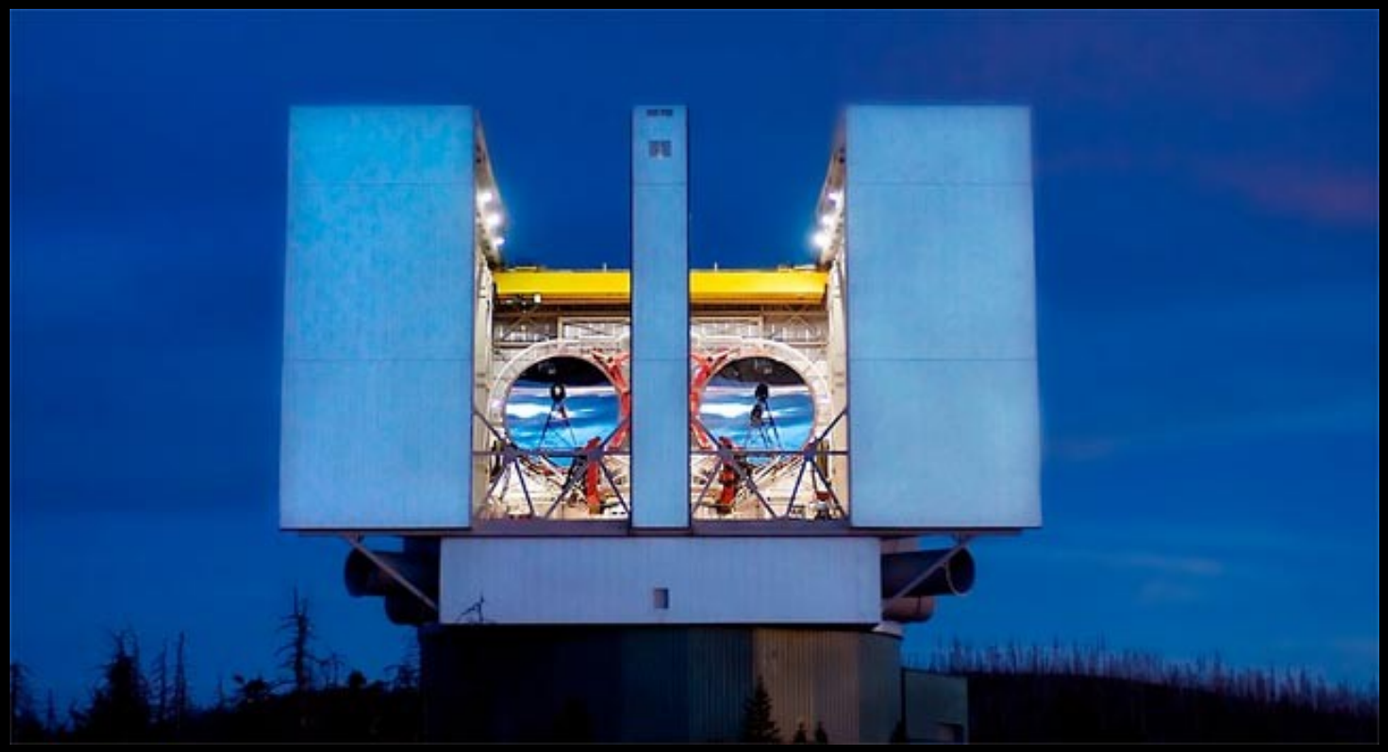
Constraining the contribution of faint AGN to the ionizing background at z~4 with LBT



Andrea Grazian (INAF-OAR)

E. Giallongo, S. Cristiani, F. Fontanot, E. Vanzella, F. Fiore et al.

June 23rd, 2017 LBT2017 User Meeting (Firenze)

The Reionization Epoch

Hydrogen reionization
End of Dark Ages

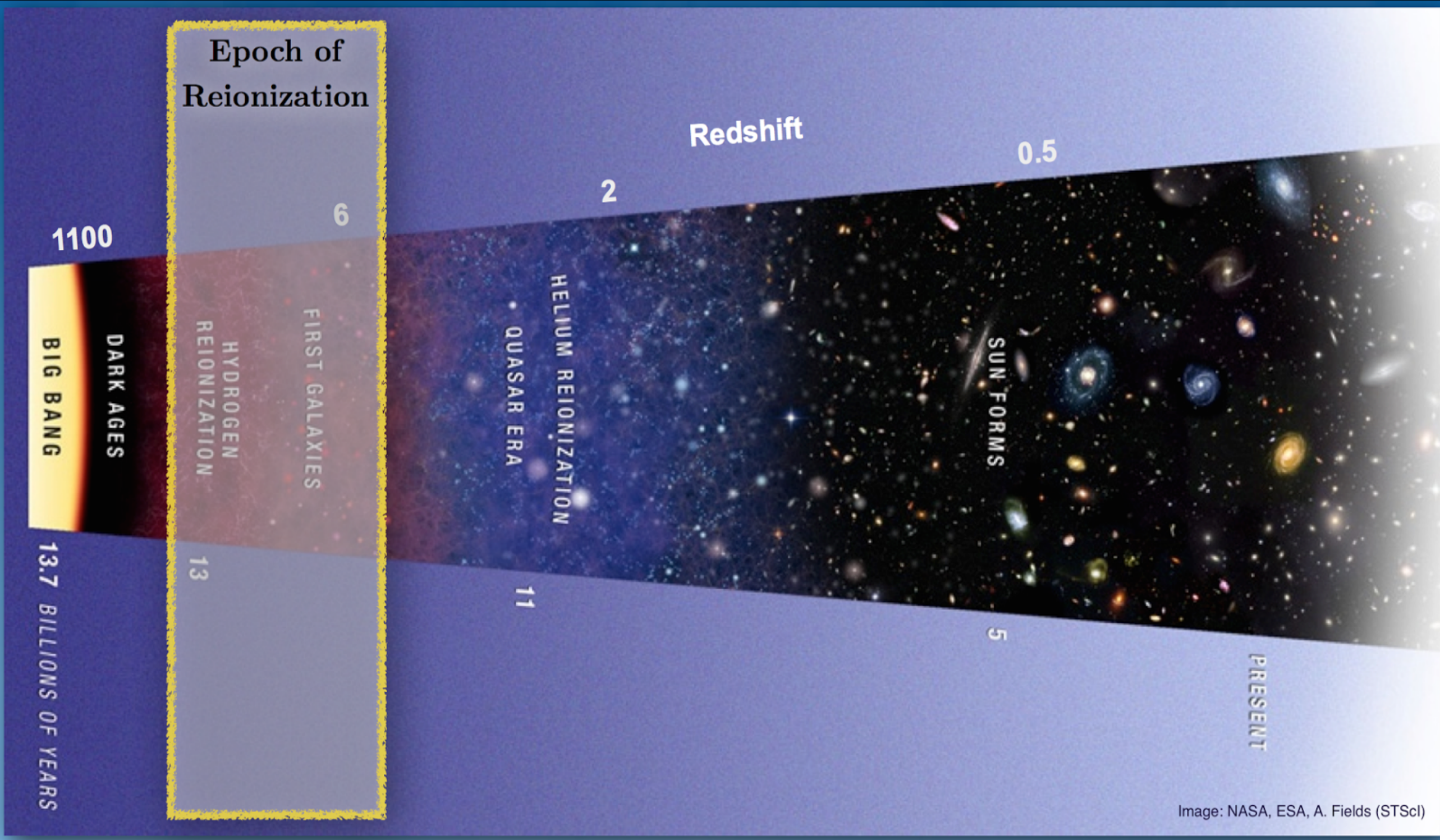
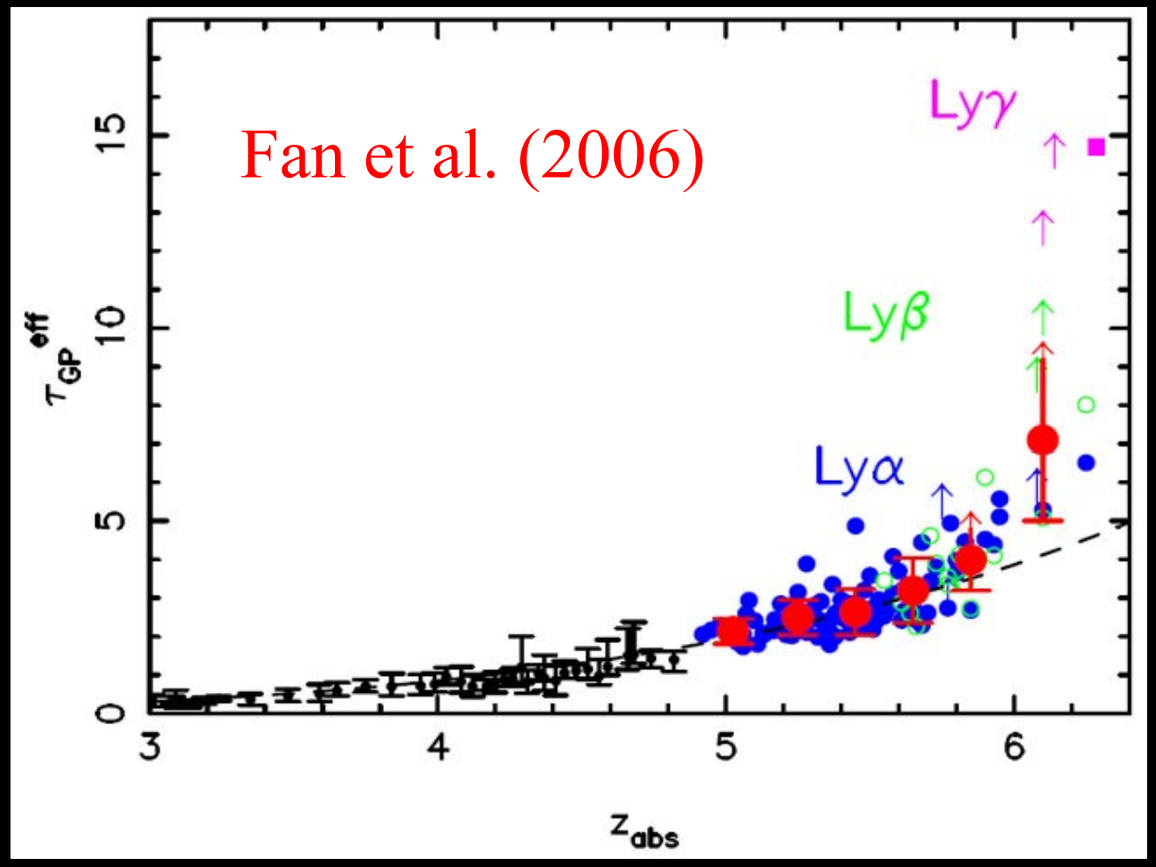
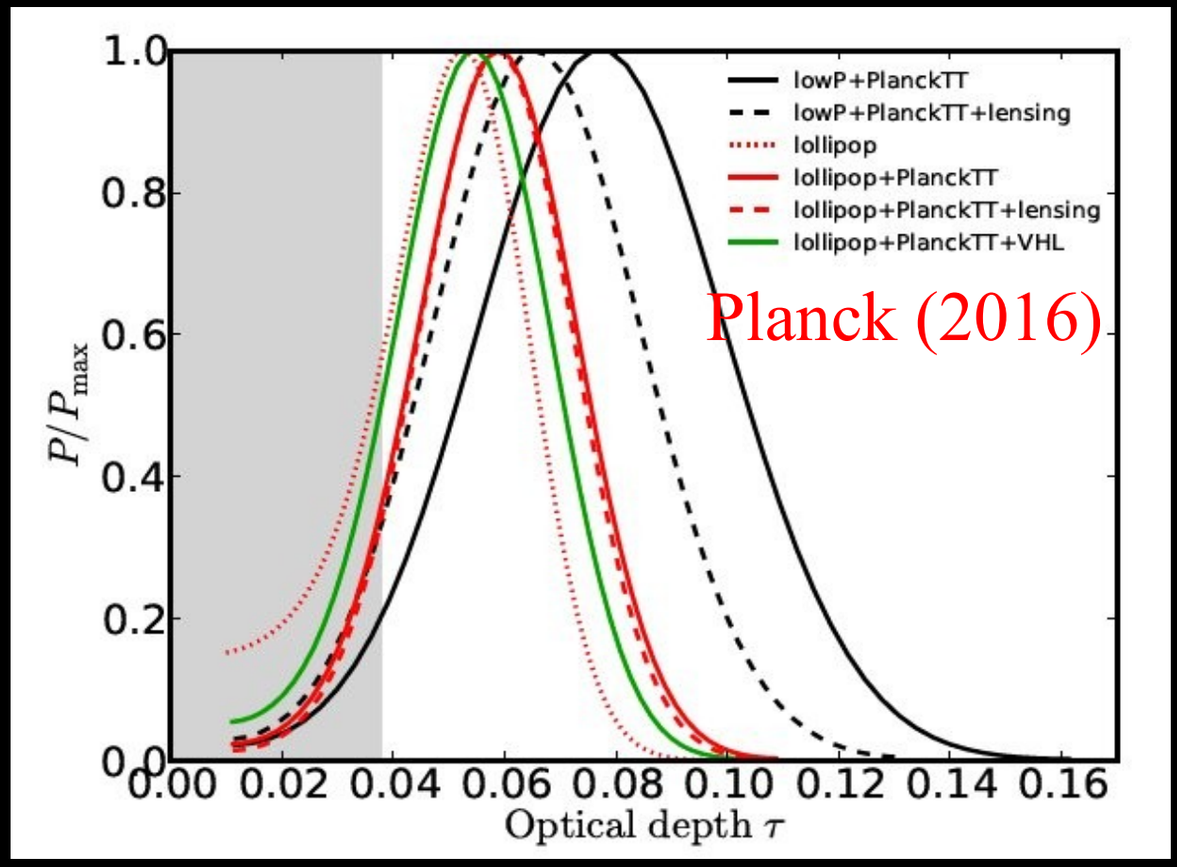
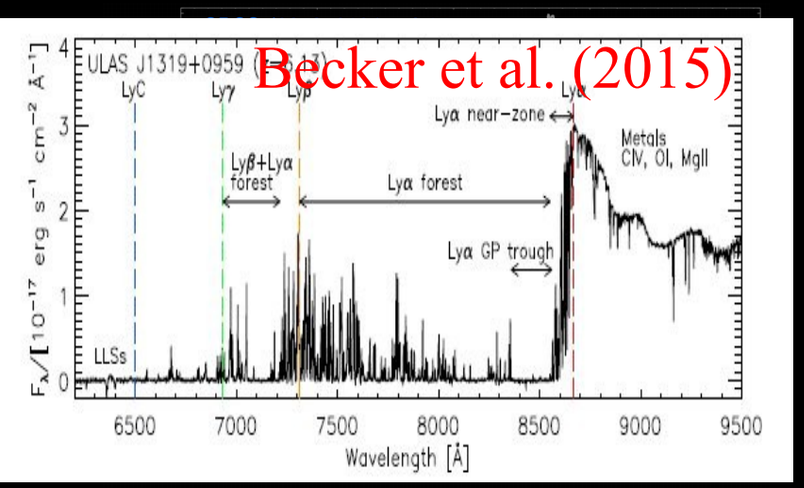


