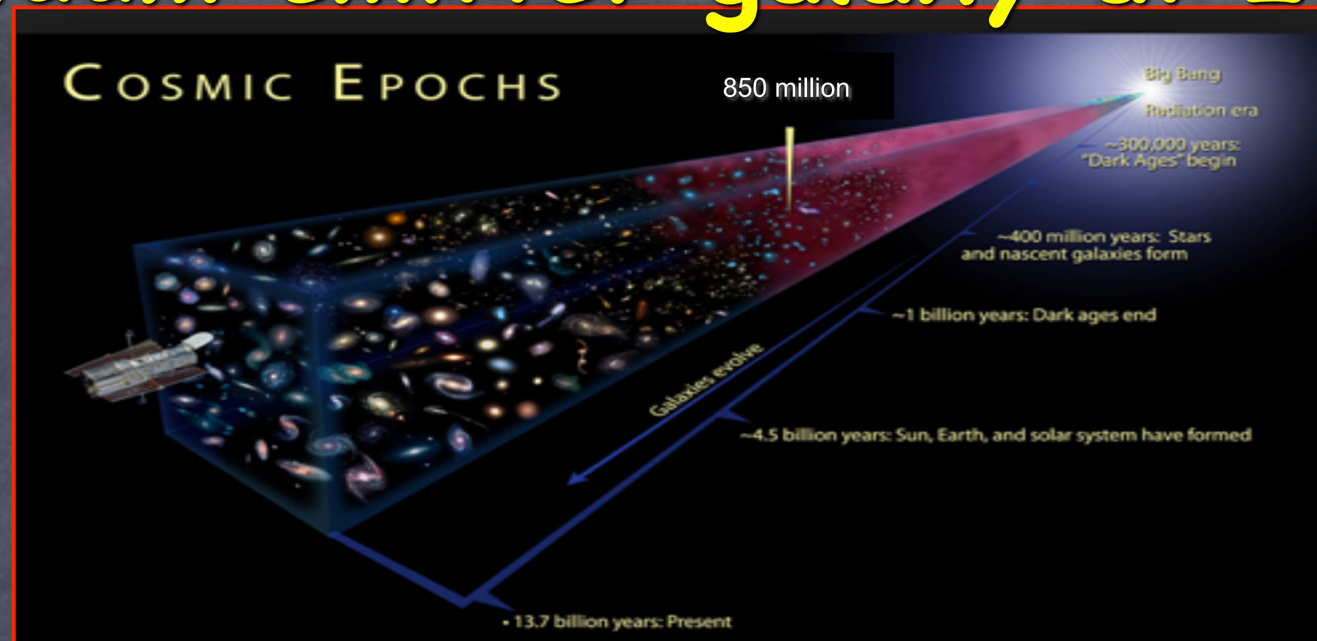
The physical properties of a star-forming Lyman continuum emitter galaxy at z=3.212



&

The star-formation main sequence at z=4: prospect for the NIRSpec instrument

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Stephane De Barros

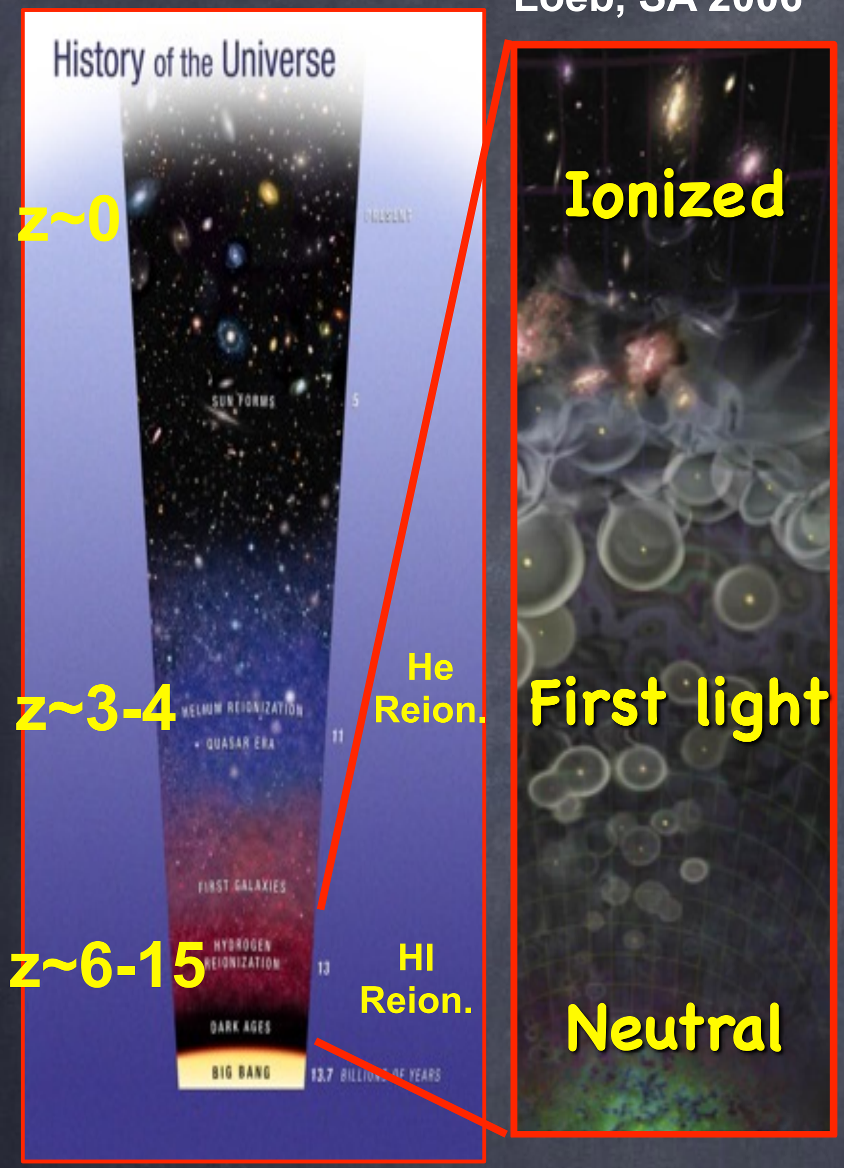
INAF - Astronomical Observatory of Bologna

Collaborators:

E. Vanzella (INAF-OABO), B. Mobasher(UCR), G. Hazinger (U. Hawaii), A. Grazian (INAF-OAR), H. Nayyeri (UCI), G. Zamorani (INAF-OABO), B. Siana (UCR), L. Pentericci (INAF-OAR), D. Schaerer (U. Geneva) et al.

Motivation: HI reionization epoch and the nature of ionizing sources

Loeb, SA 2006



Open questions:

When ? z, Δz ?

How ? $d[Q_{HII}]/dt$

Who ? Ionizing sources

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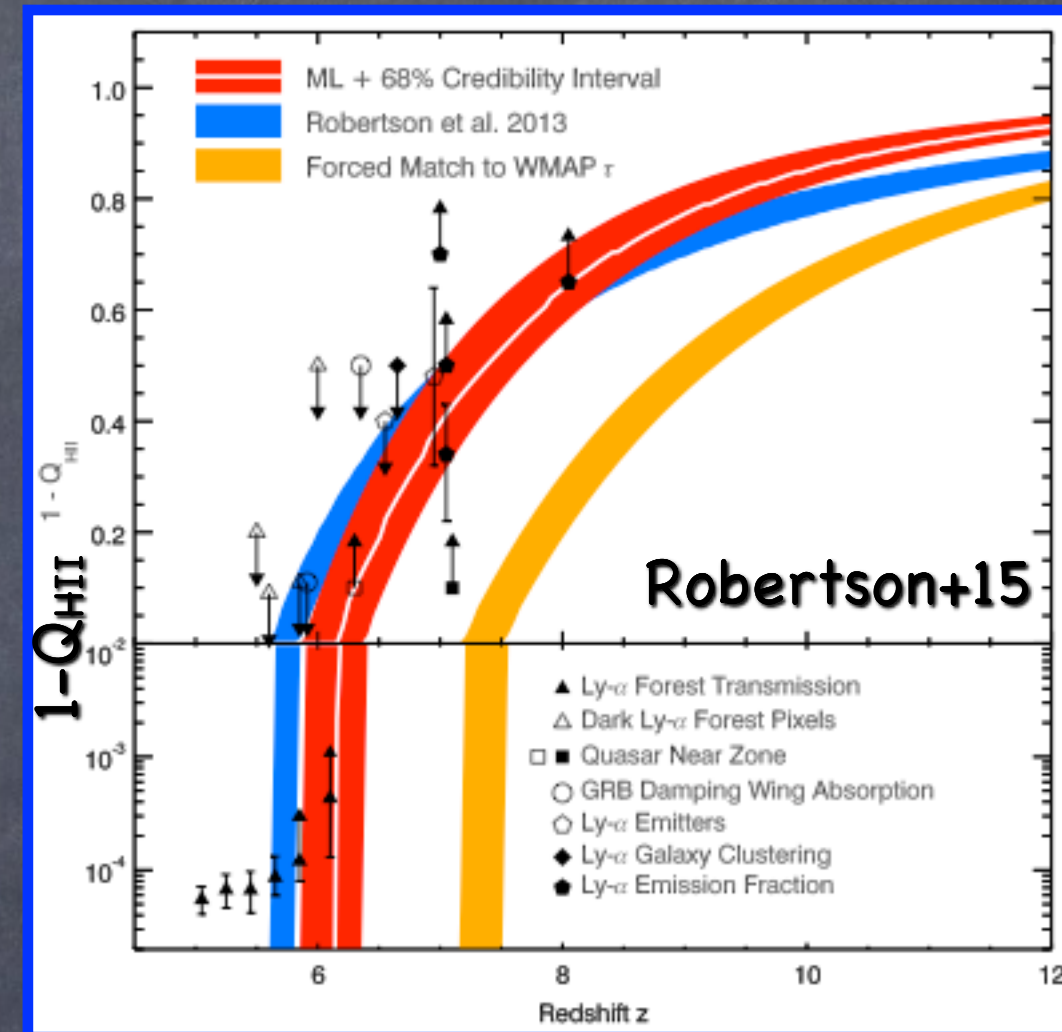

Q_{HII} volume filling factor

$$\frac{dQ_{\rm HII}}{dt} = \frac{\dot{n}_{\rm ion}}{\langle n_{\rm H}\rangle} - \frac{Q_{\rm HII}}{t_{\rm rec}(C_{\rm HII})}$$

↔

Thomson optical depth to electron scattering

$$\tau_e(z) = \int_0^z c\,\langle n_{\rm H}\rangle\,\sigma_T\, f_e\, Q_{\rm HII}(z')\frac{(1+z')^2 dz'}{H(z')}$$

Kimm & Cen (2014)

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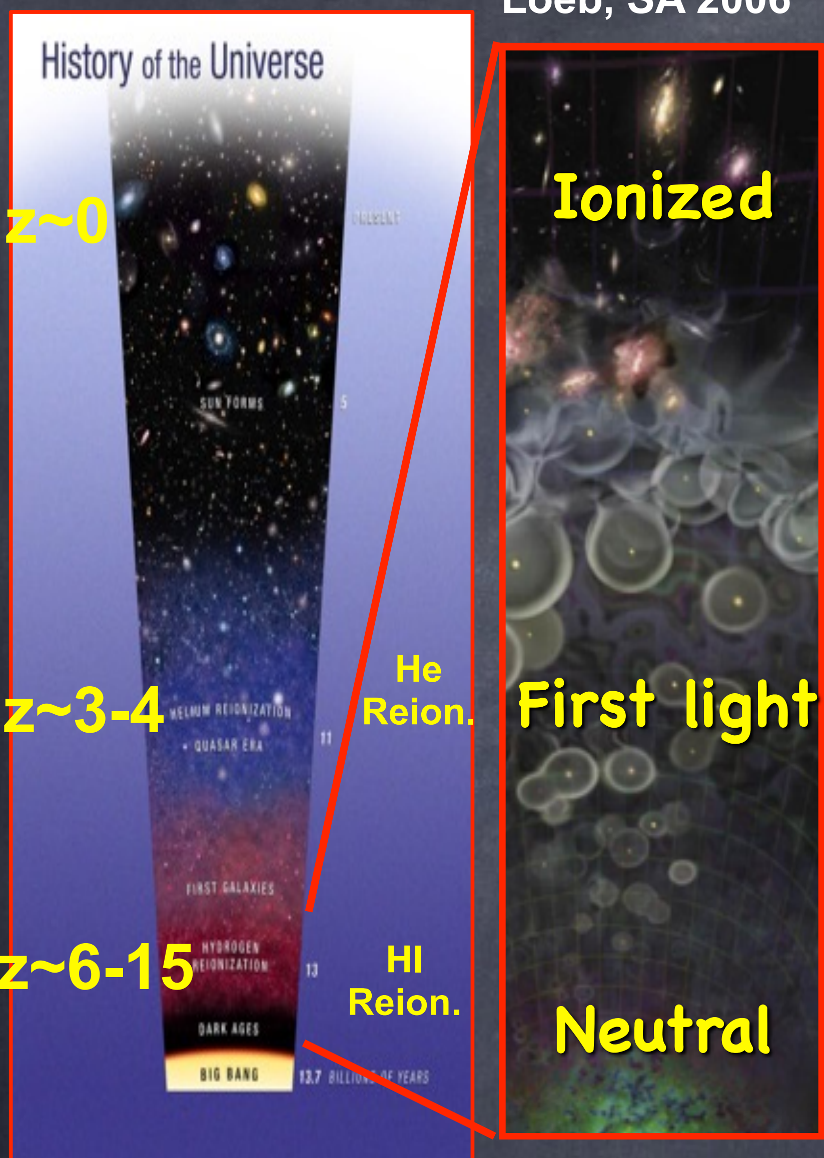

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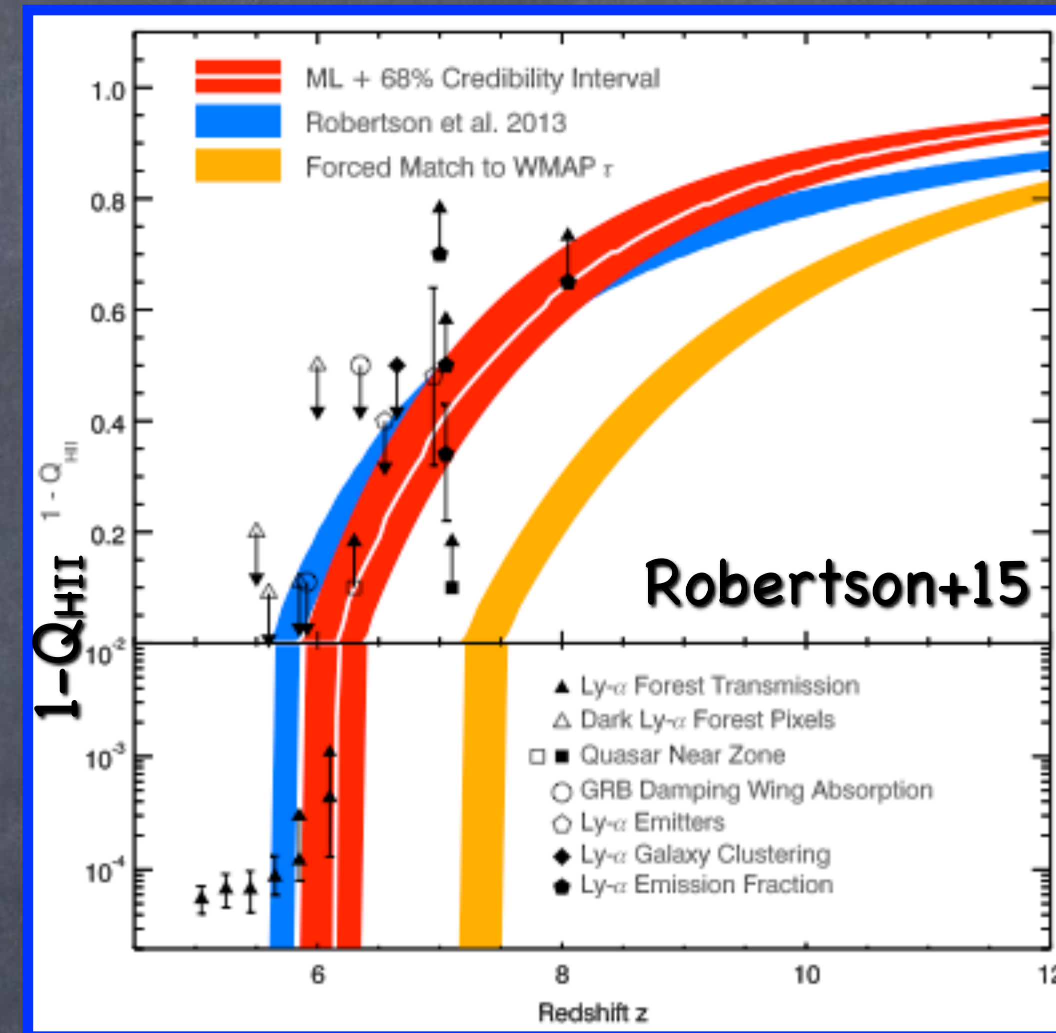

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Kimm & Cen (2014)

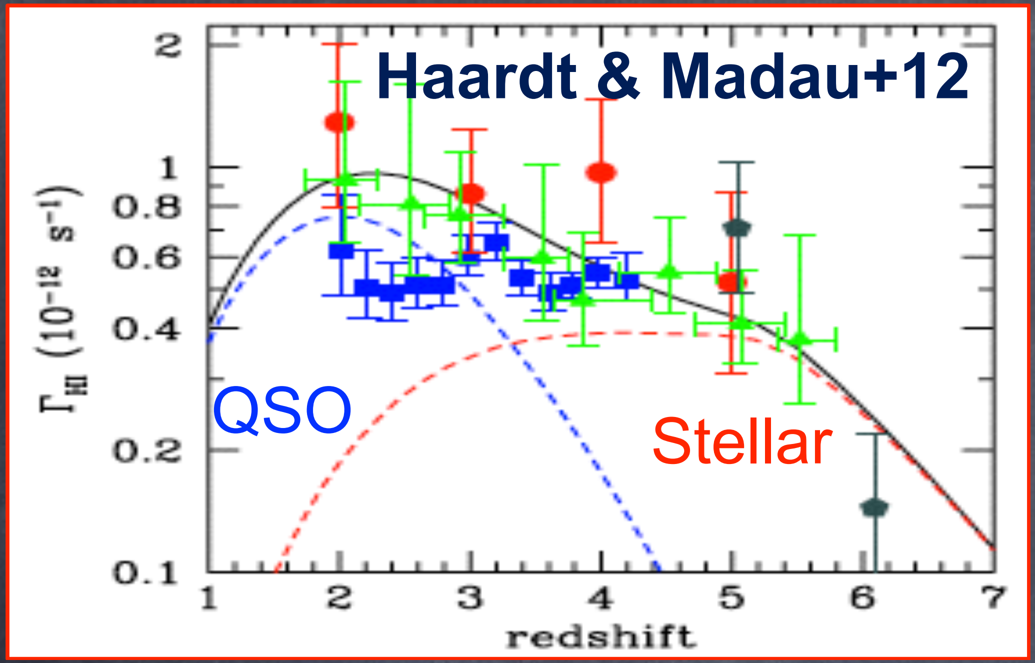
$$\dot{n}_{{\rm halo},\gamma} = f_{\rm esc} f_\gamma f_{\rm gas} f_\star M_{\rm vir}$$

Wise (2014)

Intrinsically complicated modeling: radiative transfer, time, space, source dependencies: astrophysics

Motivation: HI reionization epoch and the nature of ionizing sources

Galaxies leading candidates @ z>3



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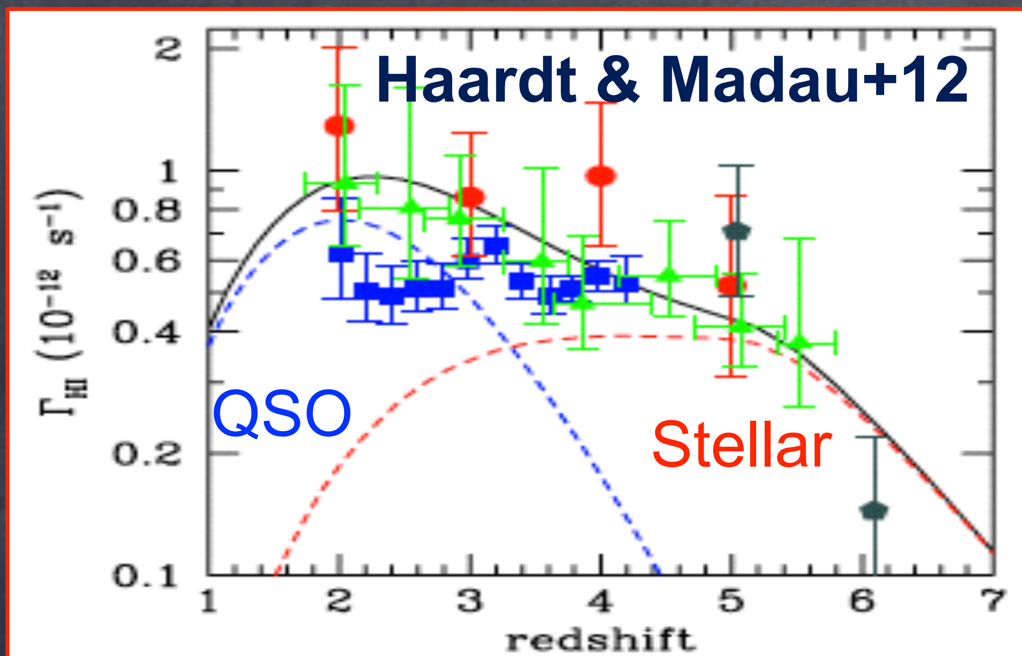
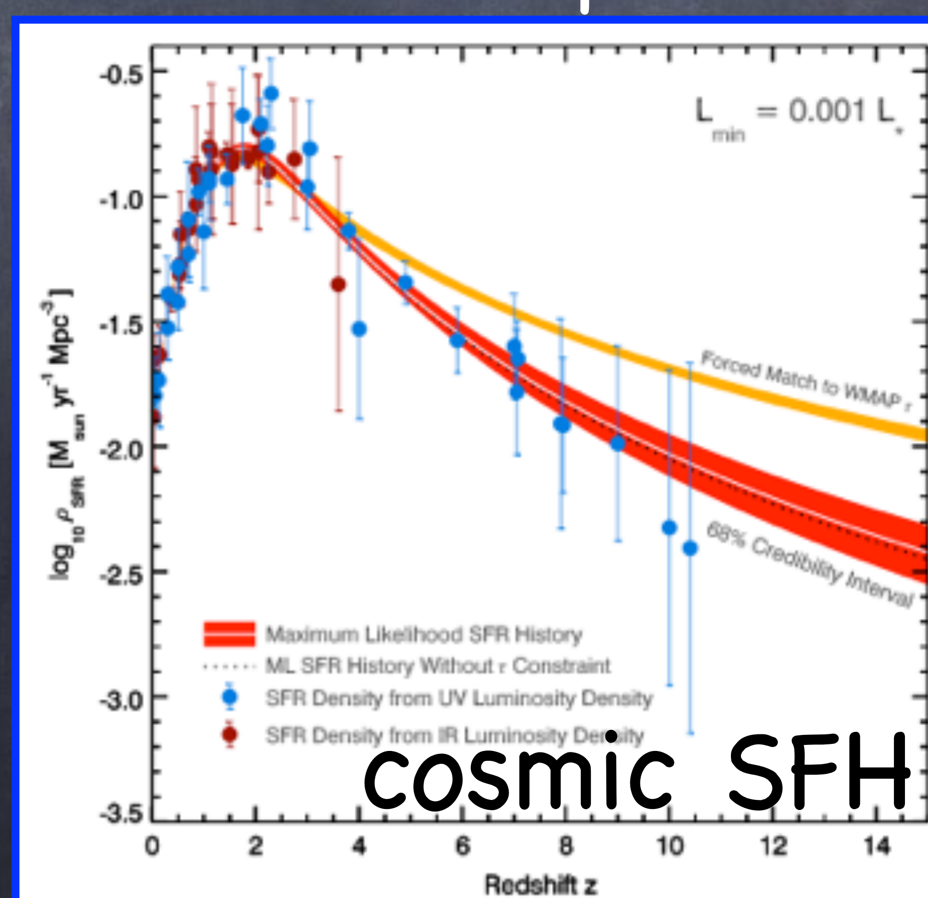


Cosmic SFH - UV photons



UV LFs,

lum. desnty (1500A)

Madau & Dickinson+14

Robertson+15

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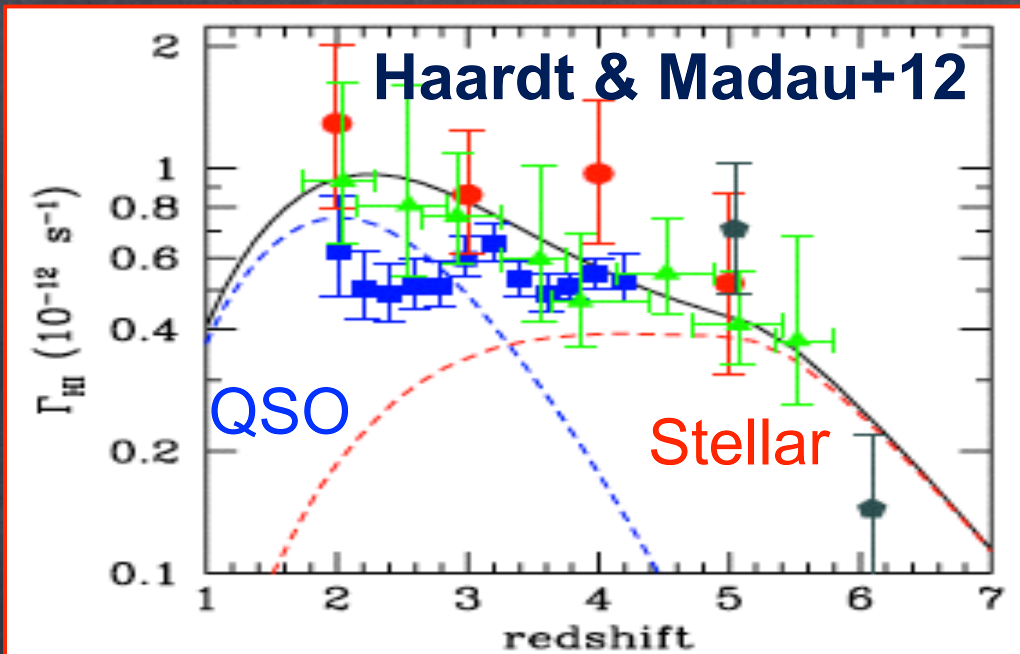


