A closer look at reionization sources

Clustering, line emission and feedback

Marco Castellano

A. Fontana, L. Pentericci, P. Dayal, E. Merlin, A. Ferrara, M. Giavalisco, E. Vanzella

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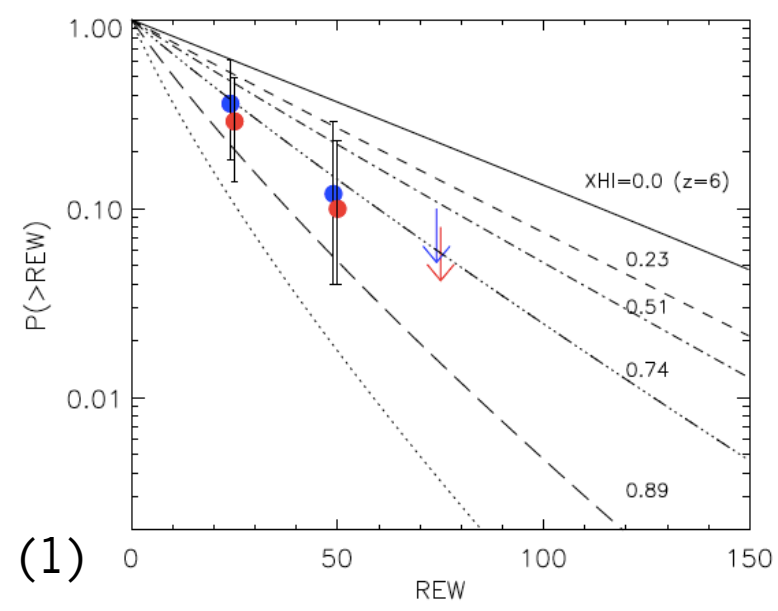
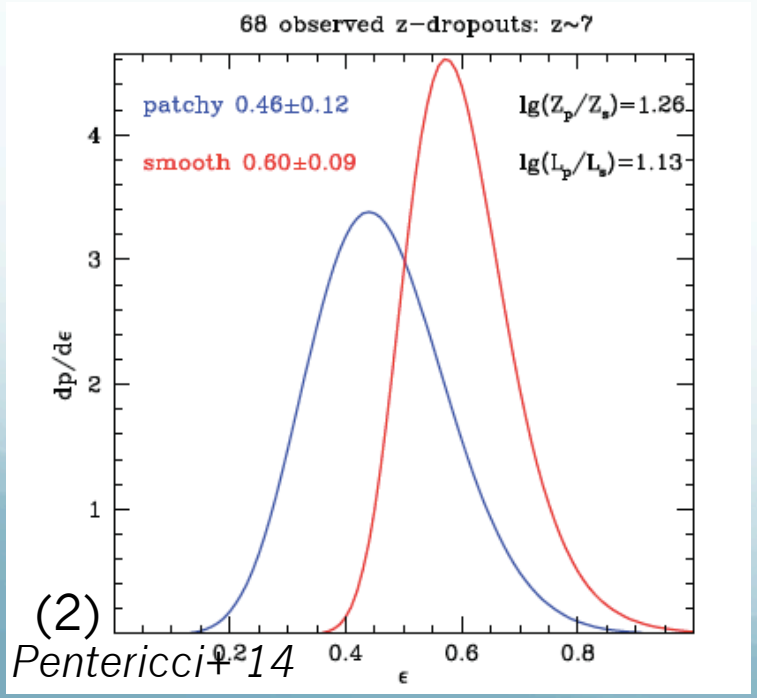
Current knowledge on reionization



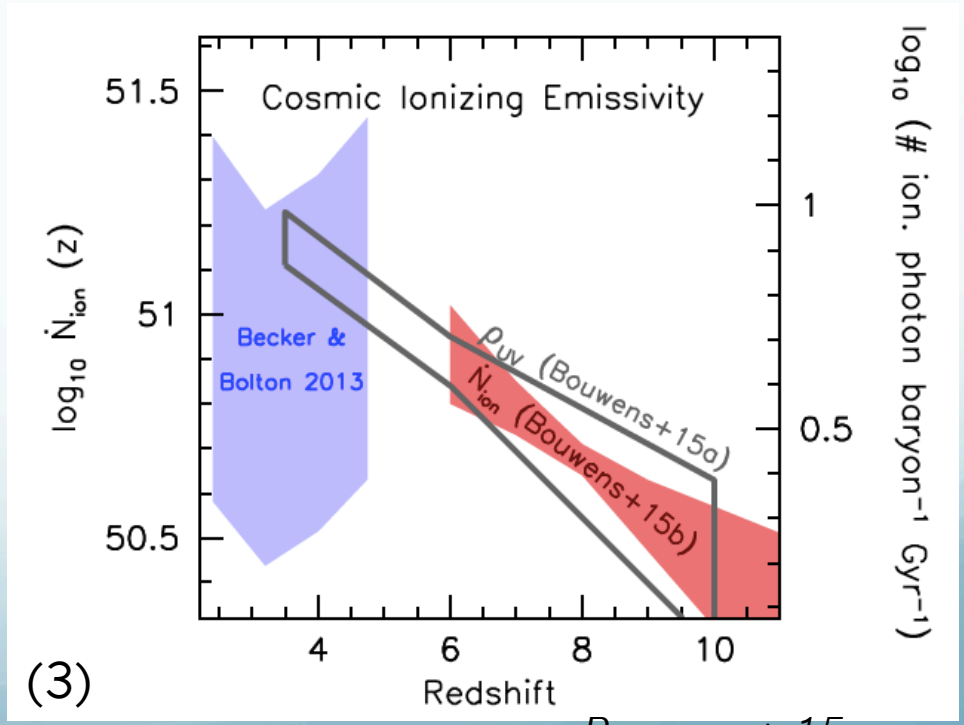
(1)

- *Timeline constrained from CMB + spectra (1)*
- *Favoured interpretation: IGM half neutral at z~7*
- *Patchy reionization favoured (2)*
- *UV emission from galaxies can explain reionization (3)*



(2)

Pentericci+14



(3)

Bouwens+ 15

Open problems

- *What distinguishes Lyα emitting and non emitting galaxies, what causes visibility patchiness?*

- *Need to strenghten the interpretation of Lyα drop*

- *Role of galaxies:*
  - *Emissivity and escape fraction*
  - *Cut-off of the LF faint end*

Open problems

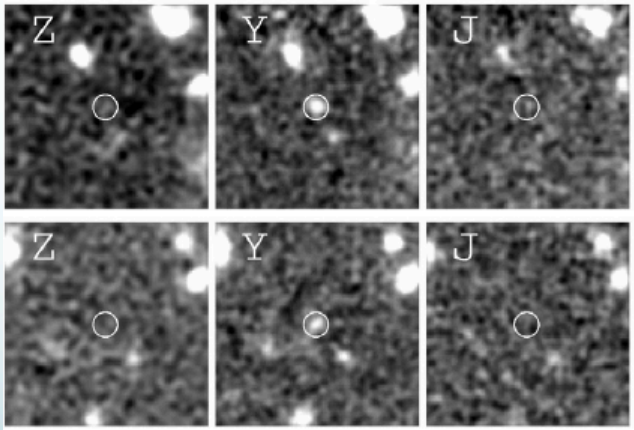
- *What distinguishes Lyα emitting and non emitting galaxies, what causes visibility patchiness?*
- *Need to strenghten the interpretation of Lyα drop*
- *Role of galaxies:*
  - *Emissivity and escape fraction*
  - *Cut-off of the LF faint end*
- *Is clustering responsible for line visibility and "patchiness"?*
- *Optical line emission in z~7 sources with and w/o Lya as a redshift and extreme fesc proxy*
- *Ultra-faint, magnified galaxies in the Frontier Fields constrain the LF cut-off*

A space oddity at z~7: clustering?

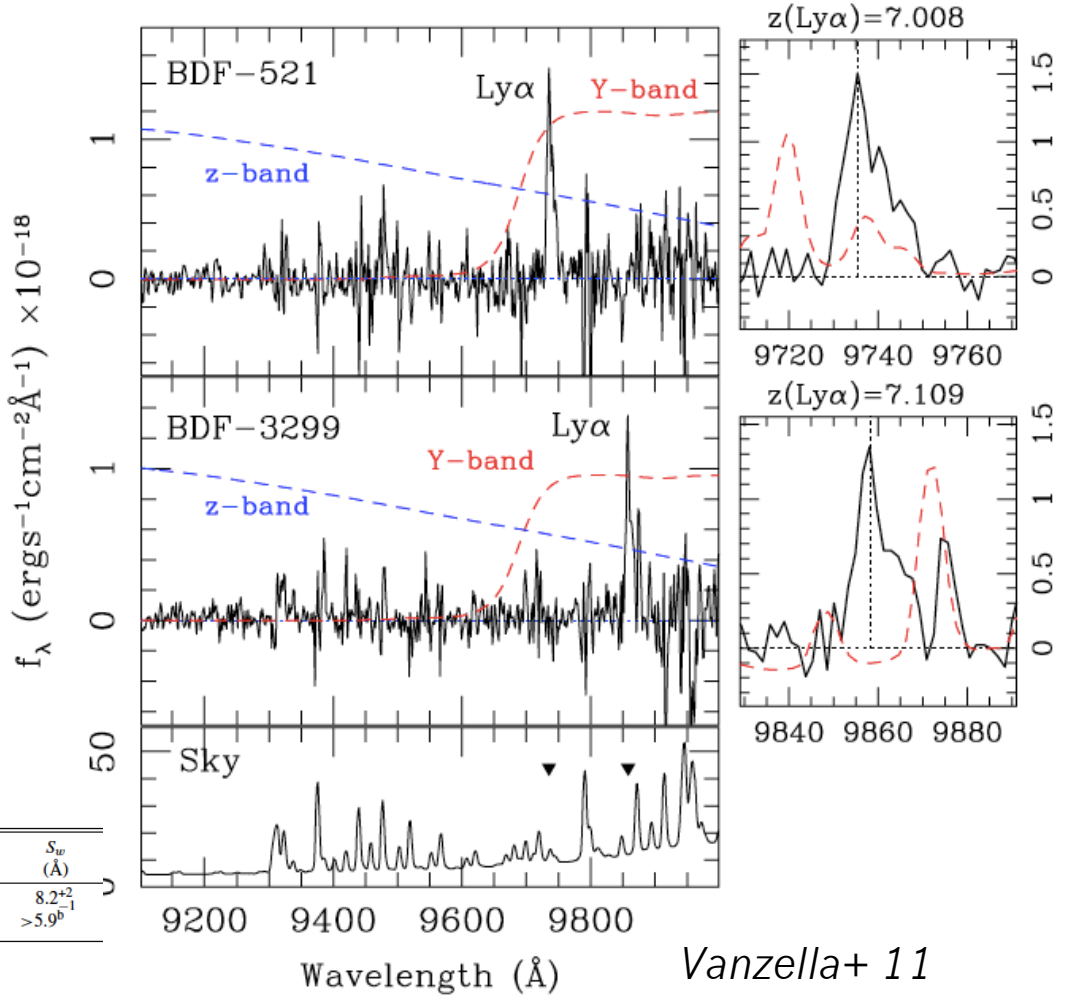
In the overall paucity of Lyα lines, one line of sight with twin bright emitters among the 8 l.o.s. investigated in Pentericci+ 14

The BDF field hosts two close-by (4.4 proper Mpc) EW>50AA emitters. Their L_{UV} cannot build a large enough HII region to explain line visibility (Vanzella+11).

