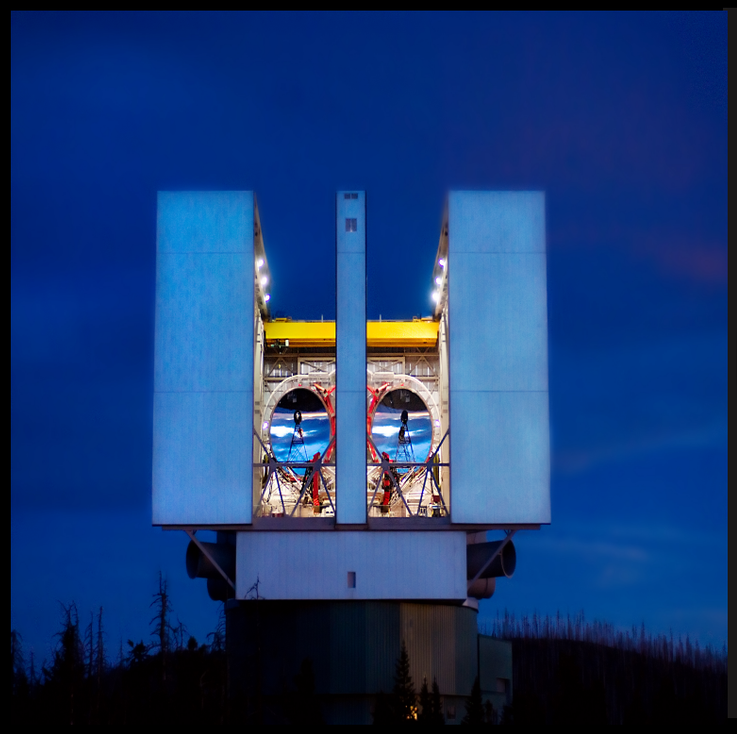
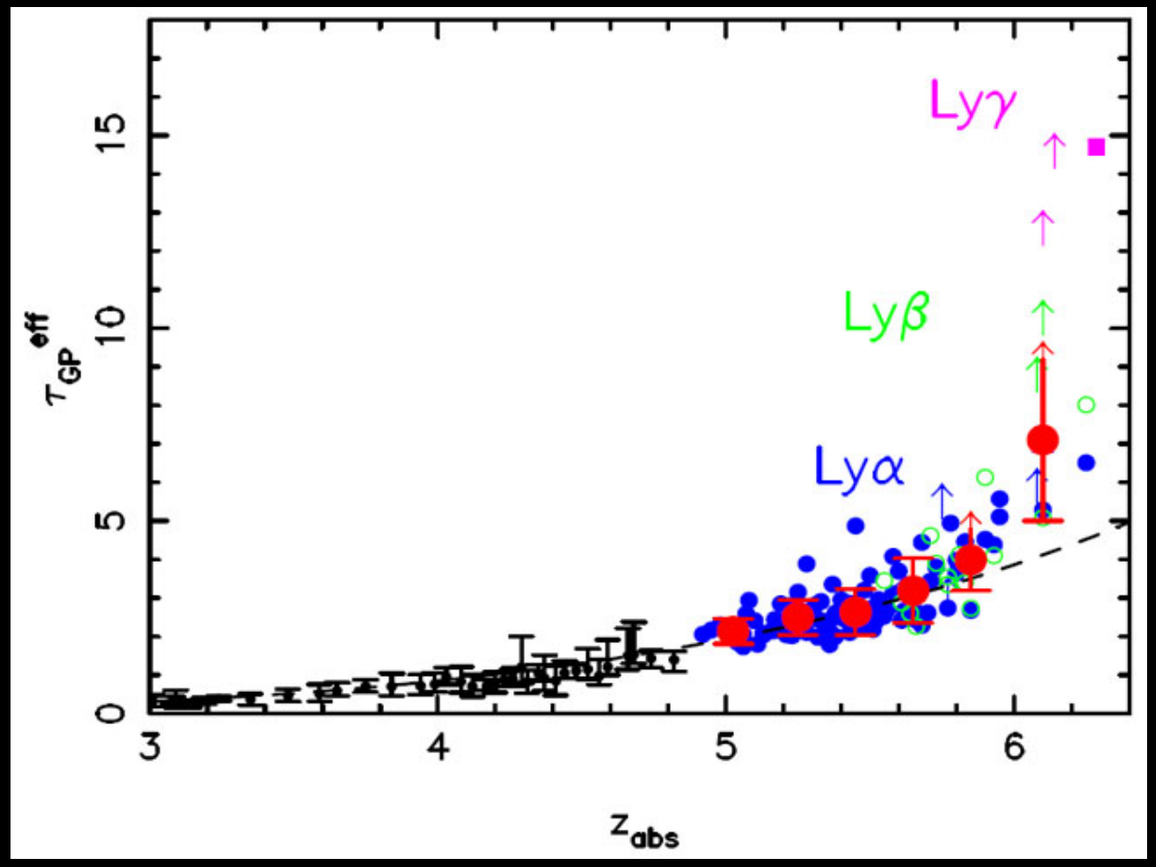
The Lyman Continuum escape fraction of z~3 star forming galaxies with LBC/LBT in the COSMOS and CANDELS fields

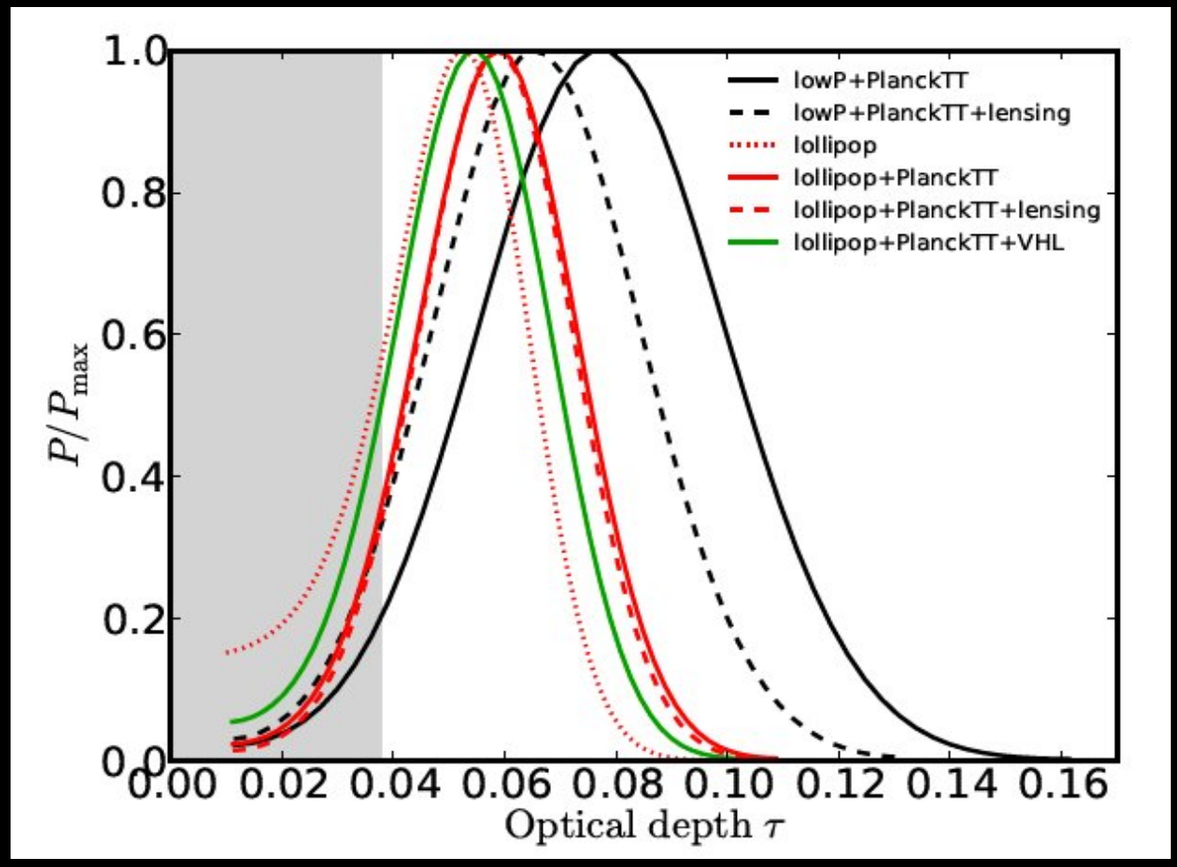


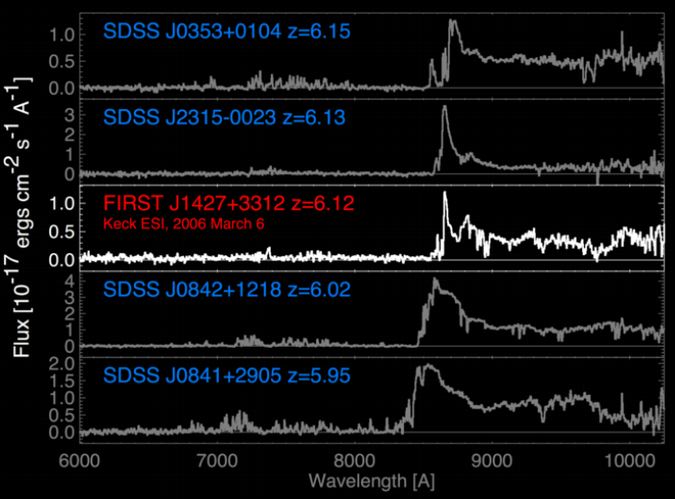
Andrea Grazian (INAF-OAR)

June 28th, 2016 Heidelberg (Germany)
“Illuminating the Dark Ages” Conference

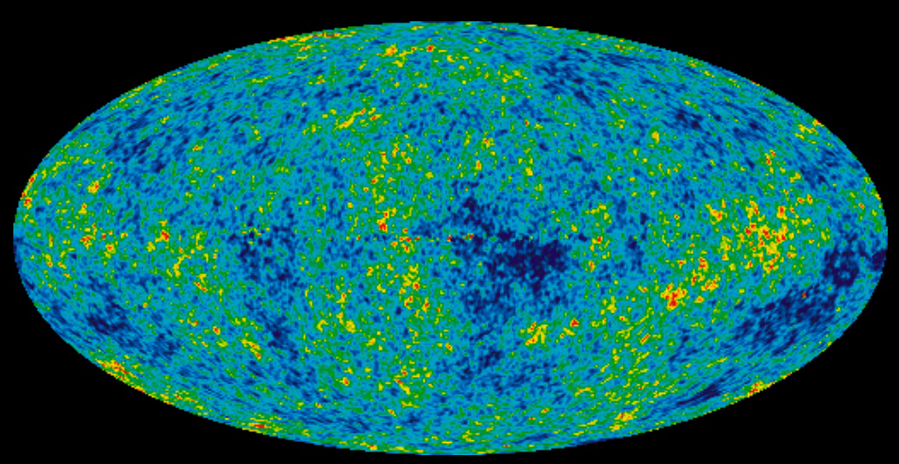
Motivation







+



=> 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

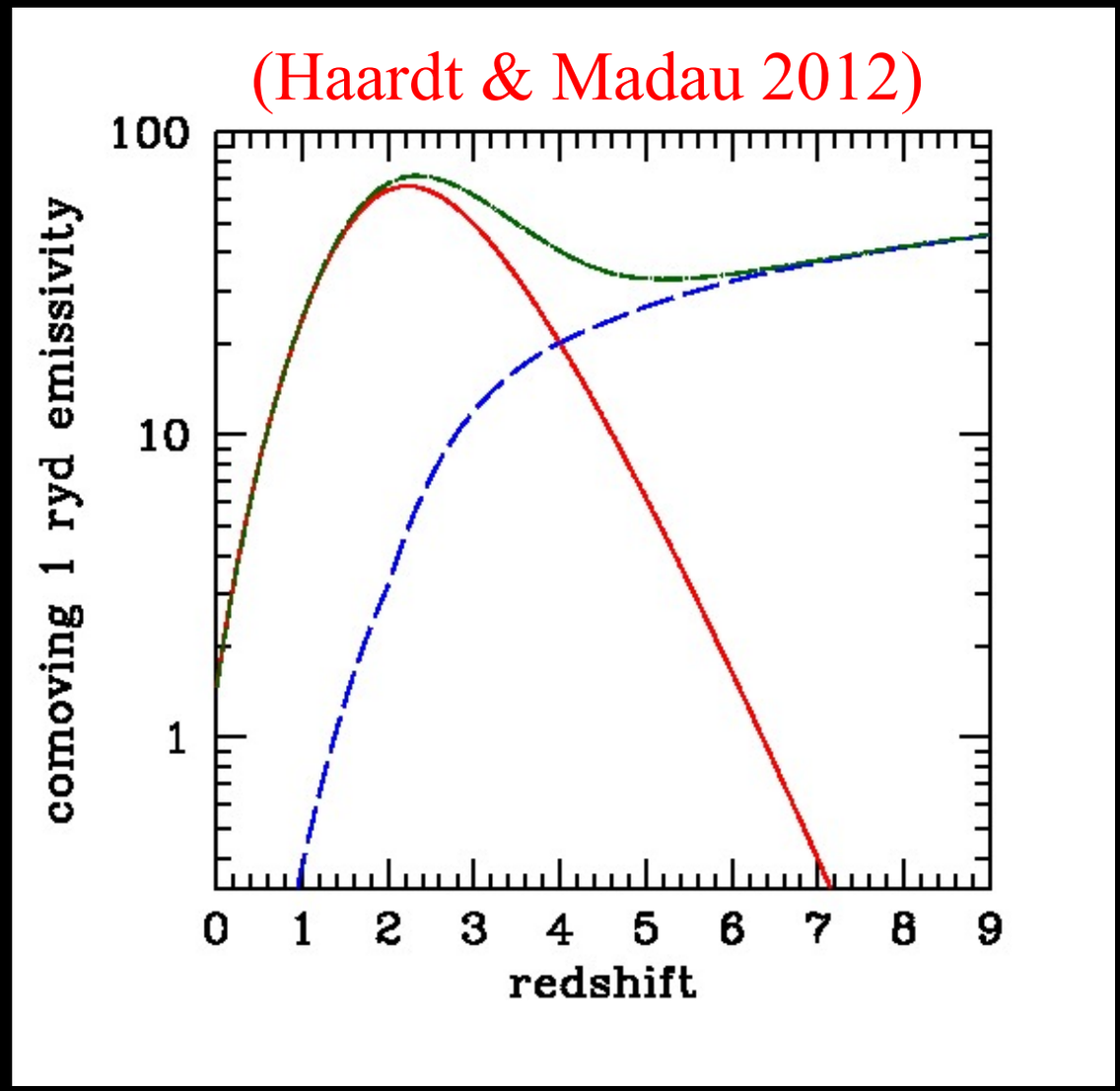
- Implies reionization at z<~9. Rapid process
- With SPT kSZ: Delta_z<2.8

Sources of Reionization

Reionization: driven by Galaxies or AGNs ?