Image: NASA, ESA, A. Fields (STScI)

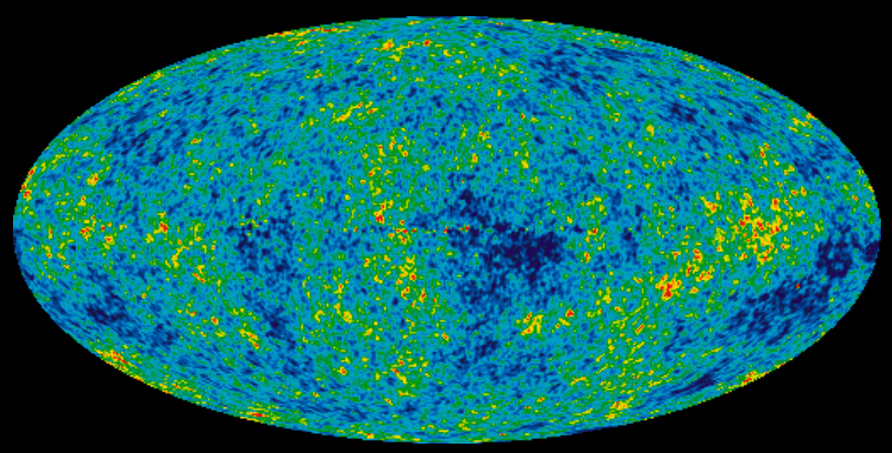
Epoch of Reionization







+



=> 6 < z < 9

- Gunn-Peterson troughs suggest reionization ending at z=6

But 10^-4 HI fraction gives τ(HI) >>1

Planck 2016 result: τ=0.055+/-0.009 z_reion=7.8+/-1.0

- Implies reionization at z<~9. Rapid process
- With SPT kSZ: Delta_z<2.8

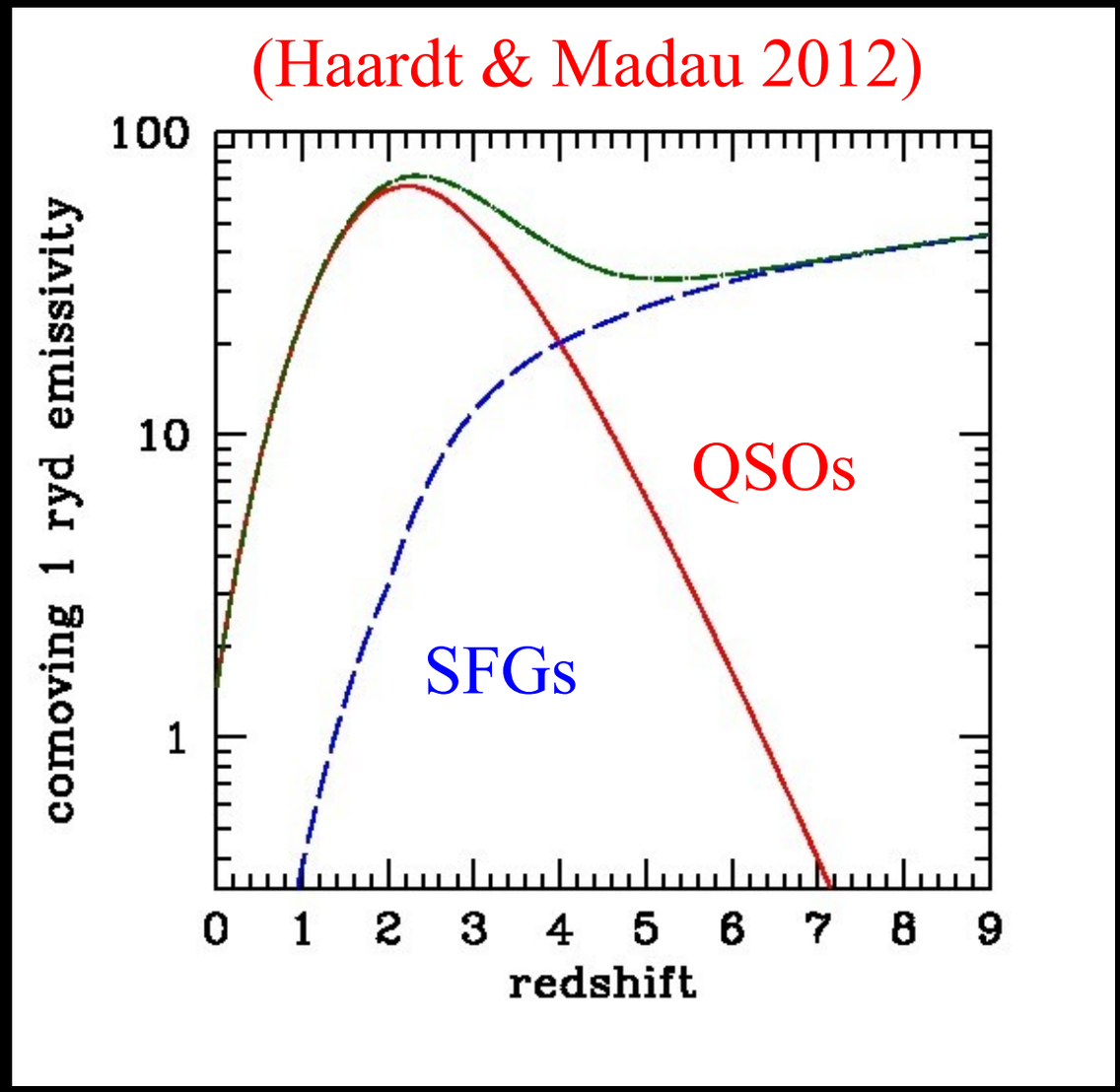
Sources of Reionization

Reionization: driven by Galaxies or AGNs ?

At high-z bright QSOs are rare. Low ionizing emissivity by QSOs at z>3 (Cowie et al. 2009).

Faint Galaxies can be Important at z>3. Steep Luminosity Functions.

Simulations indicate large contribution of faint galaxies (Muv=-10) to the ionizing background.



Production of ionizing radiation

$$\dot{N}_{ion}(z) = \rho_{UV}(z)\,\xi_{ion}\,f_{esc}$$

Density of Ionizing photons

$$\rho_{UV} = \int_{L_{min}}^{L_{max}} \phi(L) L dL$$

UV Luminosity Density at 1500A rest frame

ξ_{ion} LyC photons per unit UV Luminosity at 1500A

f_{esc} Escape fraction of LyC photons

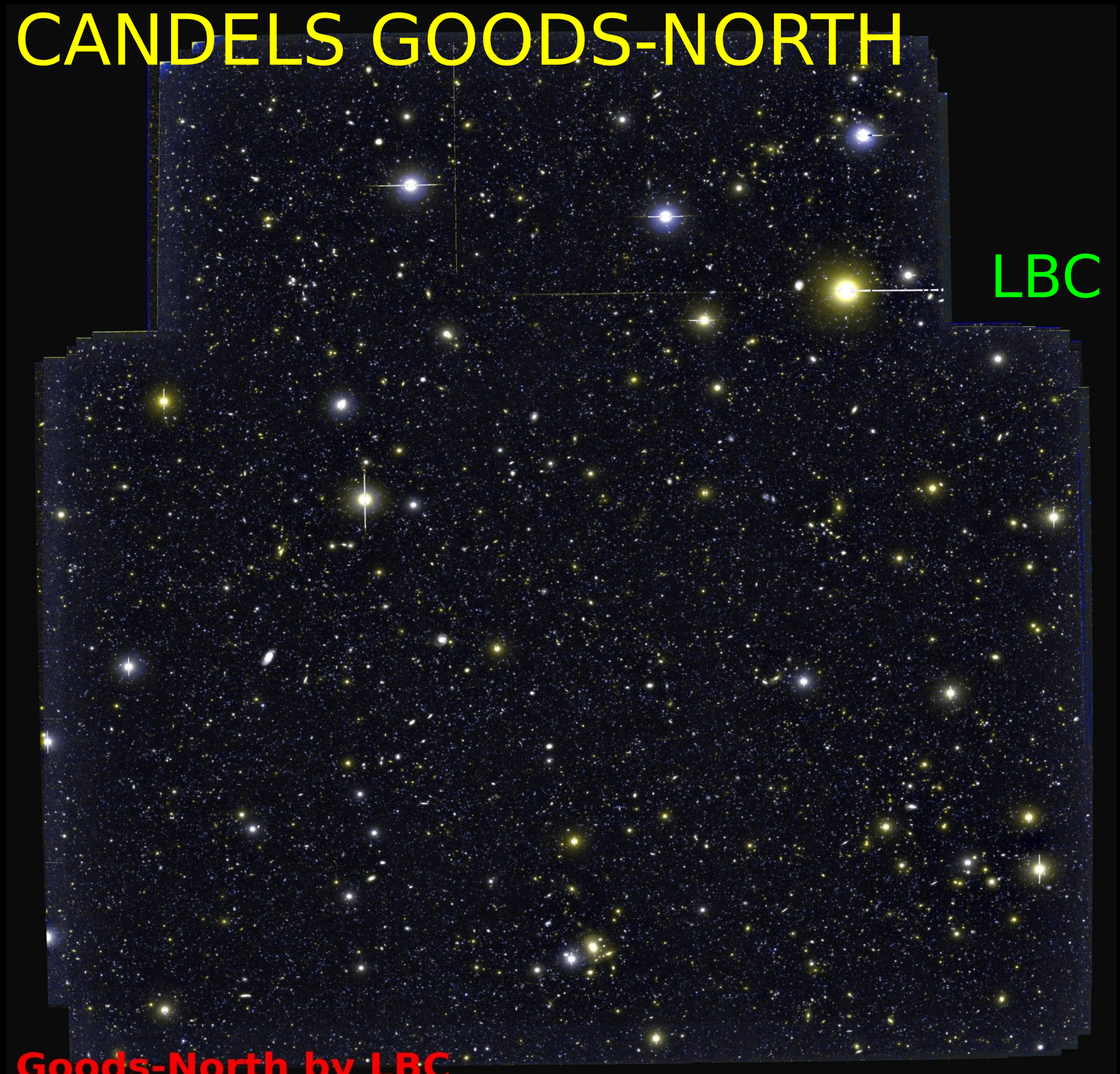
Escape fraction is the most uncertain parameter