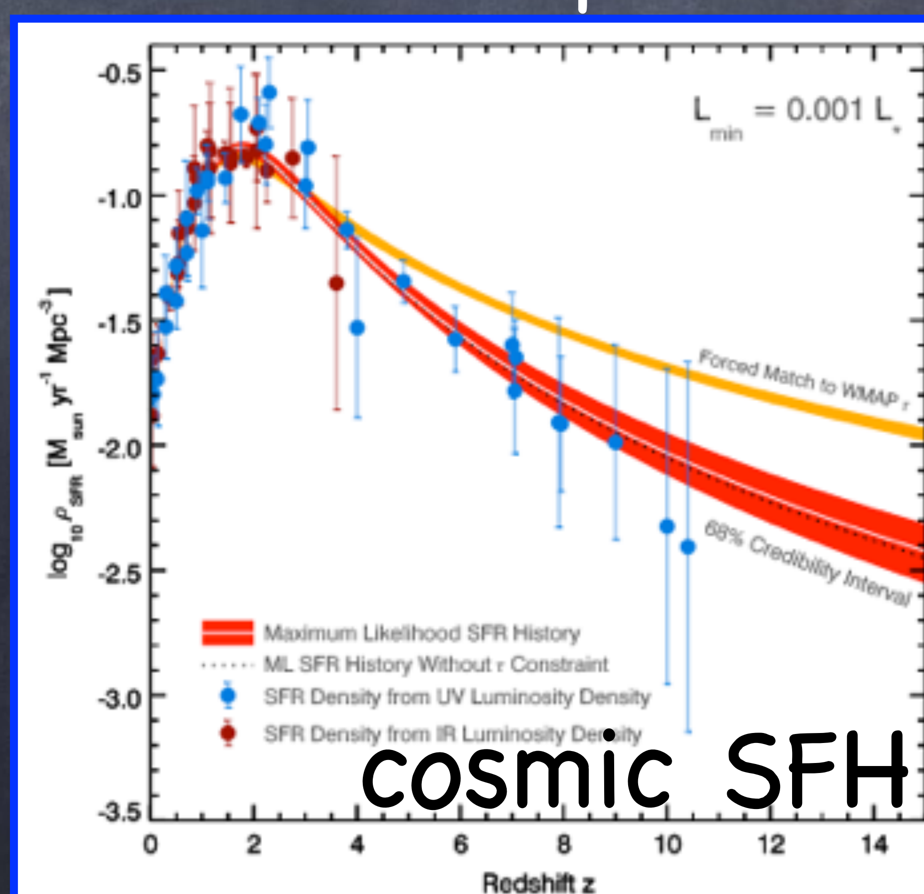
Pawlik et al. (2009)

$$C_{\rm HII} \equiv \langle n_{\rm HII}^2 \rangle / \langle n_{\rm HII} \rangle^2$$

$$\dot{\rho}_c(z) = \frac{0.027\, M_\odot}{\rm Mpc^3\, yr} \frac{\mathcal{C}/f_{\rm esc}}{30} \left[\frac{1+z}{7}\right]^3 \left[\frac{\Omega_b}{0.0465}\right]^2$$

Minimum SFRD needed to keep the Universe ionized

Cosmic SFH - UV photons



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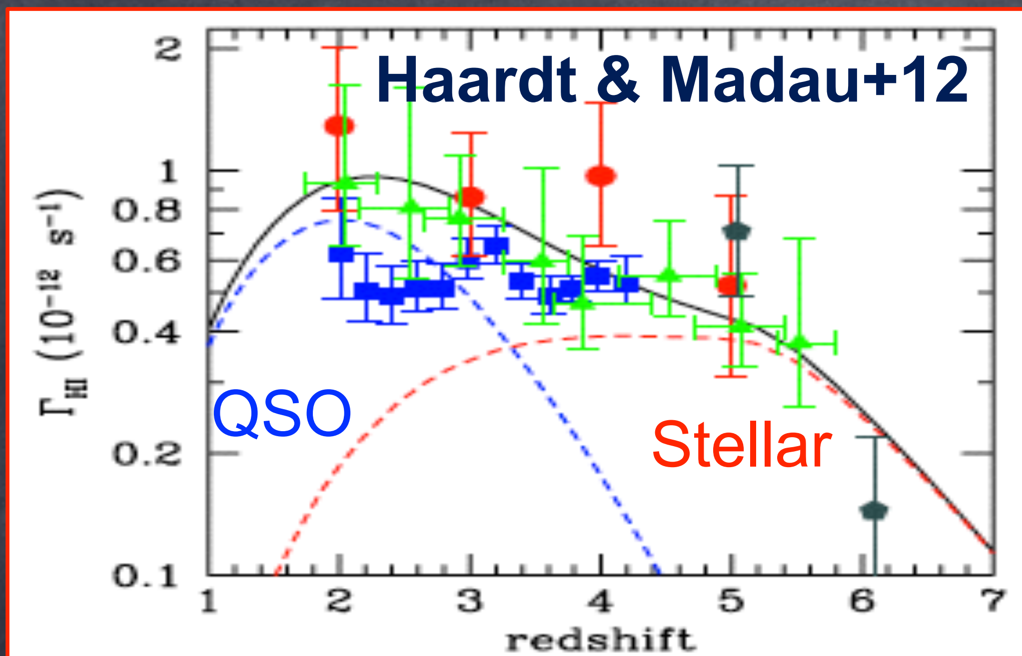

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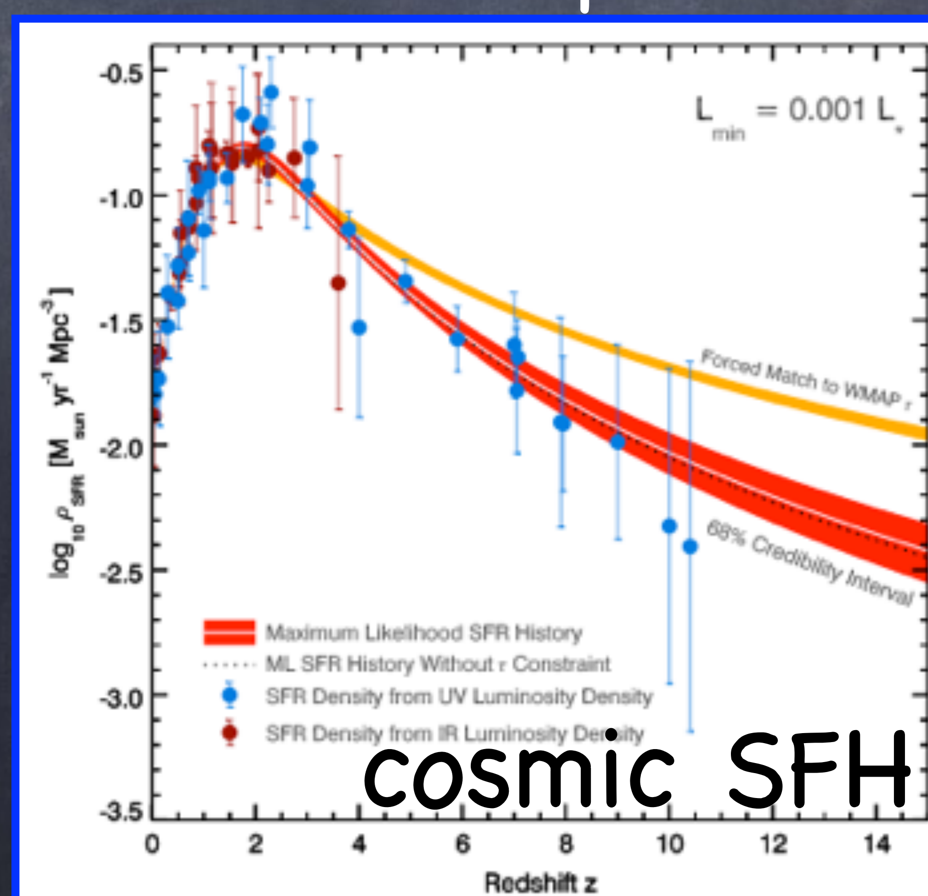

Madau & Dickinson+14
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fesc

critical parameter in any model of EoR

Modeling fesc: a quite complicated problem

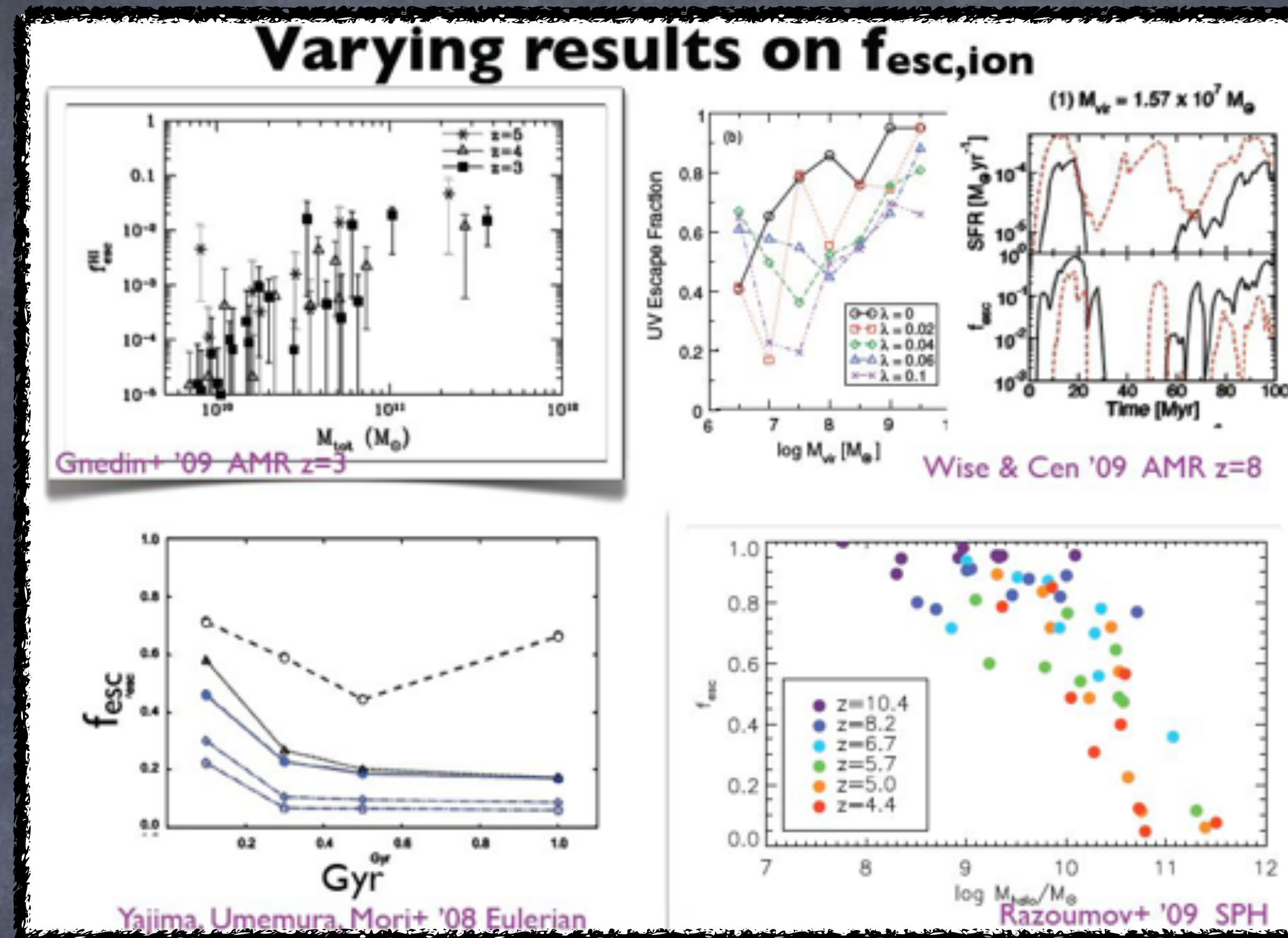
Theoretical modeling (RT+SPH):

- fesc ↓ if redshift ↑ (Wood & Loeb+00)
- fesc ↑ if redshift ↑ (Razoumov+06,+10)
- fesc ~ with redshift
  (Yajima+10; Ma et al. 2015; Gnedin+08)

- fesc ↑ if redshift ↑ [phenomenological models]
  Haardt & Madau (2012), Kuhlen & FG (2012),
  Alvarez+12, Fontanot+14

- fesc ↓ if halo mass ↑
  (Wood & Loeb+00, Ricotti & Shull+00
  Yajima+10, Razoumov+10)
- fesc ↓ if halo mass ↓ (Gnedin+08a,b)
- fesc ~ with halo mass (Ma et al. 2015)

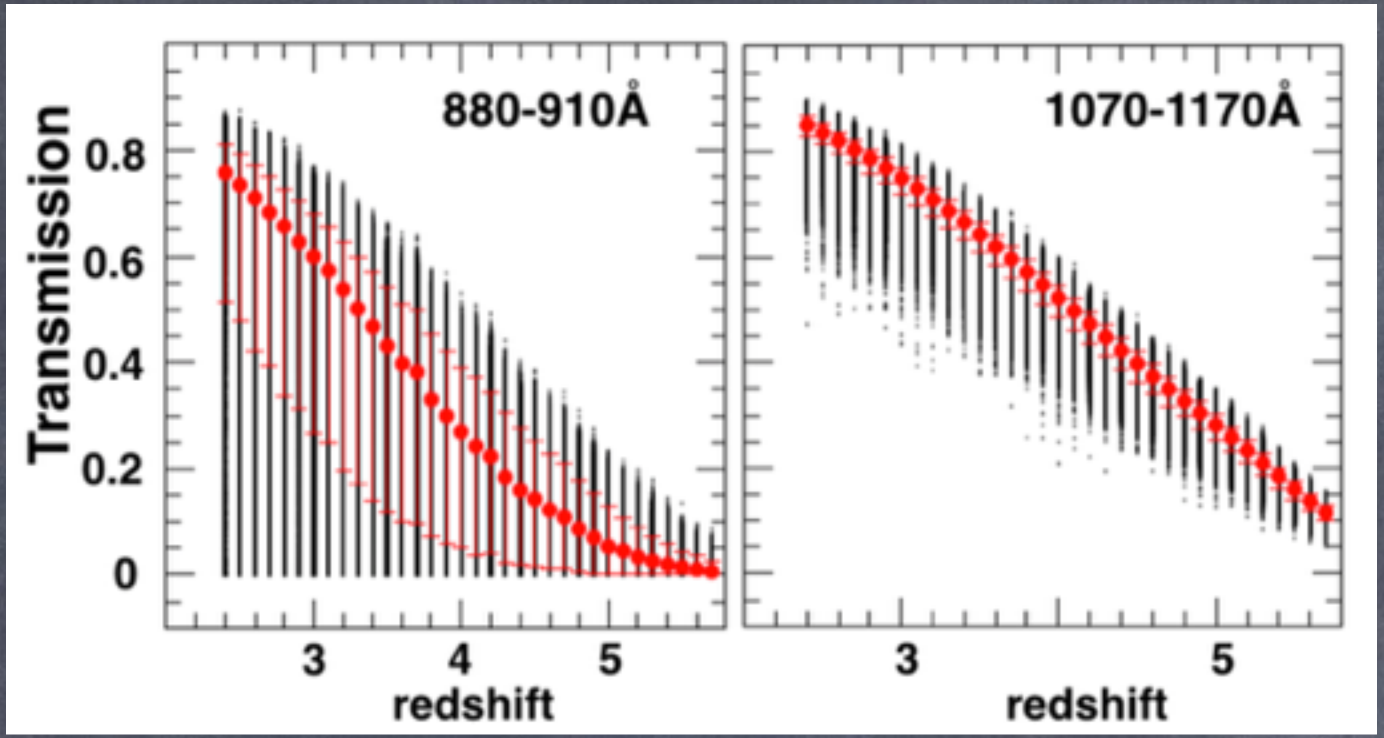
- fesc ↑ if (↓L OR ↓Mass)
Wise & Cen+09; Kimm & Cen (2014);
Wise et al. (2014); Paardekooper et al. (2015);
Roy et al. (2015); Fernandez & Shull+11;
Choudhury & Ferrara 07, Ferrara & Loeb 2012



Large variance in the predictions, in general <fesc>:
1) may increases for low mass halos / luminosities
2) may increases with redshift

Search for Lyman continuum emitters at high-redshift: current status

Impossible to detect LyC photons coming from the cosmic reionization epoch because of the IGM:



Vanzella+2015, Inoue & Iwata 2008, Inoue+2014

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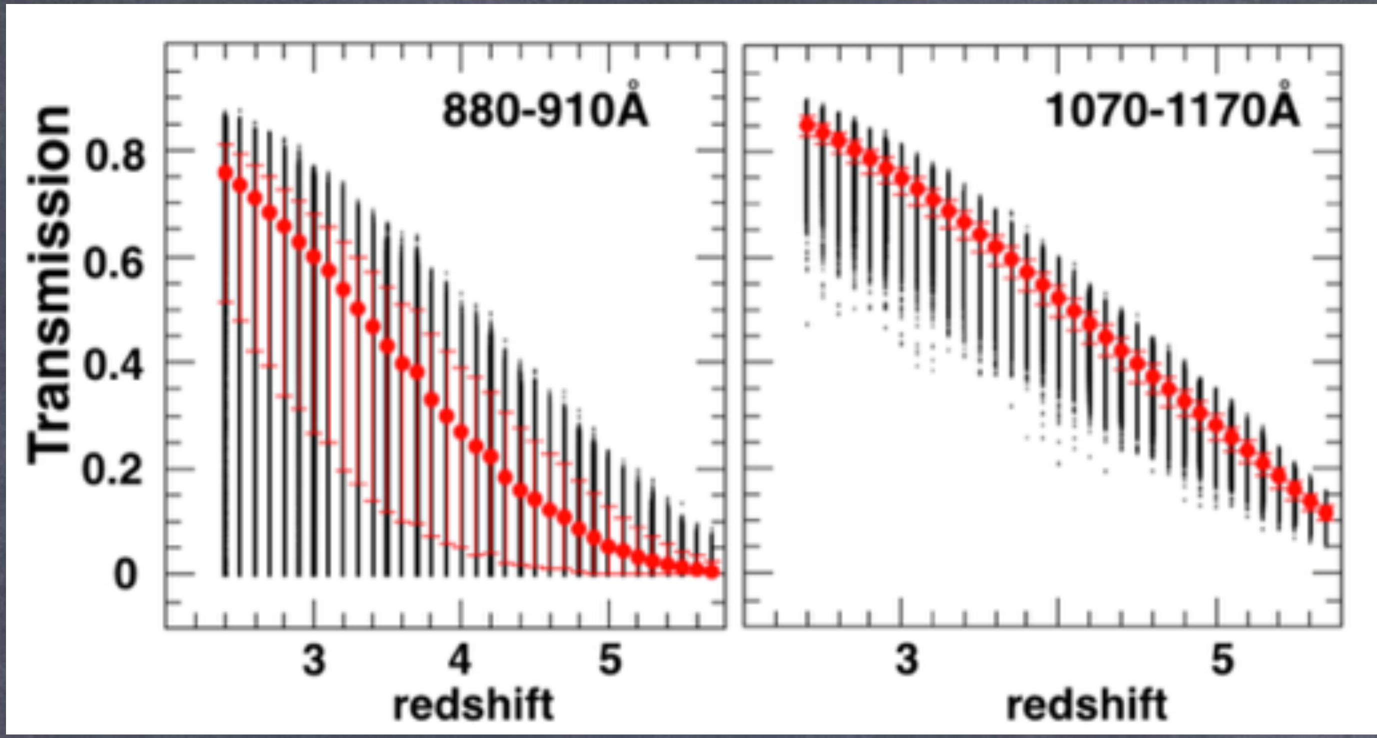

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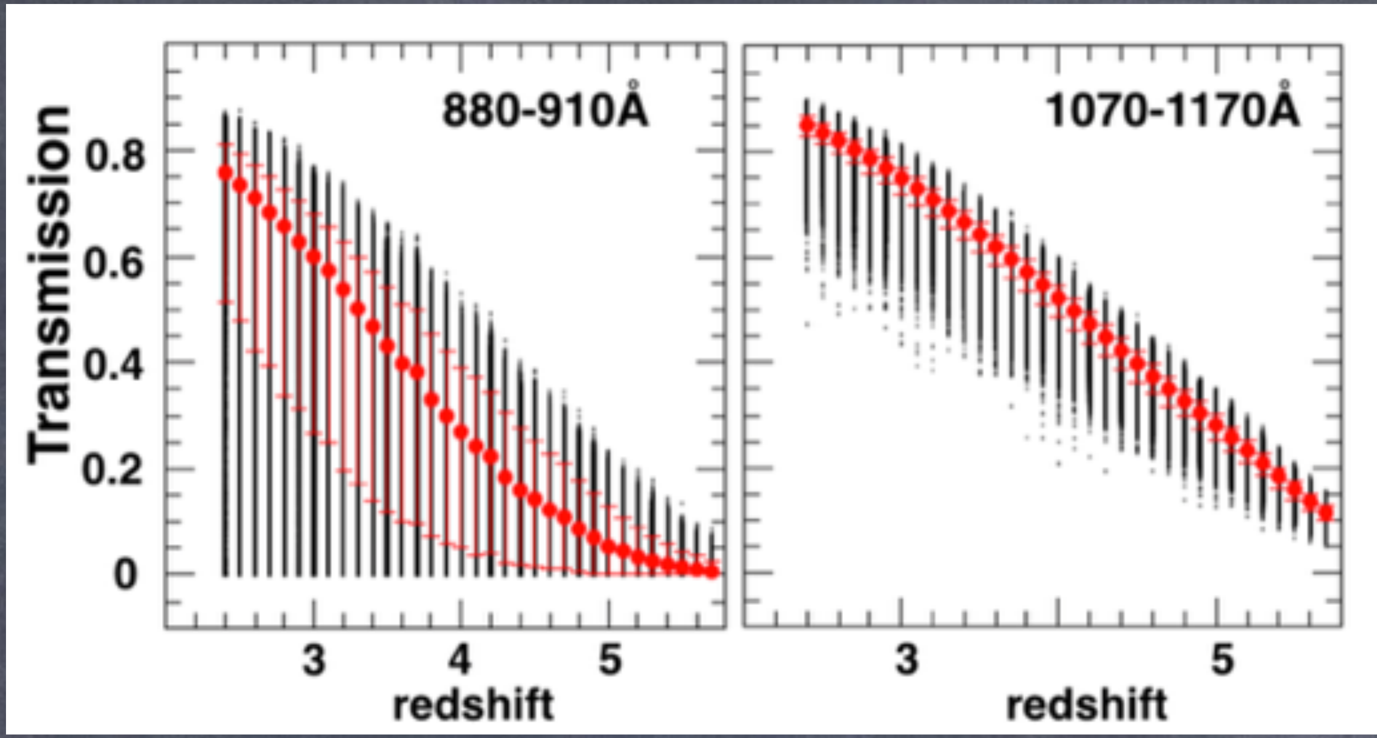

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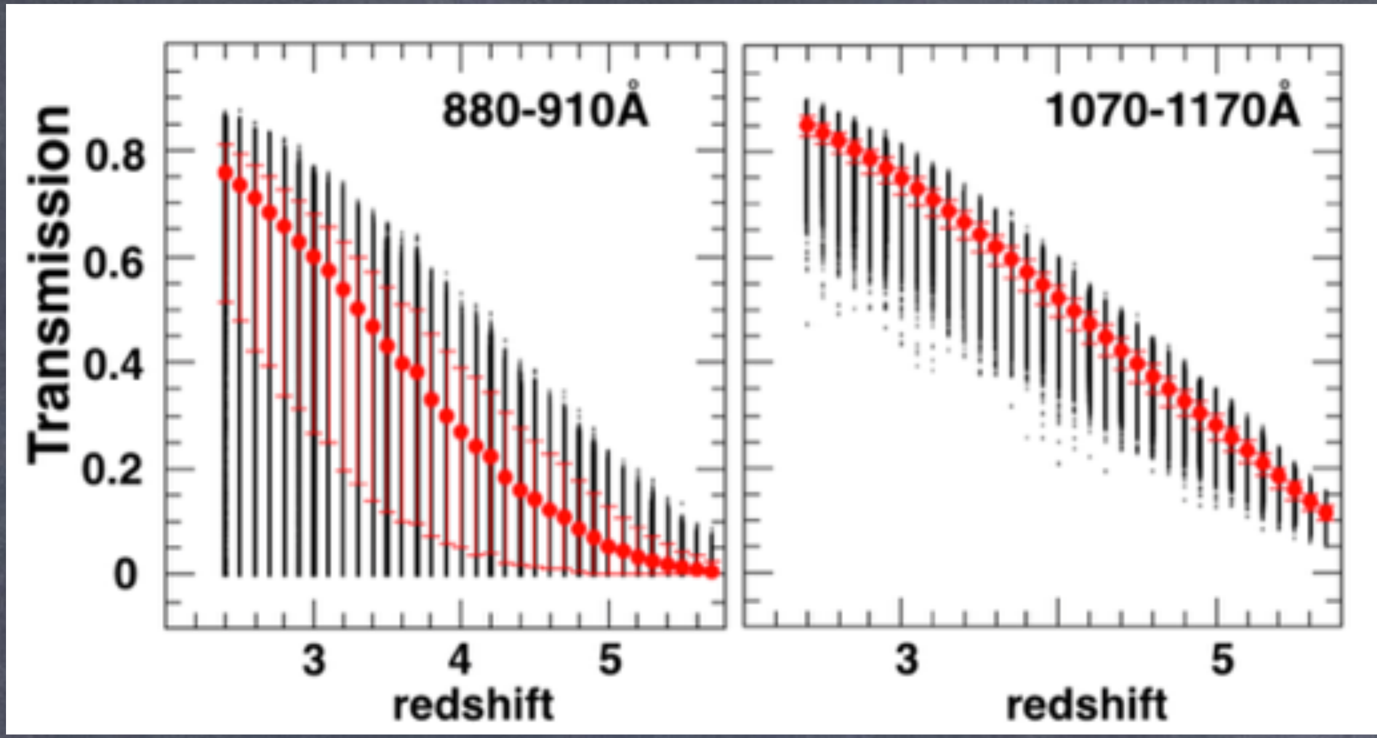

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Are we missing LyC emitters? Likely not.