Additional sources required?
(e.g. Dayal+09)



MC+ 10b

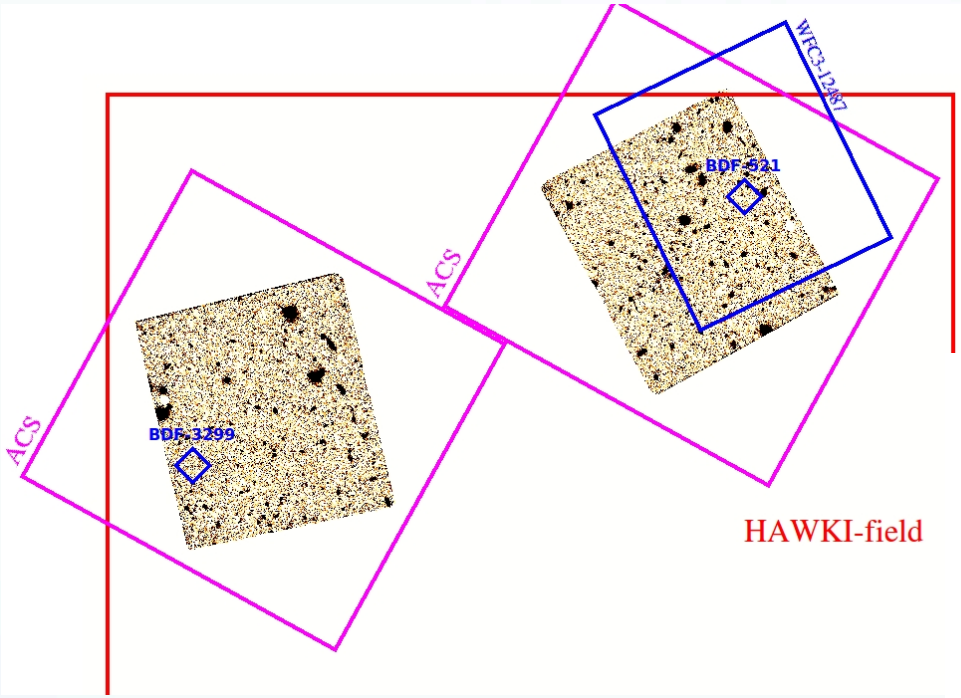


Vanzella+ 11

ID	R.A., Decl. J2000	Redshift	f(Lyα)	SFR(Lyα) ($M_\odot$ yr^{-1})	EW$_{rest}$ (Å)	FWHM[a] (km s^{-1})	S_w (Å)
BDF−521	336.9444, −35.1188	7.008 ± 0.002	1.62 ± 0.16	8.5	64	240	8.2^{+2}_{-1}
BDF−3299	337.0511, −35.1665	7.109 ± 0.002	1.21 ± 0.14	6.6	50	200	>5.9[b]

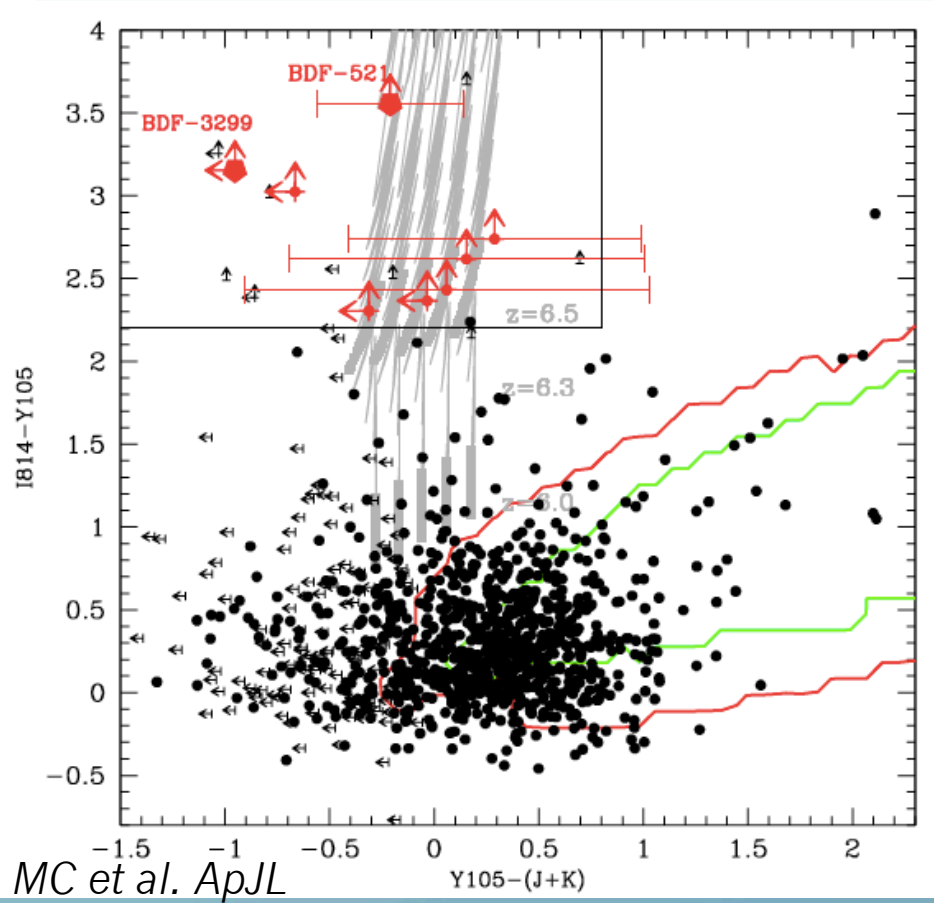
Notes. f(Lyα) in units of 10^{-17} erg s^{-1} cm^{-2} Å^{-1}.

Faint z~7 LBGs in the BDF field



HST Cycle 22 program (PI MC) to look for surrounding, fainter LBGs.

14 orbits with V606, I814, Y105.



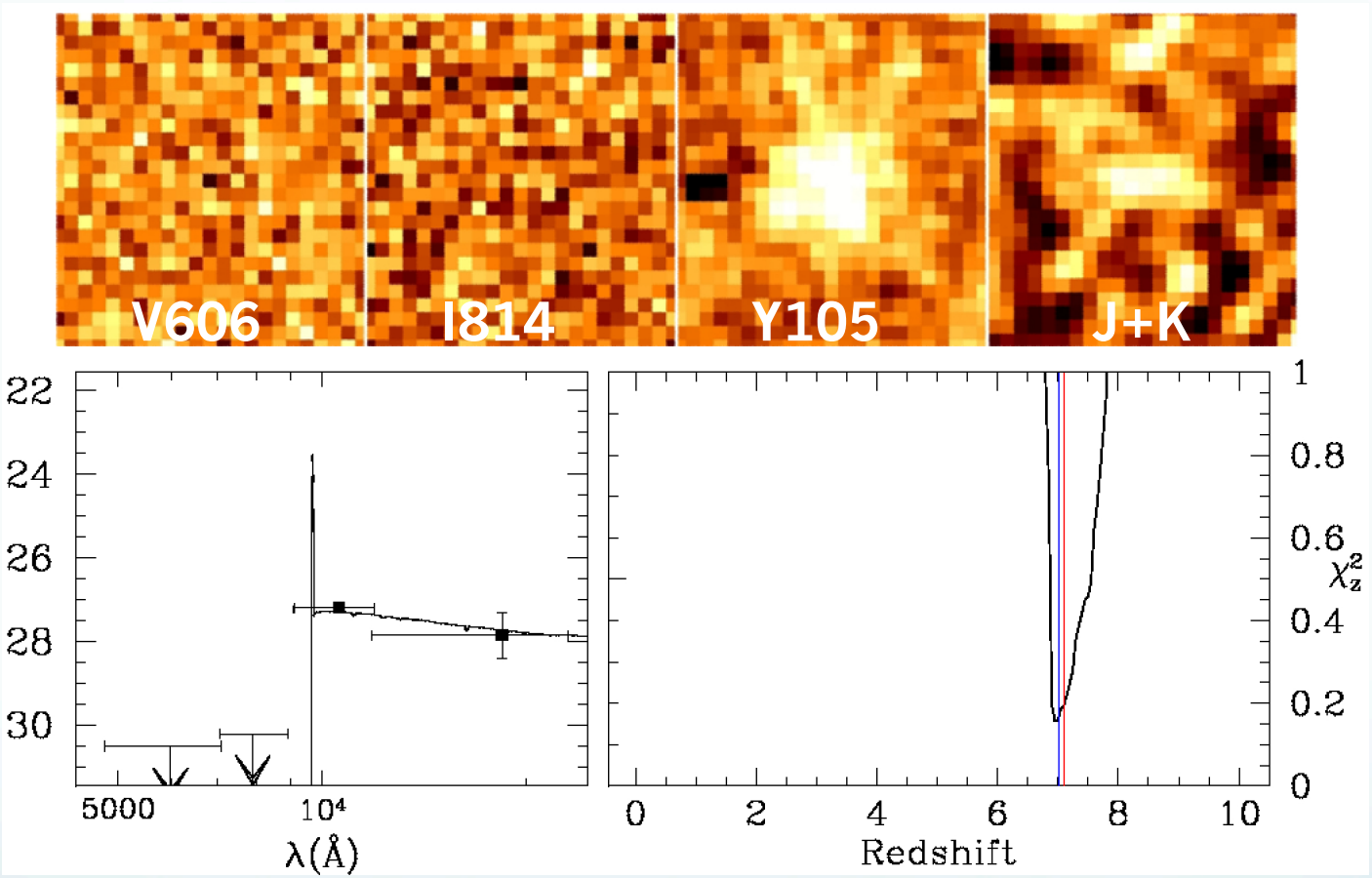
Previous Hawk-I data limited to Y~26.5.