CANDELS GOODS-NORTH

33 hours in the U-band
Seeing=1.1”

26 hours in the R-band
Seeing=1.0”

Data reduced by LSC (INAF-OARoma) see talk by D. Paris

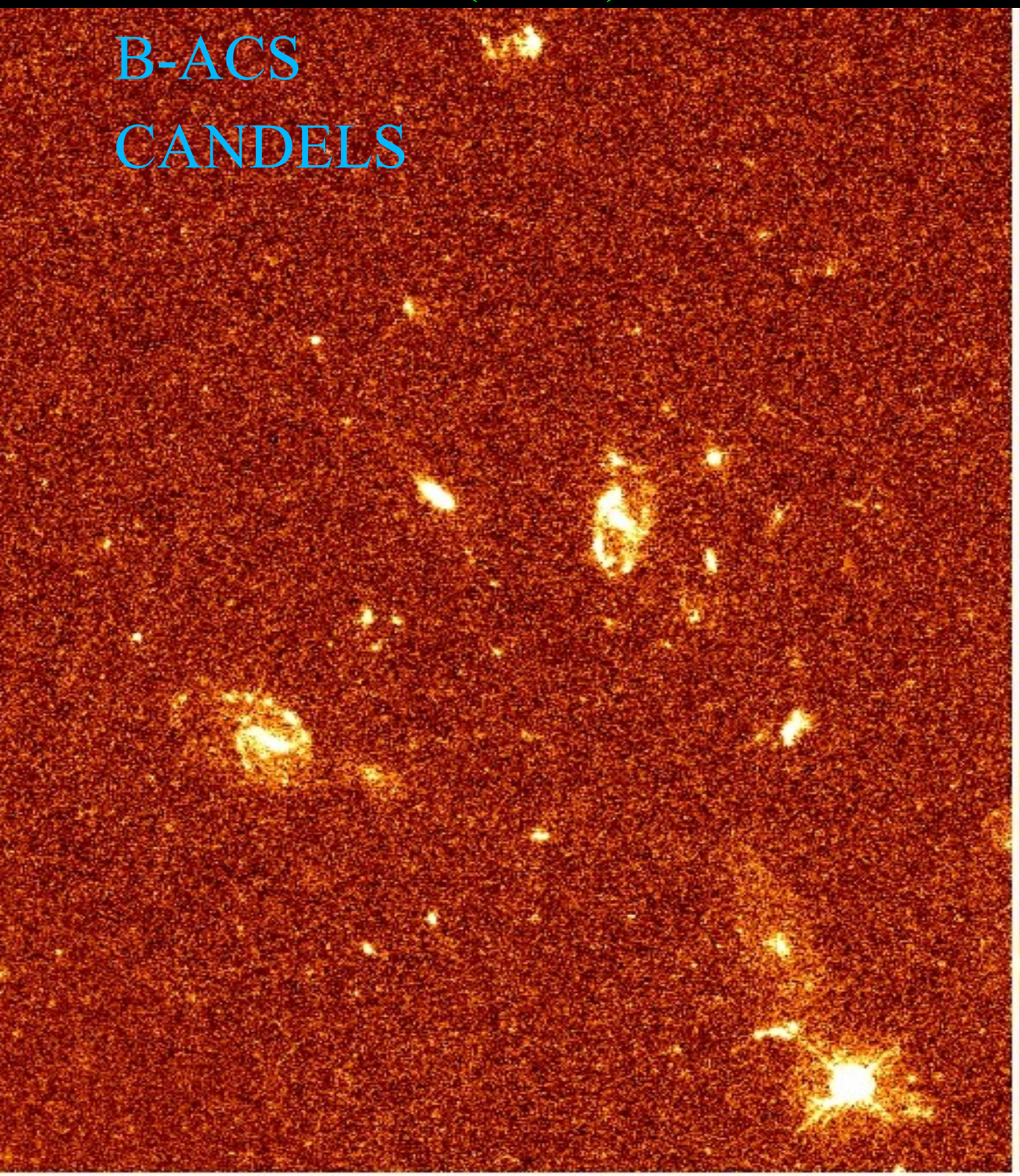


One of the Deepest U-band images of the World…

(see talk by T. Ashcraft)

Giavalisco et al. (2004)

U=30.2 AB mag (1 sigma)



