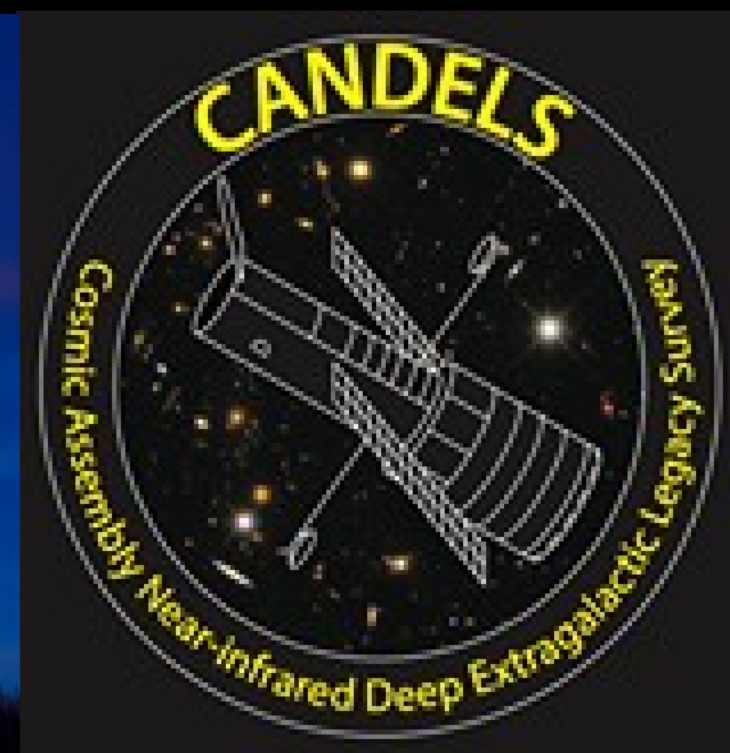
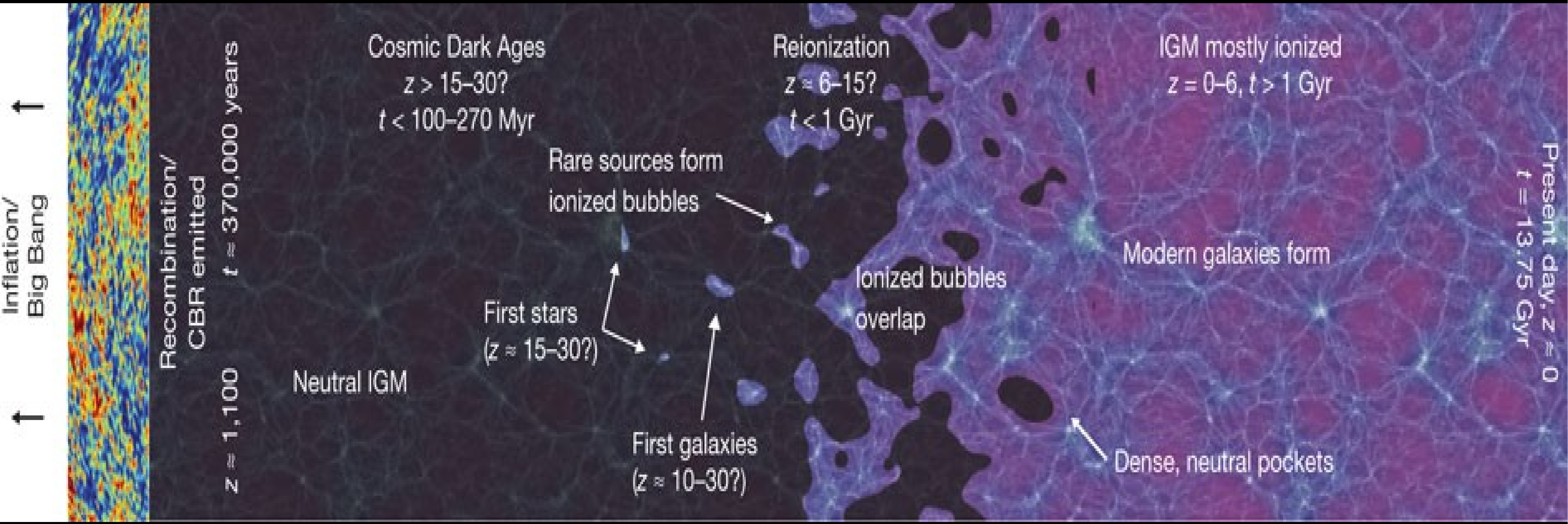
The Lyman Continuum escape fraction of z~3 star forming galaxies with LBC/LBT: the COSMOS and CANDELS galaxy labyrinths



Andrea Grazian (INAF-OAR)

April 27th, 2016 Kolymbari (Crete)
"Escape of Lyman radiation from galactic labyrinths" Conference

Sources of Reionization



Reionization $6<z<10$: Galaxies or AGNs ?

This is an important topic since it is related to the detailed physical mechanisms of the feedback on the ISM.

Estimating fesc: Method

$$f_{\mathrm{esc,rel}} \equiv \frac{(L1500/L900)_{\mathrm{int}}}{(F1500/F900)_{\mathrm{obs}}} \exp\left(\tau_{900}^{\mathrm{IGM}}\right)$$

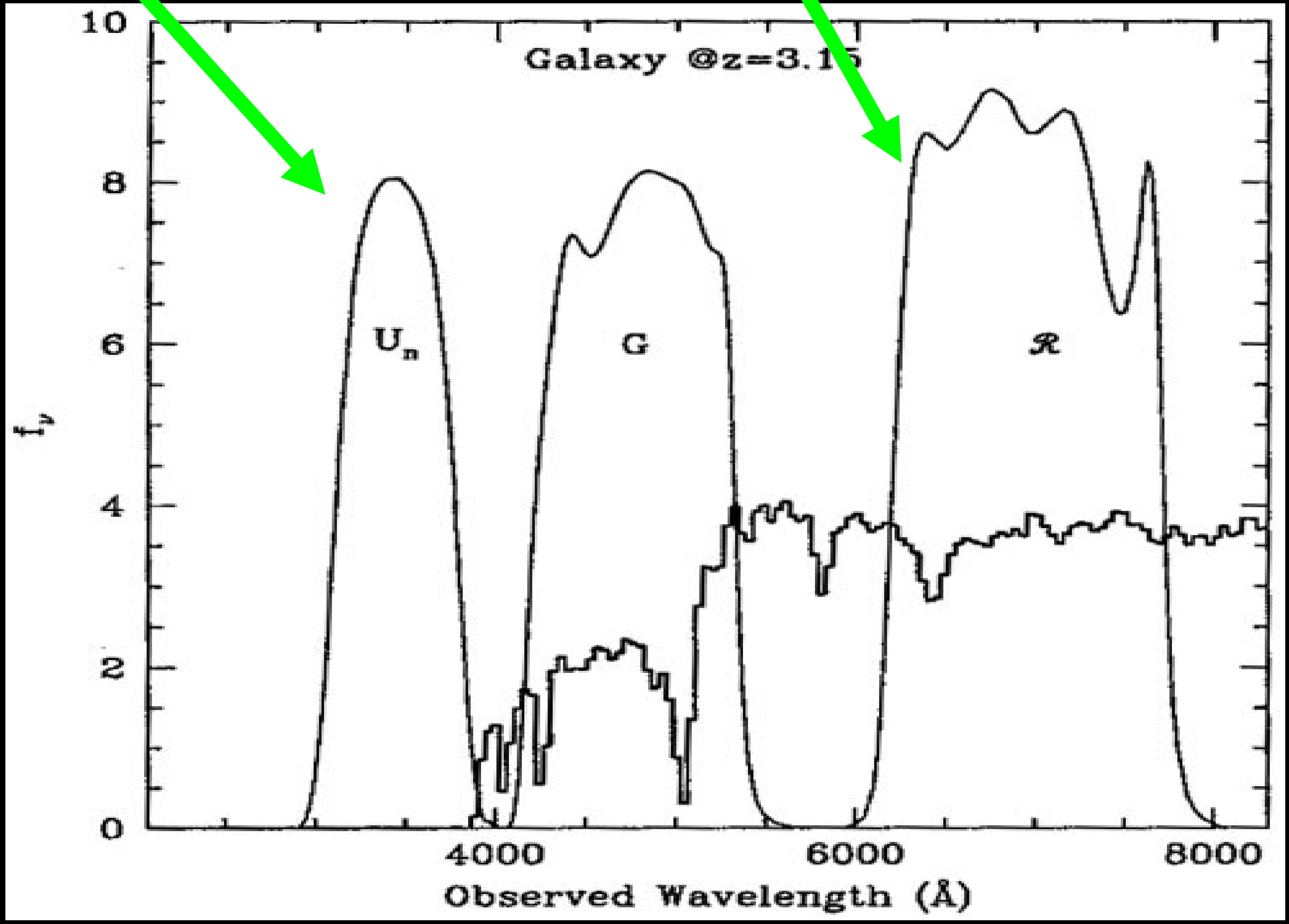
$$f_{\mathrm{esc}} = 10^{-0.4A_{1500}} f_{\mathrm{esc,rel}}$$

(Steidel et al. 2001, Shapley et al. 2006)

Measuring fesc:
commonly adopted strategy is to compare the observed flux at LyC to the observed Flux at a frequency where the intrinsic emissivity can be inferred.

U band=900A at z~3

R band=1500A at z~3



If fesc=10%
U-R=5 mag
Need very deep UV

Fesc=100%
U-R=2.5 mag

Required Ingredients...

To measure fesc of galaxies with deep imaging

1-Deep imaging at 900 A and 1500 A rest frame

2-HST imaging to avoid spurious contamination by foreground sources

3-Spectroscopic redshifts in a narrow range ($3.27<z<3.40$ for LBC U-band)

4-Large numbers of zspec to beat down the IGM stochasticity

5-X-ray data to avoid AGNs

Starting Sample

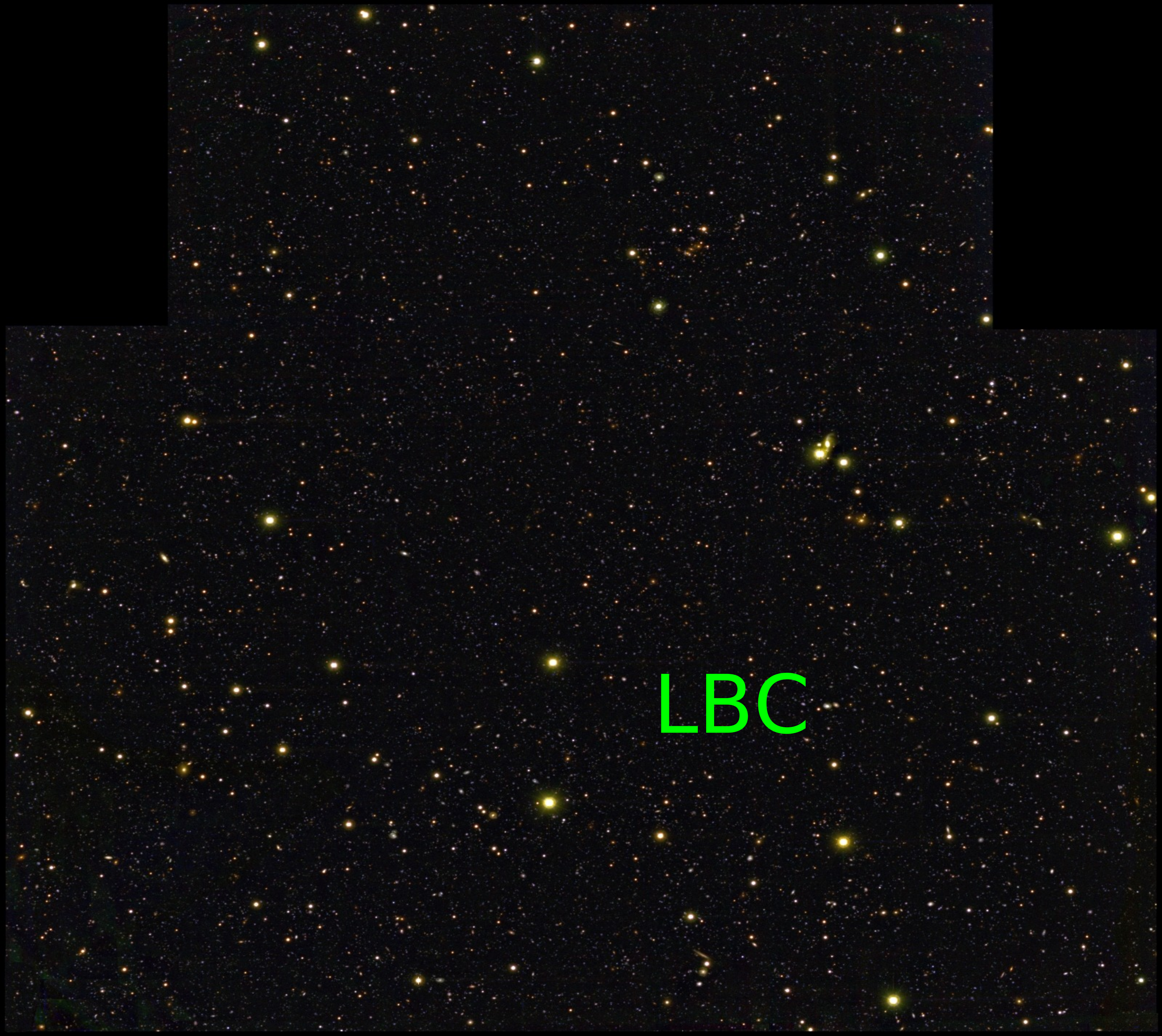
Deep U and R band imaging with LBC at LBT