Six new robust LBGs recovered at Y105~26.5-27.5 (at S/N>10)

$$(S/N(I_{814}) < 1) \wedge (I_{814} - Y_{105} > 2.2)$$
$$Y_{105} - (J + K) < 0.8$$
$$(S/N(Y_{105}) > 10) \wedge (S/N(V_{606})) < 1,$$

MC et al. ApJL

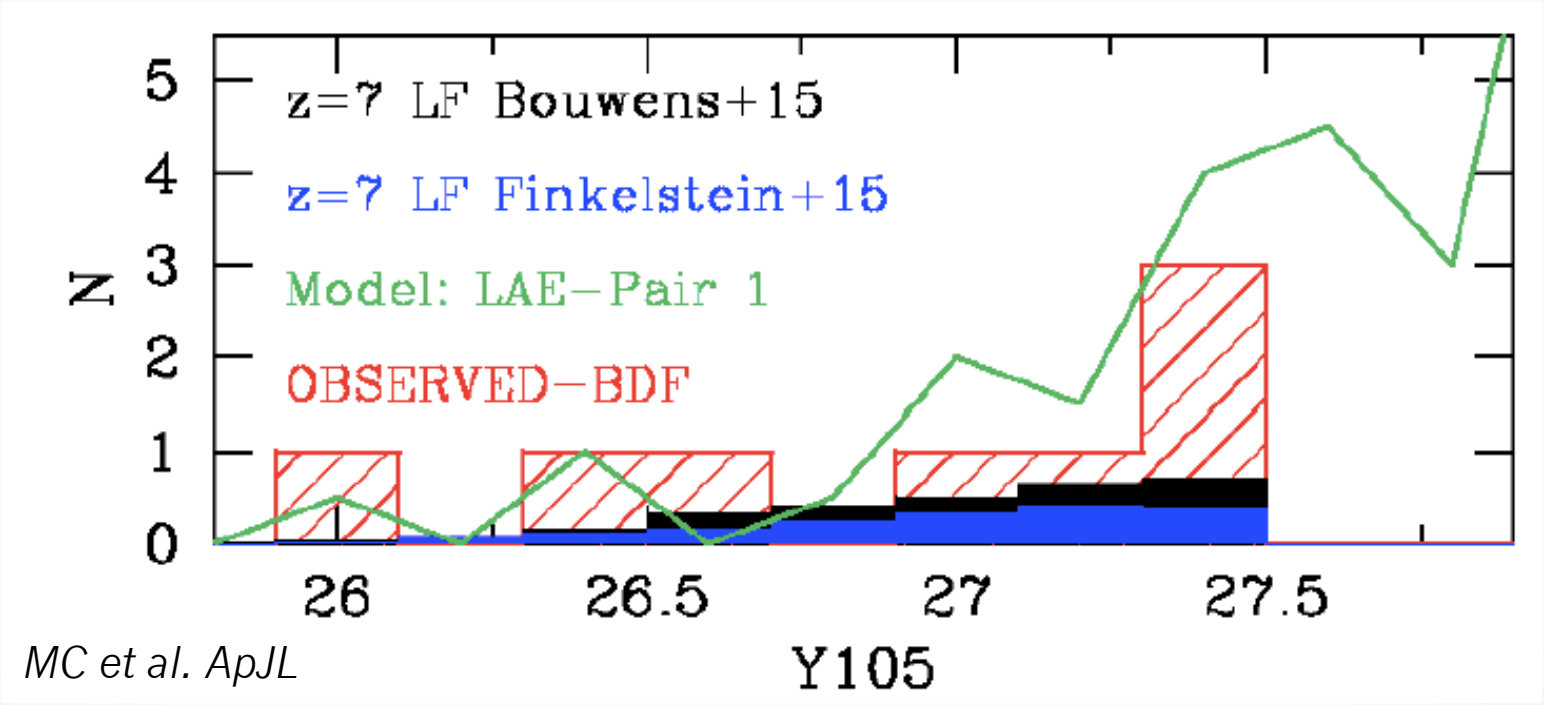
Faint z~7 LBGs in the BDF field



Stacking of the six new LBGs: V606 and I814 undetected at >30.2 mag, I814-Y105>3, S/N~2 detection in J+K.

Z_{phot}=6.95. **Consistent with the objects being at the same *z* of the emitters**

The BDF region is overdense



MC et al. ApJL

Observed= 8 objects in two pointings. Expected ~1.8-2.9 objects.

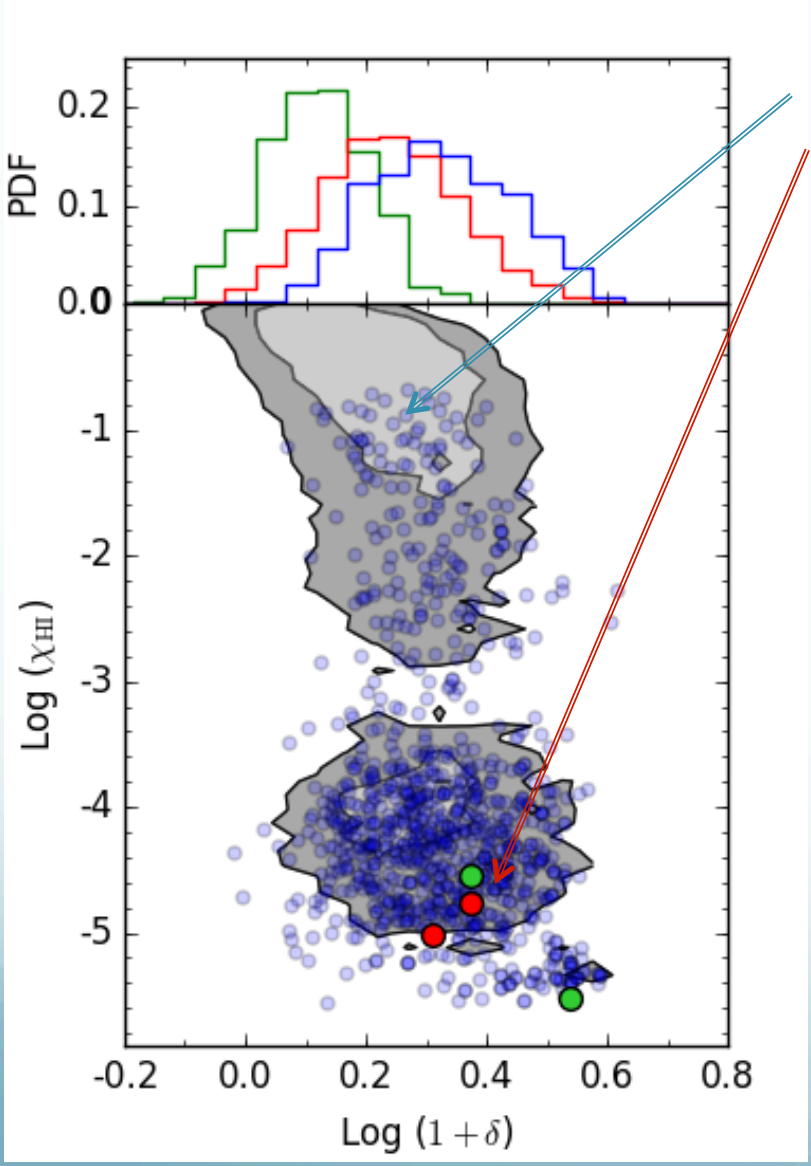
No clustering around z~7 GOODS-S galaxies (objects lacking Lyα emission).

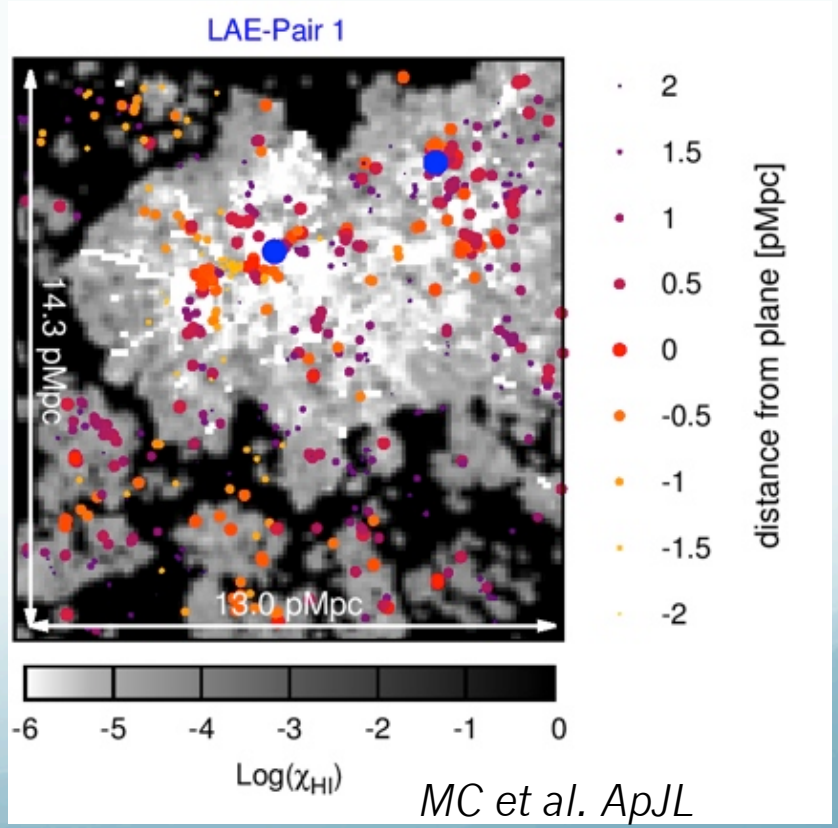
The BDF field is 3-4x overdense wrt average: consistent with a positive relation between line visibility and galaxy density as in ***inside-out reionization scenarios.*** (e.g. McQuinn+ 07, Wyithe&Loeb 07, Dayal+ 09).

Galaxy density drives reionization

Comparison with SPH model (Hutter+14,+15).

