The Lyman Continuum escape fraction of Star-forming galaxies at z~3: The UV side of CANDELS with LBC/LBT

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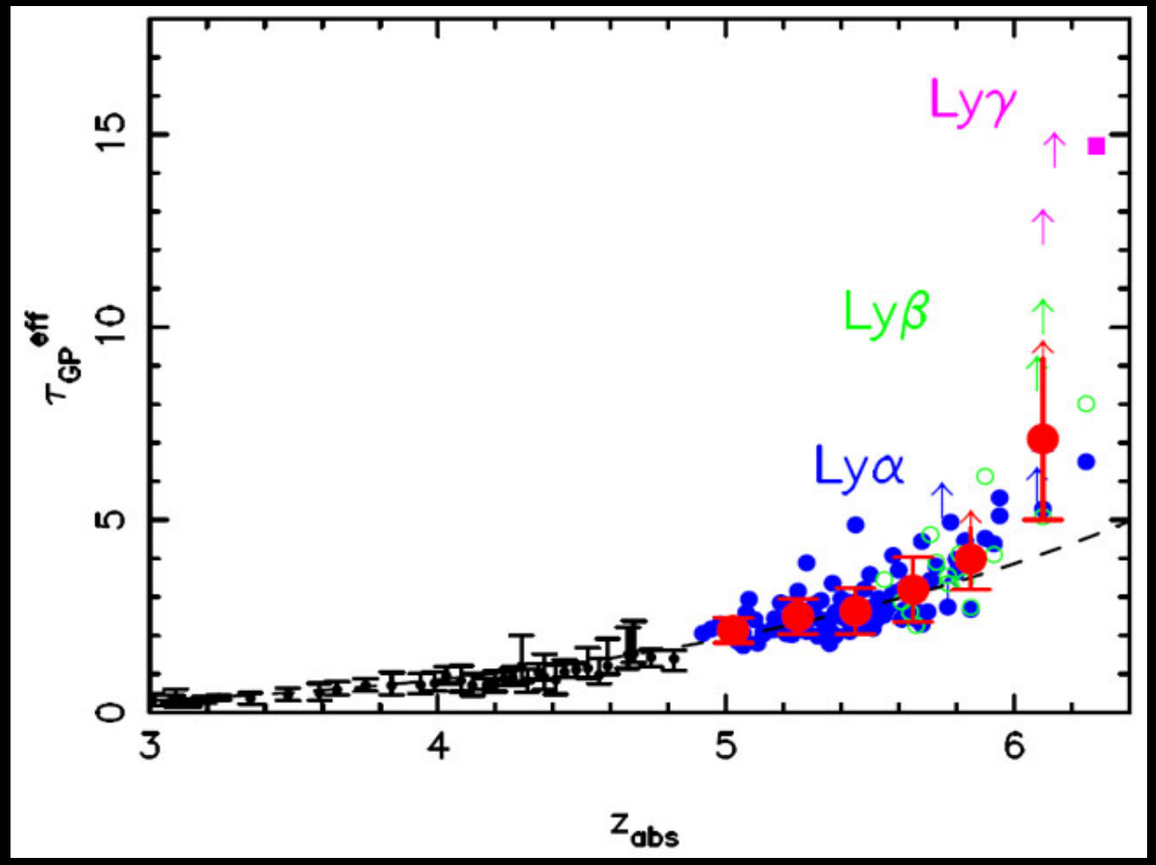
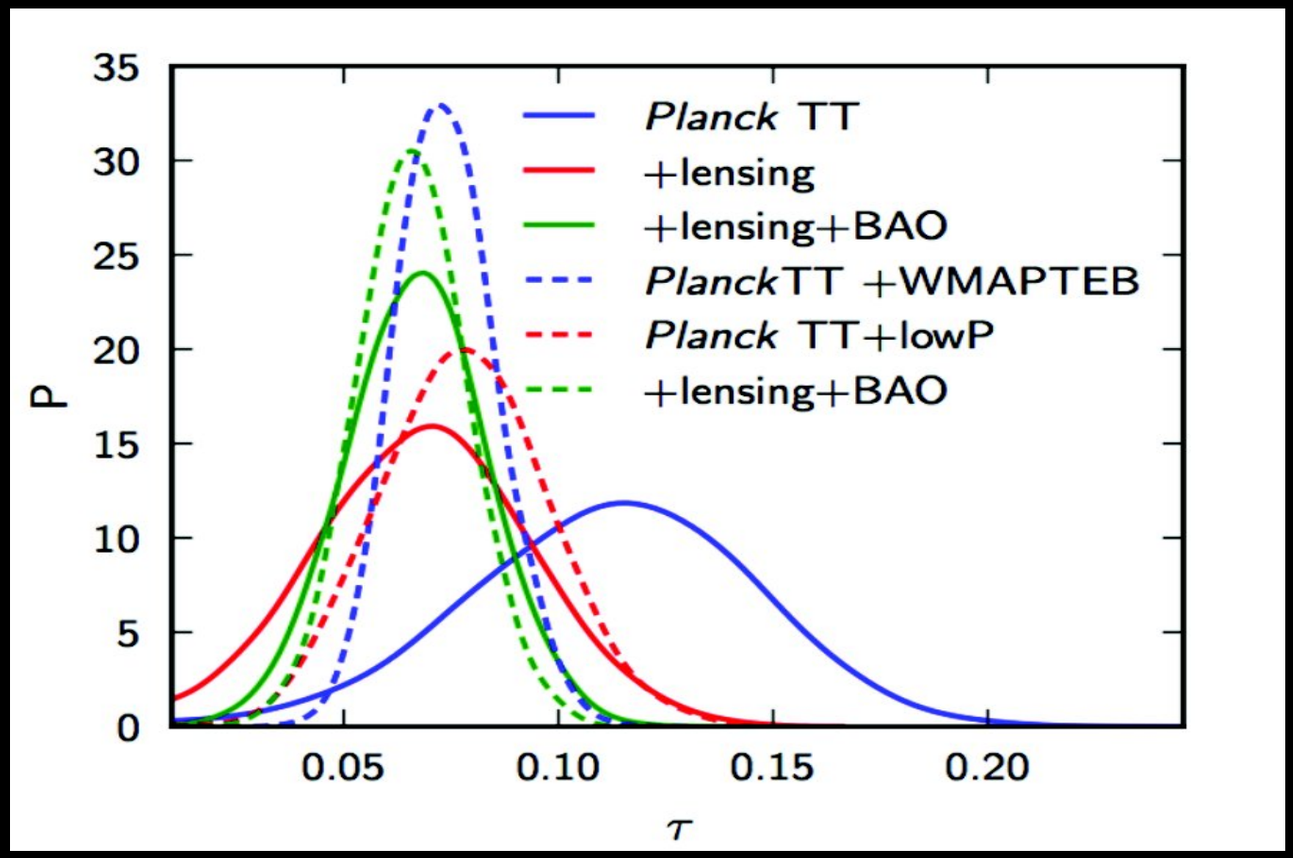
E. Giallongo, A. Fontana, M. Nonino, E. Vanzella, R. Windhorst, R. O'Connell, C. Scarlata, M. Dickinson, L. Pentericci, M. Castellano, R. Amorin, L. Guaita, R. Gerbasi, et al.

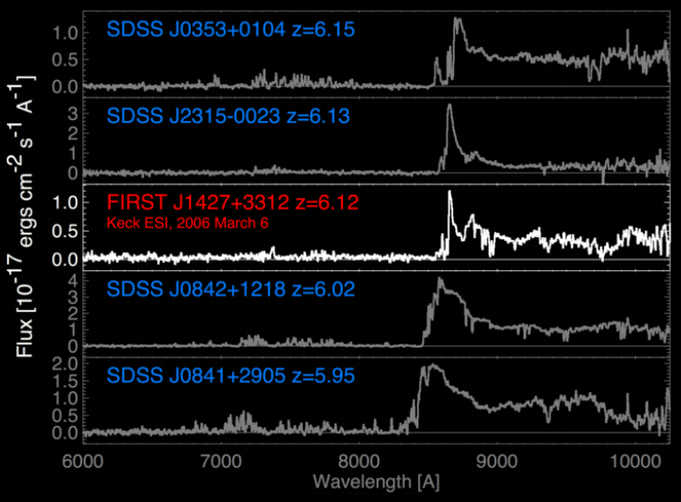
January 26th-30th, 2015 Sesto Pusteria (Italy)

The SED of high-z Galaxies: lessons learned and open questions

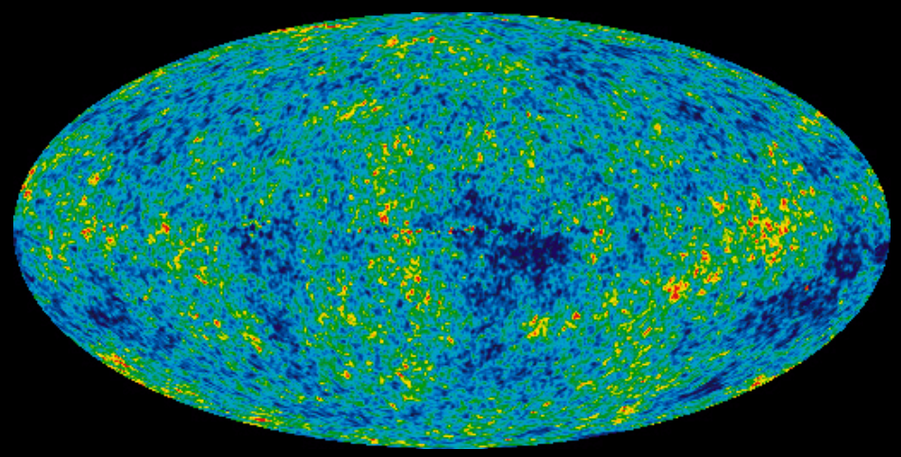
Motivation







+



=> 6 < z < 11

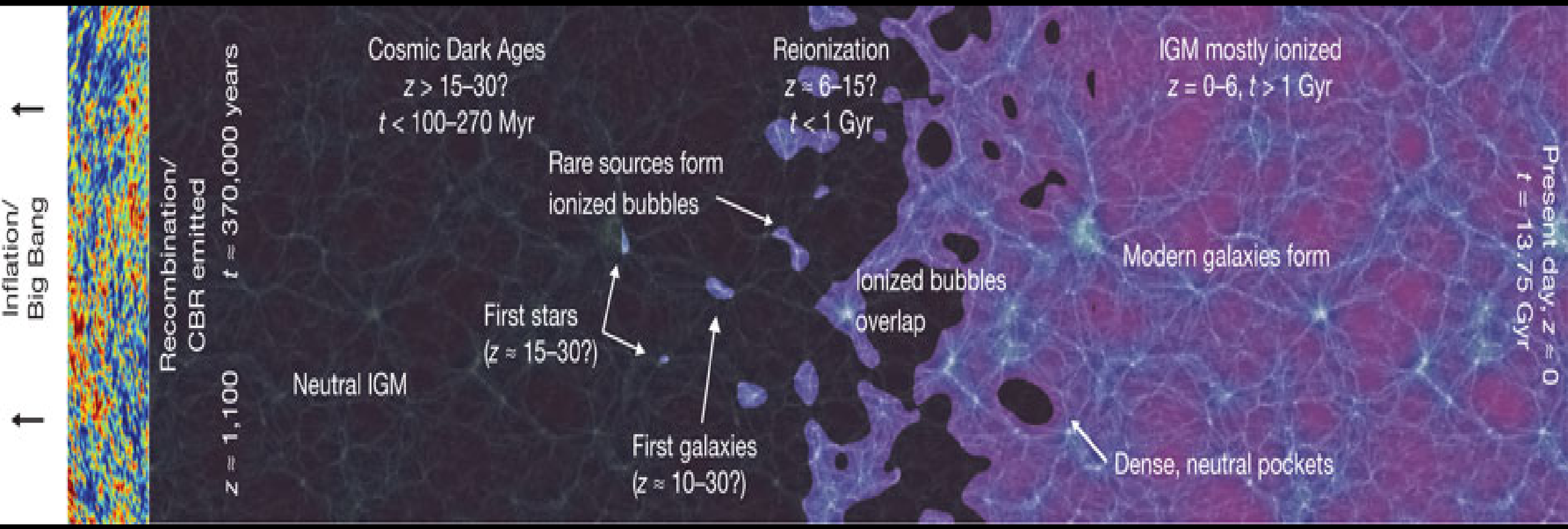
- Gunn-Peterson troughs suggest reionization ending at z=6

But 10^-4 HI fraction gives τ >>1

Planck 2014 preliminary results suggest τ=0.079+/-0.017 (or lower!)