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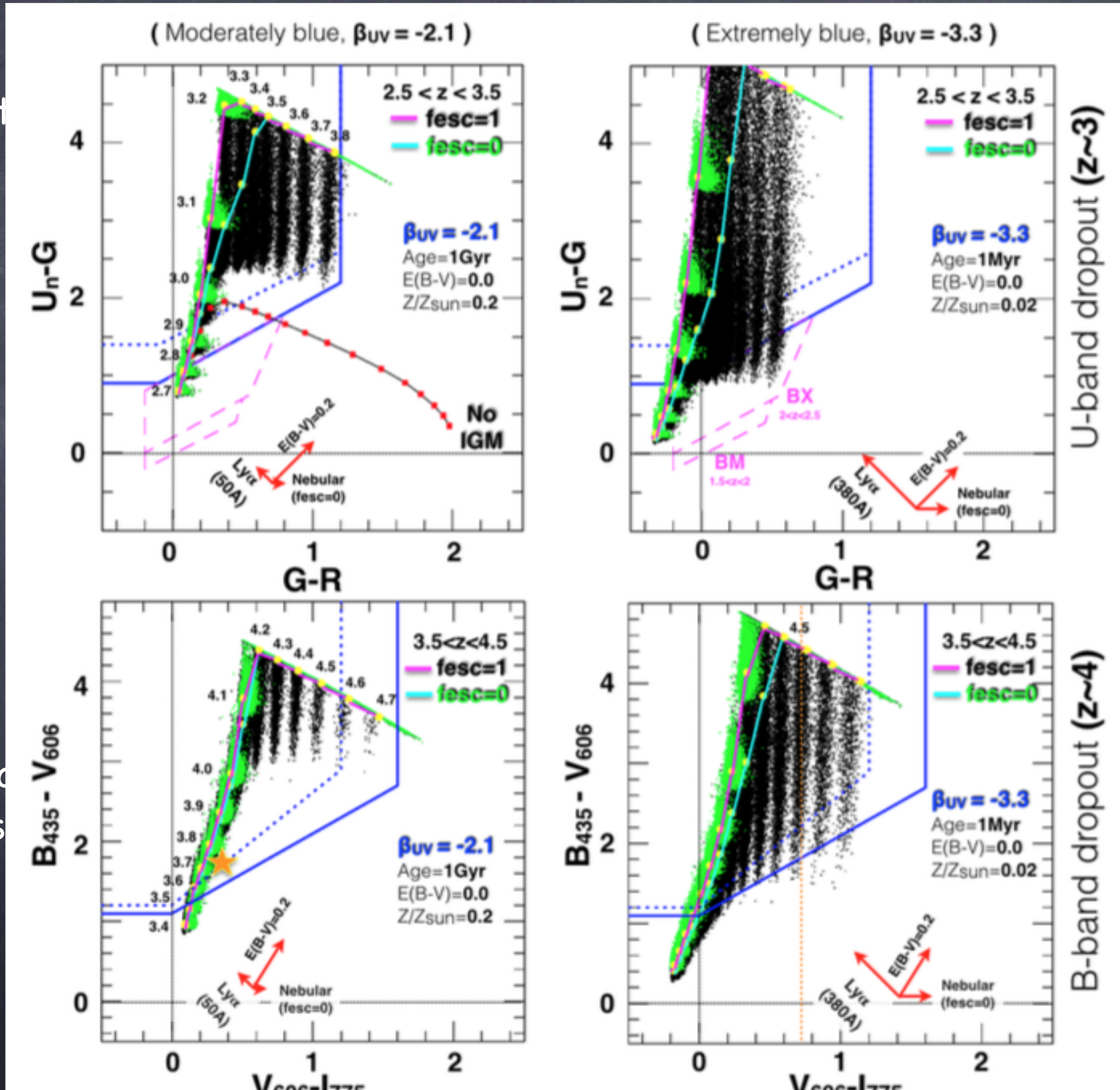

Galaxy selec
Are we miss

Search for Lyman continuum emitters at high-redshift:

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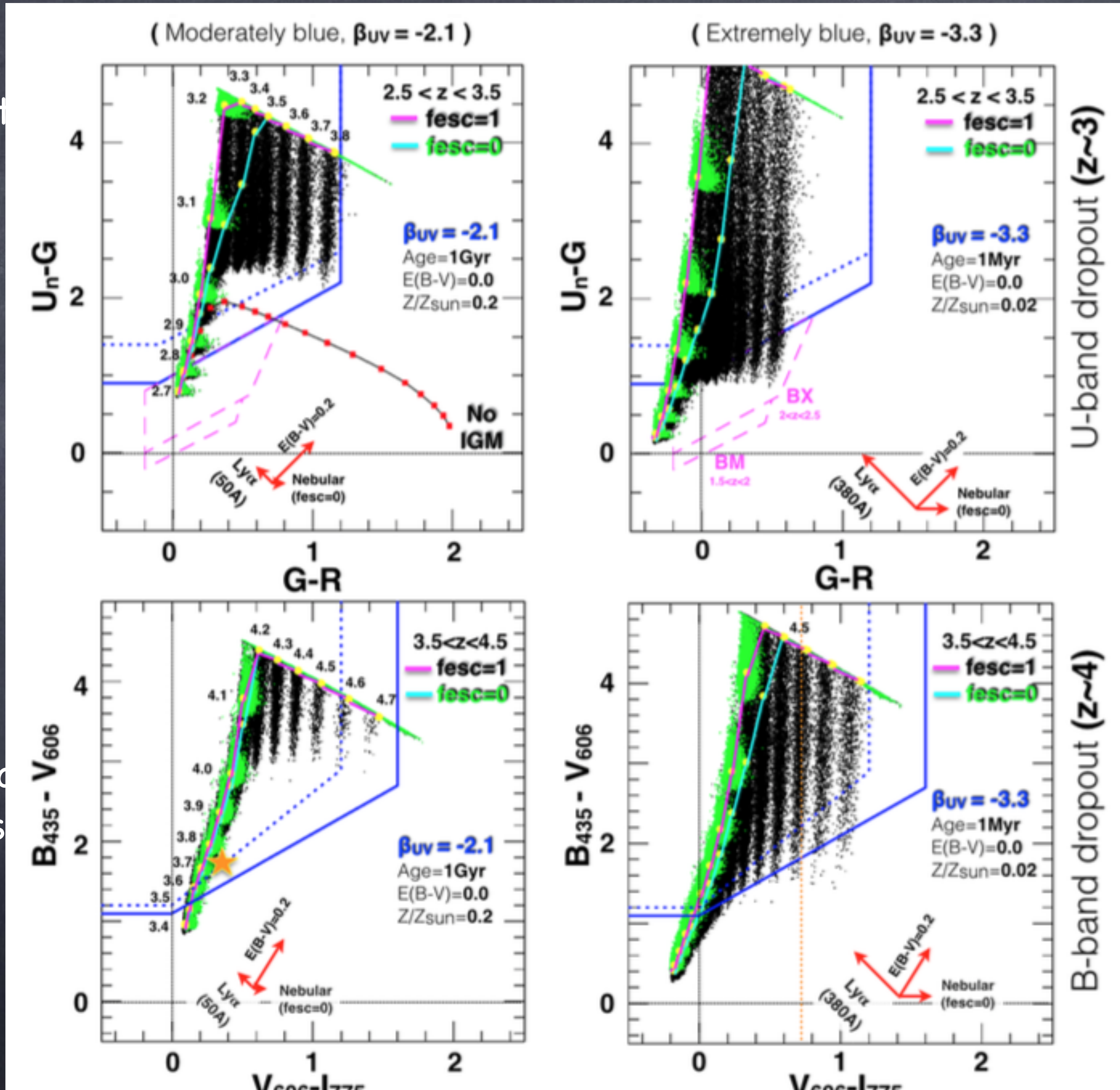

Galaxy selec[…]
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Vanzella+15

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Claims of detection or identification of candidates:

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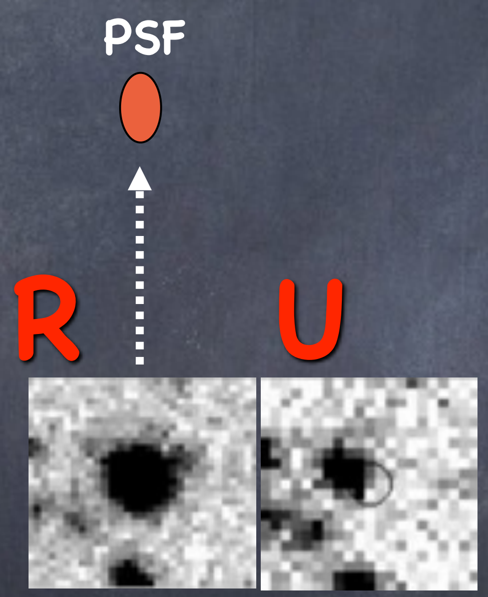

Ground based:

fesc ≈ 30%

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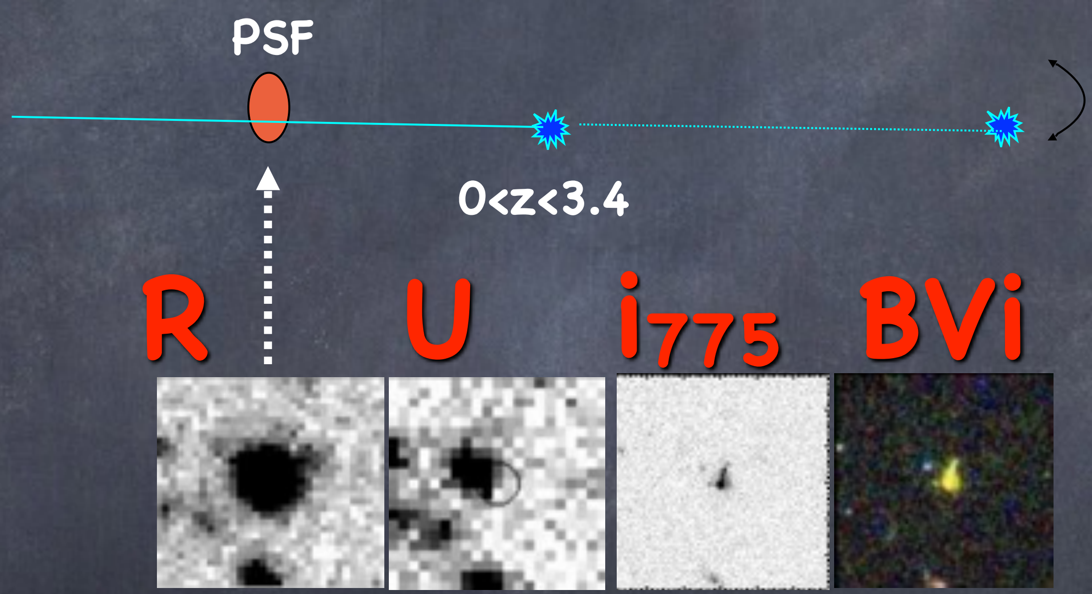

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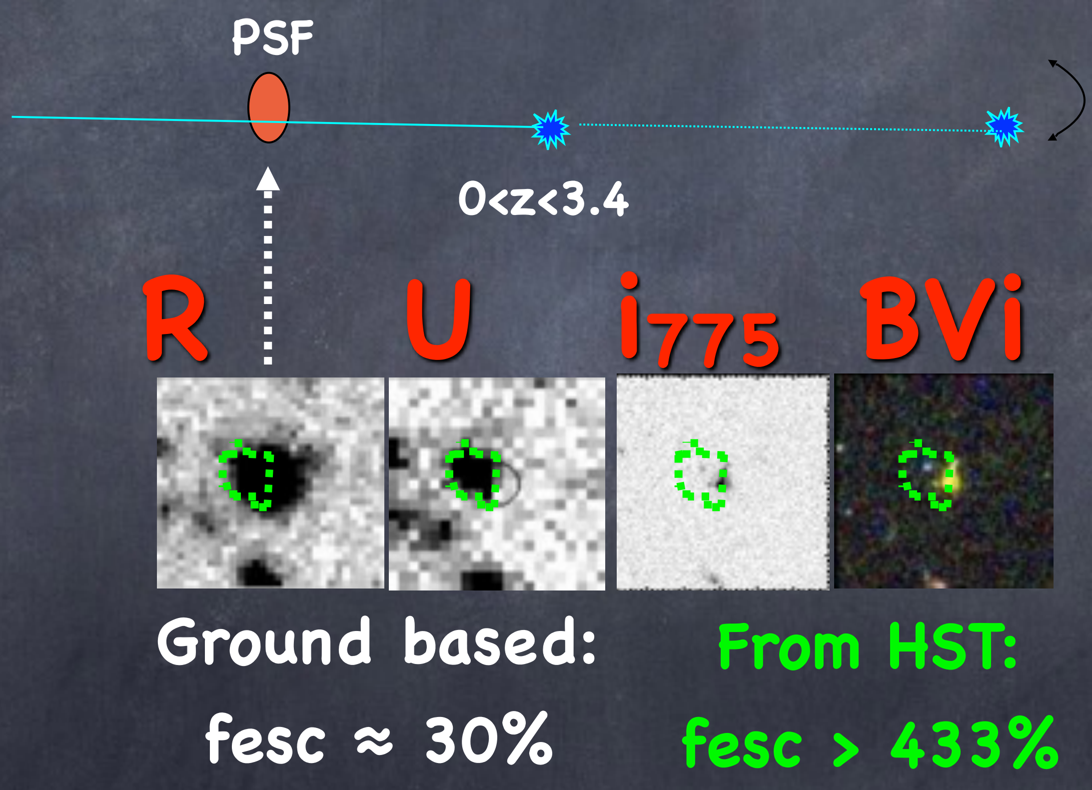

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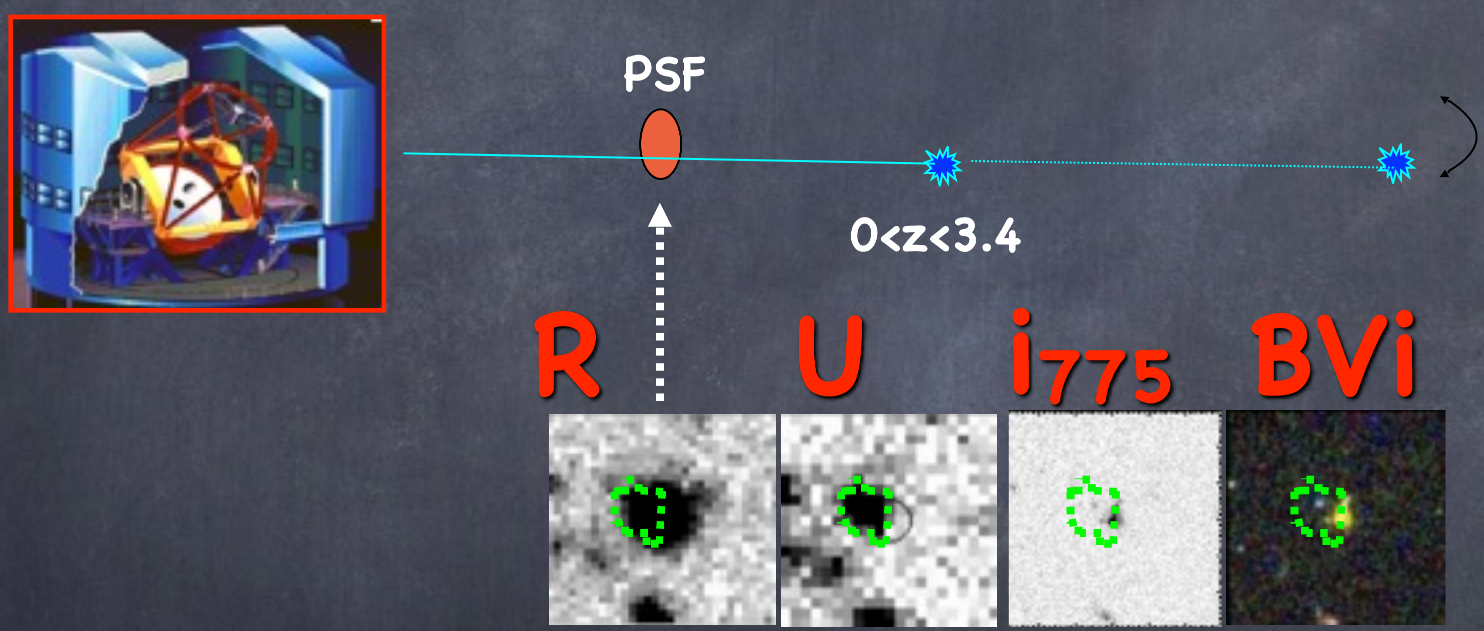

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From HST:

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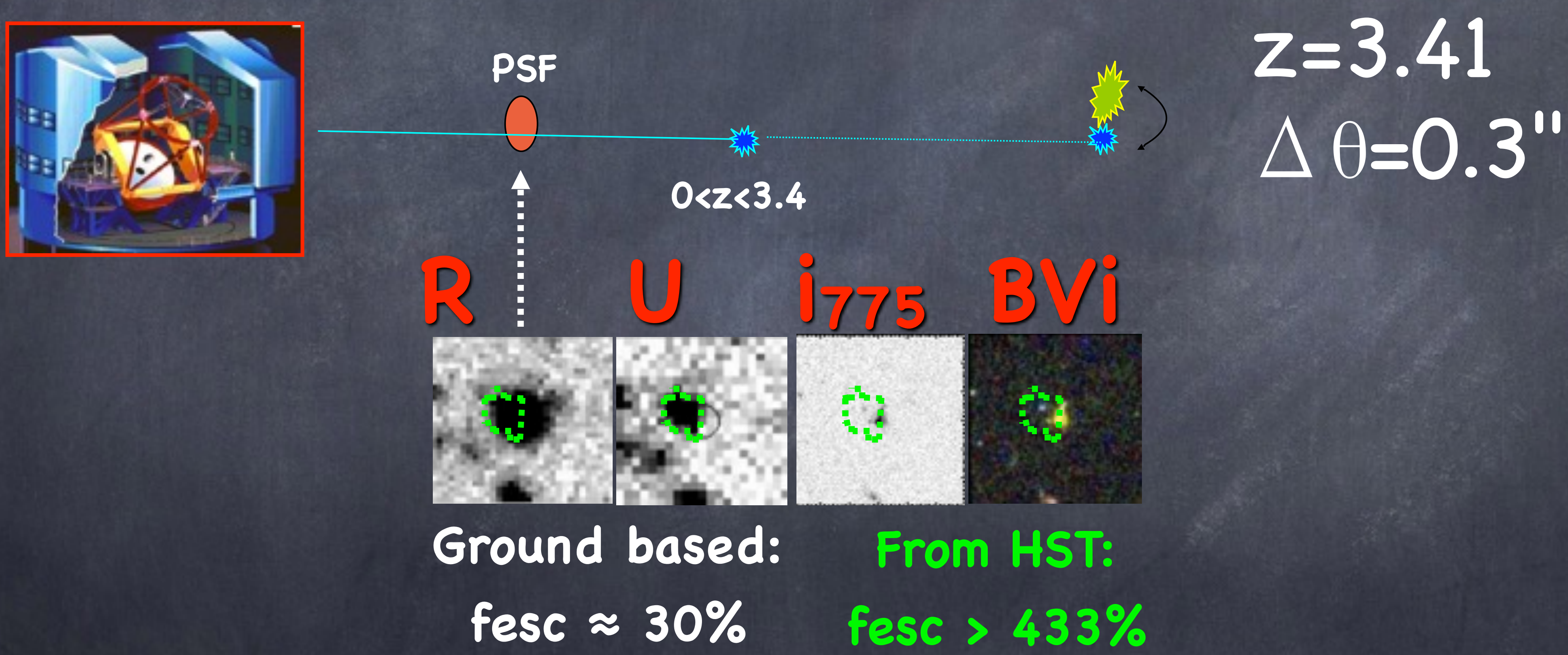

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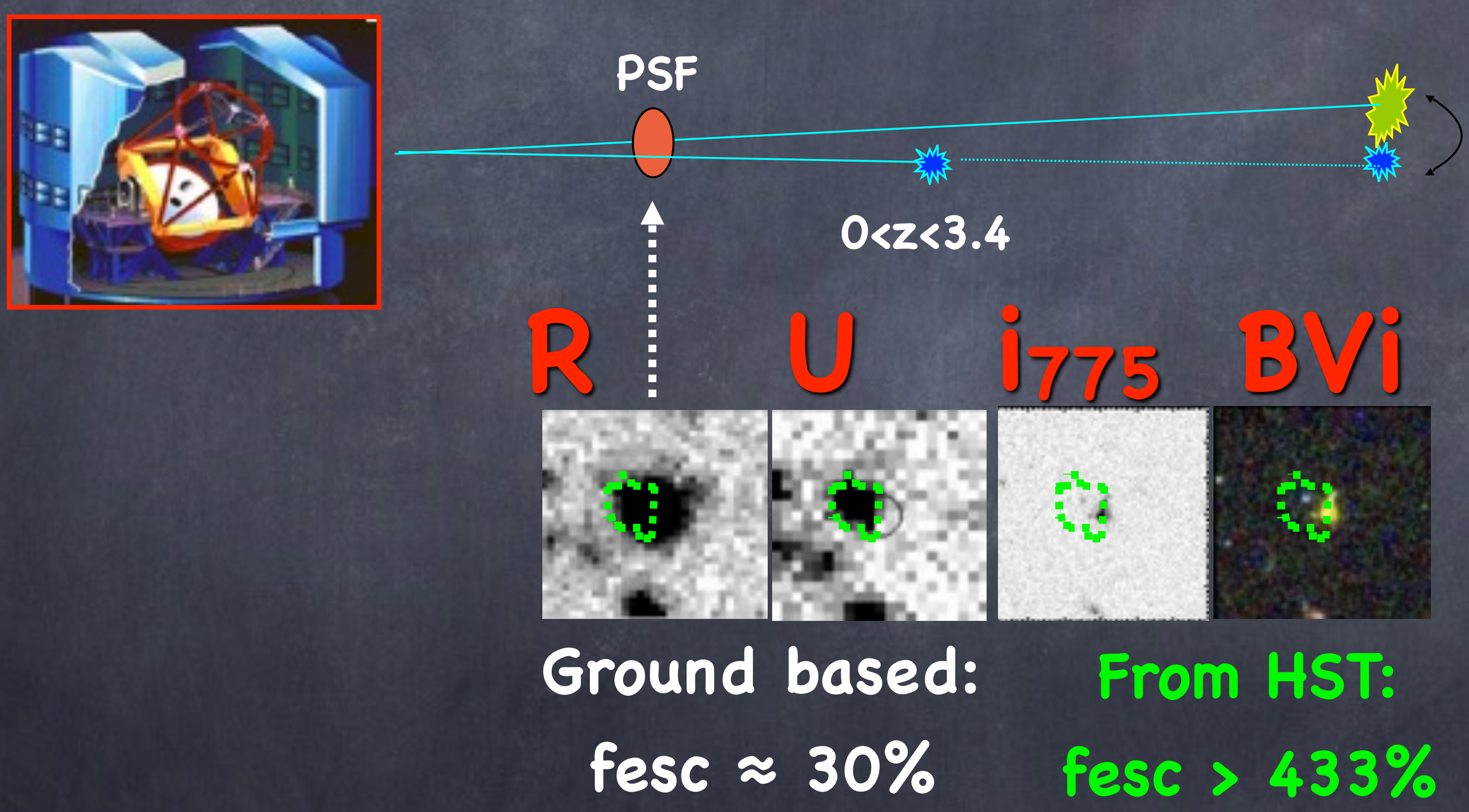

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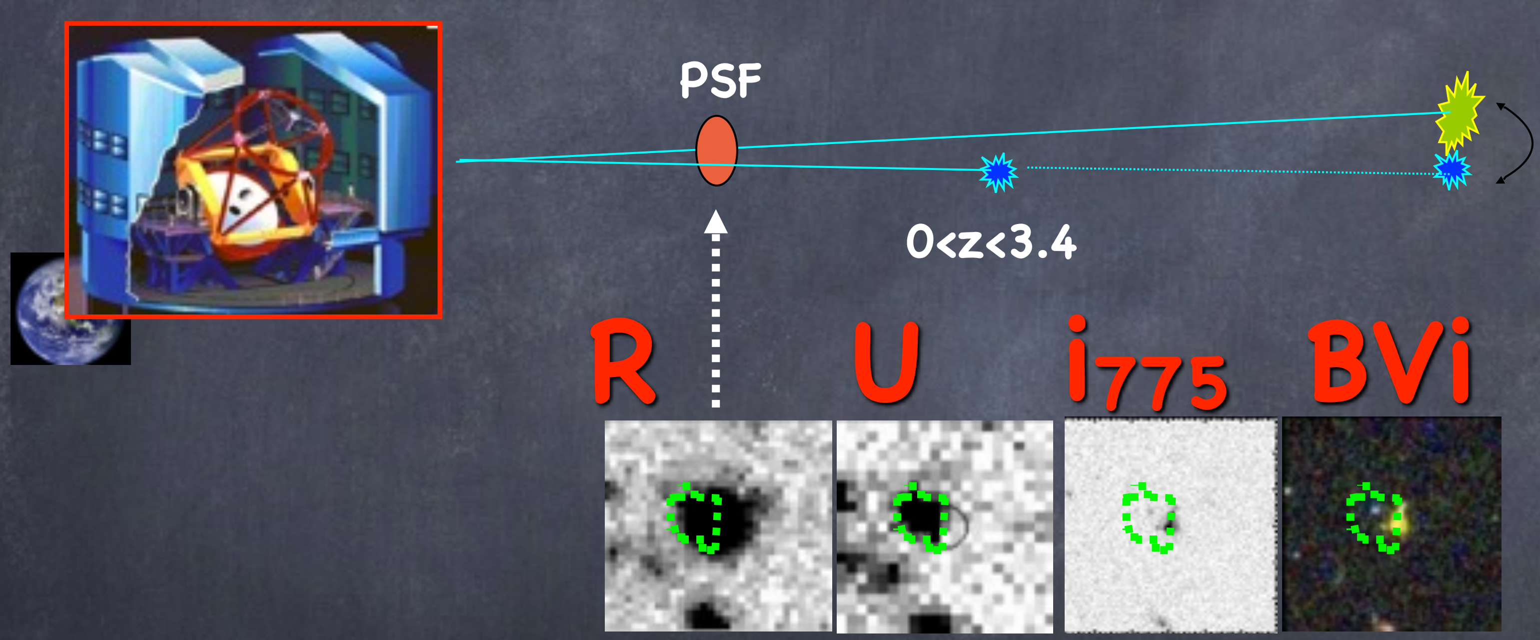

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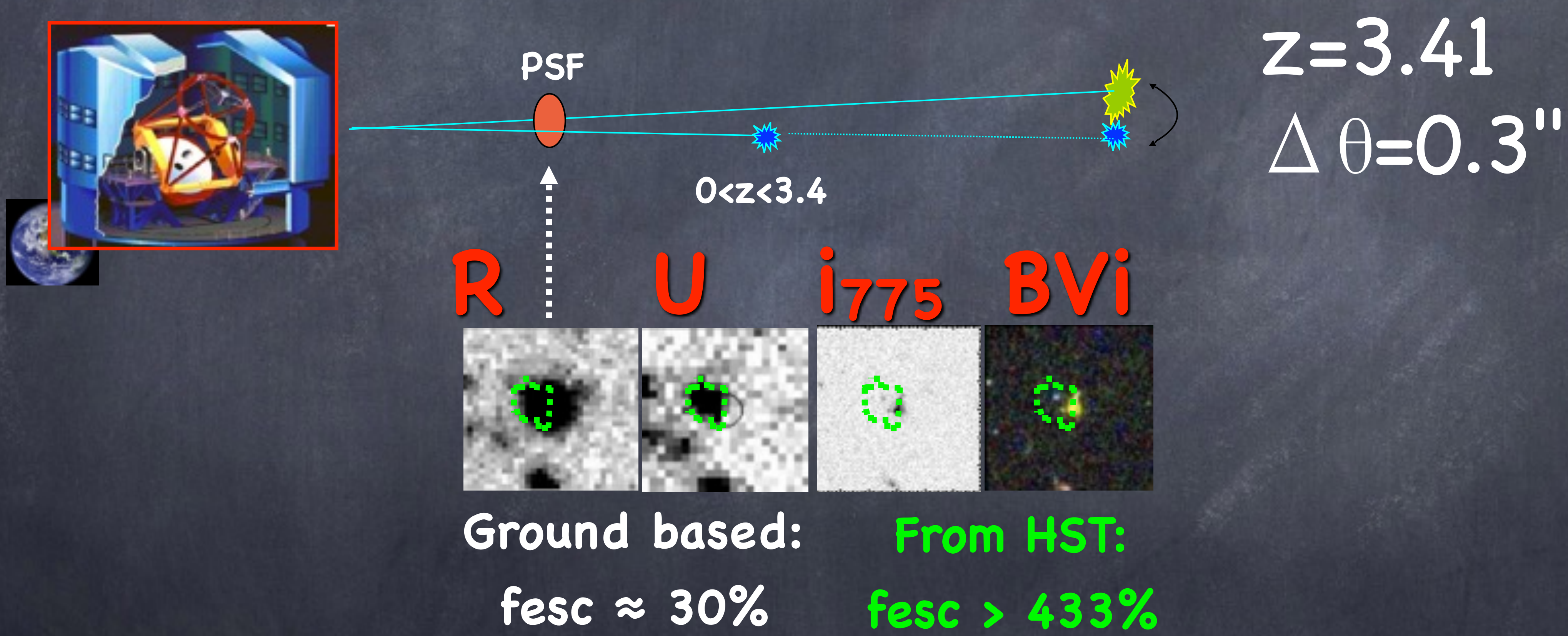
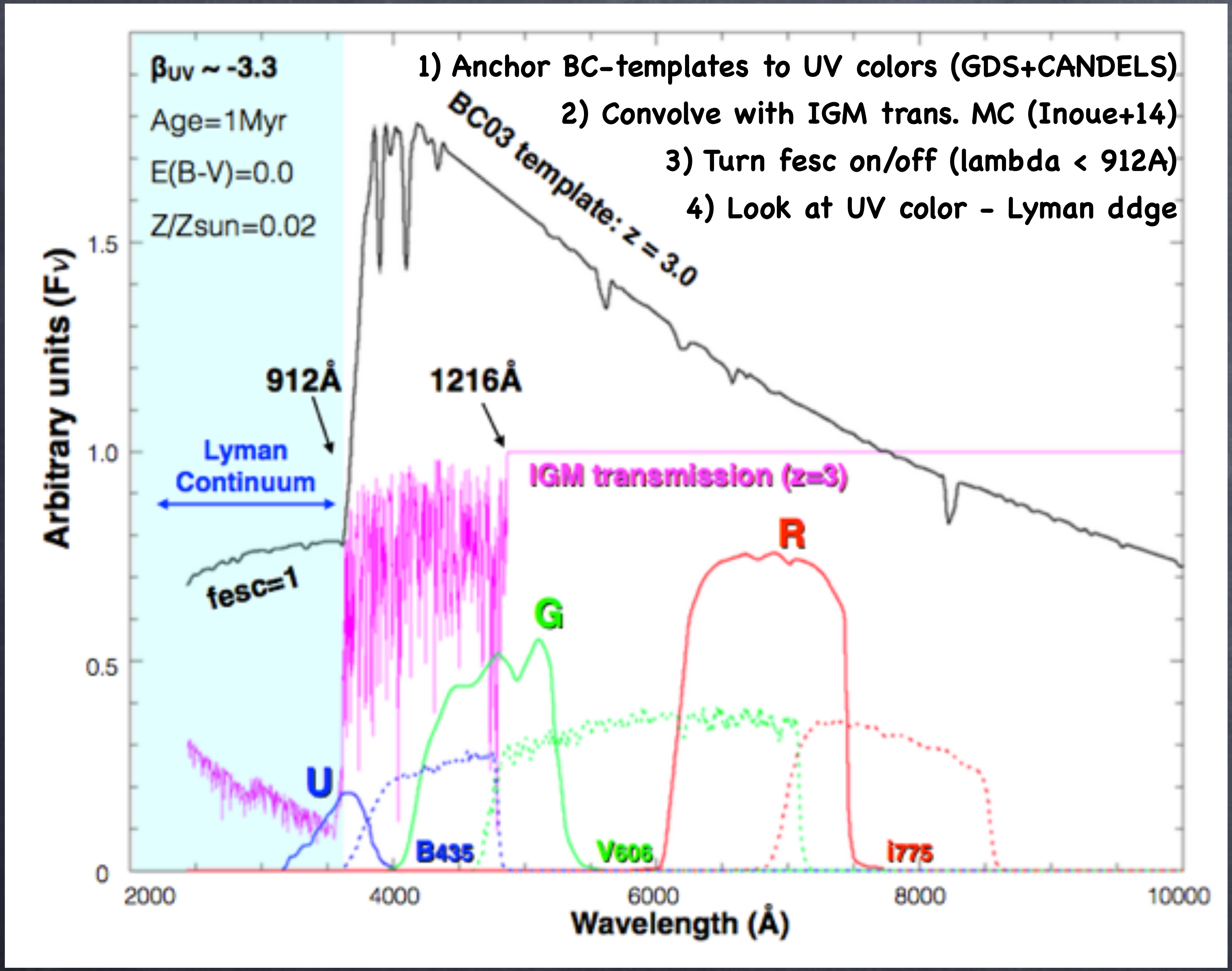


After 15 years of search, a (large) sample of LyC emitters is still missing!

