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Lyman Continuum Signal from z~3 star-forming galaxies with available multi-wavelength coverage ?

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Outline

- Motivation
- Project idea
  - sample, available data
  - properties vs other sources
- Method
  - flux measurement
- Results and implications
- Summary and on-going work

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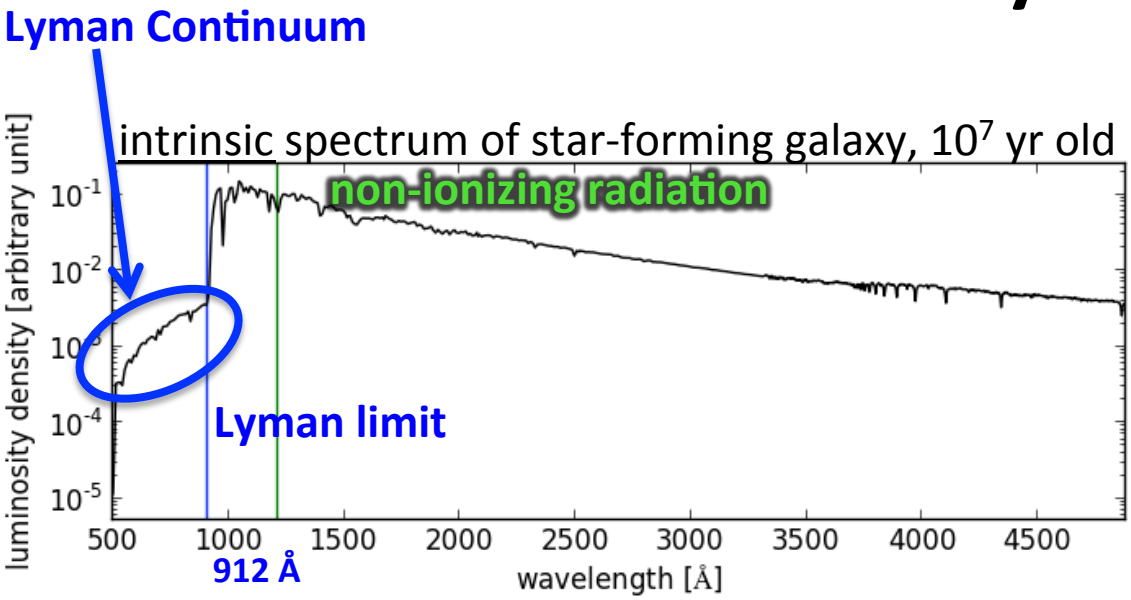
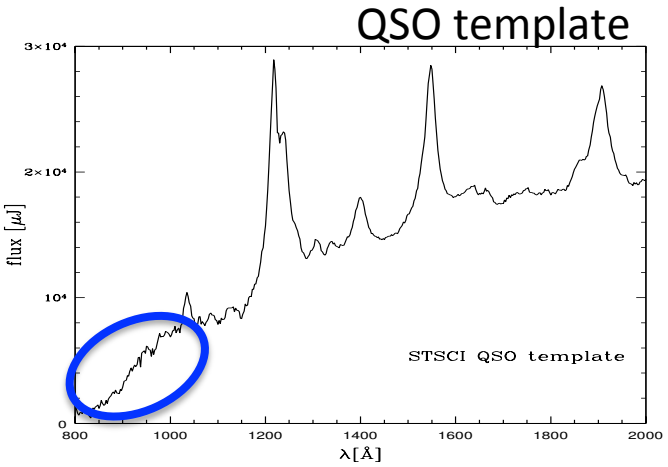
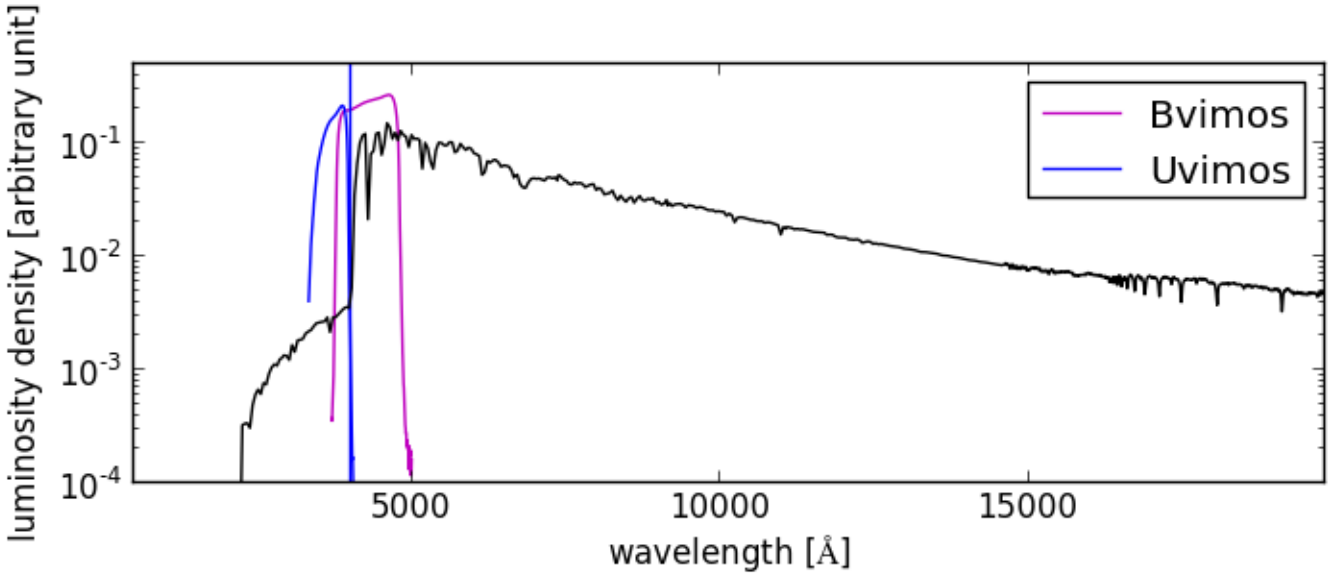
Lyman Continuum Signal







z~3

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

1) Galaxy properties and evolution (e.g. *Avedisova 1979, Roy 2014*)

- **SF**: O stars, young (<5 Myr) and low-Z (Z~0.2$Z_\odot$) galaxies, PopIII stars
- **ISM**: low NHI within 10pc, M(DMH)<1E+8 $M_\odot$, (e.g. *Yajima 2011, Paardekooper 2015*
  M(DMH)>1E+8 $M_\odot$ **if** SNs create channels *Wise 2014*)
  low-mass disks , clumpy medium, sight lines (e.g. *Zackrisson 2013, Roy 2014*)
- **IGM**: gas accretion, galaxy SF and evolution