- Implies reionization at z<~11 But it is an integral quantity.
- SPT kSZ George+2014: Delta_z<5.4

Sources of Reionization

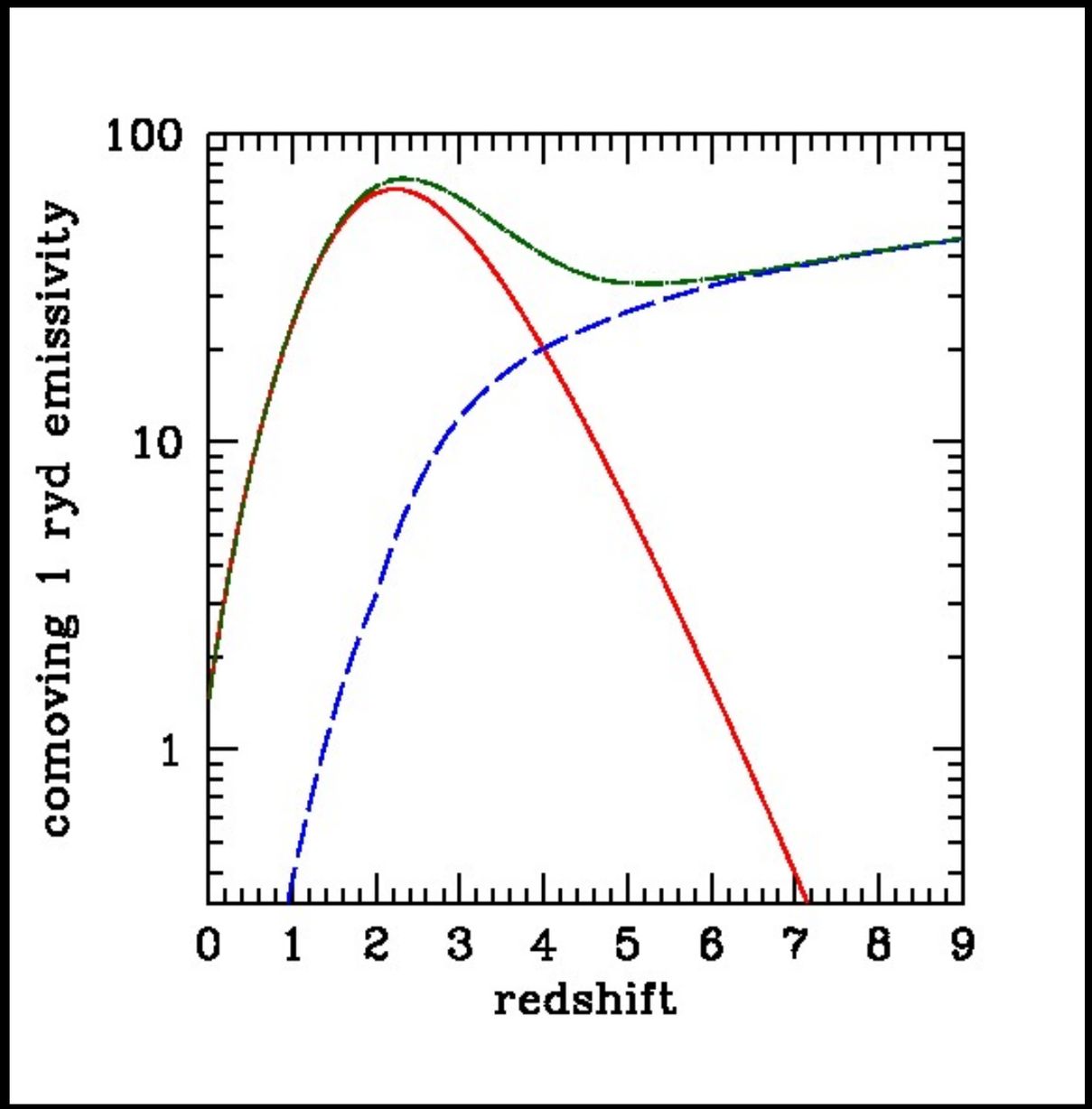


Reionization 6<z<11: Galaxies or AGNs ?

Bright QSOs (Haardt & Madau 2012)

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

Galaxies can be Important at z>3.



Direct detection of LyC from galaxies is possible at z~3.

At higher redshift it is <u>assumed</u> that the escape fraction is 20-50%

Estimating fesc: Method

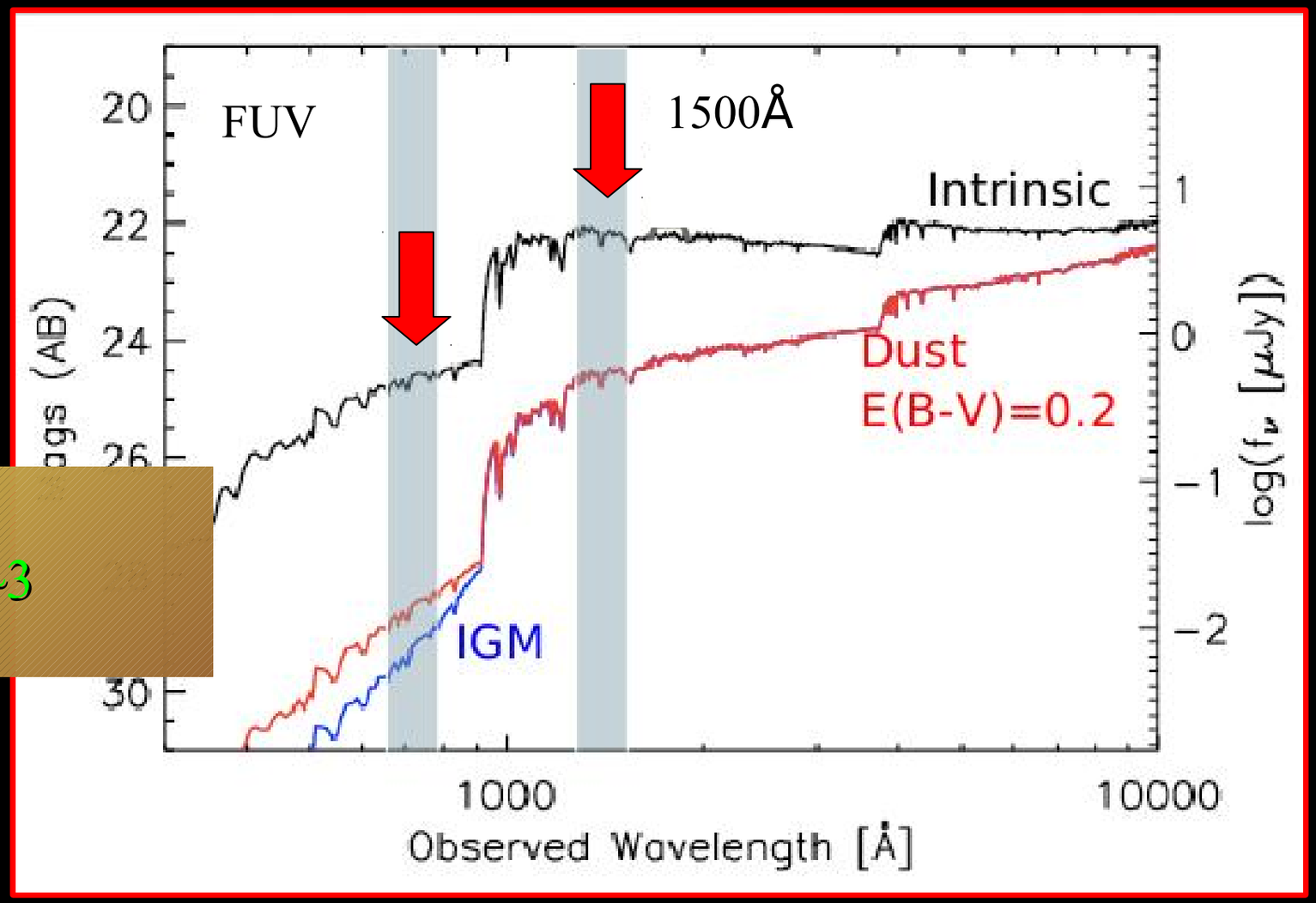
$$f_{\rm esc,rel} \equiv \frac{(L1500/L900)_{\rm int}}{(F1500/F900)_{\rm obs}} \exp\left(\tau_{900}^{\rm IGM}\right)$$

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

(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.