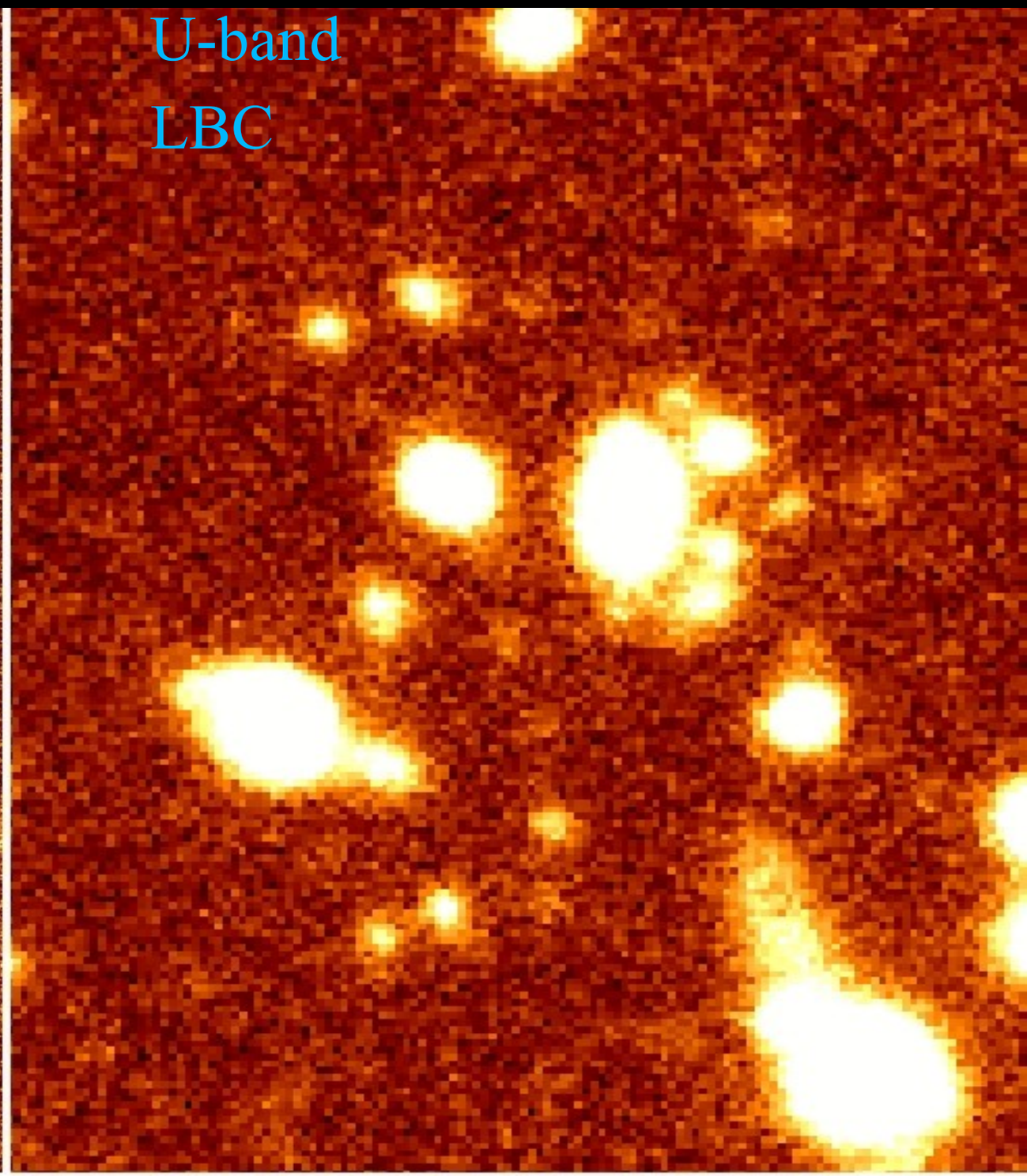


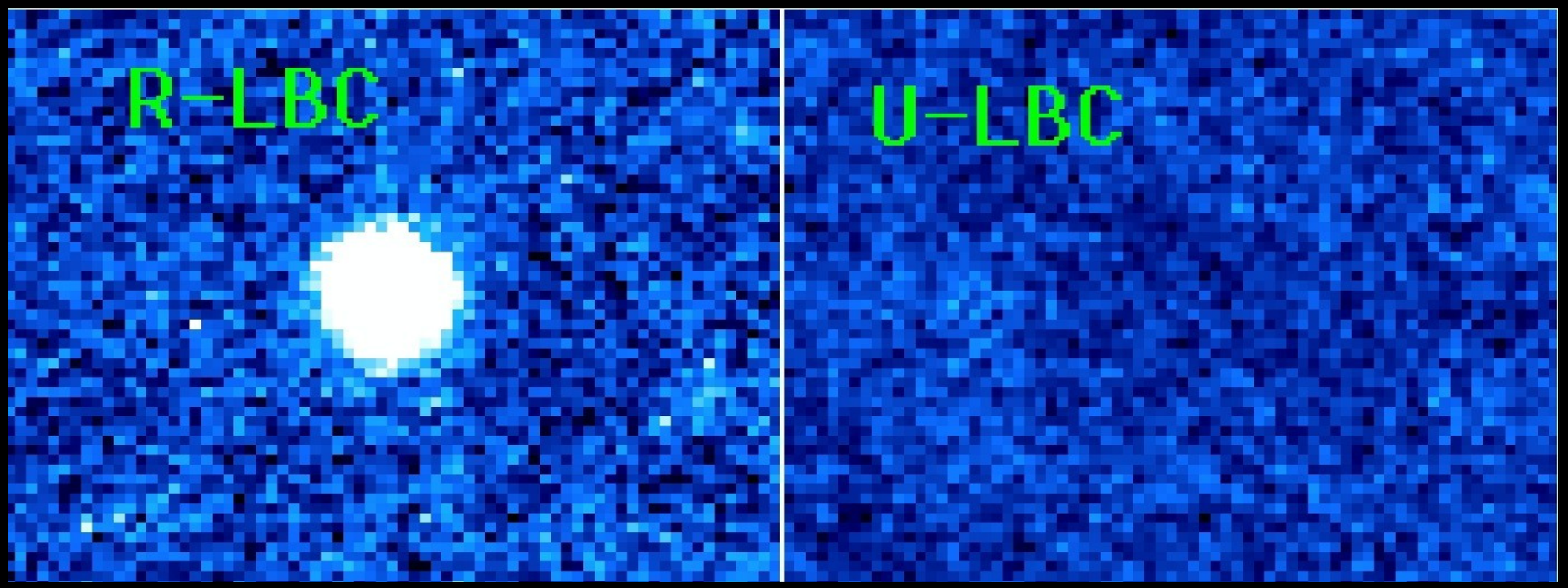
Image stacking in U and R

R band LBC

1500A rest frame at z~3

900A rest frame at z~3

U band LBC



69 galaxies at z~3 in COSMOS+GOODS-NORTH+EGS

No detection at U=31.74(AB) at S/N=1

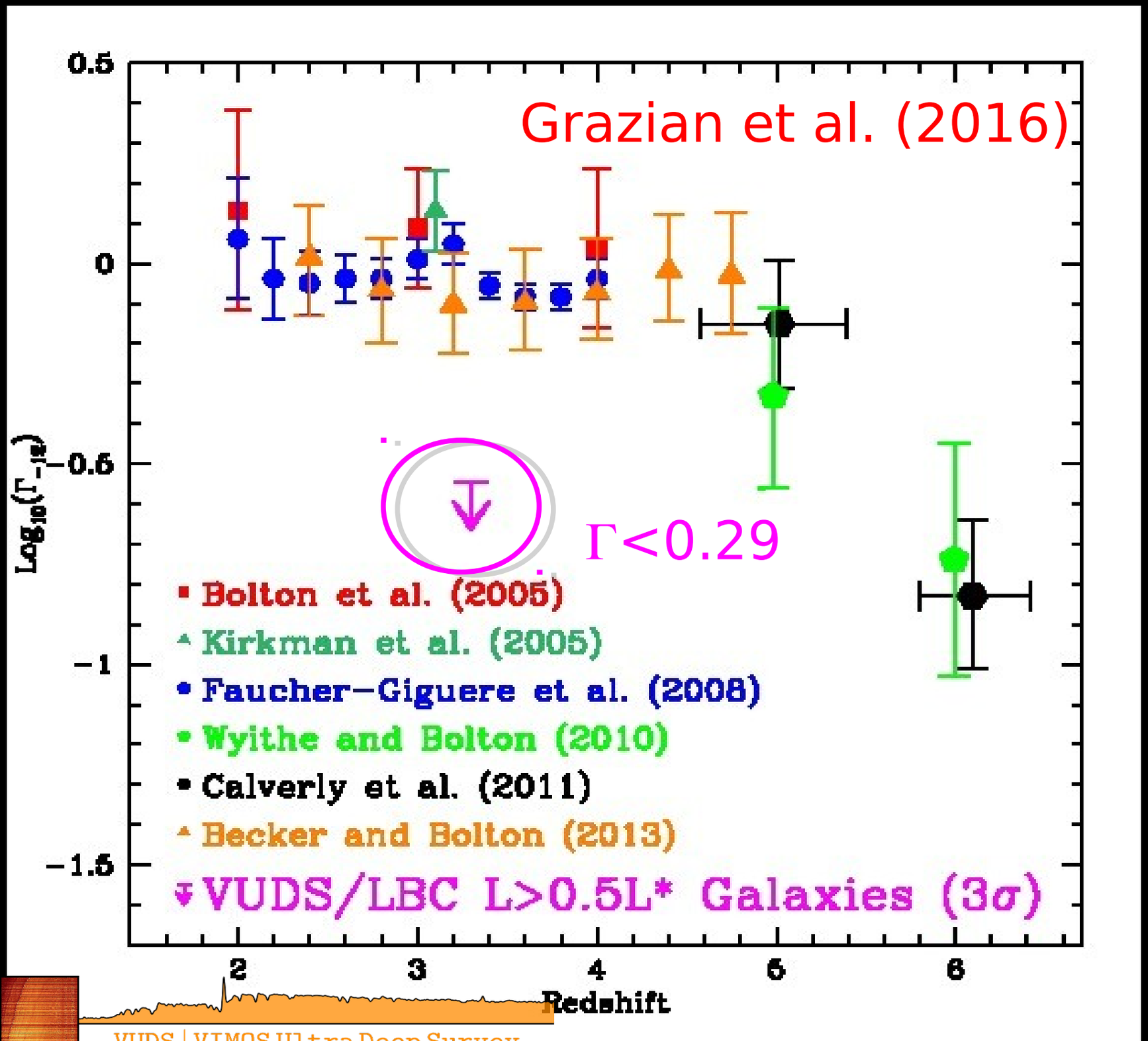
f1500/f900obs>640.2

fesc_rel<1.7% (1 sigma) at z=3.3 for R<26.5

Consistent with Vanzella et al. (2010), Guaita et al. (2016), Smith et al. (2016), Japelj et al. (2017) and Marchi et al. (2017).

Grazian et al. (2017)

HI Photoionization rate
UVB by bright galaxies (L>0.5L*)



Alternative solutions to study Reionization

Bright galaxies have small LyC fesc.

Bright QSOs are very rare.

What about Faint AGNs ?....

Giallongo et al. (2012, 2015)

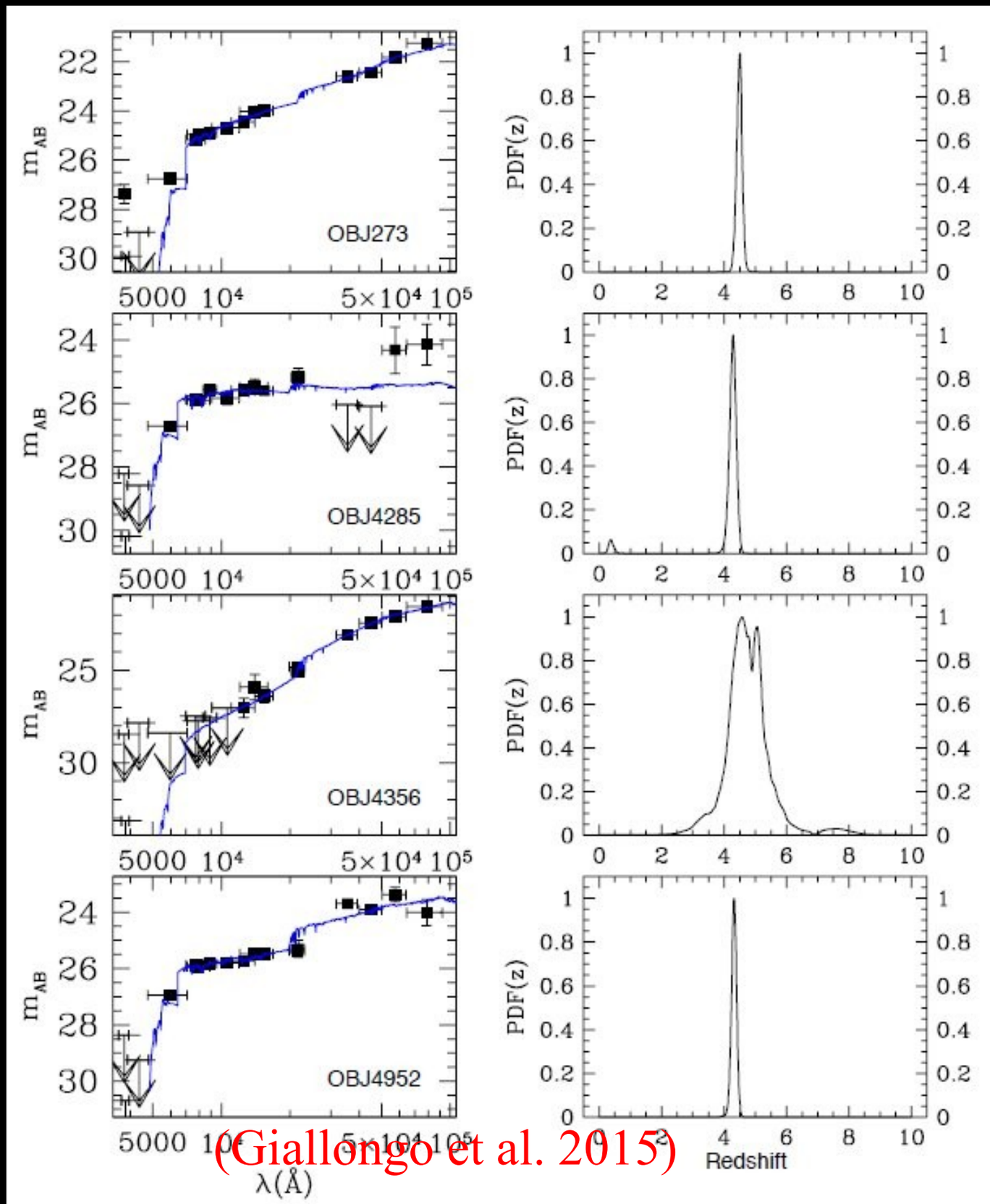
Searching for faint AGNs in GOODS-South

Parent sample:
CANDELS HAB<27.0
galaxies
with z>4 in GOODS-South

Photometric z from
galaxy SEDs fitting (Dahlen
et al. 2013; Guo et al. 2013)

redshift constrained by
UV-rest dropout due to IGM
absorption

22 Galaxies with X-ray
detection in 4 Msec CXO
Giallongo et al. (2015)



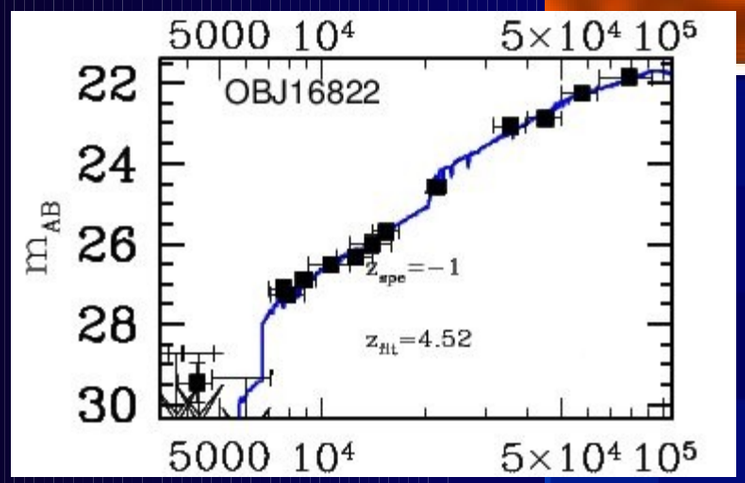
(Giallongo et al. 2015)