Andrea Grazian's talk

2) LyC escape responsible for the re-ionization of the Universe at z>6

- sources (**SFGs, AGNs**): try to measure fesc(LyC) from test sources at lower-z and **extrapolate**
- simulations: try to predict physical properties of LyC leakers at z>6
  probably **star-forming low-mass** galaxies below detection limits
  a few massive with active feedback

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

- z~3 is ideal because IGM transmissivity is ~40% (*Inoue 2014*): chance of identify LyC leakers and infer if galaxies with the same characteristics are common at z>6 (e.g. *Vanzella 2012,2015*)

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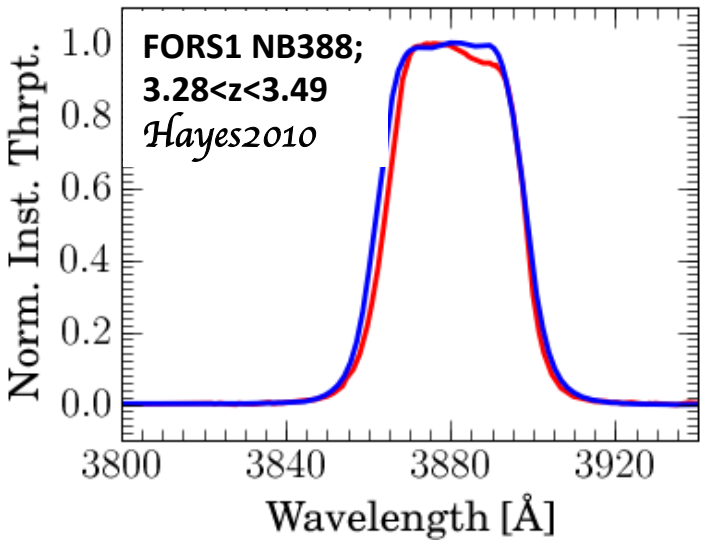
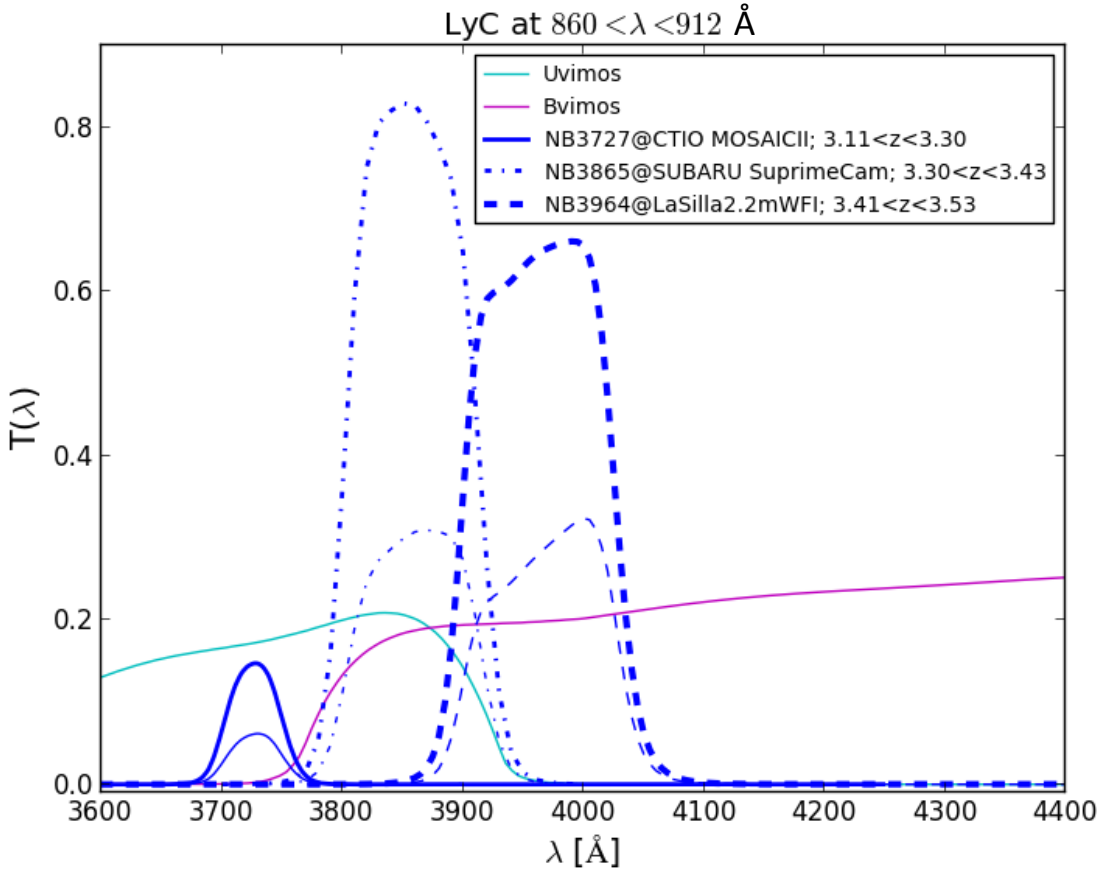
- sample of **spectroscopically confirmed** SFGs and AGNs **at z~3 in ECDFS (clean regions)** (FORS,VIMOS CDFS MASTER CATALOG + literature + MUSYC LAEs at z~3.1)
- take advantage of HST images/spectra to reduce low-z nearby-source contamination on individual source basis
- take advantage of CANDELS/ECDFS **multi-wavelength photometry** to study their physical properties