Difficult measure !
Δm~5 → fesc~8% @ z~3

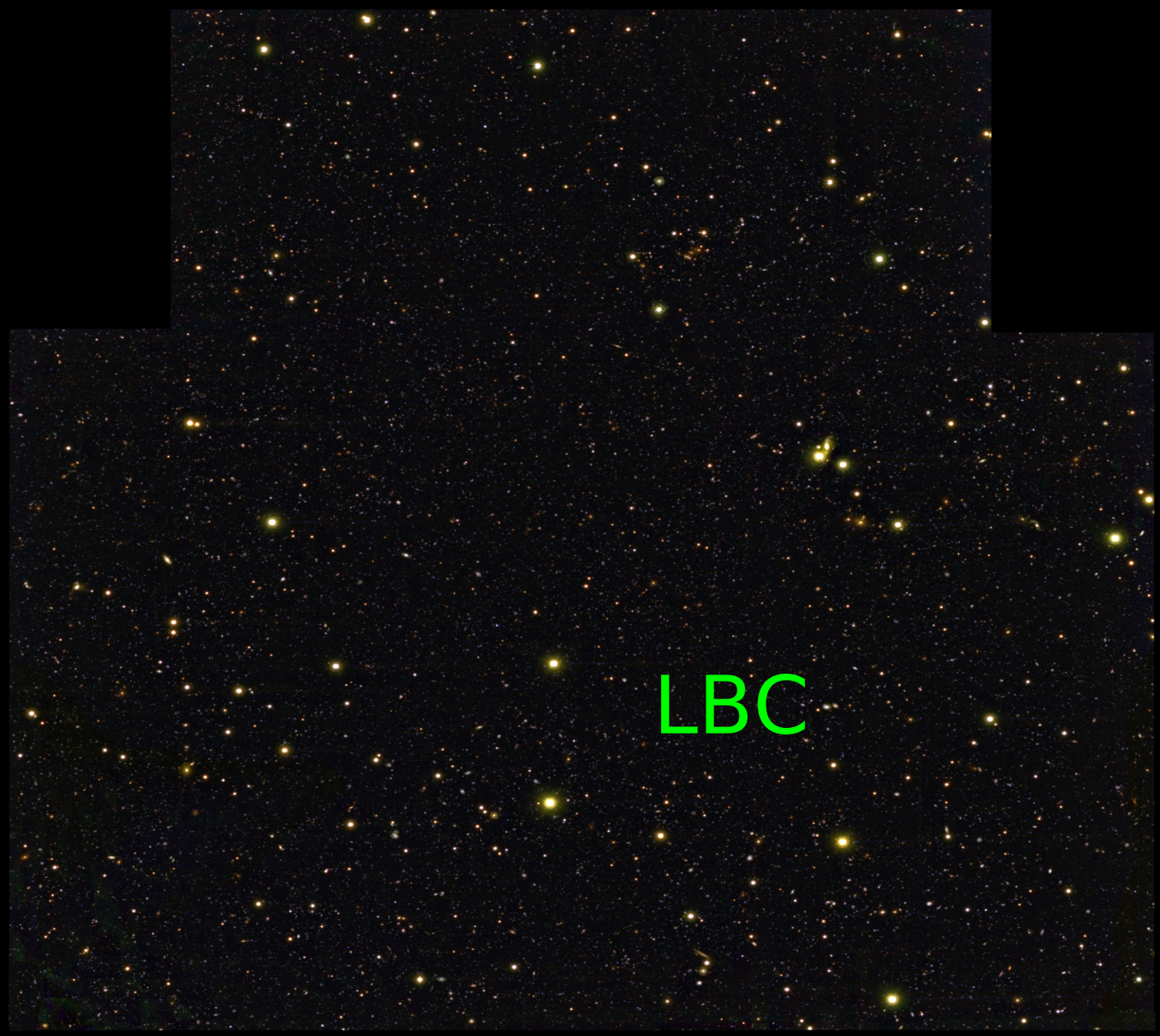


Ionizing Escape Fraction at z~3.3

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. arcmin2
Boutsia+2014

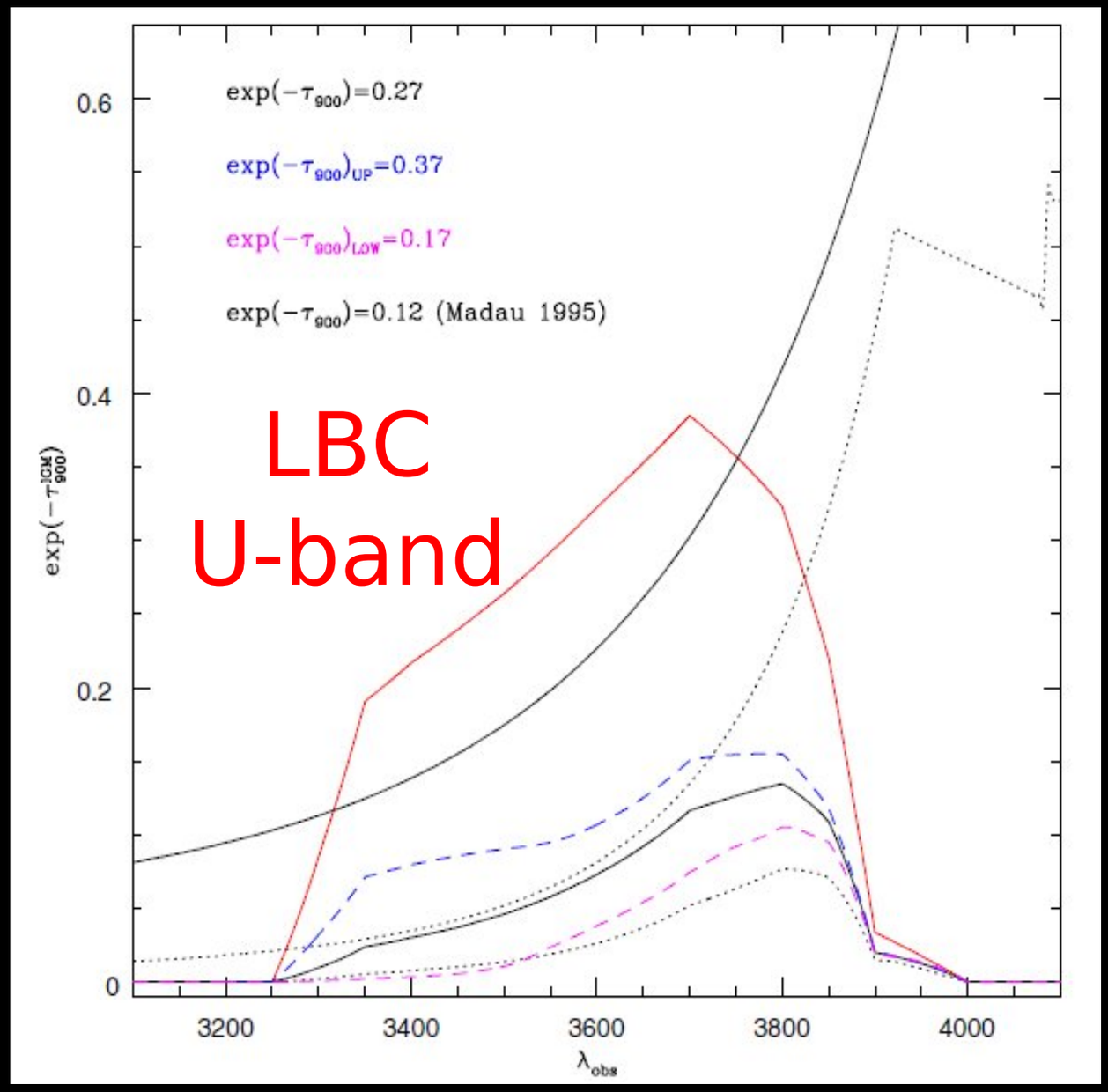
Lots of zspec available



Ionizing Escape Fraction at z~3.3

Selected 45 LBGs with zspec 3.27<z<3.40 in COSMOS
34 from VUDS (+11 from Boutsia+2011)
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)

Effective wavelength:
860A rest frame



Vimos Ultra Deep Survey

Le Fevre et al. (2014)
10000+ zspec 2<z<6.7

Contaminated sources
stack Boutsia et al. (2011)
stack all sources
stack Bright
stack Faint
Individual sources
U=29.7
f_{esc}^{rel}
magR
0
0.2
0.4
0.6
0.8
23
24
25

Contaminated sources

stack Boutsia et al. (2011)

stack all sources

stack Bright

stack Faint

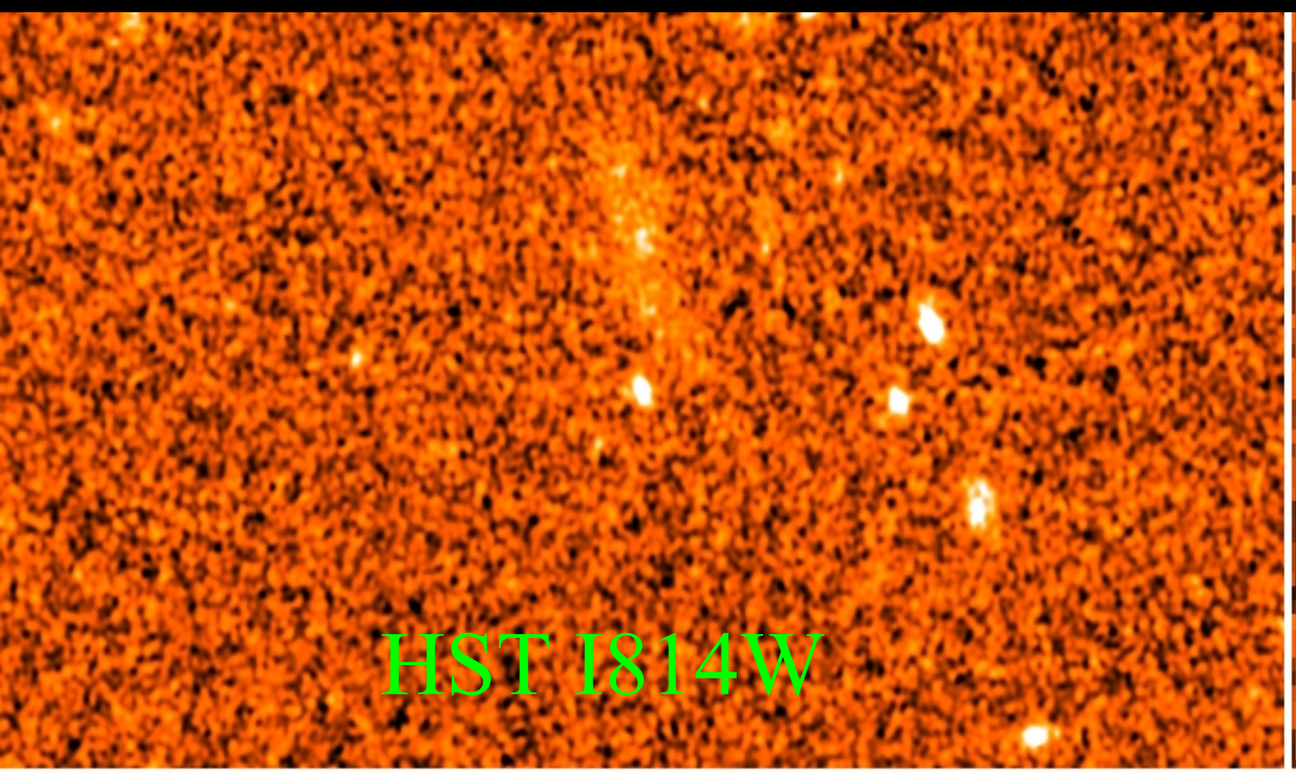
Individual sources

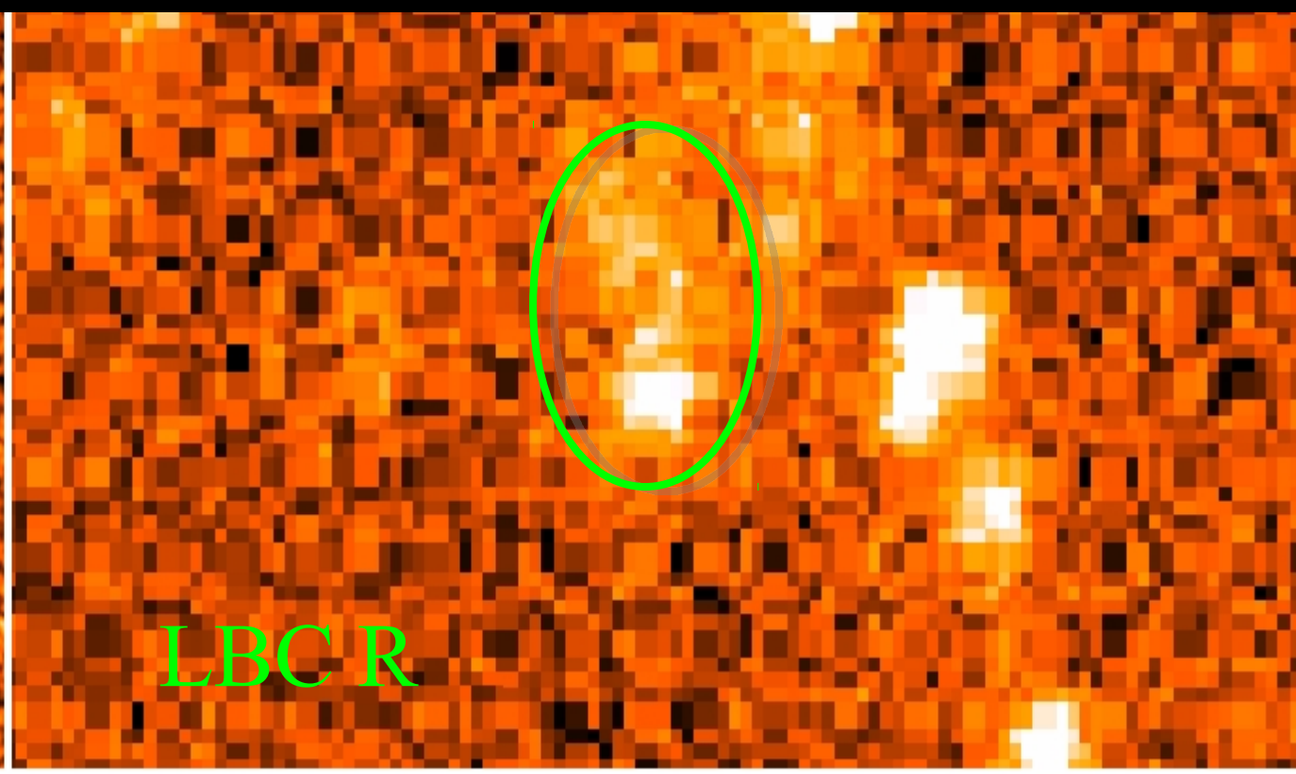
U=29.7

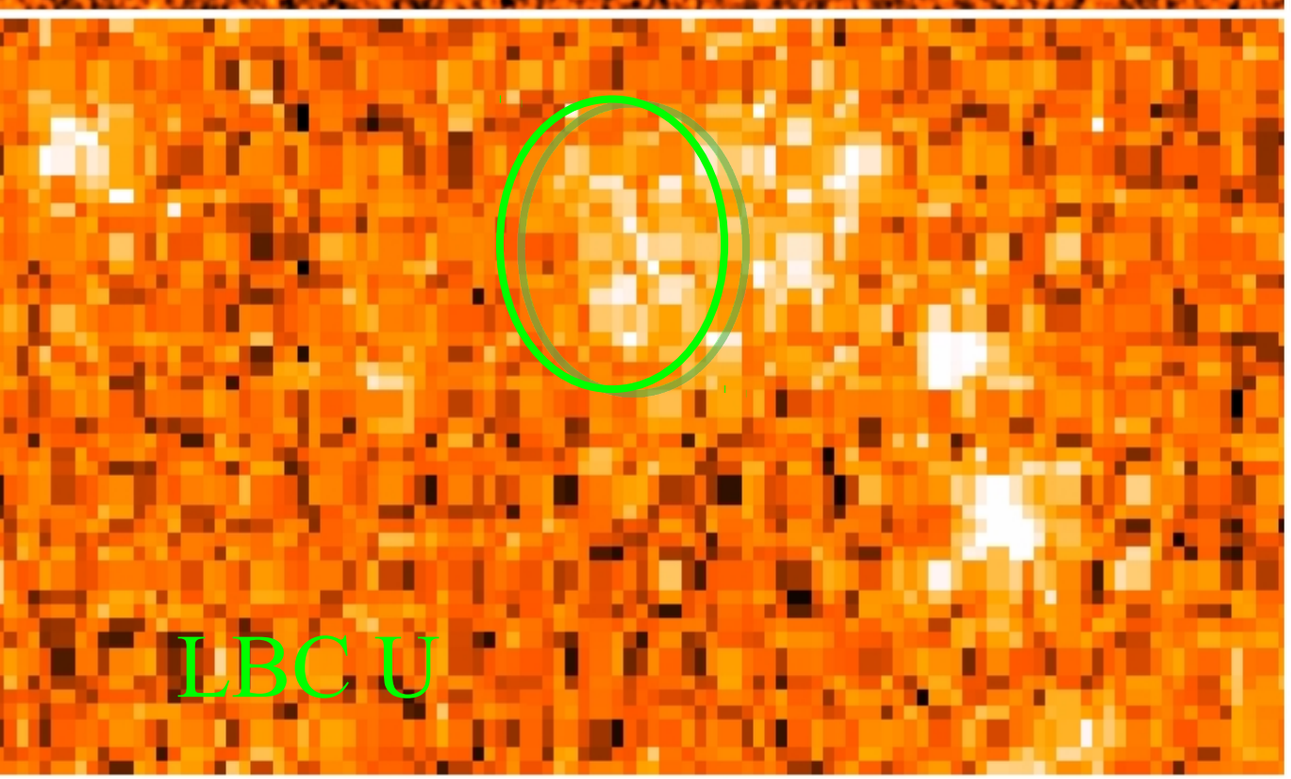
f_{esc}^{rel}

magR

Id=16669 magR=24.4







Global fesc=230%

Local fesc=520%

Contamination by
Foreground galaxy ?