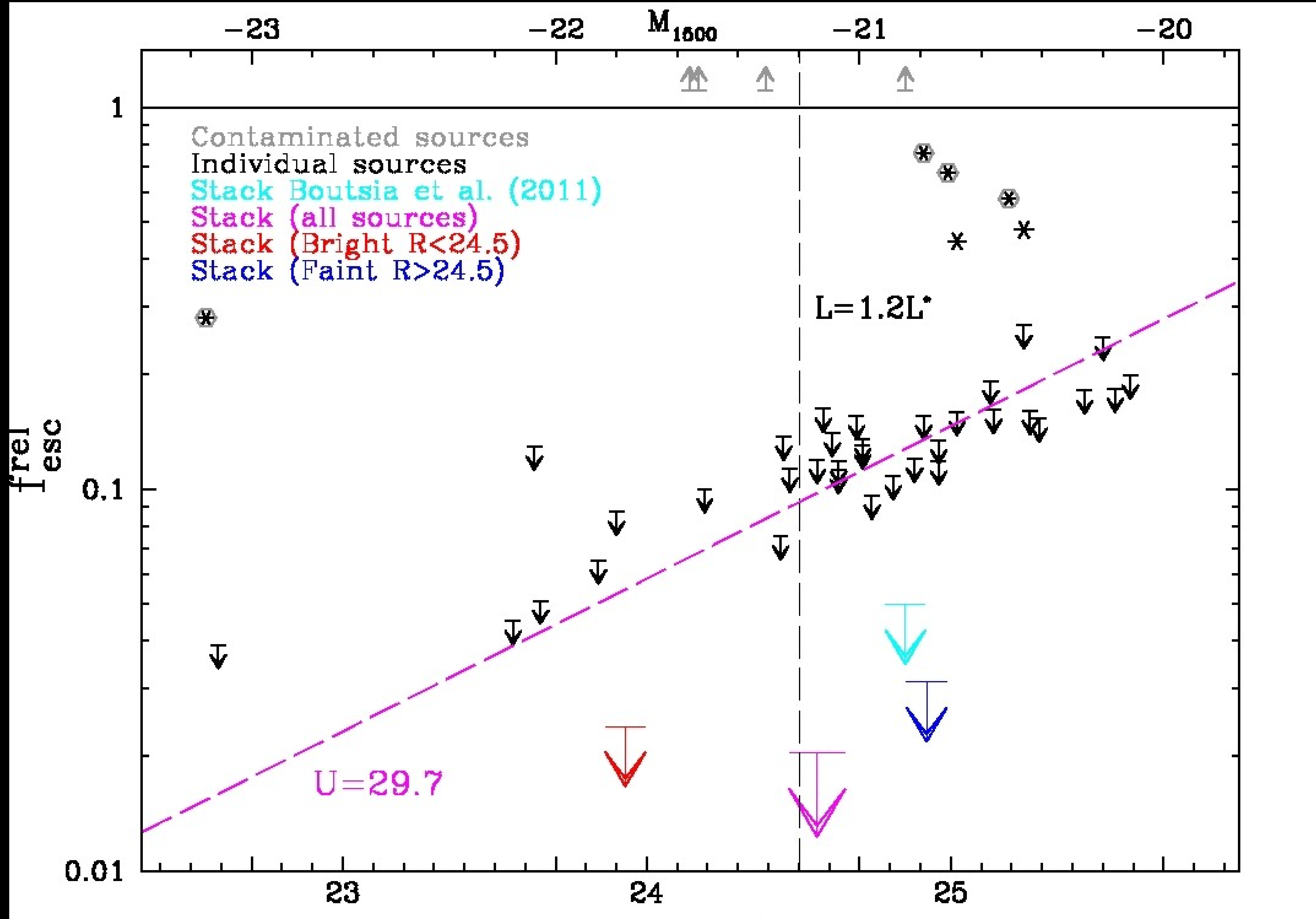
3 LBC fields in UGR
(Q0933, COSMOS, Q1623)
exptimeU=2-8h each
U=29.7(AB) at S/N=1
Area>2400 sq. arcmin.
Boutsia et al. (2014)

Lots of zspec available

Vimos Ultra Deep Survey

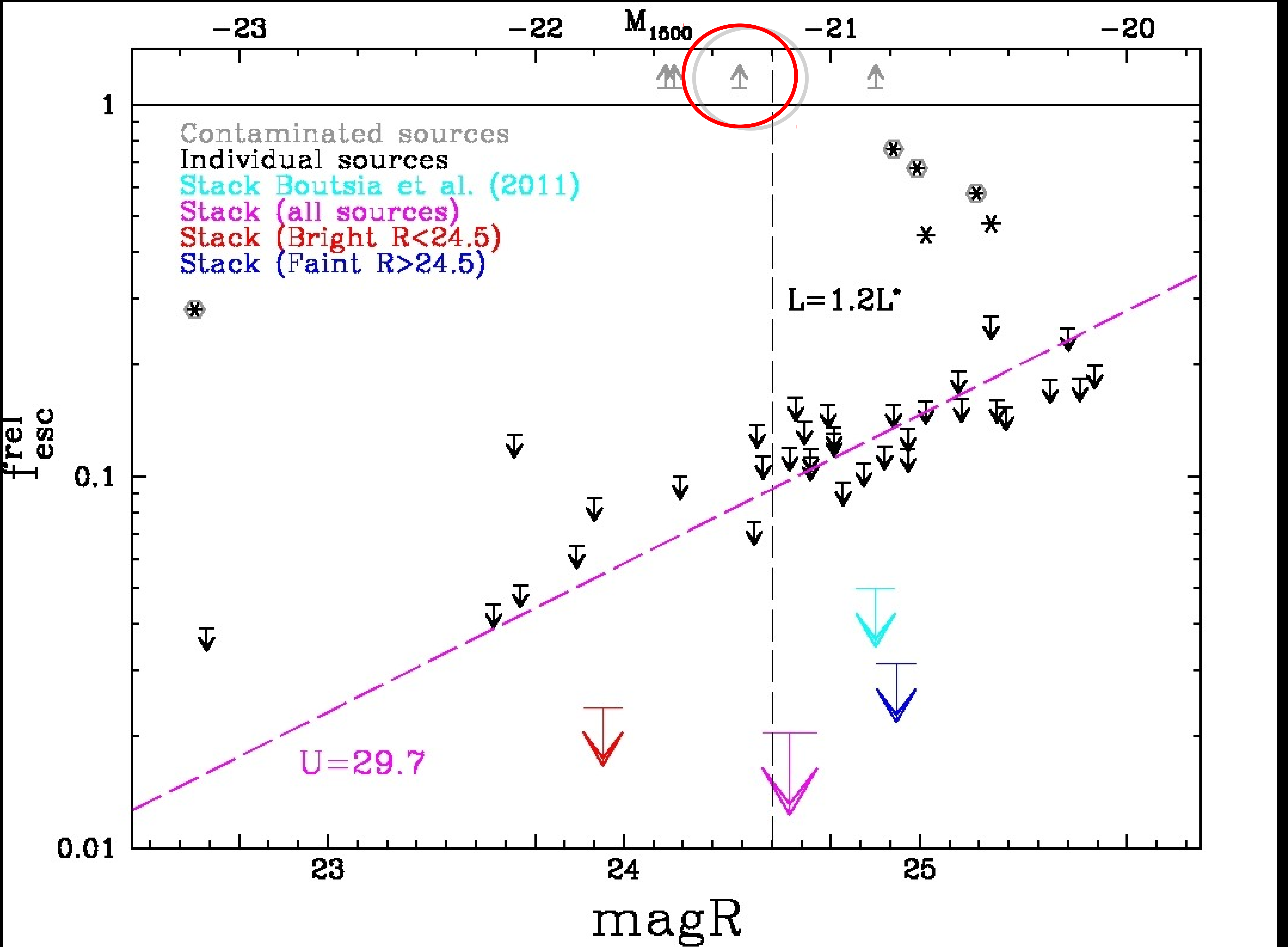
Le Fevre et al. (2015)
10000+ zspec 2<z<6.7





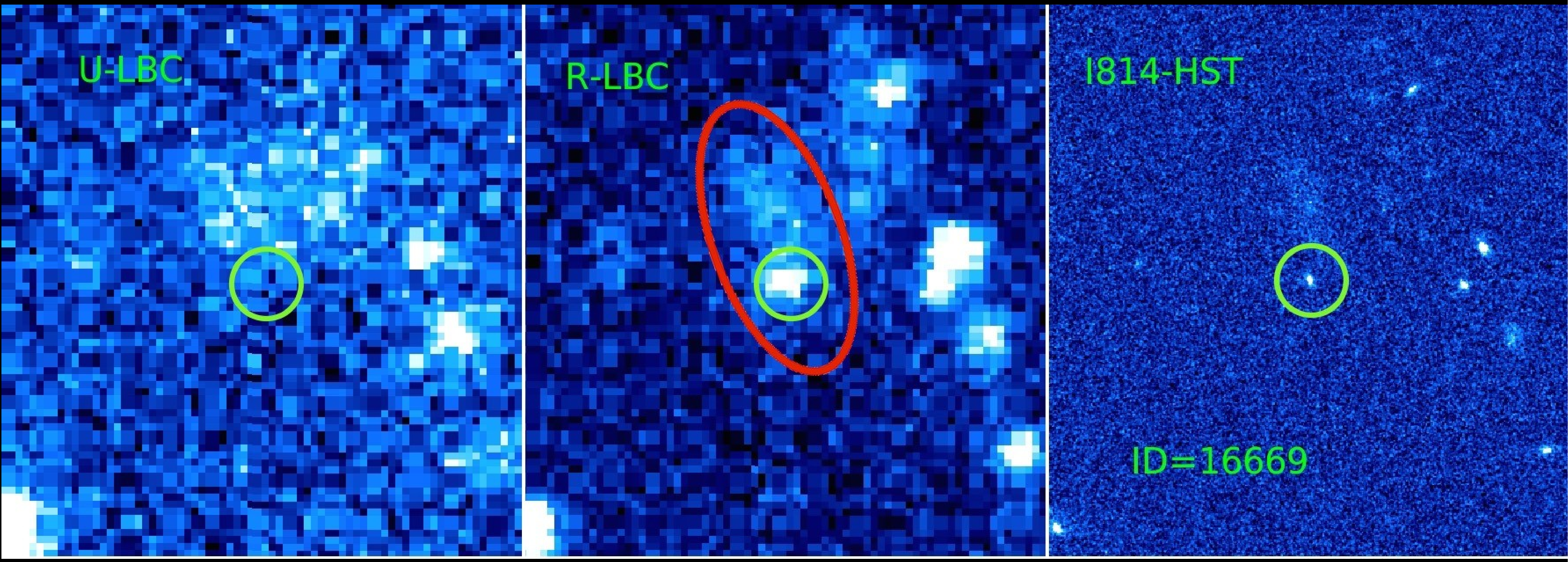
VUDS-LBC/COSMOS

Grazian et al. (2016)



M1500
−23
−22
−21
−20
1
0.1
0.01
Contaminated sources
Individual sources
Stack Boutsia et al. (2011)
Stack (all sources)
Stack (Bright R<24.5)
Stack (Faint R>24.5)
L=1.2L*
U=29.7
f^{rel}_{esc}
23
24
25
magR