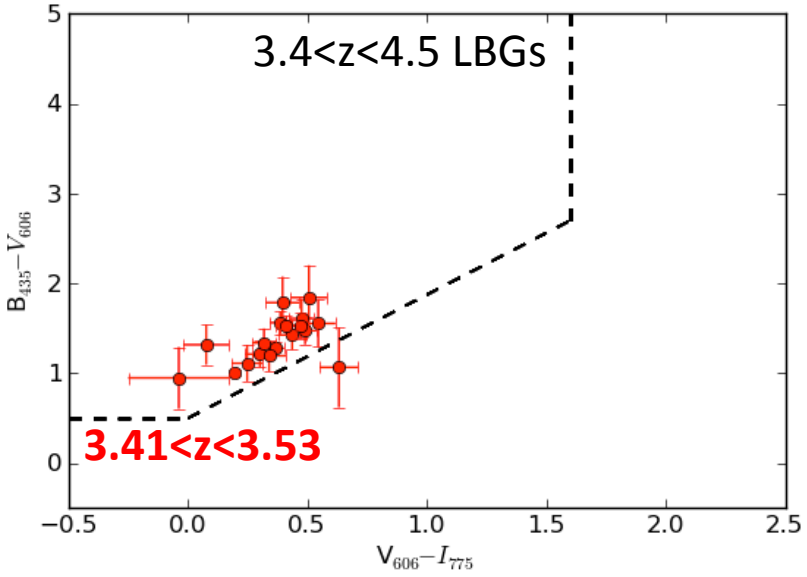
⇒ measure LyC flux in **NB** images at the position of the source

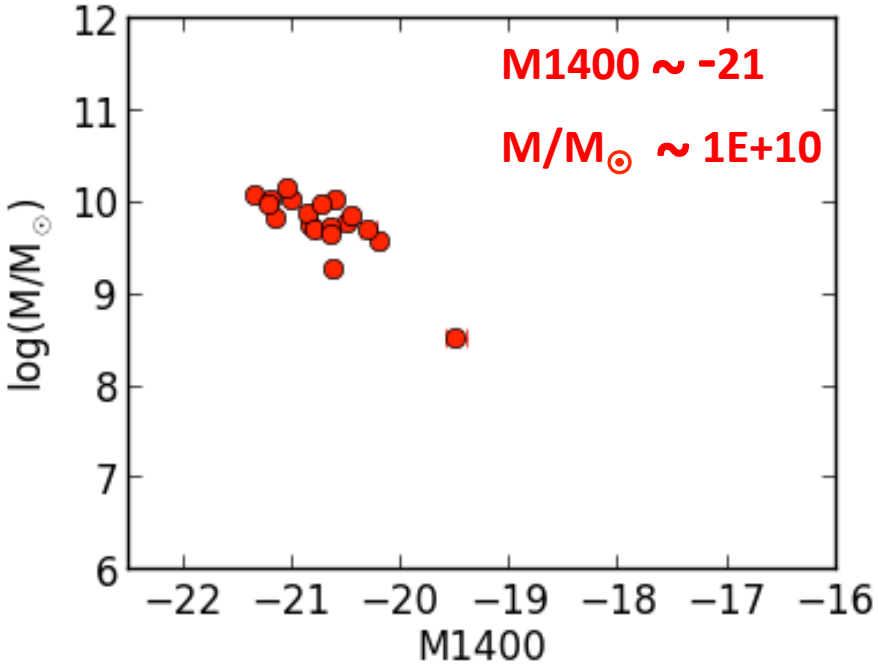
NB396, 3.41 < z(LyC) < 3.53
Ngal=27 Nagn=2
3σ det lim (PSF=0.94'') = 27.5



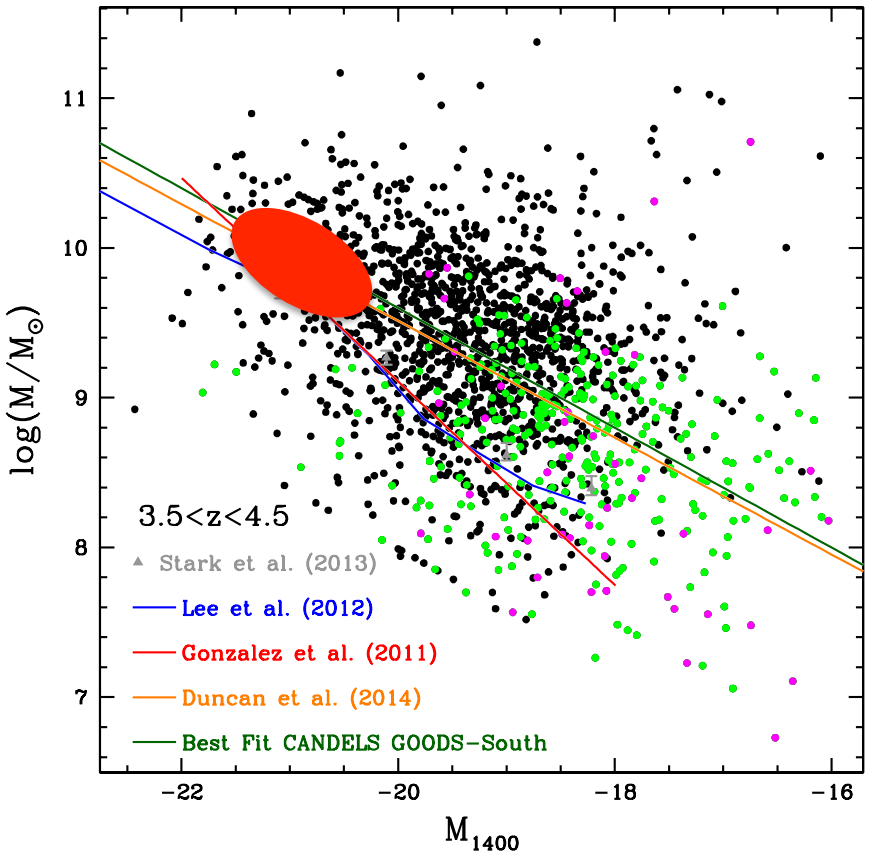


spec confirmed sources in clean regions, CANDELS photometry (*Santini 2009, Grazian 2015, Vanzella 2015*)





