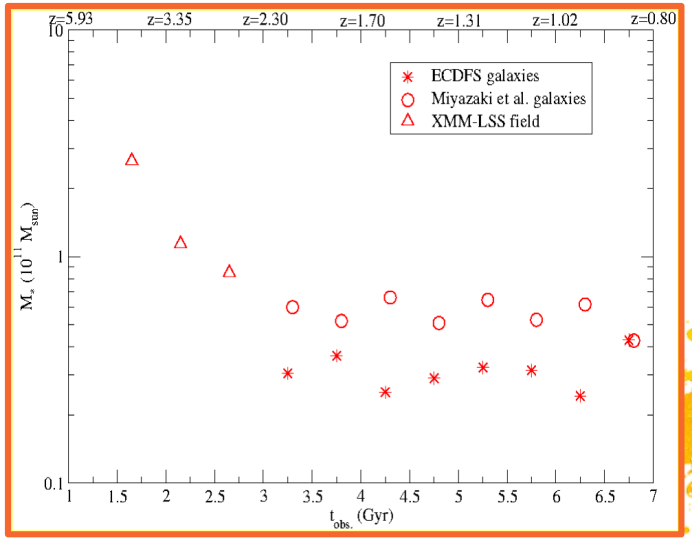
Redshift	COLOR Criteria
0.8<z<2.5	$(i_{775} - K)_{AB} > 2.42$ $(J - K)_{AB} < 0.20(i_{775} - K)_{AB} + 0.39$
2.5<z≤3.5	J-[3.6]>2.55 K-[3.6]<0.39 +0.19(J-[3.6])
3.5<z≤4.5	H-[4.5]>2.41 K-[4.5]<0.56 +0.29(H-[4.5])
4.5<z≤5.5	H-[5.8]>3.02 $[3.6]$-[5.8]<0.35 +0.14(H-[5.8])
5.5<z≤ 6.5	K-[5.8]>2.43 $[3.6]$-[5.8]<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])