- Relation between density and HI fraction
- LAE pairs live in overdense regions with low HI
- BDF analogs are reionized, overdense bubbles





MC et al. ApJL

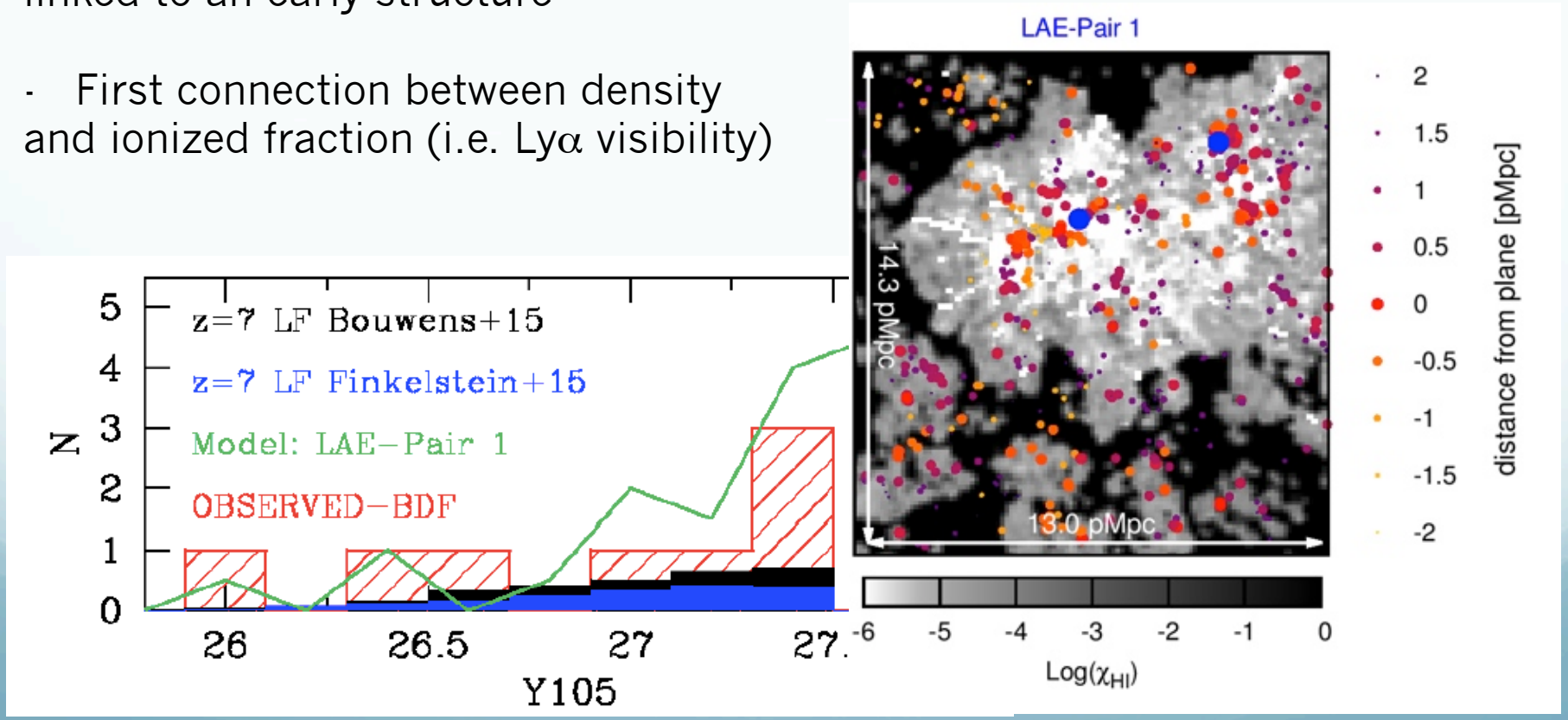
A closer look at z~7 sources: clustering

Conclusions:

- Two close-by z~7 LAEs in the BDF field are embedded in an overdensity. Patchy scenario due to clustering.

- Support for the presence of overlapping reionized "bubbles" of ~5Mpc rad., linked to an early structure

- First connection between density and ionized fraction (i.e. Lyα visibility)



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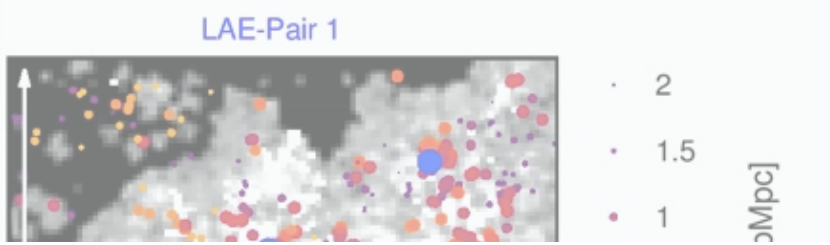
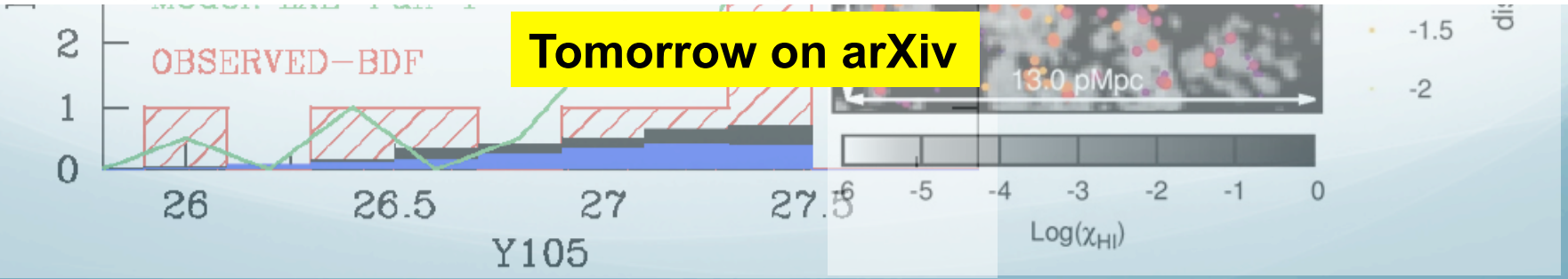


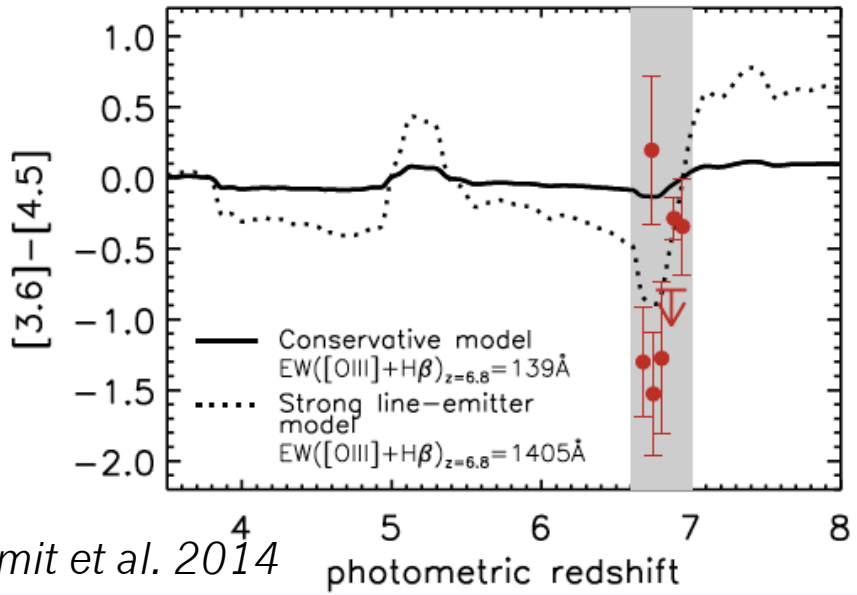
FIRST OBSERVATIONAL SUPPORT FOR OVERLAPPING REIONIZED BUBBLES GENERATED BY A GALAXY OVERDENSITY

M. Castellano[1], P. Dayal[2,3], L. Pentericci[1], A. Fontana[1], A. Hutter[4], G. Brammer[5], E. Merlin[1], A. Grazian[1], S. Pilo[1], R. Amorin[1], S. Cristiani[6,7], M. Dickinson[8], A. Ferrara[9], S. Gallerani[9], E. Giallongo[1], M. Giavalisco[10], L. Guaita[1], A. Koekemoer[5], R. Maiolino[11,12], D. Paris[1], P. Santini[1], L. Vallini[9,13], E. Vanzella[14], J. Wagg[15]



Tomorrow on arXiv

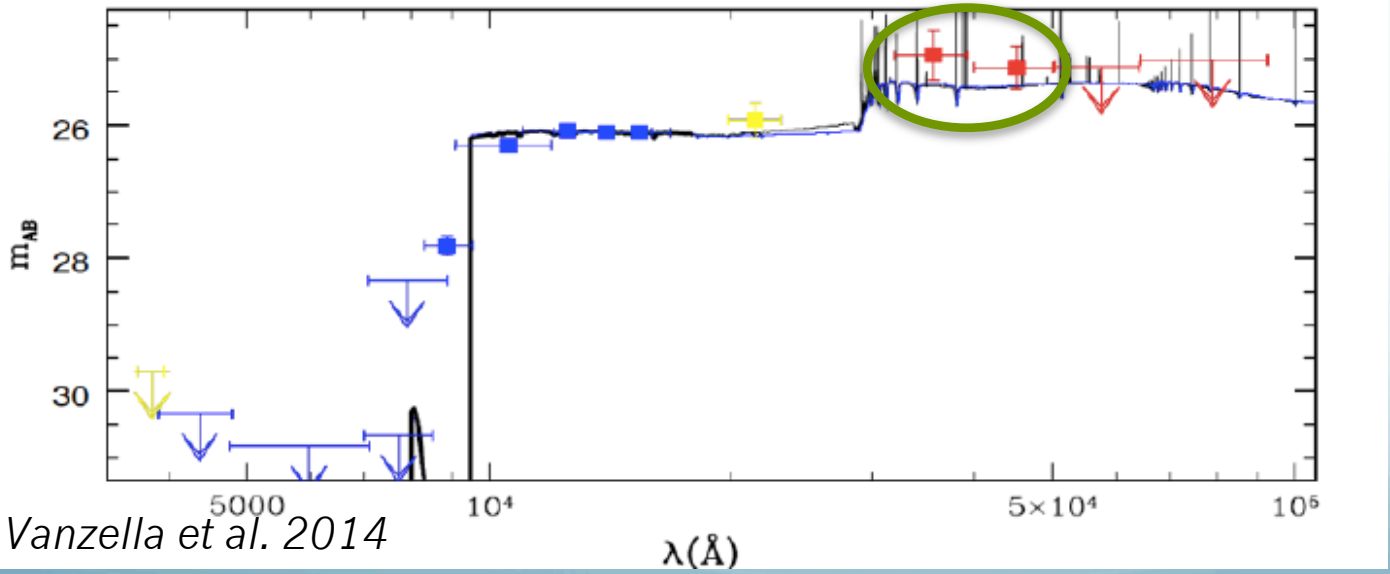
A closer look at z~7 sources: optical line emission



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)

Good redshift indicator: <u>we can check reliability of LBGs lacking Lyα confirmation.</u>