3.5<z<4.5 sources in GOODS-South



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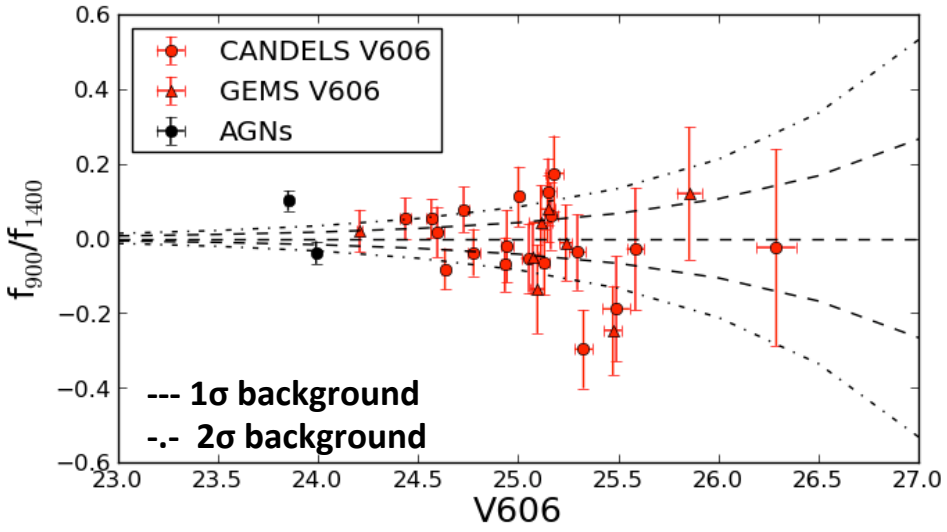
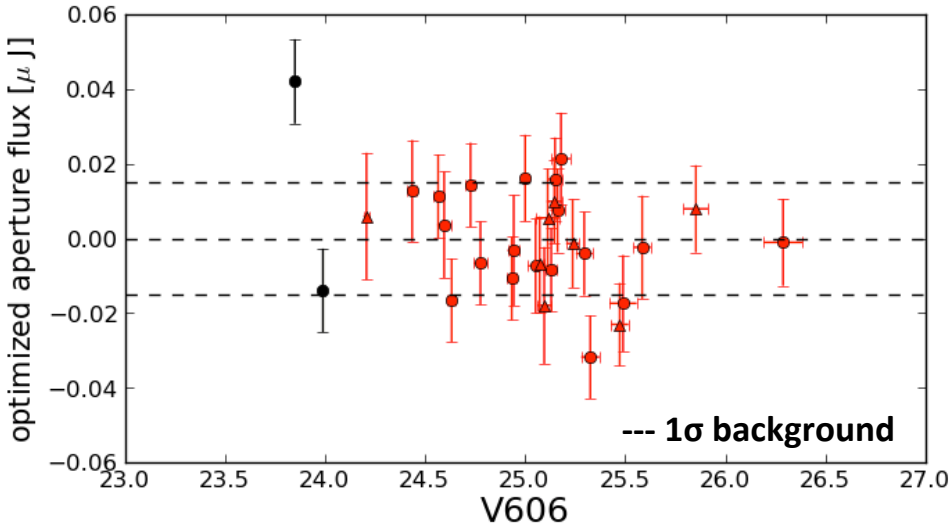
- We take V flux from CANDELS or/and GEMS (**global**)

- We built a NB detection catalog (kernel=PSF filtering, threshold=1σ)
  we search for matches of z-spec sample in NB catalog within r=2xPSF searching radius
  (this would take into account eventual offset between ionizing/non-ion emissions up to 10kpc
  but sensitive to low-z contamination)
  (e.g. *Mostardi 2013*)

- We measure the flux directly in the position of a source
  (diam aperture optimized for the highest S/N of point sources in NB396
  and 2xPSF to include eventual offset between ionizing/non-ion emissions up to 10kpc)
  (e.g. *Vanzella 2010, Boutsia 2011, Grazian 2015b*)



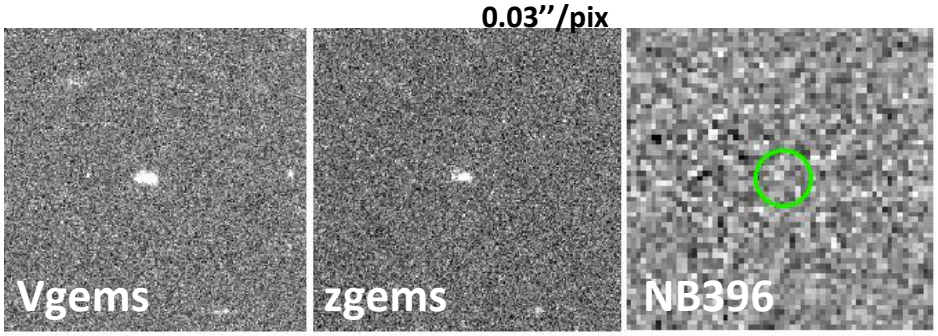


consistent with background

Example of sources in clean regions

circle radius = 1''

GEMS coverage
id882



CANDELS coverage
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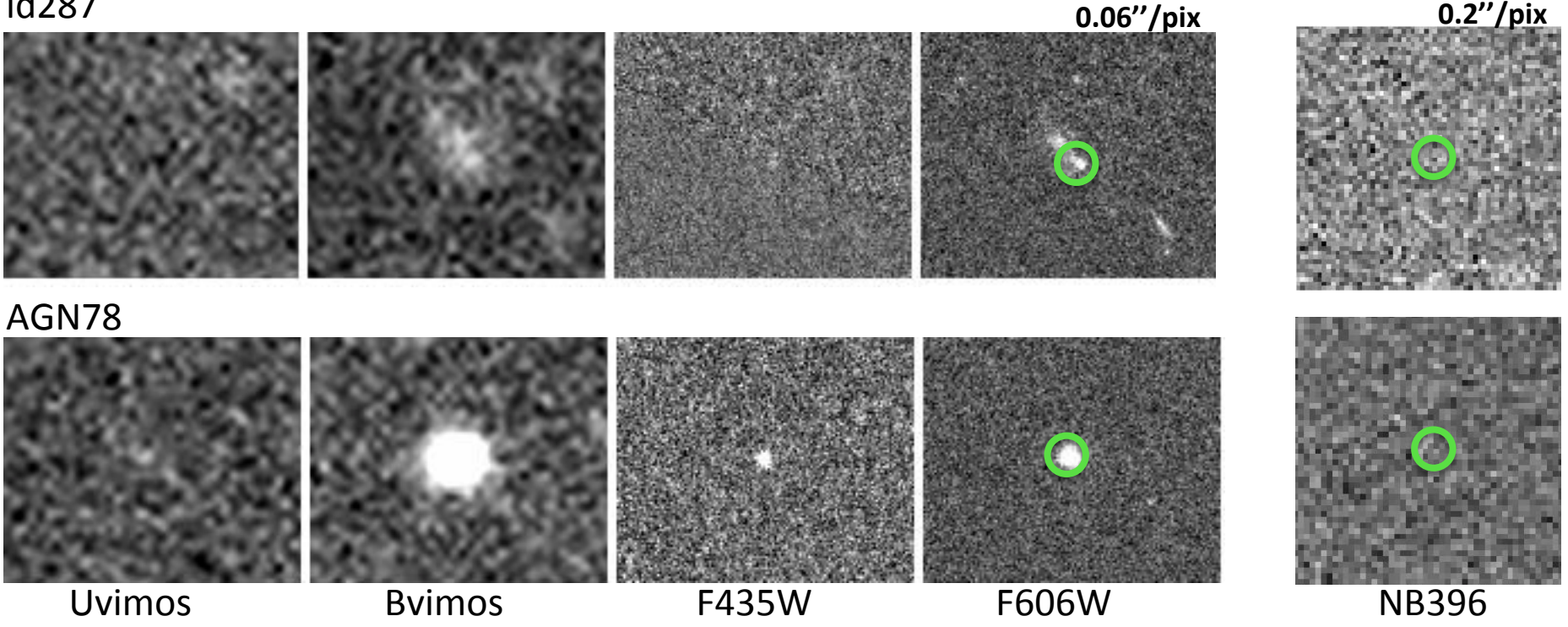