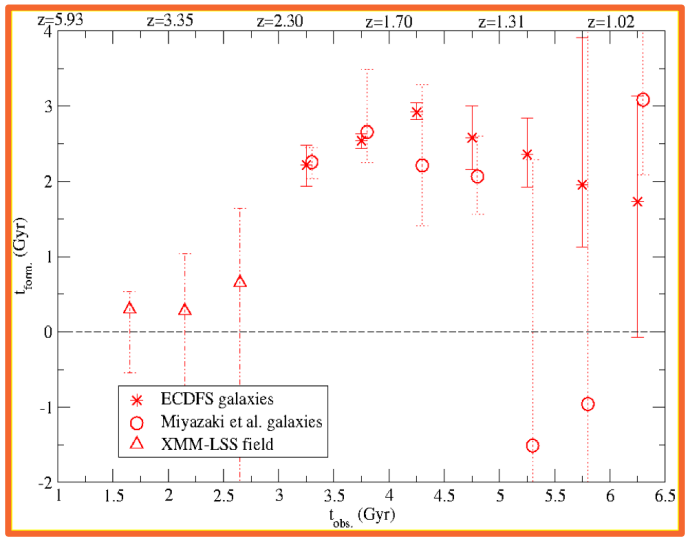


Castro-Rodríguez et al. 2012

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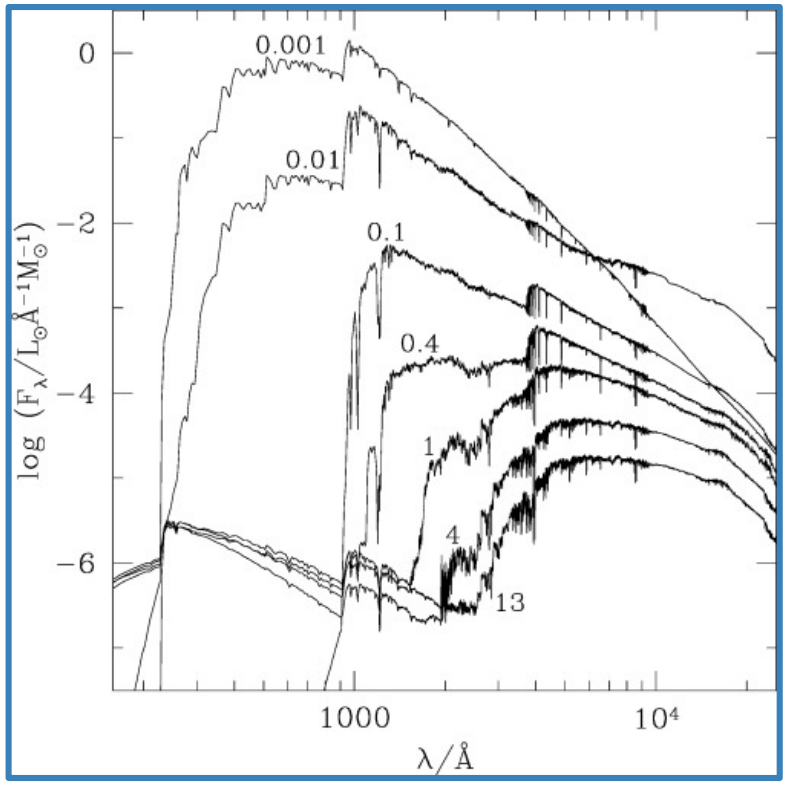


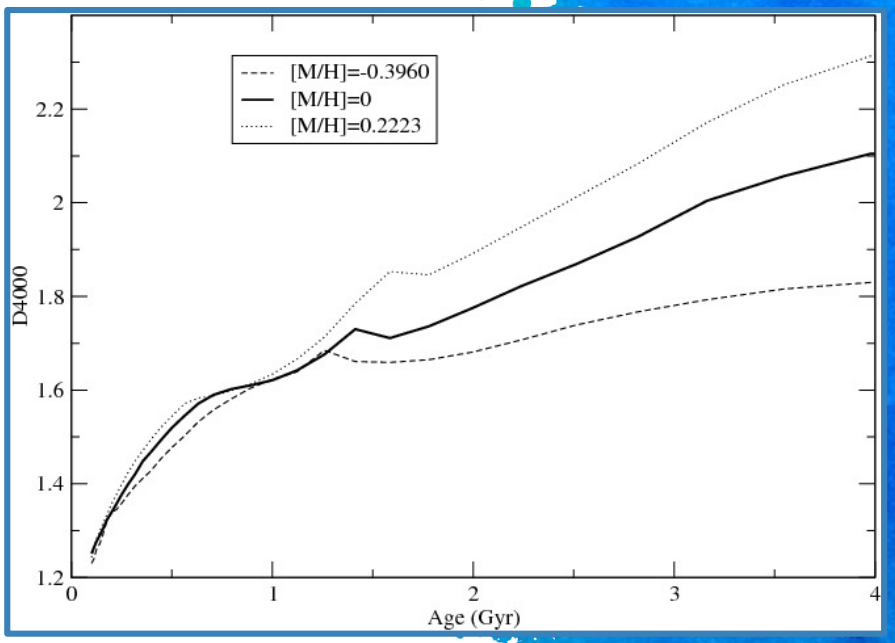
> 5x10¹⁰ M⊙

Castro-Rodríguez et al. 2012

$$\frac{\partial t_{form}}{\partial t_{obs}} = -0.9 \pm 0.3 Gyr \qquad \frac{\partial t_{form}}{\partial \log M_*} = -4. \pm 1.8 Gyr$$