Ion2: a z=3.212 star-forming galaxy with escaping ionizing radiation?

Properties reported in Vanzella+2015



Ion2: CANDELS ID = 18320

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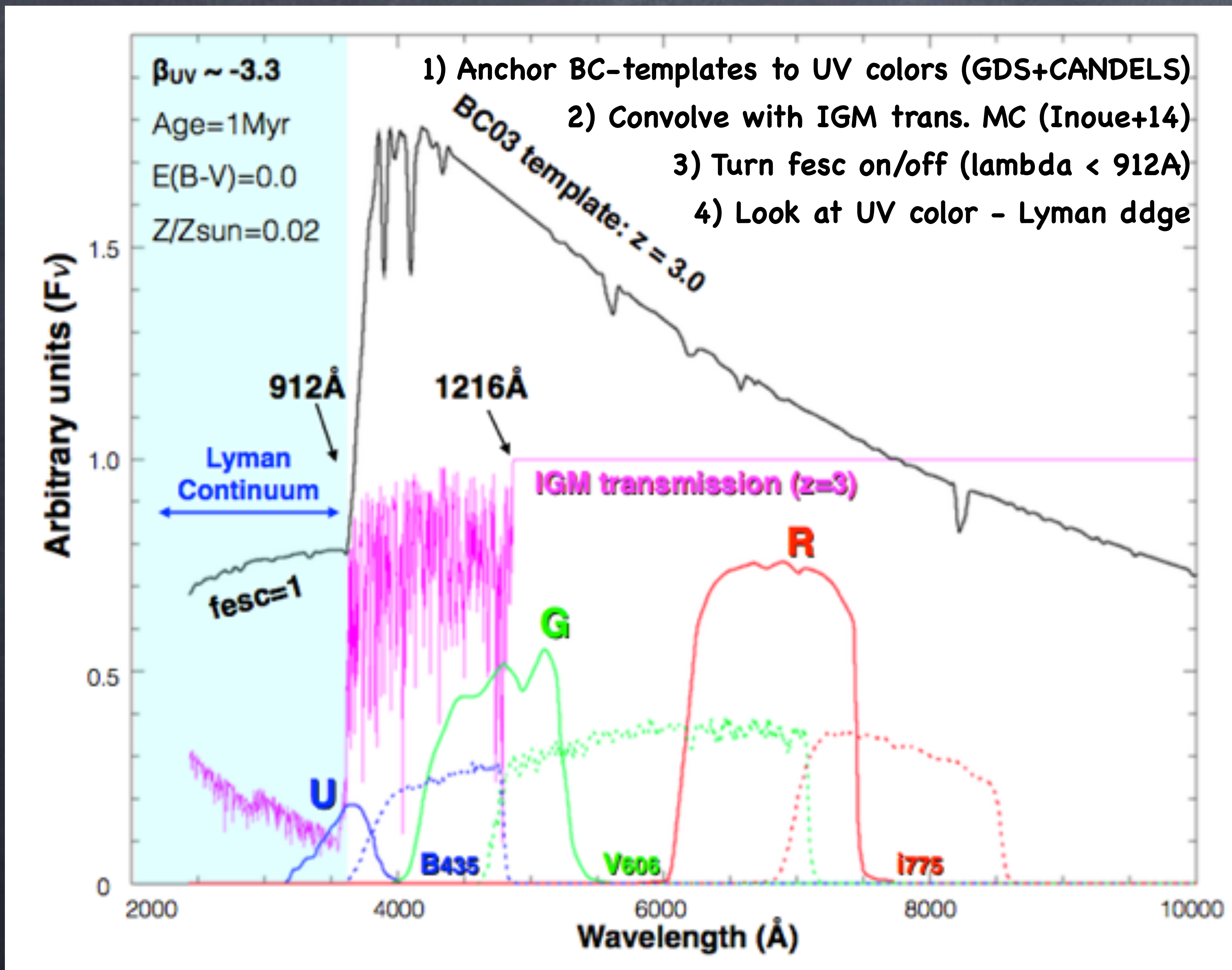

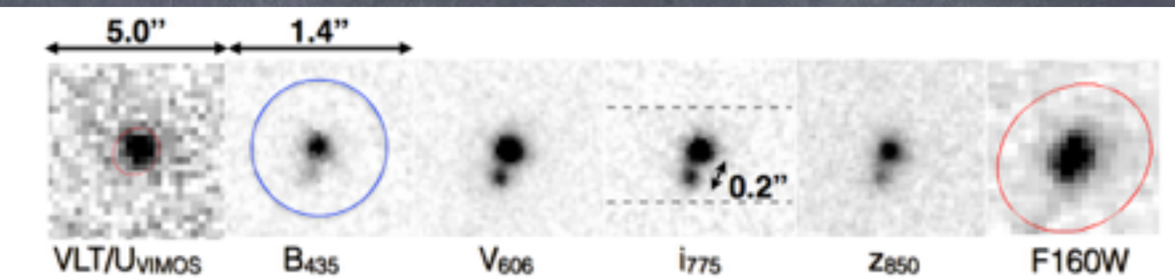

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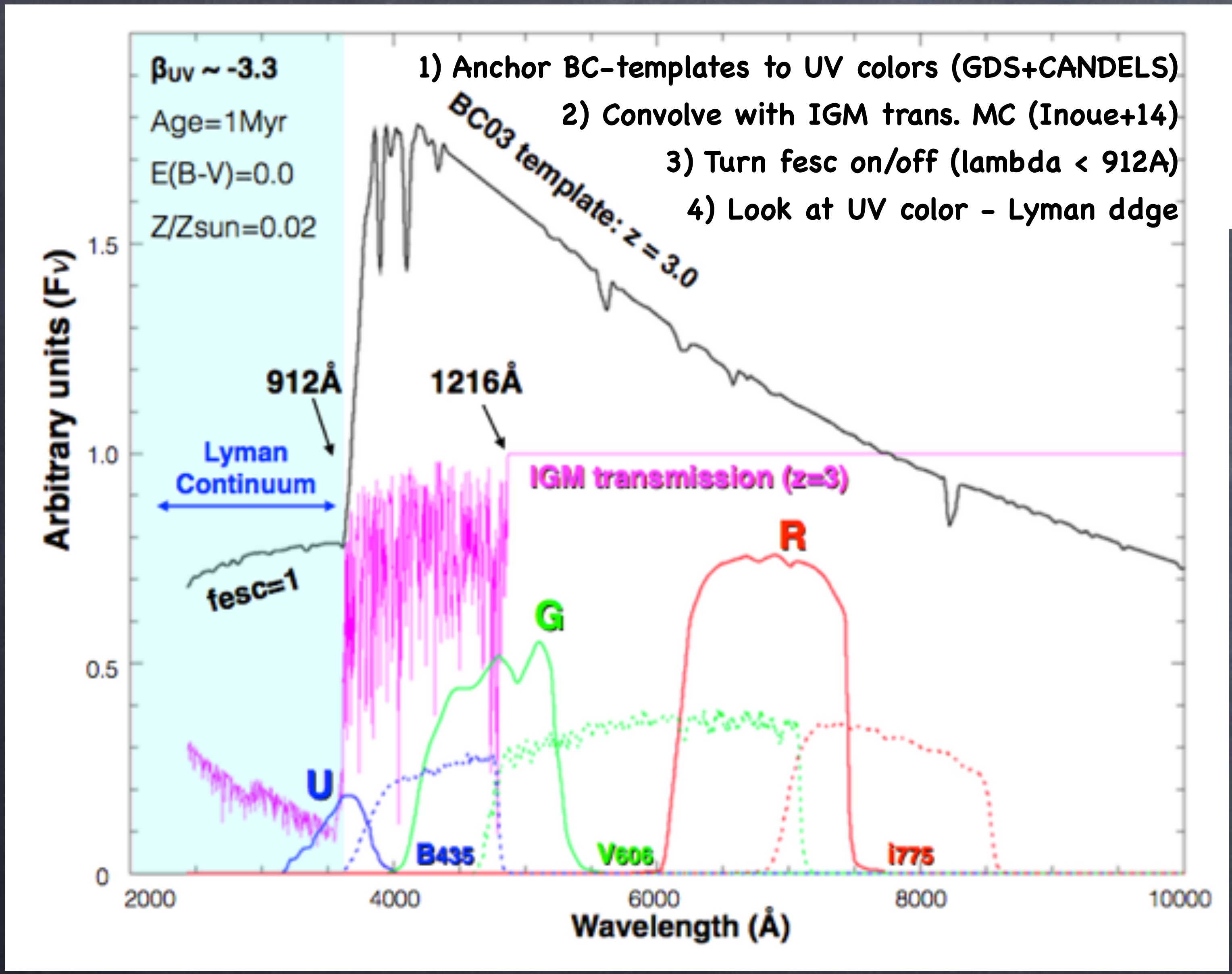

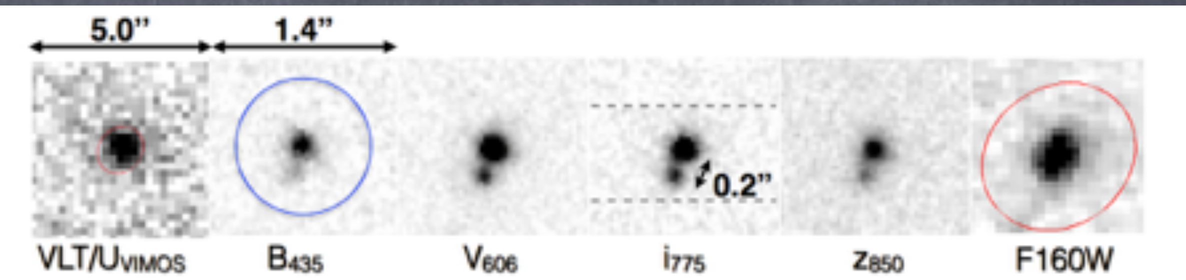

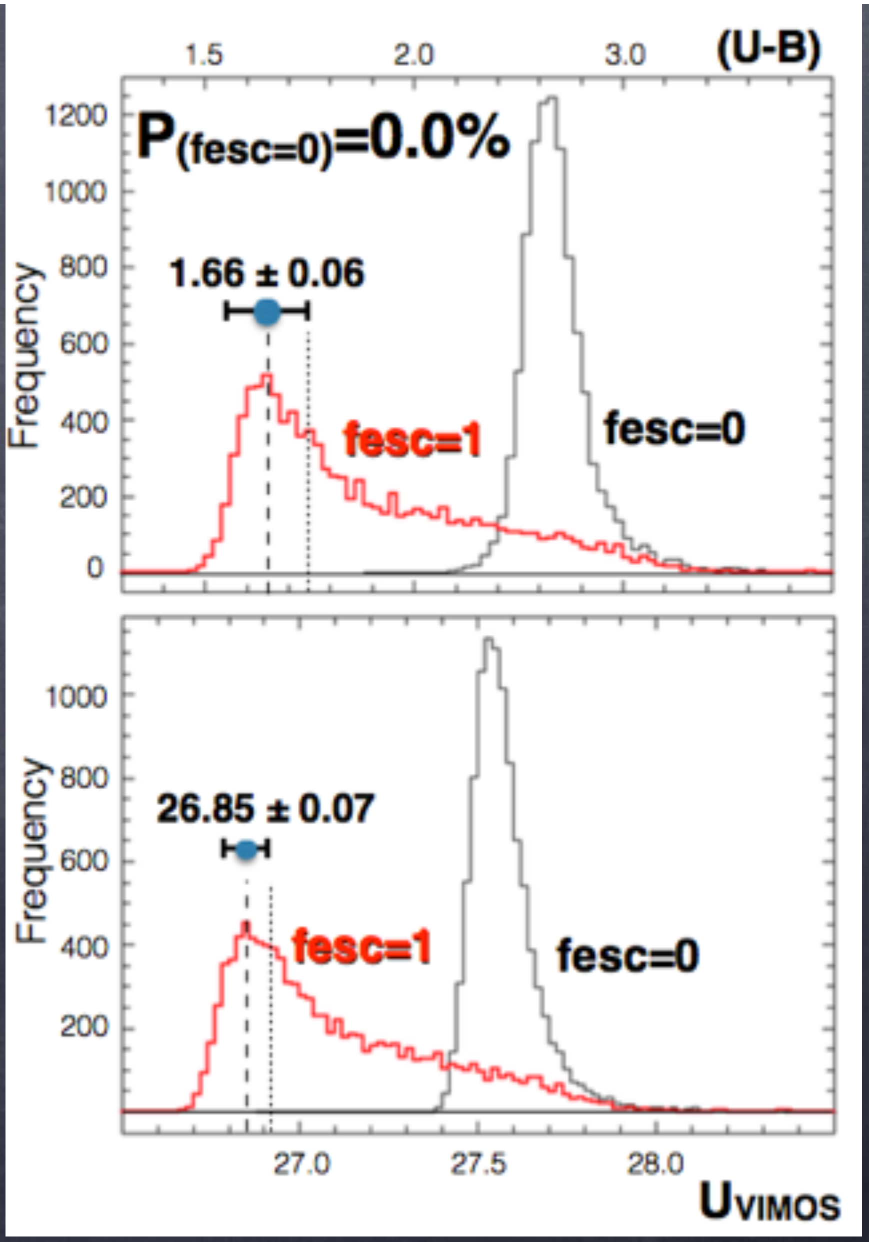

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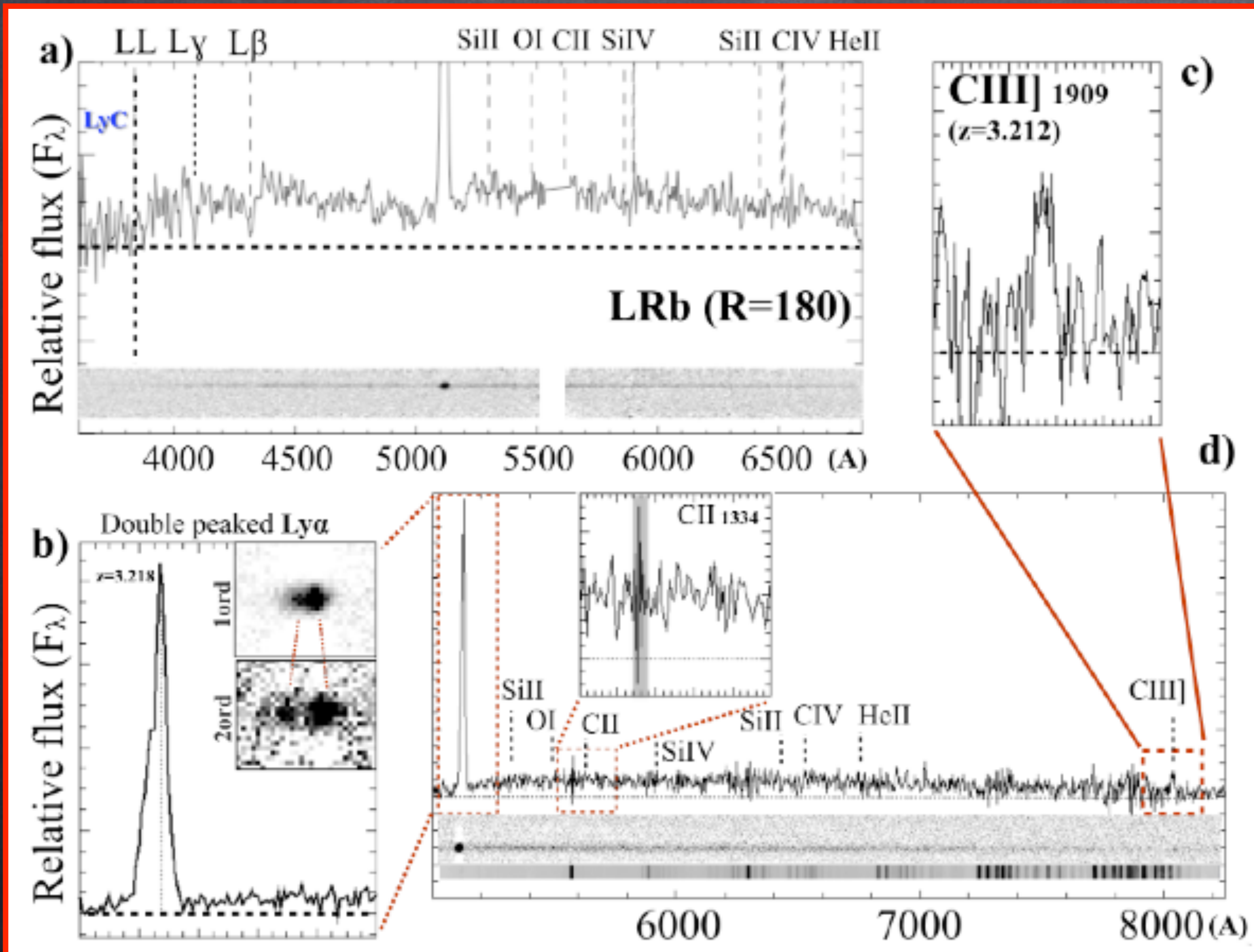

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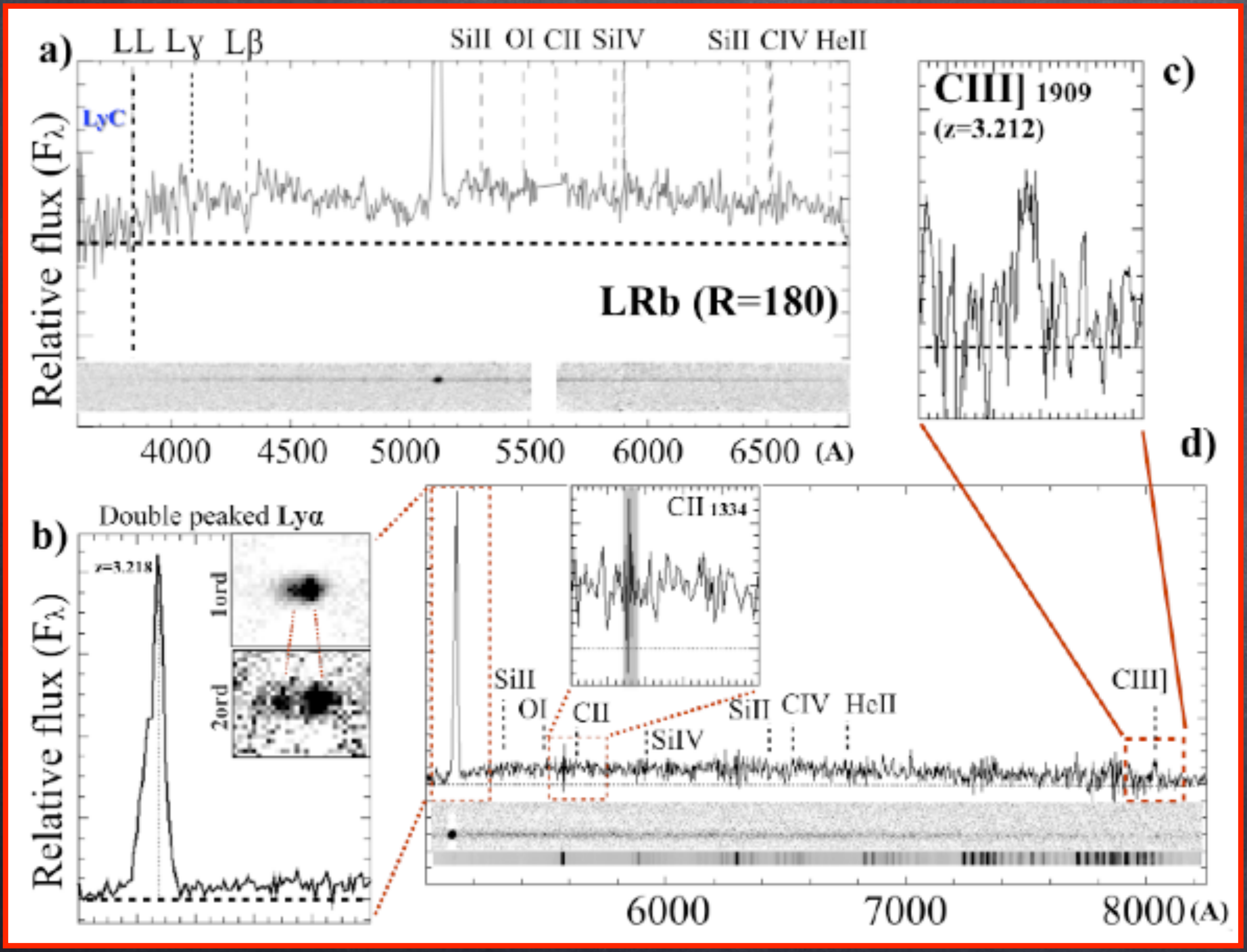

(1) **non-zero Lya flux at the systemic redshift** (Schaerer +11; Behrens+14;Verhamme +14)

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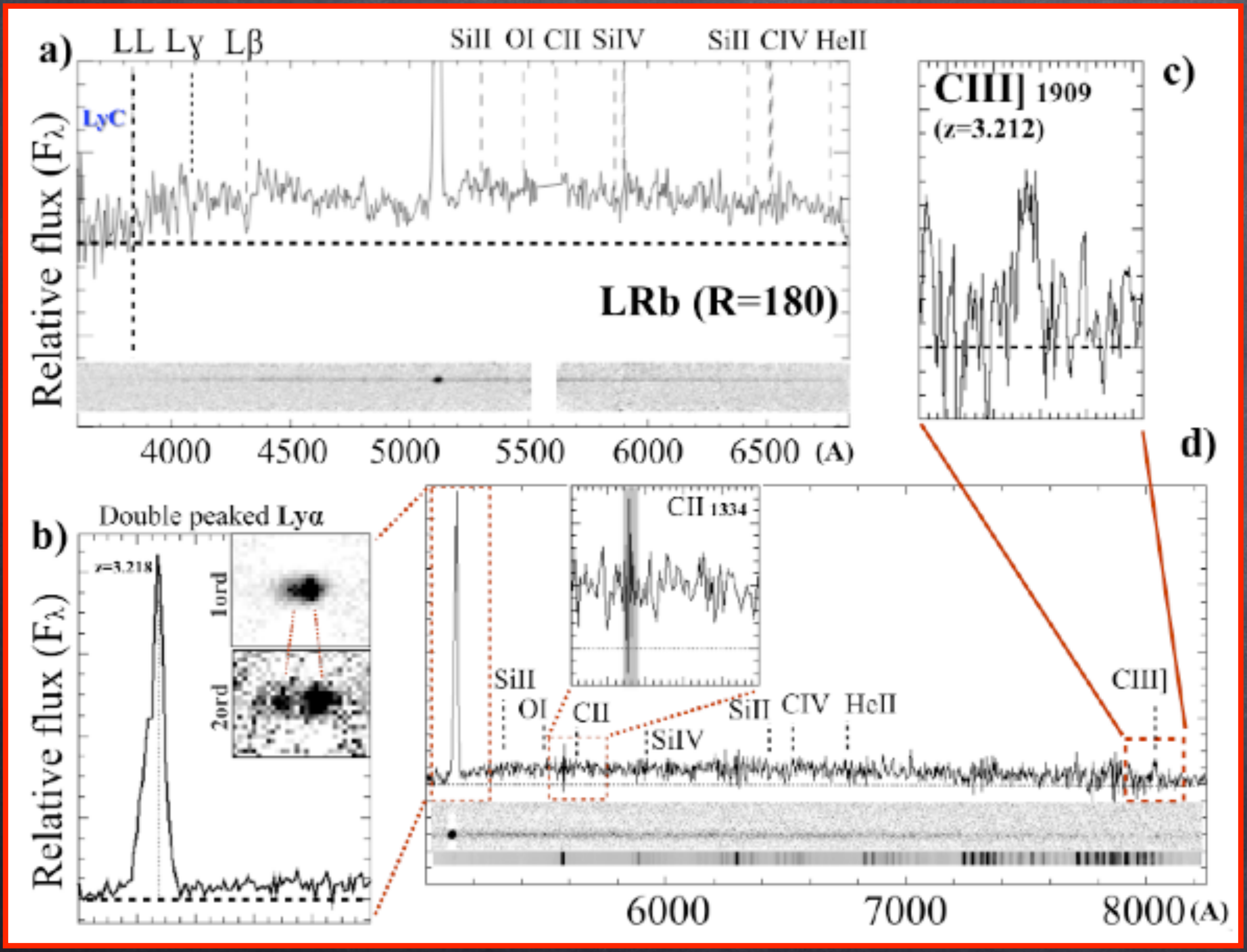

(1) **non-zero Lya flux at the systemic redshift** (Schaerer +11; Behrens+14;Verhamme +14)

(2) **weak low absorption lines:** low covering fraction NHI (Jone+13, 14; Heckman +11)