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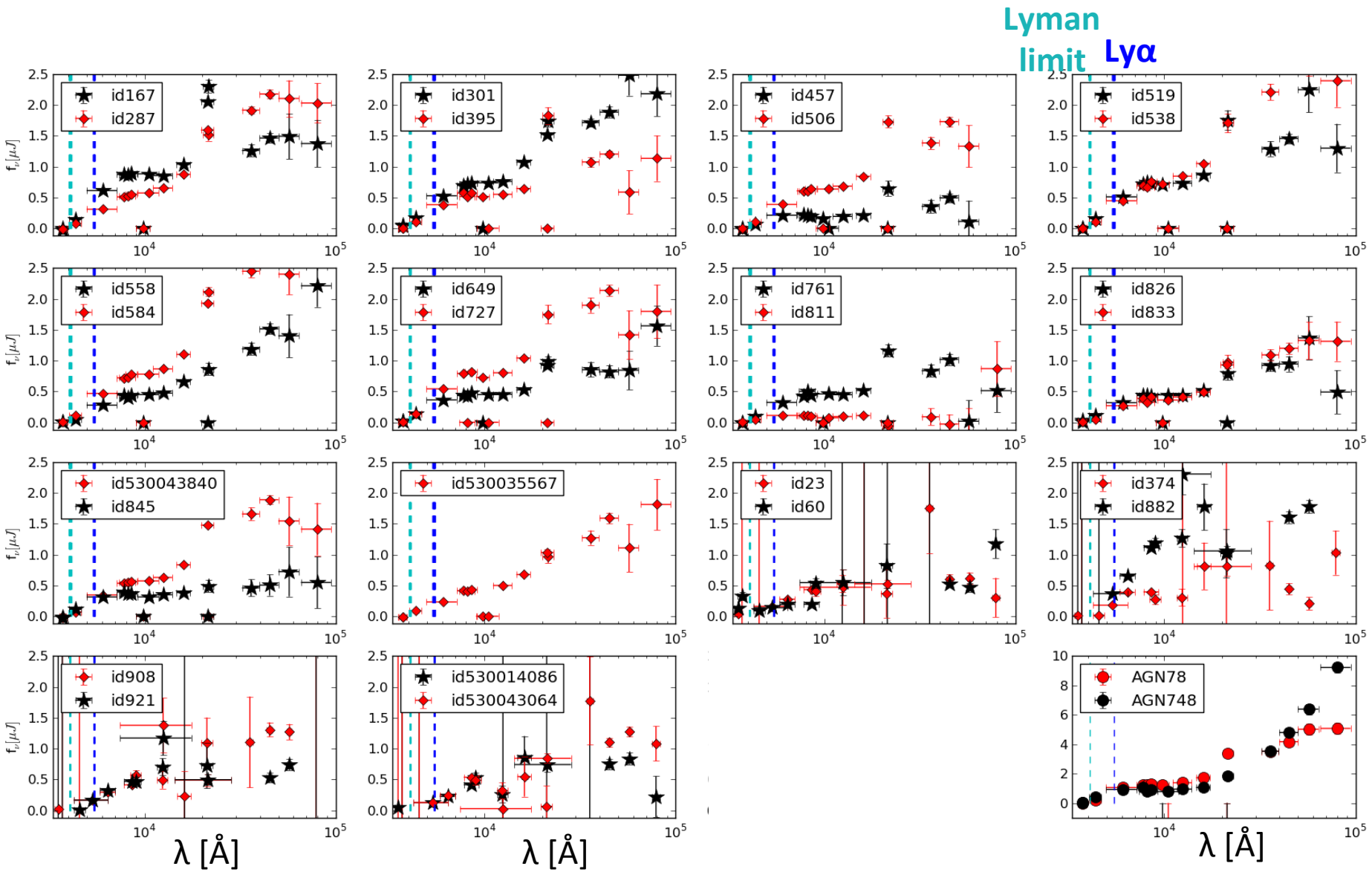
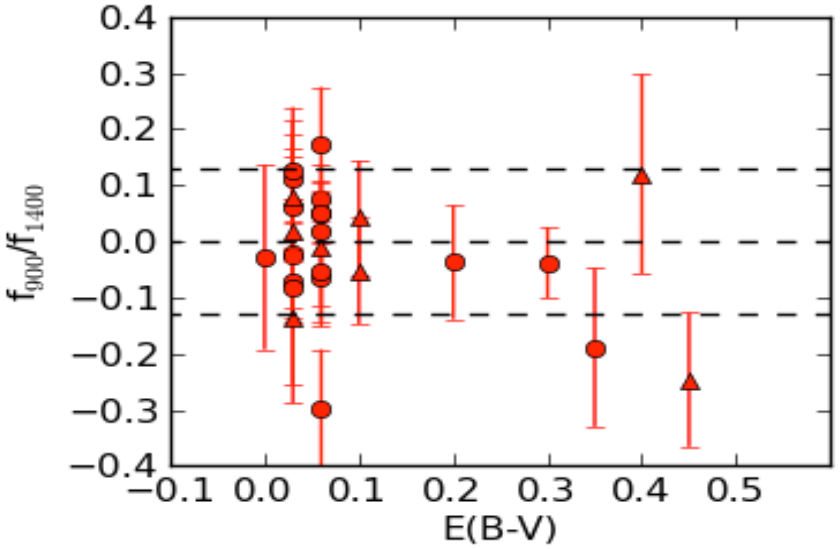
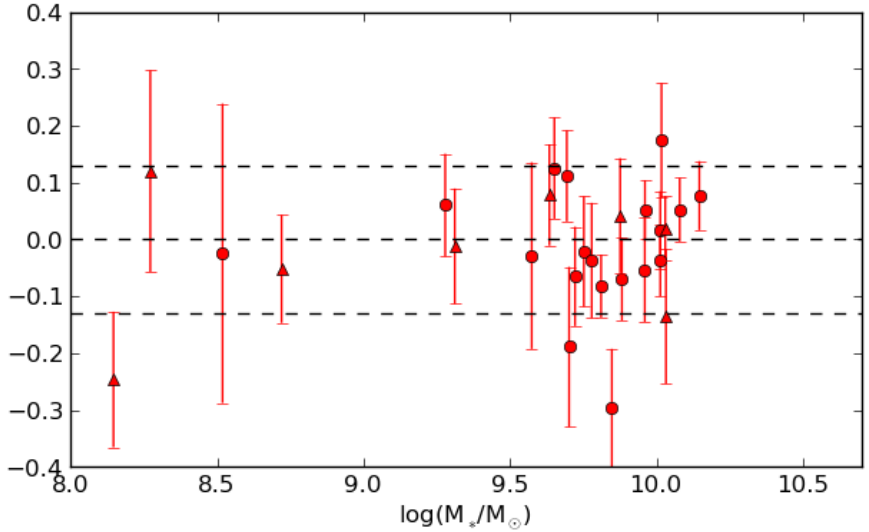
sources' complete SEDs