Spectroscopic determination of the age



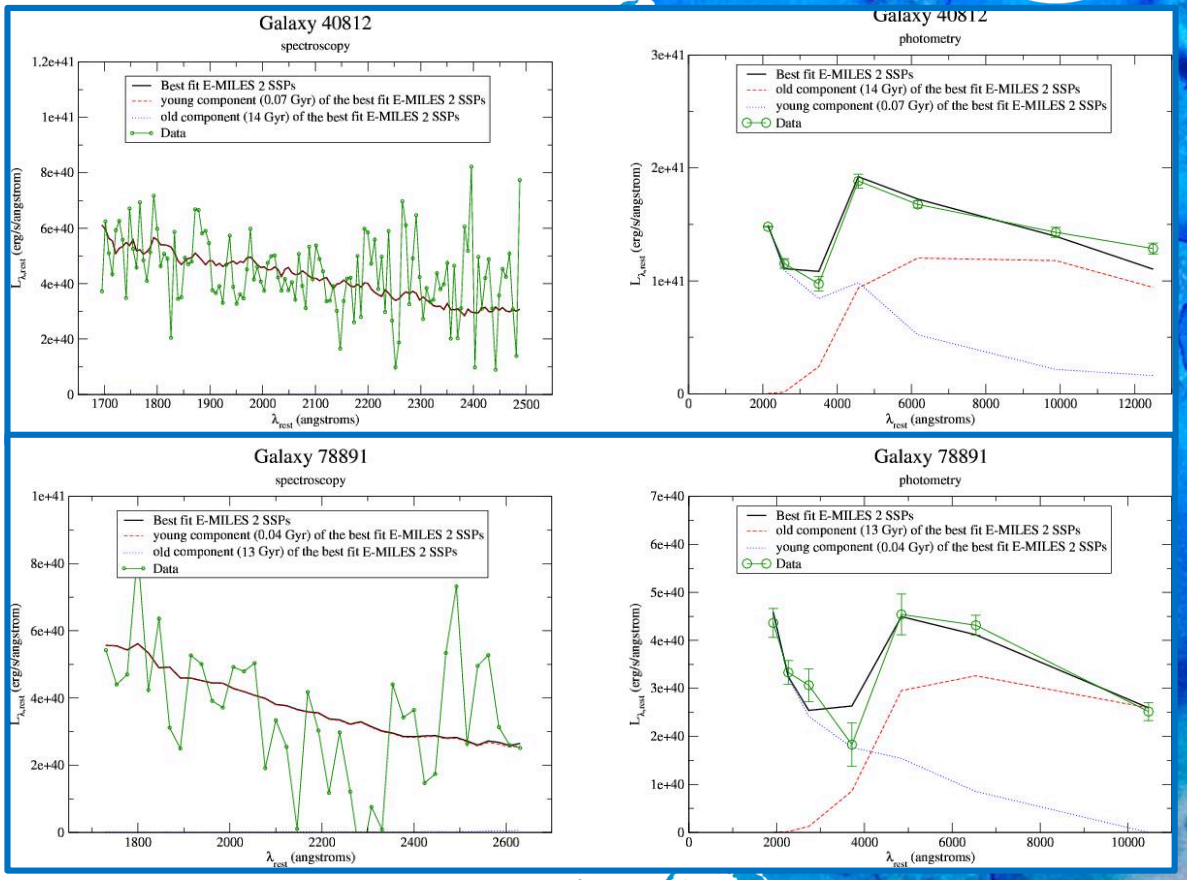


Break of 4000 angstroms (Balmer). Left from synthesis model of Bruzual & Charlot (2003); Right: from MILES (Vazdekis et al.)