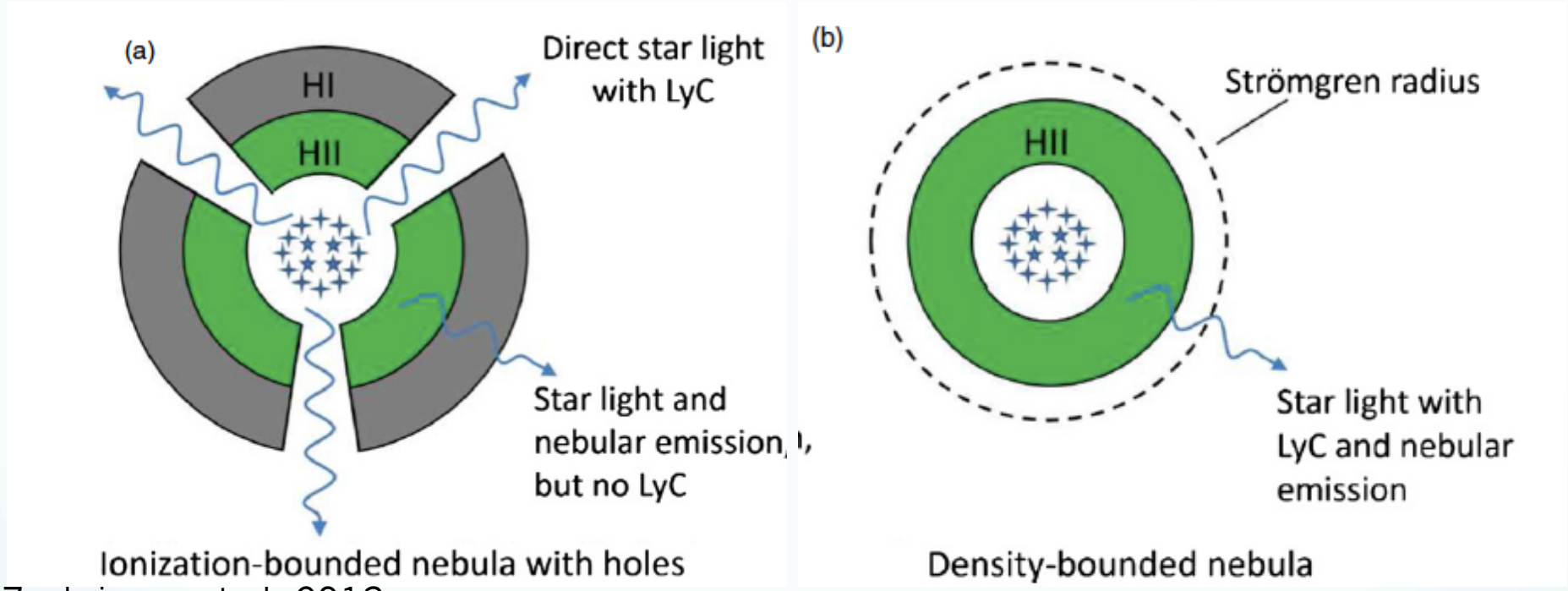


Vanzella et al. 2014

EW(Lyα)<9A from 52hrs FORS2 spectrum

A closer look at z~7 sources: optical line emission

An extreme escape fraction can erase the Lyα line, what about other lines?



Zackrisson et al. 2013

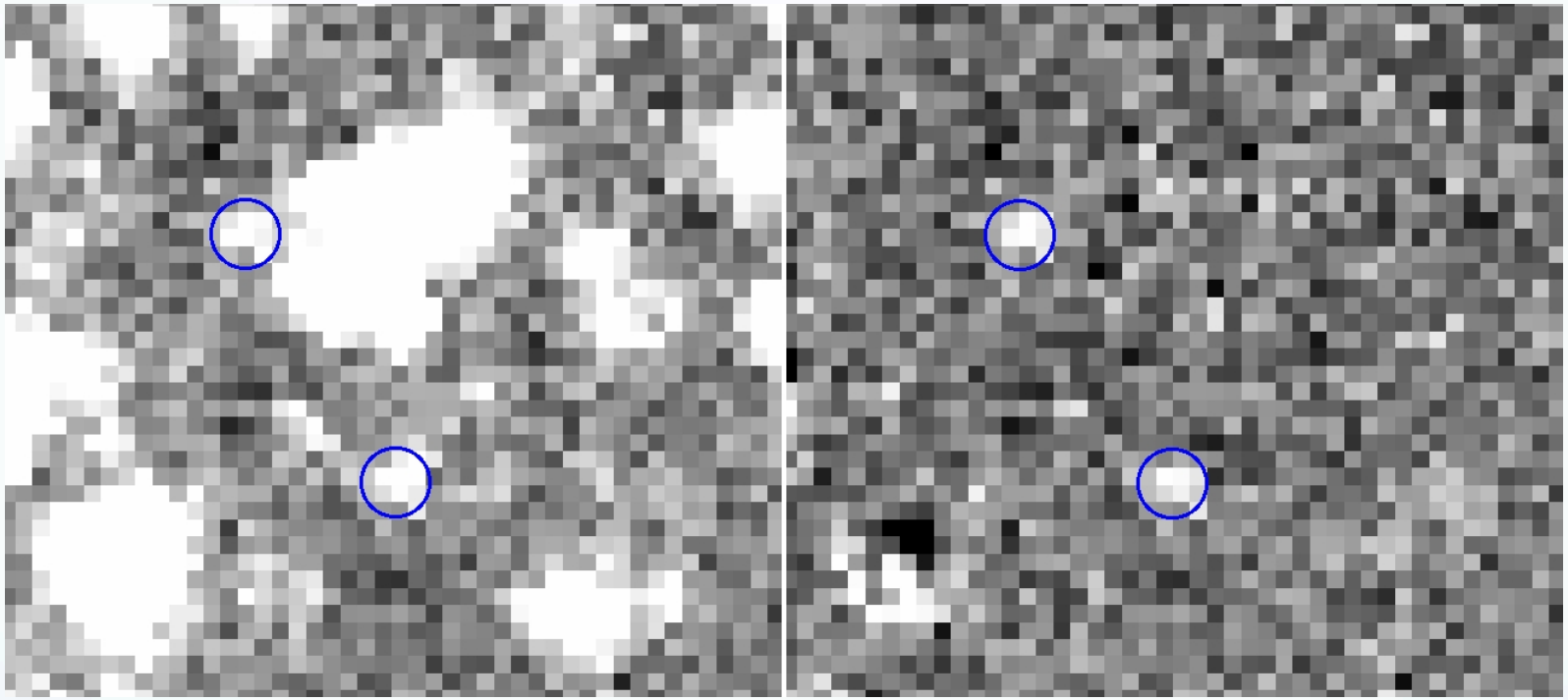
a) Em. lines disappear when fesc →1

b) Strong high ionization lines

Nakajima&Ouchi 2014: high [OIII]/[OII]
see also Stasinska et al 2015
D. Schaerer and S. De Barros talks

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

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 **T-PHOT**
(Merlin+2015, *http://www.astrodeep.eu/t-phot/*)

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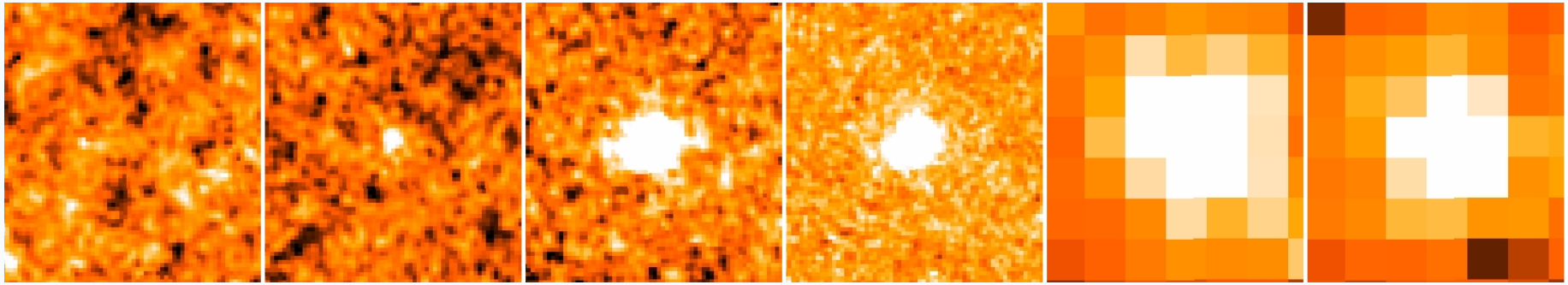

V606 I814 J125 H160 [3.6] [4.5]