At high-z bright QSOs are rare. Low ionizing emissivity at z>3.

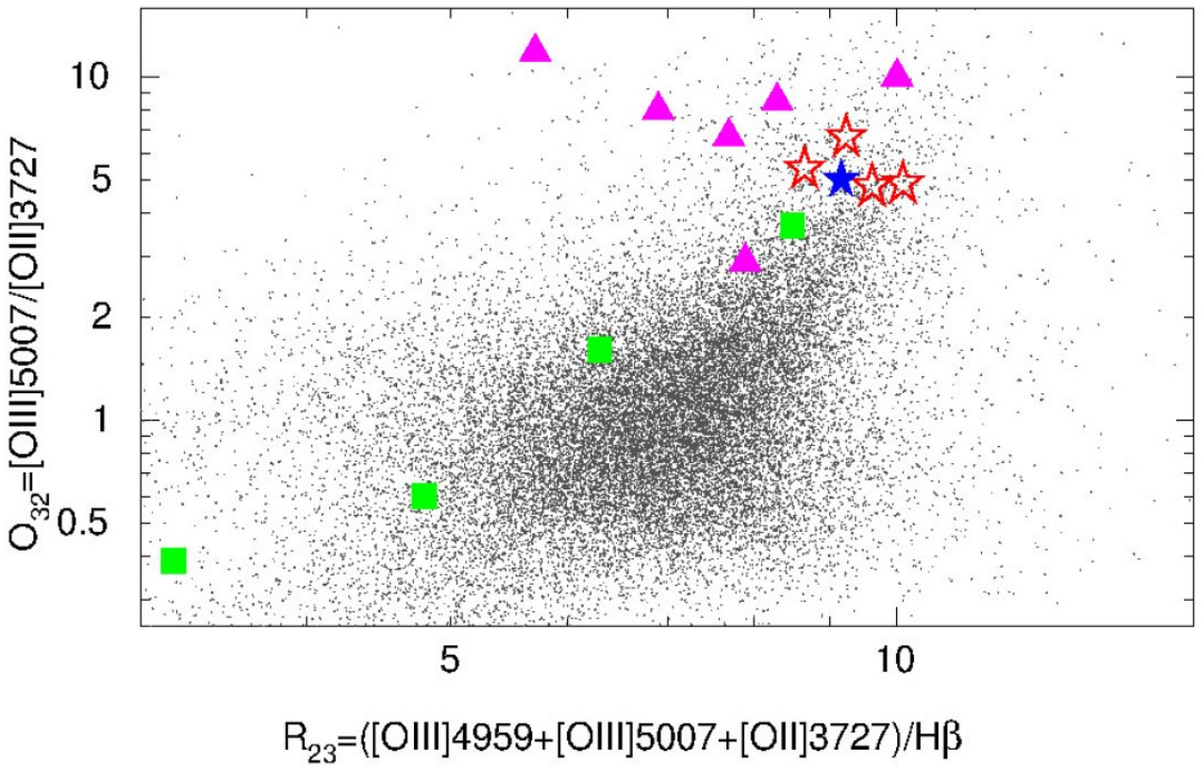
Faint Galaxies can be Important at z>3. Steep Luminosity Functions. Simulations indicate high fesc for faint galaxies (Muv=-10).

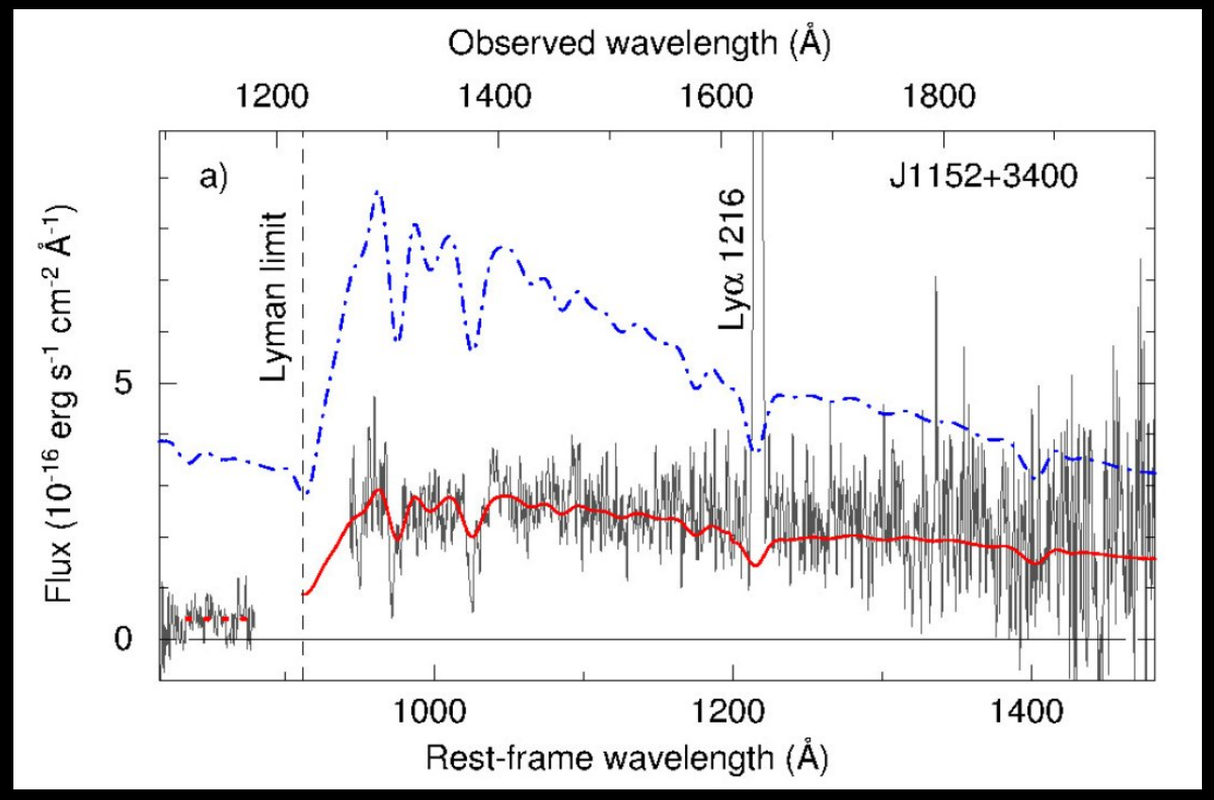


At high redshift it is <u>assumed</u> that the escape fraction is >10-20%

At z<3 the escape fraction of SFGs is <1%

Local LyC Emitters

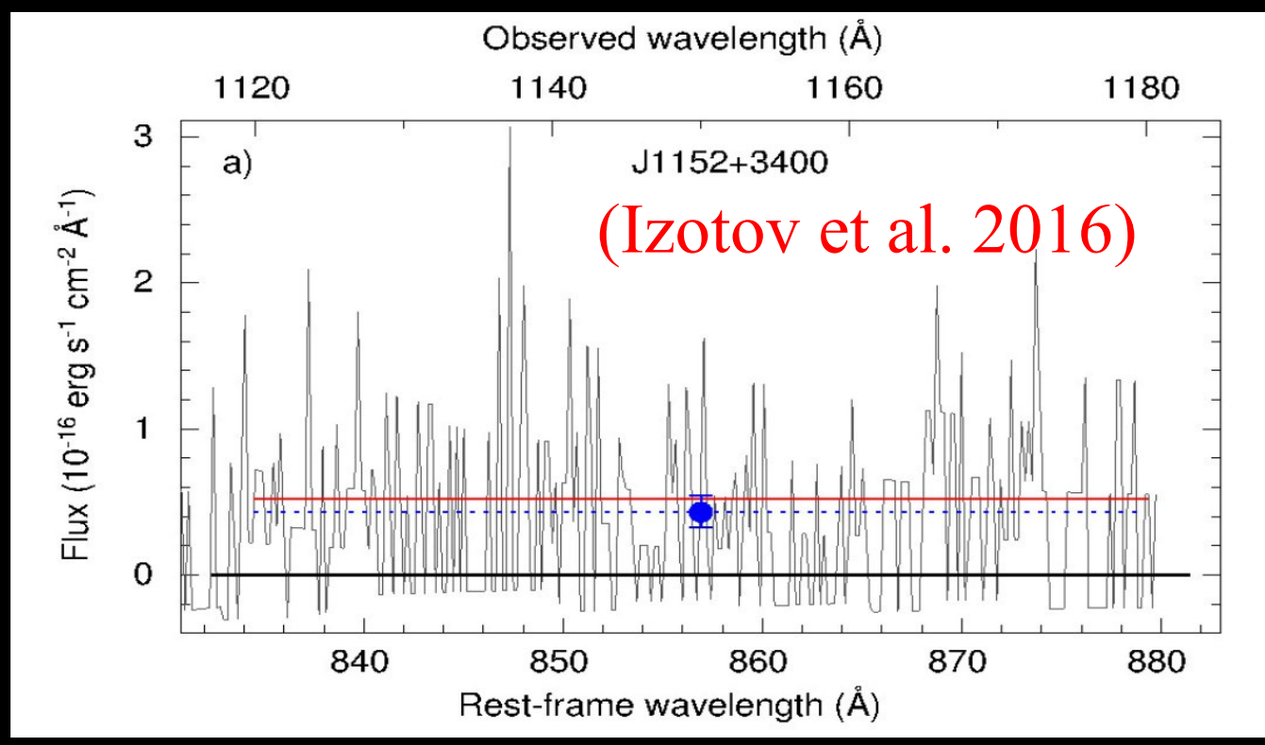




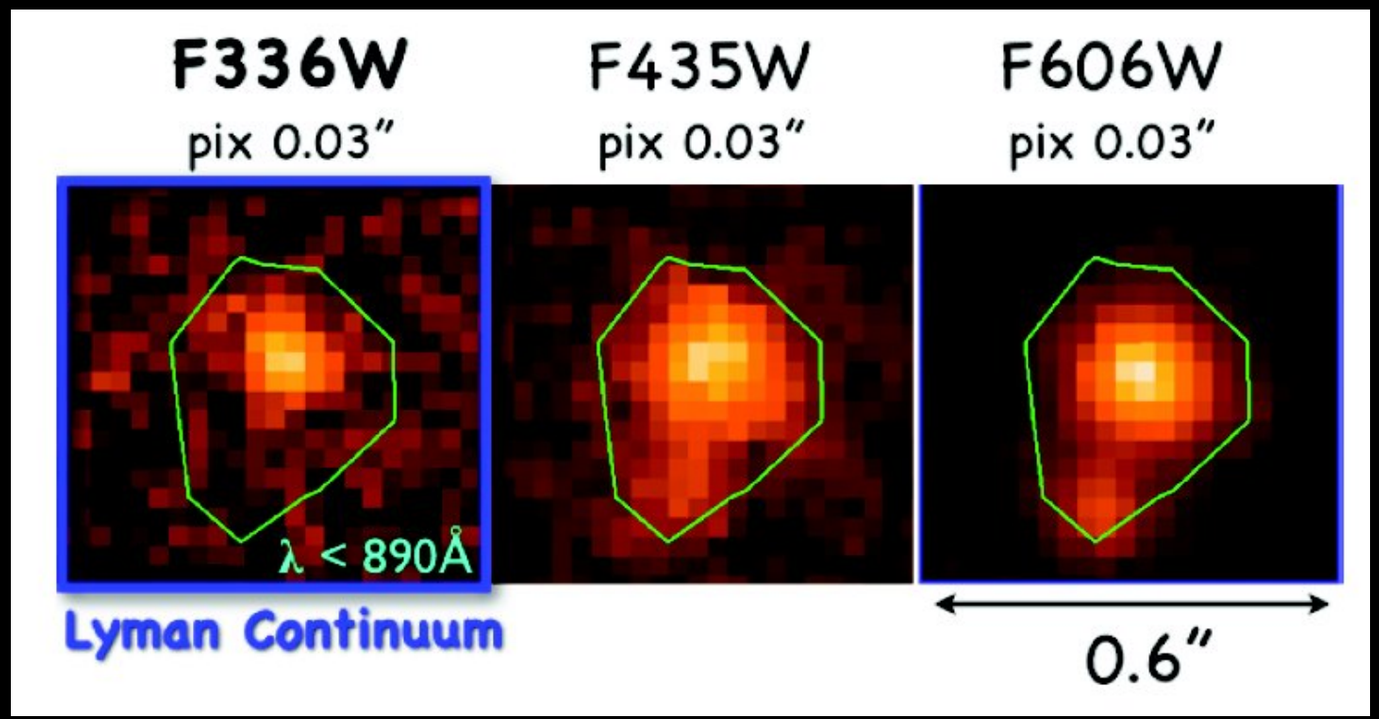
Local galaxies with OIII/OII>5 and compact morphology. Muv~-20

High ionizing photon production efficiency (Schaerer et al. 2016)