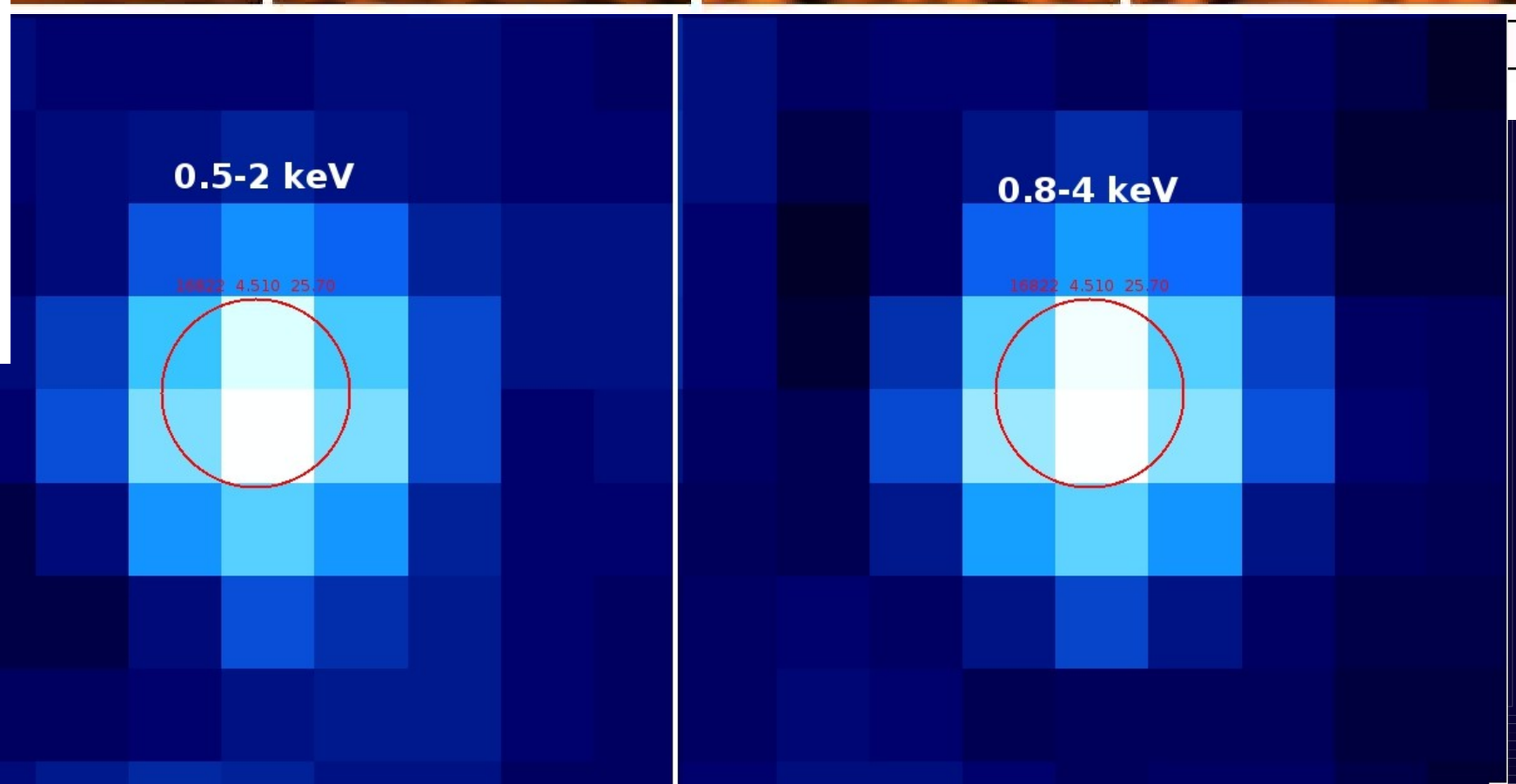
Candels 16822 z=4.5

U,B435,V606,I775

850,Y1.05,J1.25,H1.6

Irac 3.6,4.5,5.8,8





z>4 AGN Luminosity Function

LF corrected for H band counts incompleteness and X/Opt incompleteness

Adding SDSS QSO data points 2 power law fit

Faint-end slope 1.5-1.8

Bright-end slope 3.1-3.3

Break unconstrained M*=-23.2/-23.6

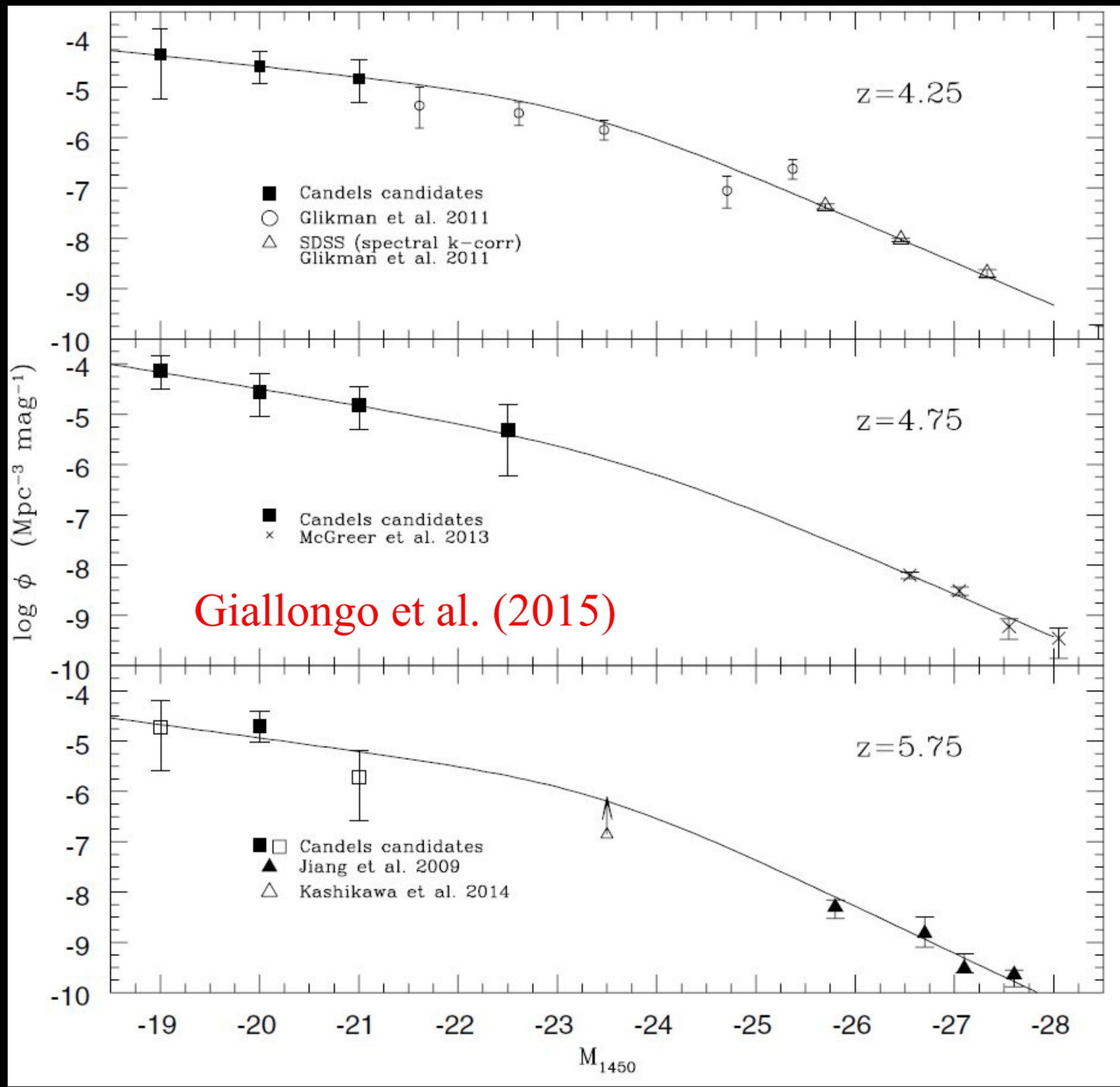
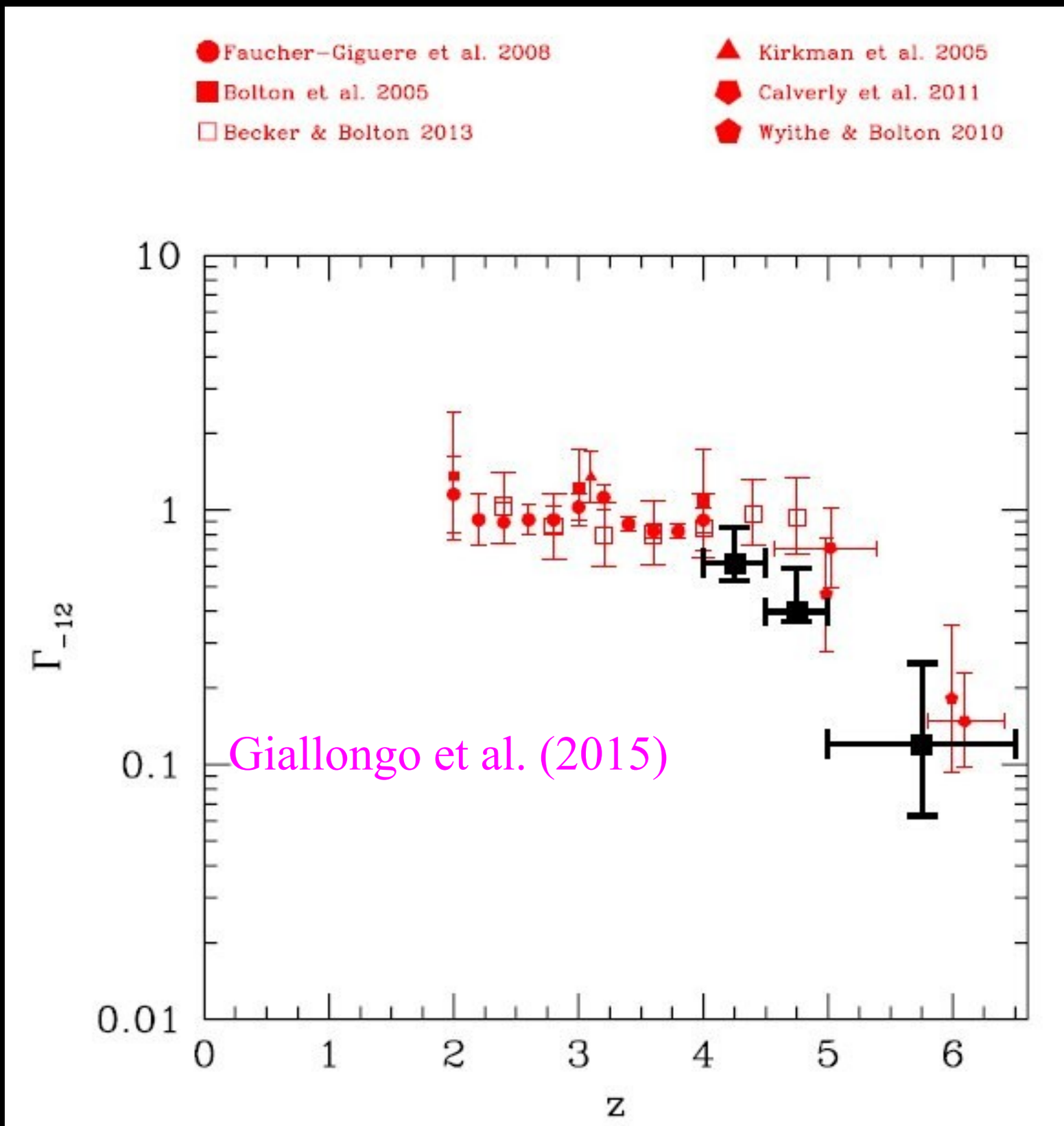


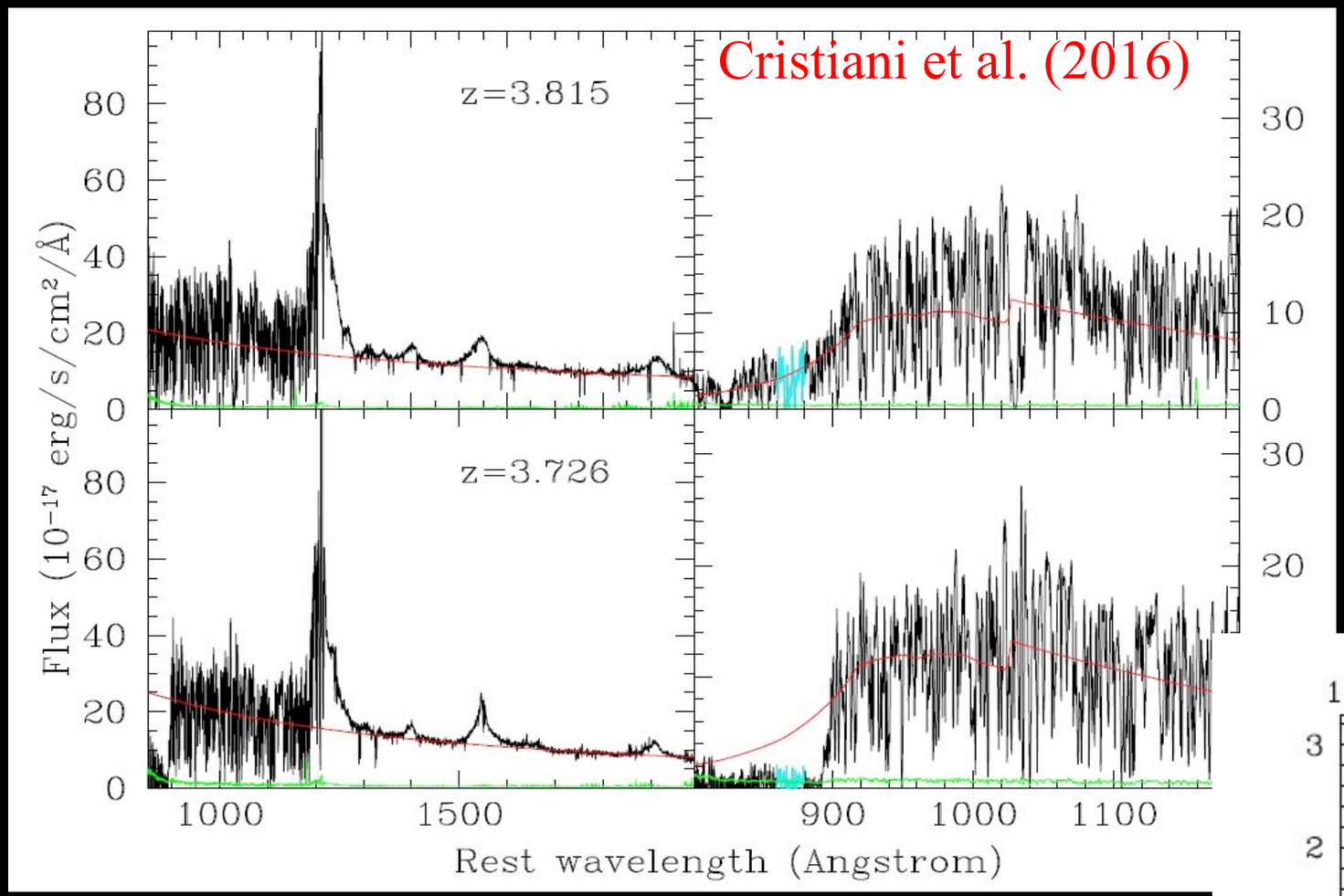
Photo-ionization rate

A decline by a factor ~10 from z~4 to z~6 due to decrease of both emissivity and mean free path

