Constraints on reionization from a multi-λ analysis of z>6.5 galaxies

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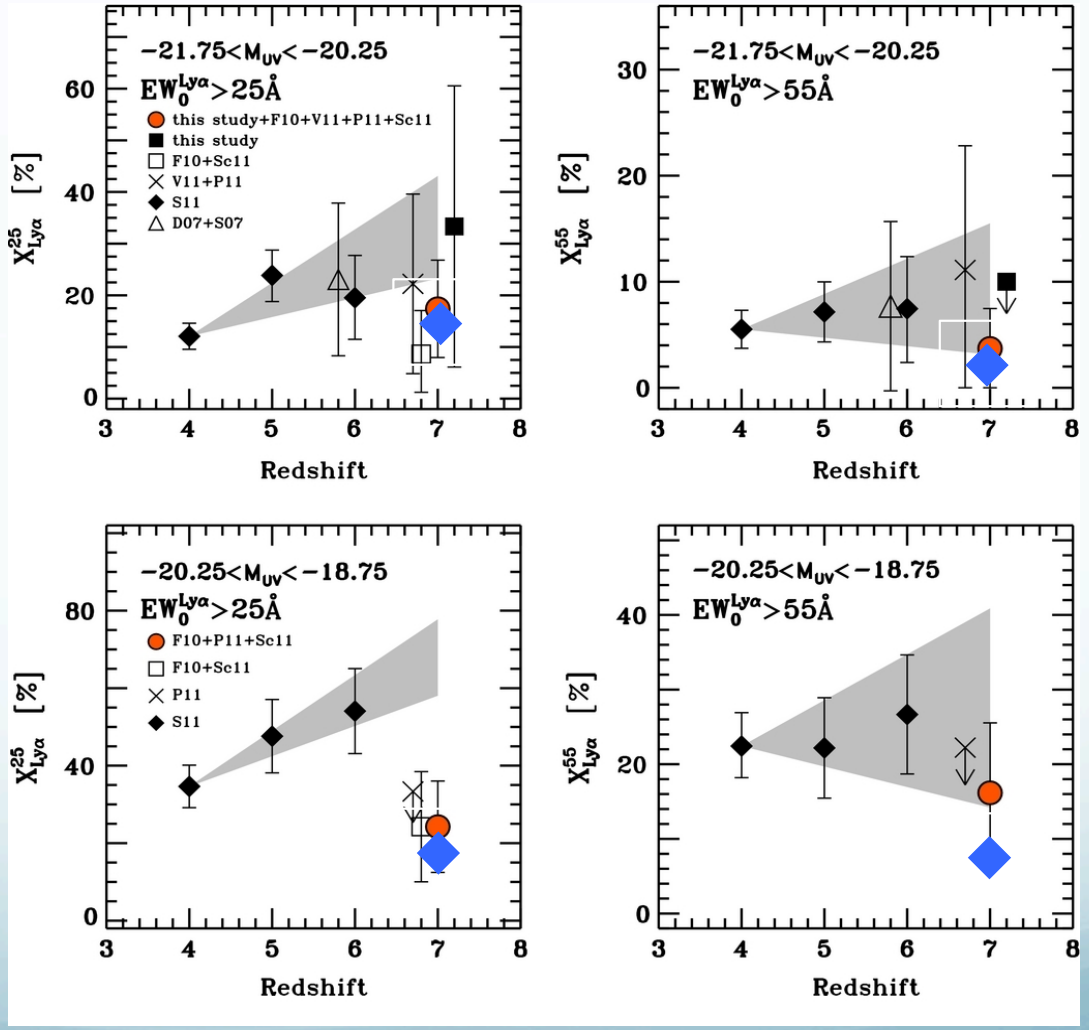
Including new Large Program data plus earlier literature plus some archival spectra we have assembled a sample of ≈120 solid z-dropouts.

Points at z=4,5,6 are derived from the large samples of Stark et al., Vanzella et al Stanway et al. Shaded areas are the uncertainties.

◆ new z=7 limits (LP et al. 2015 in prep)

● limits Ono et al. 2012



bright galaxies (M_{UV}<-20.25)

faint galaxies (M_{UV}>-20.25)

EW > 25 Å

EW > 55 Å

Possible explanations for the LAE fraction drop

1) There is an increase in the amount of neutral hydrogen in the surrounding IGM that quenches the Lyα emission.

→ Assuming no change in galaxy properties X_{HI}>0.6 at z~7

2) There is an increase in the Lyman Continuum escape fraction.