Low resolution optical spectra

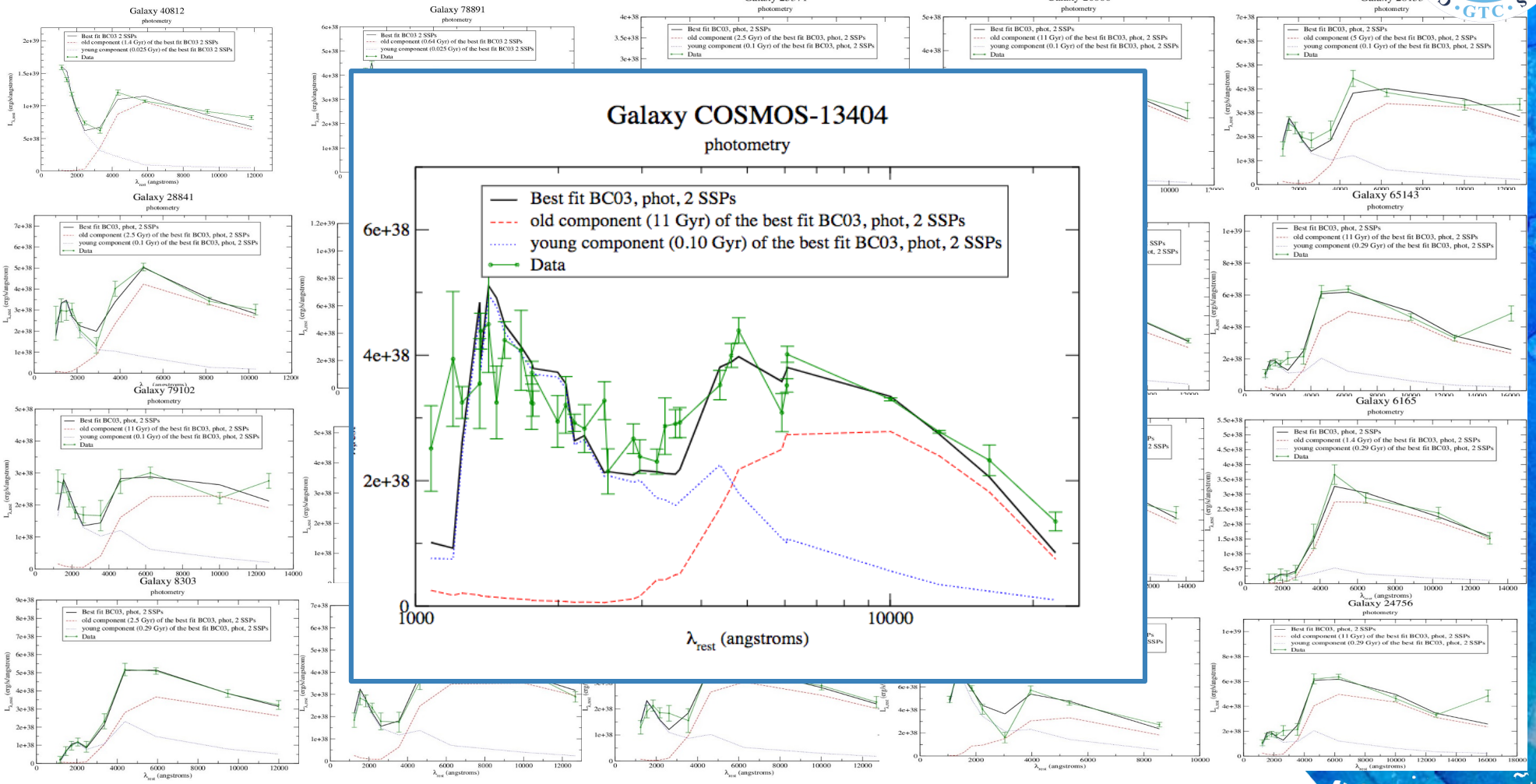
- 2 galaxies (z 2.5 and 2.7)
- **GTC/OSIRIS (4800-10000 Å; at restframe aprox. 2000 Å)**
- Break that depends on the age (*Bruzual & Charlot 2003: BC03*)
- Fit models: *BC03* and *E-MILES*
- No break at 2000 Å
- Only one SPP is not enough
- **Dominat very old population**
- **Small component aprox. 100 Myr (< 2%)**
- Older stars than in previous works

Older than the Universe??



López-Corredoira et al. 2017

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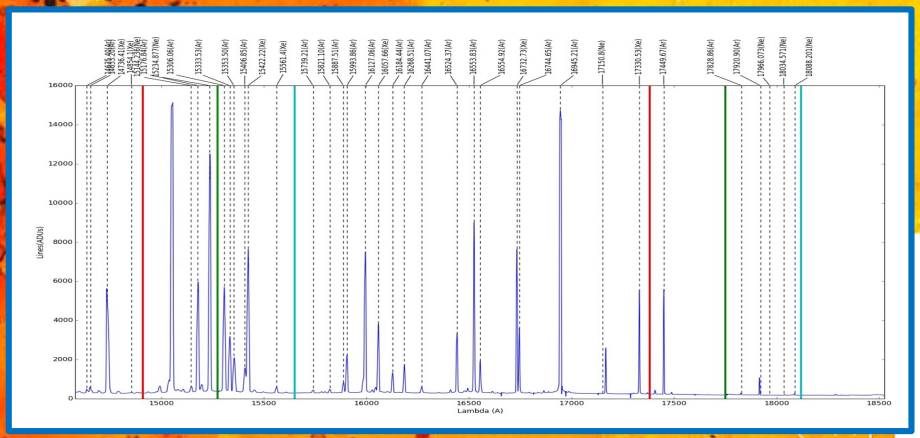
EMIR