See also Leitet et al. 2013; Borthakur et al. 2014; Leitherer et al. 2016; Bergvall et al. 2016;



LyC Emitter at z=3.2

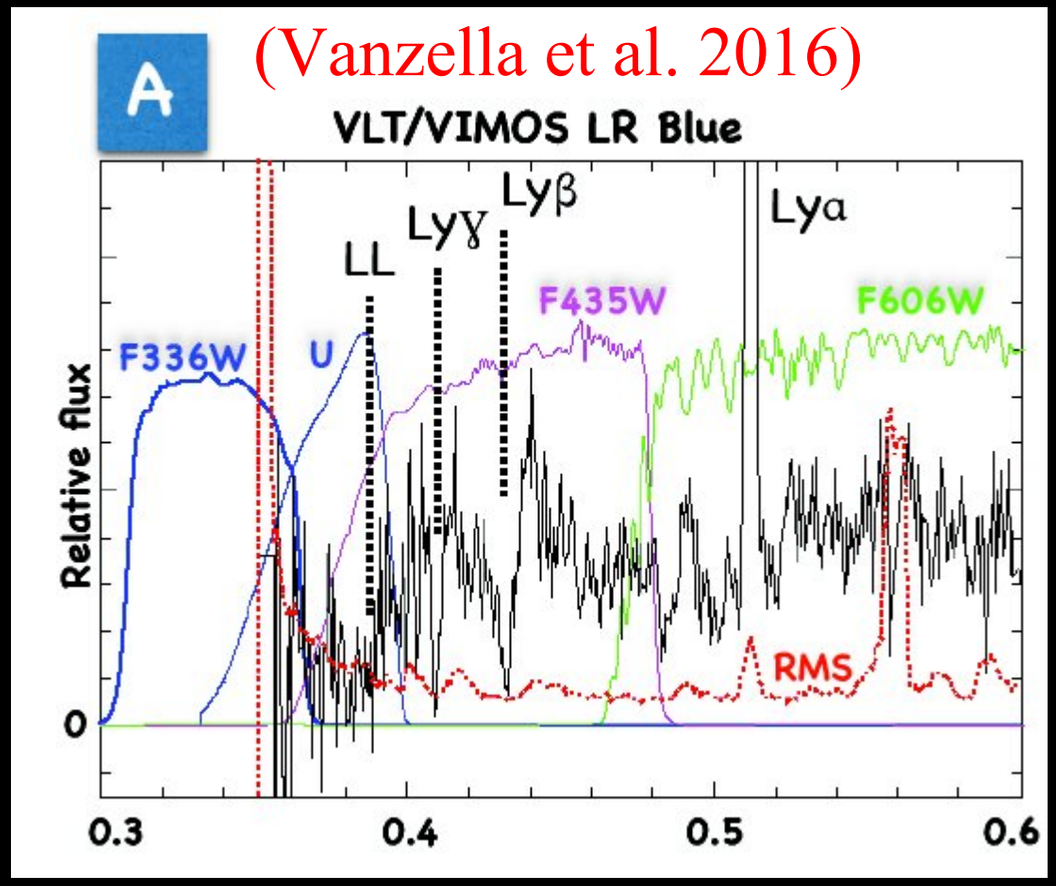


Similar properties of galaxies by Izotov et al. 2016 OIII/OII>10 and compact morphology in LyC. Muv~-21

See also Steidel et al. 2001; Shapley et al. 2006; Nestor et al. 2013; Shapley et al. 2016; Reddy et al 2016;

Important to understand their physical properties at z<4:
Find LyC emitter analogs at z>6
With indirect technique.

Study the LyC emission of whole population of SFGs



Required Ingredients...

To measure the relative escape fraction of galaxies with deep imaging

1-Deep imaging at 900 A and 1500 A rest frame (U and R band): LBC/LBT

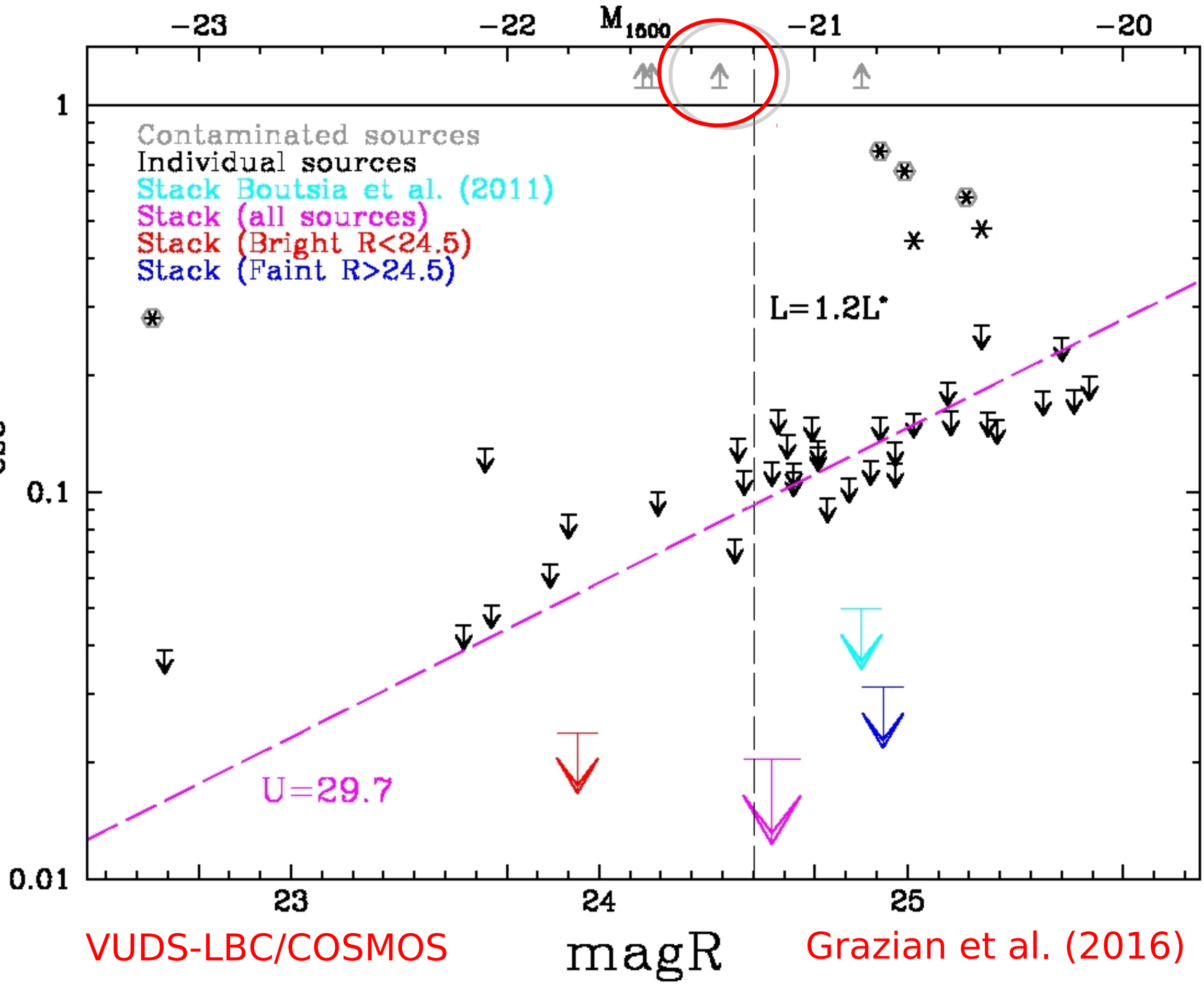
2-HST imaging to avoid spurious contamination by foreground sources

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

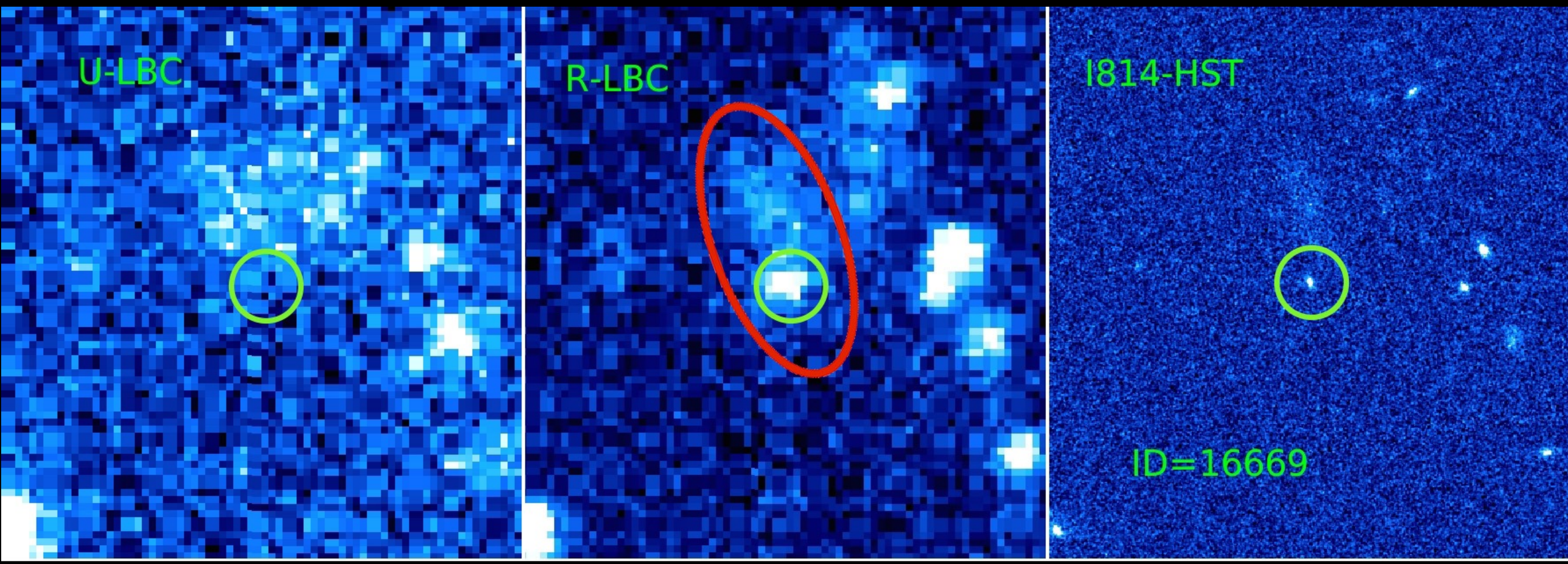
4-Large numbers of galaxies to beat down the IGM stochasticity

5-X-ray data to avoid AGNs

COSMOS; CANDELS/GOODS-North; CANDELS/EGS


−23
−22
M1500
−21
−20
1
0.1
0.01
frel esc
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
VUDS-LBC/COSMOS
Grazian et al. (2016)

Id=16669 magR=24.4

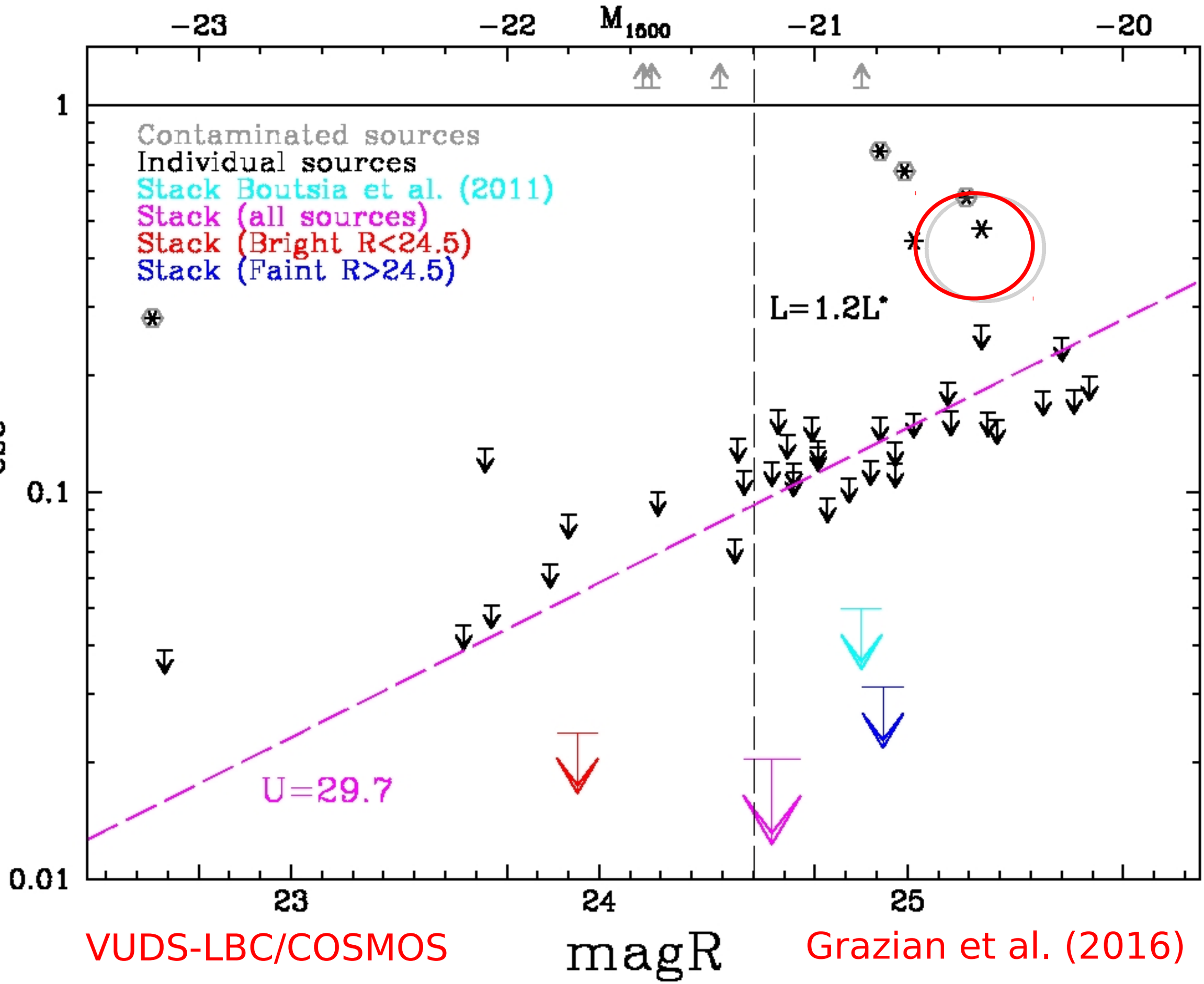


See also Siana et al. (2015)