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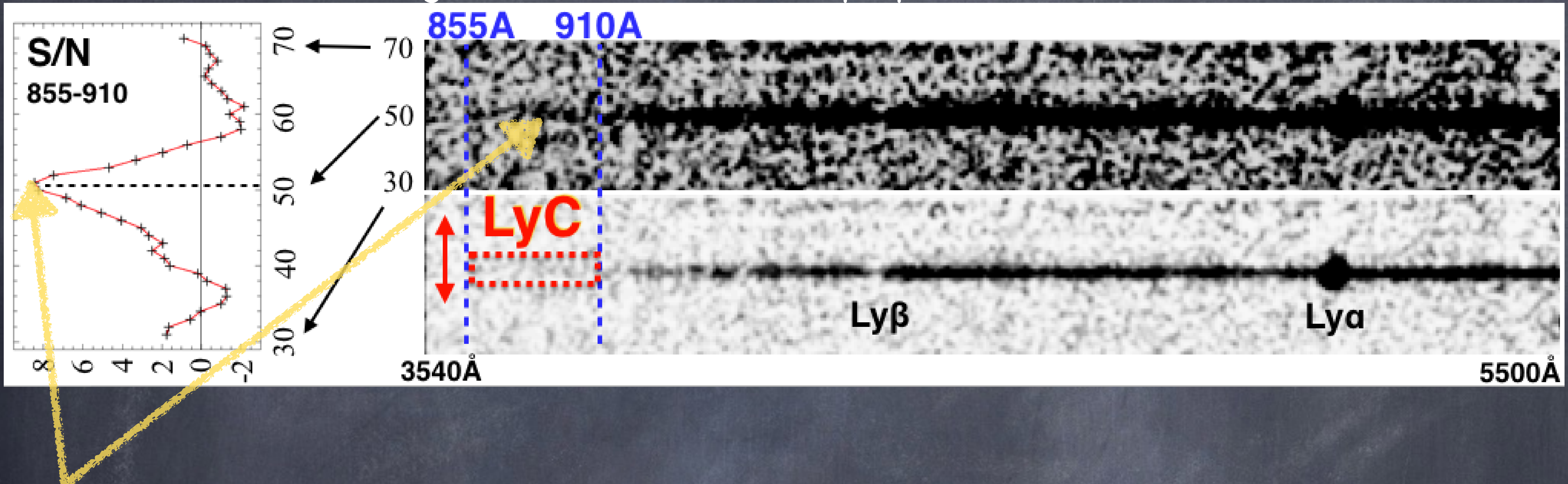
Result of further investigations (de Barros+15, in prep):



S/N=8

The faintest blob is too faint to be detected in the UV spectrum

Only explanation: Lyman continuum photons

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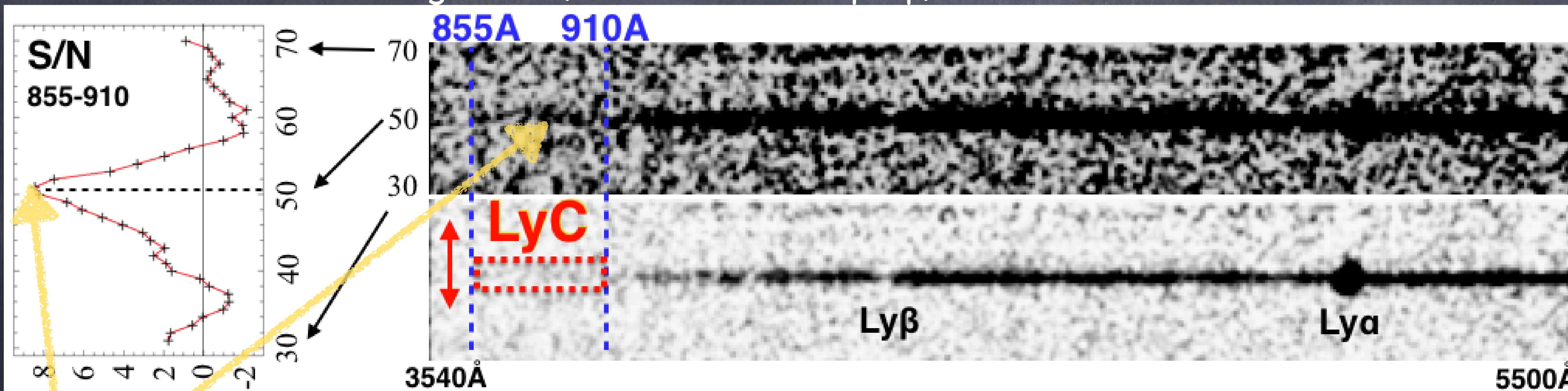

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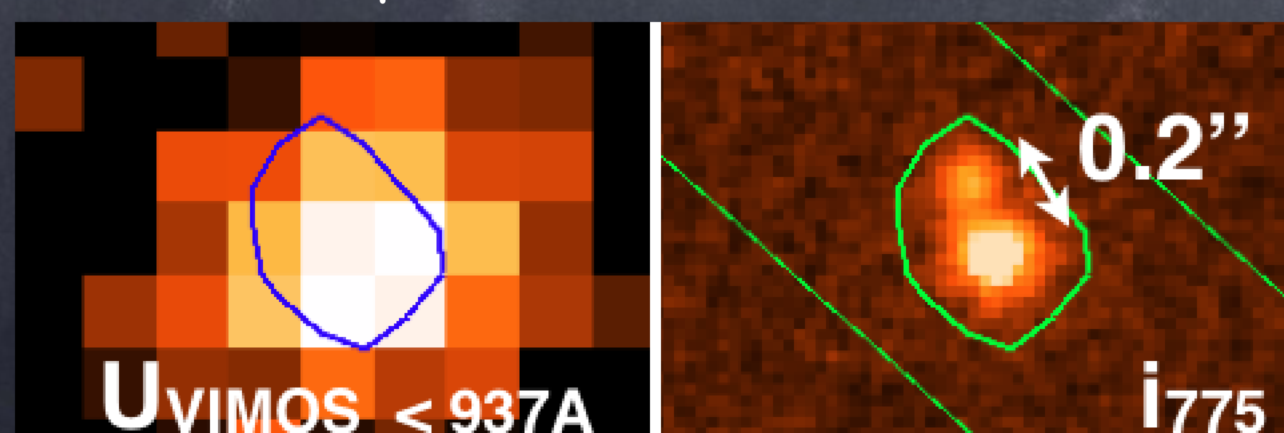

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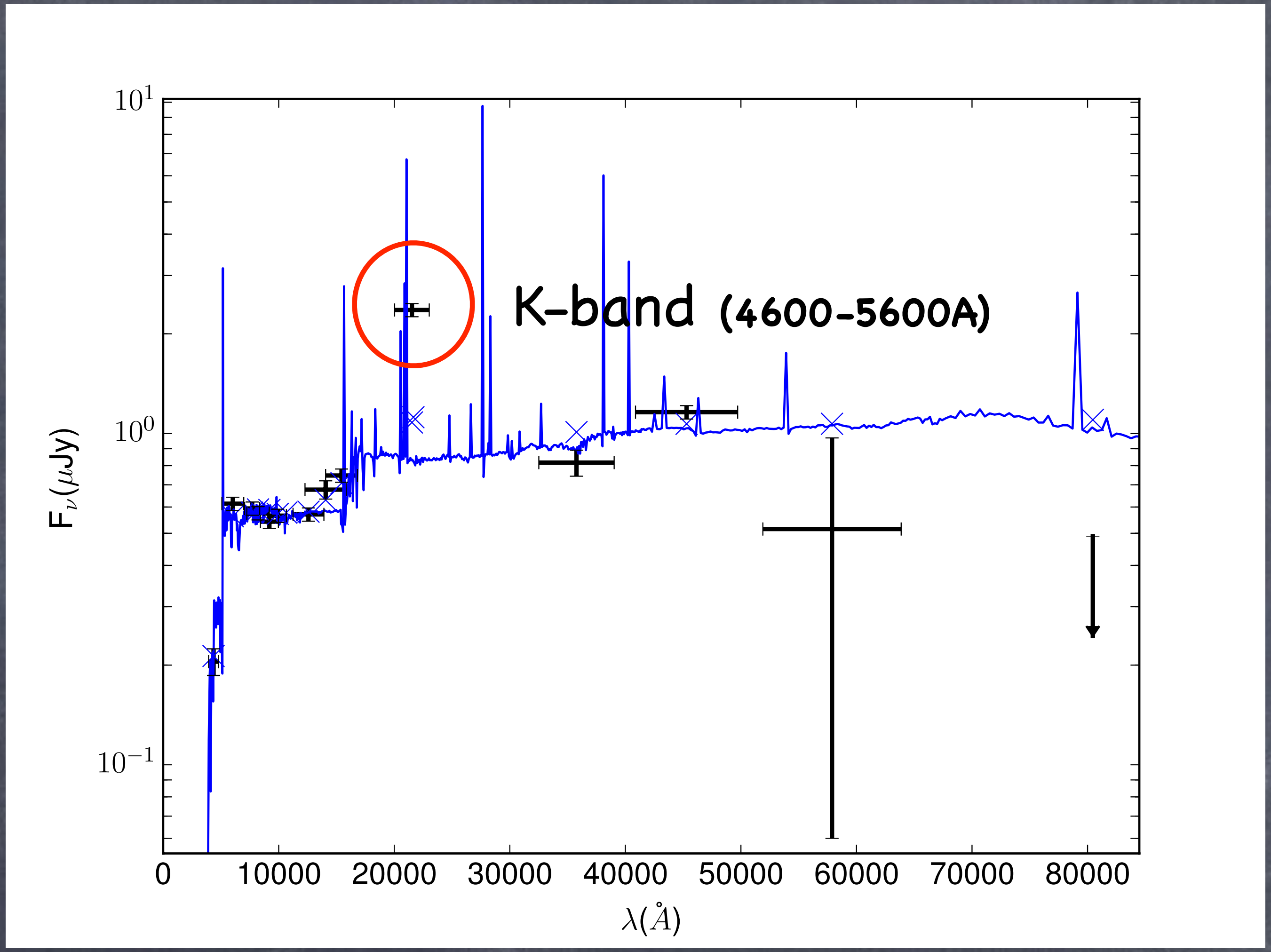

Stellar mass: 10^9 solar mass
Age: 10^7-8 yrs
The K-band excess implies EW(OIII+Hβ) >1000A!

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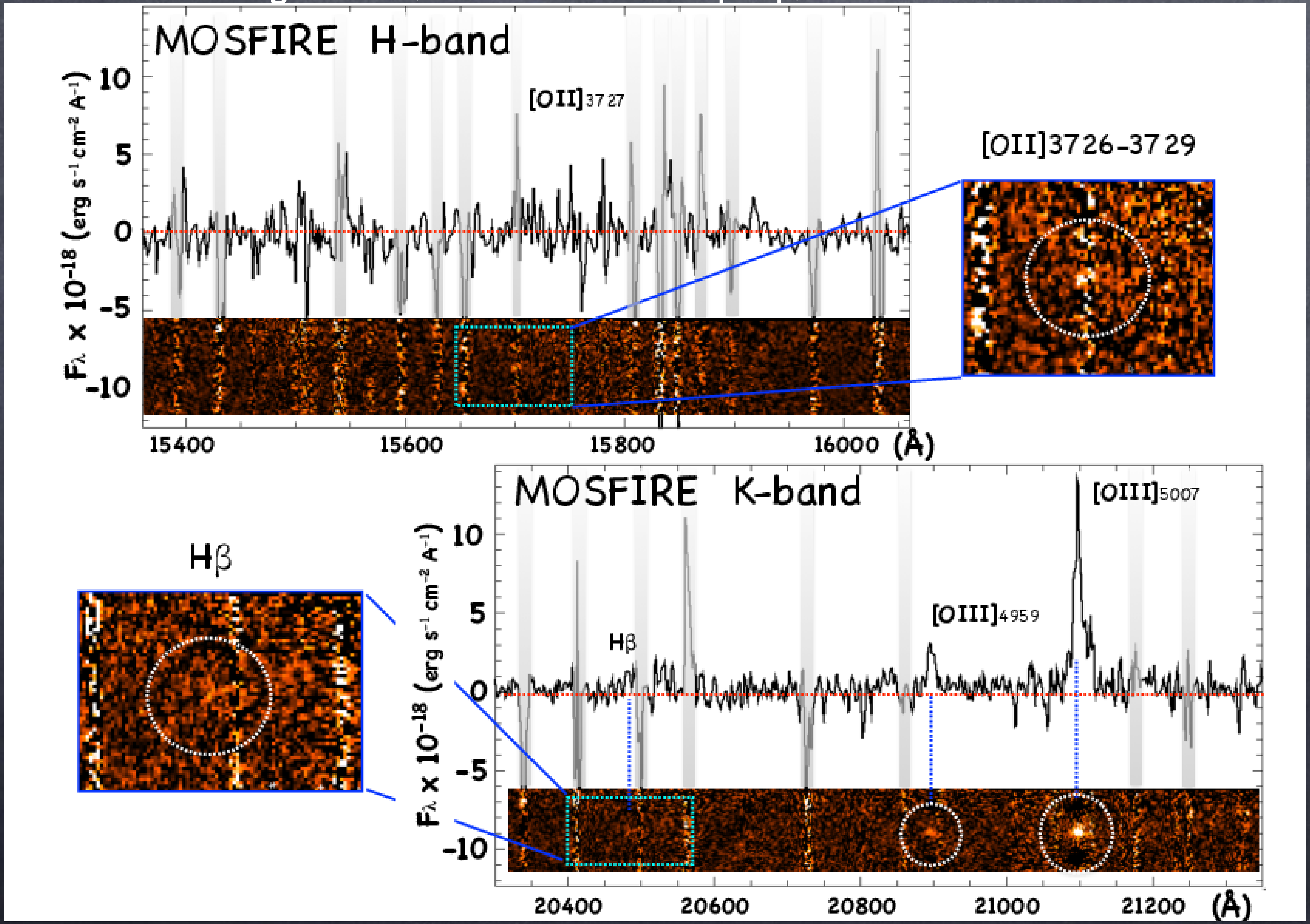

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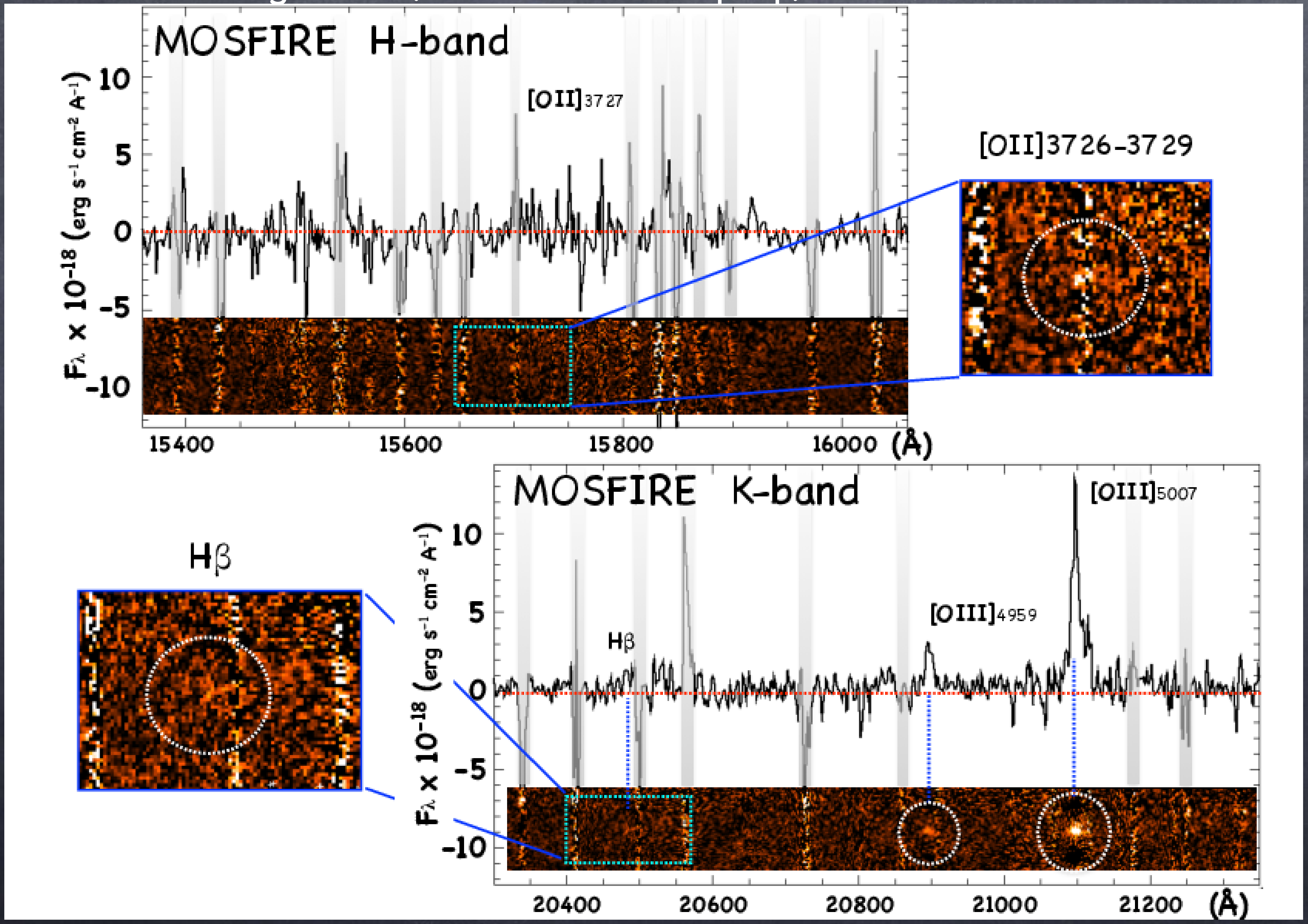

Spectrum: courtesy G. Hasinger & H. Suh

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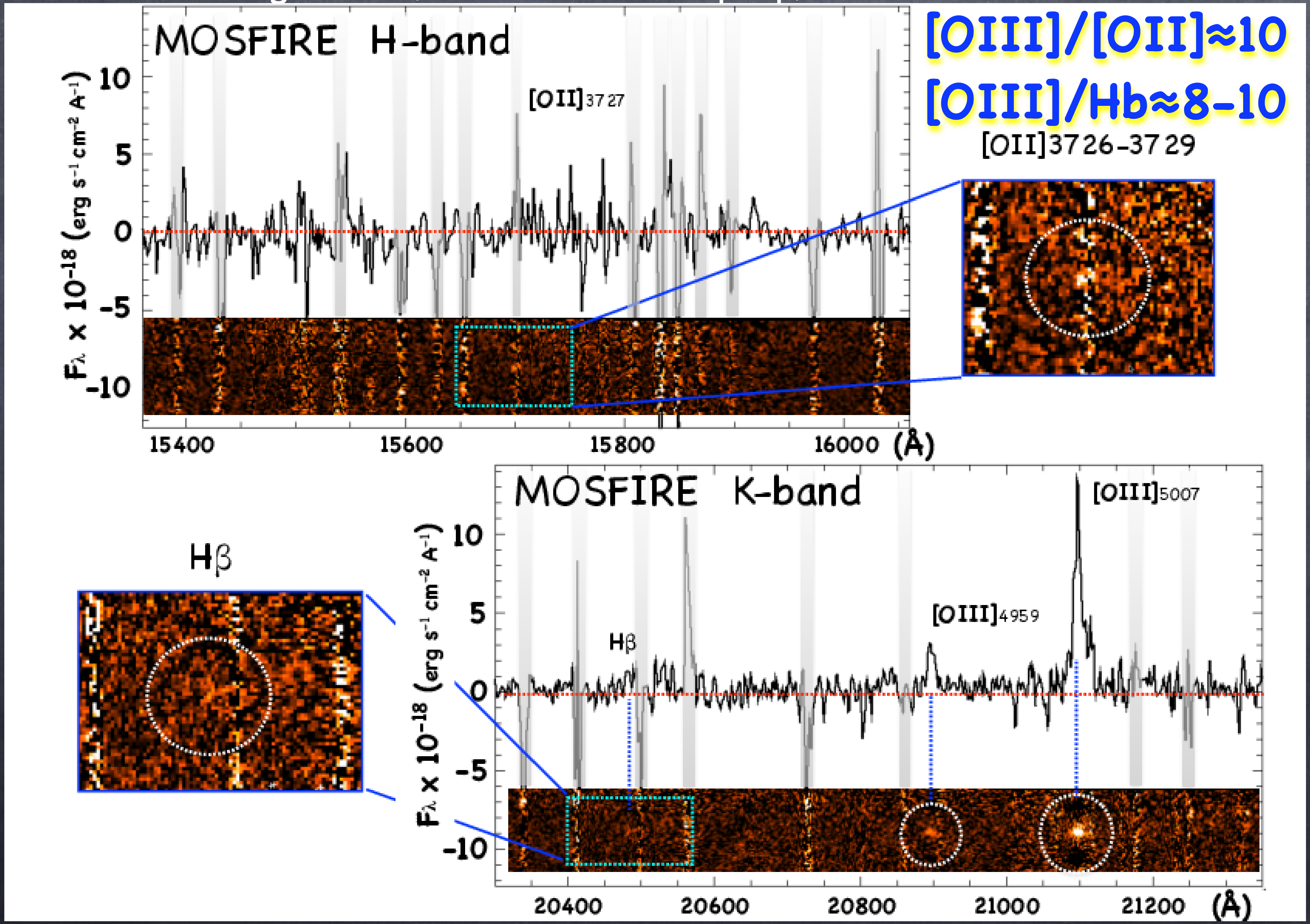

Spectrum: courtesy G. Hasinger & H. Suh

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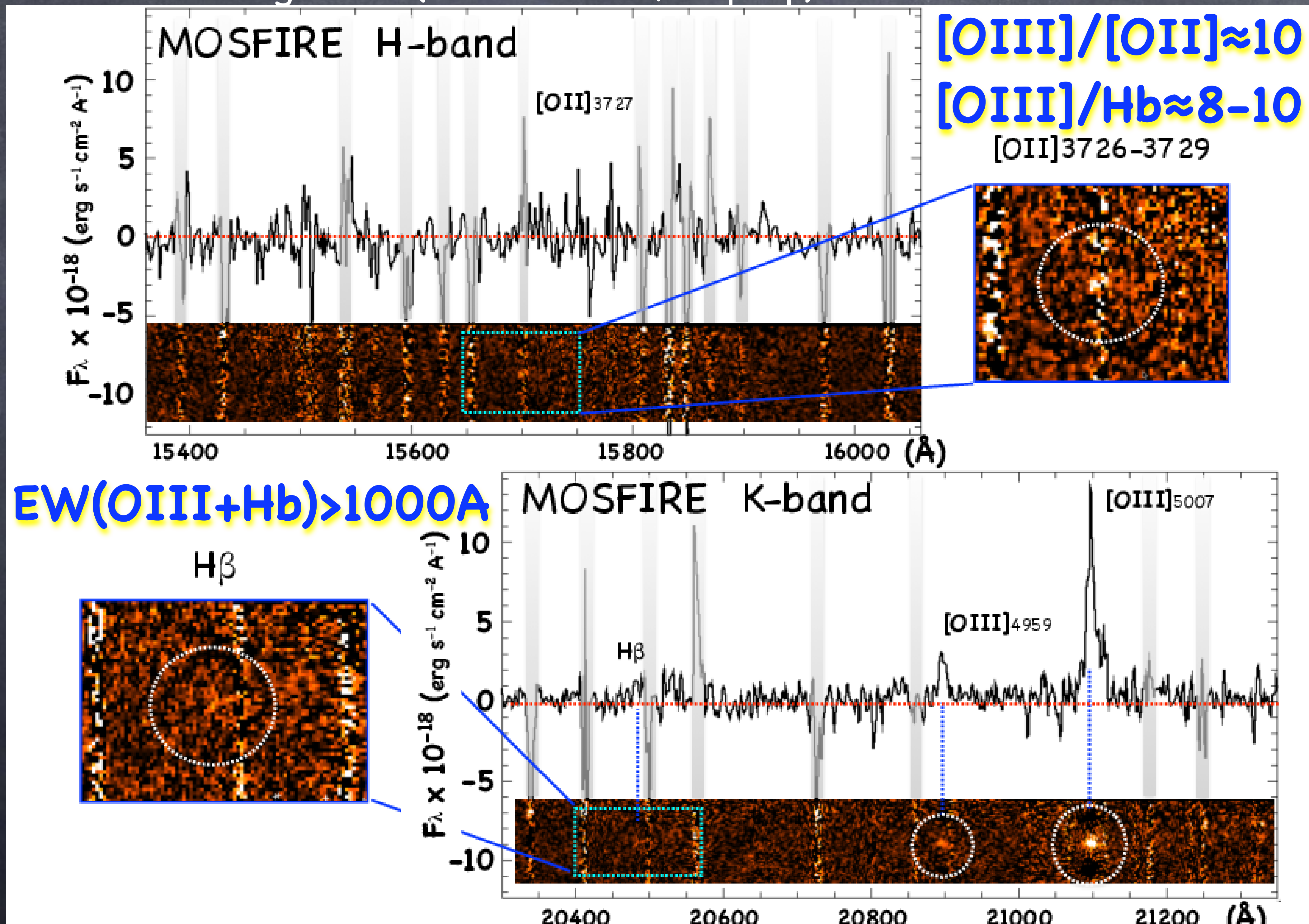

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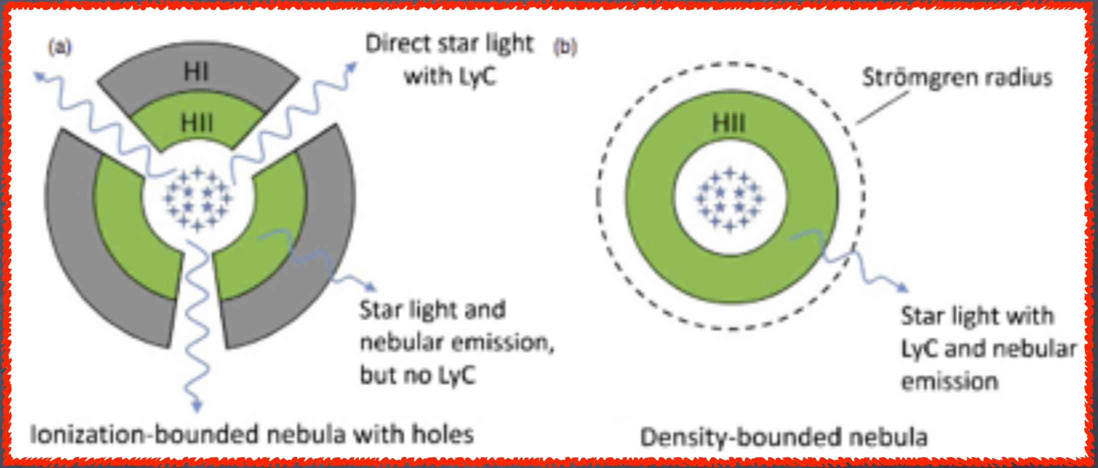