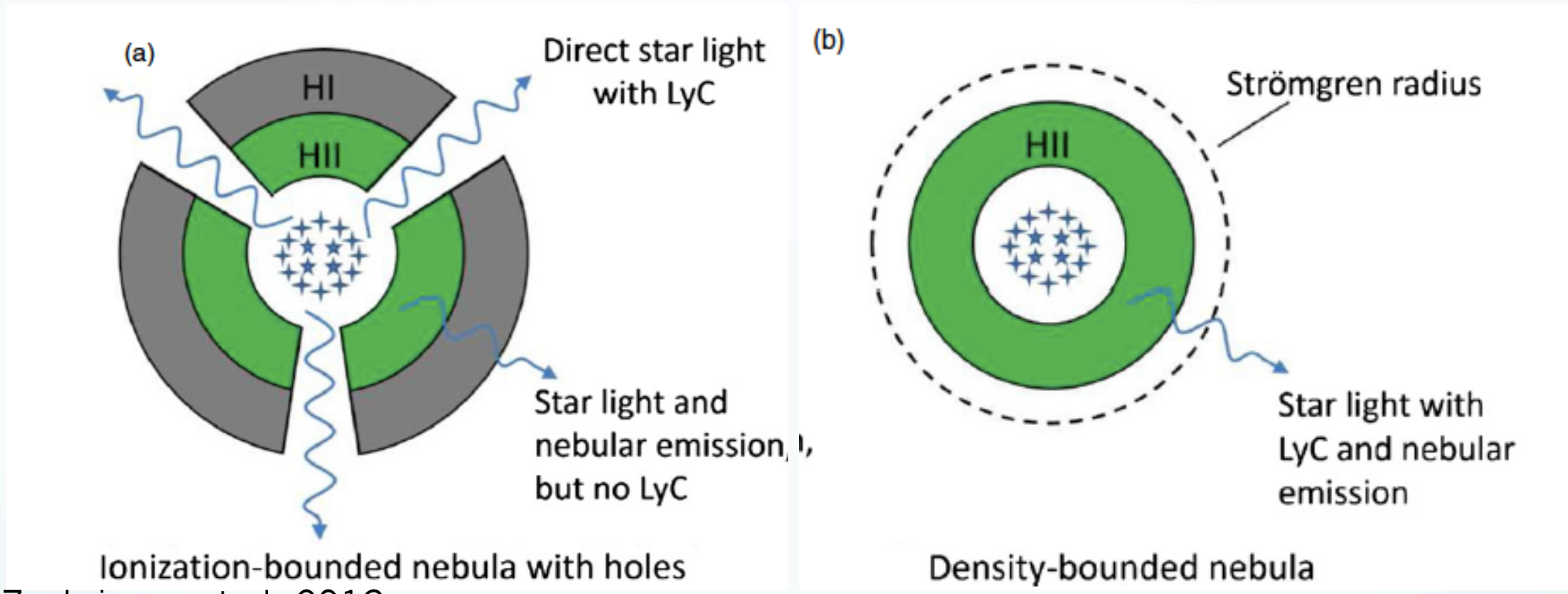
3) There is a sudden increase in dust extinction.

4) A significant fraction (> 60-70%) of selected galaxies is not at z~7.

Possibly V-faint low-z galaxies showing extreme line emission that can mimic the Lyman break (e.g. Hayes et al. 2012).

Is there evidence for extreme escape fraction?

If an extreme escape of ionizing photons erases Lya line, what about other lines?



Zackrisson et al. 2013

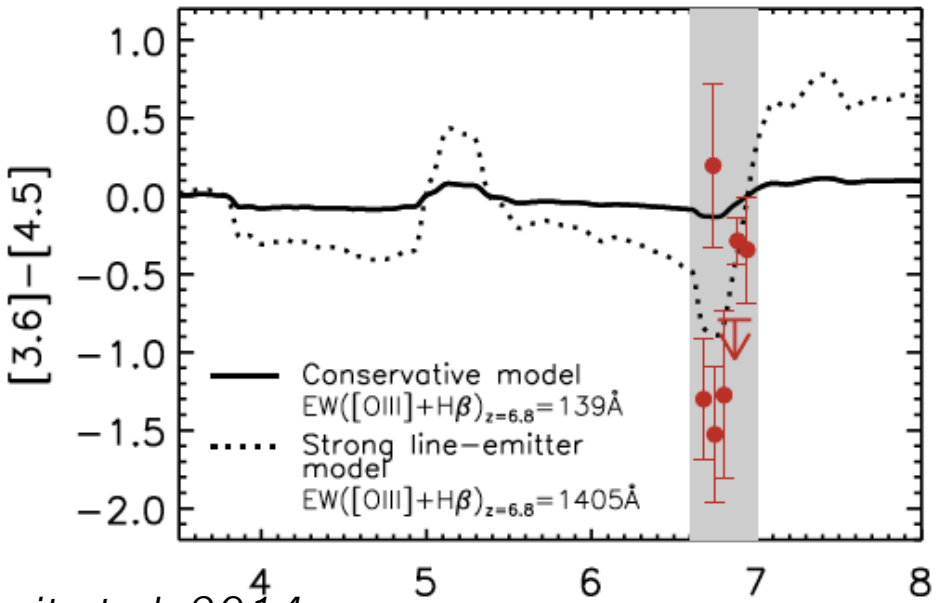
a) Em. lines disappear when fesc →1

b) Strong high ionization lines

Nakajima&Ouchi 2014: high [OIII]/[OII]
see also Stasinska et al 2015
E. Vanzella talk this conference