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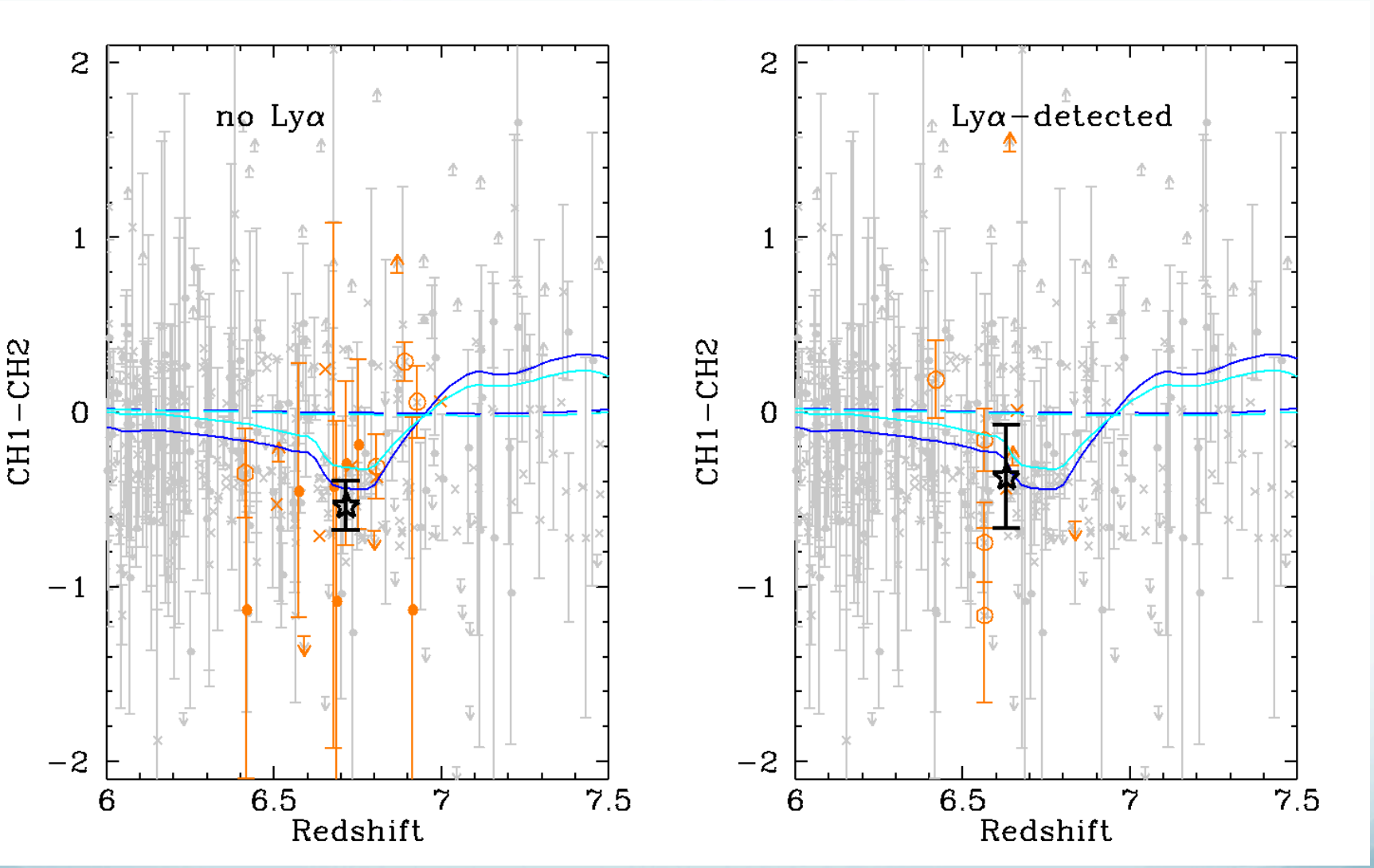
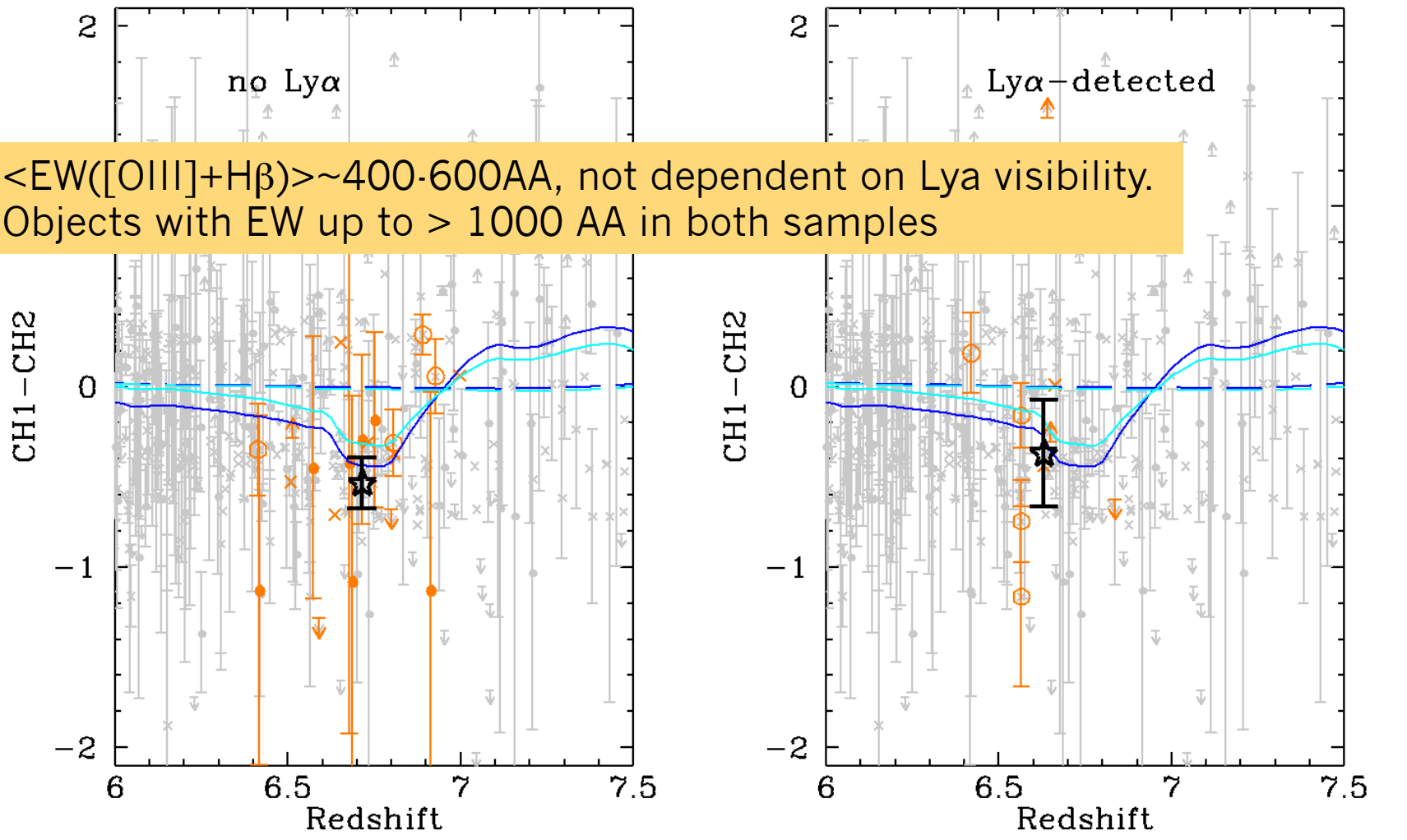


Stacking of targets in UDS and GOODS fields (deep IRAC available):
Lyα undetected sources $6.4<z_{phot}<7.0$; Lyα detected sources $6.4<z<7.0$

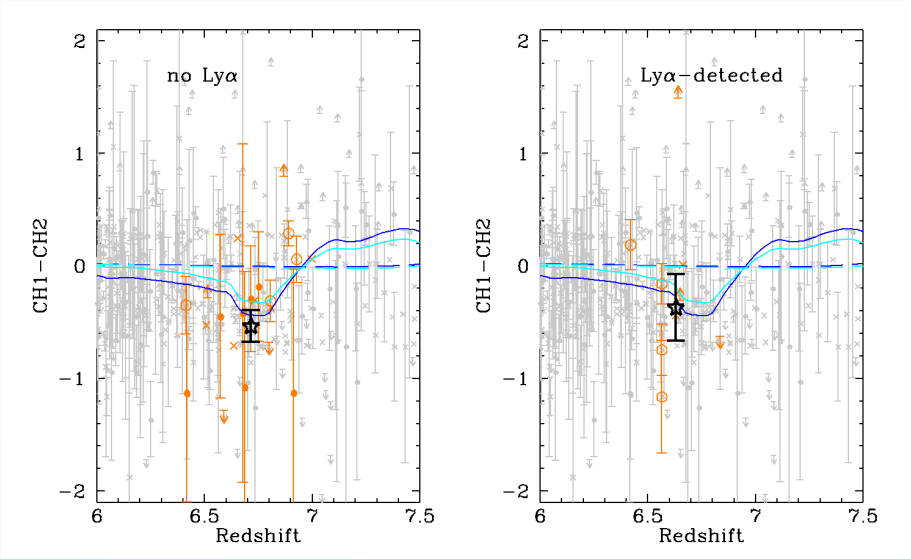
IRAC colours of our deep spectroscopic sample



<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)

A closer look at z~7 sources: optical line emission



Still preliminary....

Conclusions:

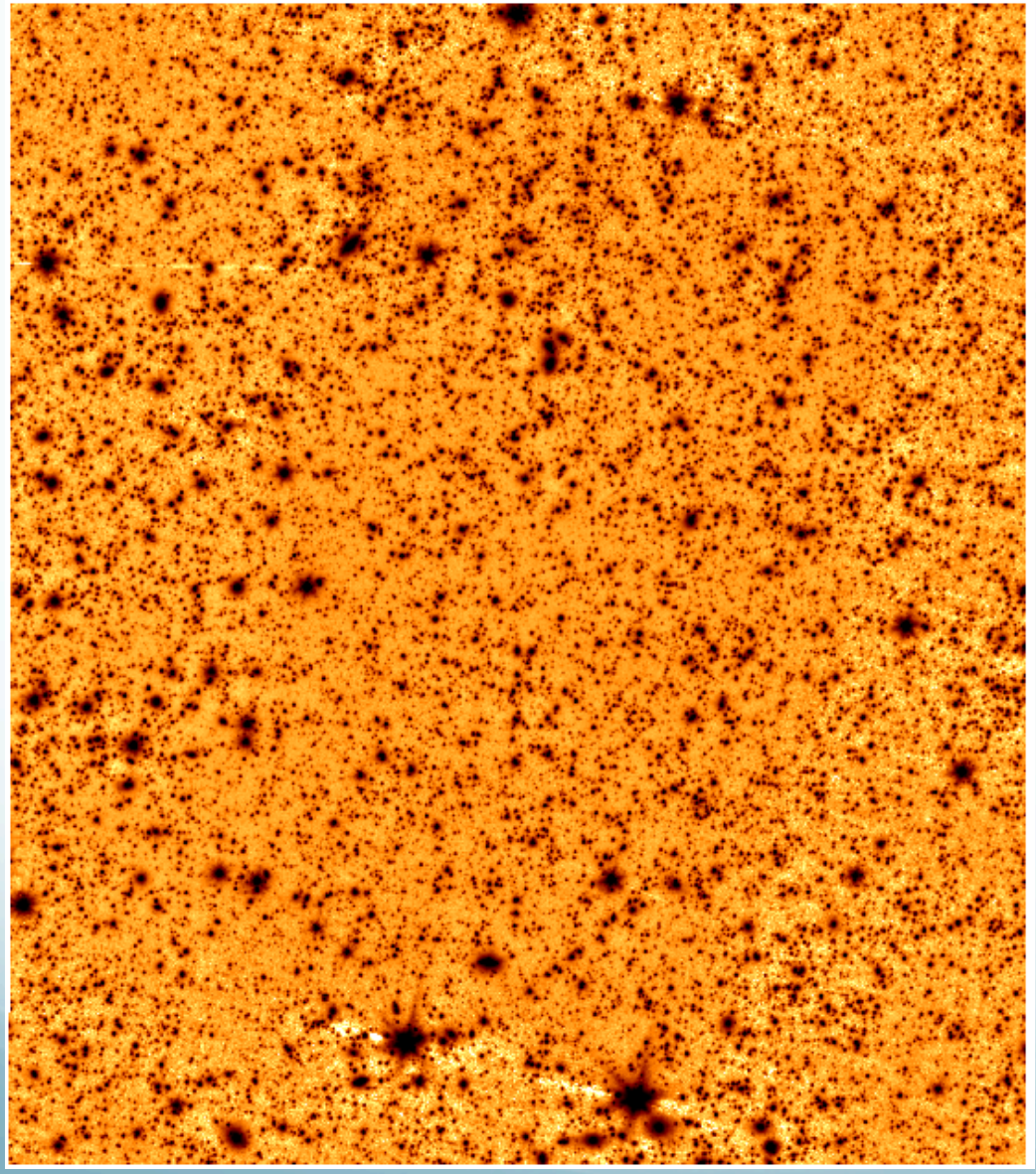
- Ubiquitous evidence for strong optical line emission: no difference between Lyα detected and undetected objects.

- No likely massive escape fraction from ionization bounded nebulae.