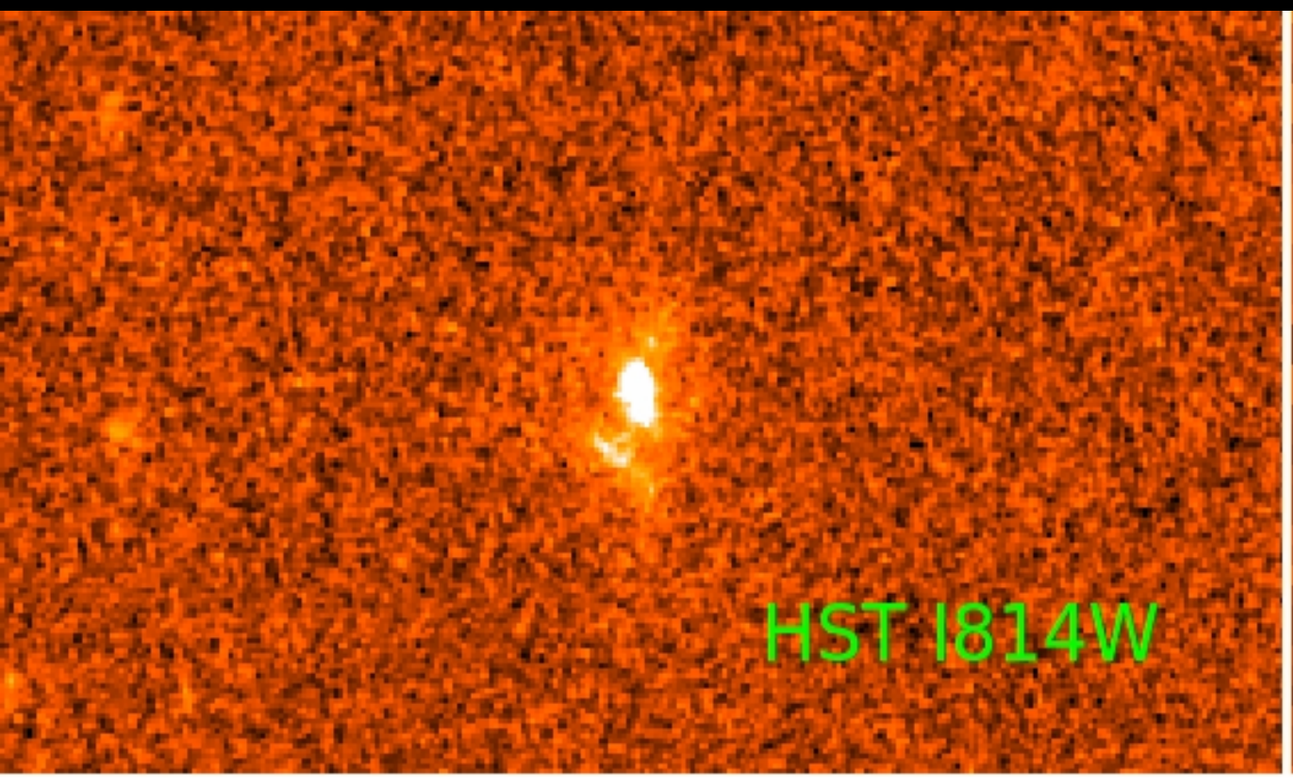
Contaminated sources
stack Boutsia et al. (2011)
stack all sources
stack Bright
stack Faint
Individual sources

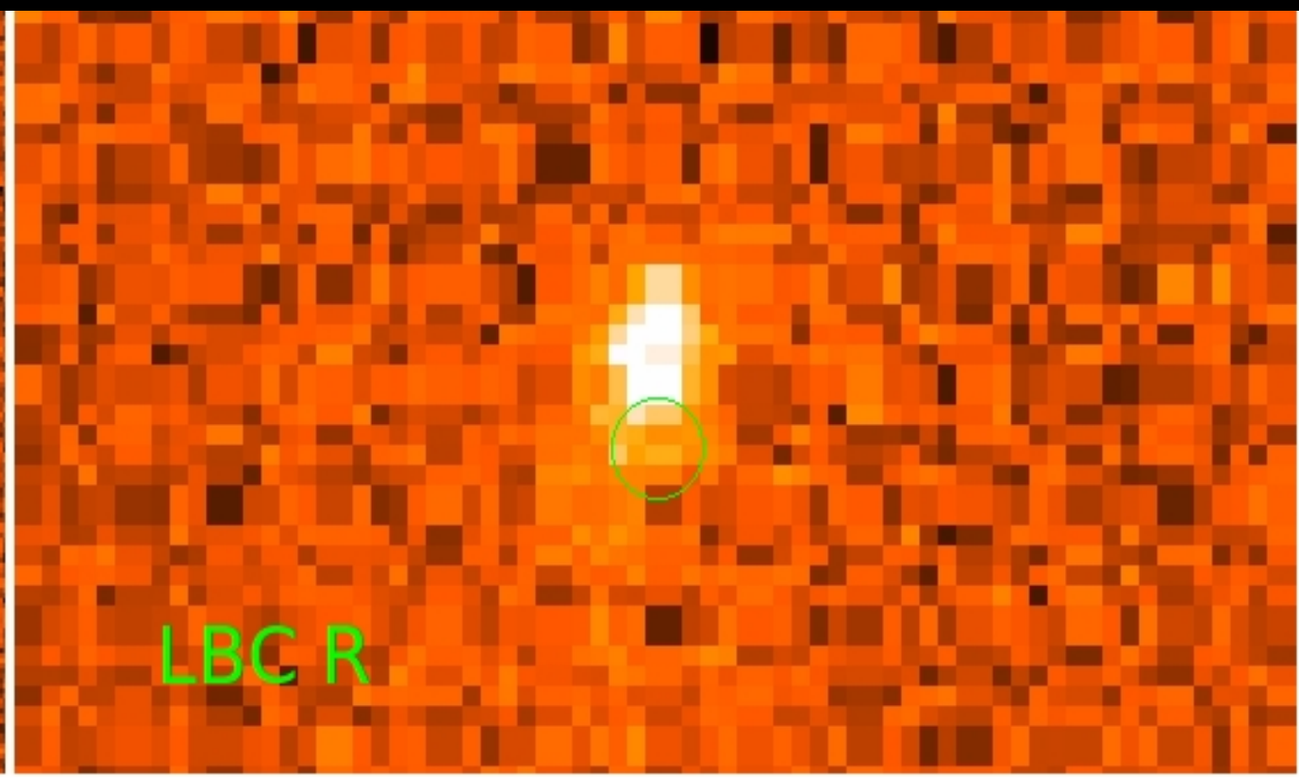
U=29.7

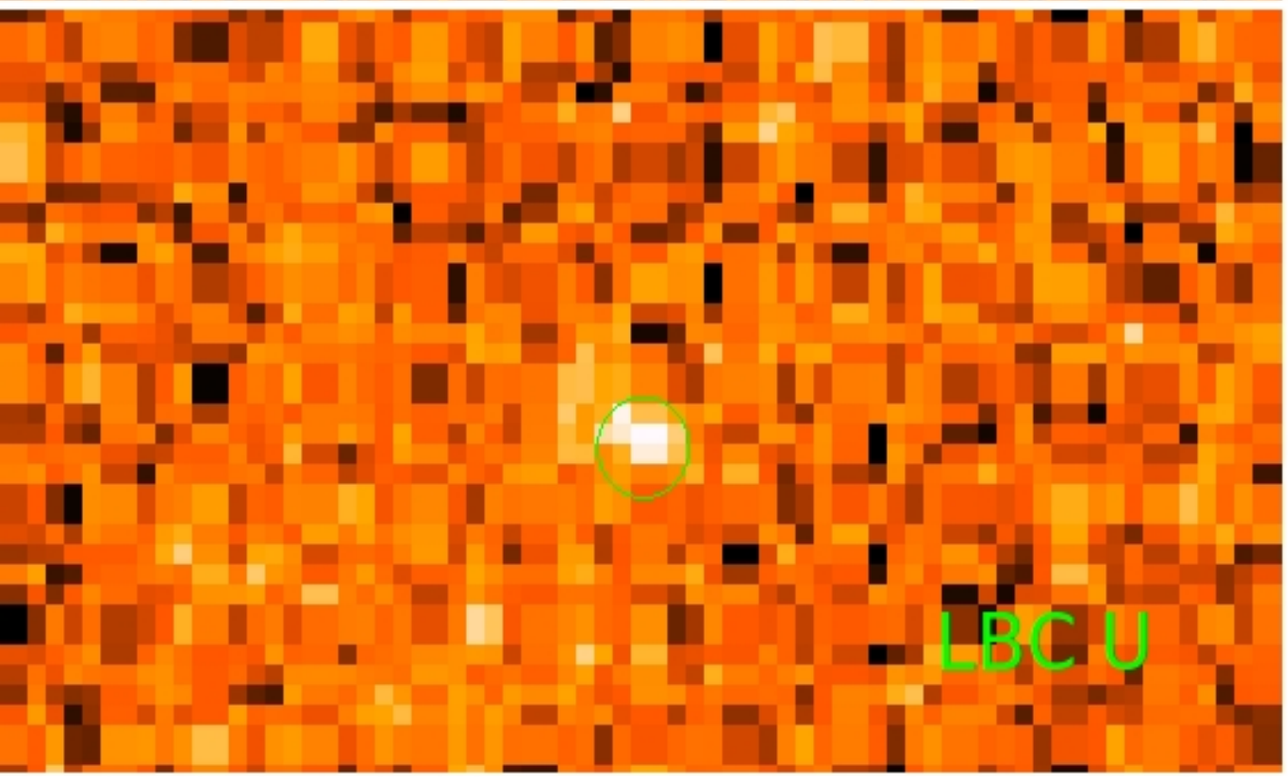
f_{esc}^{rel}

magR

Id=19521 magR=22.55







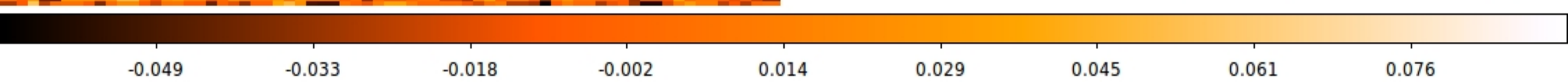
Fesc=28%

Locally estimated

fesc=175%

See Vanzella et al. (2012)

for similar cases in CDFS



Contaminated sources

stack Boutsia et al. (2011)