Still consistent with the degree of ionization of IGM

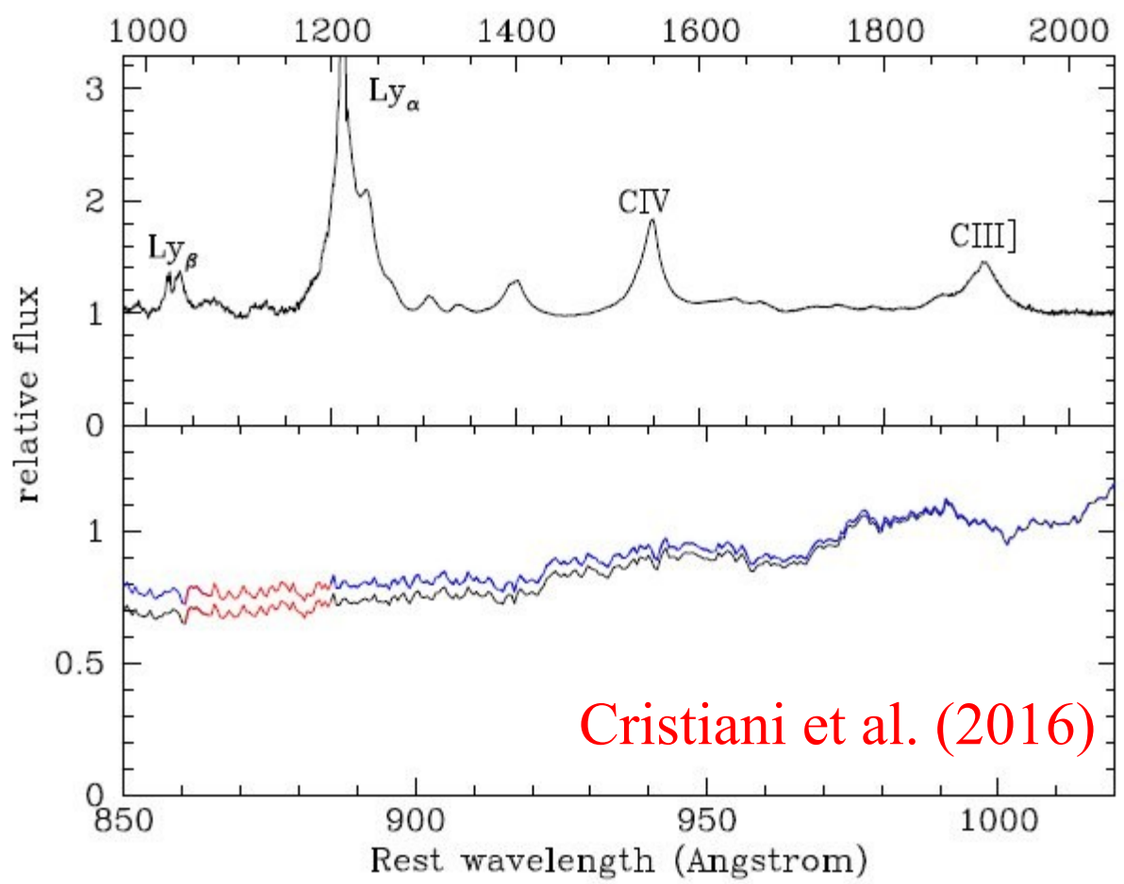


The LyC Escape Fraction of bright QSOs

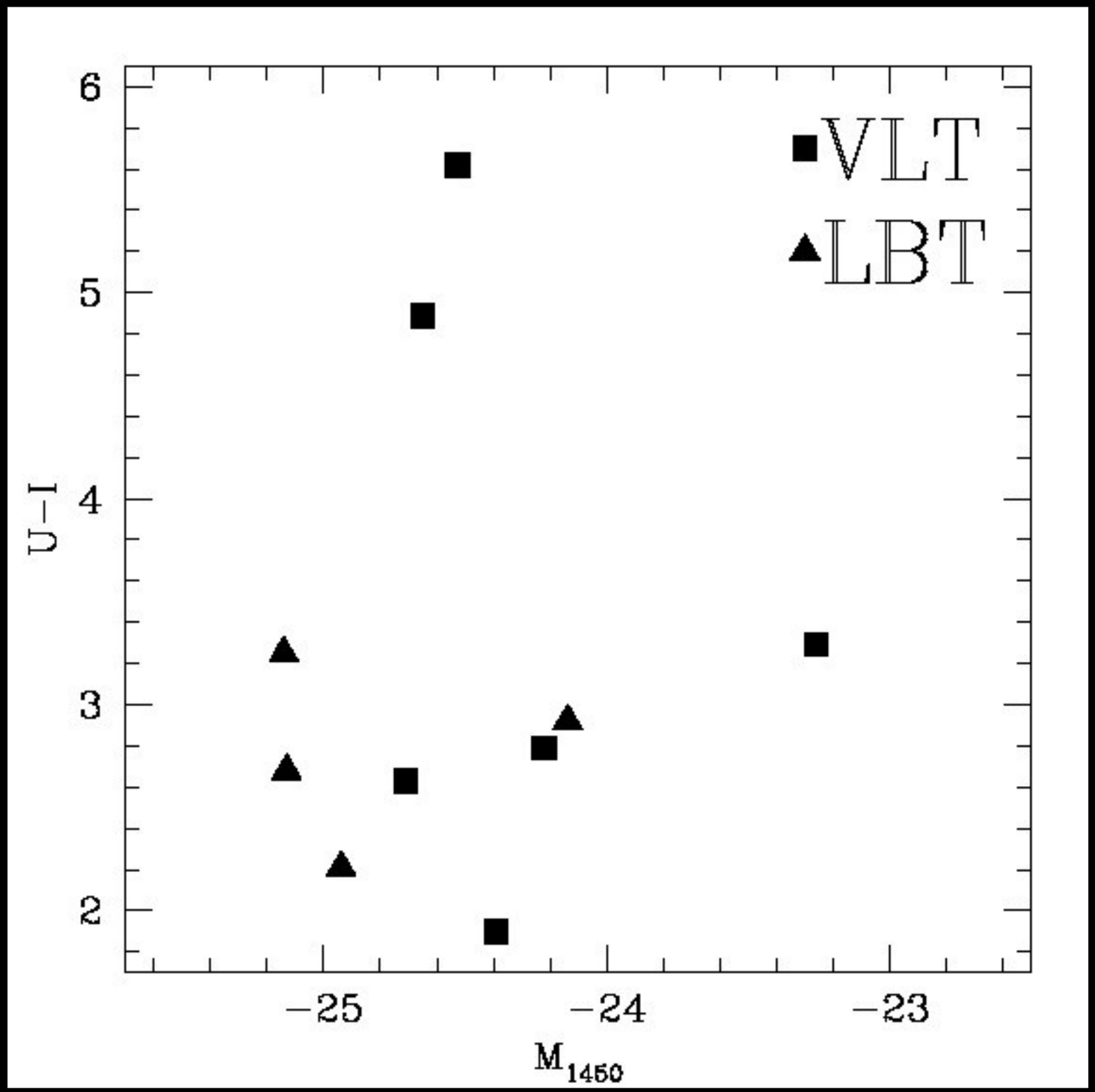


M1450=-26 QSOs (L~5L*) have fesc~75% (or more).

What about fainter AGNs ?



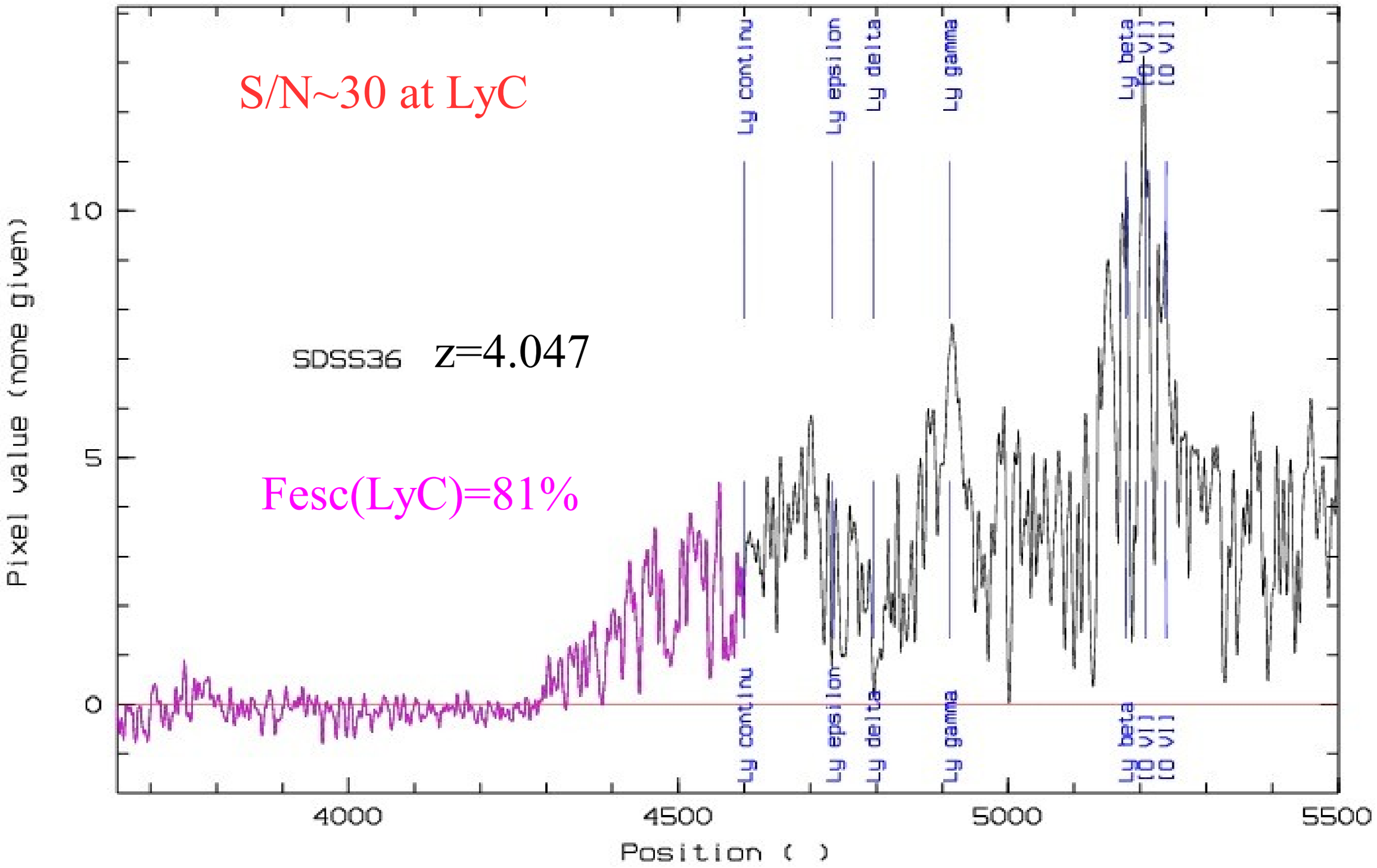
The LyC Escape Fraction of faint AGN



22 hours of MODS at LBT and two nights in visitor mode with FORS2 at VLT and have been devoted to measure the LyC fesc of 10 faint AGNs at $3.6<z<4.2$ with $I>21.0$ ($L>0.5L^*$).