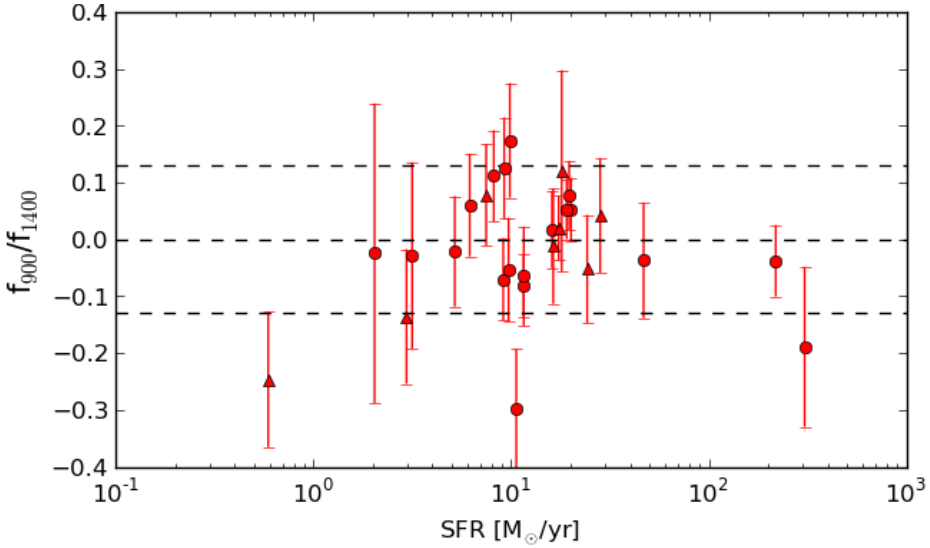


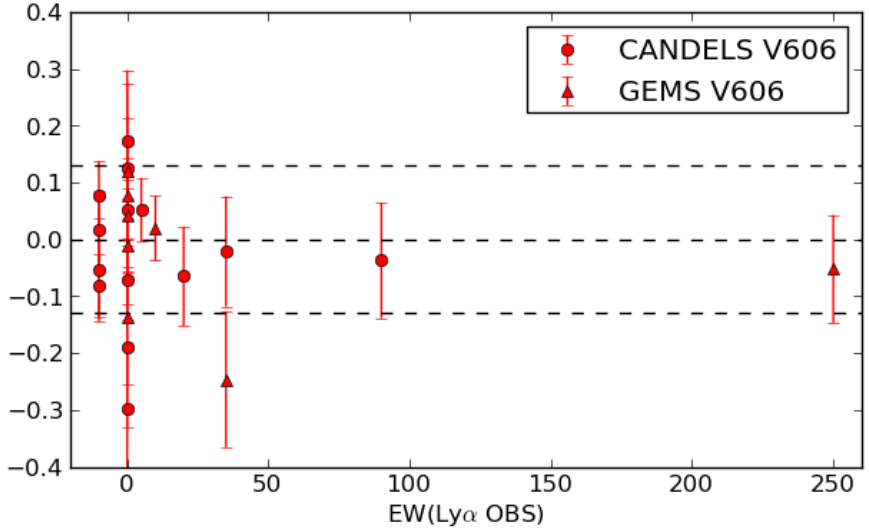
-> physical parameters

f_{900}/f_{1400} vs physical parameters









AGN $\log(M_*/M_\odot)$ = 10.4-10.5

not any clear correlation **yet**

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

fesc(LyC) relative to the intrinsic

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

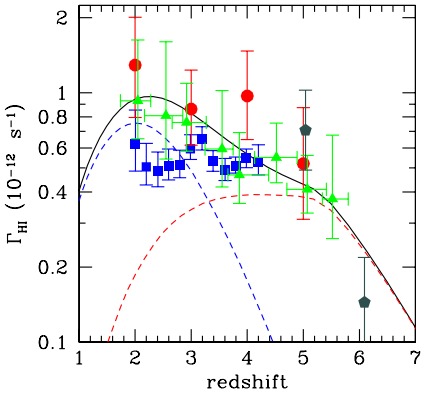
star-forming galaxies

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

AGNs **1-2**

total Hydrogen photoionization rate

$$\Gamma_{-12} = \frac{10^{12} \cdot \rho_{900}^{esc} \cdot \sigma_{HI} \cdot \Delta l \cdot (1+z)^3}{h_P \cdot (3 + |\alpha_{UV}|)}$$



ρ_{900} = (fNB/fV606)corr ρ1400[erg/sec/Hz/Mpc^3]

σ = HI cross section

α_{UV} = power-law index of the ion spectrum = -0.5 (SFGs) *(Faucher-Giguere 2008)*

Δl = mfp ~ ((1+z)/5) $^{\eta}$ *(Worseck 2014a)*

Implications

27 star-forming galaxies

$f_{esc}^{rel} < 0.14$ (<0.28)

$\Gamma_{HI} < 1.1$
(Grazian 2015b assumptions)