stack all sources

stack Bright

stack Faint

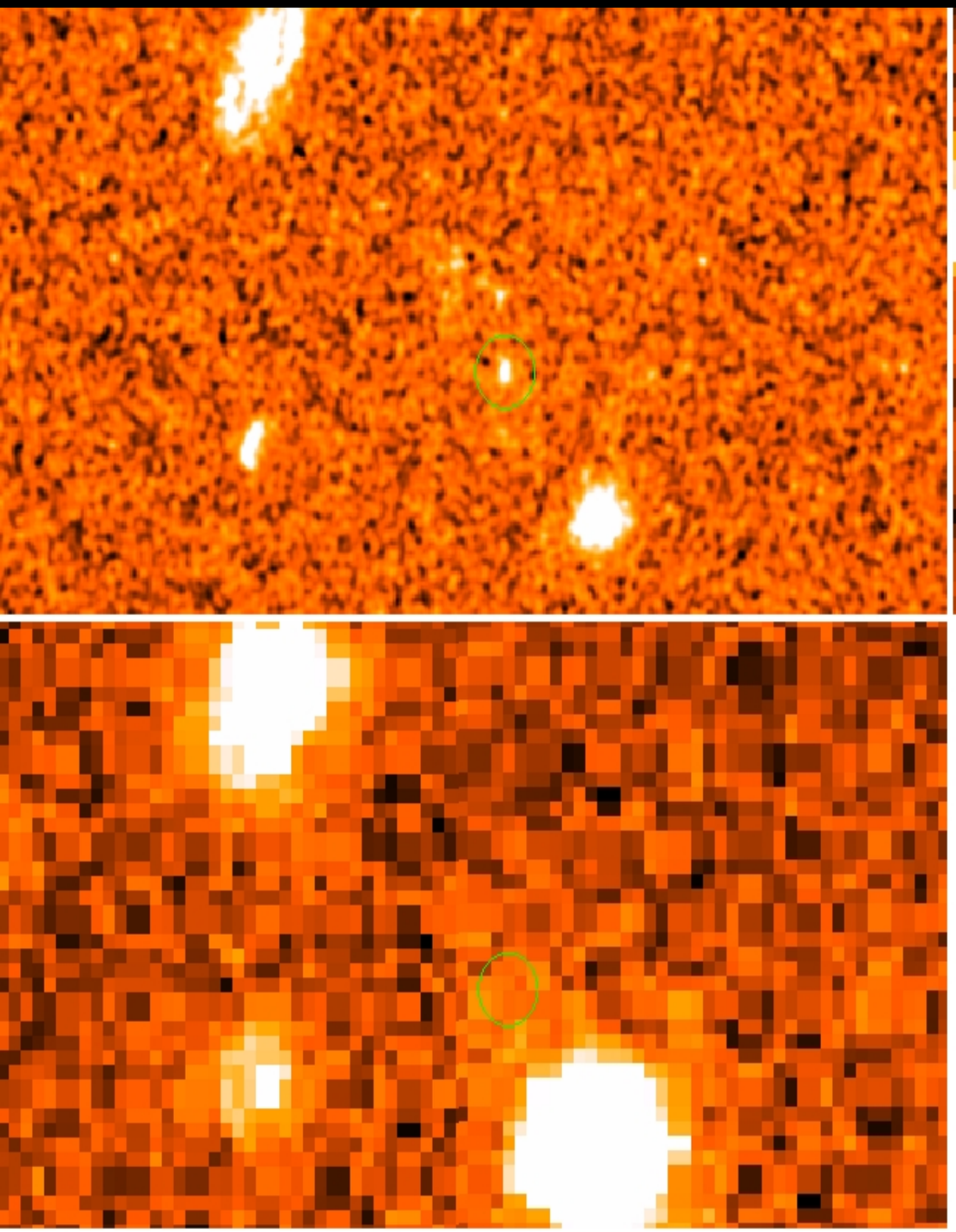
Individual sources

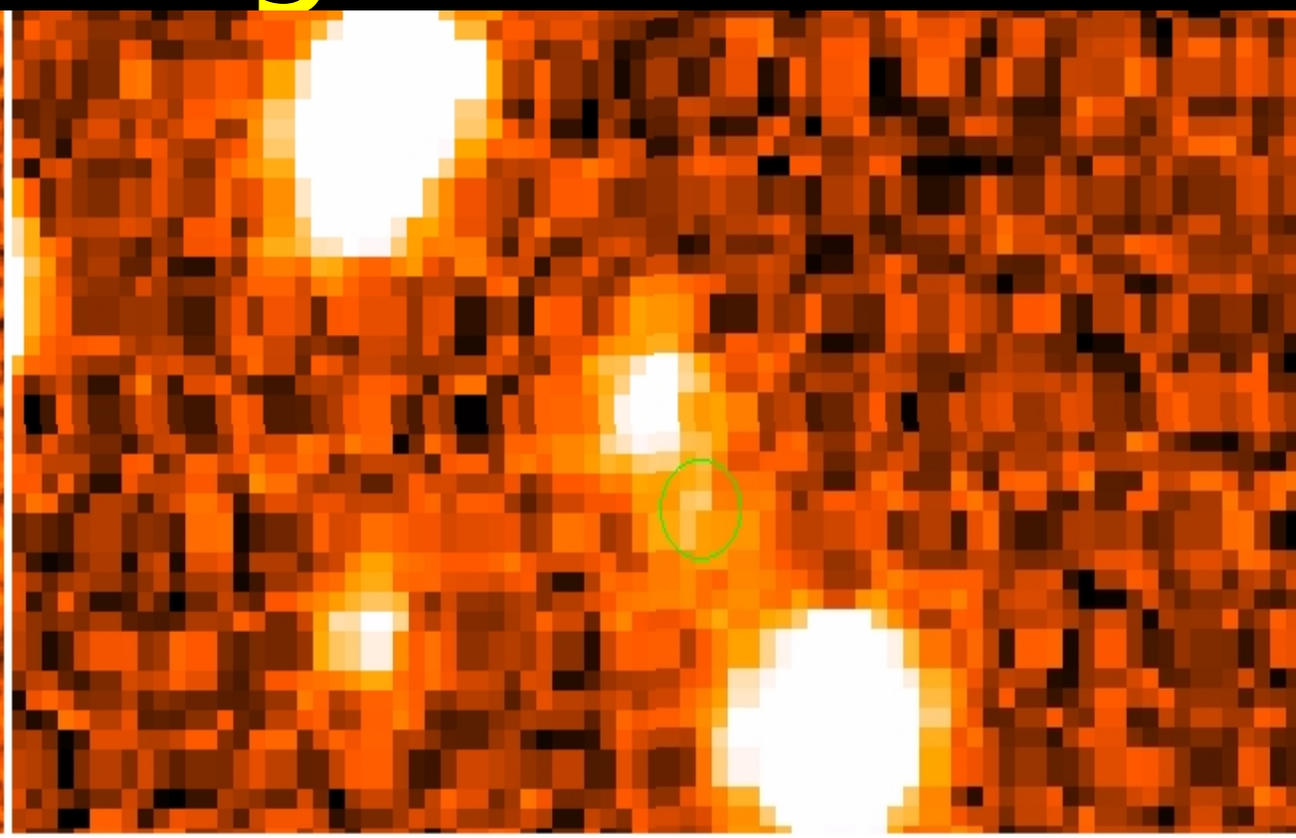
U=29.7

f_{esc}^{rel}

magR

Id=47357 magR=24.91





Fesc=76%

Locally estimated fesc=513%

Possible LyC emitter

+ other 2 similar objects

Detailed analysis ongoing...

Contaminated sources

stack Boutsia et al. (2011)

stack all sources

stack Bright

stack Faint

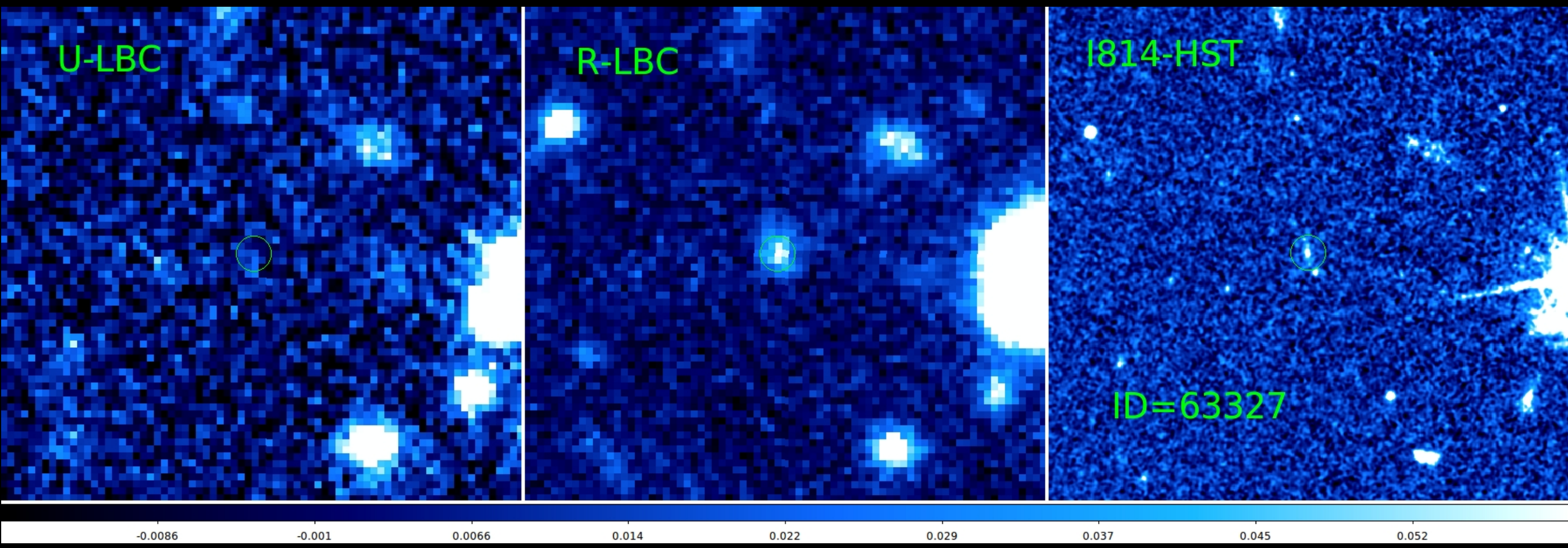
Individual sources

U=29.7

f_{esc}^{rel}

magR

Id=63327 magR=25.02



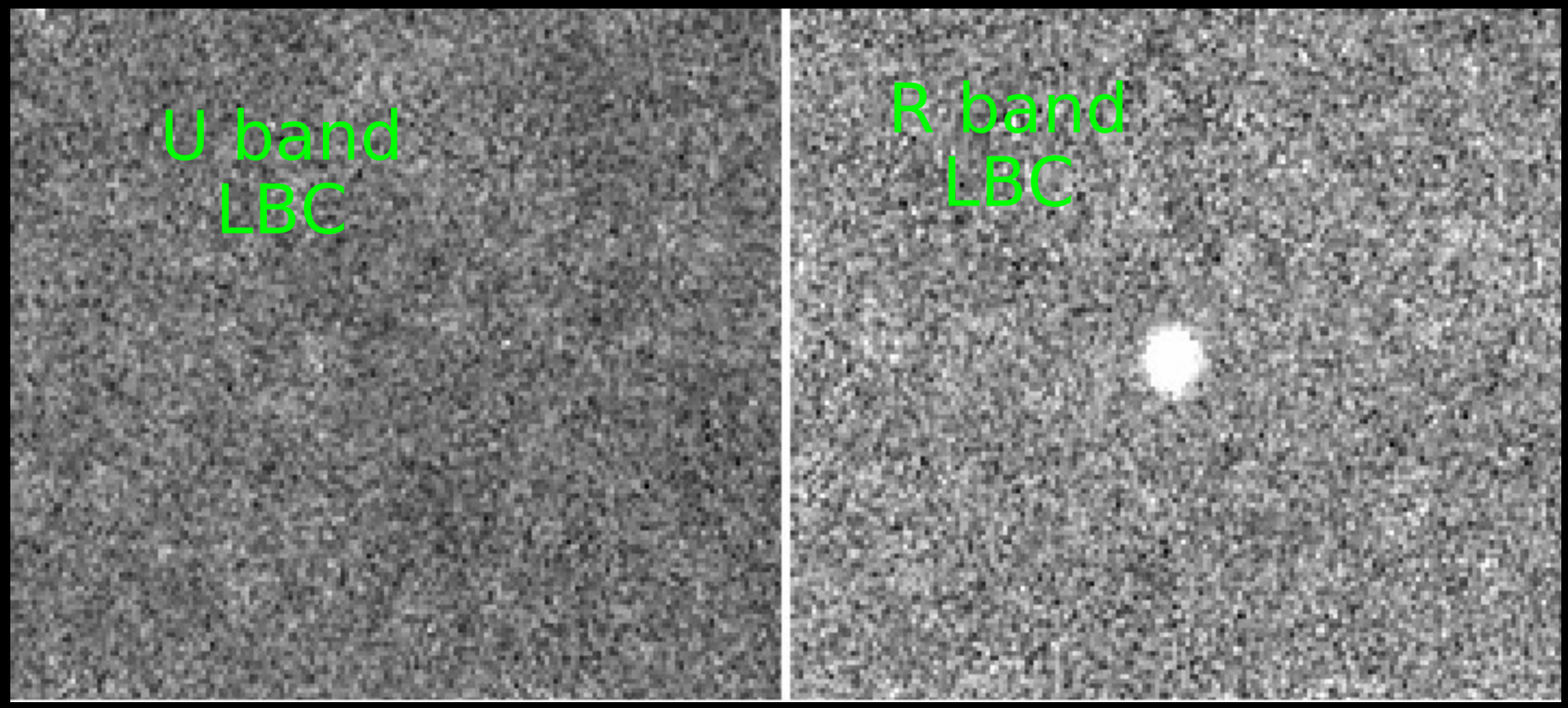
Fesc=45%

Possible LyC emitter!!!

Detailed analysis ongoing...

Contamination ???

Image stacking in U and R



No detection at U=31.44(AB) at S/N=1

f1500/f900obs>549.8

fesc_rel<2.02% (1 sigma) at z=3.3 for R<25.5

Consistent with Vanzella+2010: GOODS-South

LBC Strategic Program

Requested observations: 30 hours of Uspec_SDT and 10 hours of B-BESSEL on

GOODS-North in the Blue channel, and 40 hours of R-sloan in the Red channel.