Id=16669   magR=24.4

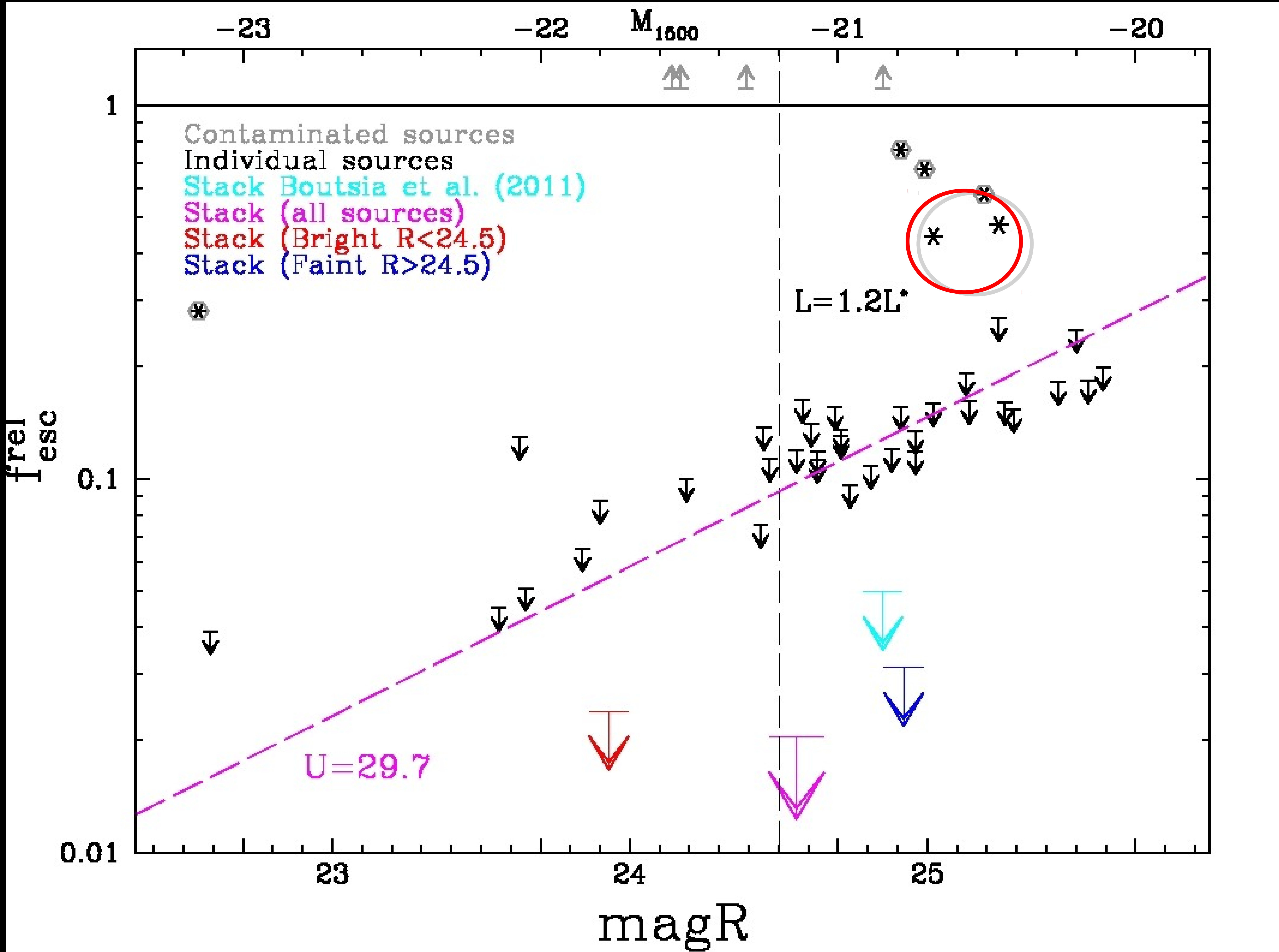


Global fesc=230%

Local fesc=520%

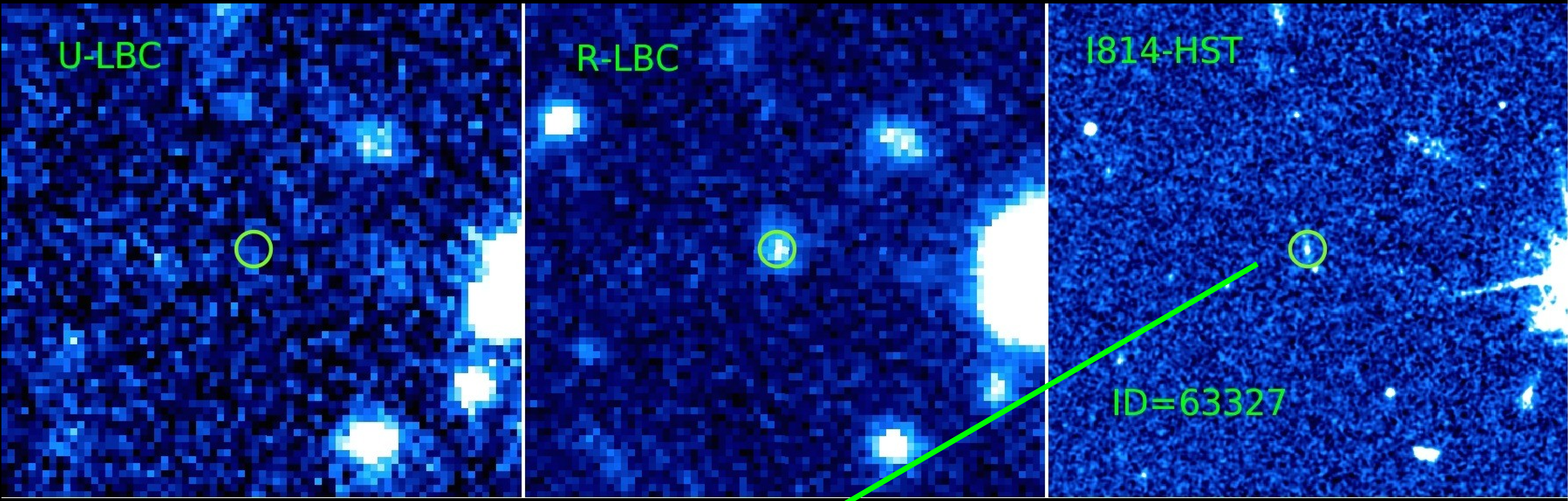
Contamination by
Foreground galaxy

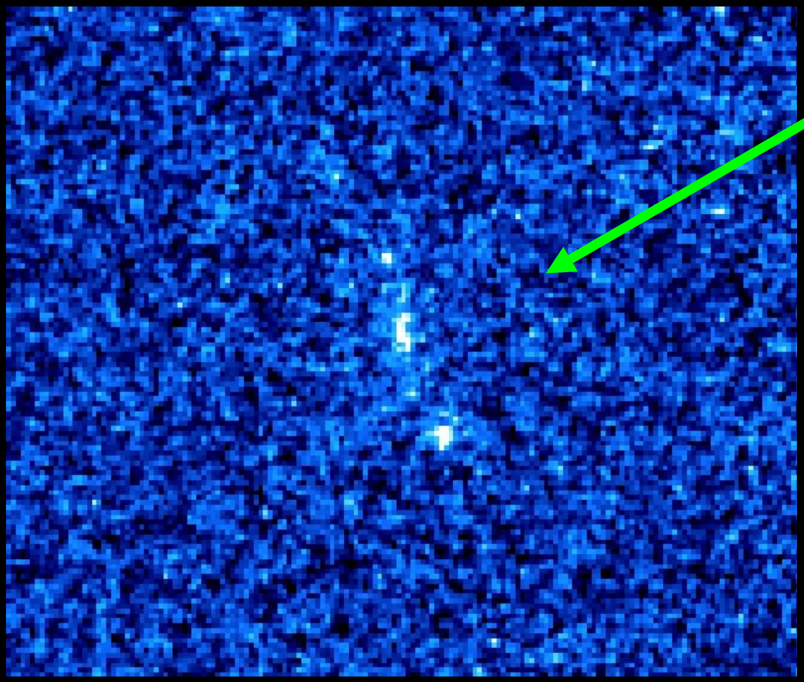
See also Siana et al. (2015)



M1500
−23
−22
−21
−20
1
0.1
0.01
Contaminated sources
Individual sources
Stack Boutsia et al. (2011)
Stack (all sources)
Stack (Bright R<24.5)
Stack (Faint R>24.5)
L=1.2L*
U=29.7
23
24
25
magR
f rel esc

Id=63327 magR=25.02





Fesc=45%

Possible LyC emitter!!!

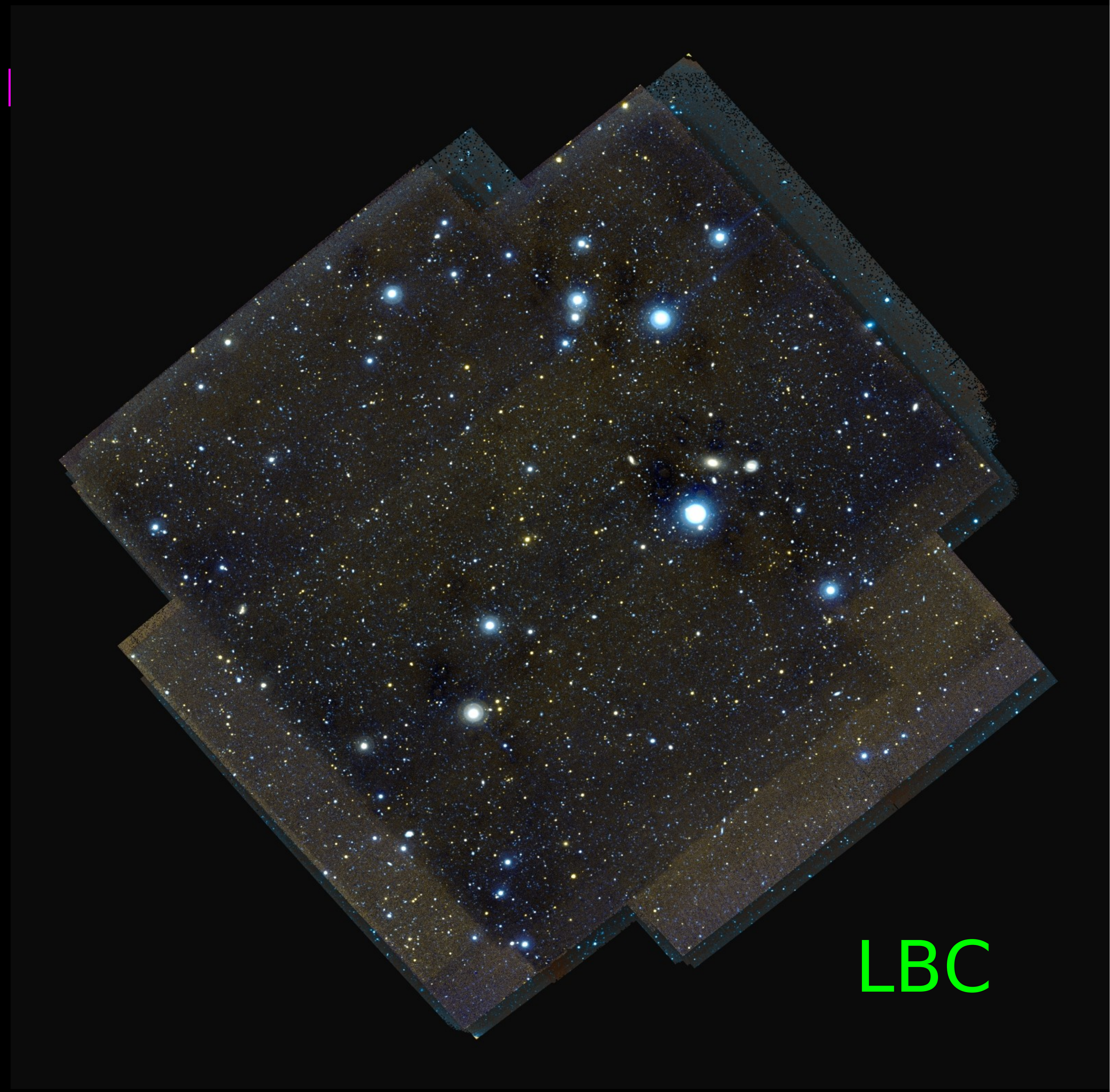
Detailed analysis on-going...

Contamination ???

Enlarging the Sample....

CANDELS EGS field

2 LBC pointings in U band l
R band from CFHT
exptimeU=7h
U=29.6(AB) at S/N=1
Area~600 sq. arcmin.



zspecs from DEEP2
(Cooper et al. 2006)

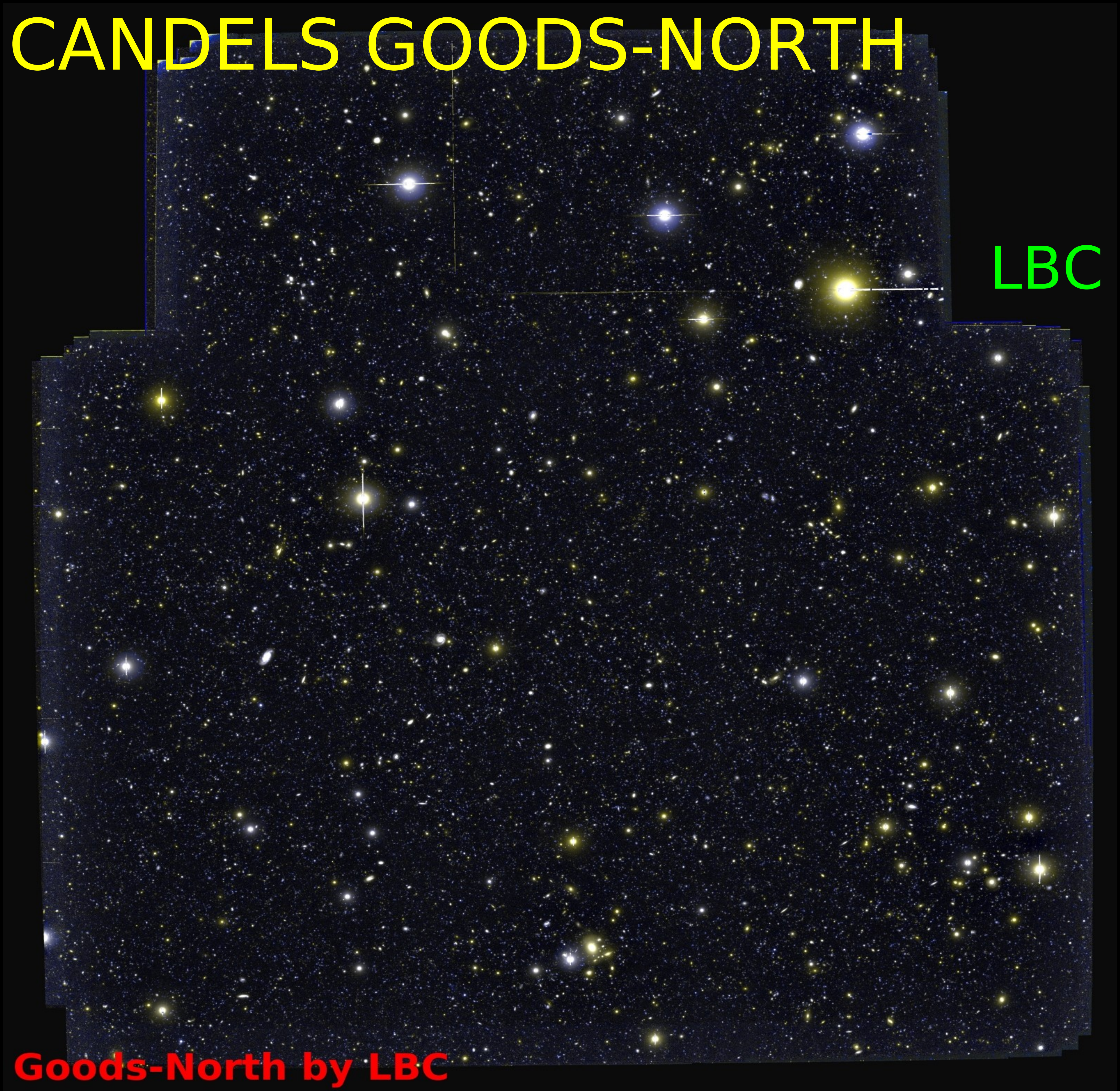
15 galaxies with
$3.27<z<3.40$

CANDELS GOODS-NORTH

33 hours in the U-band
Seeing=1.1”