- $2.5 < z_{phot} < 3.0$
- $m_H \sim 21.0$
- Stellar mass $>10^{11} M_\odot$
- Age > 1.4 Gyr
- XMML-LSS (*Castro-Rodríguez et al. 2012*)
- COSMOS, CDFS and UDS with ZFOURGE (*Straatman et al. 2016*)
- Spectroscopic confirmation: z and age

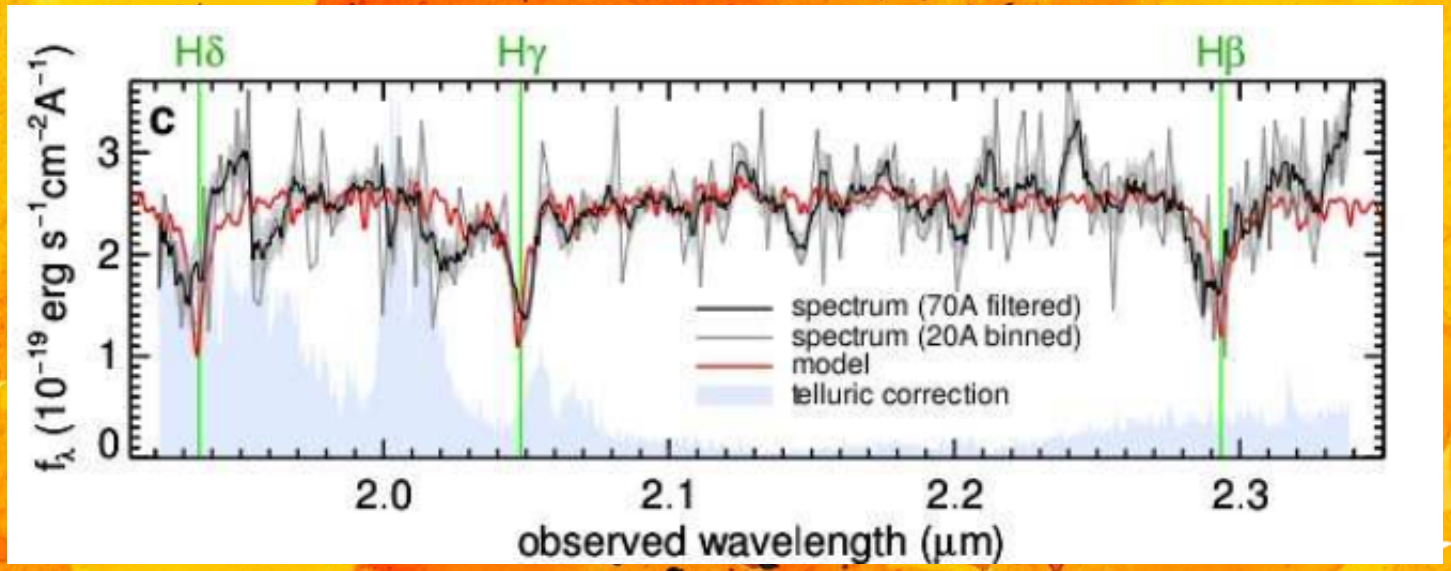
EMIR

ID	Slit X Pos (px)	λ_c (Å)	Range (Å)
H	730	~~16335~~	~~15650~18120~~
	1030	16520	15280~17750
	1330	~~16140~~	14910~17380

Rest frame:
- 3800~4425 Å
- 4340~5060 Å



- 0.8”
- 1.2 Å/px
- Binning in spectral axis: S/N ↑
- $\Delta\lambda \approx 20$ Å/px
- Brightest objects (to get started)



K-band spectrum of a quiescent galaxy at z= 3.72 and $m_{Ks,AB}$= 22.4 obtained by Glazebrook et al. (2017), with an exposure time of 7 hours using MOSFIRE.


Thanks!