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Lyman Continuum Signal from z~3 star-forming galaxies and higher redshift implications.

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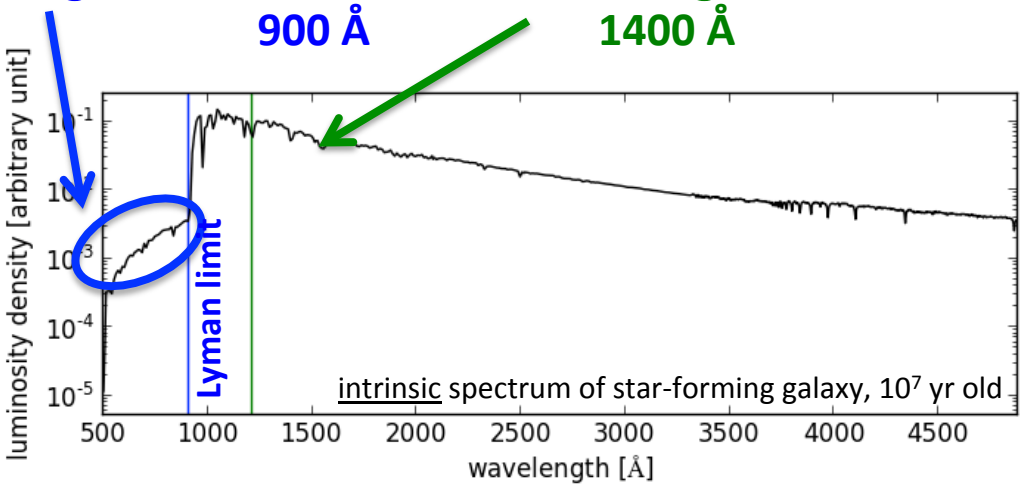
fesc(LyC) ≈ ionizing radiation flux / non-ionizing radiation flux



- ionizing radiation production (**physical properties**) vs escape (interaction with **ISM**)

[e.g. *Avedisova 1979, Roy 2014*]

- **simulations** predict ISM conditions for escape (NHI, clumpy medium, free line of sight/anisotropic escape)

[e.g. *Yajima 2011, Paardekooper 2015, Wise 2014, Zackrisson 2013, Cen 2015*]

- interaction with **IGM** (galaxy environment, re-ionization)

[z~3 IGM transmissivity is ~40%, *Inoue 2014*]

- LyC leakers are probably **low-mass, star-forming** galaxies below detection limits a few massive with active feedback

[e.g. *Heckman 2011, Haardt & Madau 2012, Borthakur 2014, Prochaska 2009, Stevans 2014*]

- **challenge**: weak signal, low-z contamination, a few favorable lines of sight

[e.g. *Vanzella 2012, Cen2015, Siana 2015, Grazian 2015*]

-> Motivation

Outline

- Motivation
- Project idea
  - Chosen sample
  - Method
- Results and implications
- Summary and on-going work

Project idea

- sample of **spectroscopically confirmed** SFGs **at z~3 in ECDFS** (about 200 redshifts)
(FORS,VIMOS GOODS-S MASTER CATALOG + literature

VUDS | VIMOS Ultra Deep Survey

= A deep VIMOS survey of the CANDELS UDS and CDFS fields

MUSYC narrow-band selected LAEs at z~3.1)

- HST coverage at least in 2 bands from CANDELS/GEMS surveys
inspect HST images to keep only source in **clean regions** (blue-red bands, knot colors, PSF)
to reduce low-z nearby-source contamination on individual-source basis

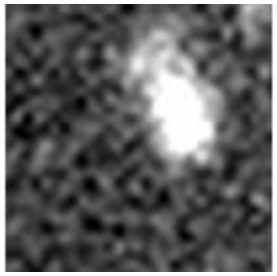
- CANDELS/ECDFS **multi-wavelength photometry** to study physical properties

- measure LyC flux in (archive) **narrow-band** images covering rest-frame 860-910 Å
at the position of the source, within optimized apertures (about **PSF,** 2xPSF)

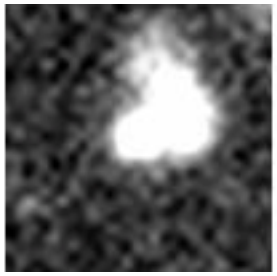
- non-ionizing radiation flux from CANDELS/GEMS V606 band flux (global)