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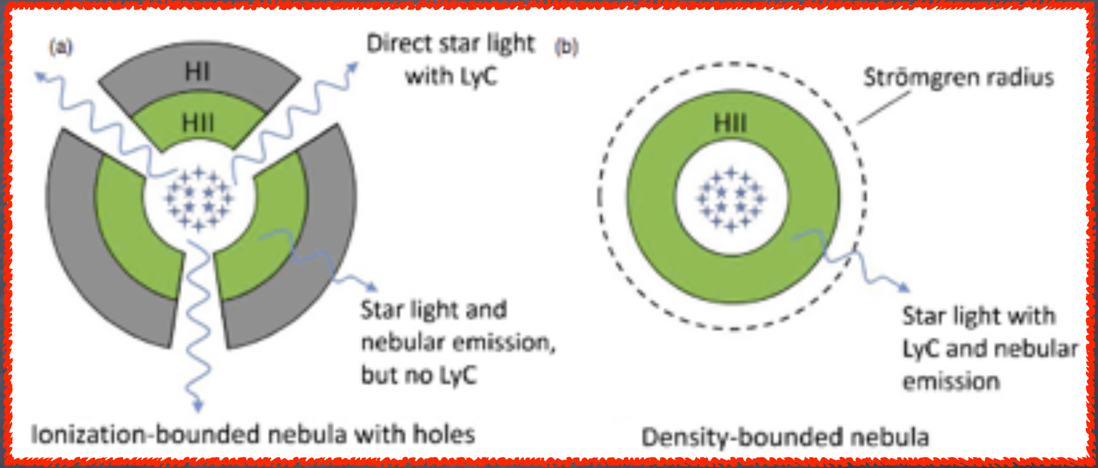

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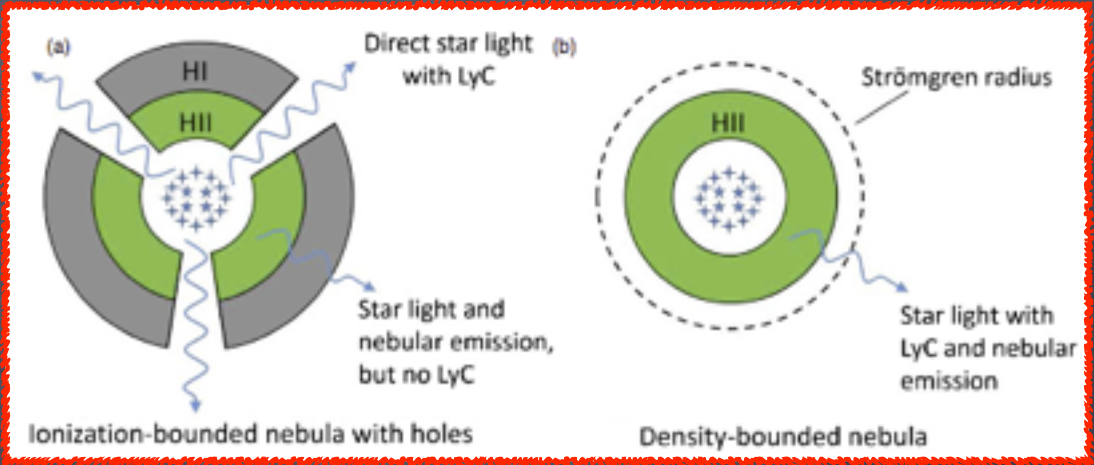


(5) **no high-ionization lines:** NV1240, CIV1550

(6) **no Spitzer/MIPS detection**

(7) **no X-ray detection in the 6Ms Chandra:** Lx < 2-3 x 10^42 erg/s, expected Lx for Type 1 AGN from [OIII] is Lx > 10^43 erg/s (Panessa+06)

(8) **no variability** (Villforth+10)

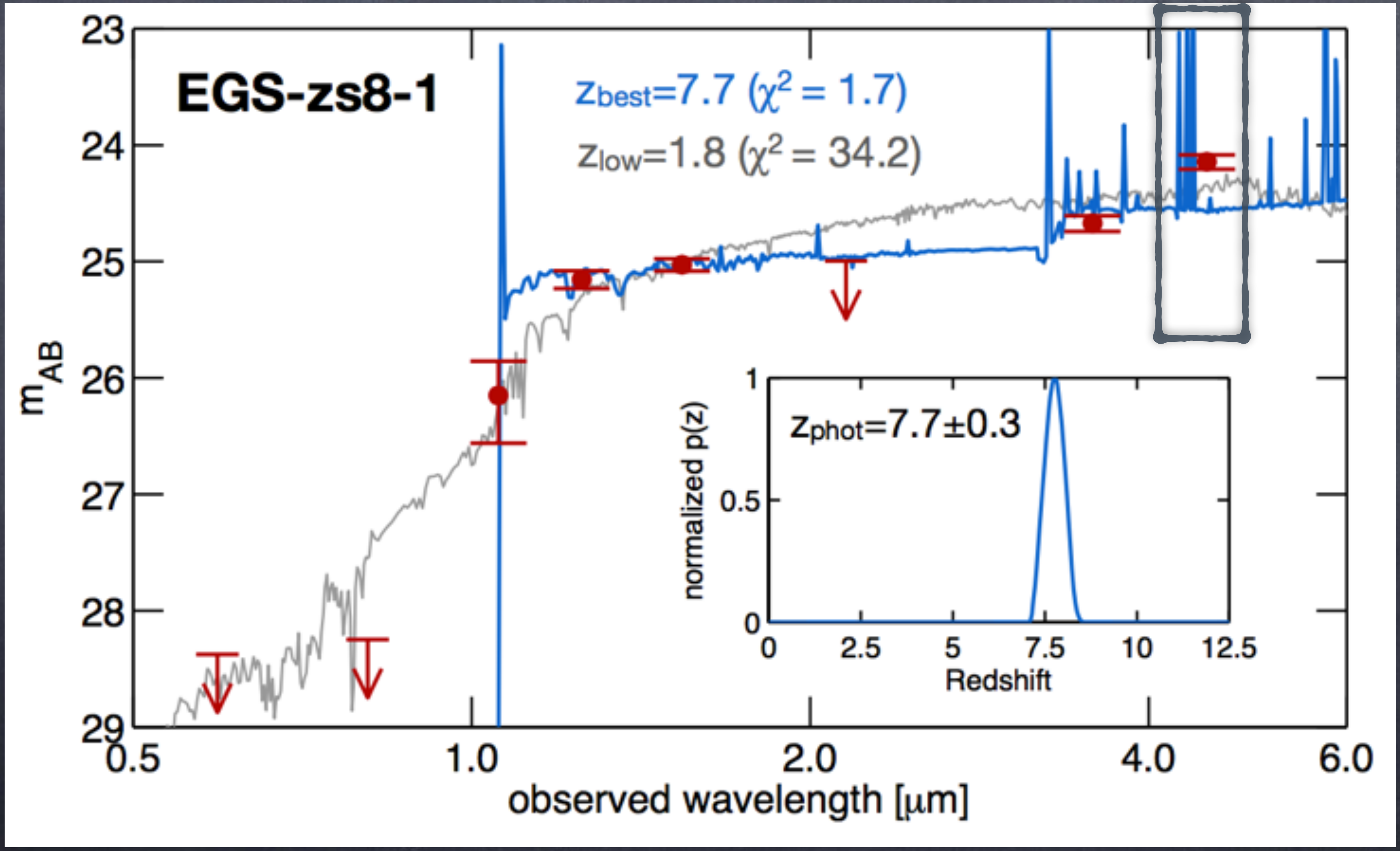
(9) **CIV1548,1550/[C III]C III]1907, 1909 < 0.xxx:** soft ionization spectrum (ratio >2 for AGN, Christensen+12)

(10) **type 2 AGN (obscured) does not allow LyC escape:** NH>10^20 vs. NH<10^18

Implication for JWST?

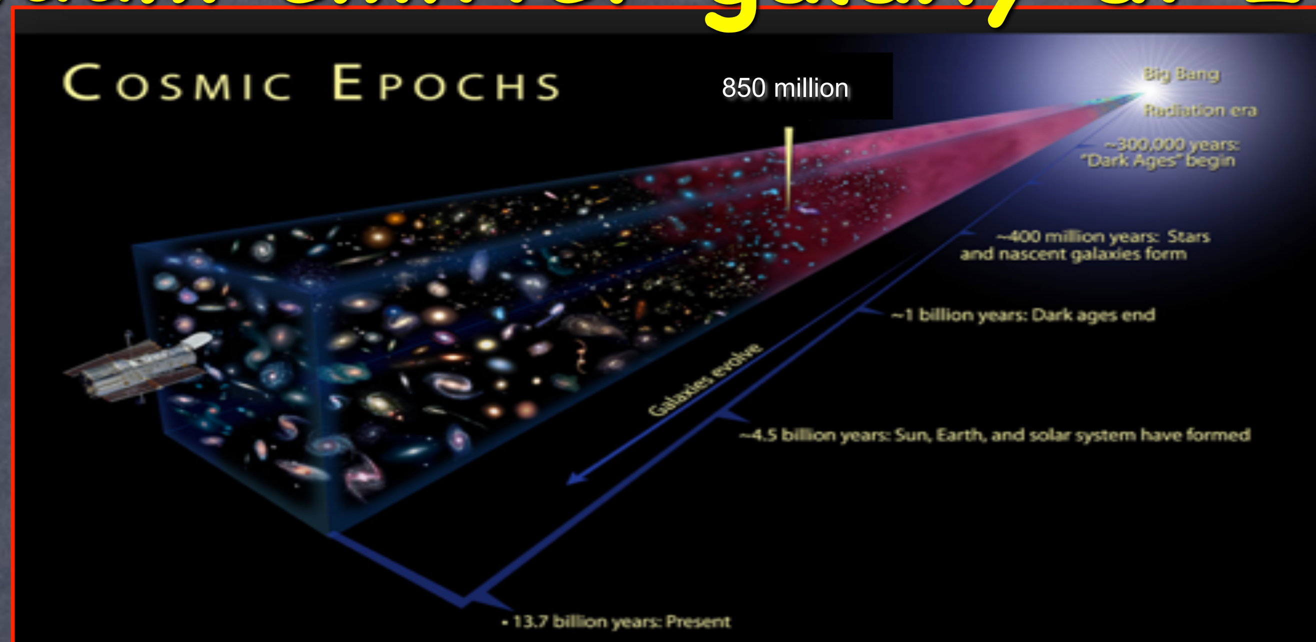
Derive a reliable emission line diagnostic to identify LyC leakers at z>4 and at the reionization epoch.

Are we already seeing LyC leakers at z=7?
E.g., Smit+14, Oesch+15



Thank you...

The physical properties of a star-forming Lyman continuum emitter galaxy at z=3.212



&

The star-formation main sequence at z=4: prospect for the NIRSpec instrument

Stephane De Barros

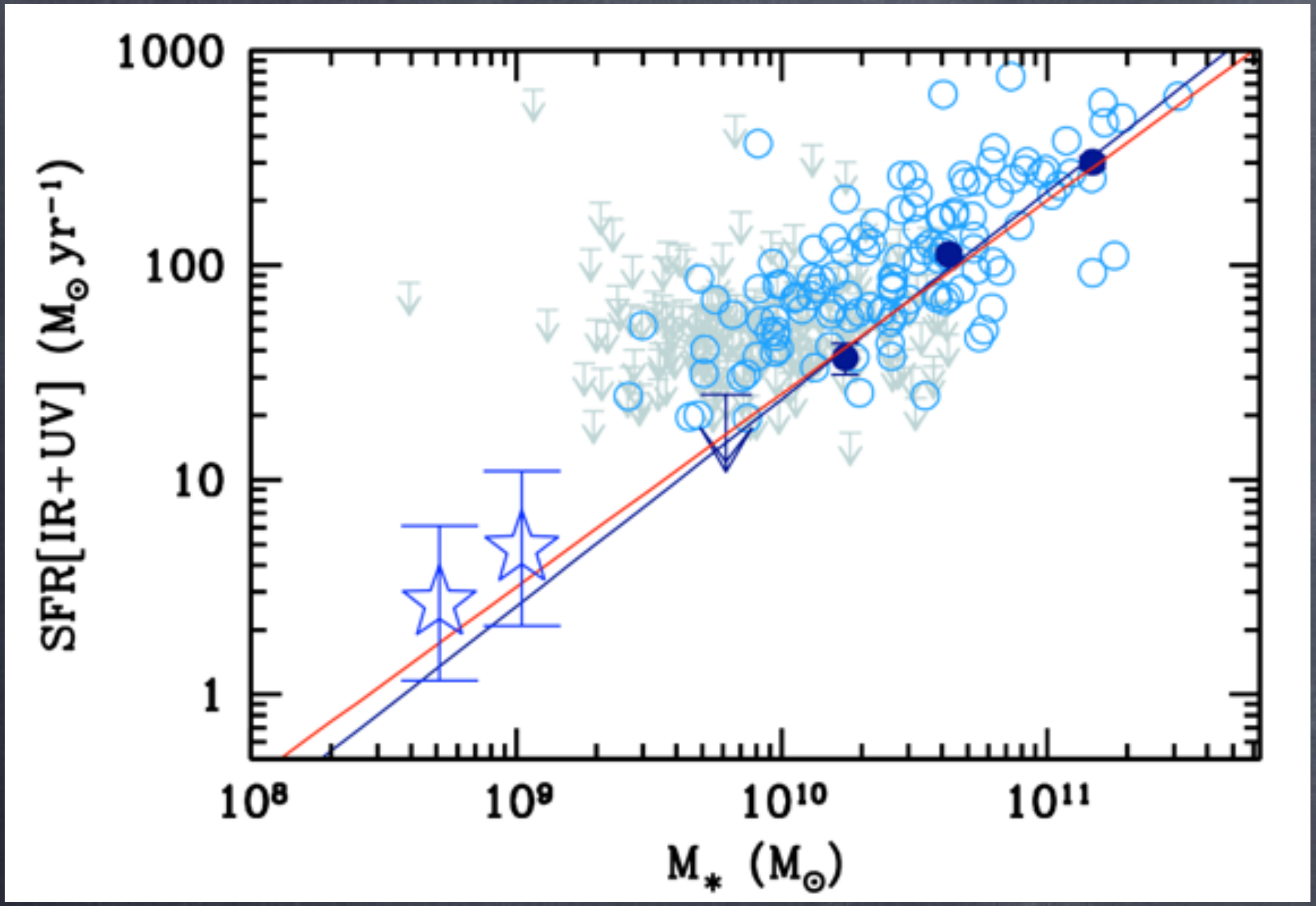
INAF - Astronomical Observatory of Bologna

Collaborators:

E. Vanzella (INAF-OABO), B. Mobasher(UCR), G. Hazinger (U. Hawaii), A. Grazian (INAF-OAR), H. Nayyeri (UCI), G. Zamorani (INAF-OABO), B. Siana (UCR), L. Pentericci (INAF-OAR), D. Schaerer (U. Geneva) et al.

The star-formation main sequence

There is a well defined relation between stellar mass and star formation rate up to z=2



Reddy+12

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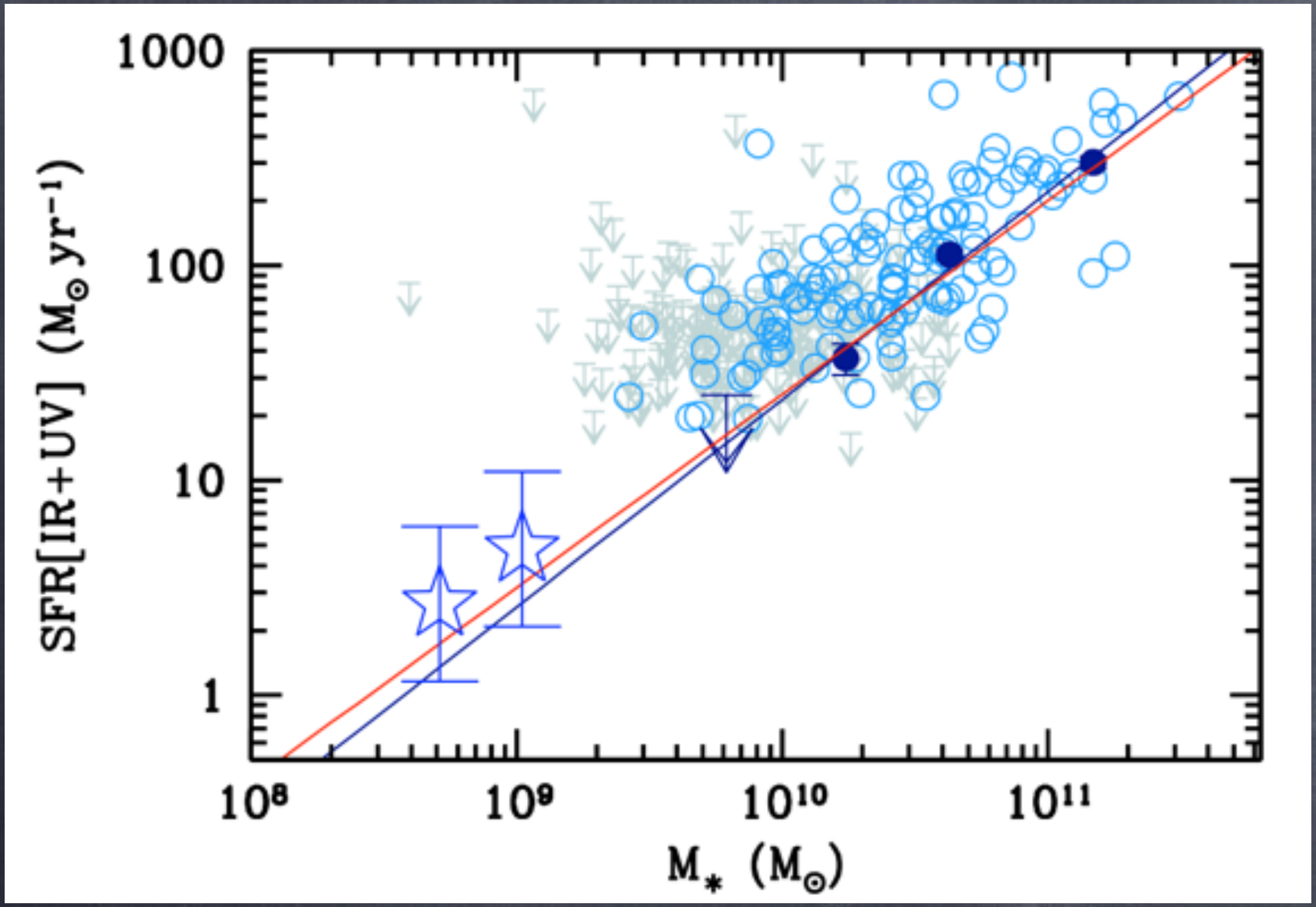

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Implications:

Rising star formation history?

No stochasticity?

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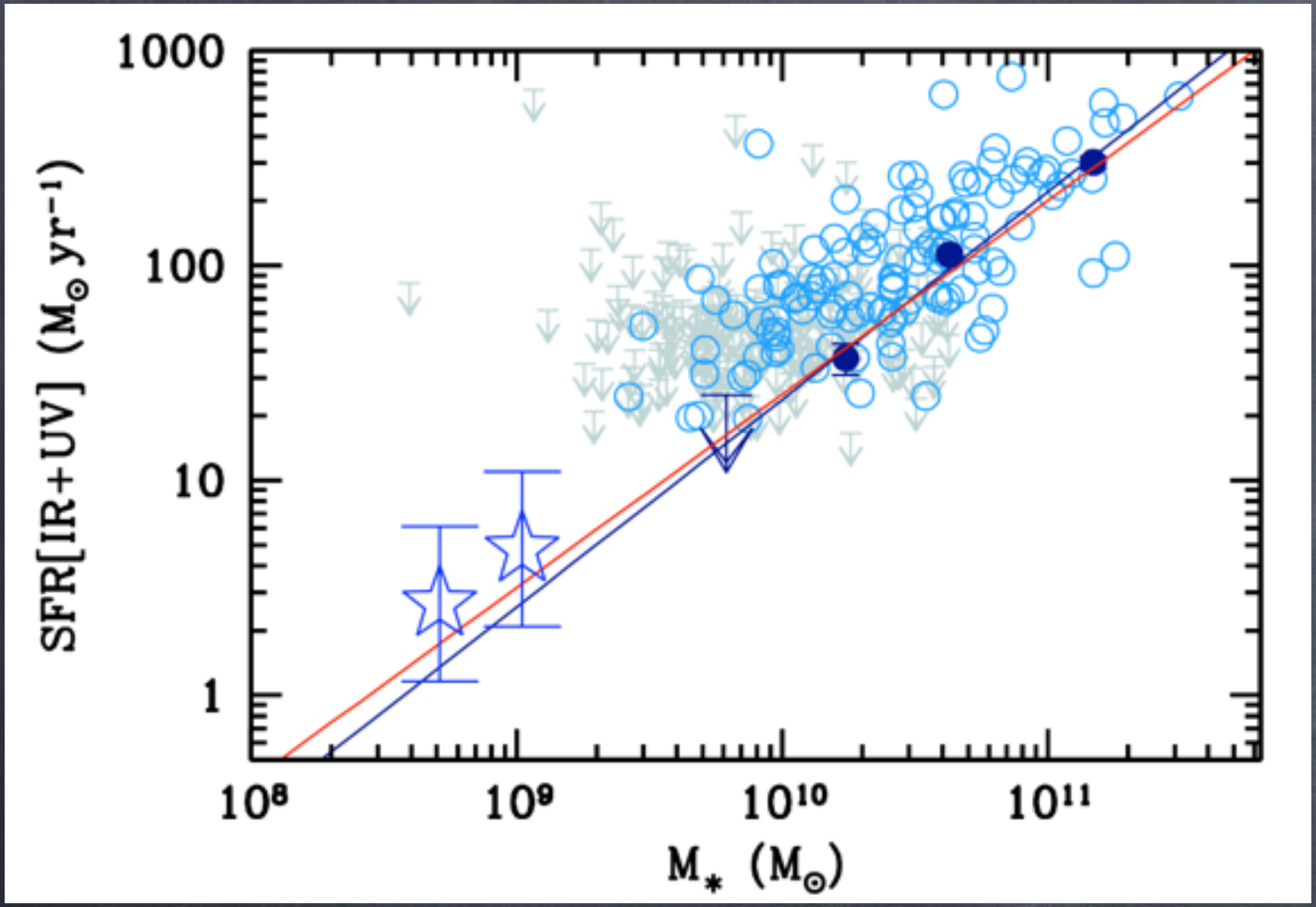

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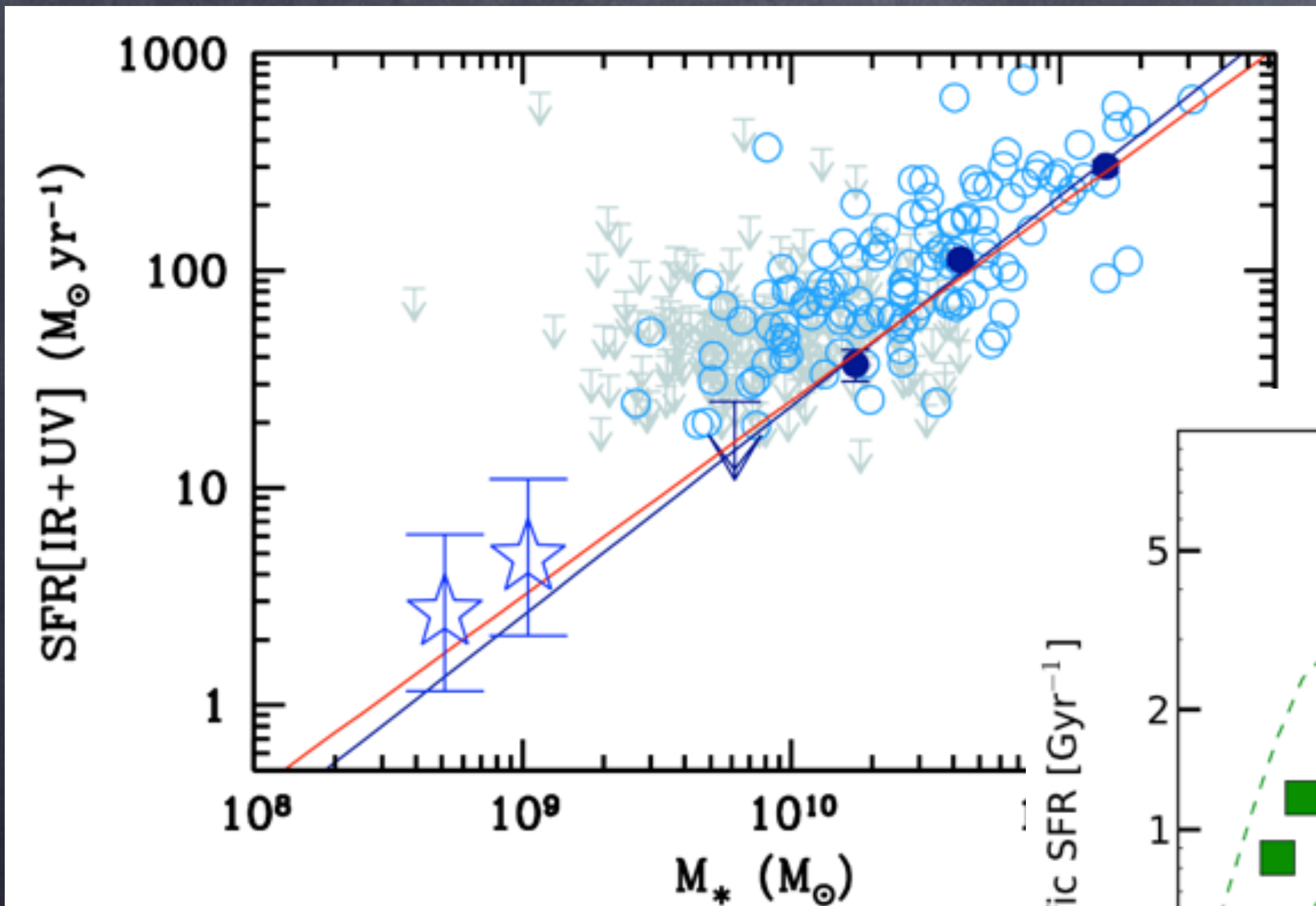

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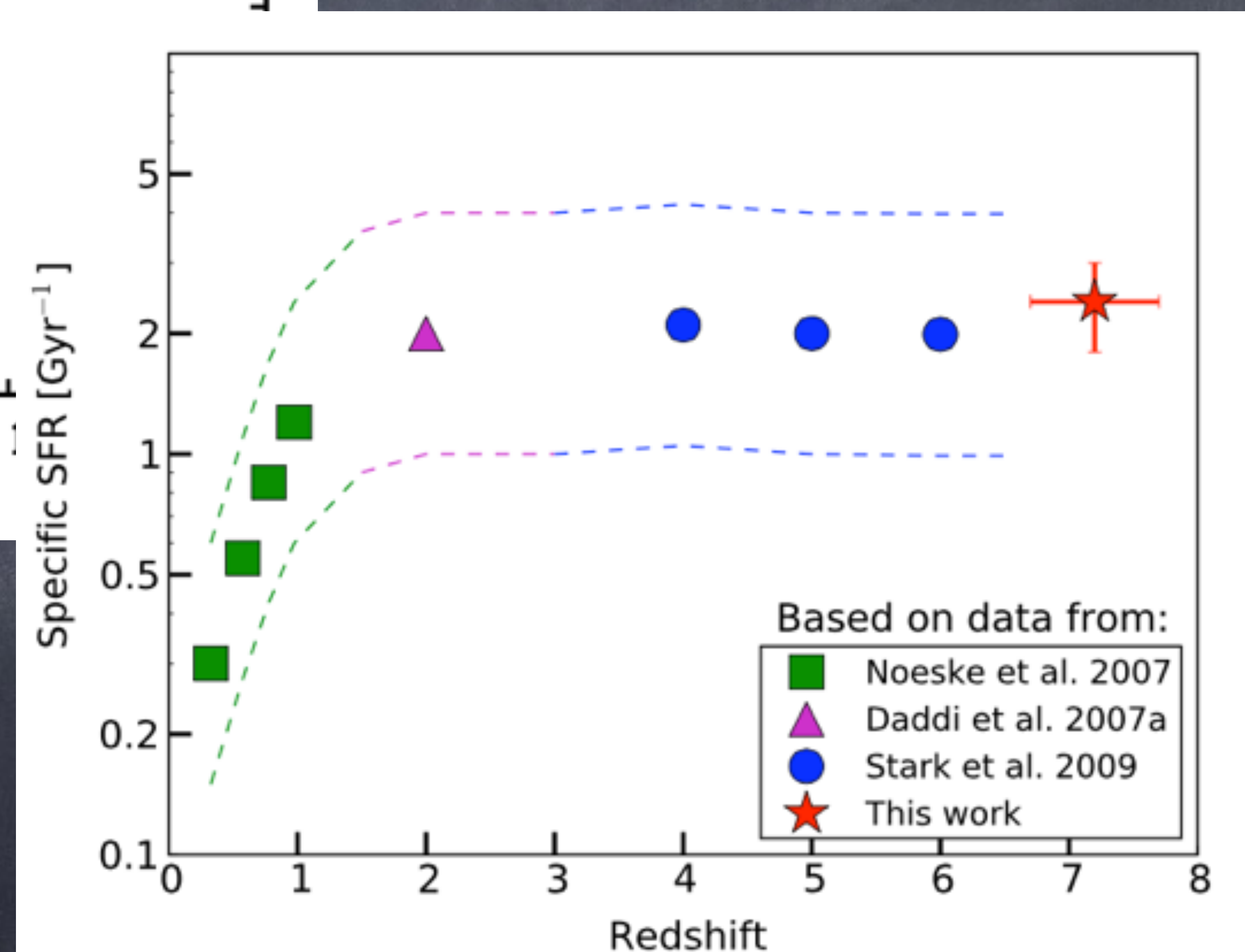