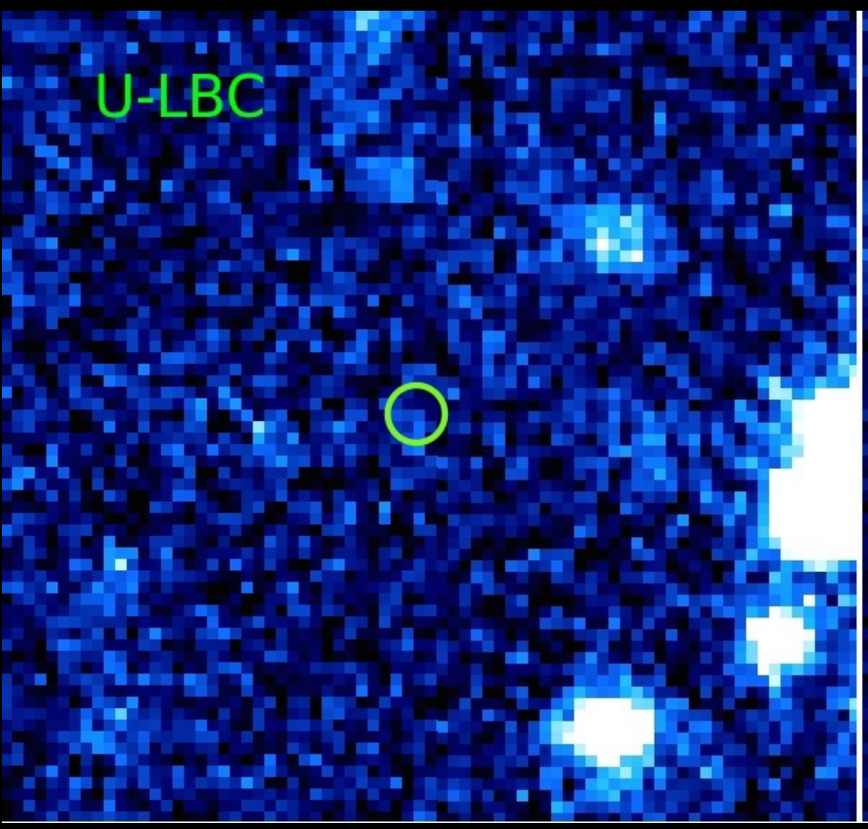
Global fesc=230%

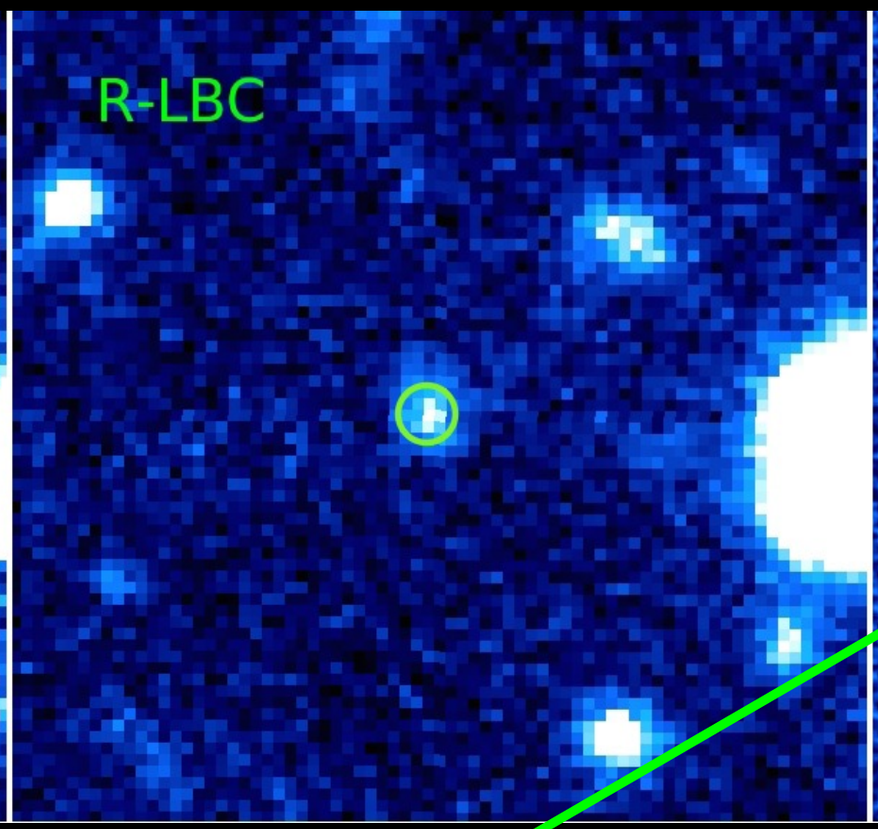
Local fesc=520%

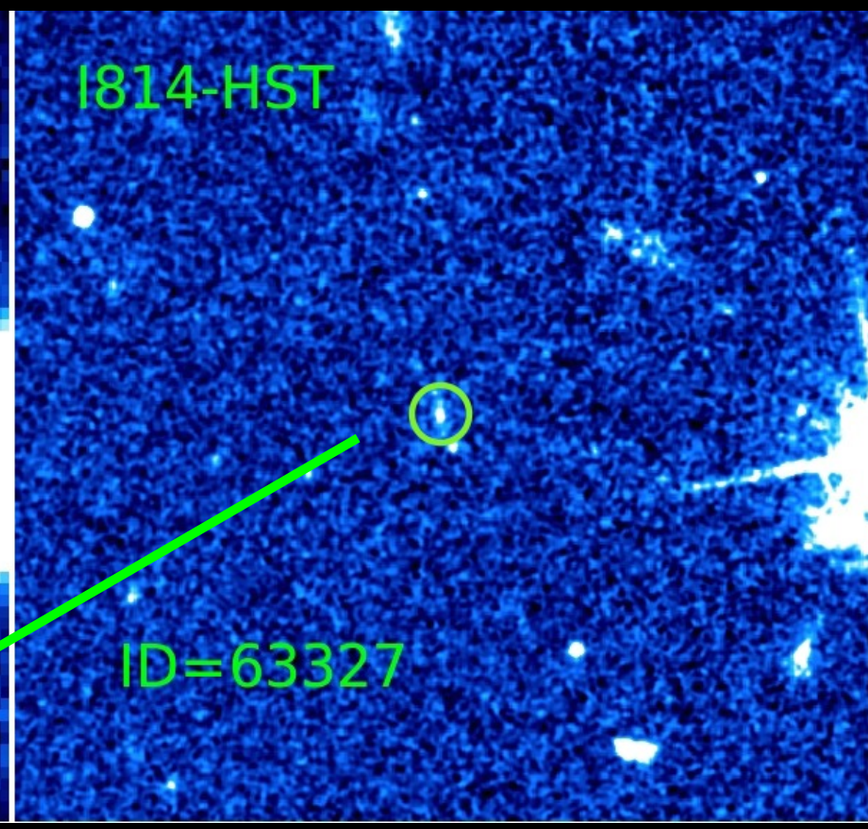
Contamination by
Foreground galaxy

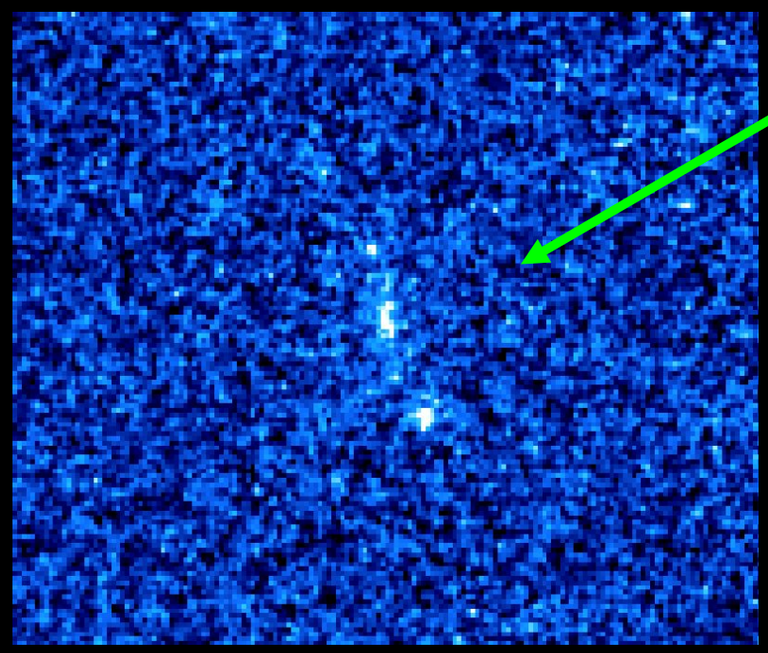

−23
−22
M1500
−21
−20
1
0.1
0.01
Contaminated sources
Individual sources
Stack Boutsia et al. (2011)
Stack (all sources)
Stack (Bright R<24.5)
Stack (Faint R>24.5)
L=1.2L*
U=29.7
23
24
25
magR
VUDS-LBC/COSMOS
Grazian et al. (2016)

Id=63327 magR=25.02









Fesc=45%

Possible LyC emitter!!!

Detailed analysis on-going...

Contamination ???

Starting Sample

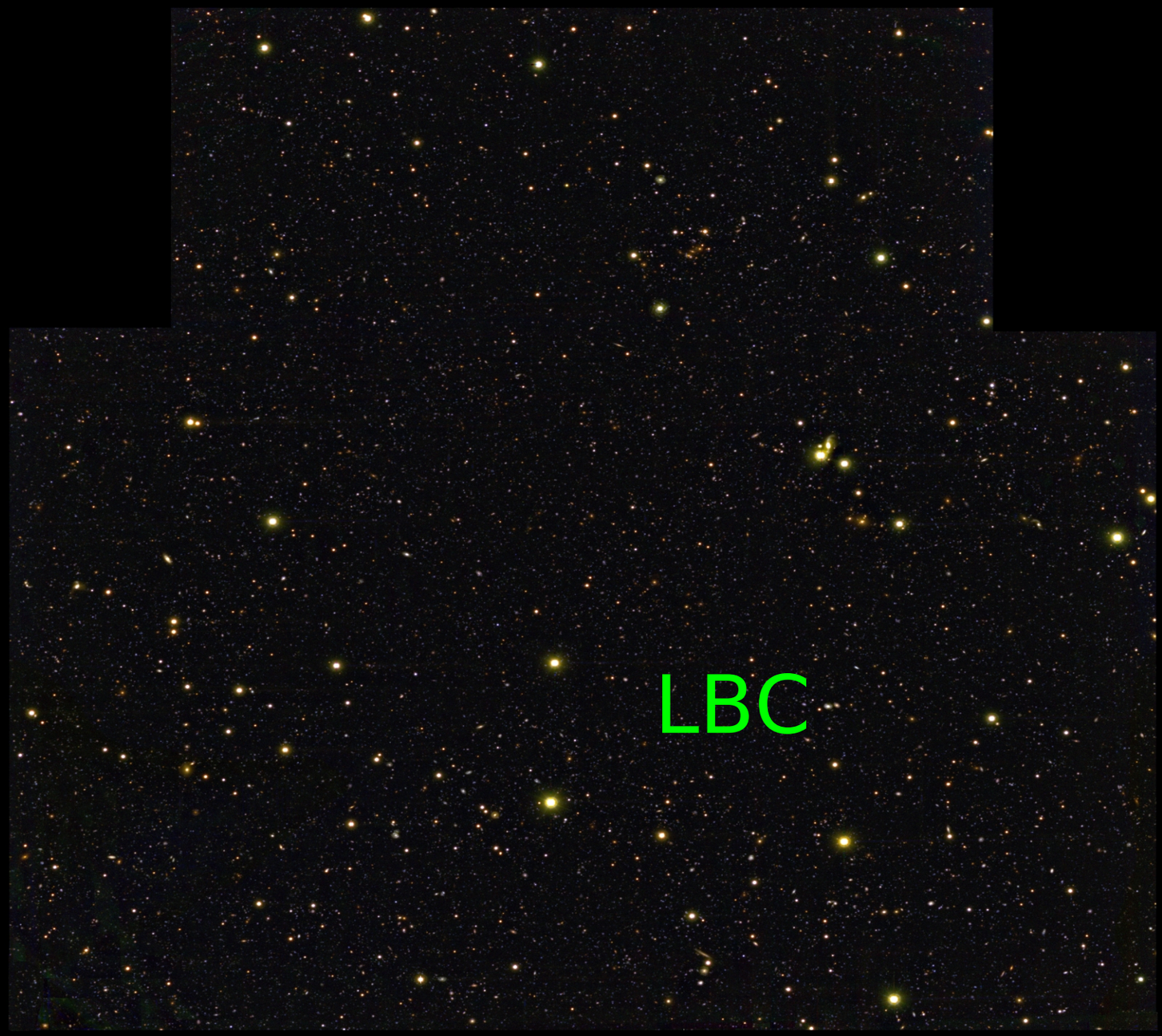
Deep U and R band imaging with LBC at LBT