removed after cleaning

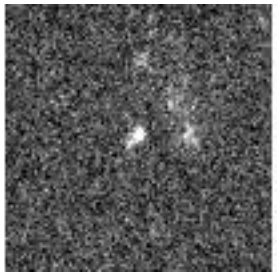
Uvimos



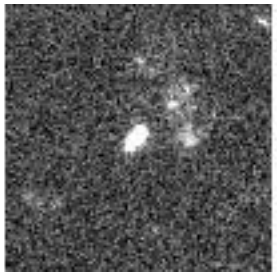
Bvimos



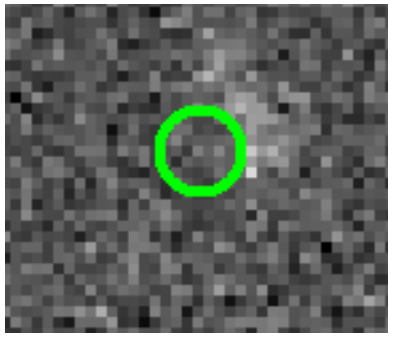
F435



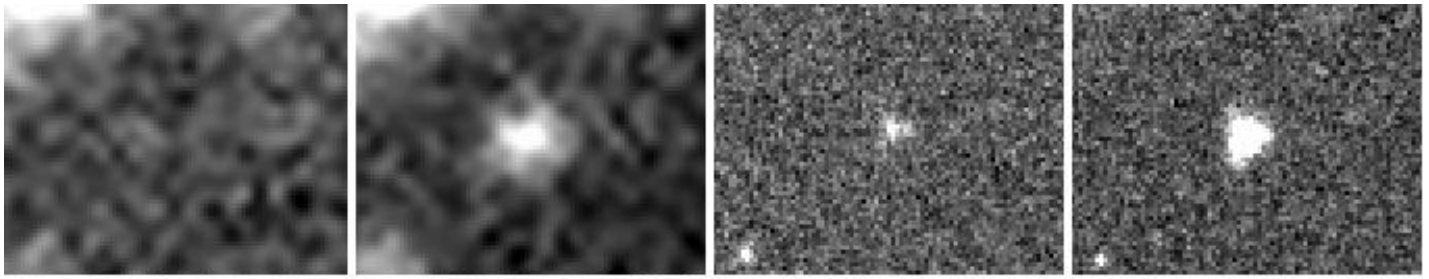
F606

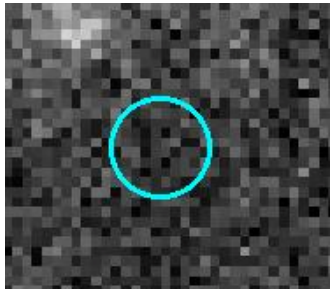


NB387

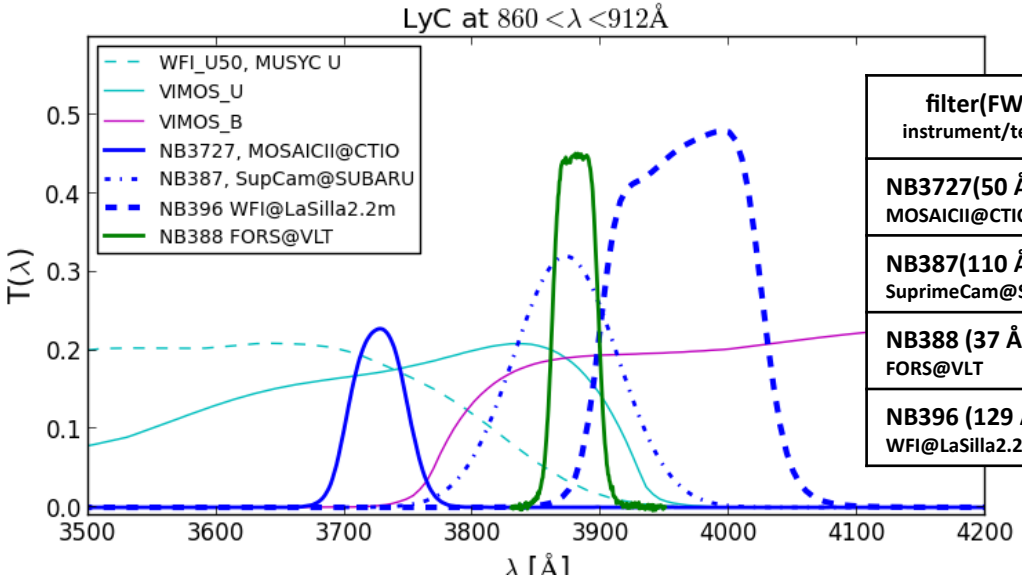


kept after cleaning





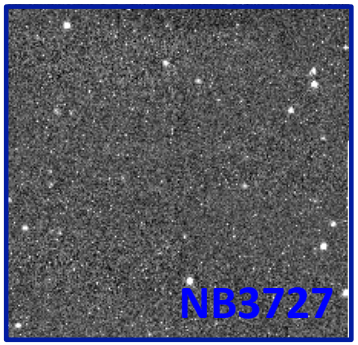
circle radius ~ 1’’