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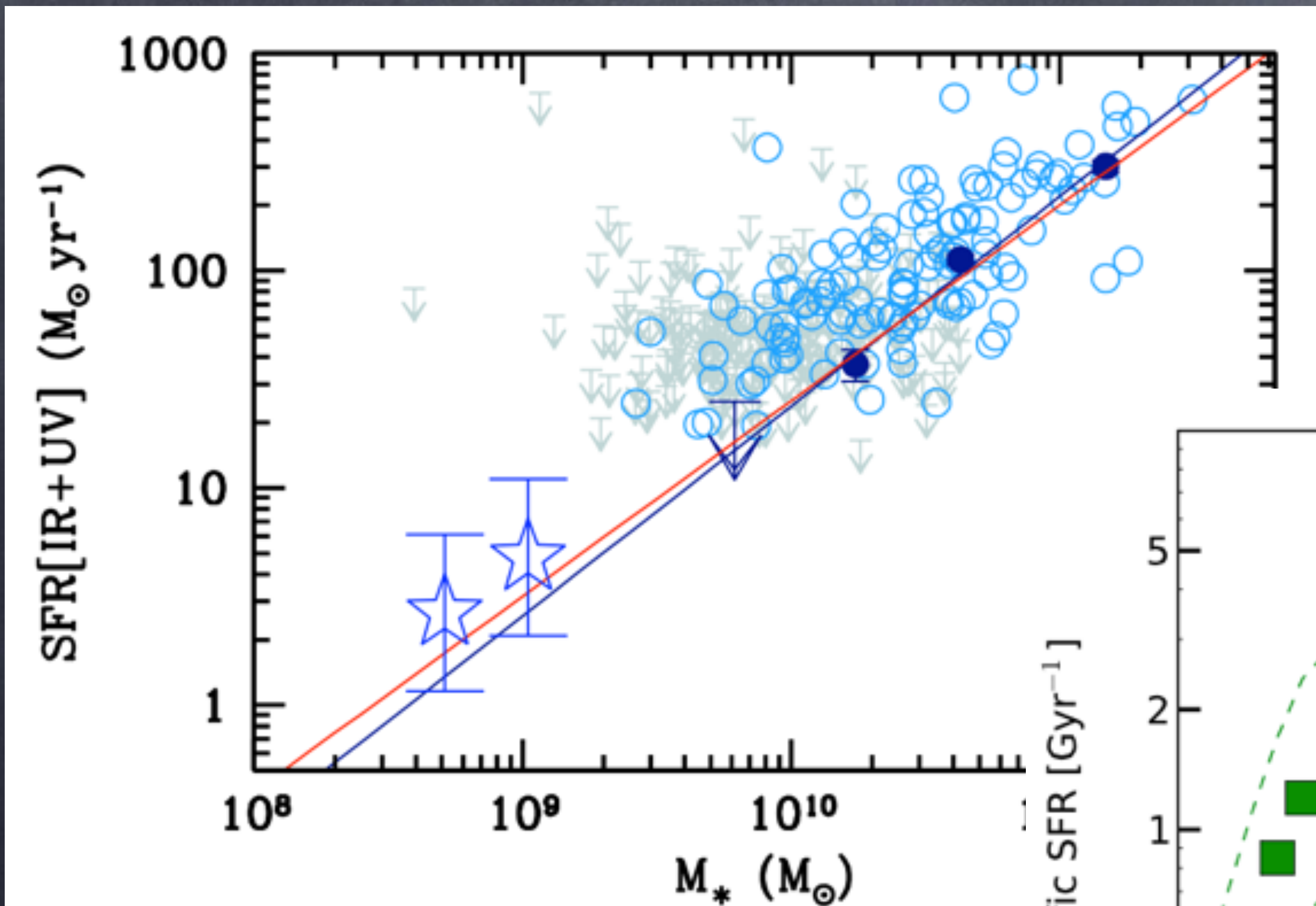

Reddy+12

Implications:

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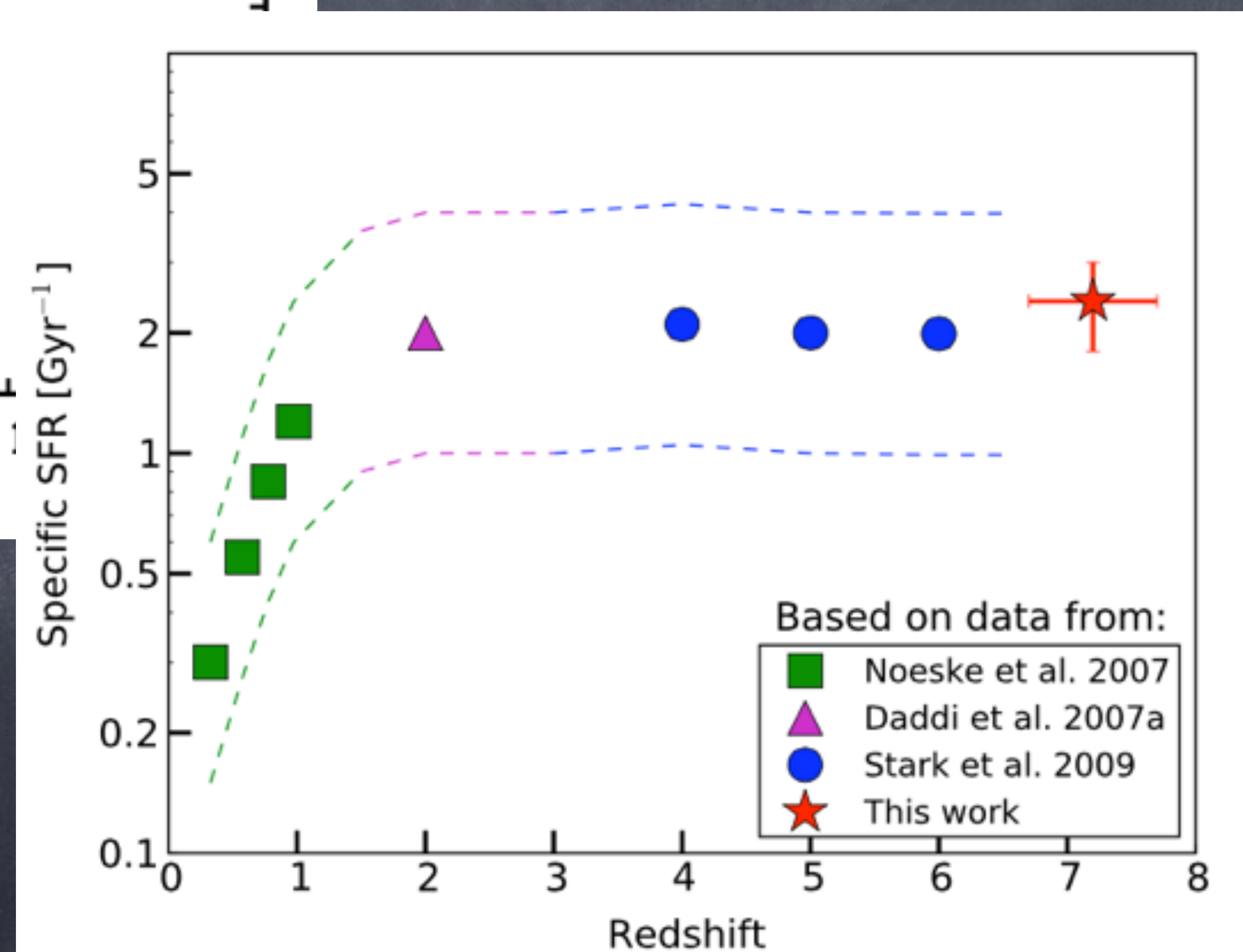
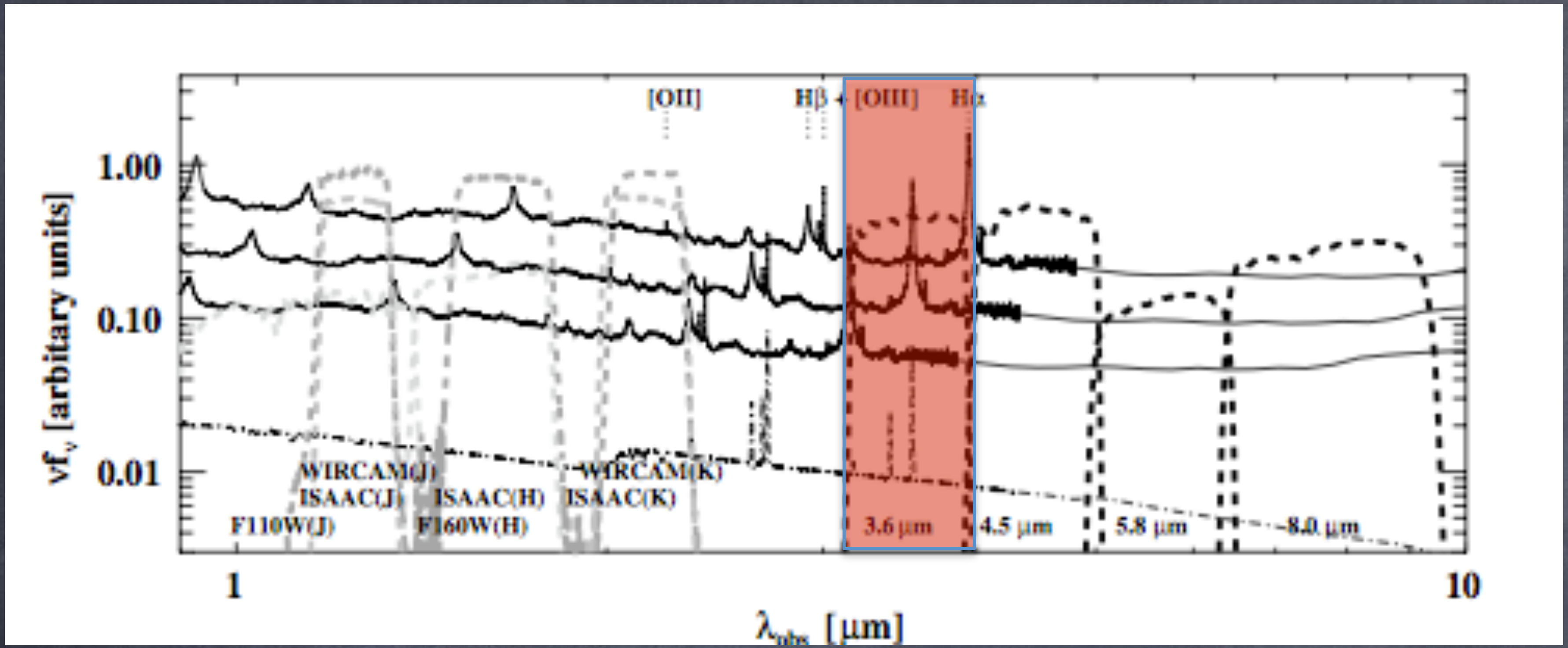
No evolution of the sequence at z>2?

Tension with theoretical prediction (sSFR should rise with z, e.g., Bouche+10)

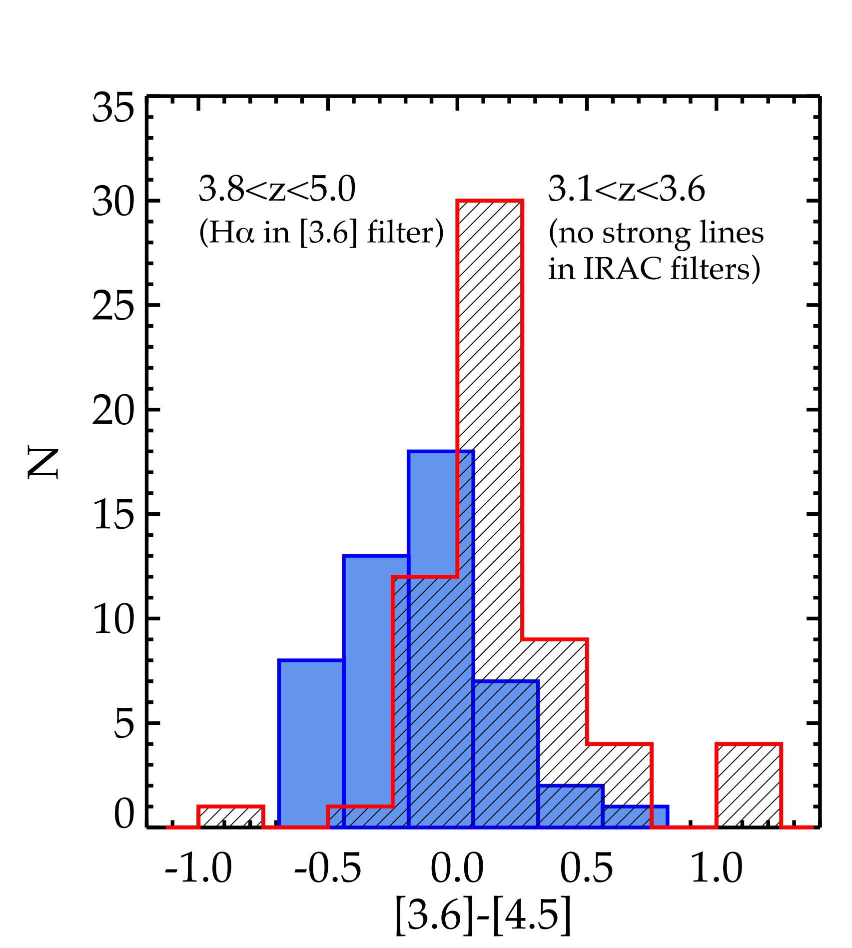


Gonzalez+10

How to derive the sequence at z>3?



Shim+11



Stark+13

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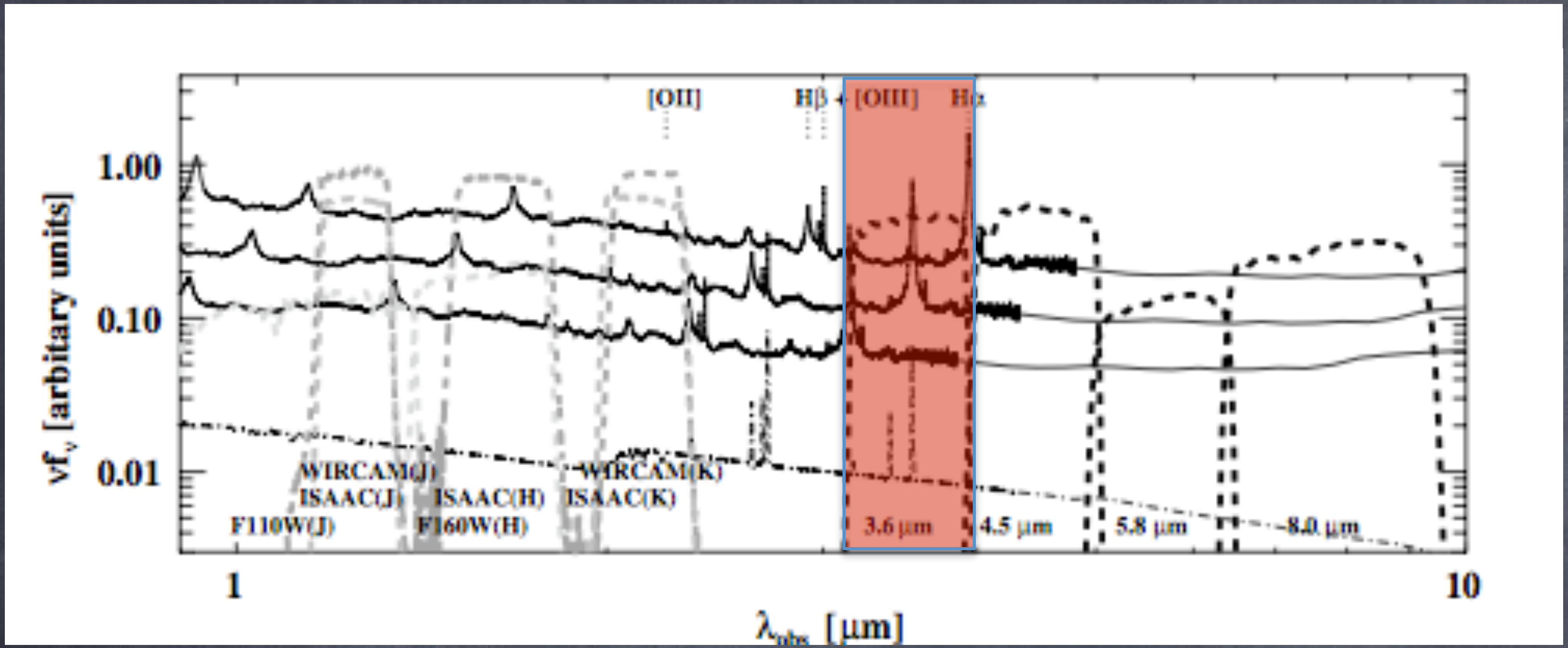
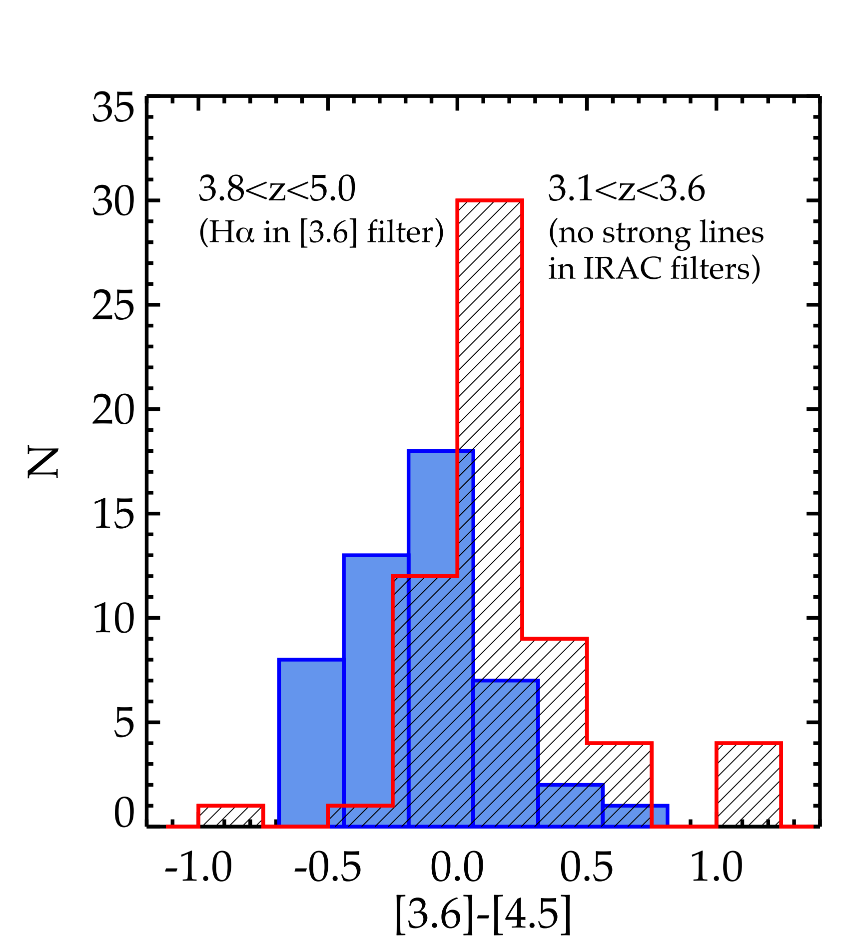


Shim+11

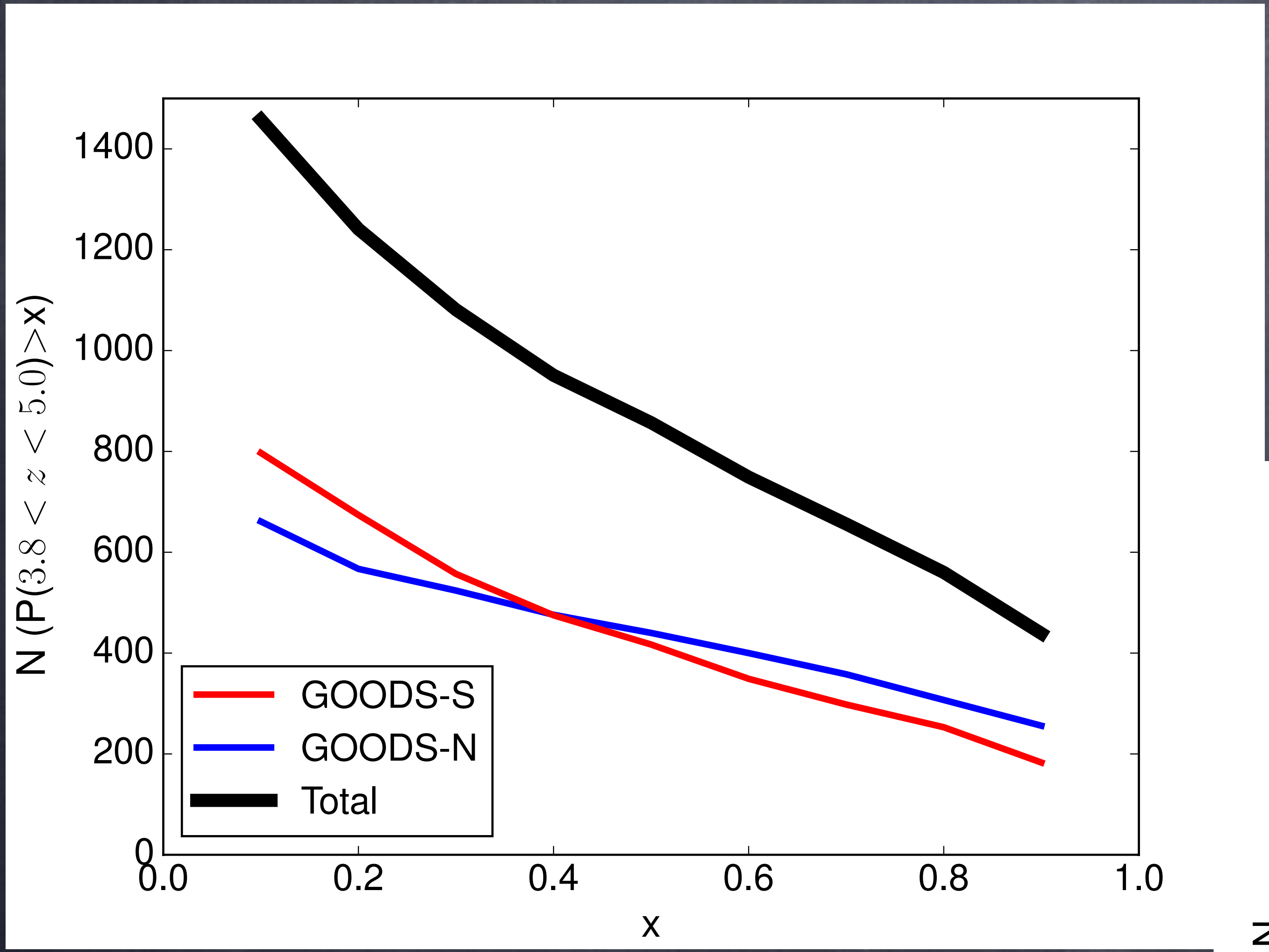
- (3.6-4.5)µm: straightforward basically model independent derivation of *observed* Hα flux
- Possibility to derive instantaneous SFR, sSFR, SFR density, the SFH (stochastic/ episodic vs smooth?)