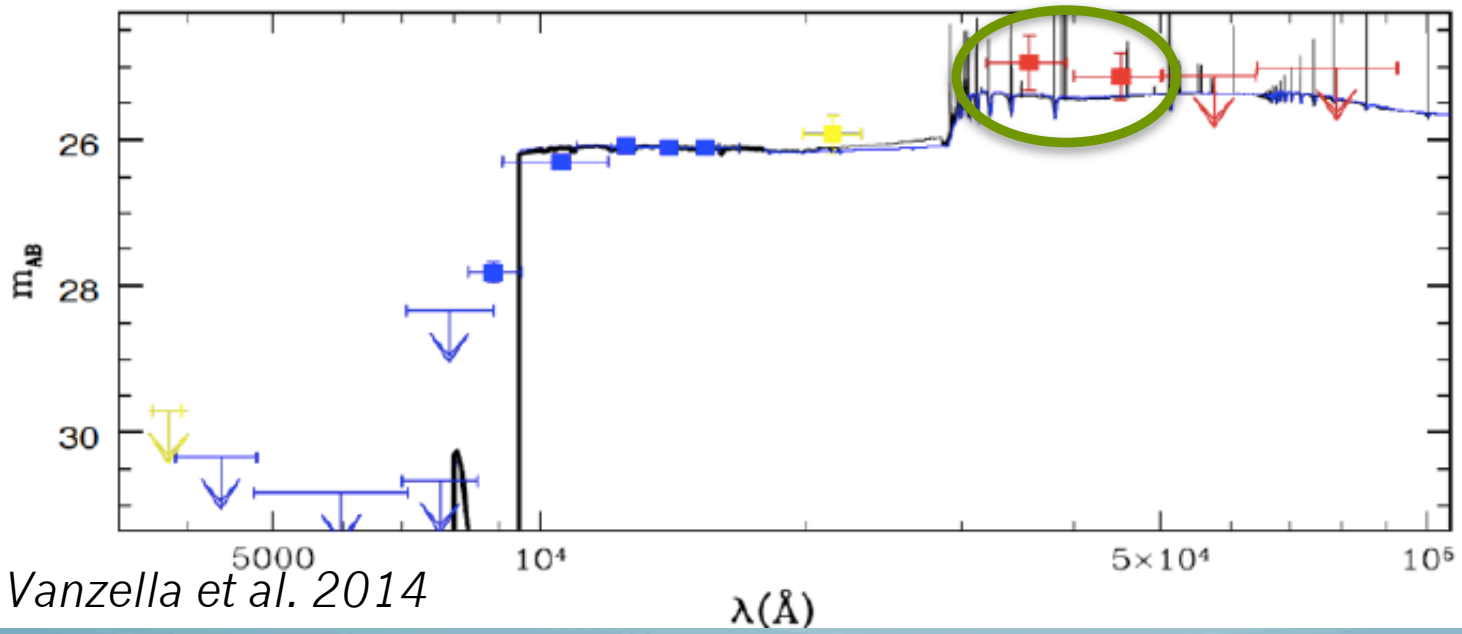
$$L_{lines} \sim (1-f_{esc}) \times Q_i$$

Is there evidence for extreme escape fraction?



Smit et al. 2014

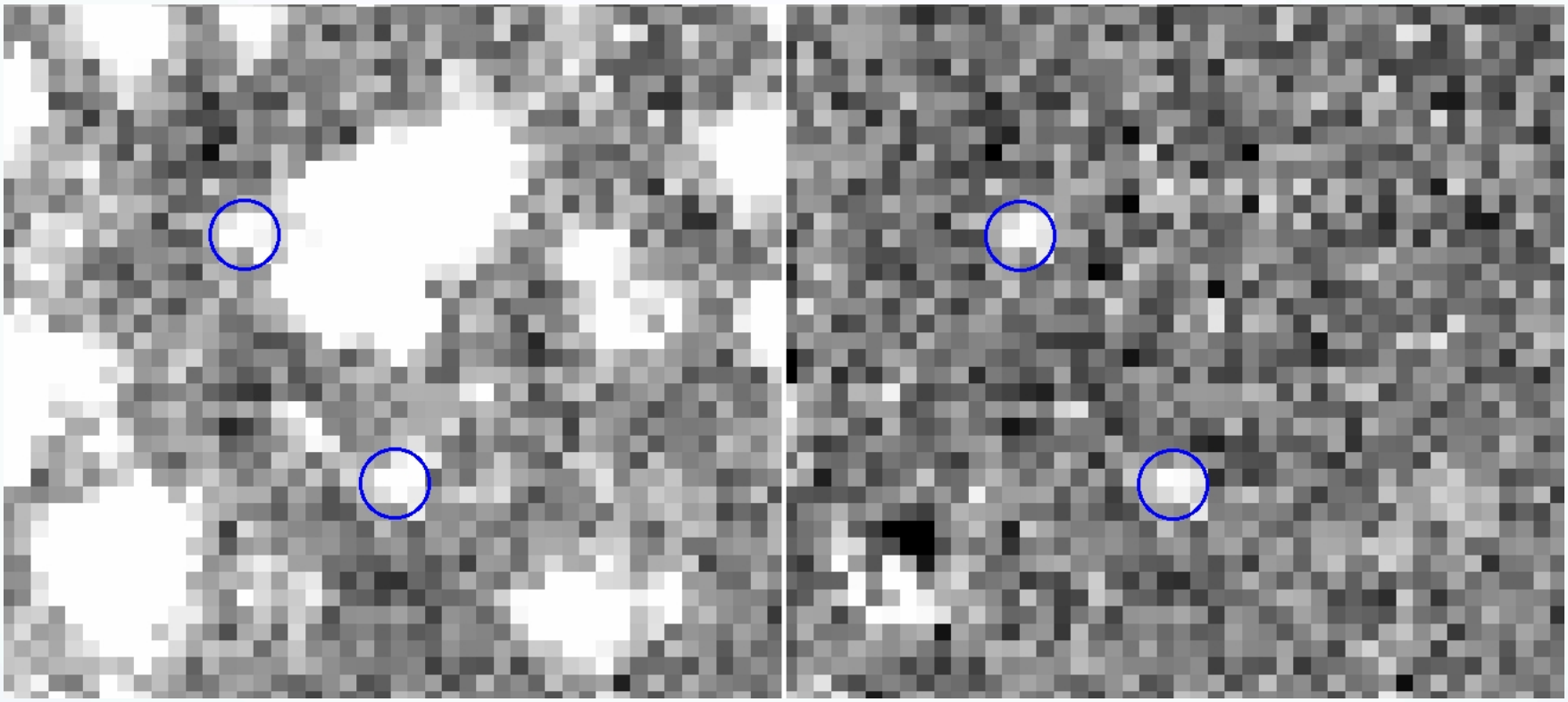
Known evidence for high-EW [OIII]+Hβ lines from IRAC colors at z~6.5-7 (Labbe et al. 2013, Wilkins et al. 2013, Smit et al. 2014)