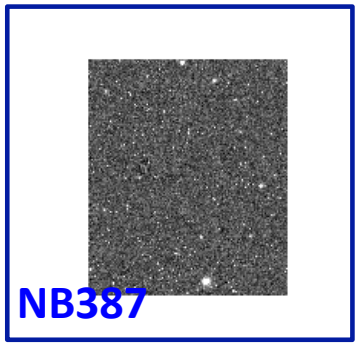


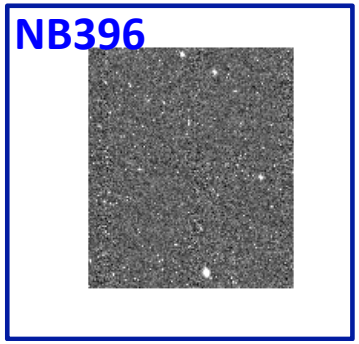
filter(FWHM) instrument/telescope	exptime	PSF	3σ det limit (PSF/2 radius)	optimal aperture
NB3727(50 Å) MOSAICII@CTIO4m	35.8 h	1.4”	26.7	1.4”
NB387(110 Å) SuprimeCam@SUBARU	8.5h	0.7”	28.8	0.8”
NB388 (37 Å) FORS@VLT	16.7h	0.8”	29.8	0.8”
NB396 (129 Å) WFI@LaSilla2.2m	13h	0.9”	27.4	1.0”

30’x30’ ECDFS

ground-based



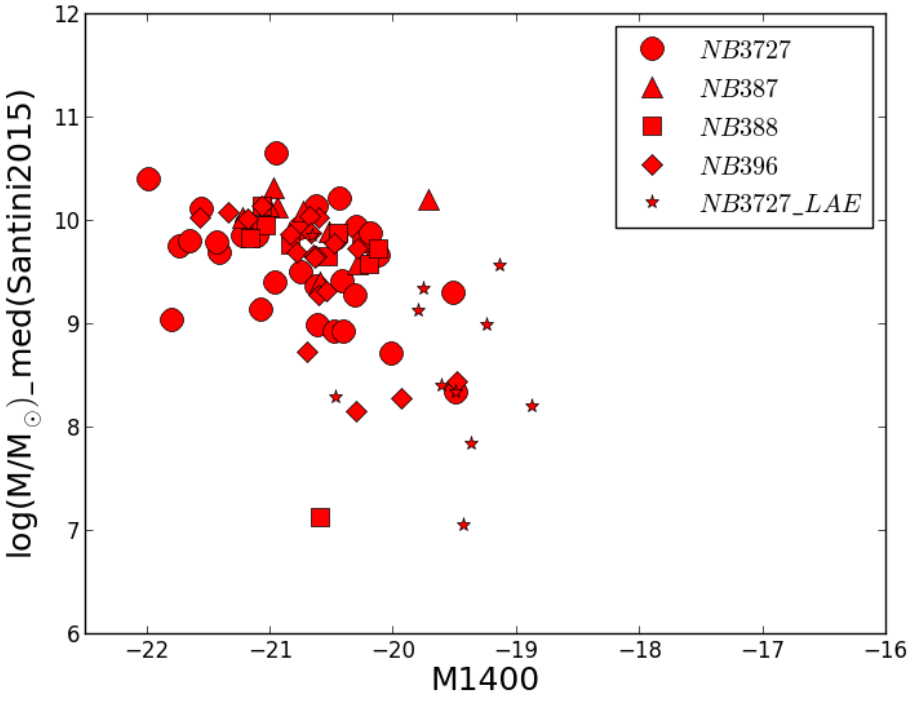




70 spectroscopically confirmed SFGs at 3.11<z<3.53 (+ 17 LAEs at z≅3.1) in clean regions (NB PSF!)

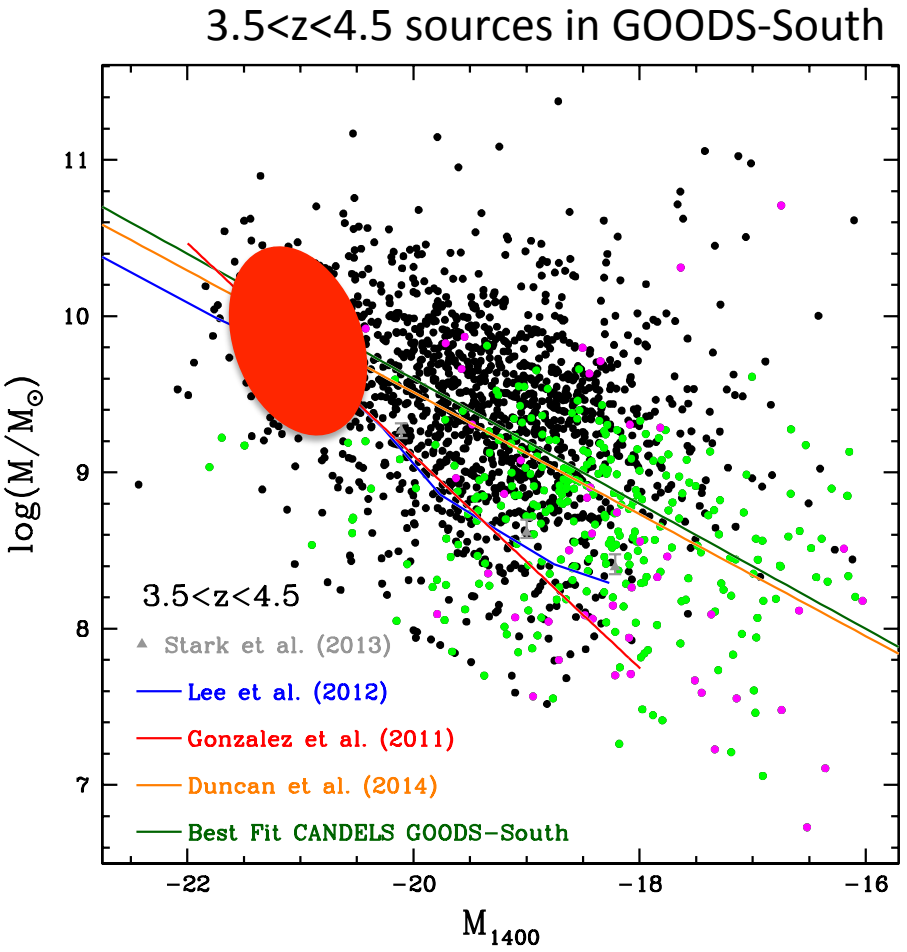
- about 50% of the sources are lost for “cleaning”