2 *known* AGNs – Xray detected

$f_{esc}^{rel} = 0.57 \pm 0.15$

$f_{esc}^{rel} < 0.17$

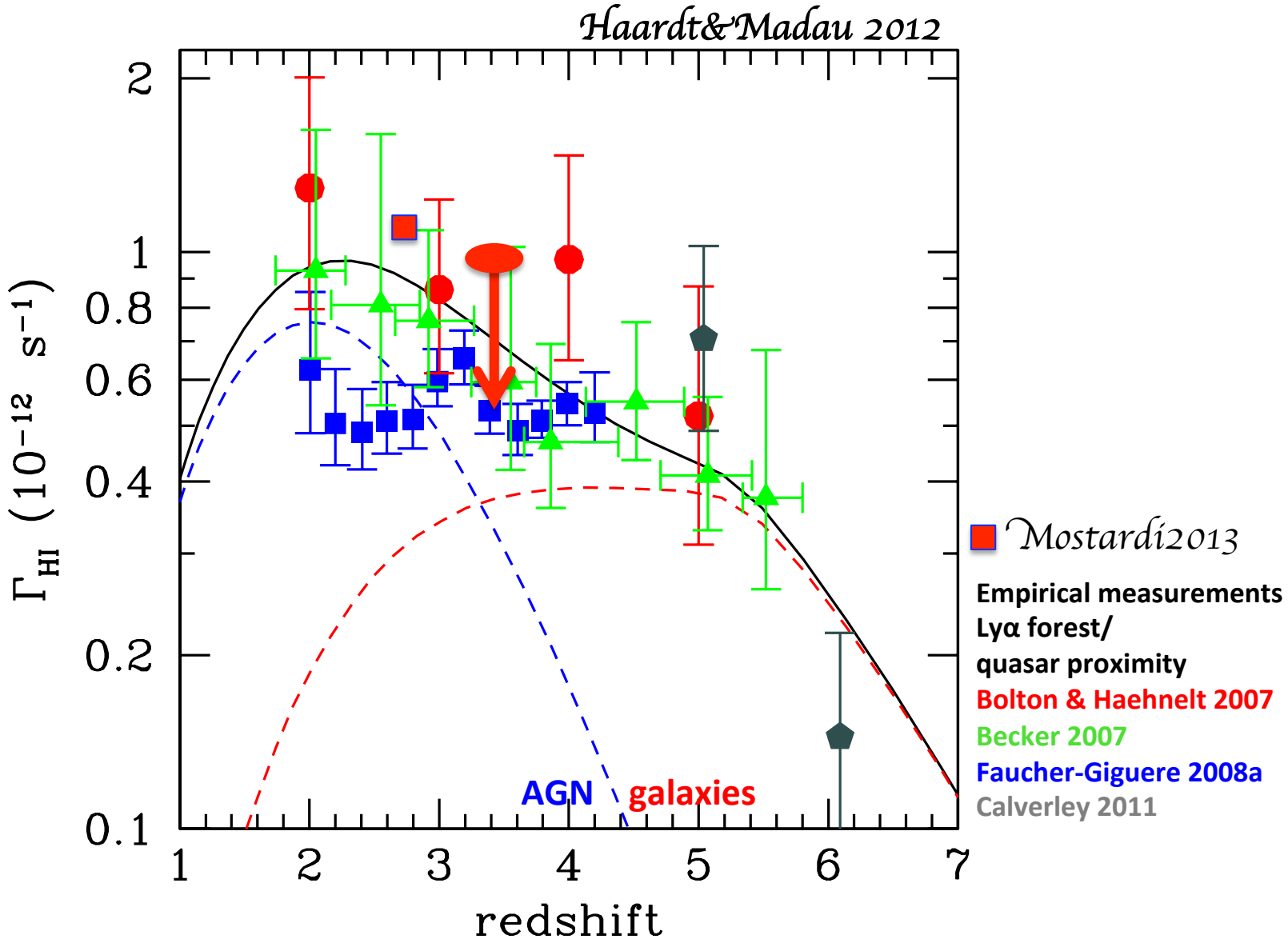
individual cases

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

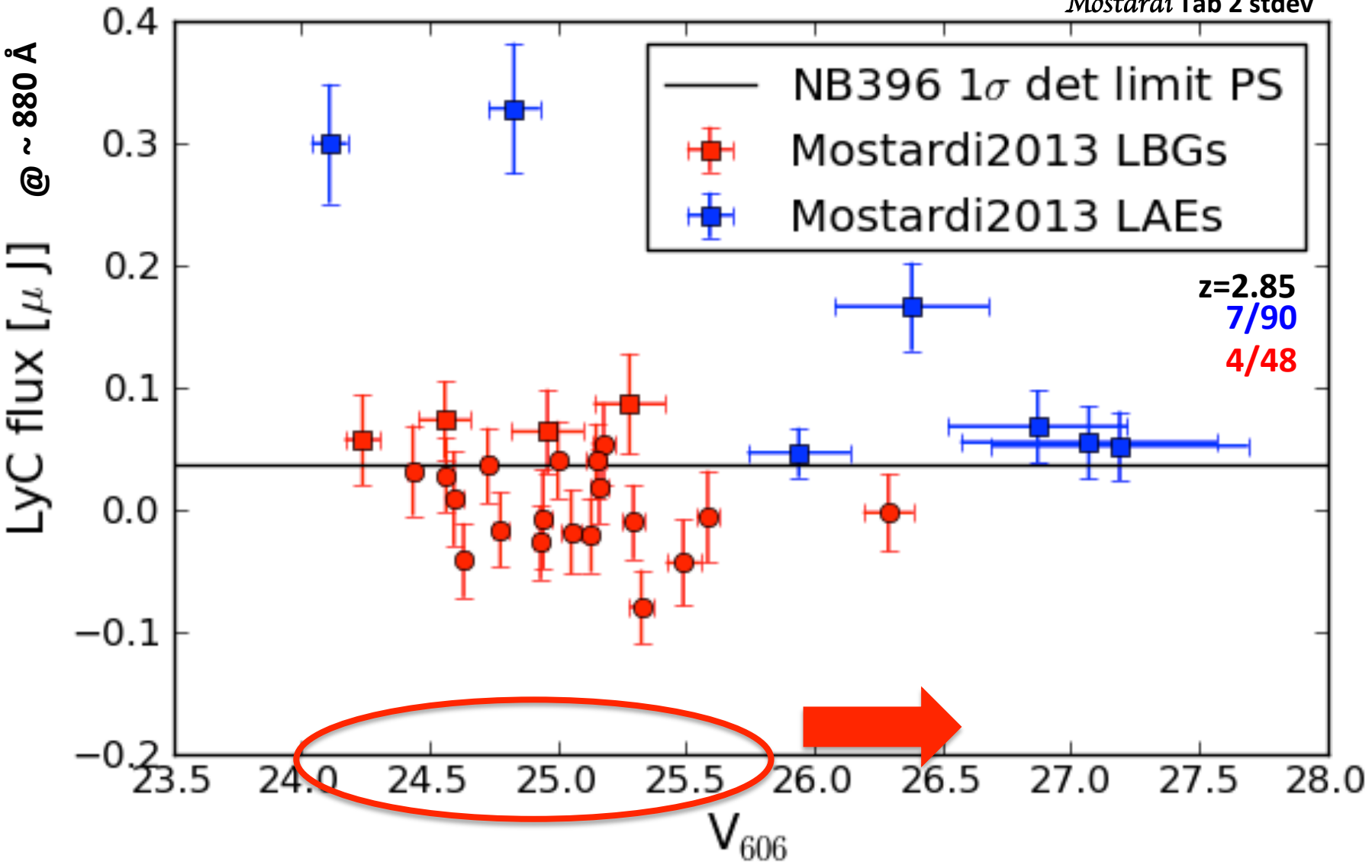
f_{esc}^{rel} (**LBGs**) < 0.05
(broad-band selected, zspec)