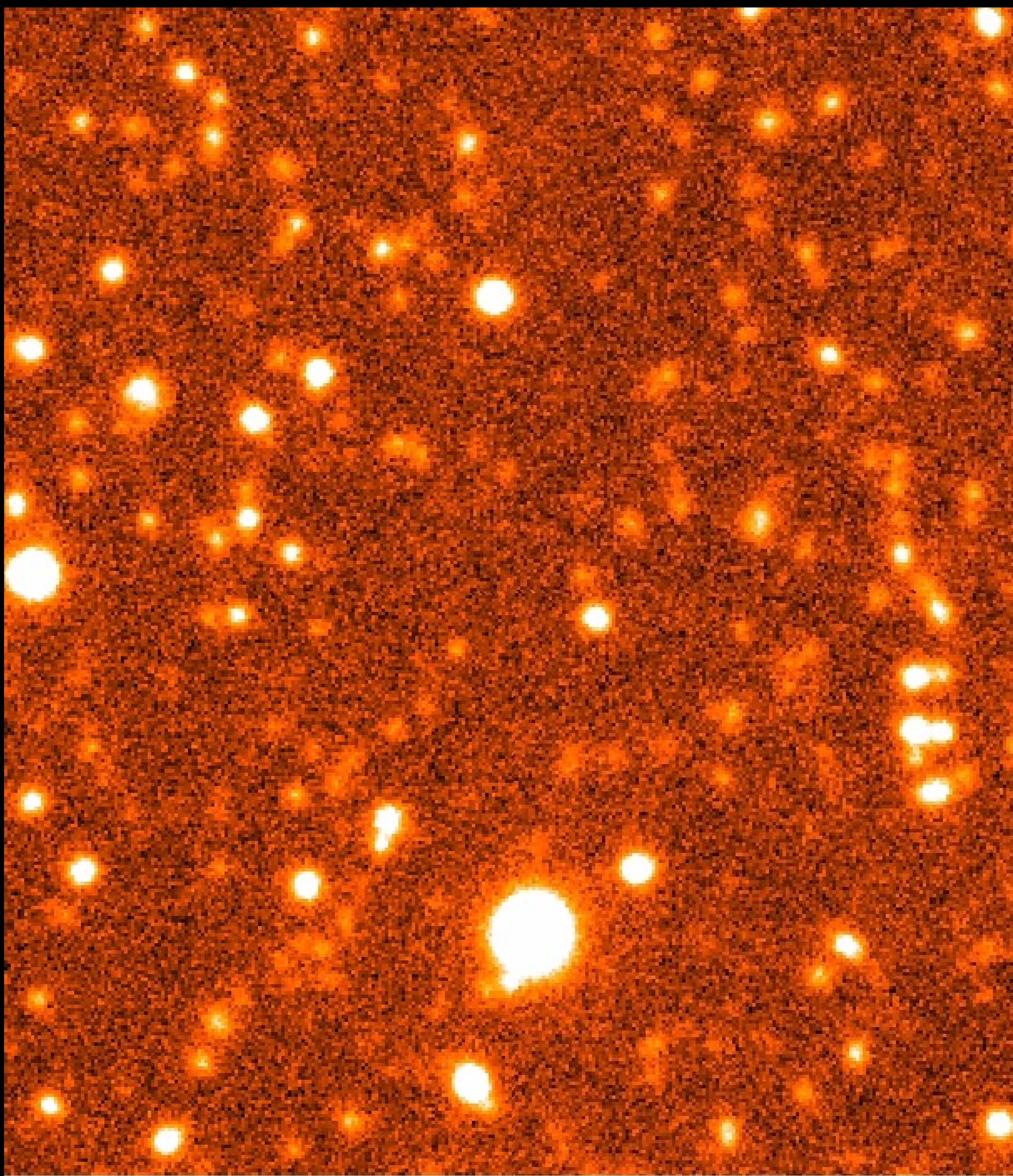
26 hours in the R-band
Seeing=1.0”

Data reduced by LSC (INAF-OARoma)