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



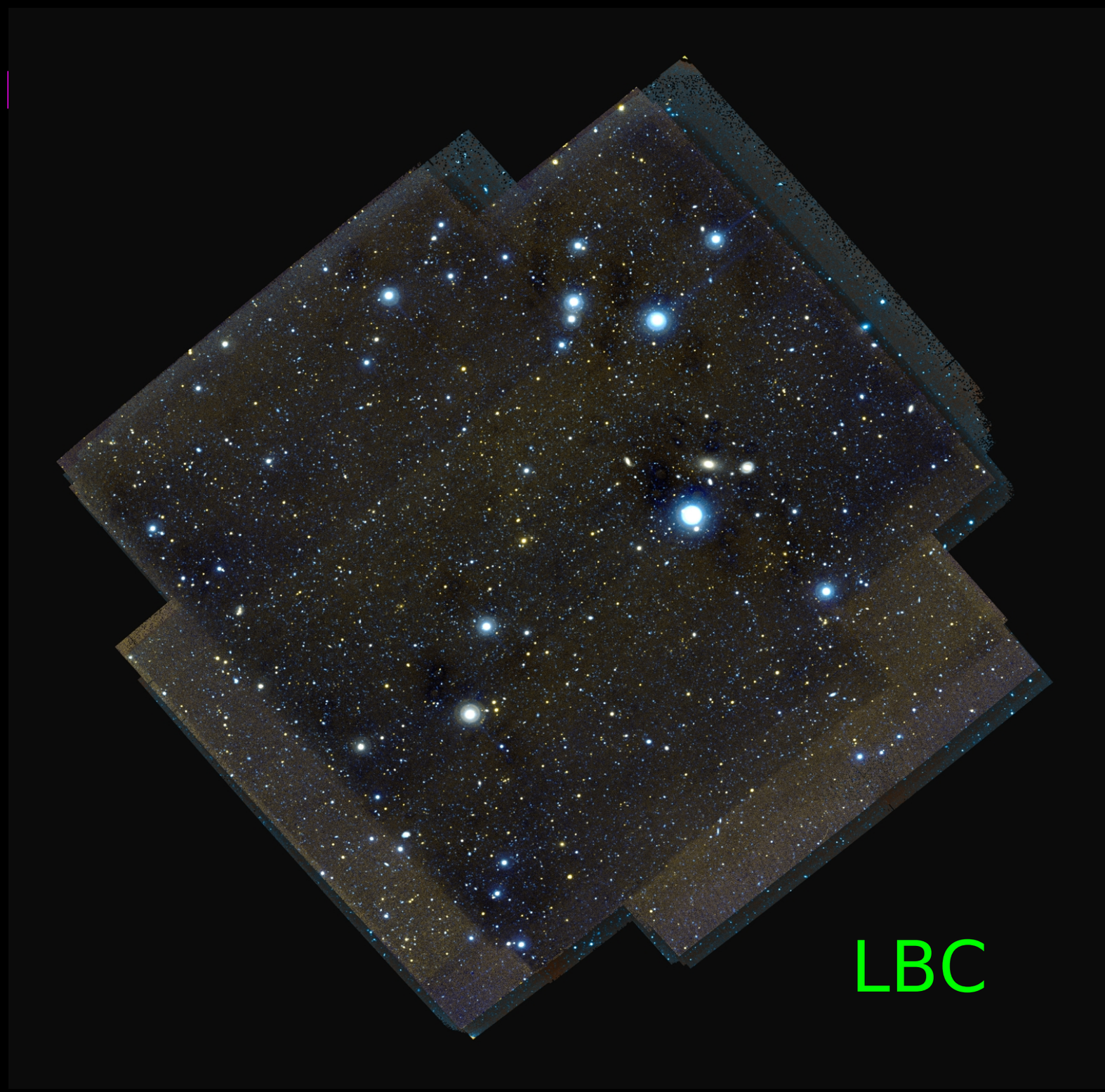
Enlarging the Sample....

CANDELS EGS field

2 LBC pointings in U band
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

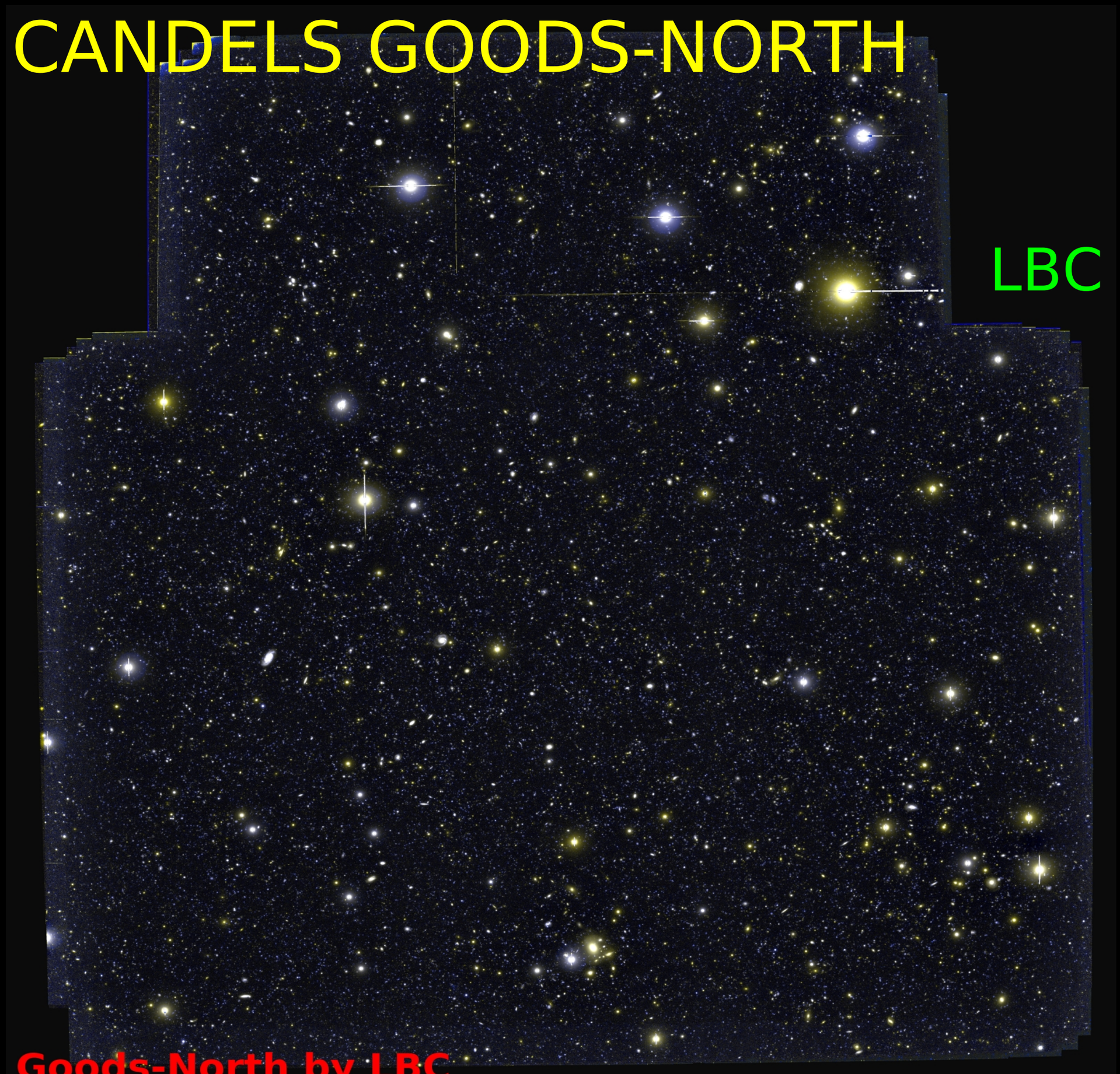


CANDELS GOODS-NORTH

33 hours in the U-band Seeing=1.1”

26 hours in the R-band Seeing=1.0”

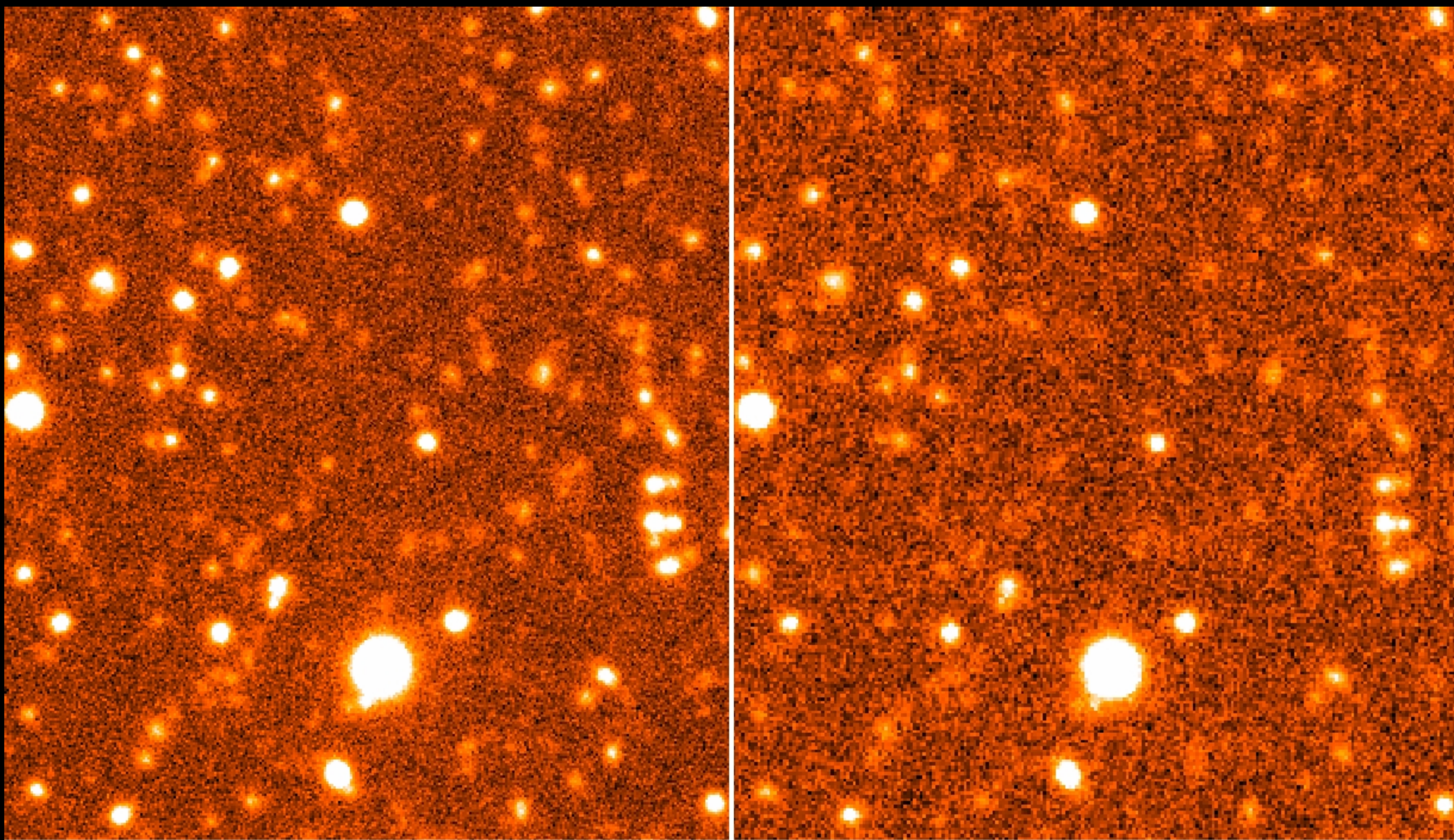
Data reduced by LSC (INAF-OARoma)