INAF – LBT OBSERVING PROGRAMS

Application for LBT observing time **Category: B**

Period Sep 2012-Jun 2013 **Deadline: May 18th, 2012, 2pm CEST** **Submit using: www.tng.iac.es/lbt/submit.ht**

1. Title **Strategic Program** X

The UltraViolet side of CANDELS

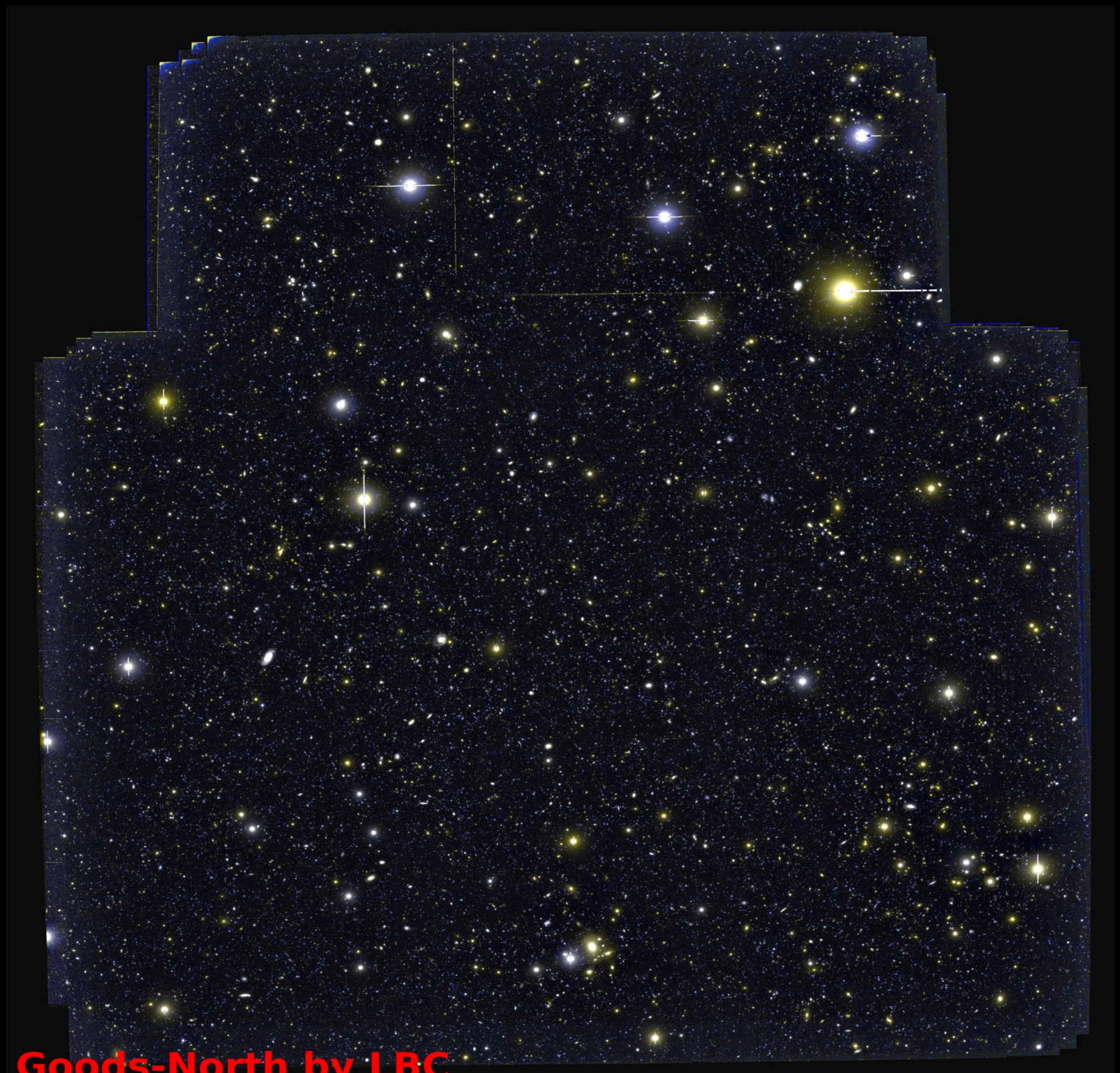
2. Abstract

We propose a 2-year Strategic program to exploit the unique combination of area+efficiency of LBC-Blue at LBT to obtain ultradeep U and B-band imaging of four CANDELS/SEDS fields (UDS, COSMOS, GOODS-North and EGS). We will combine the LBT data with ultradeep Spitzer and HST images for these ongoing legacy surveys, which are the largest award of observing time from the two space telescopes. Deep blue bands are *fundamental* to exploit the power of CANDELS data in studying the critical epoch of the Universe during the peak of star-formation history, since they are *essential* in particular to: *i)* selecting $L \sim 0.1L^*$ star-forming galaxies at $z \geq 2$, to measure their SFR, masses, ages and dust content; *ii)* derive very accurate photometric redshifts at $z \geq 2$, to study the faint side of the Luminosity Function of galaxies, *iii)* find passively evolving galaxies at $z \sim 1.5$, and *iv)* put stringent limits to the Lyman Continuum escape fraction of LBGs at $z \sim 3$, to understand whether the Universe has been reionized by primordial stars or by black holes. This LBT survey, complementing the existing CANDELS data, will constitute an invaluable legacy ahead of the advent of ELTs and JWST, enhancing, also through a number of published papers, the visibility of LBT.

33 hours in the U-band Seeing=1.1”

26 hours in the R-band Seeing=1.0”

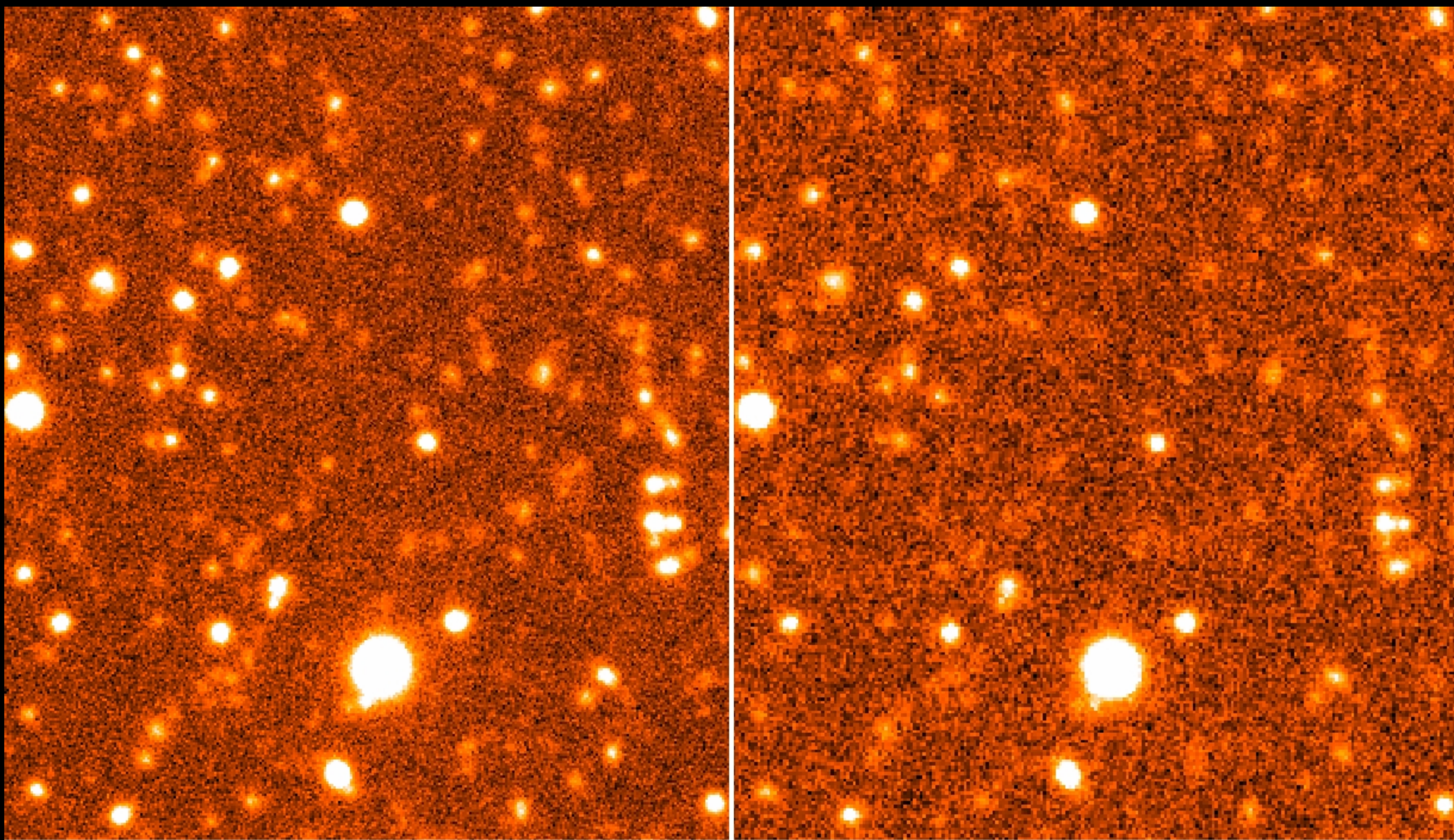
Data reduced by LSC (INAF-OARoma)