- V~25, mNB~27 (fesc(LyC)=30%, *Inoue2014*)
  V~27, mNB~29

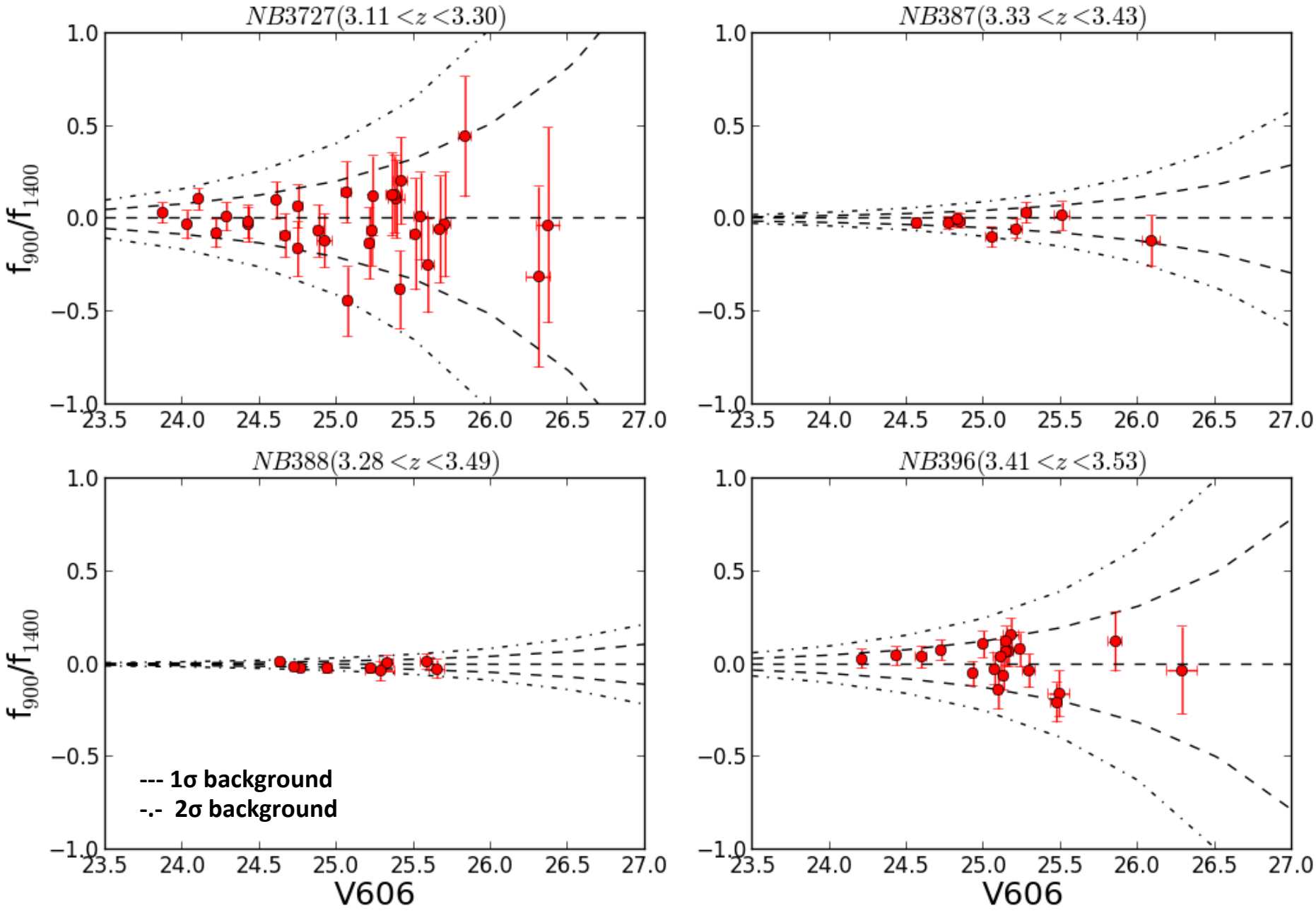


-22< M1400 < -20

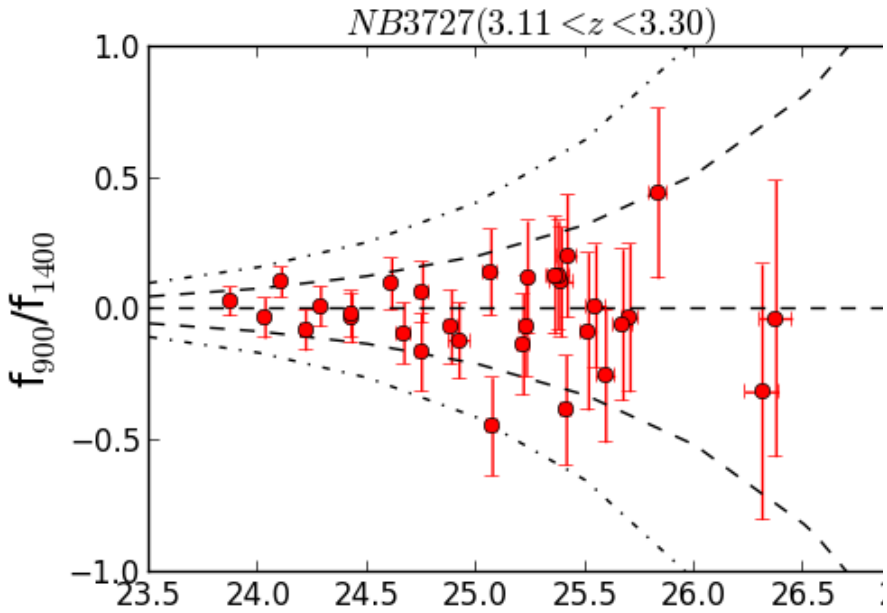
1E+8 < M/M$_\odot$ < 1E+11

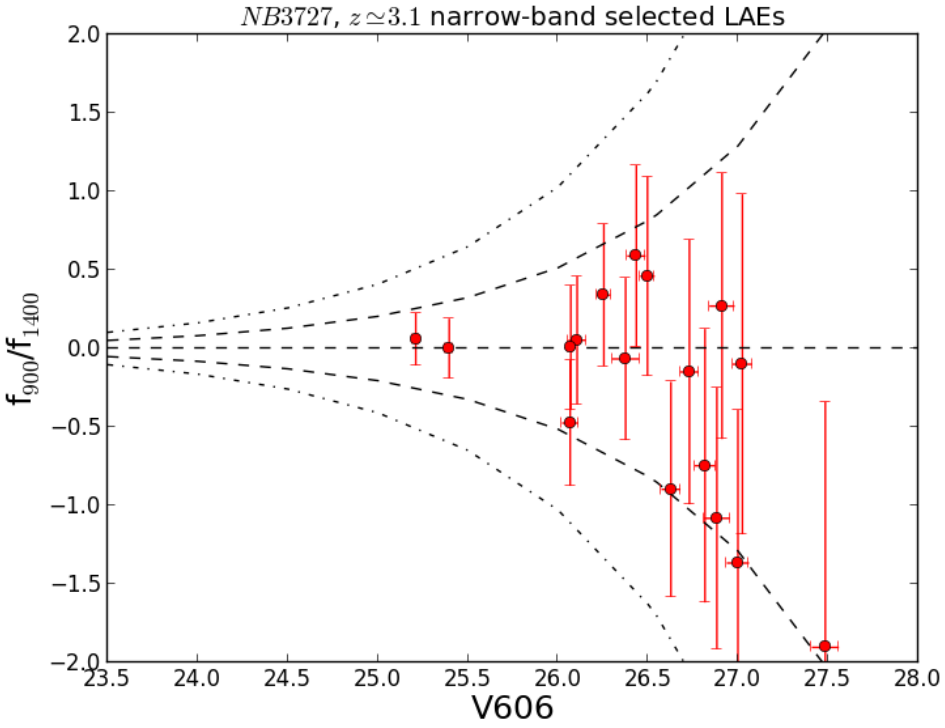