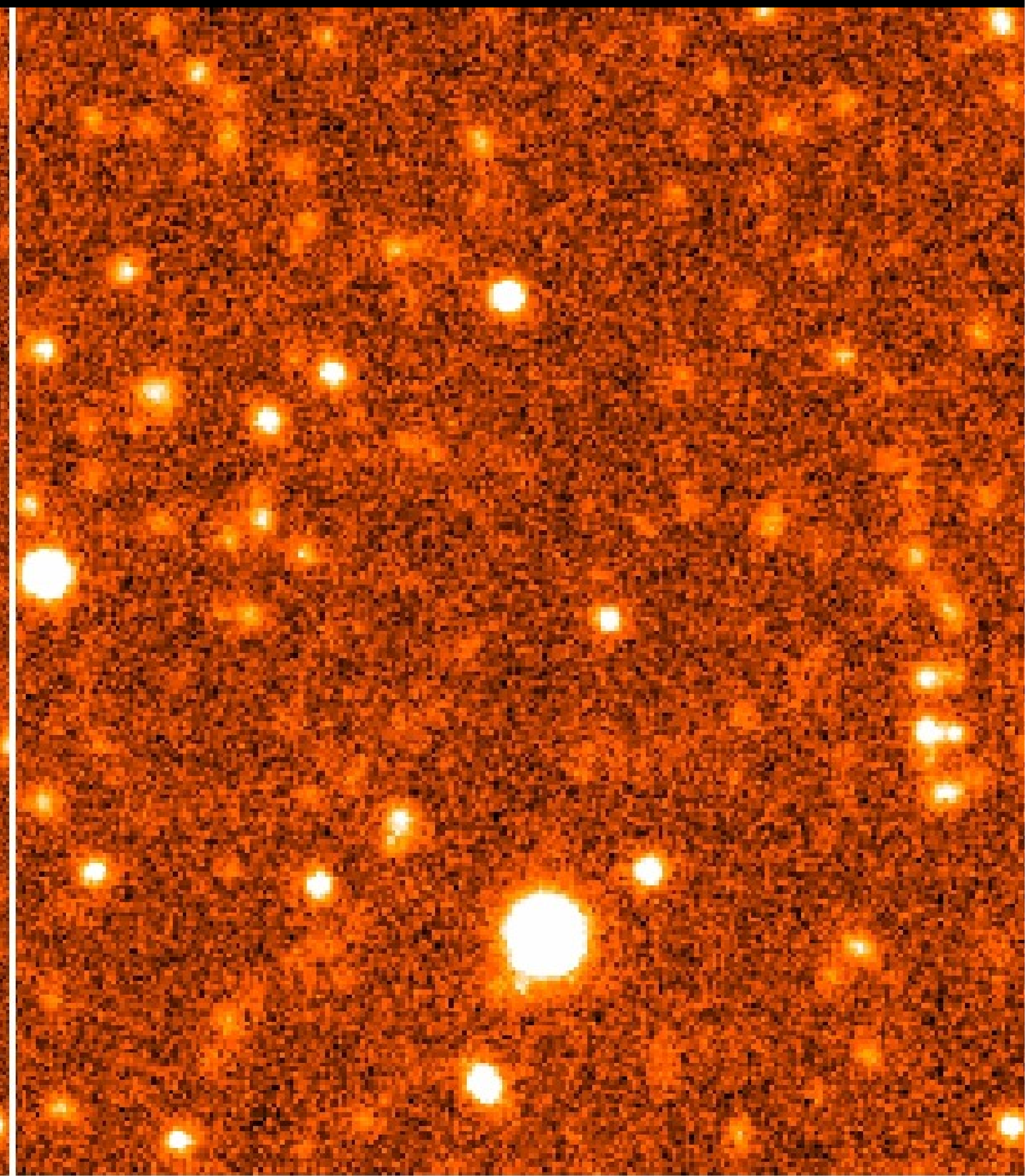


Ultra Deep U-band

LBC 33 hours



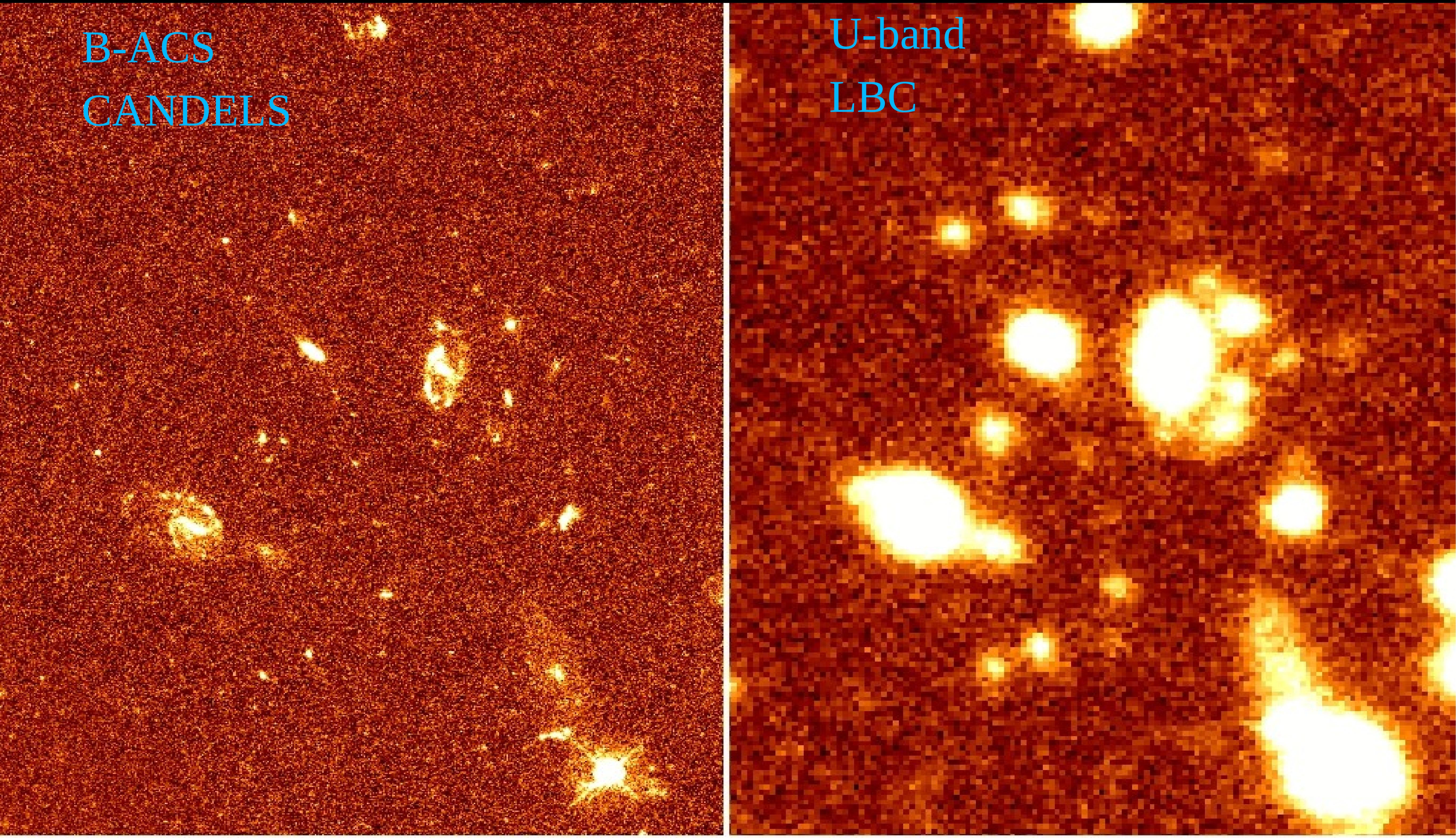
KPNO 50 hours



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

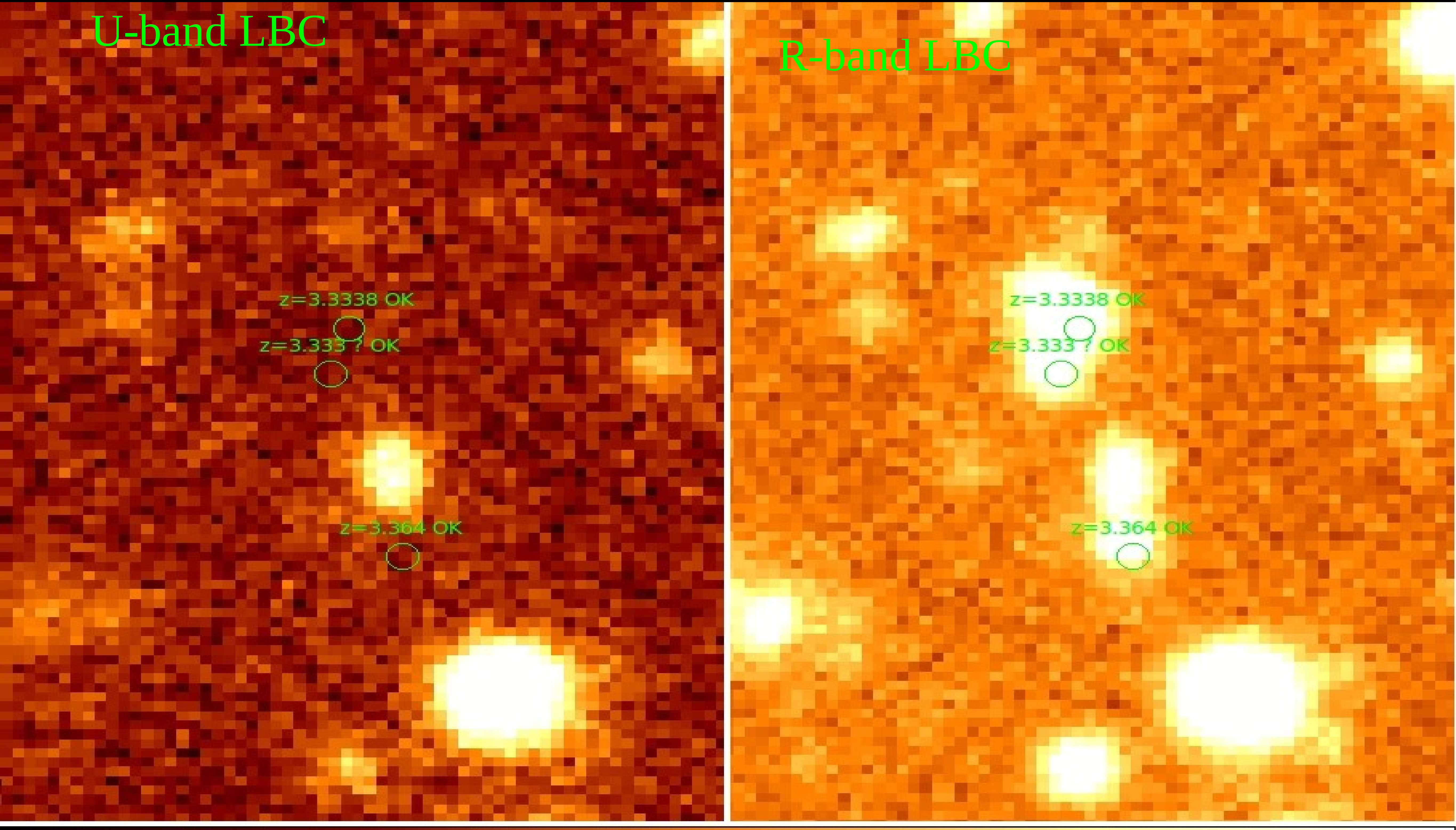
Giavalisco et al. (2004)

U=30.2 AB mag (1 sigma)



z=3.3 galaxies in GOODS-North

9 galaxies at z~3.3 have been added to the original sample.

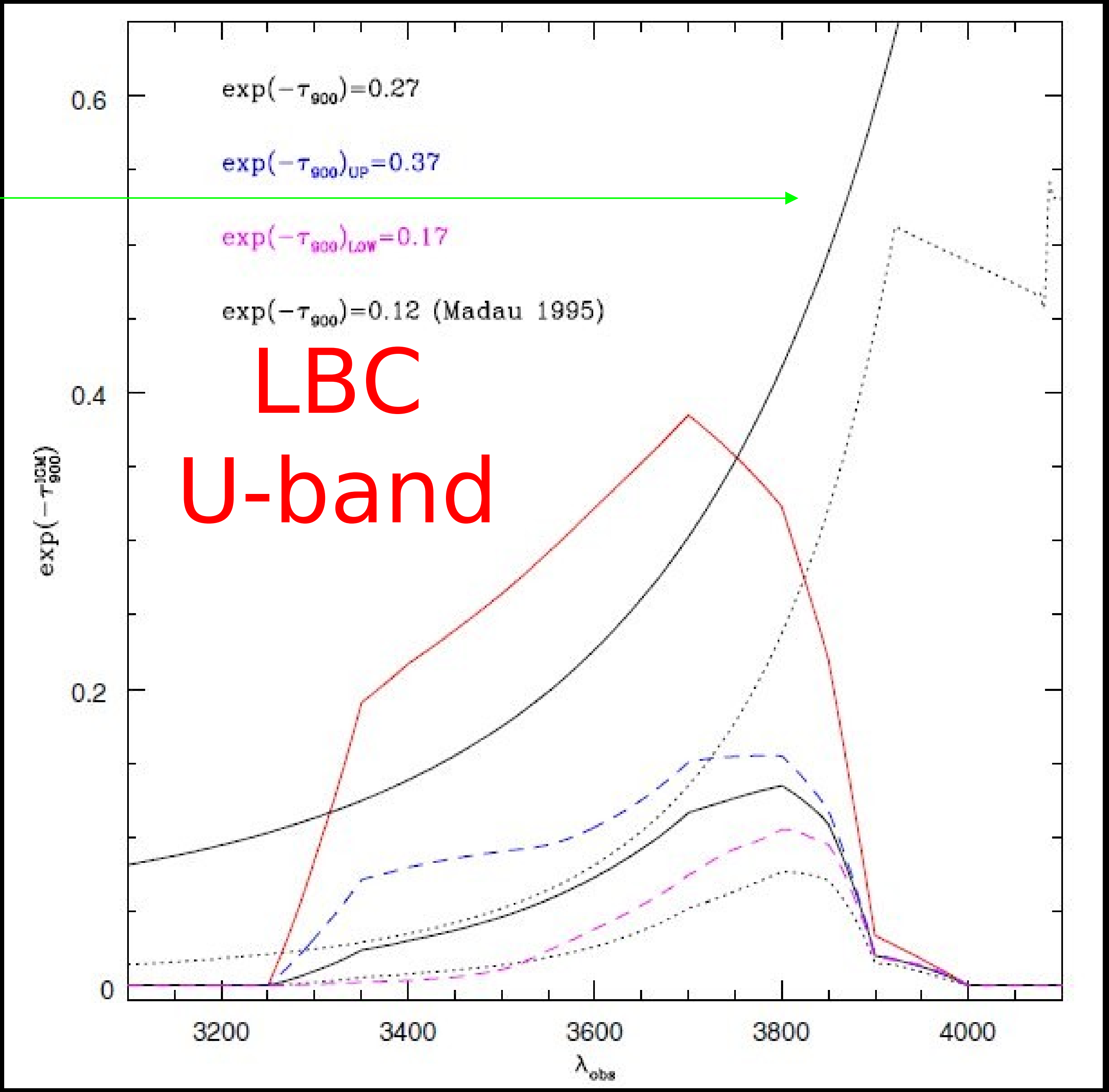


Ionizing Escape Fraction at z~3.3

Selected 69 SFGs with zspec 3.27<z<3.40 in COSMOS, EGS, GDN
45 from VUDS/COSMOS Grazian et al. (2016)
15 from CANDELS/EGS; 9 from CANDELS/GOODS-NORTH
LBC deep imaging in U and R bands
z>3.27 U-LBC filter samples the
Lyman Continuum (<912A)
IGM extinction:
Prochaska et al. (2009)
Worseck et al. (2014)
Inoue et al. (2014)