Ultra Deep U-band

LBC 33 hours

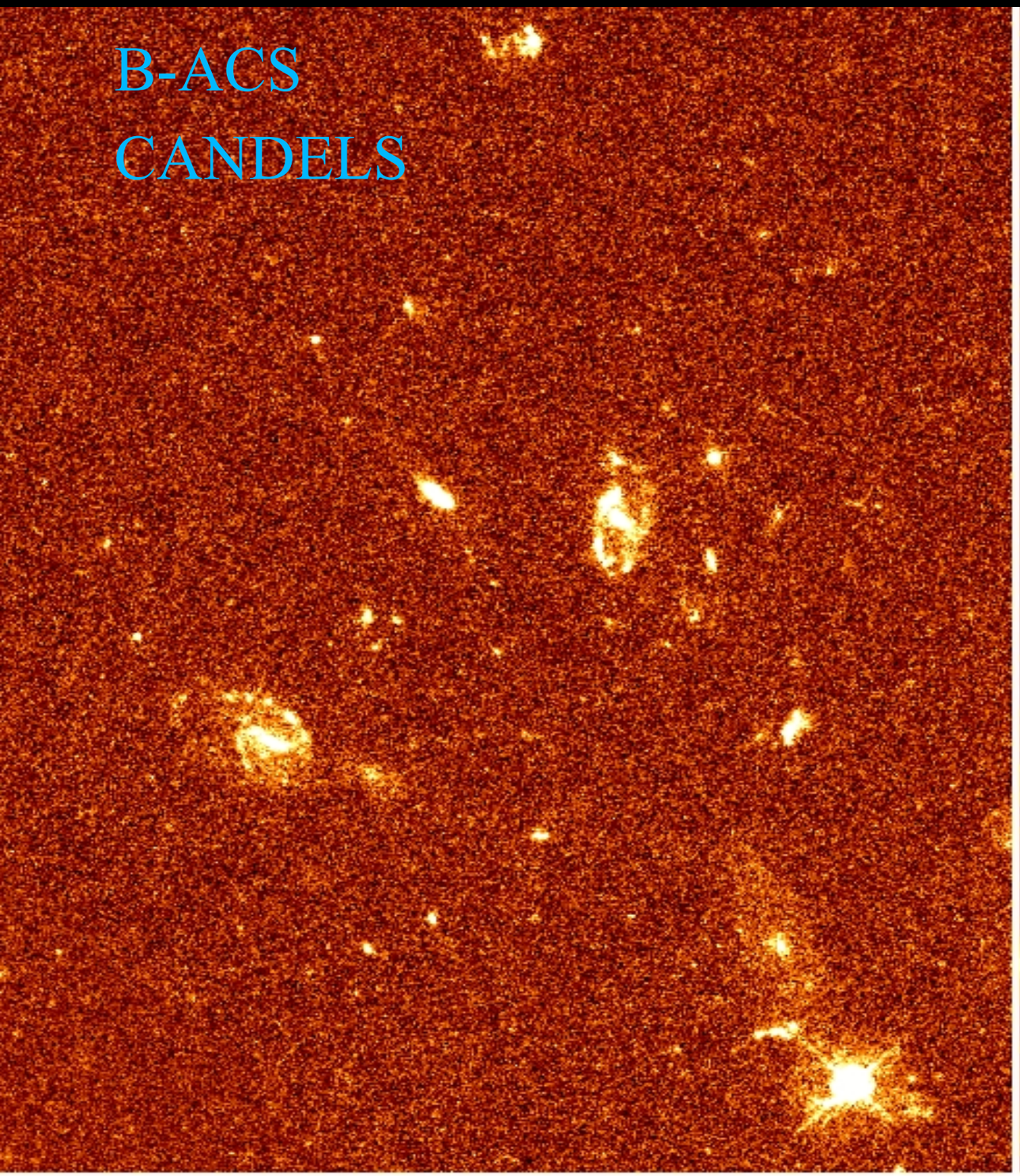
KPNO 50 hours

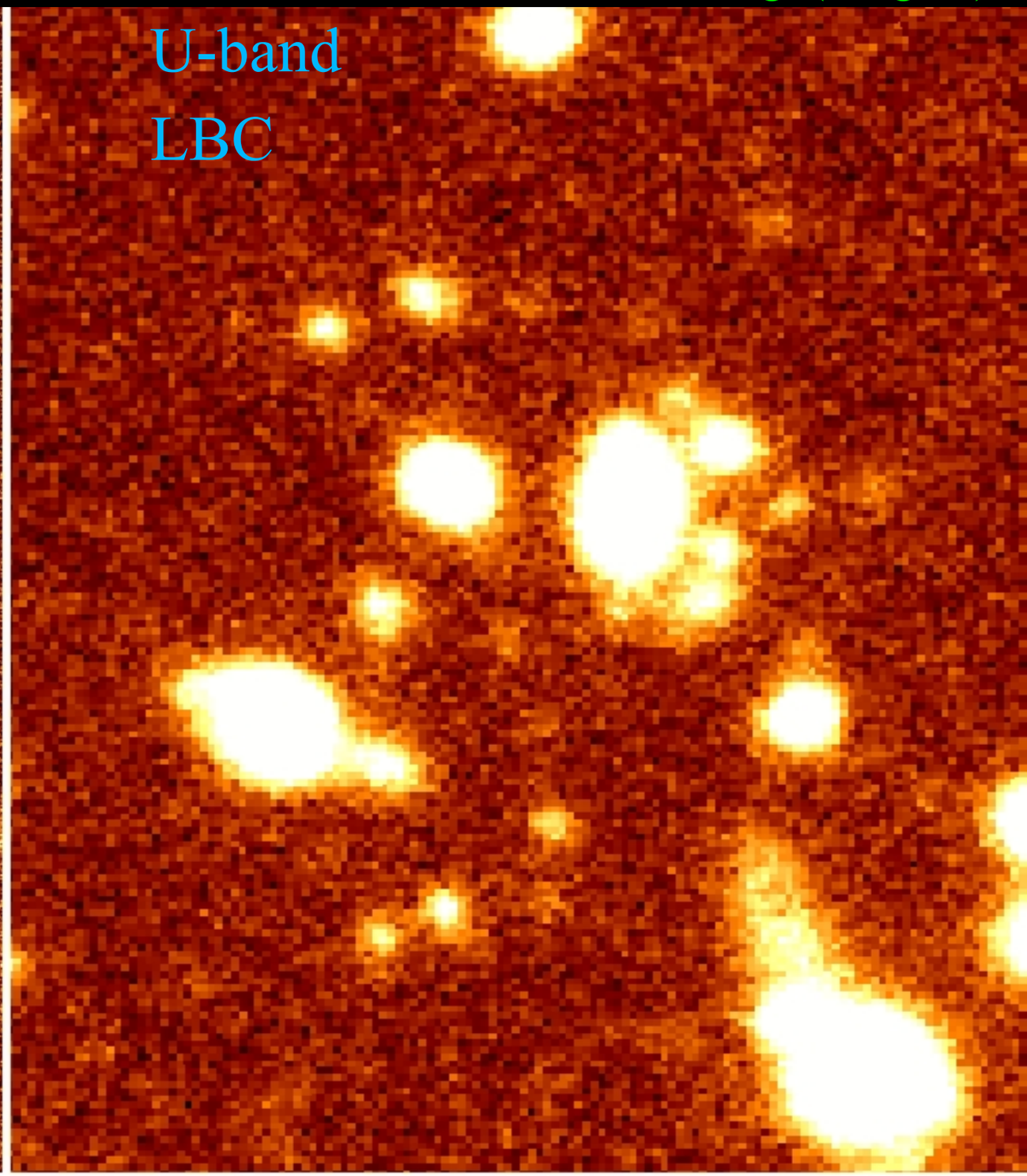


One of the Deepest U-band images of the World....

Nonino et al. 2009 VIMOS

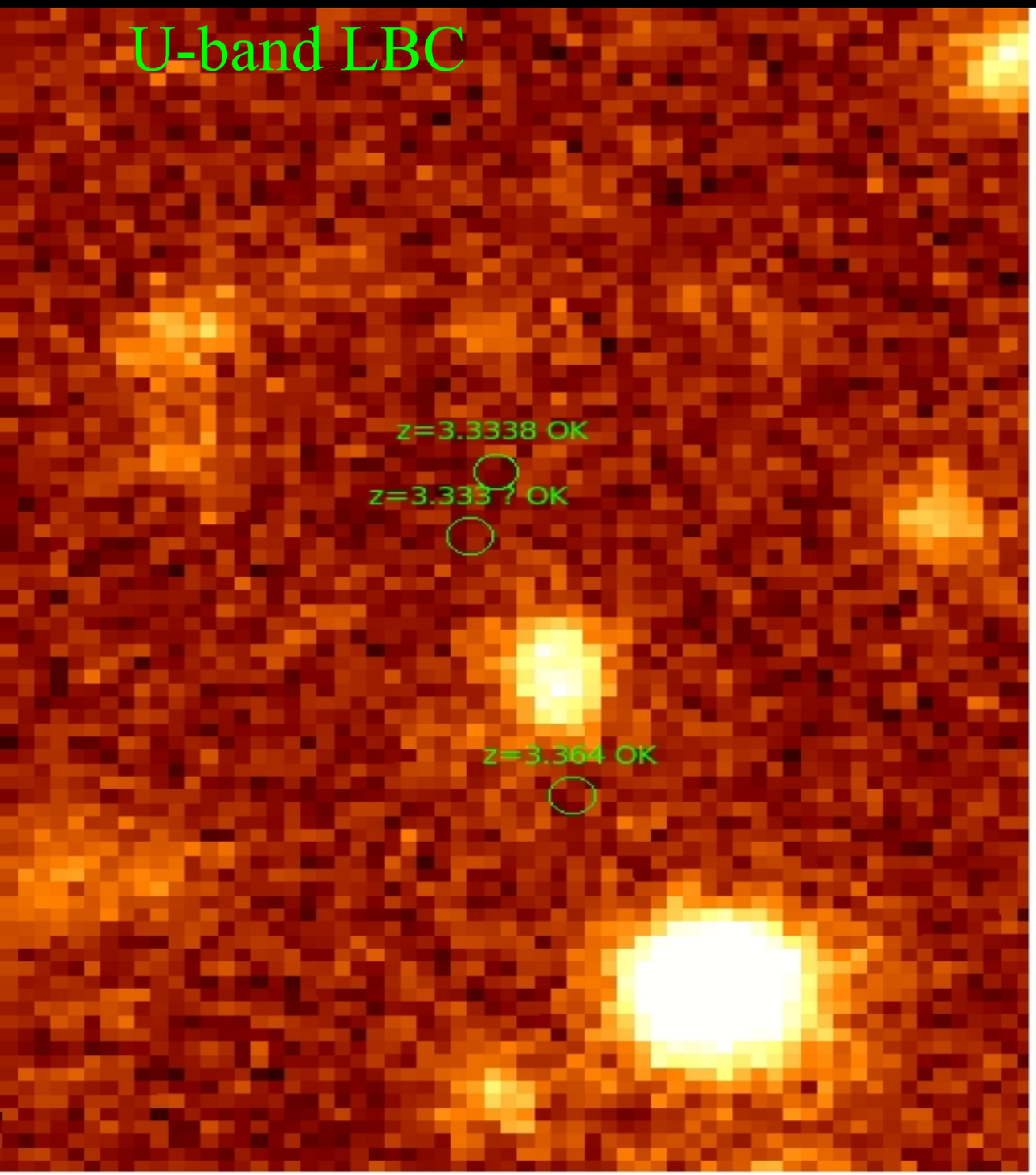
U=30.5 AB mag (1 sigma)