Ultra Deep U-band

LBC 33 hours

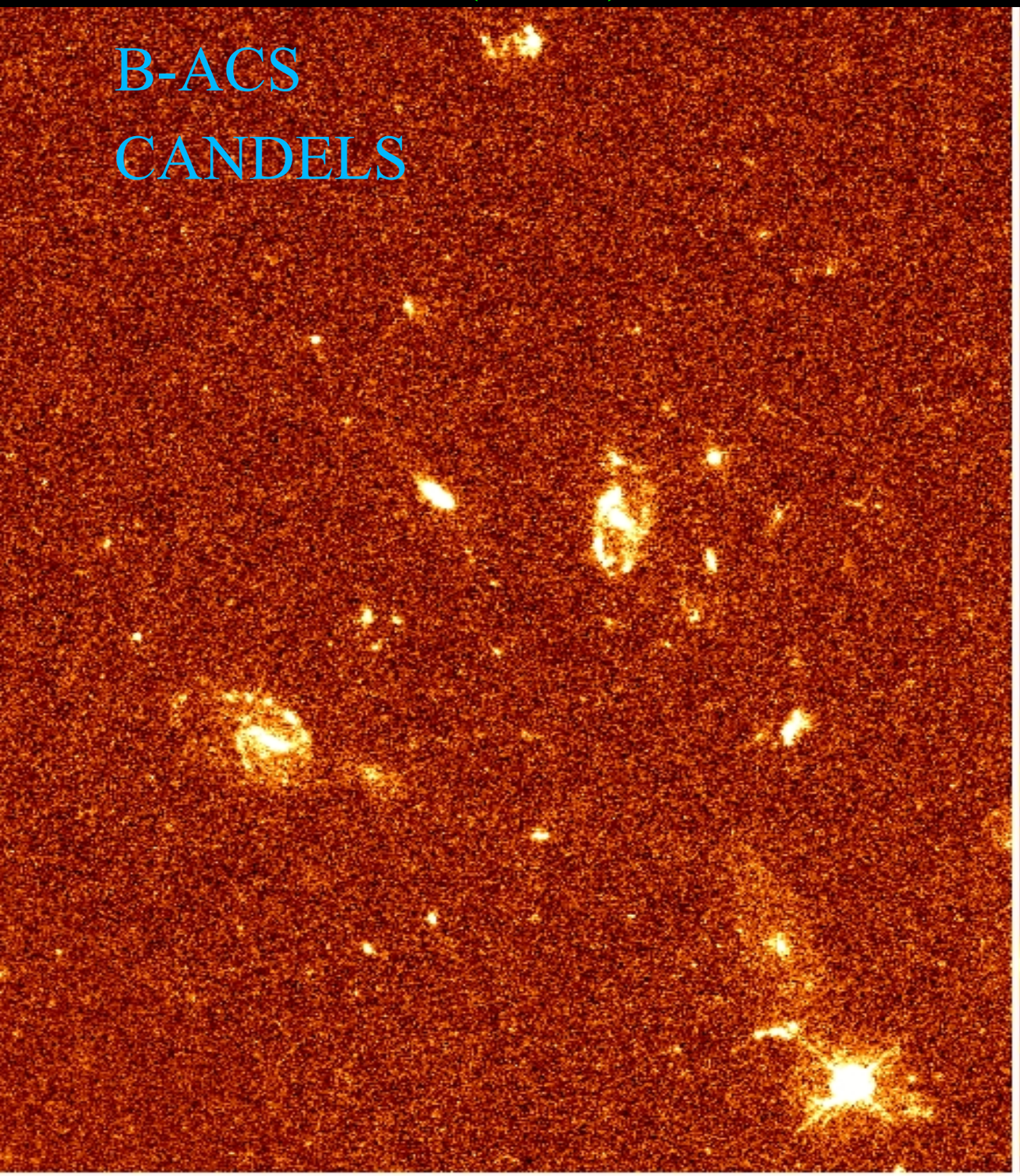
KPNO 50 hours

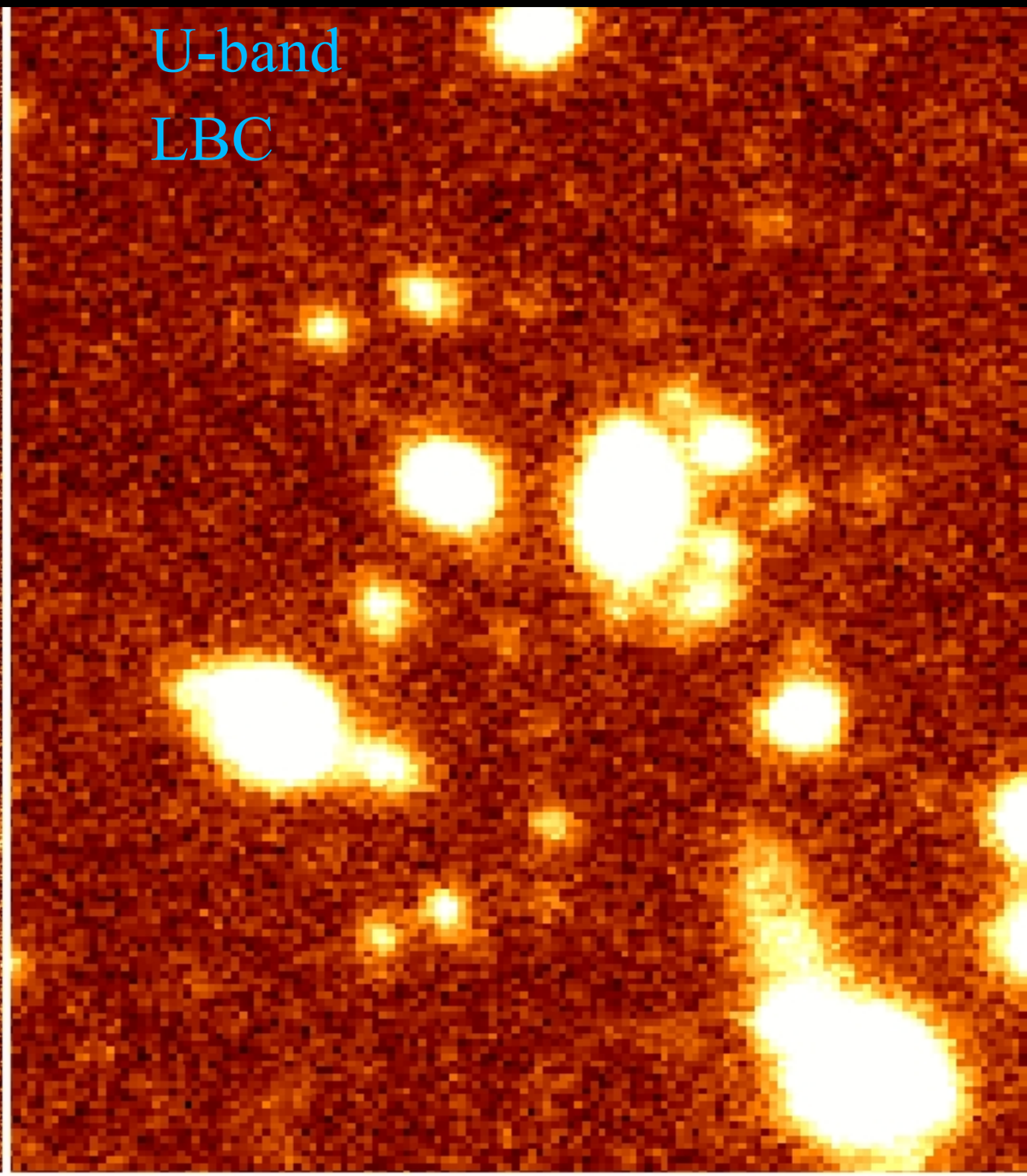


One of the Deepest U-band images of the World...

Giavalisco et al. (2004)

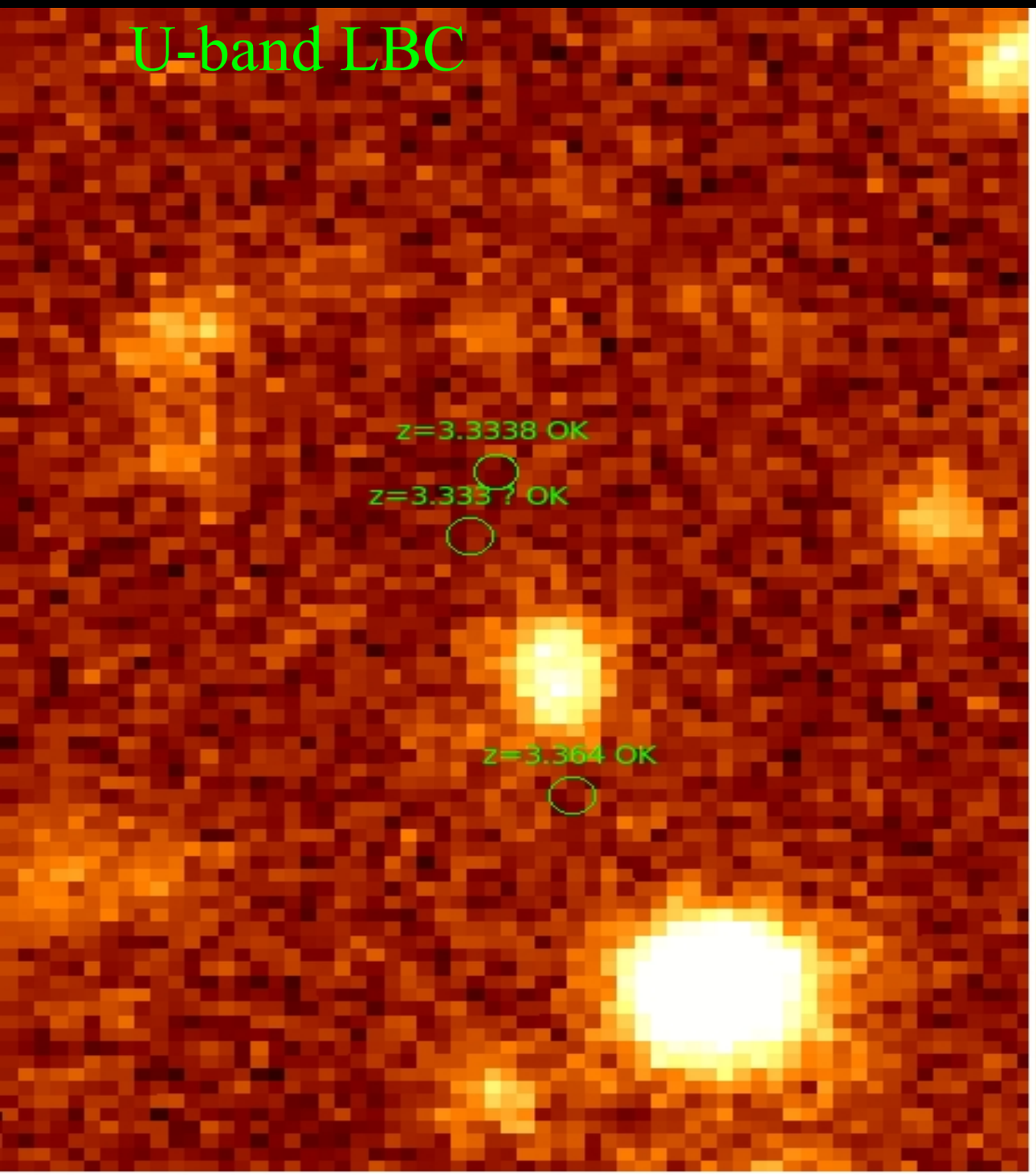
U=30.2 AB mag (1 sigma)