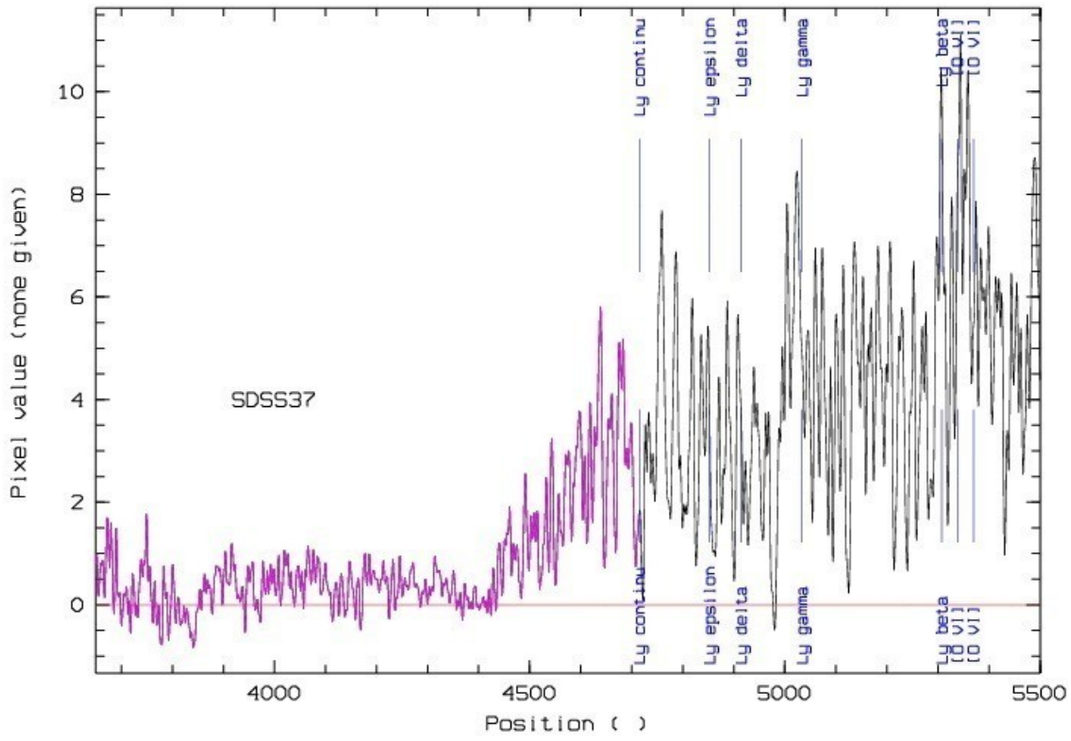
LBT MODS1-2 Spectra

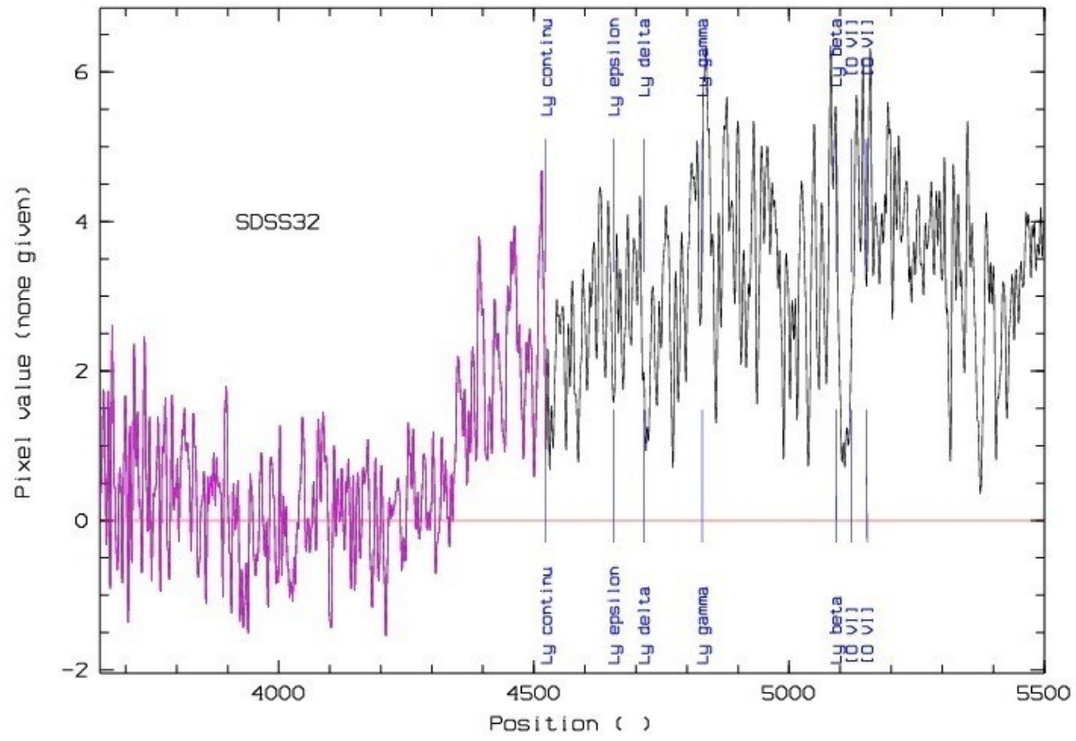
Data reduced by Spectroscopic center in Milano (see talk by A. Marchetti)