Vanzella et al. 2014

EW(Lyα)<9A from 52hrs FORS2 spectrum

IRAC colours of our deep spectroscopic sample



Stacking of IRAC bands, main concern: *confusion/blending/overlapping* of sources due to low resolution.

Close-by sources "removed" with improved version of TFIT template-fitting code: **T-PHOT (Merlin+2015, in prep.): A code for PSF-matched photometric analysis of multiwavelength data using priors**

http://www.astrodeep.eu/t-phot/

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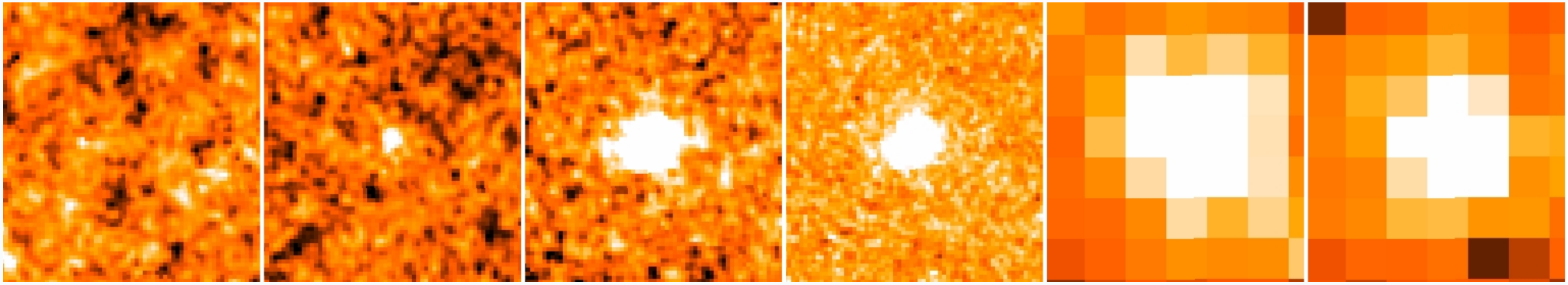

V606 I814 J125 H160 [3.6] [4.5]