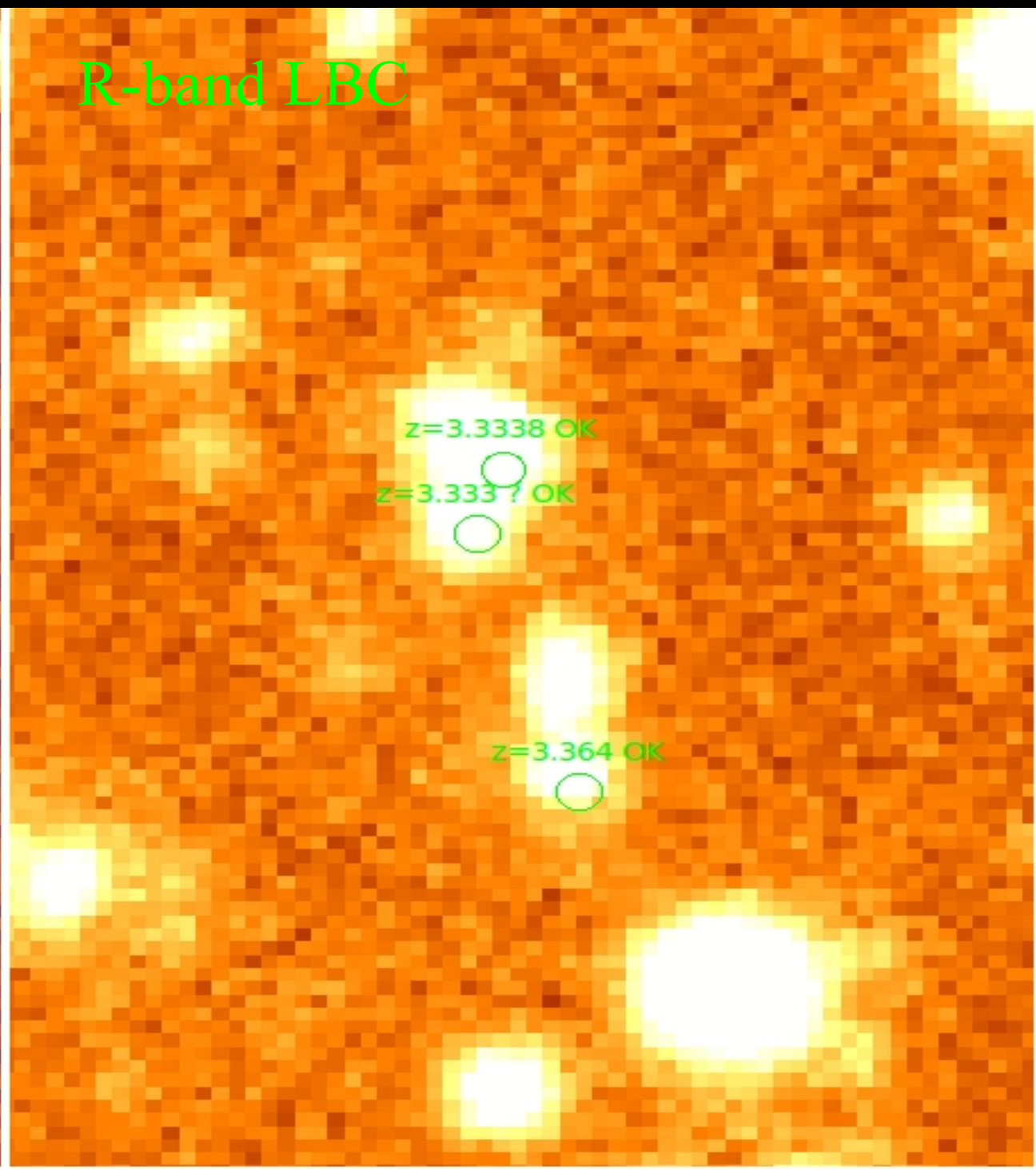




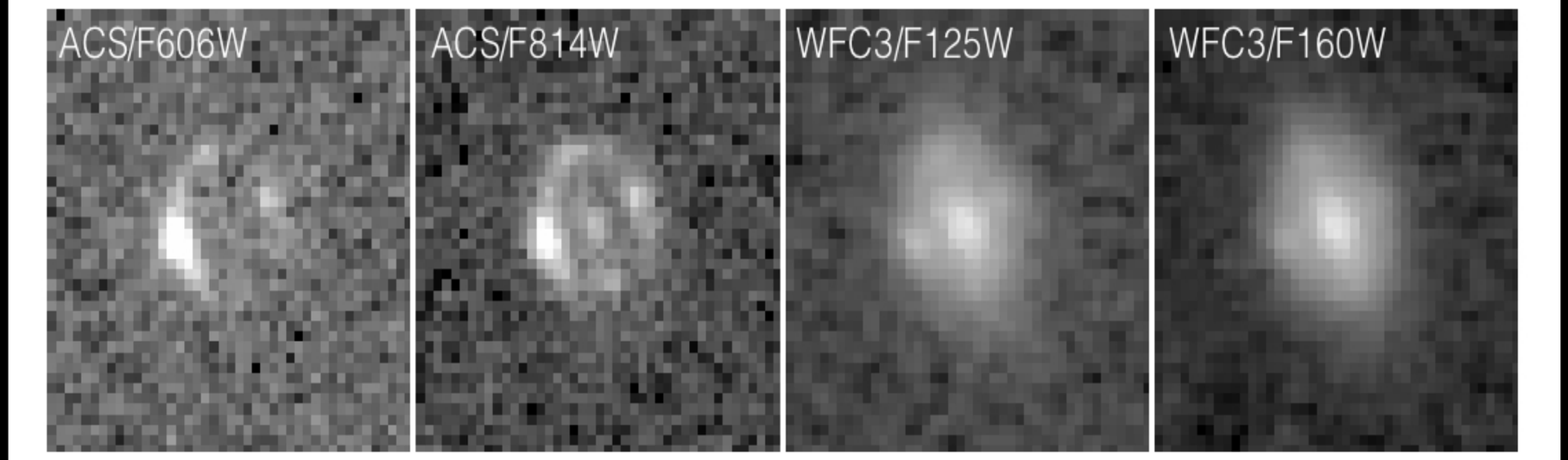
z=3.3 galaxies in GOODS-North

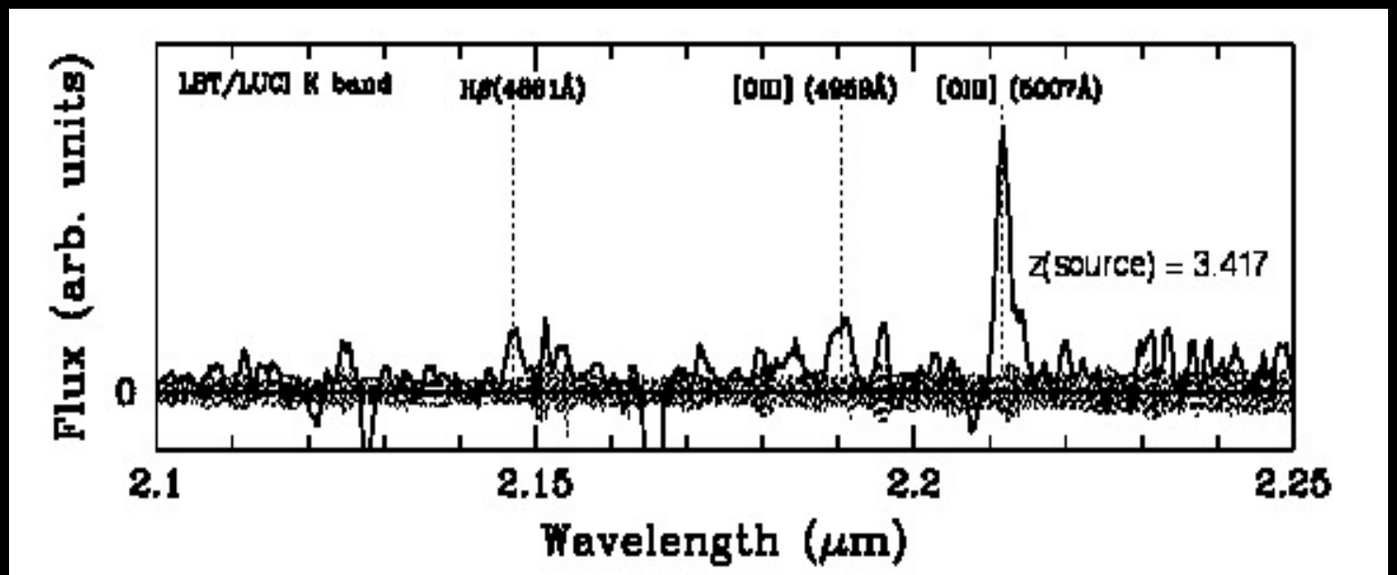
9 galaxies at z~3.3 have been added to the original sample.





Galaxy-Galaxy strong lensing





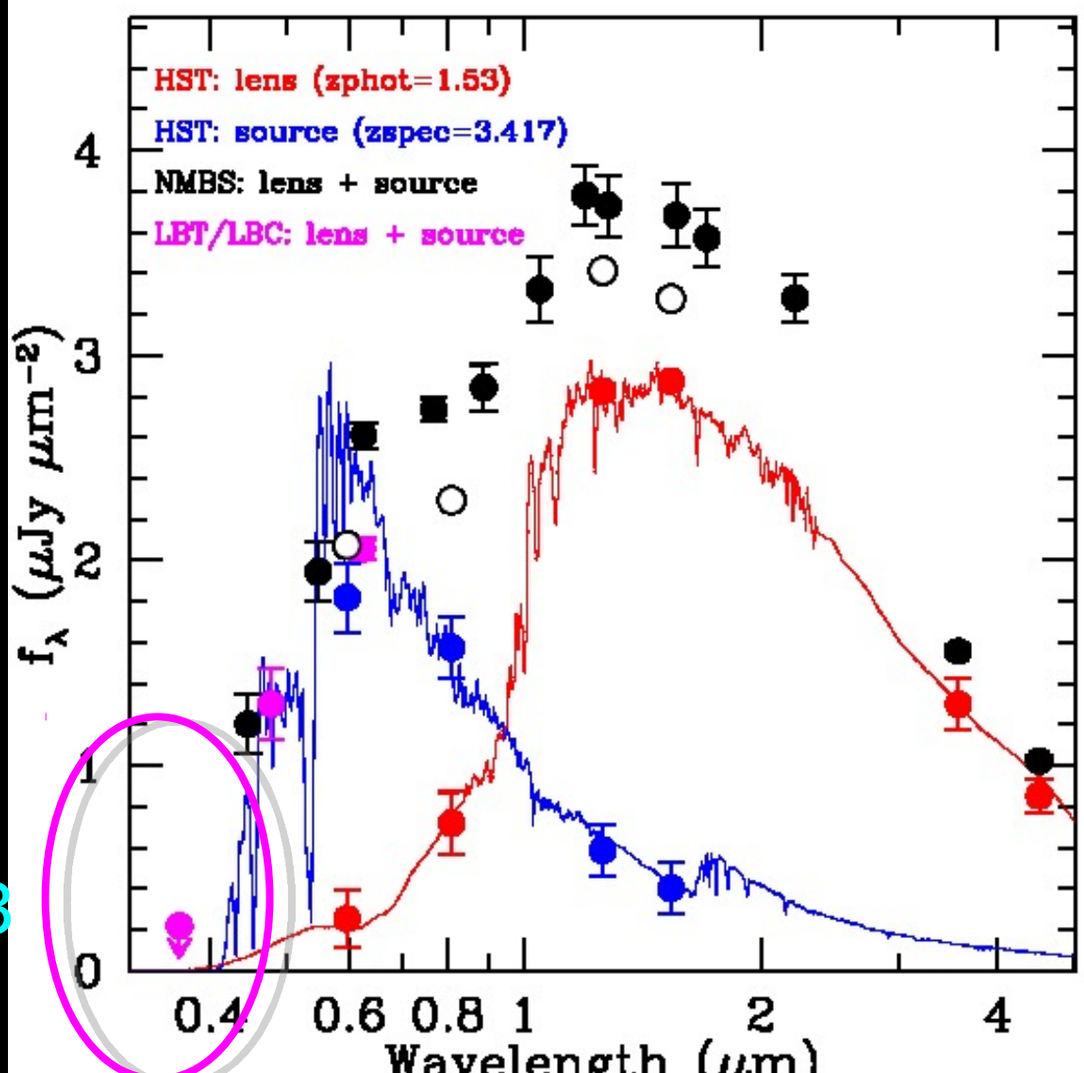
z=3.417 mu=40x

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)



LyC Escape Fraction of z~3 Galaxies

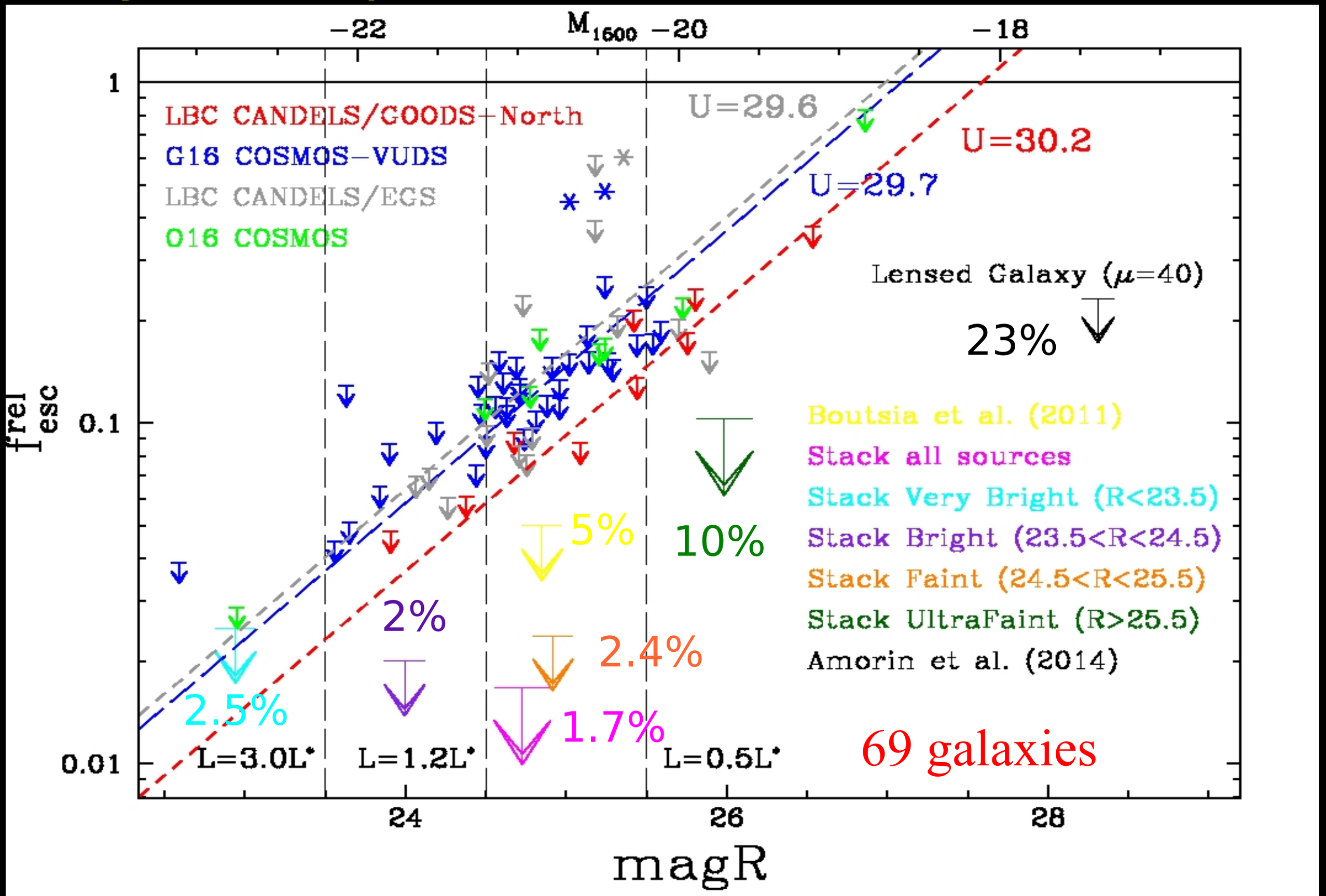
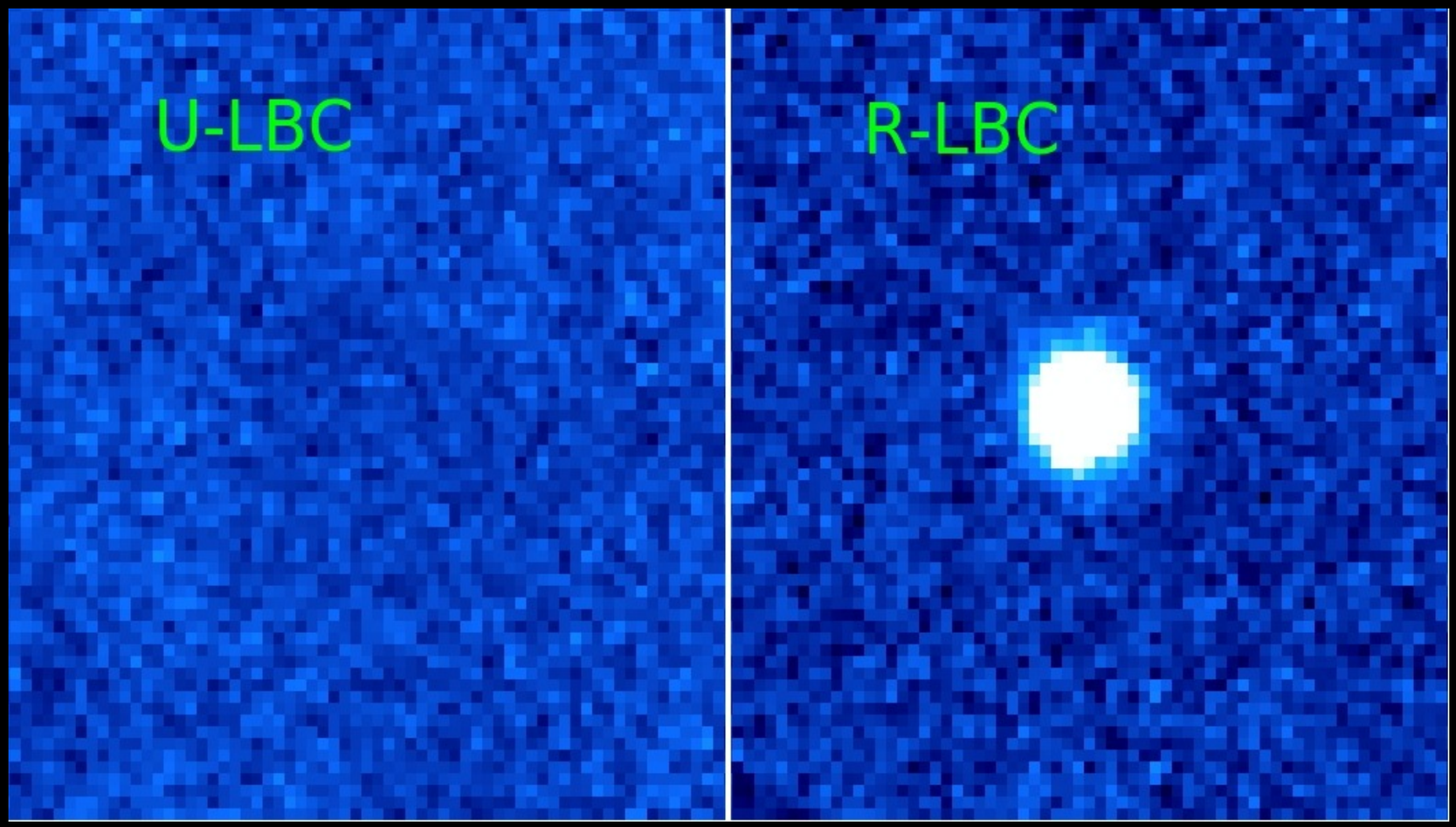