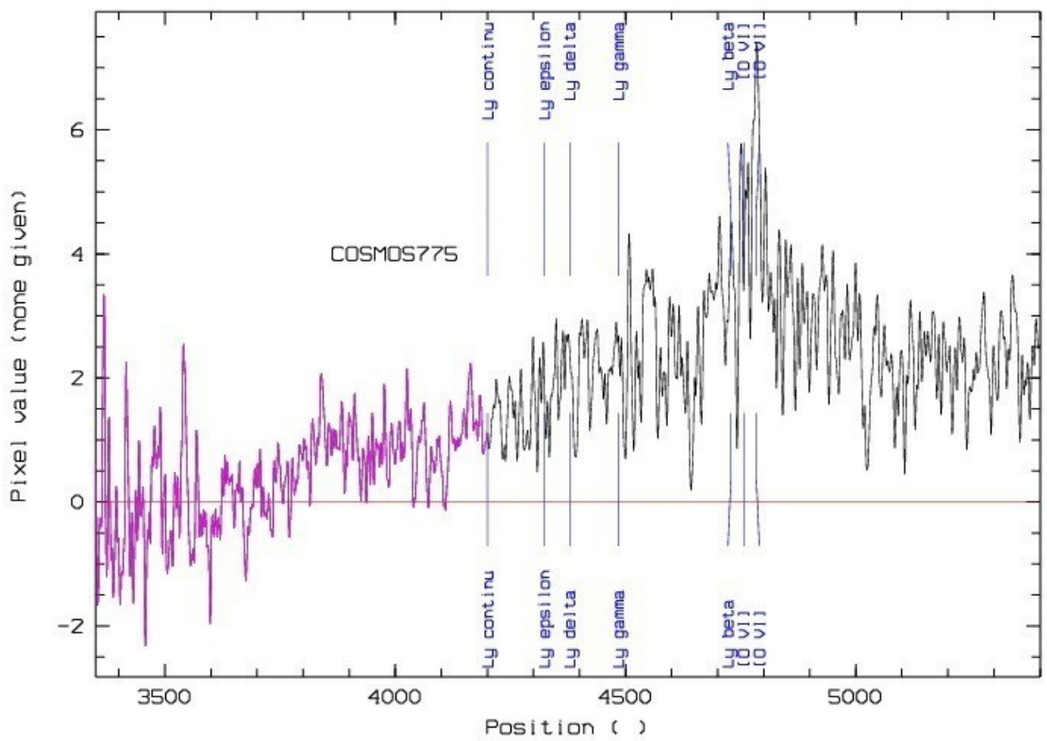


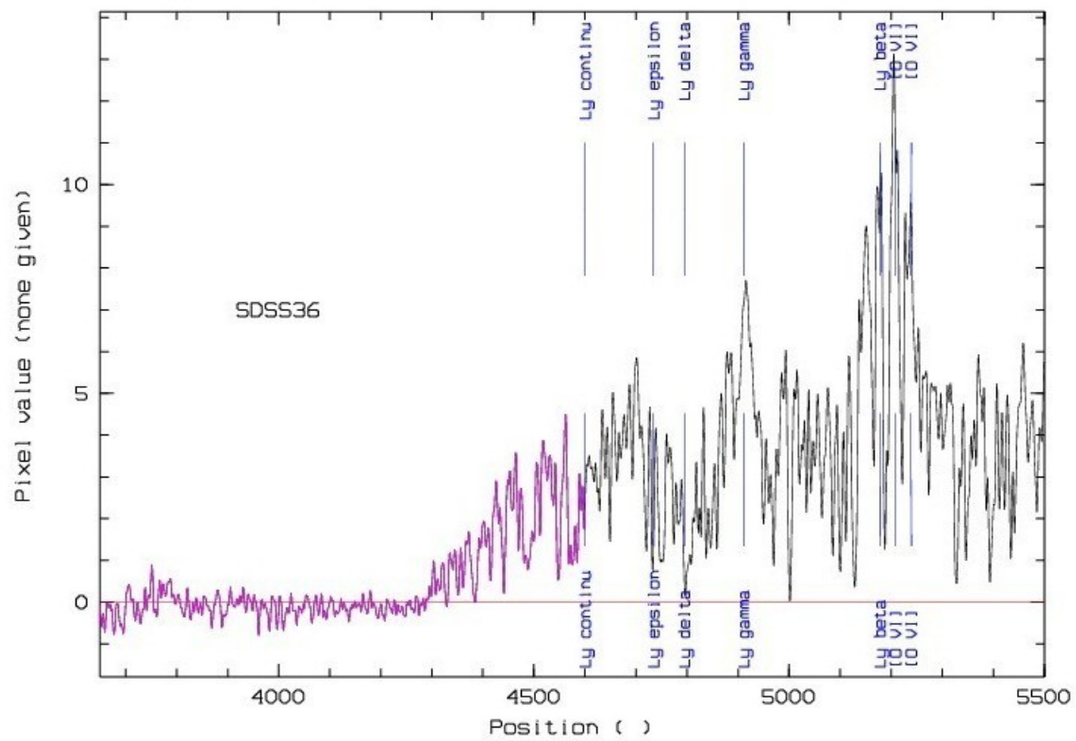
LBT MODS1-2 Spectra

LyC escape fraction >50% detected in all the observed AGNs

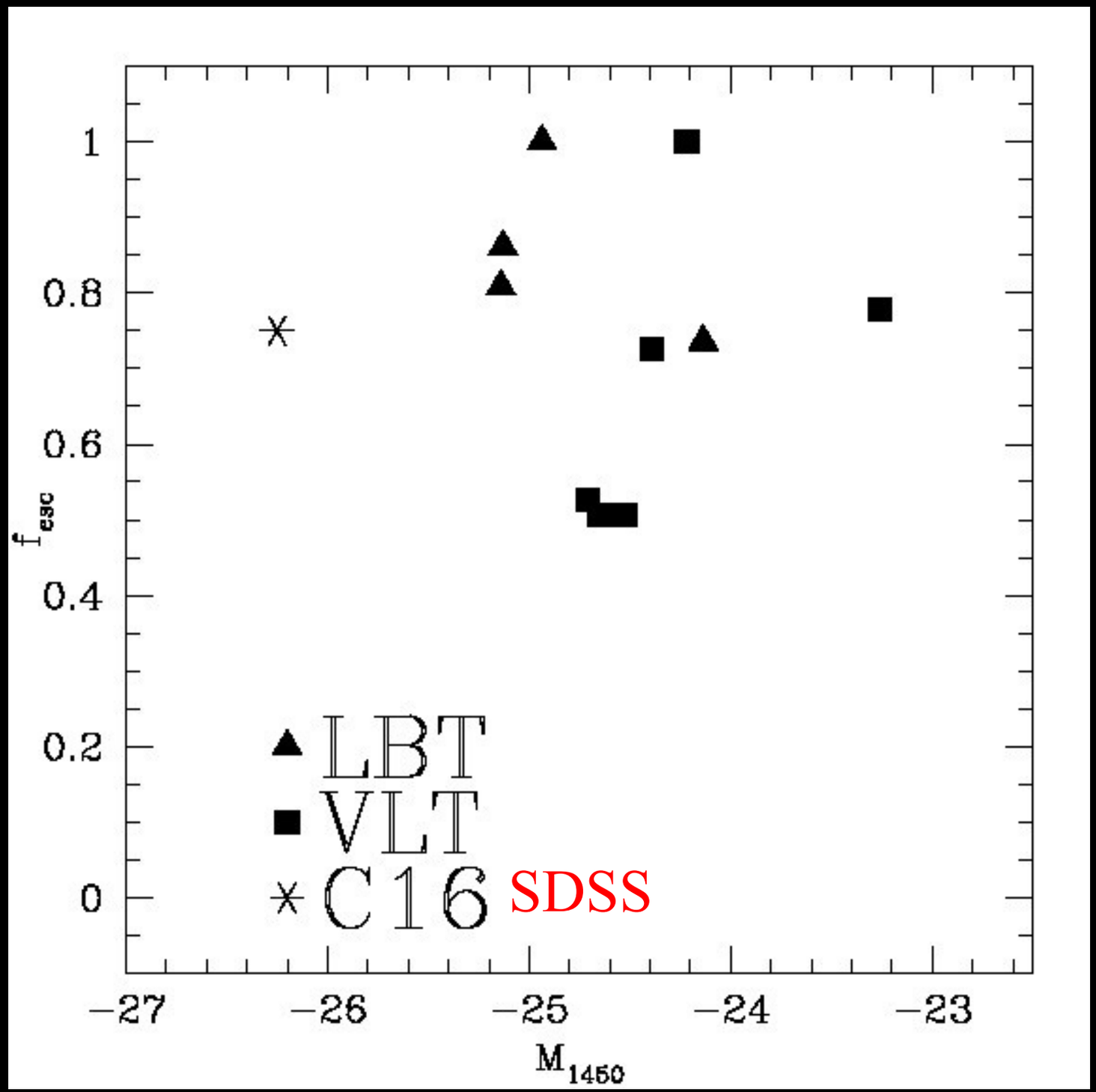








The LyC Escape Fraction of faint AGN

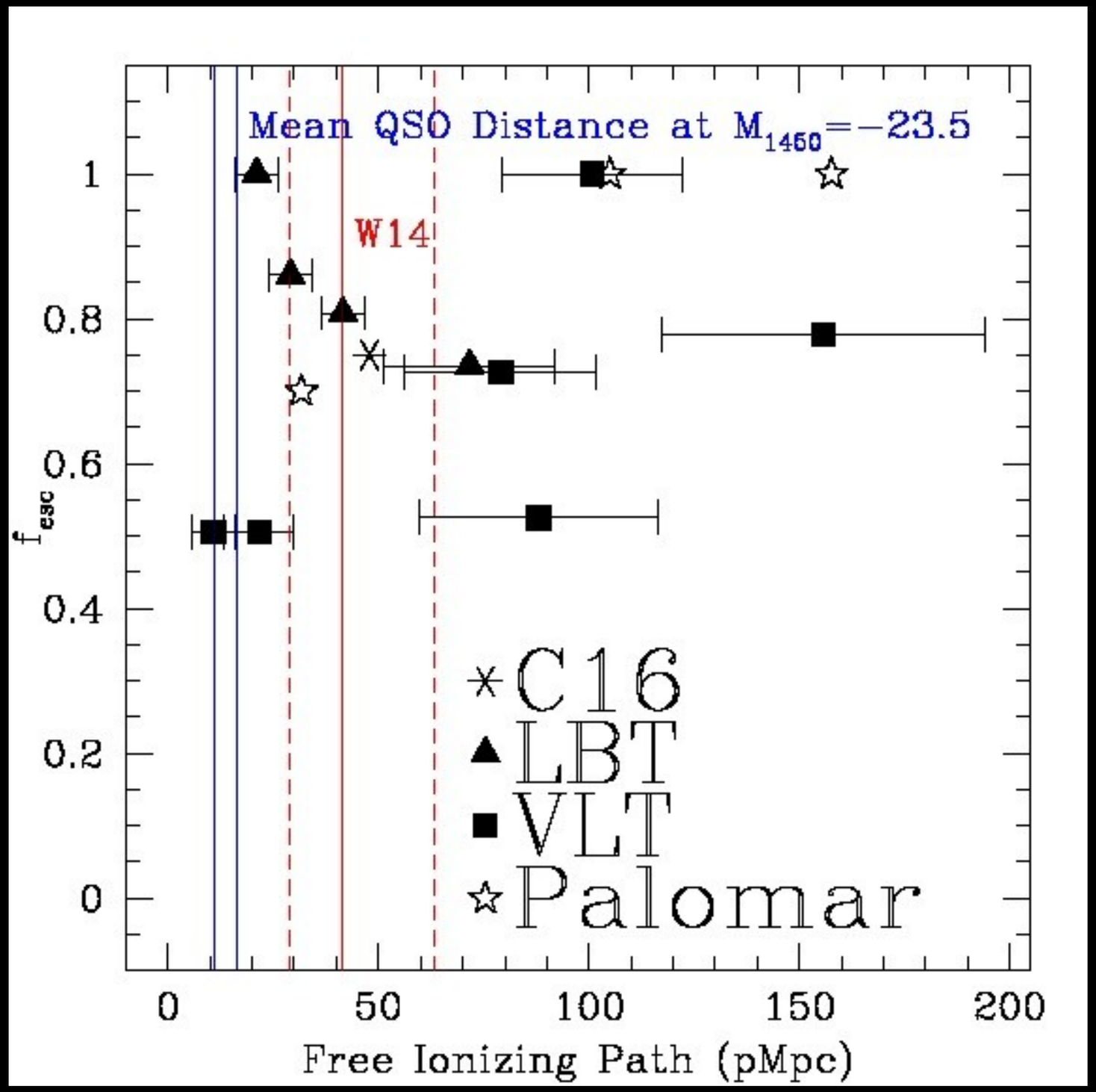


Mean fesc~75%

No trend with luminosity

Consistent with the results of Cristiani et al. (2016) for 10x brighter QSOs (SDSS)

The LyC Escape Fraction of faint AGN



Mean free paths of faint AGNs are consistent with that of brighter QSOs (Worseck et al. 2014)

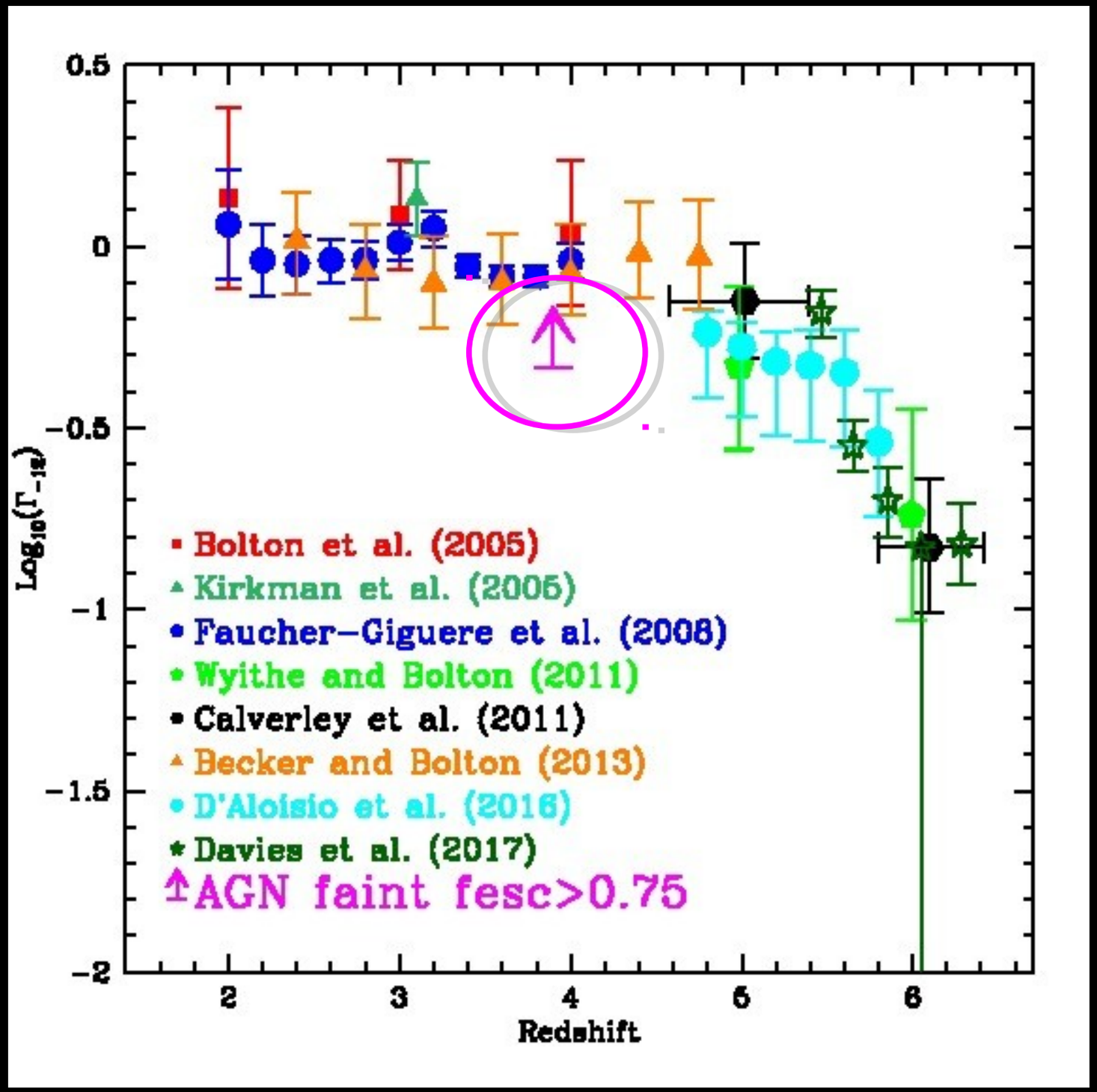
No trend of fesc with MFP/FIP

Mean Free Path of faint AGNs are larger than mean distance at M1450=-23.5

MEAN=51 pMpc

Worsek et al. (2014) MFP=41 pMpc

The contribution of faint AGN to the Photoionization rate



AGNs at z~4 can produce >65-85% of the UVB, assuming the G15 Luminosity Function and fesc=75% down to M1450=-18 (0.01L*).

In the future it will be crucial to study the LF near L* and measure fesc for AGN fainter than M1450=-22.

Summary

Galaxies:

30 hours of LBC in the U-band have been stacked to obtain one of the deepest U-band images of the World.

Direct constraints to the ionizing escape fraction of z=3.3 star forming galaxies.

At z=3.3 bright galaxies have fesc_rel<1.7%!

Galaxies alone cannot provide the observed UVB at z~3.3 unless their LyC escape fraction increases at low luminosities and LF steep at faint Luminosities.

AGNs:

HST+Chandra deep data in the CANDELS fields seem to indicate that the space density of faint AGNs at z>4 is relatively high.

A pilot project with MODS at LBT seems to indicate that the escape fraction of faint (M1450<-23) AGNs at z>4 is substantial (~75%).

Faint AGNs at z>4 could be the main drivers of the Reionization process.

Thank you!