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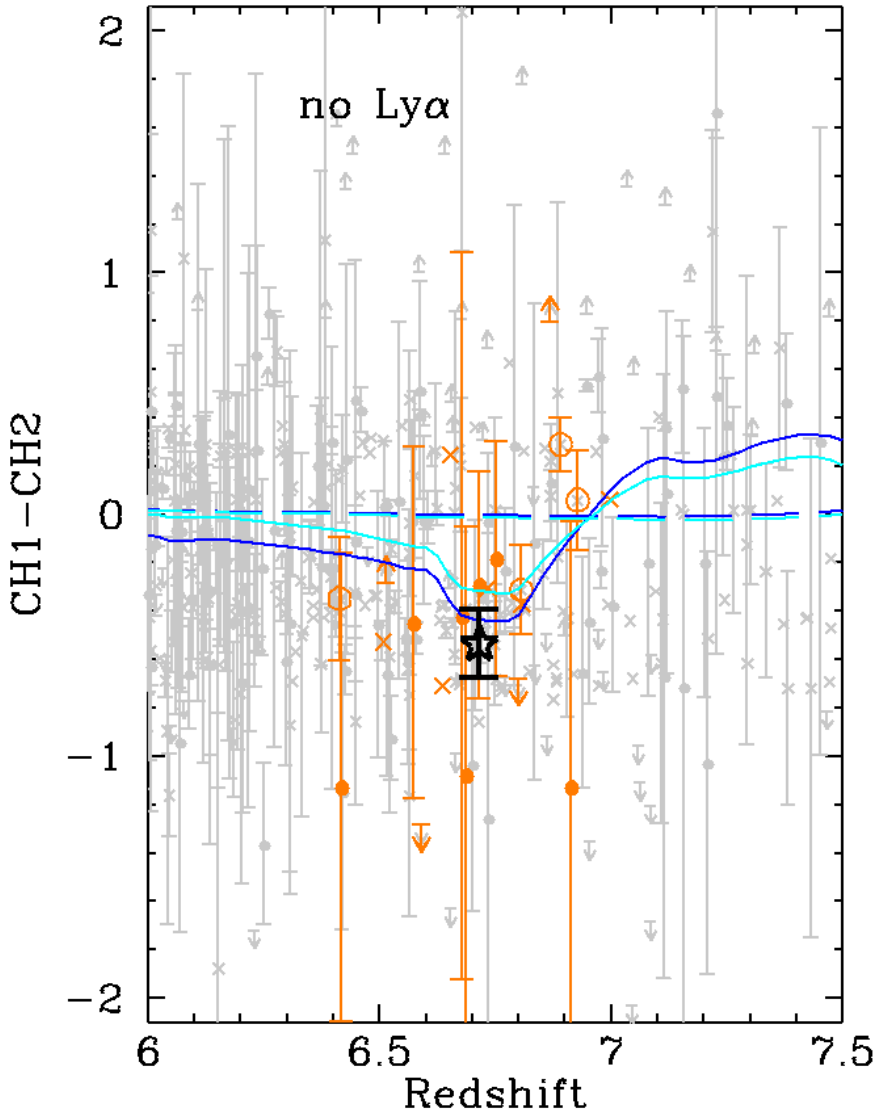