- Only with JWST we can fully constrain the presence of density bounded HII regions (e.g. Zackrisson et al. 2013, Nakajima&Ouchi 2014, De Barros+ 2015)

- Possible f_{esc} increase combined with IGM HI increase (Dijkstra et al. 2014)

Yet another ASTRODEEP catalog: GOODS-S 2nd Generation



ASTRODEEP is preparing a revised + improved version of the CANDELS GOODS-S catalog:

- IRAC CH1 and CH2 supermaps (GOODS+S-CANDELS and all available programs on CDFS, Labbe + 15)

- 18 medium band images

- Deep optical coverage in U, B, R bands (VIMOS)

- Full Herschel photometry

- X-ray Chandra photometry

Everything reprocessed with improved procedures (TPHOT)

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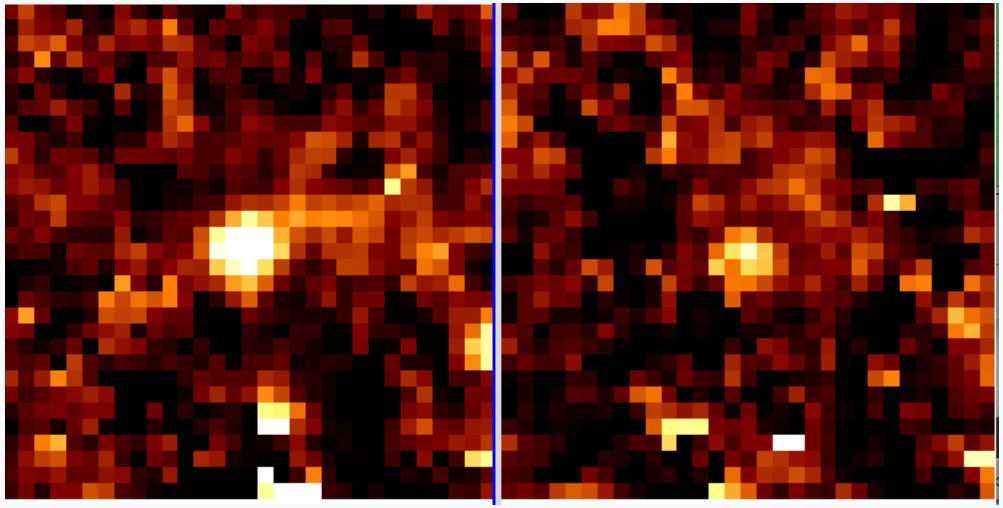
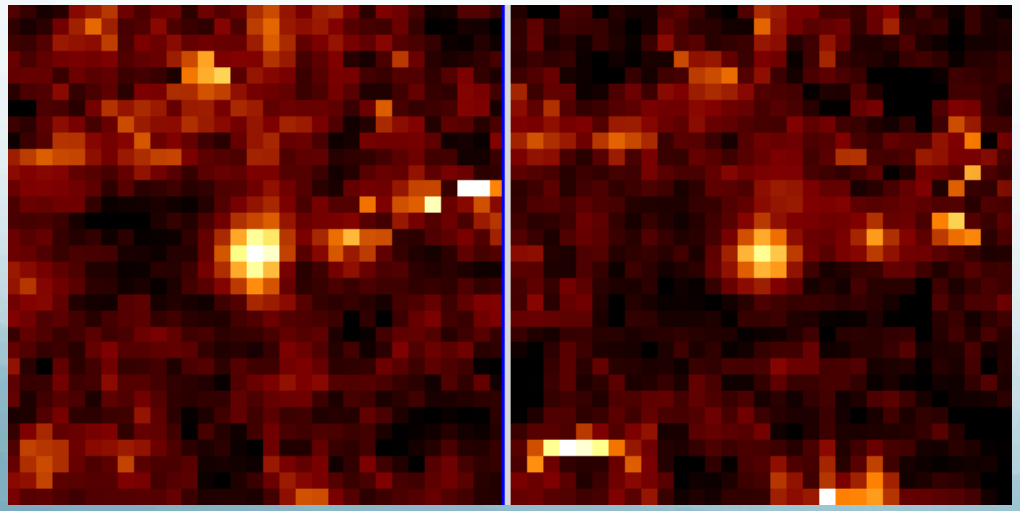


Lyα-detected



Lyα-undetected

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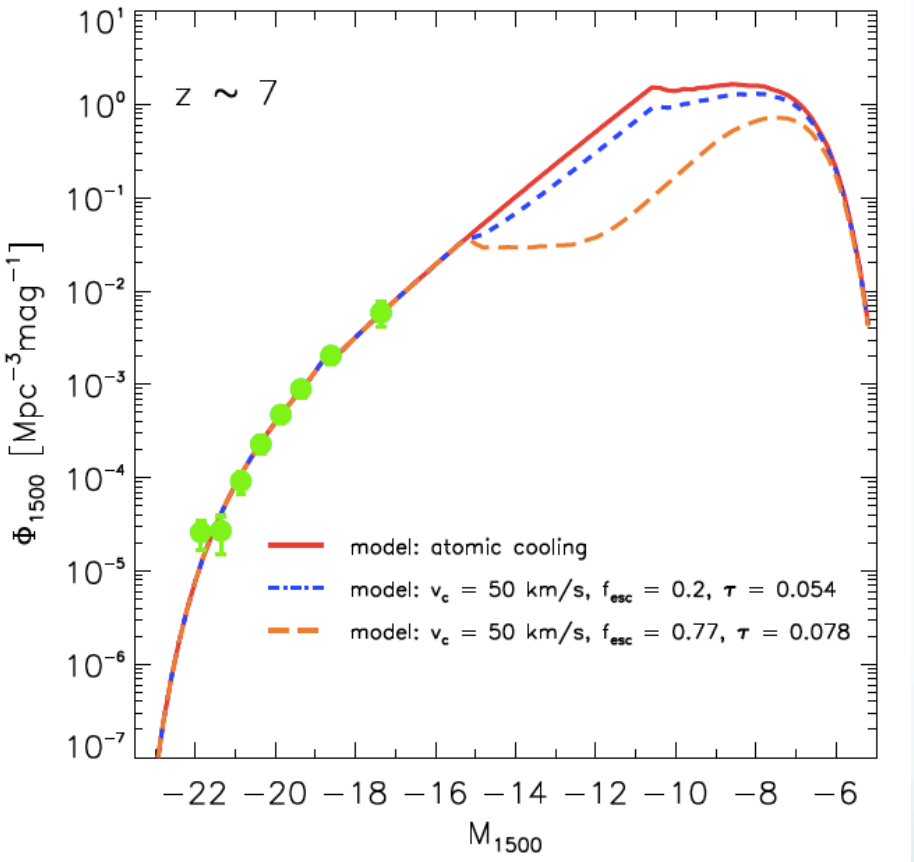
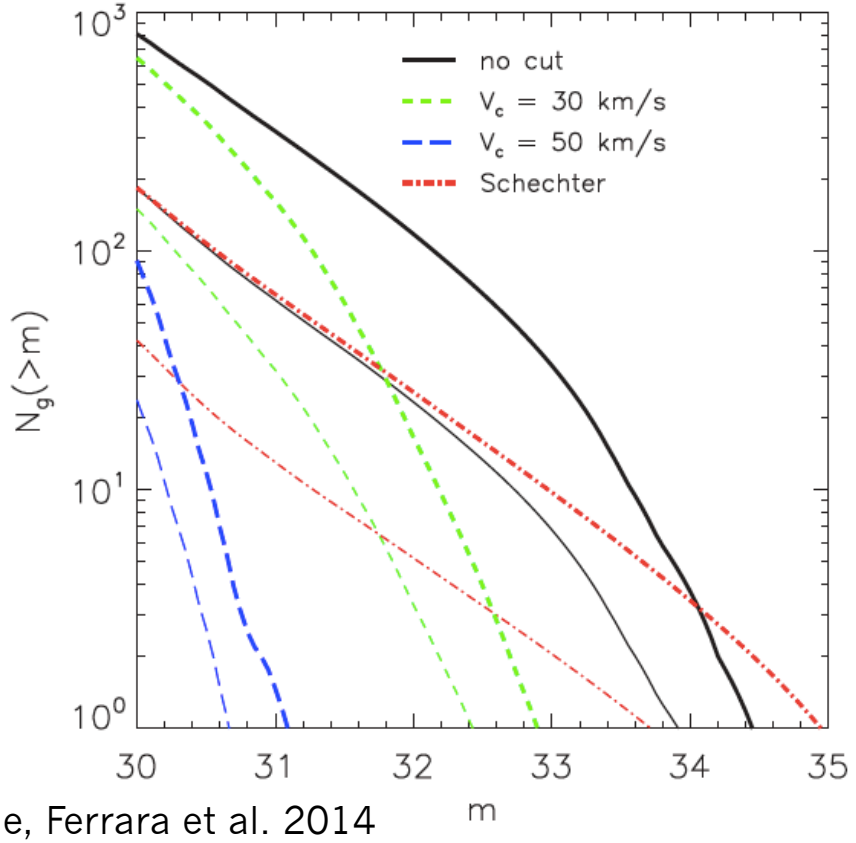
A closer look at z~7 sources: LF cut-off and feedback



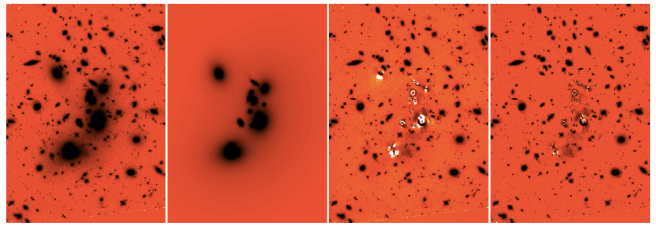


Yue, Ferrara et al. 2014

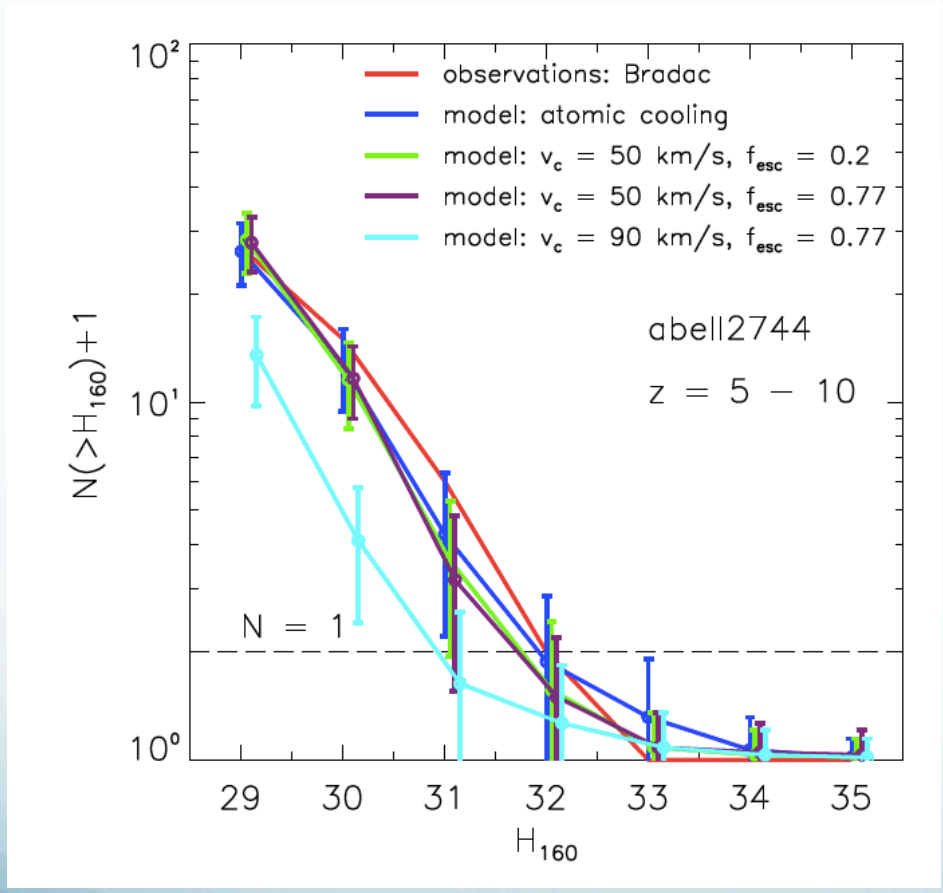
The LF cut-off (feedback due to UV background) affects the number counts of highly magnified sources