(*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



just consistent with previous measurements



We could have detected their candidates in our NB if the same flux at 900 Å, but lower-z but LAEs

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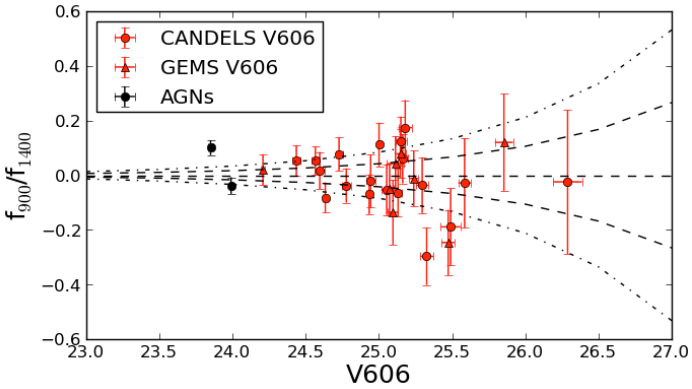
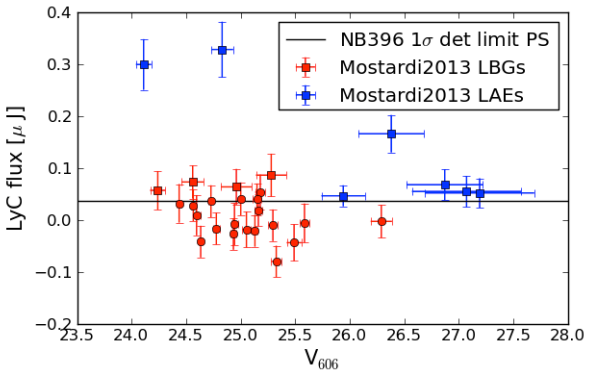
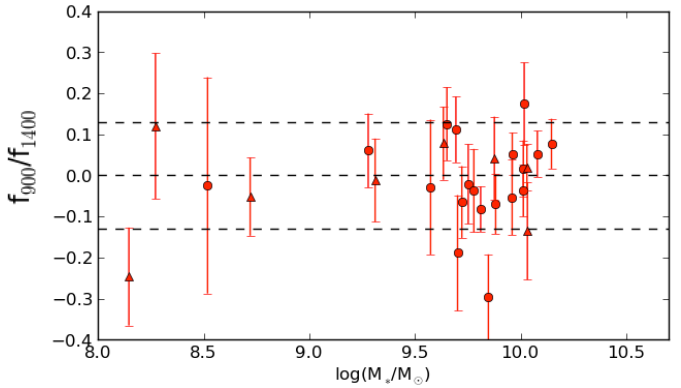
- **Sample**: spectroscopically-confirmed GALAXIES and AGNs at z=3 in ECDFS
  HST coverage at least in 2 bands, multiwavelength photometry
  Lyman Break Galaxies, M*~1E+10 $M_\odot$, M1400 ~ -21
  AGNs, M*~1E+10.5 $M_\odot$, 1E+10.4 $M_\odot$,
- NB flux is measured in aperture ≤ 2 x PSF for sources in **clean** regions
- **Advantage**: reduce source confusion
  and low-z contamination, highest S/N in NB



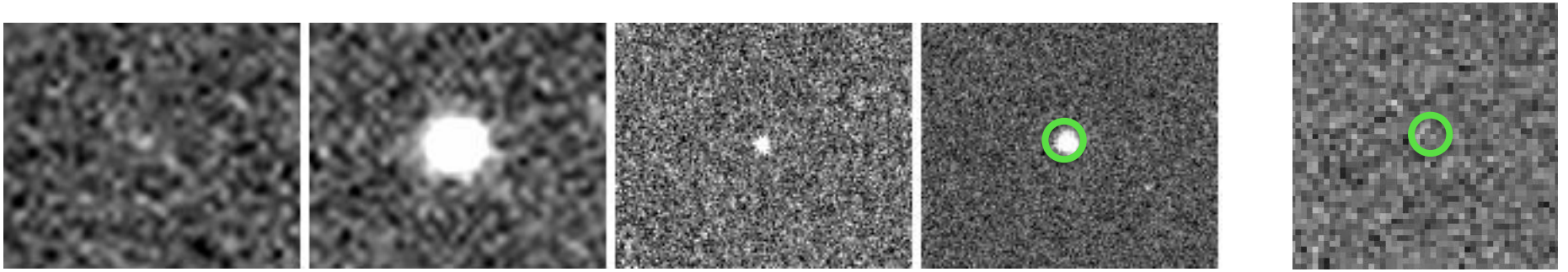
- We do not find any convincing case for these gals … **yet**
- We can set upper limits on fesc(LyC)^{rel} < 0.14, Γ_{HI} < 1.1

- We do not see any correlation between LyC signal and galaxy properties … **yet**
- **Reasons**: line of sight, statistics, redshift/IGM, V, stellar mass, mergers (e.g. *Gnedin2009, Bridge 2010*)





- We measure fesc(LyC)^{rel} = 0.57 ± 0.15 for 1 AGN (over 2) == individual case



Uvimos | Bvimos | F435W | F606W=23.85±0.1 | NB396=26.3±0.3

→ Other NBs + some additional redshifts **higher statistics of same kind of galaxies**

→ Narrow-band selected LAEs **lower mass galaxies**

Thanks