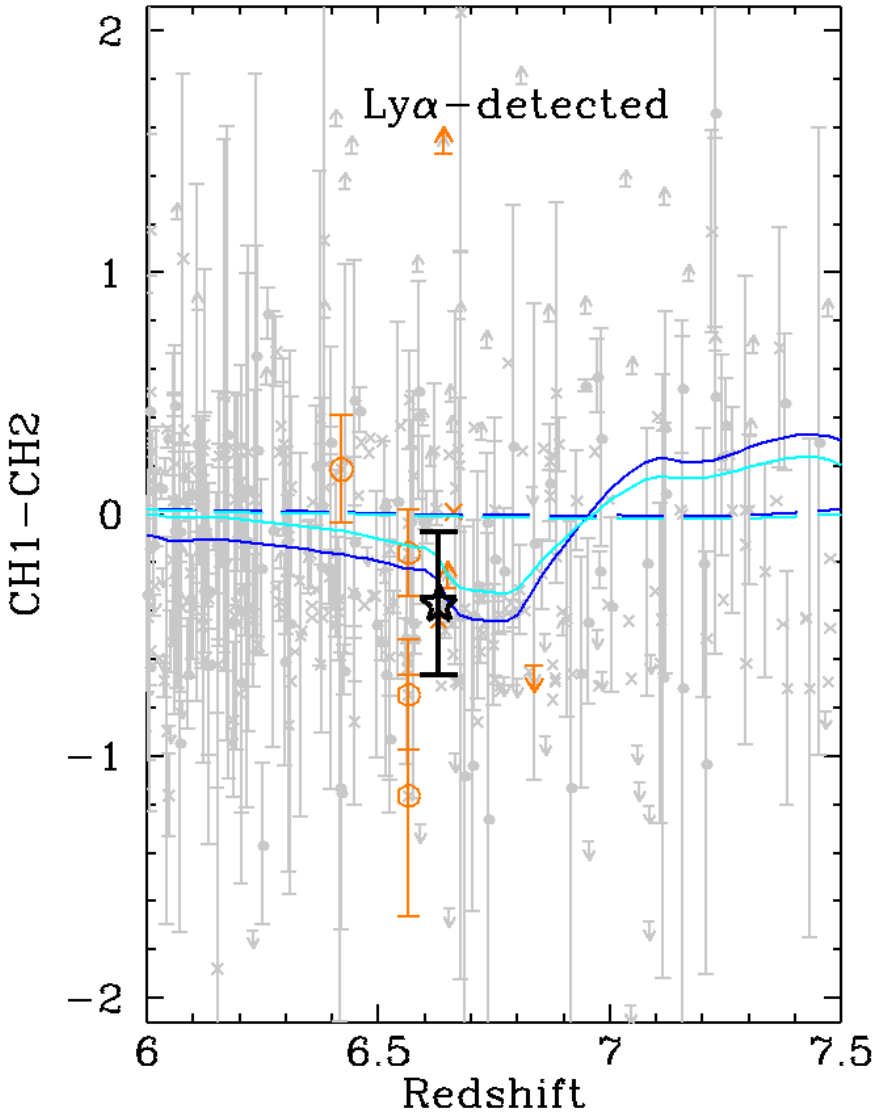
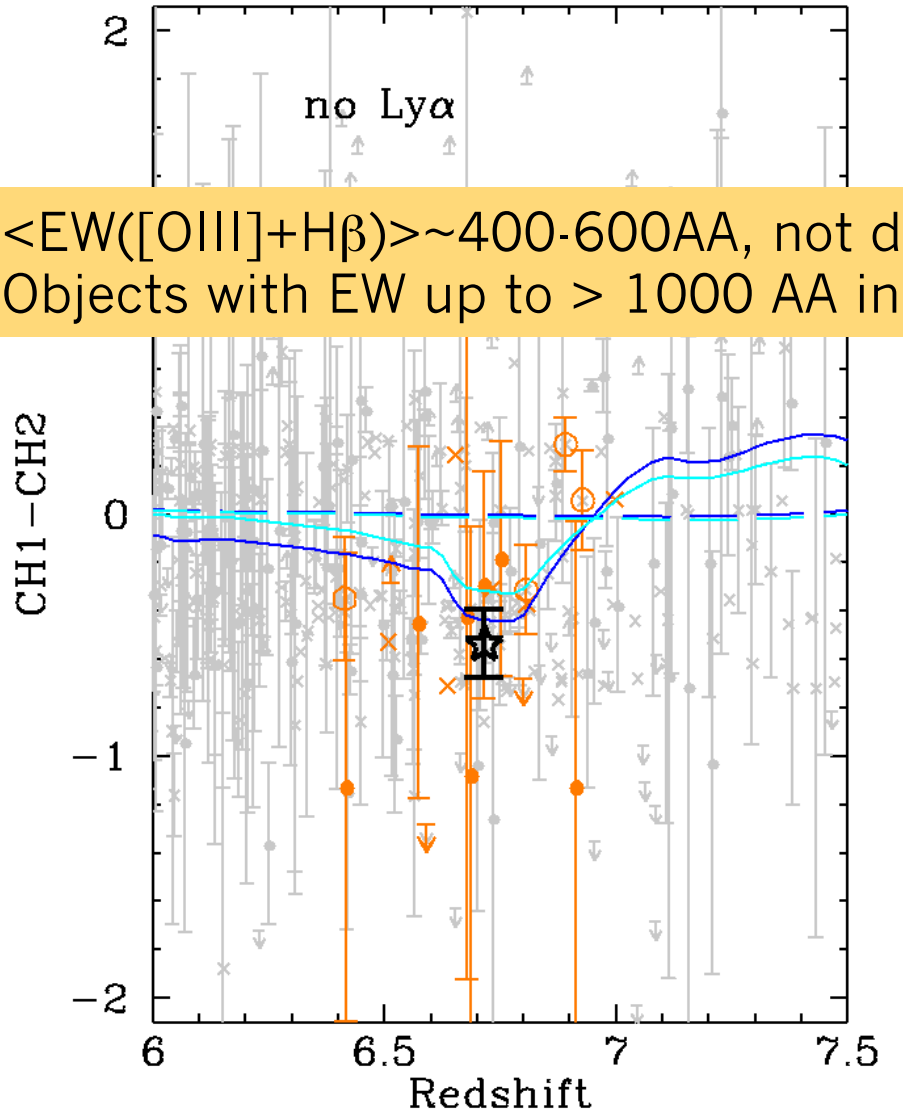
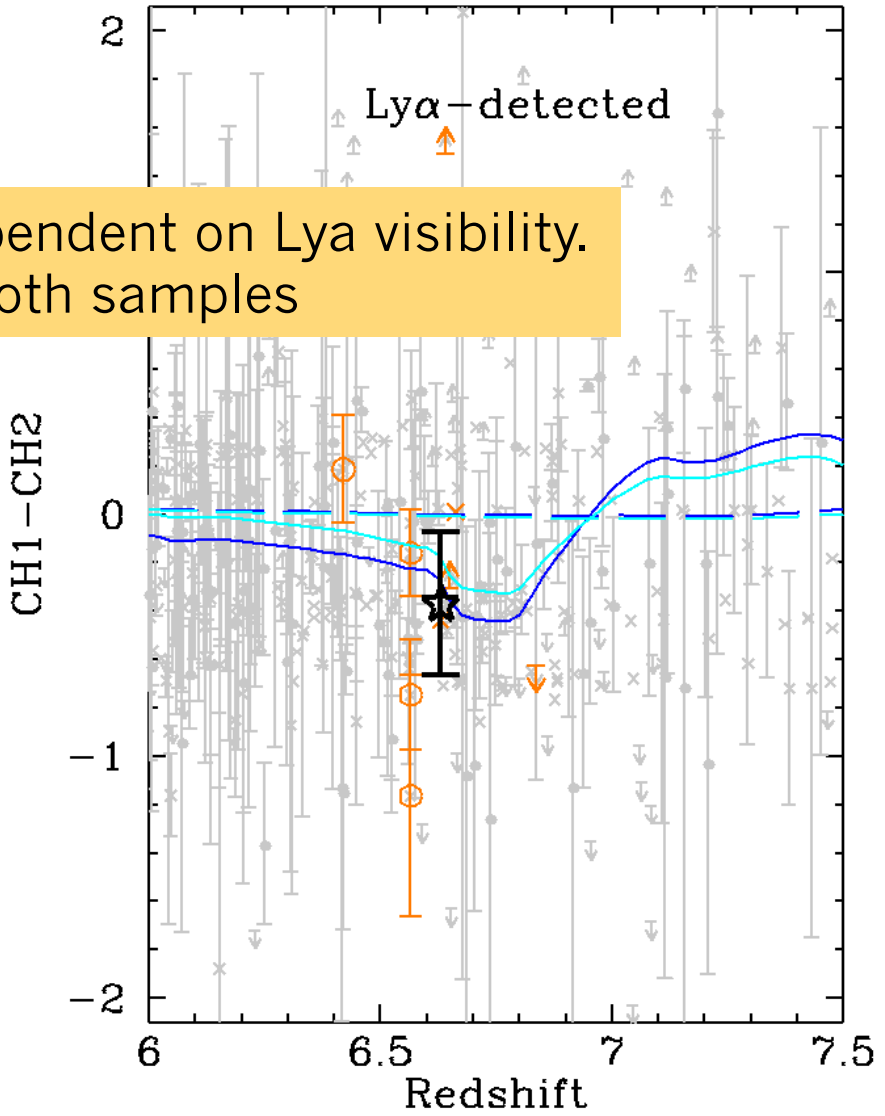