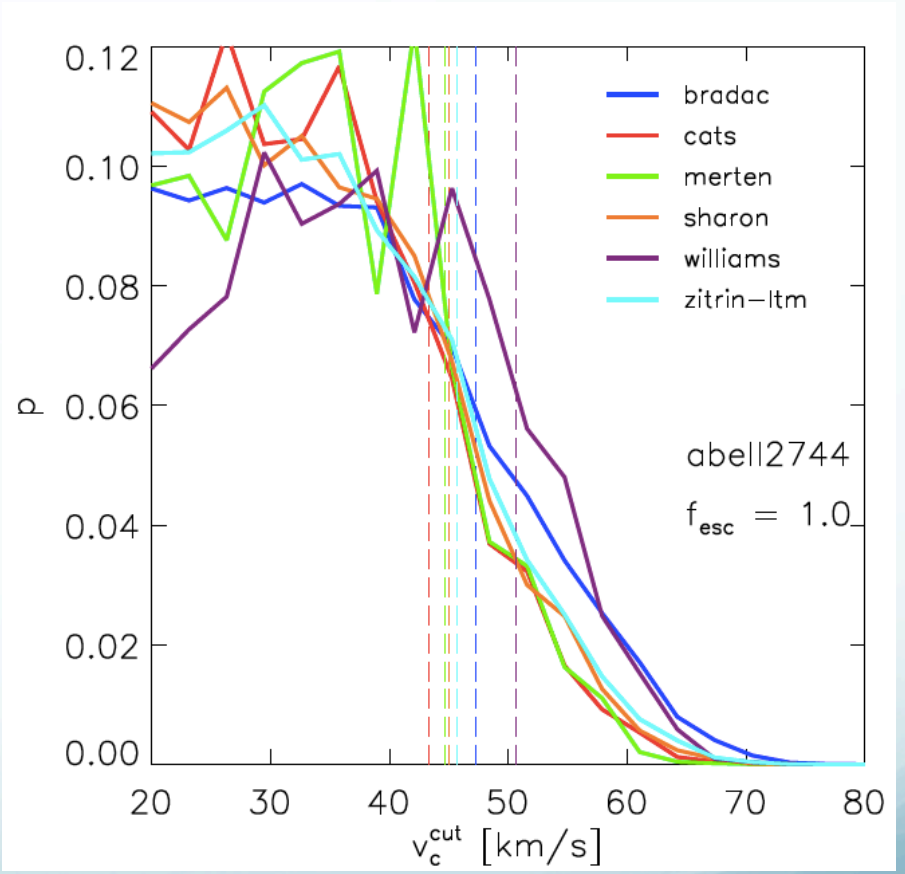
We can probe the cut-off of the LF thanks to the Frontier Fields survey

A closer look at z~7 sources: LF cut-off and feedback



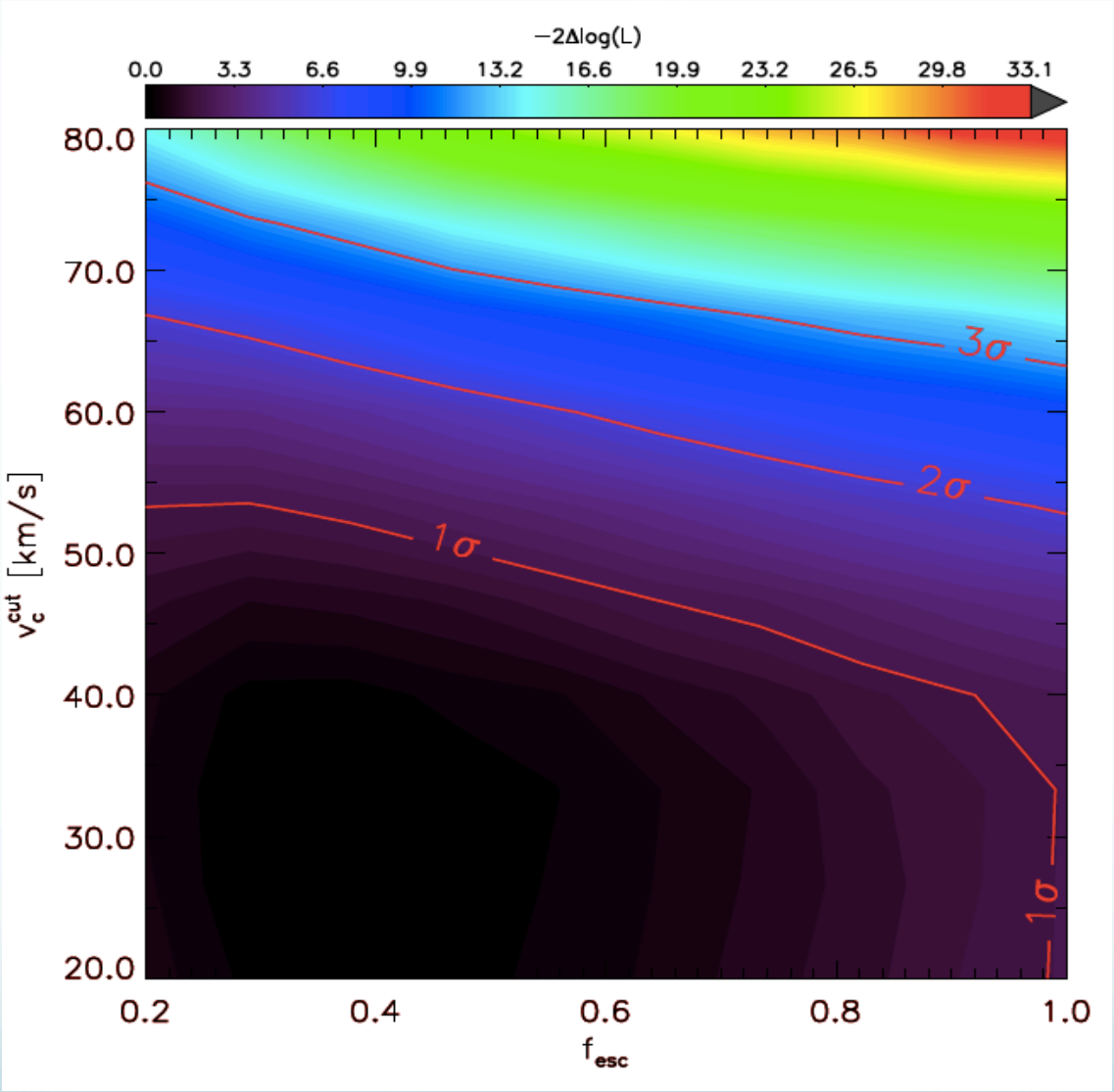
From ASTRODEEP catalogues of A2744 and MACS0416





Comparison between Yue&Ferrara model and observed counts
All lensing models used to build a global likelihood minimizing systematics

A closer look at z~7 sources: LF cut-off and feedback



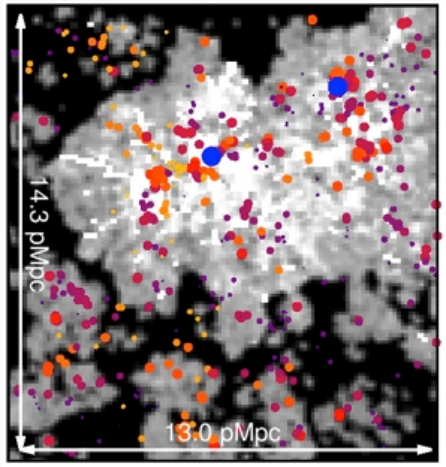
First constraints on the cut-off circular velocity for galaxy populations at z>5

A closer look at reionization sources: summary

Clustering & IGM patchiness

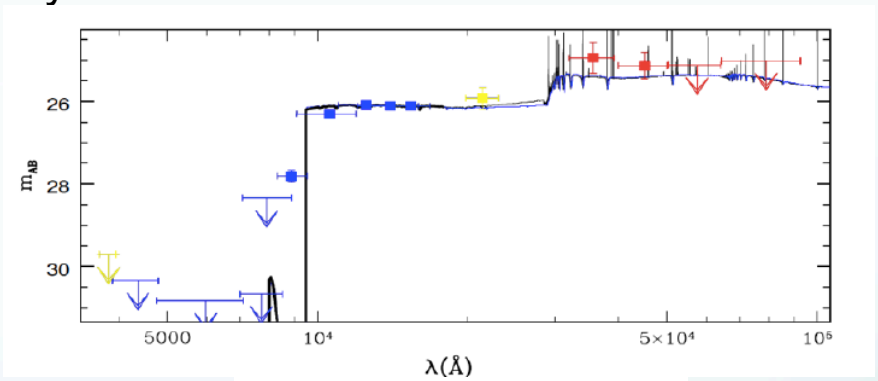
- Two close-by z~7 LAEs in the BDF field are embedded in an overdensity.

- Support for the presence of overlapping reionized "bubbles" of ~5Mpc radius, first connection between density and ionized fraction/line visibility.



Optical line emission & Lyα emission

- Ubiquitous evidence for strong optical line emission: no difference between Lyα detected and undetected objects. Ongoing analysis of deeper IRAC data.



LF cut-off & feedback

- First constraints Vc<40-50 Km/s on the cut-off circular velocity at z>5 from number counts of highly magnified FF galaxies.