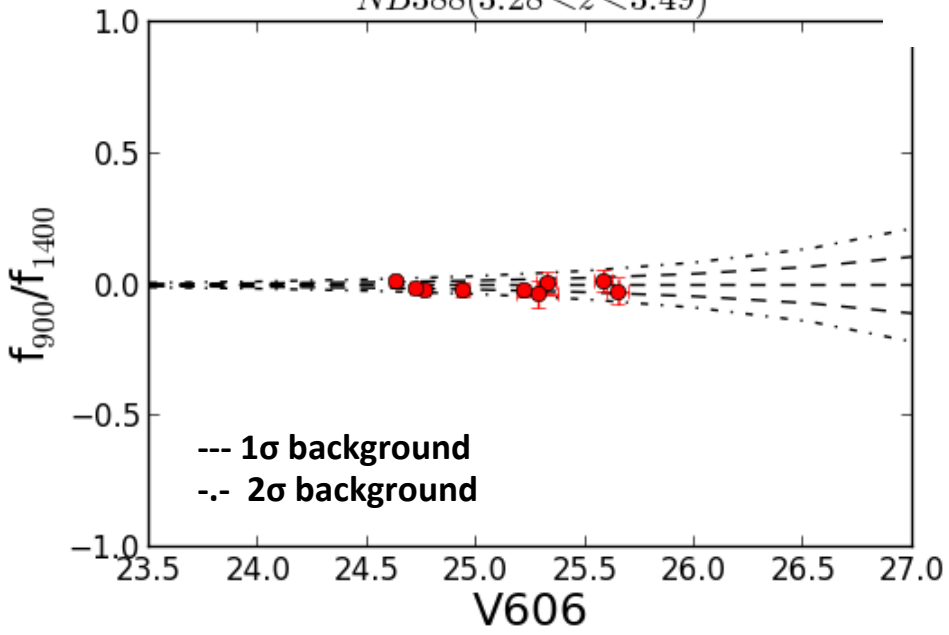
Santini 2015, Grazian 2015

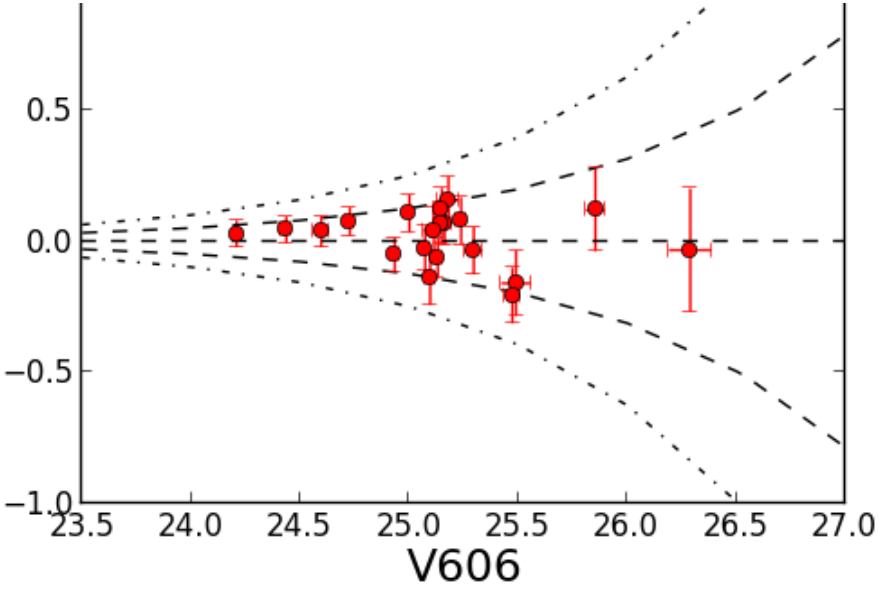


consistent with background





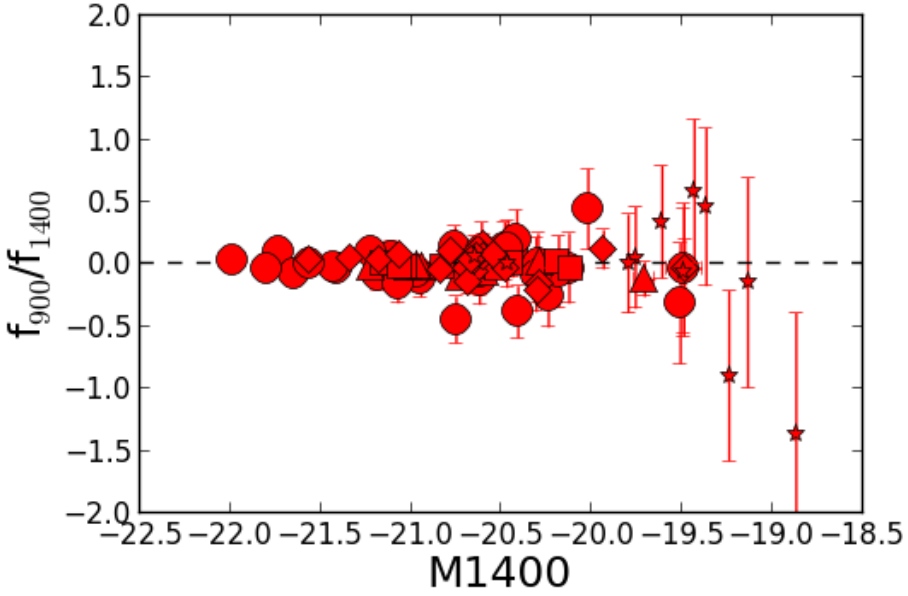