Stacking of targets in UDS and GOODS fields (deep IRAC available):
Lyα undetected sources $6.4<z_{phot}<7.0$; Lyα detected sources $6.4<z<7.0$

IRAC colours of our deep spectroscopic sample





<EW([OIII]+Hβ)>~400-600AA, not dependent on Lya visibility.
Objects with EW up to > 1000 AA in both samples

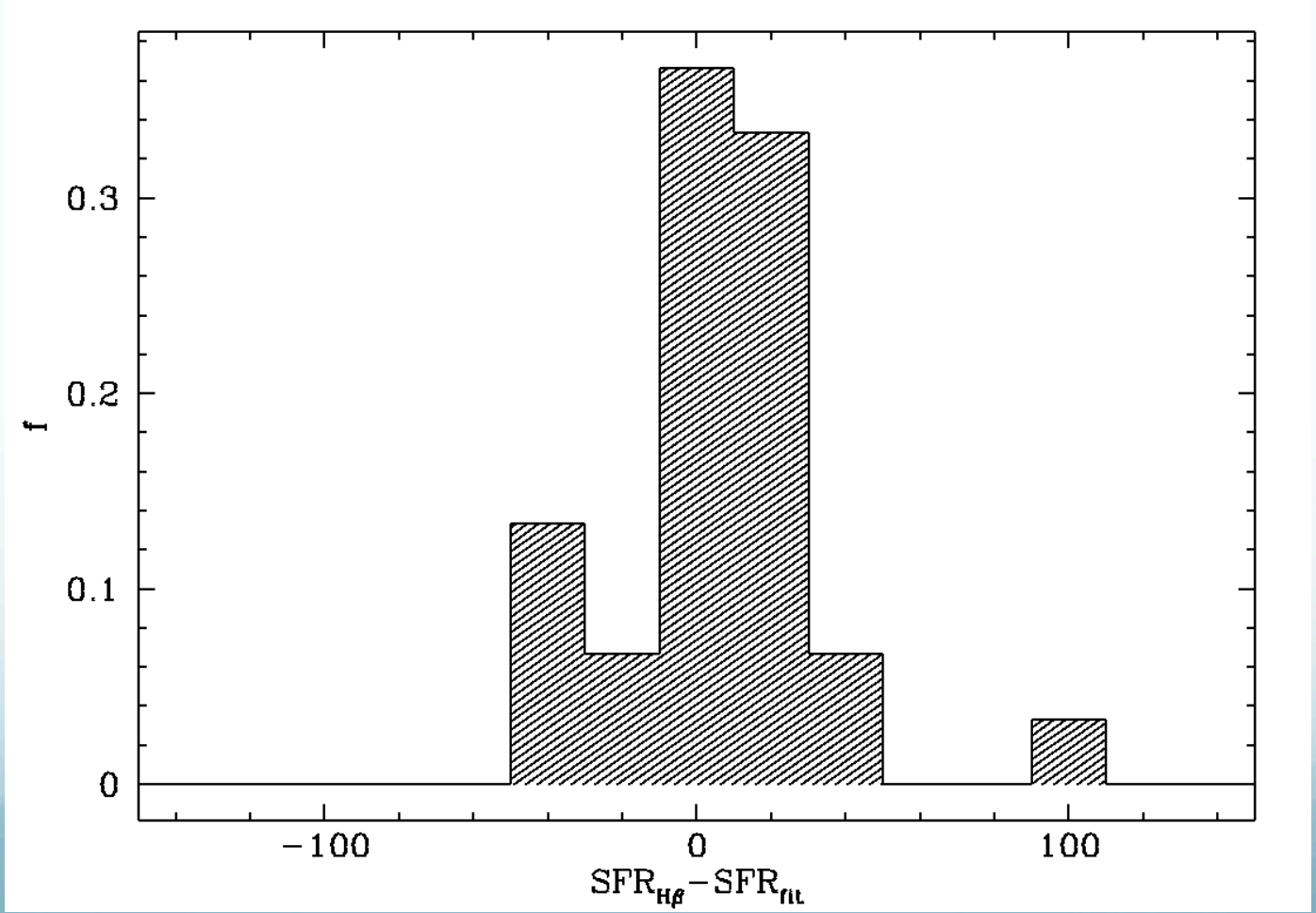
Consistent with positive evolution with redshift (Smit et al. 2014)

Is there evidence for extreme line ratios?