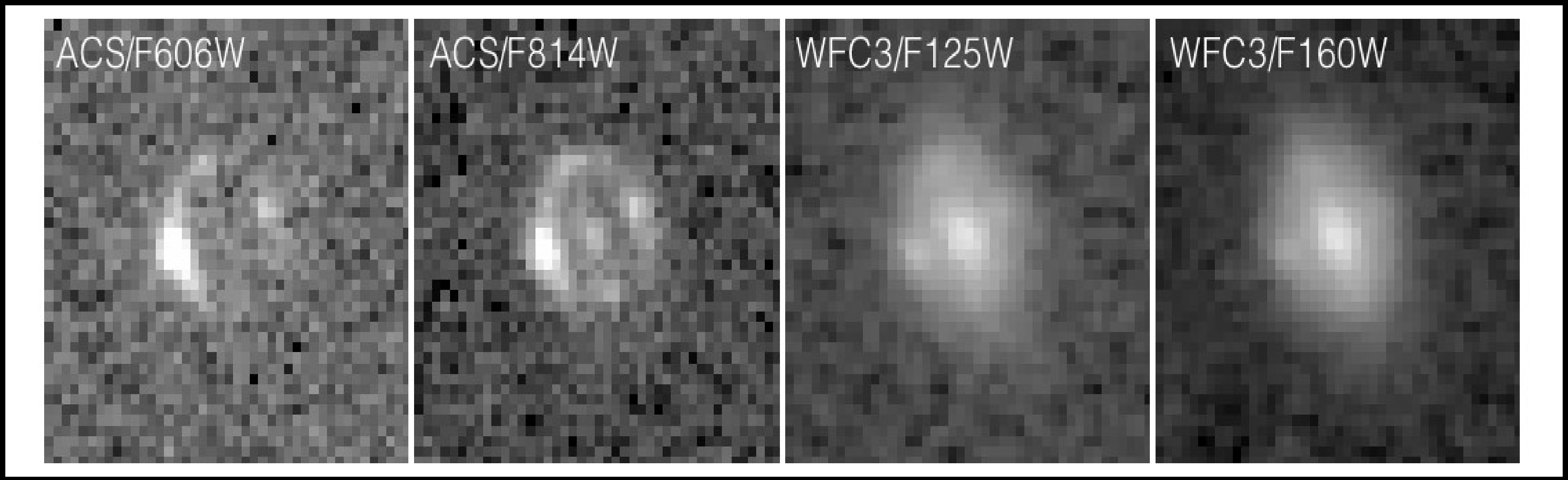
Effective wavelength:
860 A rest frame

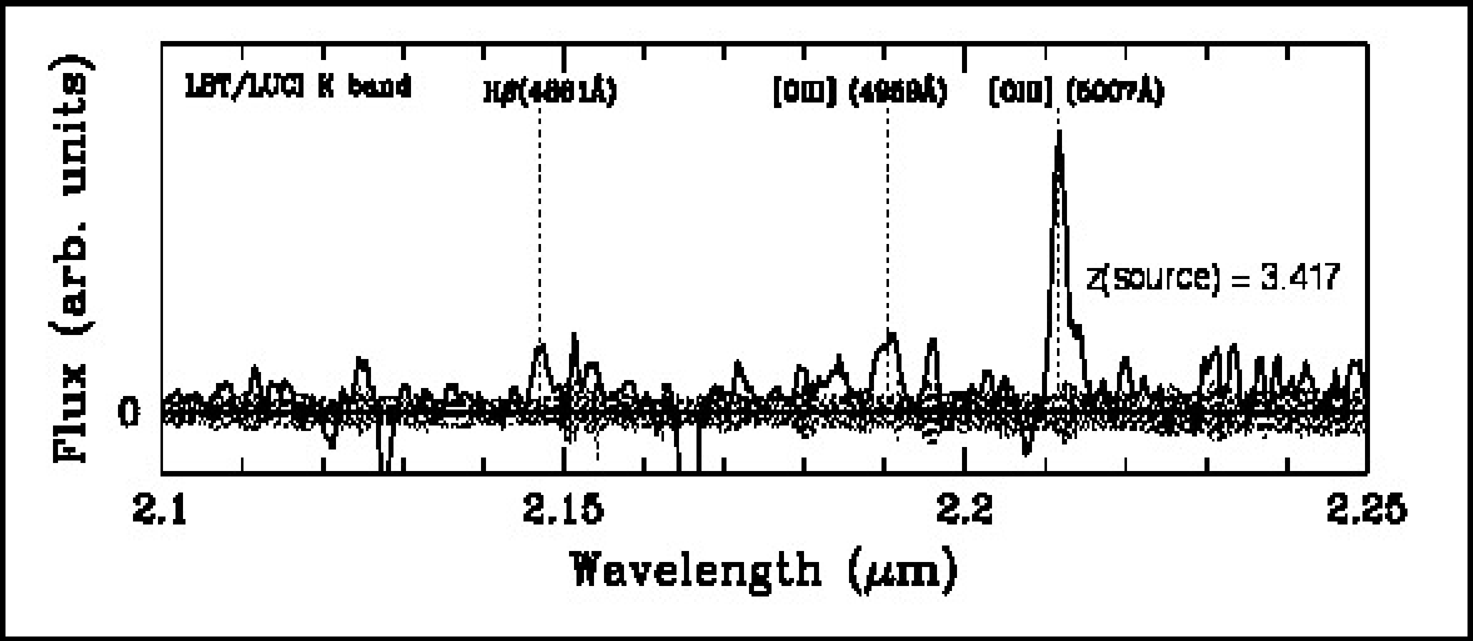
Mean IGM correction: 0.28



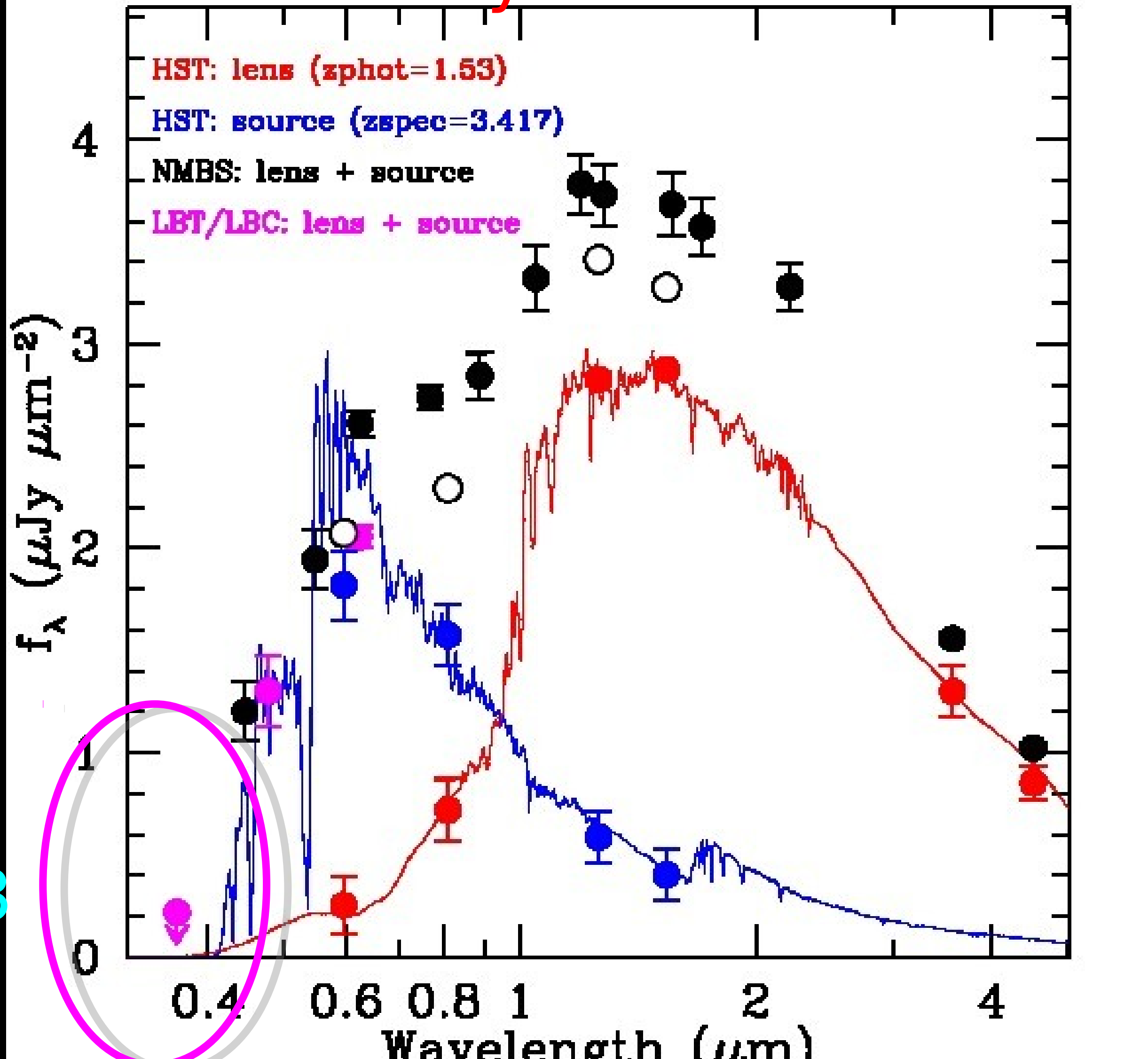
Boutsia et al. (2011)

Galaxy-Galaxy strong lensing





Talk by R. Amorin



z=3.417 mu=40x

Uobs>28.9 Robs=24.3 Rintr=28.3

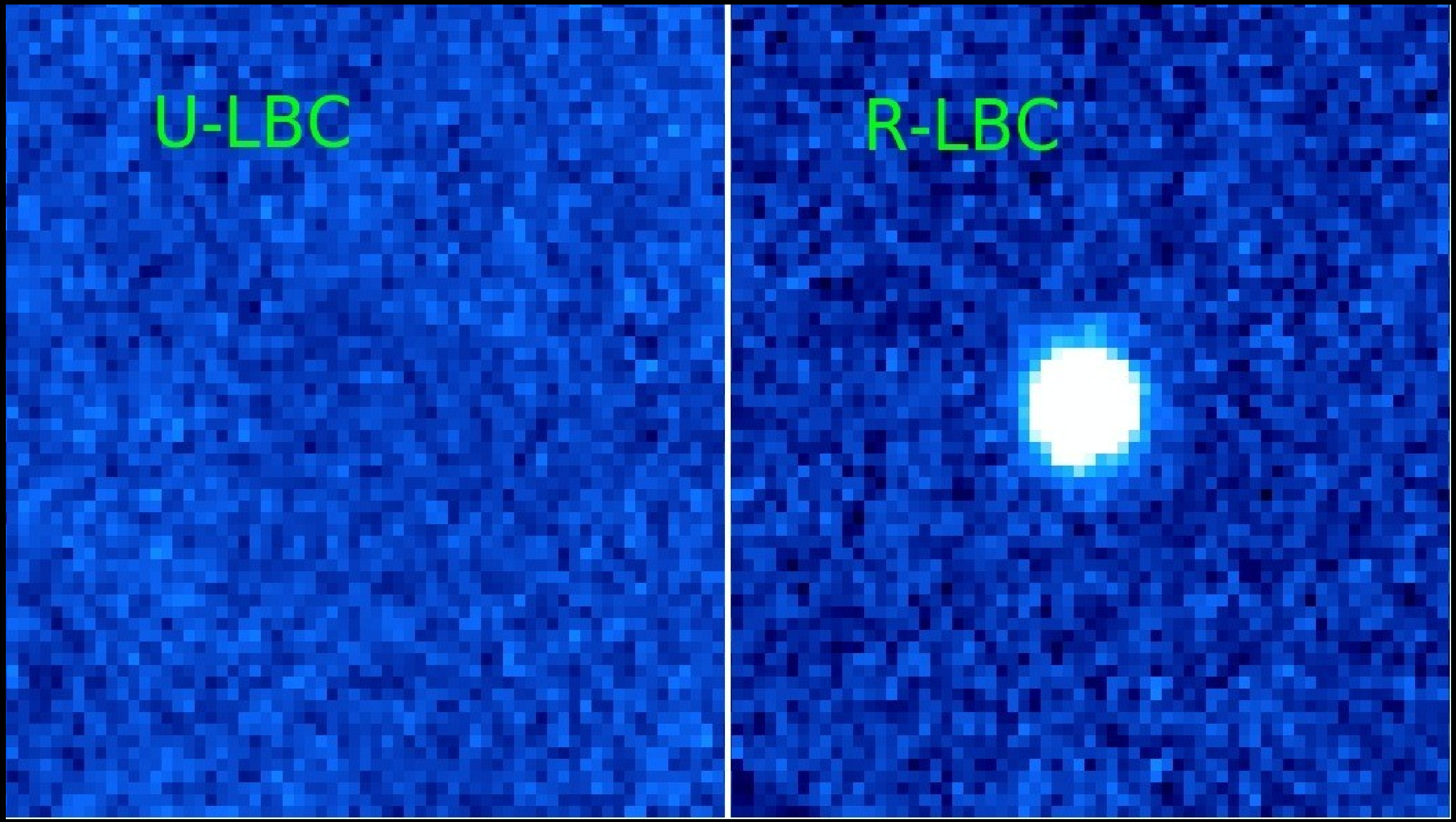
Fesc<23% (1 sigma) L=0.05L*

LBT LUCI+LBC; van der Wel et al.2013

Amorin et al. (2014)

Image stacking in U and R

U band
LBC



R band
LBC

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

f1500/f900obs>640.2

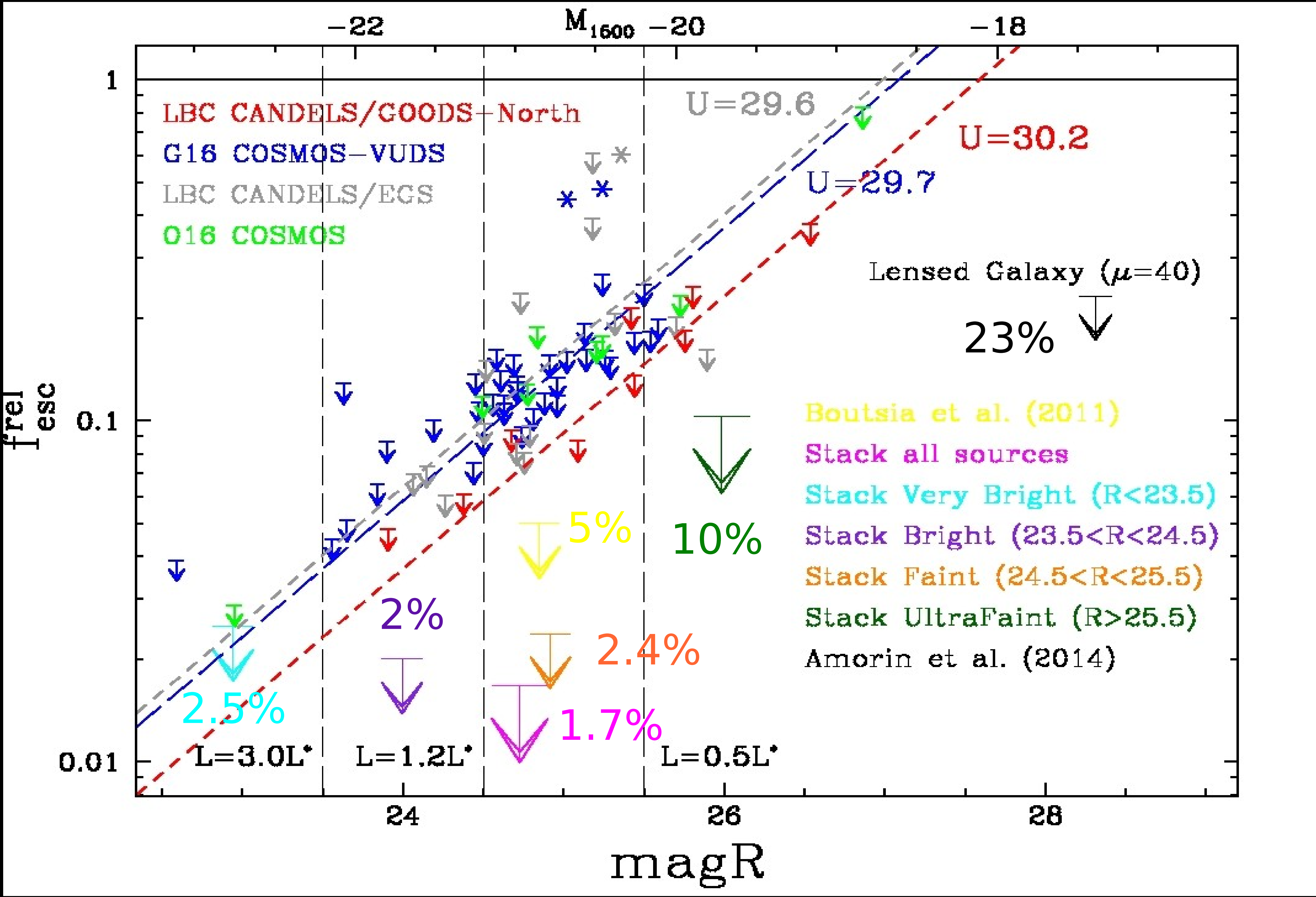
fesc_rel<1.7% (1 sigma) at z=3.3 for R<26.5