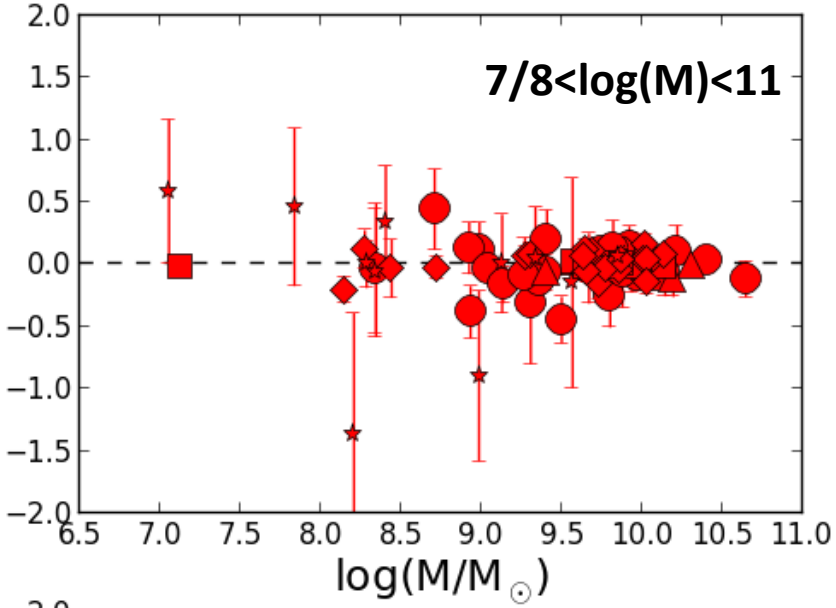


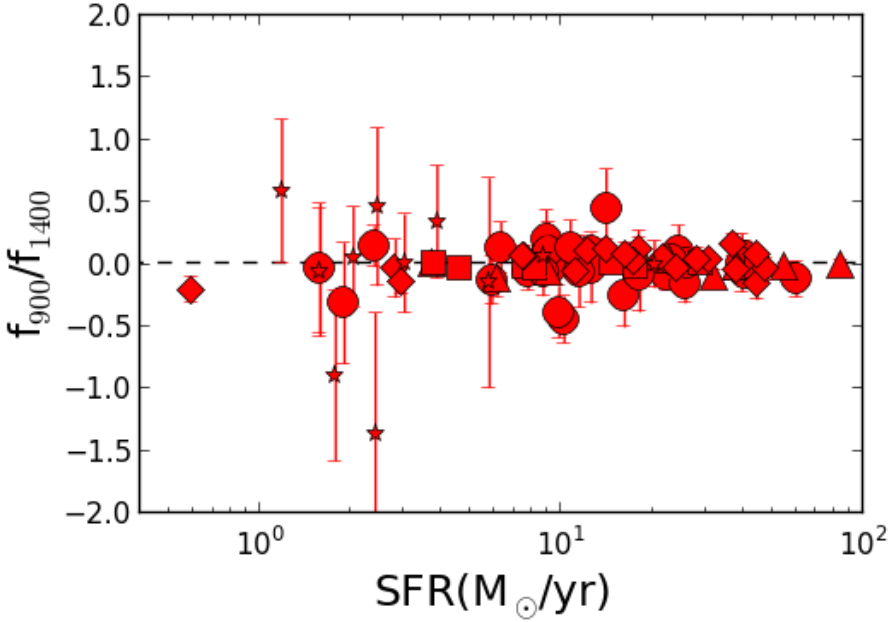
consistent with background

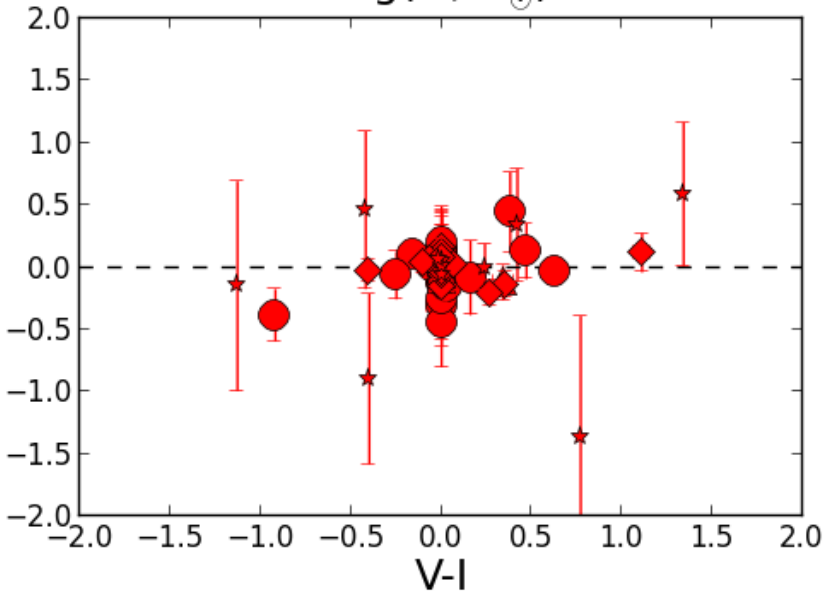
Results and implications

NBs with different depths









not any clear correlation (sub-samples)

fesc(LyC) relative to the intrinsic

$$fesc(LyC)^{rel} = \left(\frac{f_{NB396}}{f_{V606}}\right)_{obs} \frac{(L_{\nu,non-ion} / L_{\nu,ion})_{\rm int}}{\exp(-\tau_{IGM,z})}$$