Image stacking in U and R

U band
LBC



R band
LBC

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

f1500/f900obs>640.2

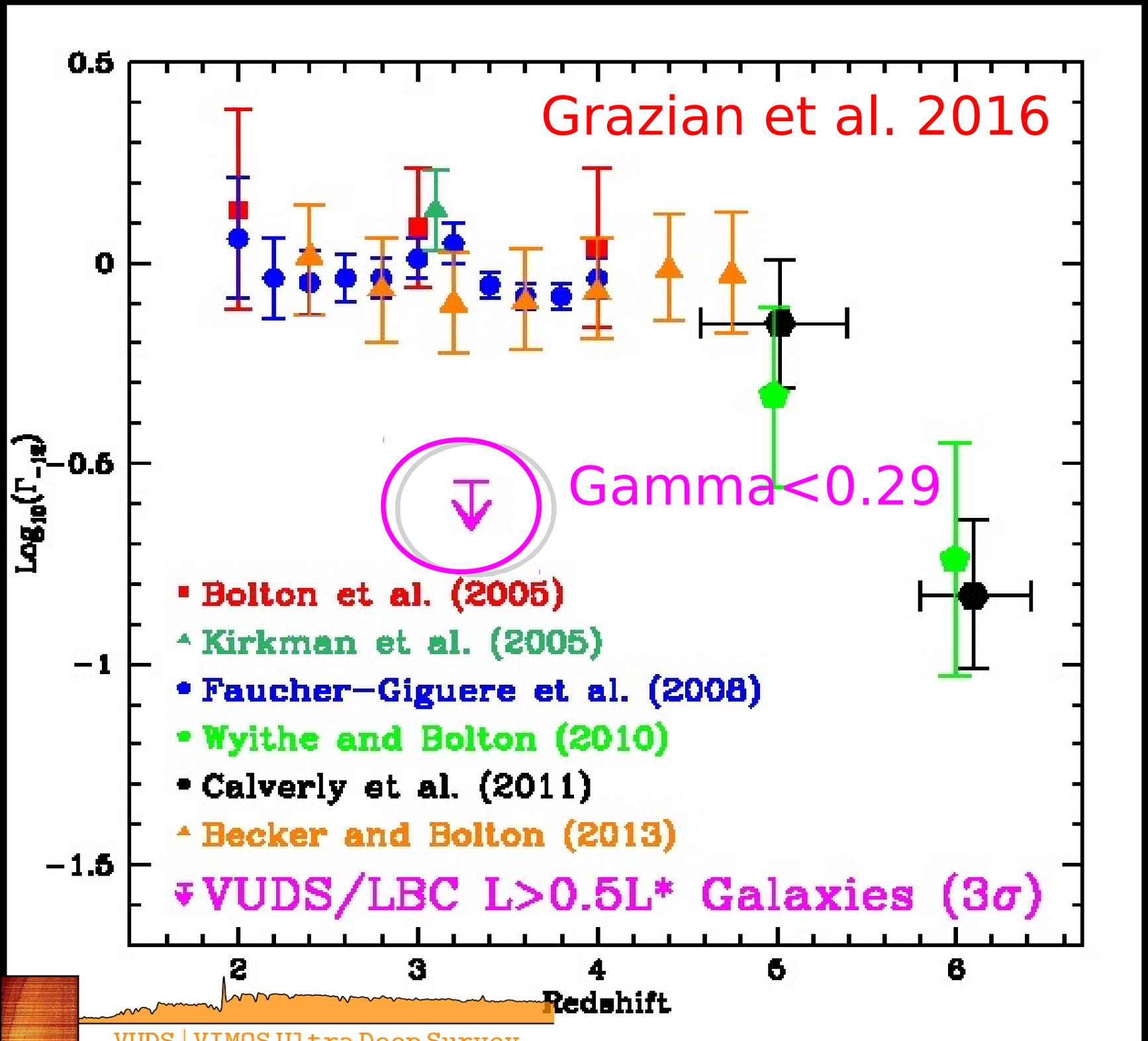
fesc_rel<1.7% (1 sigma) at z=3.3 for R<26.5

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

Grazian et al. (in prep)

COSMOS+GOODS-NORTH+EGS

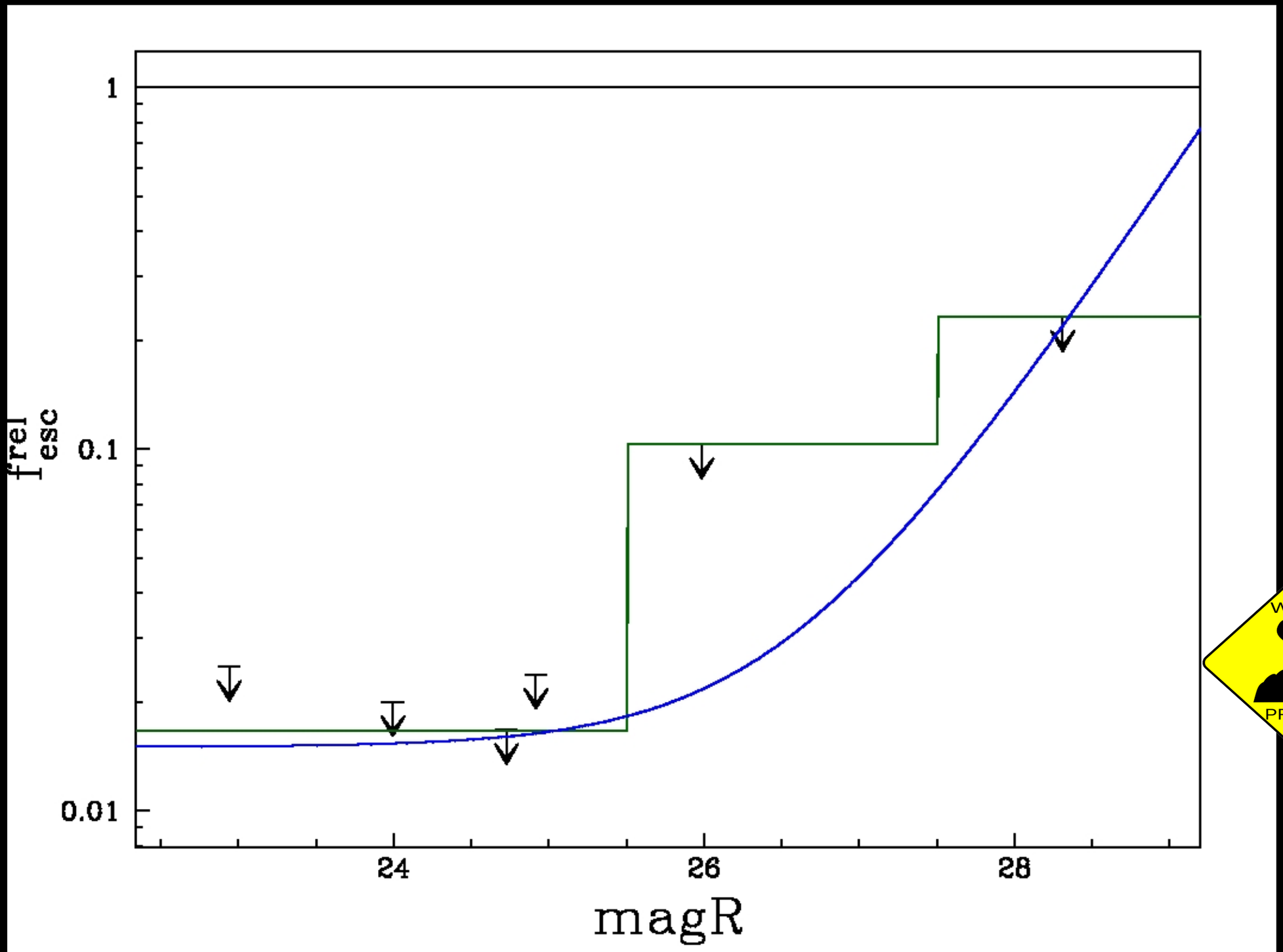
HI Photoionization rate
UVB by bright galaxies (L>0.5L*)



Bright Galaxies have low fesc

What about faint galaxies ?

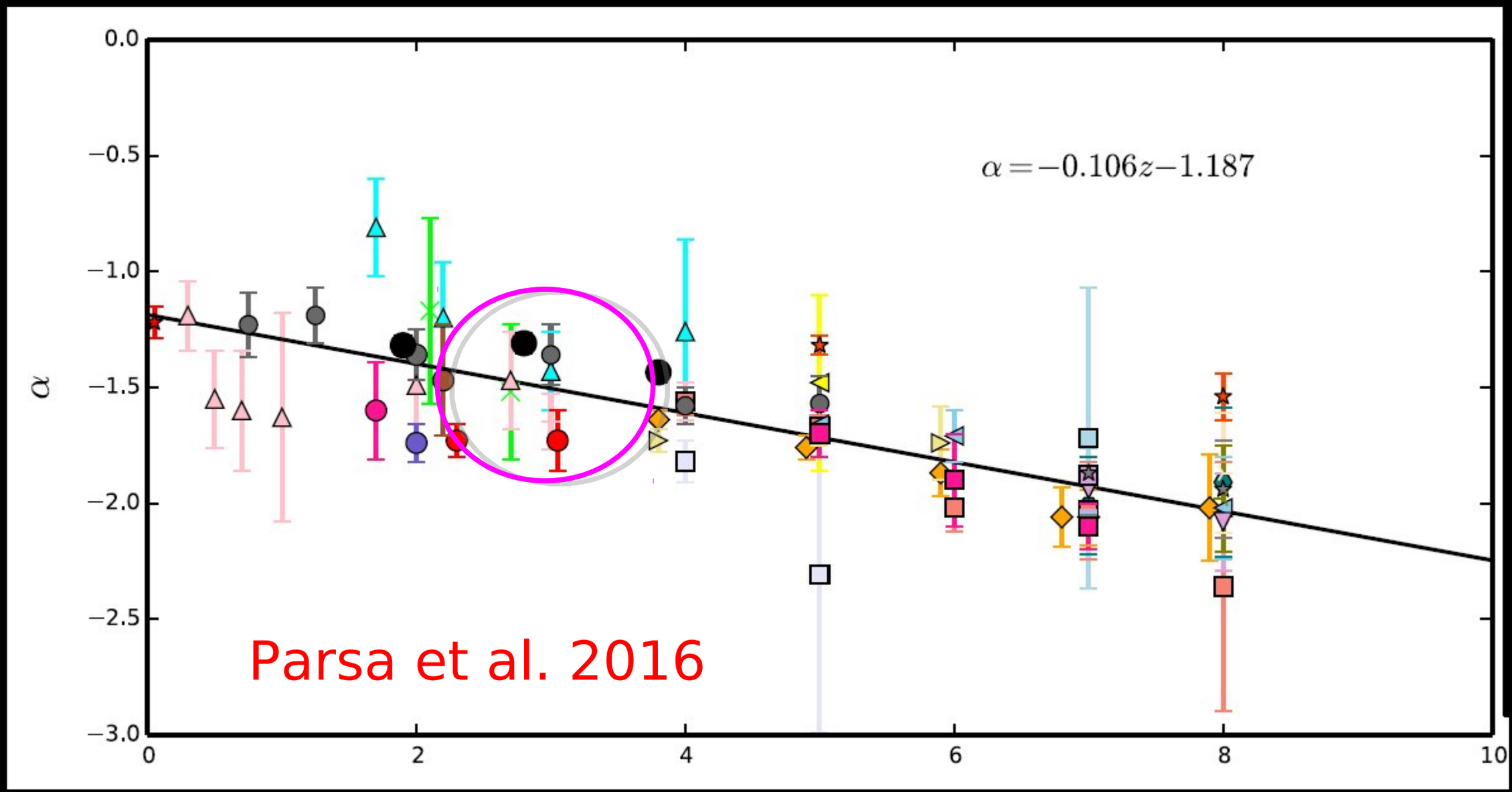
Evolution of fesc with Luminosity



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



Alternative solutions to study Reionization

Bright QSOs are very rare.

What about Faint AGNs ?....

See talk by E. Giallongo

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 and rapid reionization by Planck 2016.
Patchy reionization scenario: Treu et al. (2012) and Pentericci et al. (2014).

Thank you!