Consistent with Vanzella et al. (2010) and Guaita et al. (2016):
GOODS-South

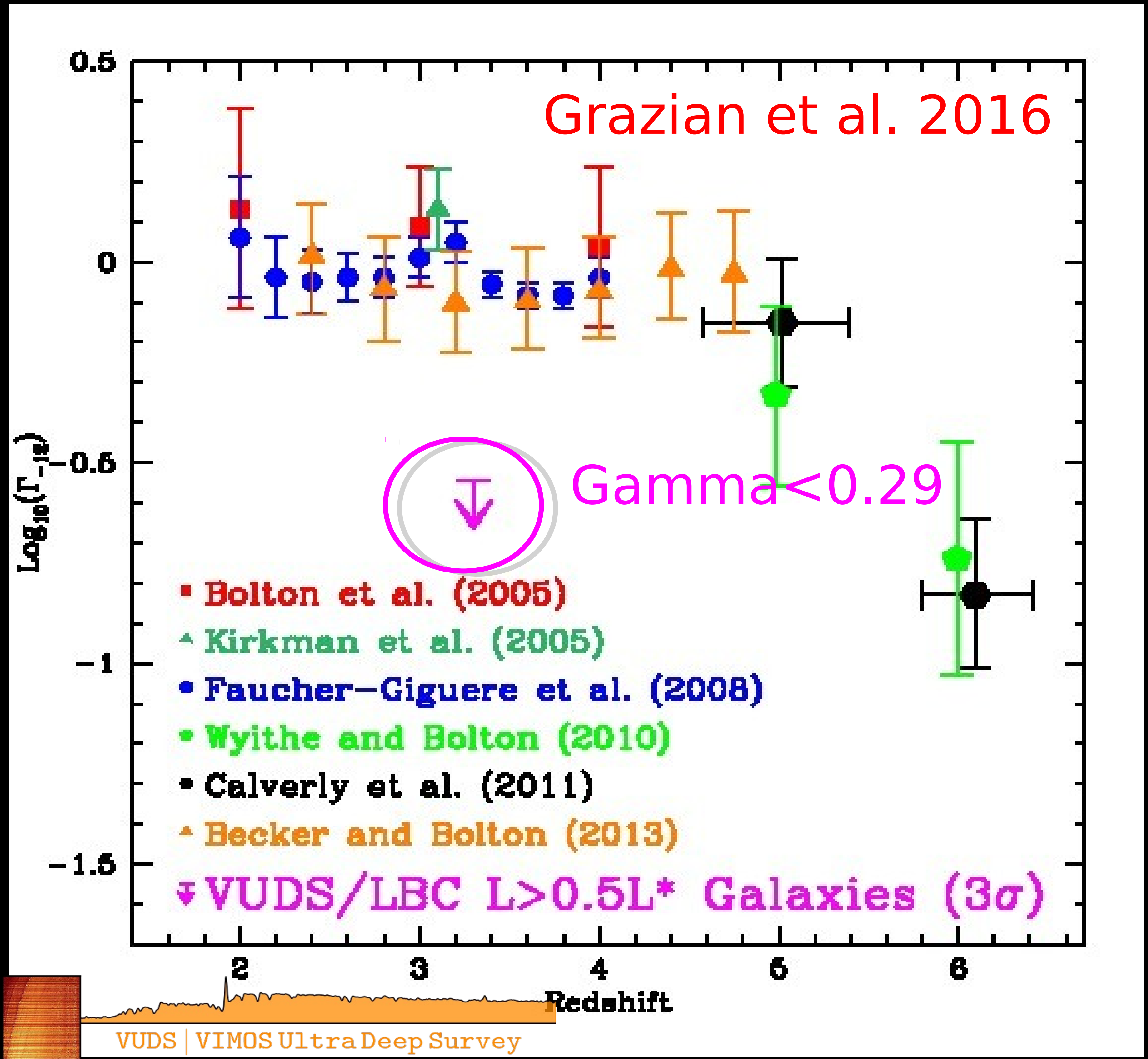
Grazian et al. (in prep)

COSMOS+GOODS-NORTH+EGS

LyC Escape Fraction of z~3 Galaxies



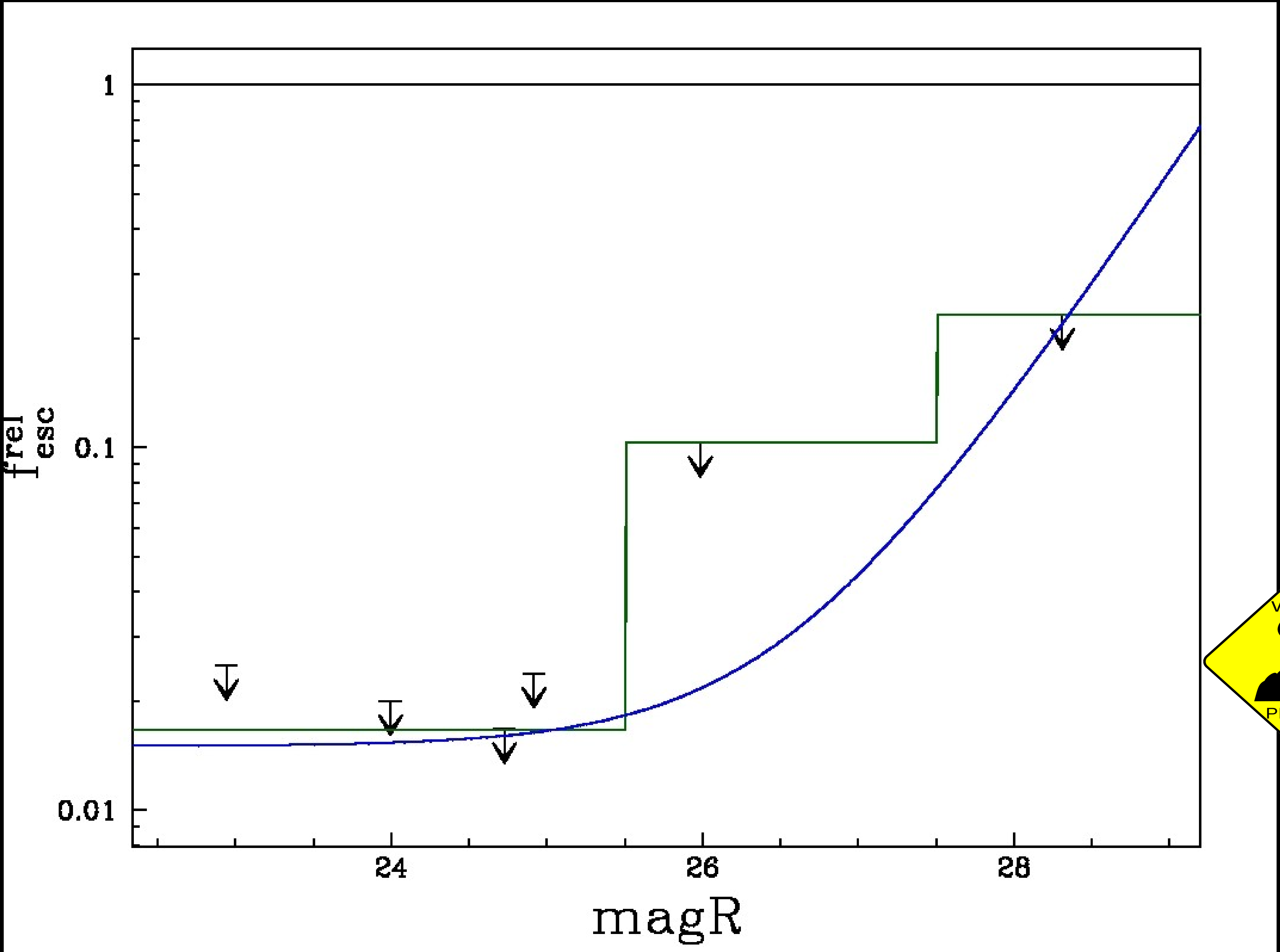
HI Photoionization rate
UVB by bright galaxies (L>0.5L*)



Bright Galaxies have low fesc

What about faint galaxies ?

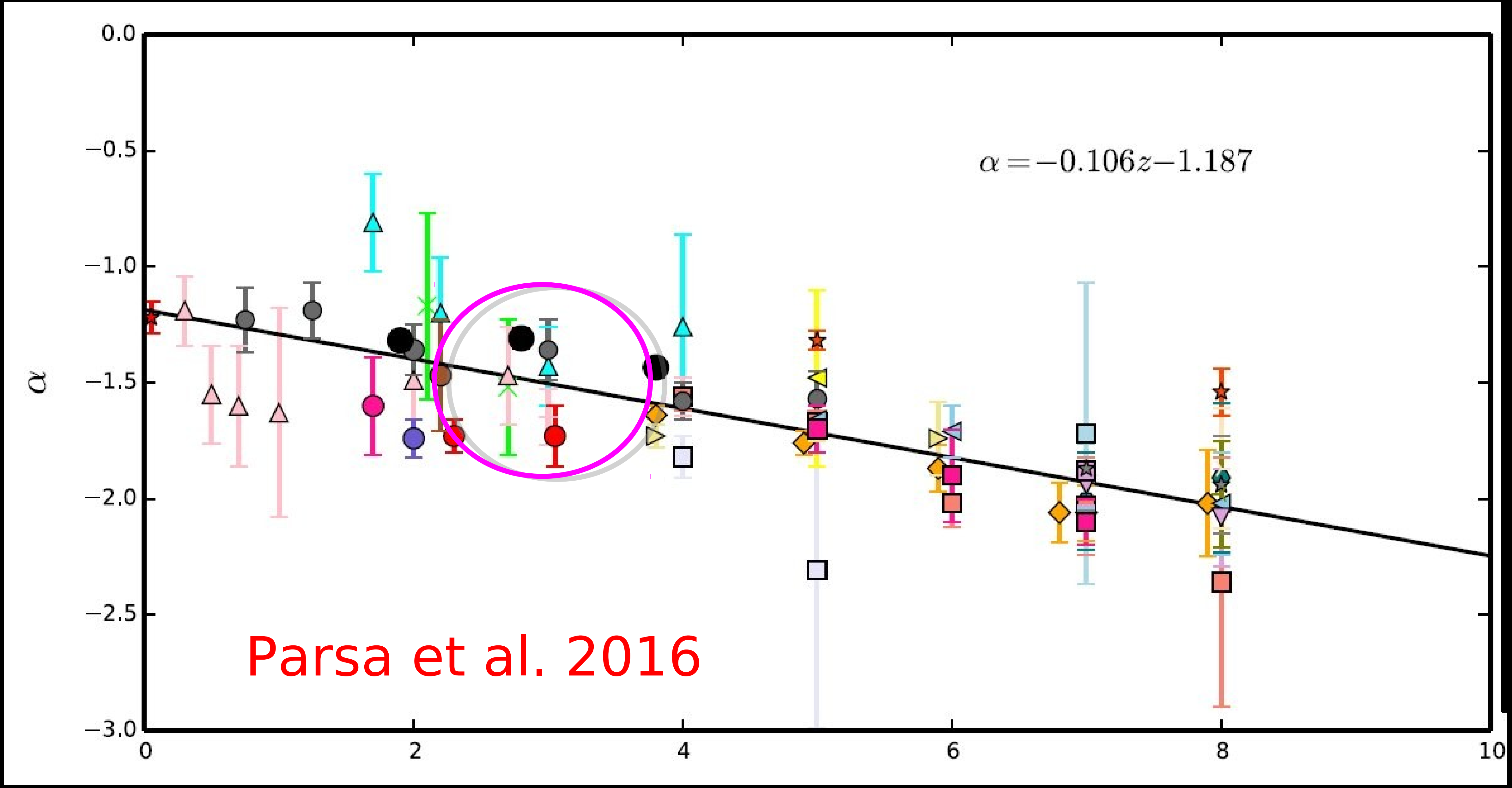
Evolution of fesc with Luminosity



Faint Galaxies: they can keep the Universe reionized at z=3.3, only if the Luminosity Function is steep (<-1.7) and going down to Muv=-13

The slope of the LF at the faint end at z~3

Is still uncertain



Future Activities

Next steps: 1-compute the Luminosity Function at z~3 with deep LBC data in the CANDELS/GOODS-North field down to faint magnitudes.

This will allow us to measure the slope of the LF with small uncertainties and to derive a robust estimate of the contribution of star-forming galaxies to the UVB.

2-Explore the faint galaxies with strong gravitational lensing.