Boutsia 2011, Nestor 2013, Mostardi 2013, Grazian 2015b

Age[c] (yr)	Z[d]	cSFR, 3.05<z<3.12 fesc intr
10^6	0.004	1.98
...	0.020	1.90
10^7	0.004	3.59
...	0.020	4.20
10^8	0.004	6.17
...	0.020	6.38

70 spectroscopically confirmed SFGs at 3.11<z<3. 3.53 (+ 17 LAEs at z≅3.1) in clean regions (weighted mean 1σ error)

fesc ^{rel} (SFGs) < 0.06 (<0.12)

fesc ^{rel} (LAEs) < 0.90 a few! faint V!

fesc ^{rel} (**LBGs**) = 0.05-0.08
(broad-band selected, zspec)
fesc ^{rel} (**LAEs**) = 0.18-0.49
(narrow-band selected, zspec)

fesc ^{rel} (**LBGs**) < 0.05
(broad-band selected, zspec)

(*Mostardi 2013, Nestor 2013* **z=2-3**)
Keck-NB3420 3σ det limit (PSF=0.7'')= 28.7

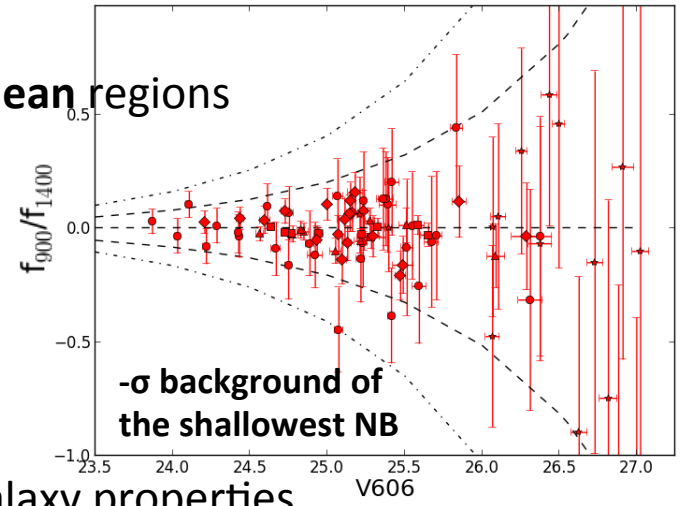
(*Boutsia 2011*, **z=3.3**)
LBC-U 3σ det limit (PSF=0.9'')= 29.9

Summary

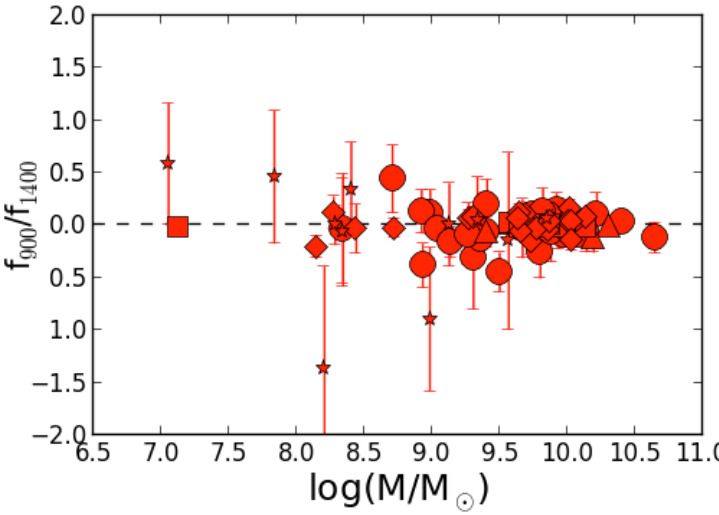
- Sample: spectroscopically-confirmed SFGs at z=3 in ECDFS
  HST coverage at least in 2 bands, multiwavelength photometry

  SFG: -**22< M1400 < -19, 1E+8 < M/M$_\odot$ < 1E+11**

  LAEs: -**20< M1400 < -19, 1E+8 < M/M$_\odot$ < 1E+9**
- NB flux is measured in aperture ≤ 2 x PSF for sources in **clean** regions
- **Advantage**: reduce source confusion
  and low-z contamination, highest S/N in NB



- We can set upper limits on fesc(LyC)^{rel} < 0.06 (0.12)
- We do not see any correlation between LyC signal and galaxy properties



- **Possible reasons**:
  LyC escape is low on average in a sample of SFGs
  SFGs with these physical properties are not LyC leakers
  leak less than NB detection limit
  no special line of sight/not enough statistics

⇒ cleaning

⇒ increasing the sample focusing on
≤0.8'' PSF images

Thanks