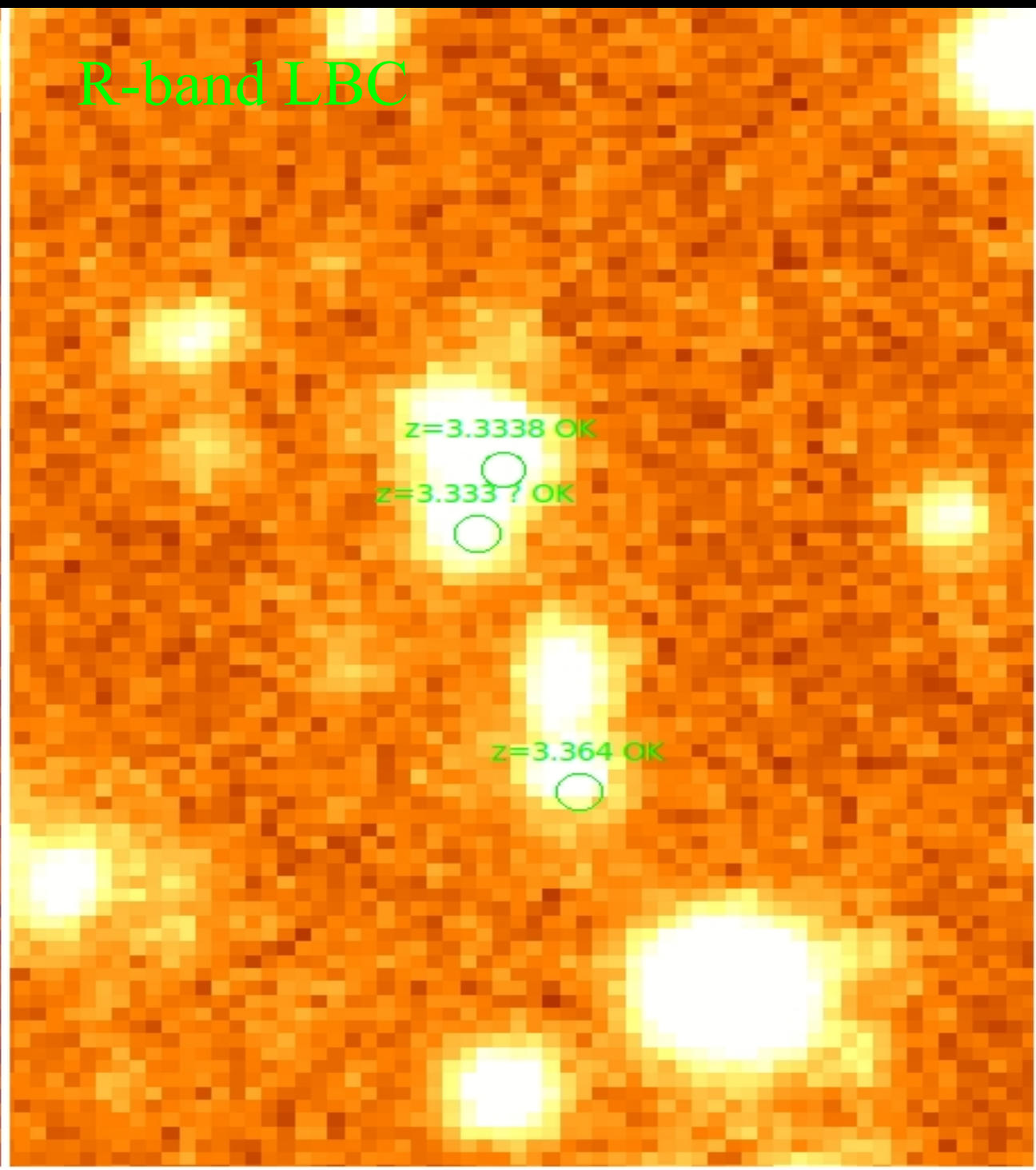




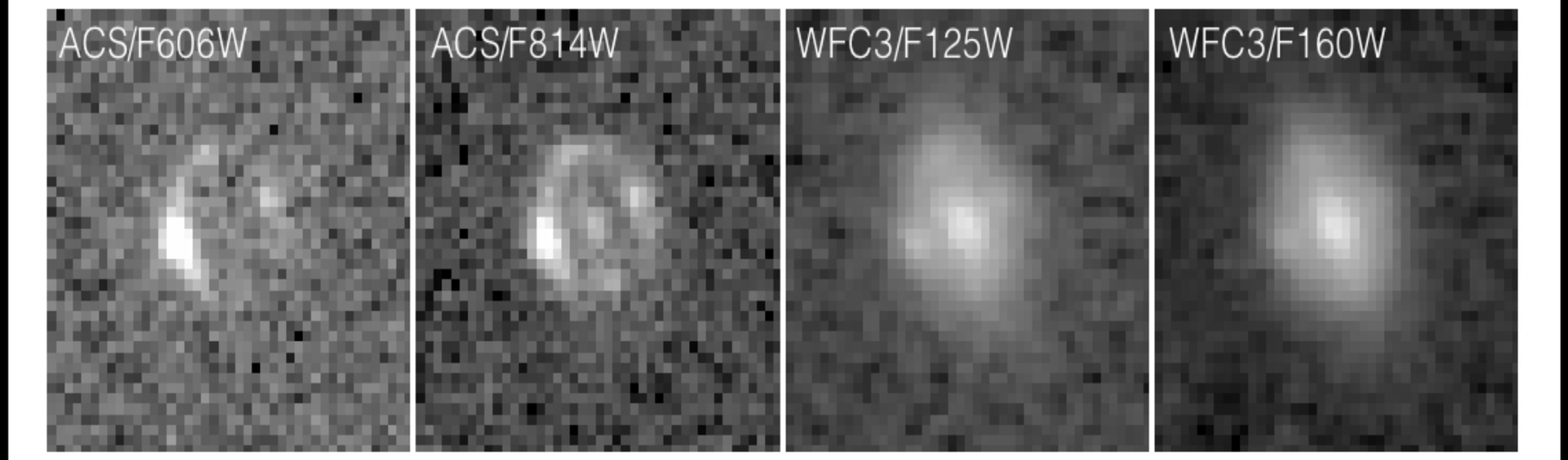
z=3.3 galaxies in GOODS-North

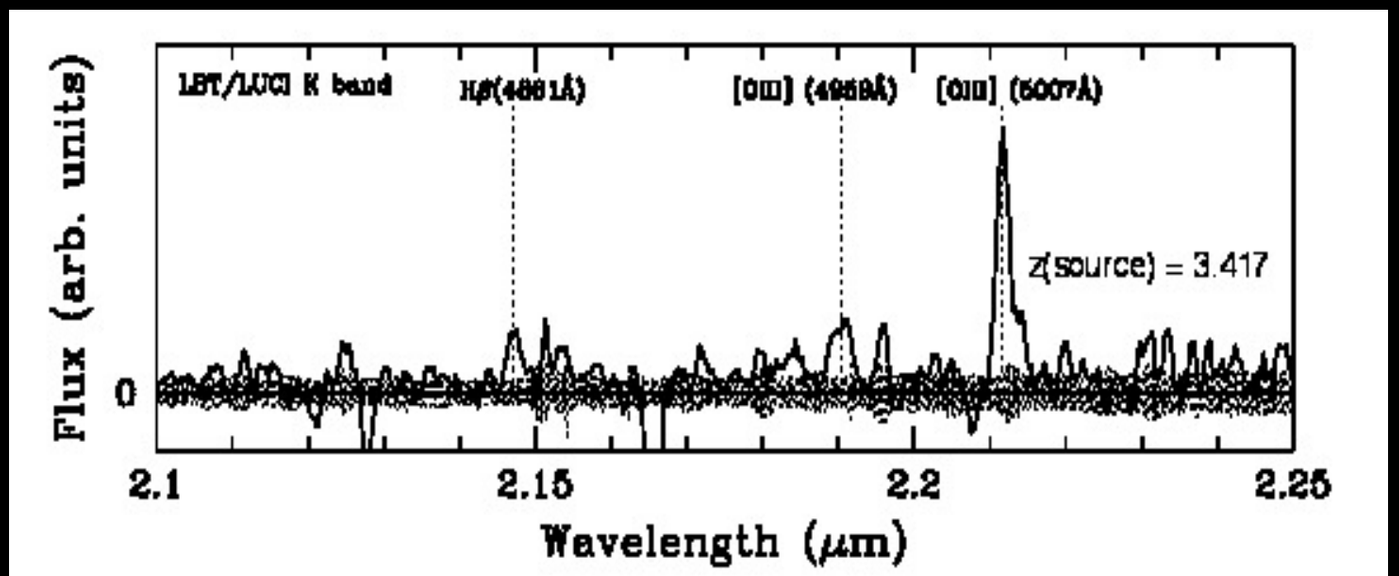
8 galaxies at z~3.3 have been added to the VUDS sample.





Galaxy-Galaxy strong lensing





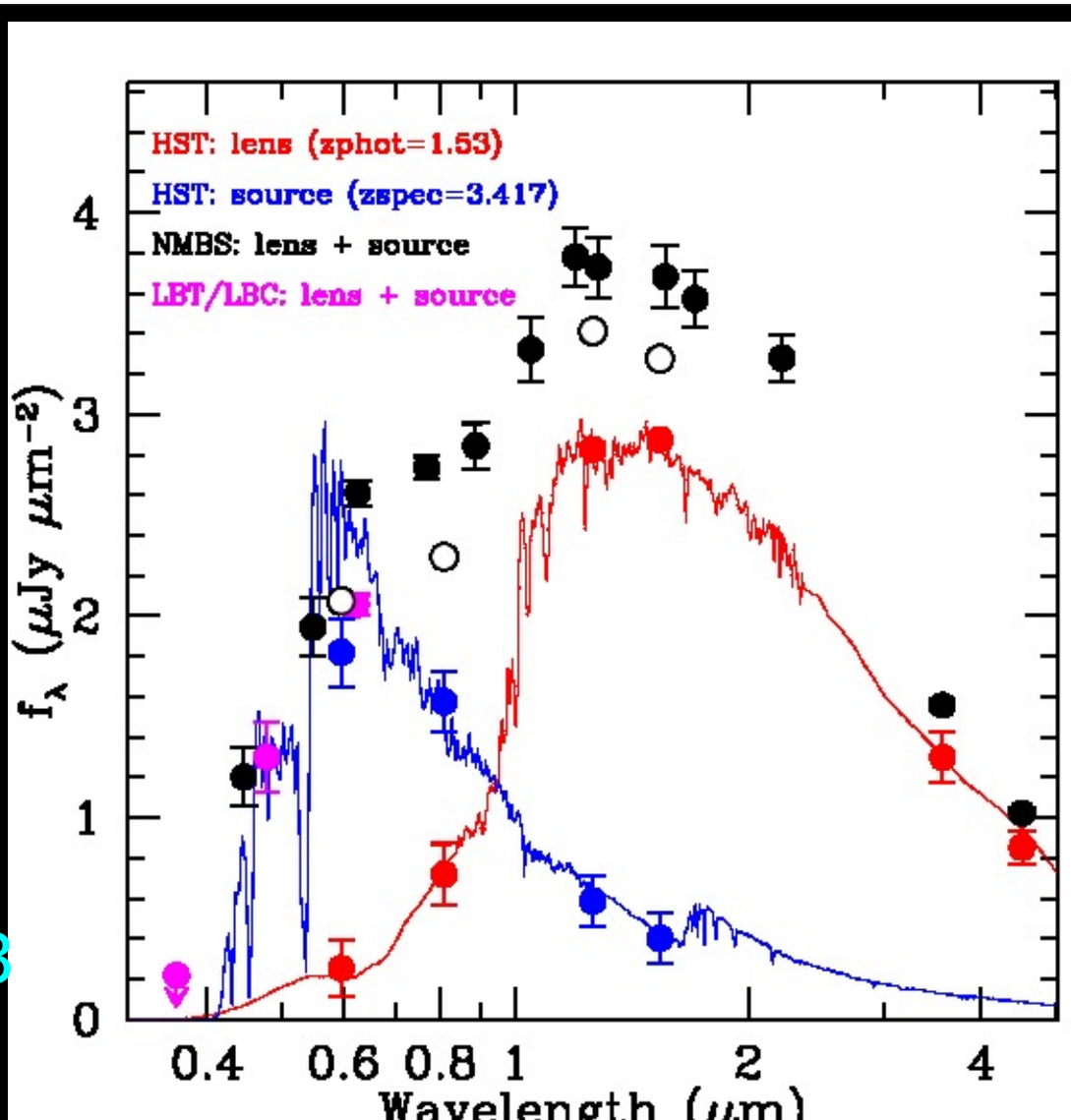
z=3.417 mu=40x

Uobs>28.9 Robs=24.3 Rintr=28.3

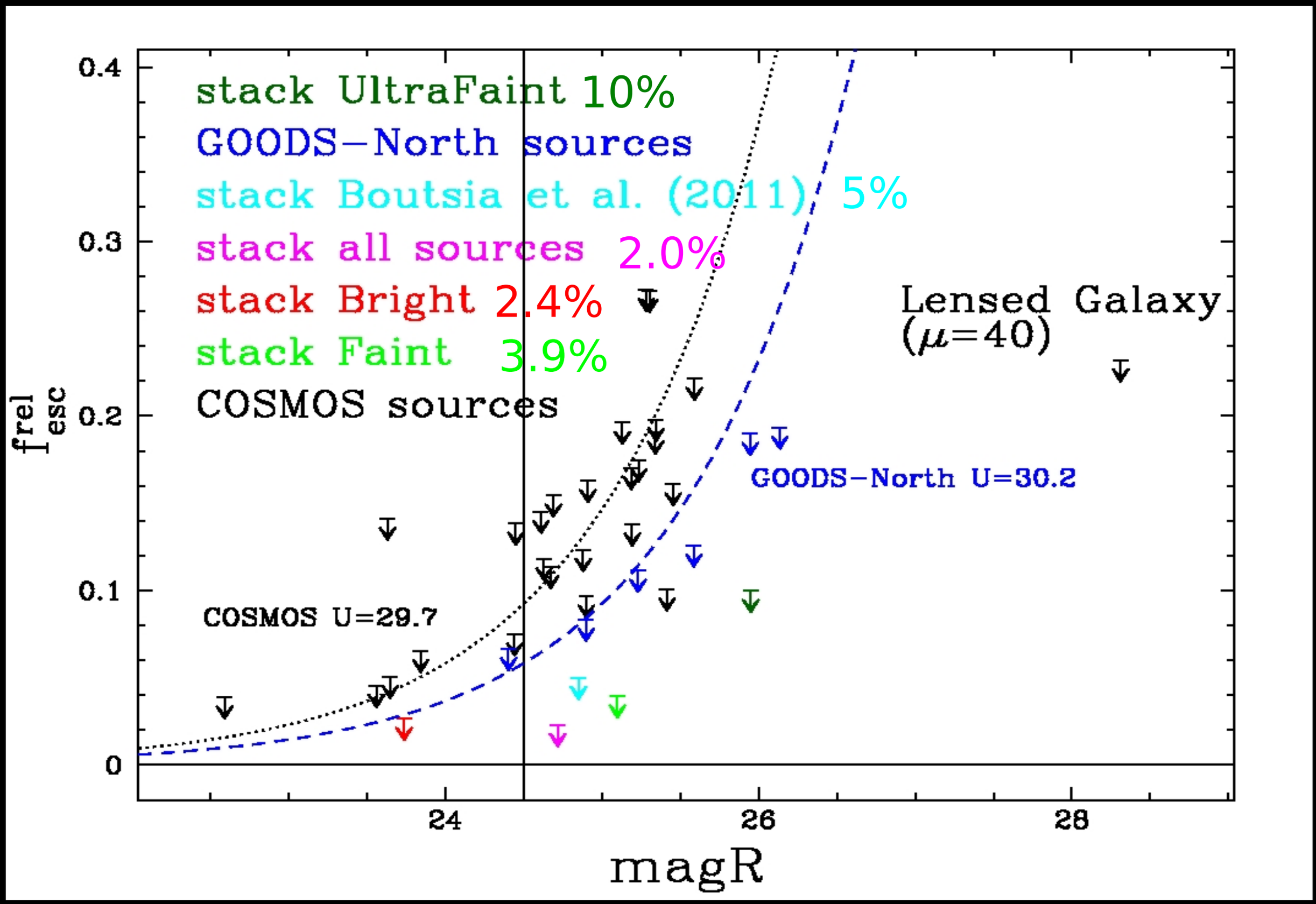
Fesc<23% (1 sigma) L=0.05L*

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

Amorin et al. 2014



Slow evolution of fesc with magnitude ?



Contribution to the UV Background

$$\rho_{900,esc} = \rho_{1500}\frac{L_{900}}{L_{1500}}f_{esc}^{rel} = \rho_{1500}\left(\frac{f_{900}}{f_{1500}}\right)_{obs} exp\left(\tau_{900}^{IGM}\right)$$

Assuming that all galaxies emit with fesc=2.0%

L>L* Gamma=0.03 << 0.86
Gamma_observed=0.86 (Bolton et al. 2005)
L>0.1 L* Gamma=0.16 < 0.86

L>0.01 L* Gamma=0.26 < 0.86

Luminosity density at 1500A from Reddy et al. (2009)

Bright Galaxies have low fesc

Faint Galaxies: if low fesc, they cannot keep the Universe reionized, unless there is a significant increase of fesc towards high redshift and/or low luminosity

What about Faint AGNs ?....

Summary

First LBT Strategic Program Completed: Ultradeep UV observations of the CANDELS GOODS-North field.

>30 hours of LBC in the U-band have been stacked to obtain one of the deepest U-band images. Plus 3 shallower pointings in COSMOS.

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

At z=3.3 bright galaxies have fesc_rel<2.0%!

Galaxies alone cannot provide the observed UVB at z~3.3 if fesc does not evolve with Luminosity.

In the near future strong lensing will be the key to go beyond the current instrumental limitations (CLASH, FrontierFields).

Faint AGNs at z>3 as the main drivers of the Reionization? Work in progress...

Thank you!