Green Pea at z=3.6252

Bayliss et al. (2014)

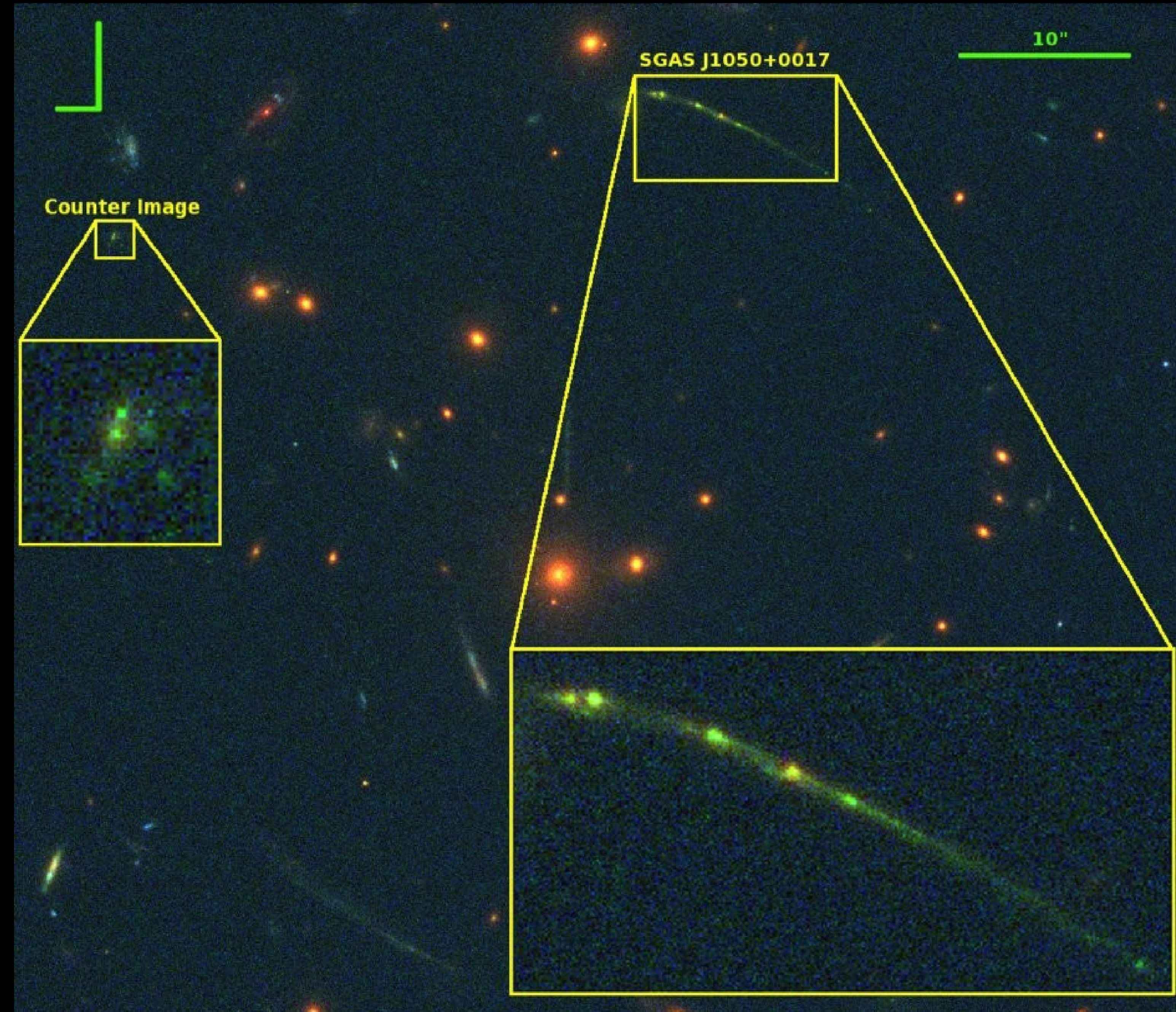
M1500=-20.5

logN_HI=21.5

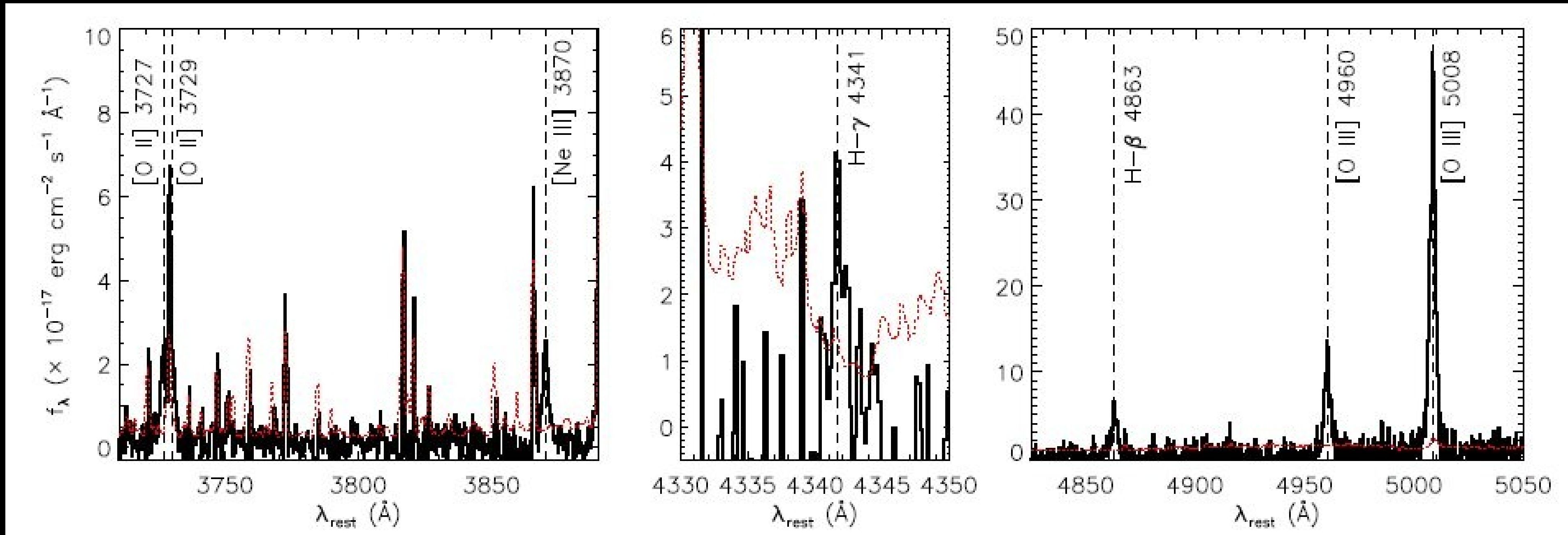
magnification=30x

F606W=21.48

Fesc~0.00 ?



See talks by R. Amorin and E. Vanzella



Alternative solutions to study Reionization

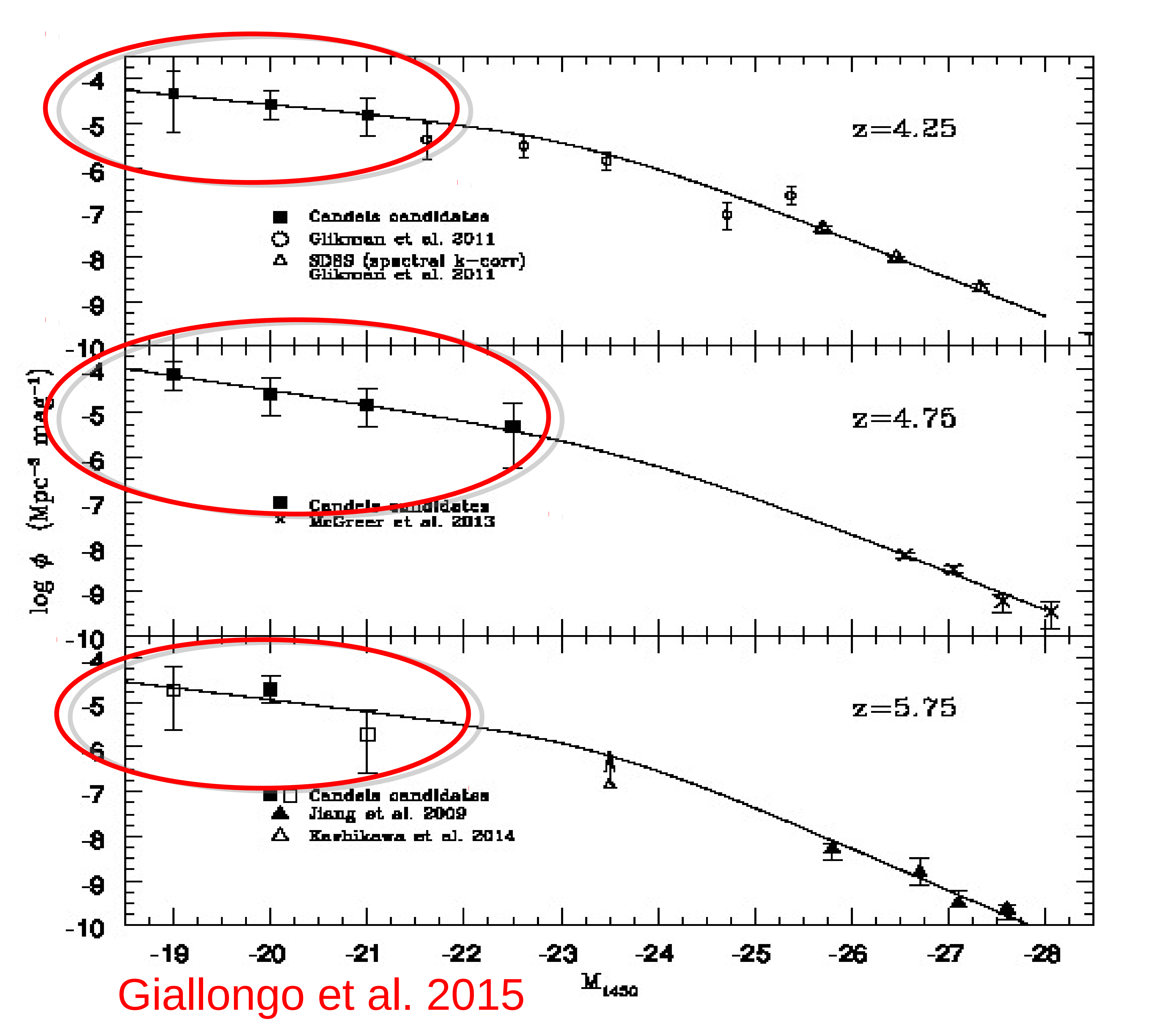
Bright QSOs are very rare.

What about Faint AGNs ?....

Luminosity Function of faint AGNs at z>4

LF corrected for
H160 incompl.
and
X/H incompl.

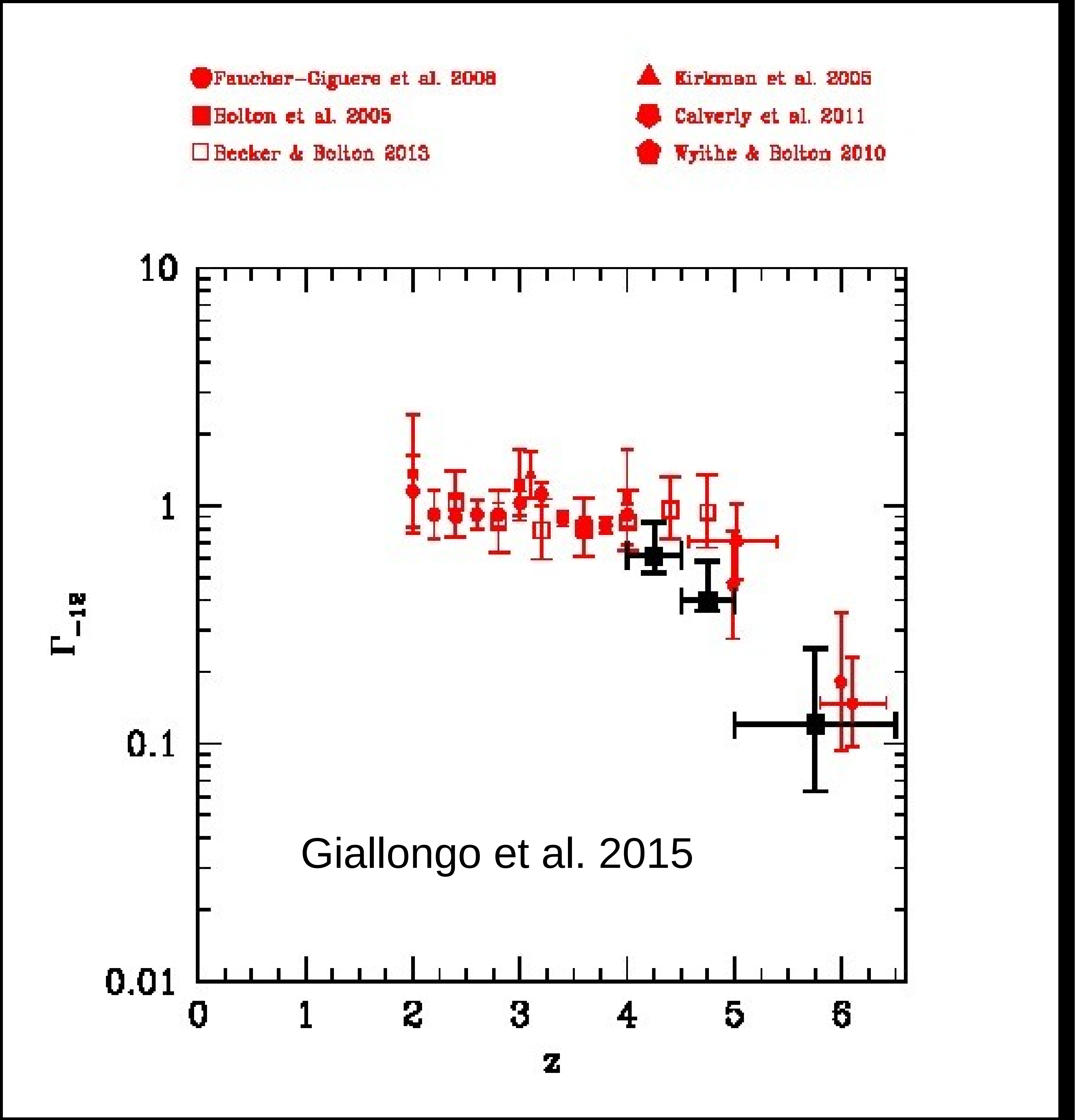
Steep slope
<-1.5 at the
faint end



Giallongo et al. 2015

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



Conclusions

Bright galaxies ($L>0.5L^*$) are not able to keep the Universe reionized at z~3. Faint galaxies are providing the measured UVB at z~3 only if their escape fraction increases at faint luminosity and LF is steep.

Our results are consistent with evidence of late reionization by Planck 2015.

Also consistent with patchy reionization scenario found by Treu et al. (2012) and Pentericci et al. (2014).

Thank you!