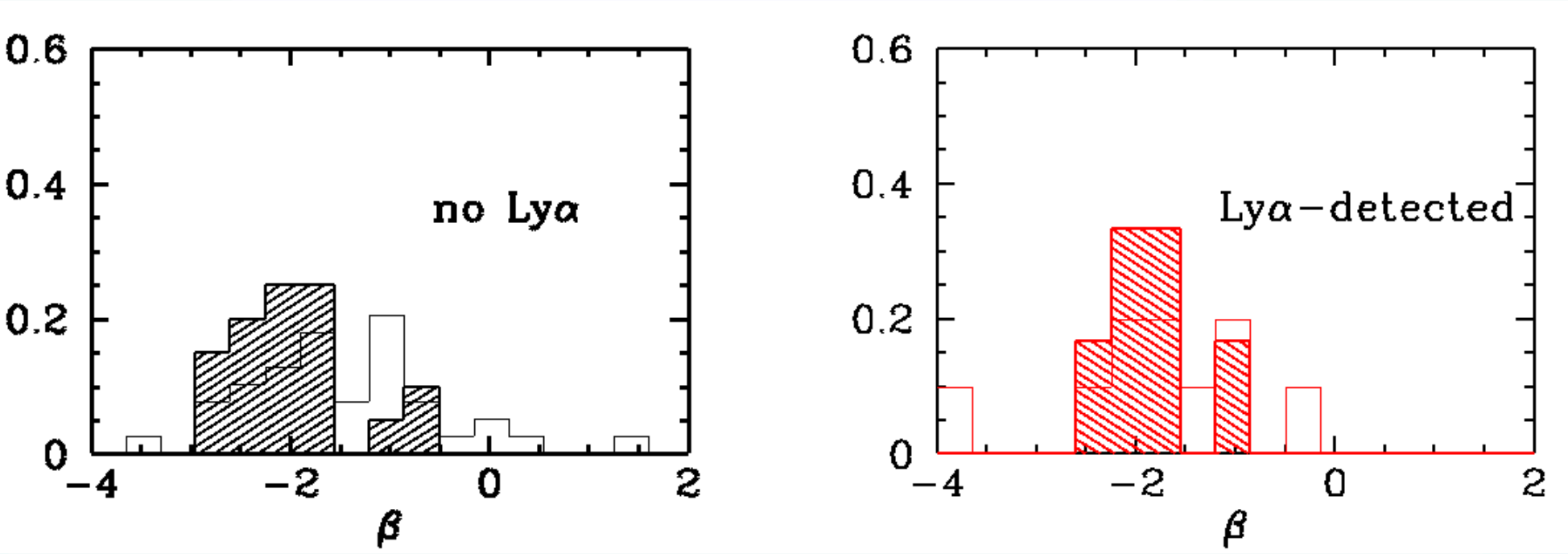
Simple exercise to check consistency with “normal” galaxies:

1) L(Hβ) from IRAC color excess assuming **standard** [OIII]/Hβ (Anders+ 2003)
2) L(Hβ) → SFR following Kennicutt 1998

→ Agreement between SFRs from Hβ and SED-fitting (0.2Zsun models)



Dust extinction in our deep spectroscopic sample



No reddening of the UV slopes found in the literature: tyipical beta constant or decreasing at z>6 (Bouwens et al. 2014, Dunlop et al. 2013)

Our spectroscopic sample consistent with the parent population.

No evidence for effects of high dust extinction in Lyα-undetected objects.

Conclusions

- We investigated multi-λ properties of our deep spectroscopic sample to constrain alternative explanations to the lack of Lyα lines at z~7

* Increase in the Lyman Continuum escape fraction?

- Ubiquitous evidence for strong optical line emission: no difference between Lyα detected and undetected objects.
- Consistent with standard [OIII]/Hβ ratio
- Only probing high-ionization lines with JWST we can fully constrain the presence of density bounded HII regions (Zackrisson et al. 2013, Nakajima&Ouchi 2014, Stasinska et al. 2015)
- Possible f_{esc} increase combined with IGM HI increase (Dijkstra et al. 2014)

* Increase in dust extinction?

- No evidence of reddening of UV slopes from z~6 to z~7.
- Galaxies in our sample coherent with these results on global population.
- Only possible if an increase in dust extinction is combined with evolution of other "blueing" properties (e.g. metallicity) conspiring to make beta ~constant or bluer.

* A significant fraction (> 60-70%) of selected galaxies is not at z~7?

- Highly unlikely : stacked optical bands yield to upper limits of > 30 mags on Lyα undetected objects.