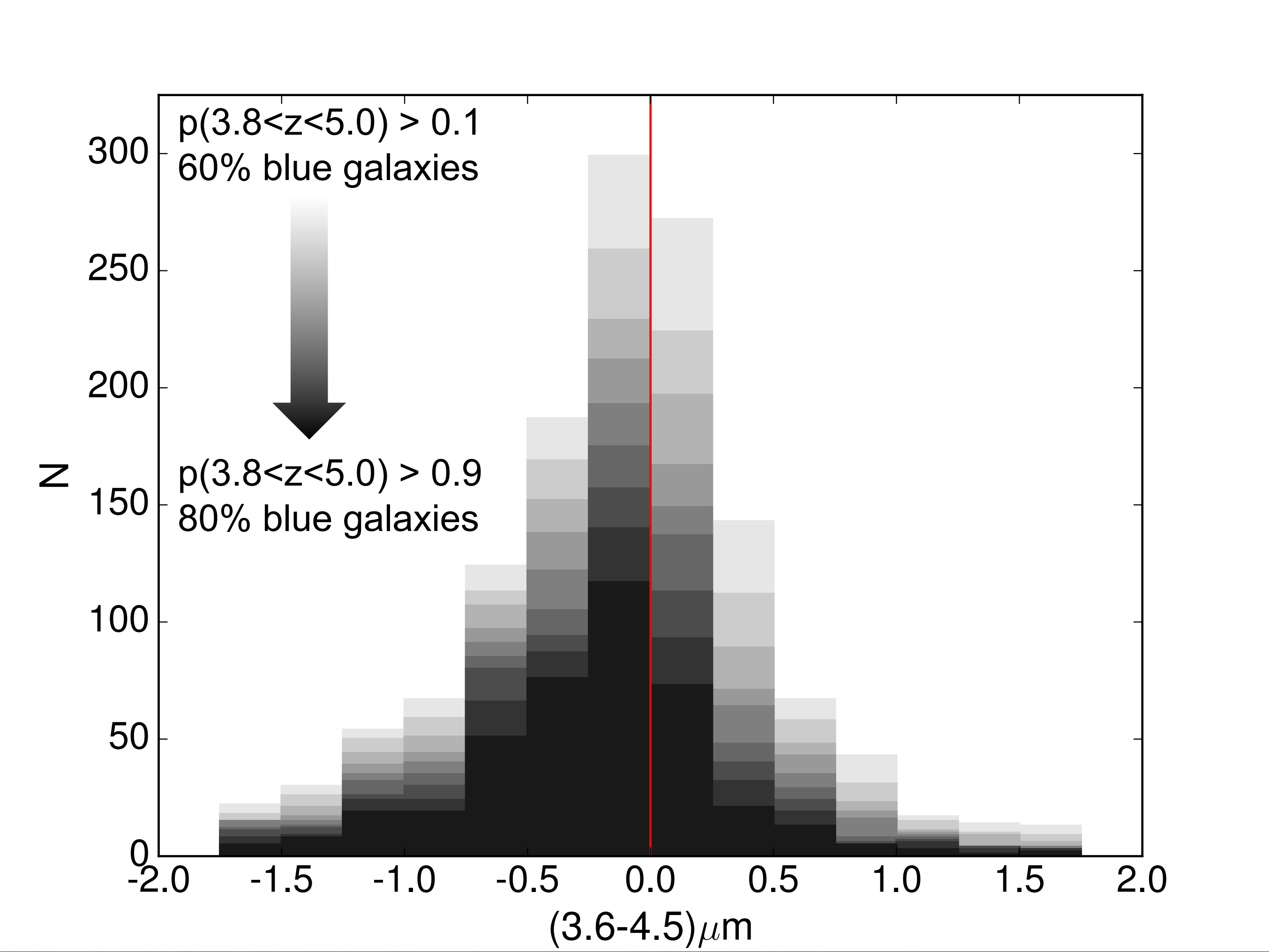


Stark+13

(3.6-4.5)μm at z=4

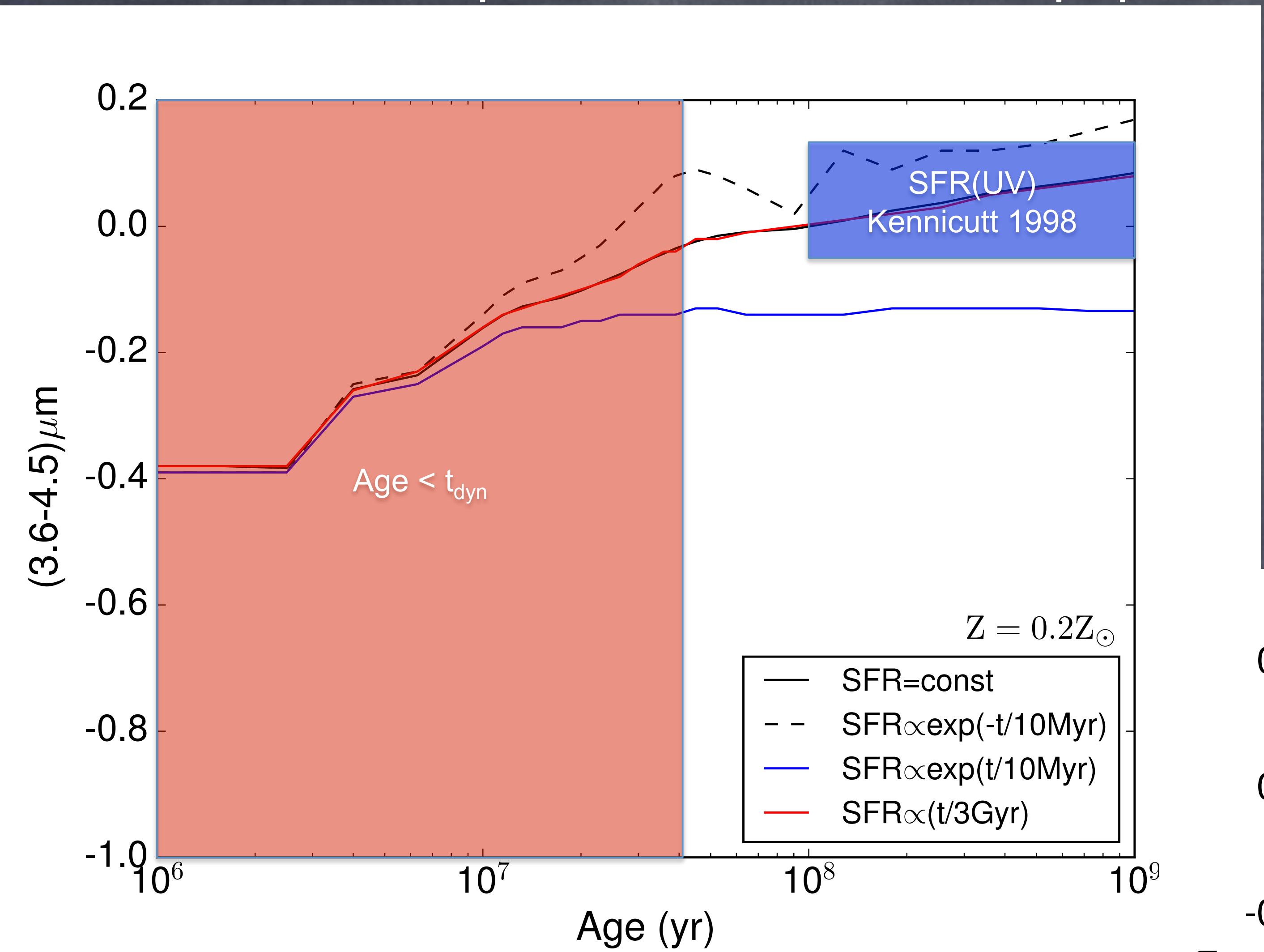
Build a large sample of B- and V-dropout galaxies from CANDELS GOODS-S and GOODS-N
Photometric redshift selection: 3.8 < z < 5.0

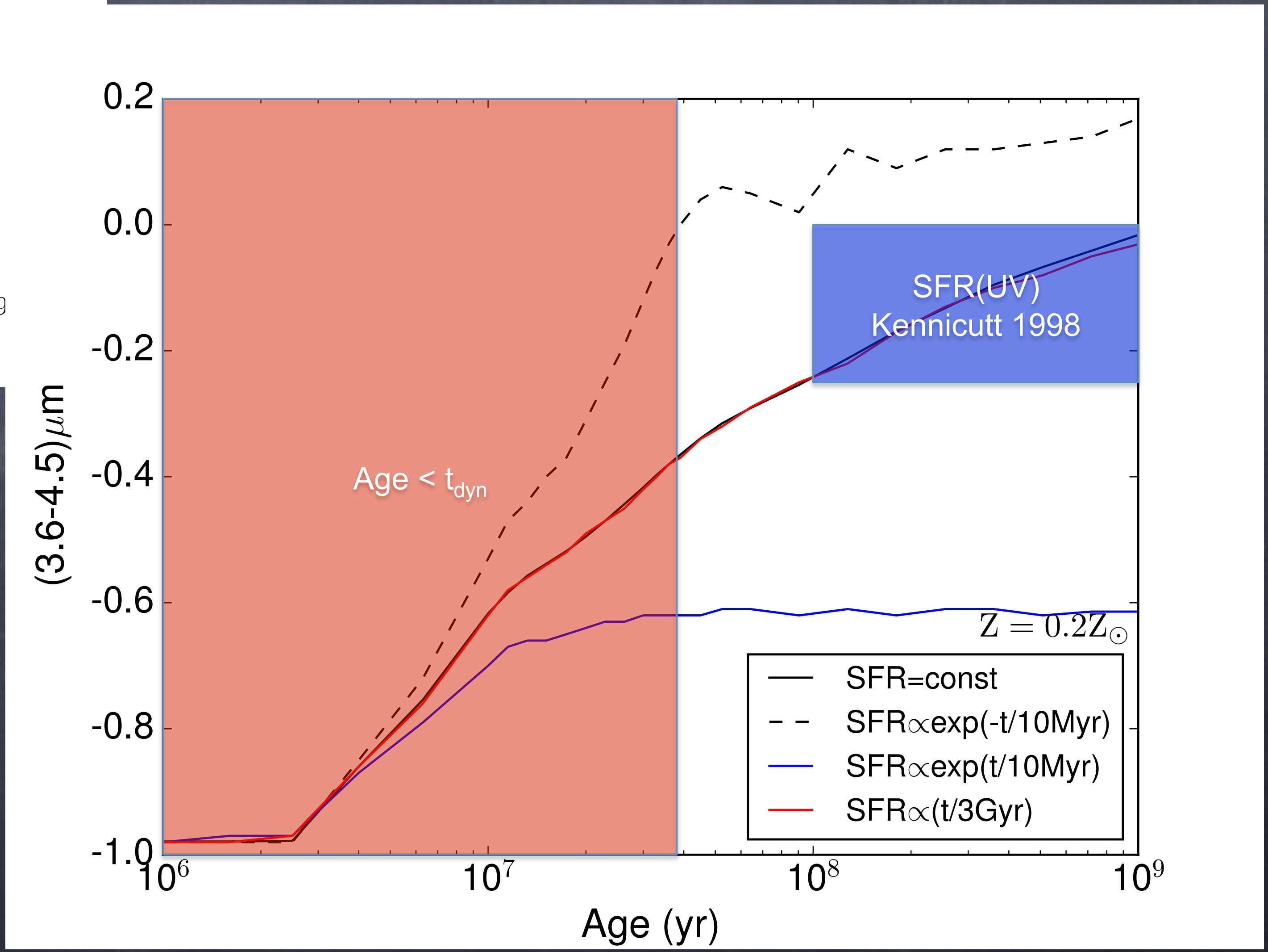




(3.6-4.5)μm at z=4

Theoretical expectations from stellar population synthesis model





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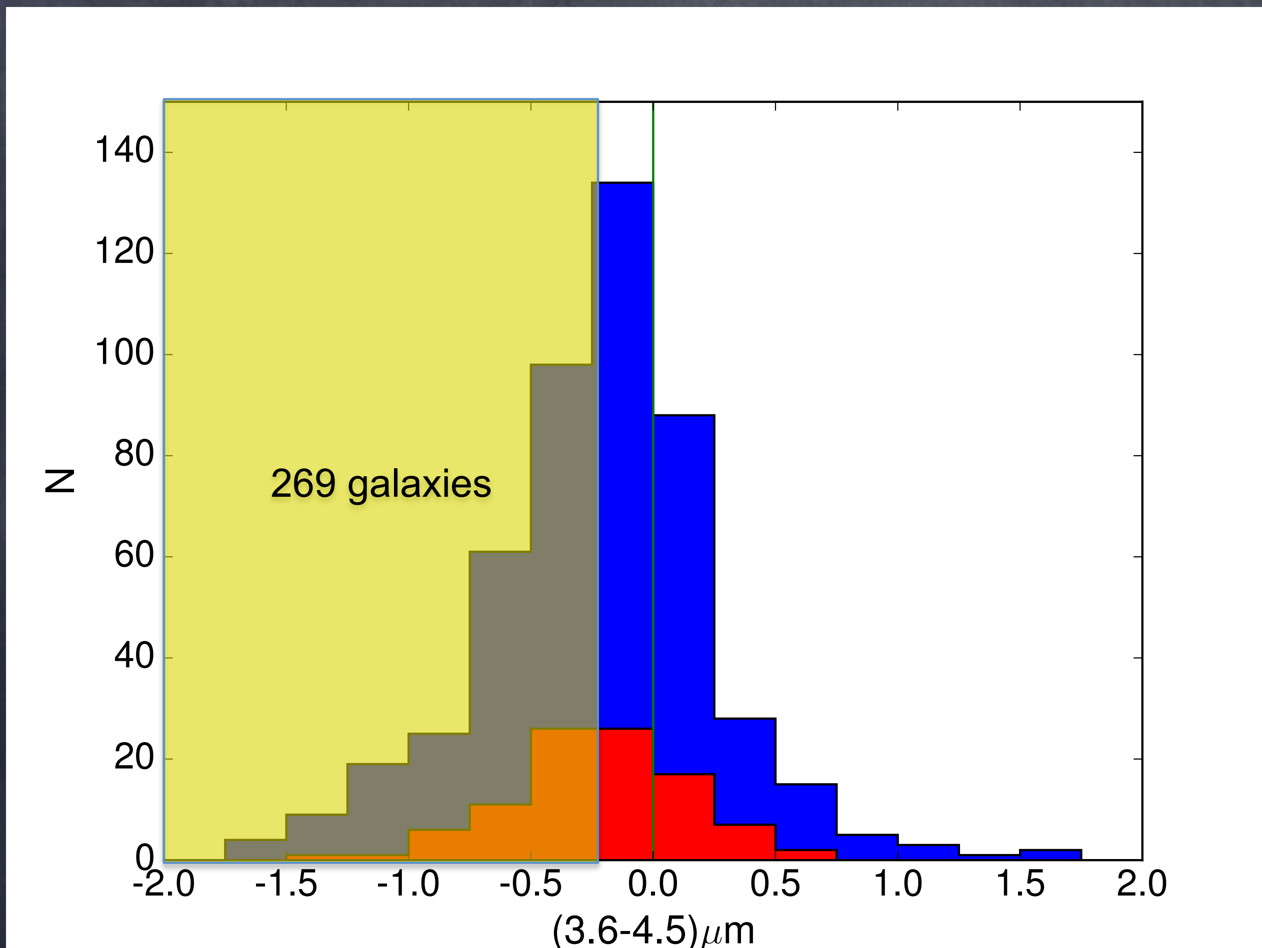
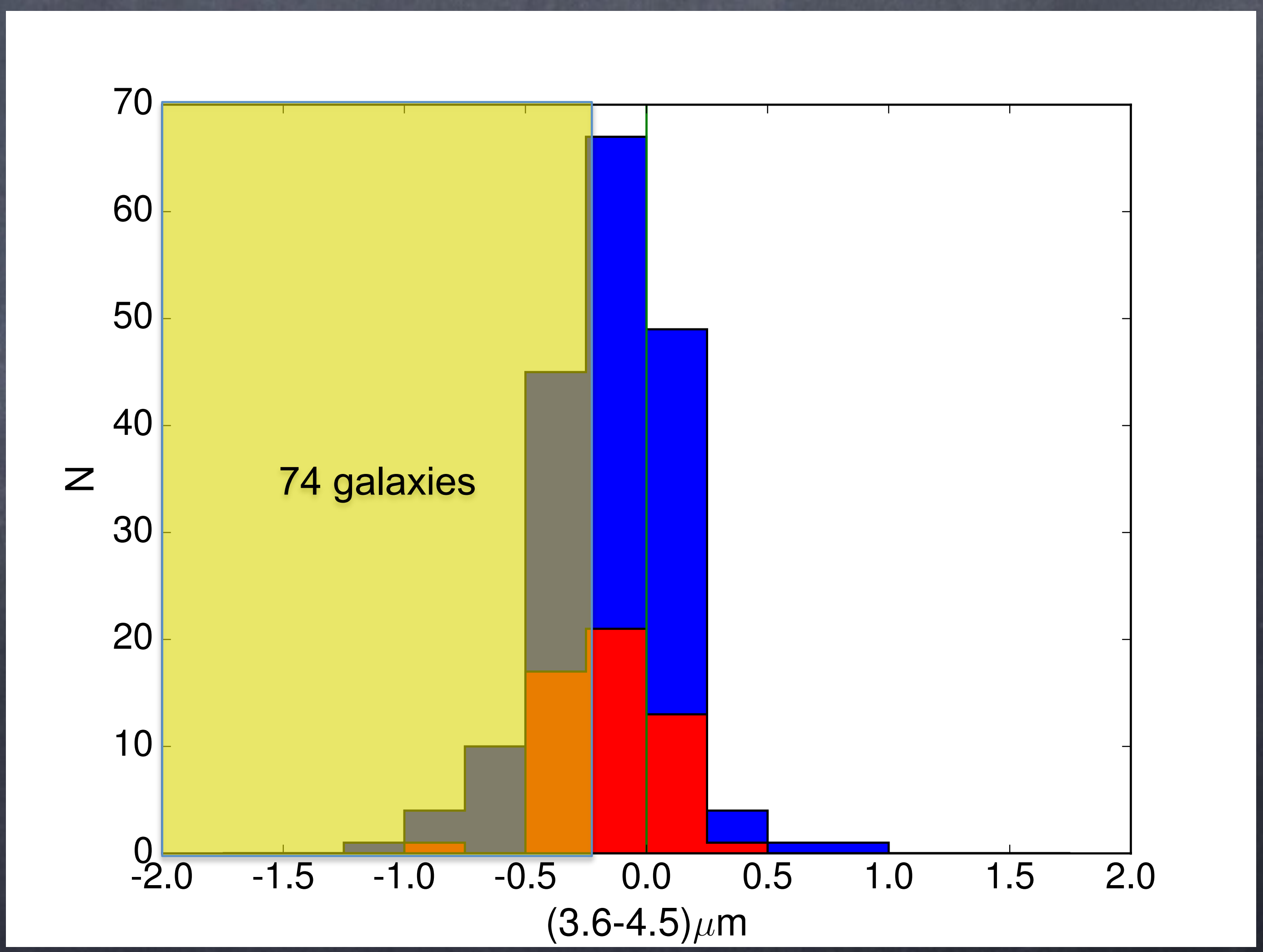
Theory vs. observations



« Secure z» sample: 519 galaxies (98 z_{spec})



« Secure z» sample + S/N(3.6μm)>5 + S/N(4.5μm)>5: 182 galaxies (53 z_{spec})

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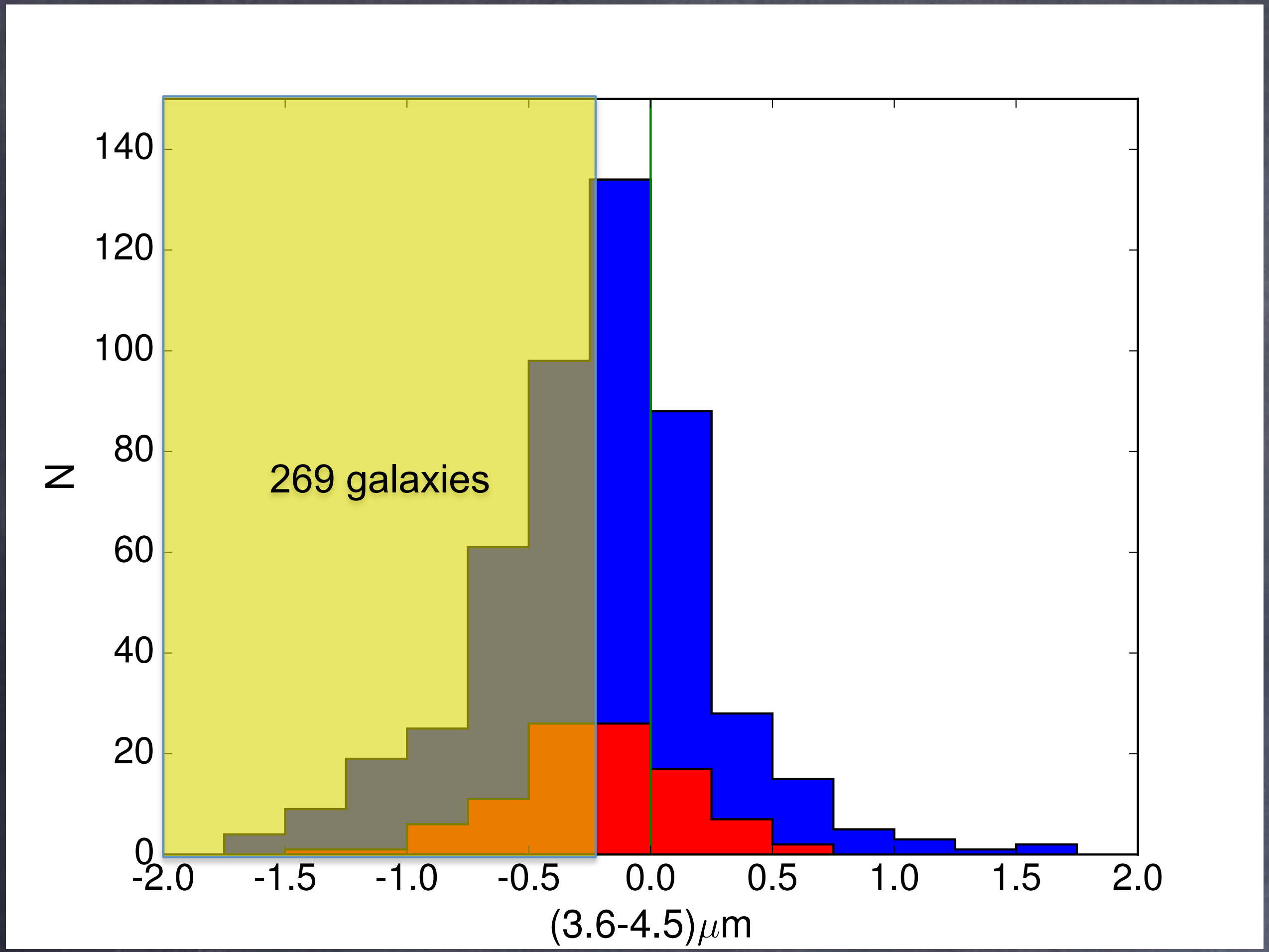

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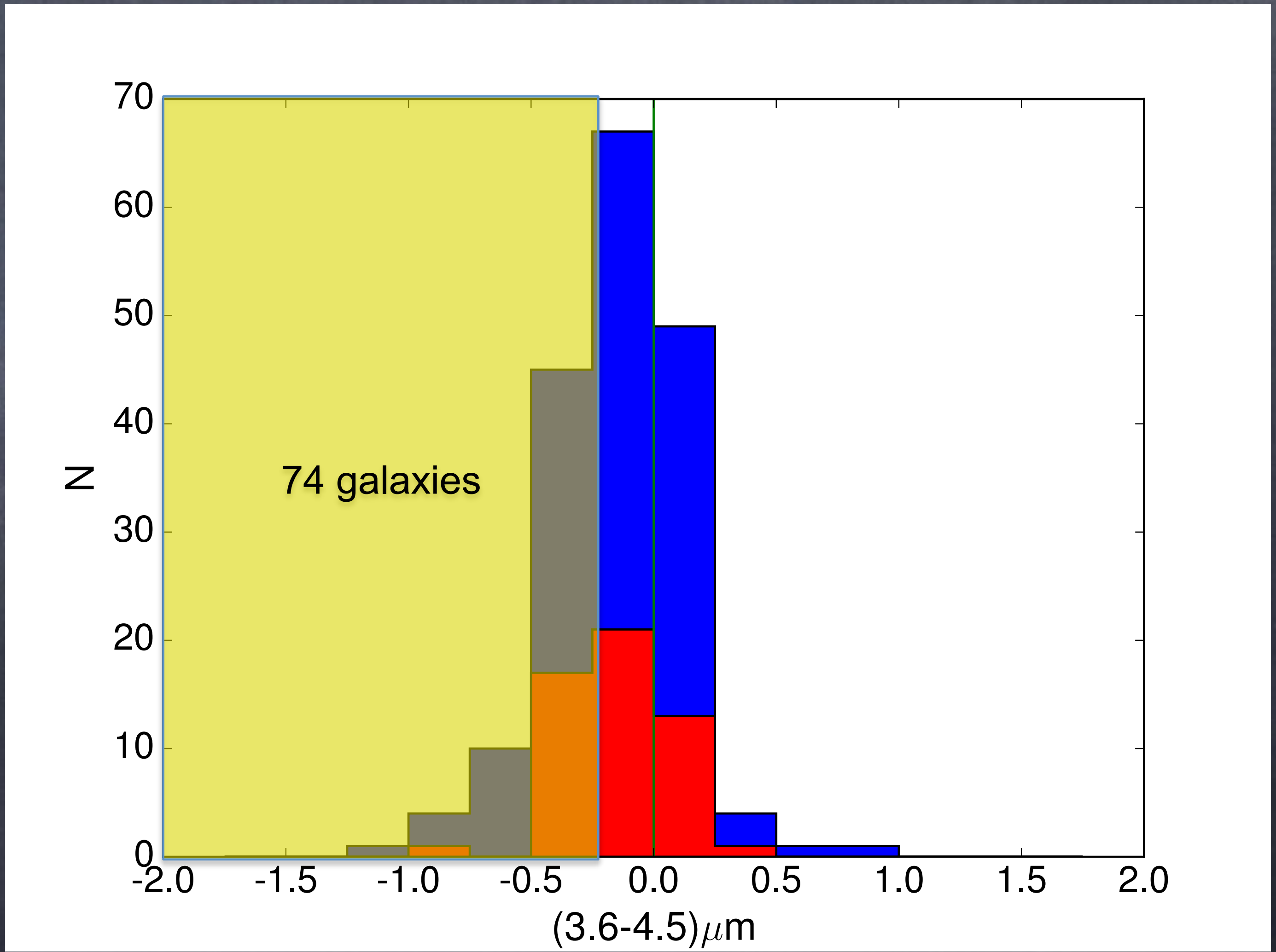
For 1/3 of the sample: galaxies too blue compared to expectations but...



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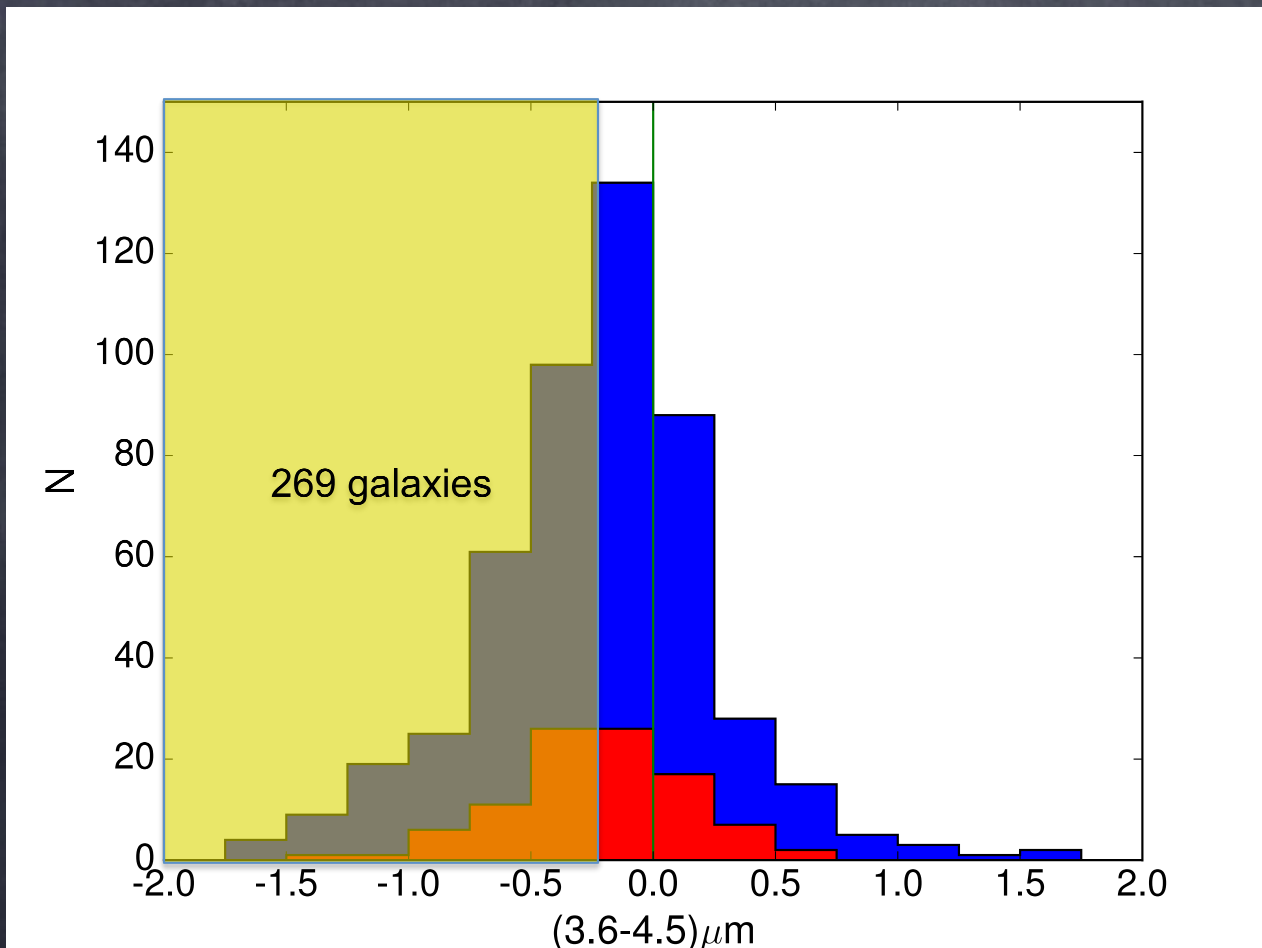

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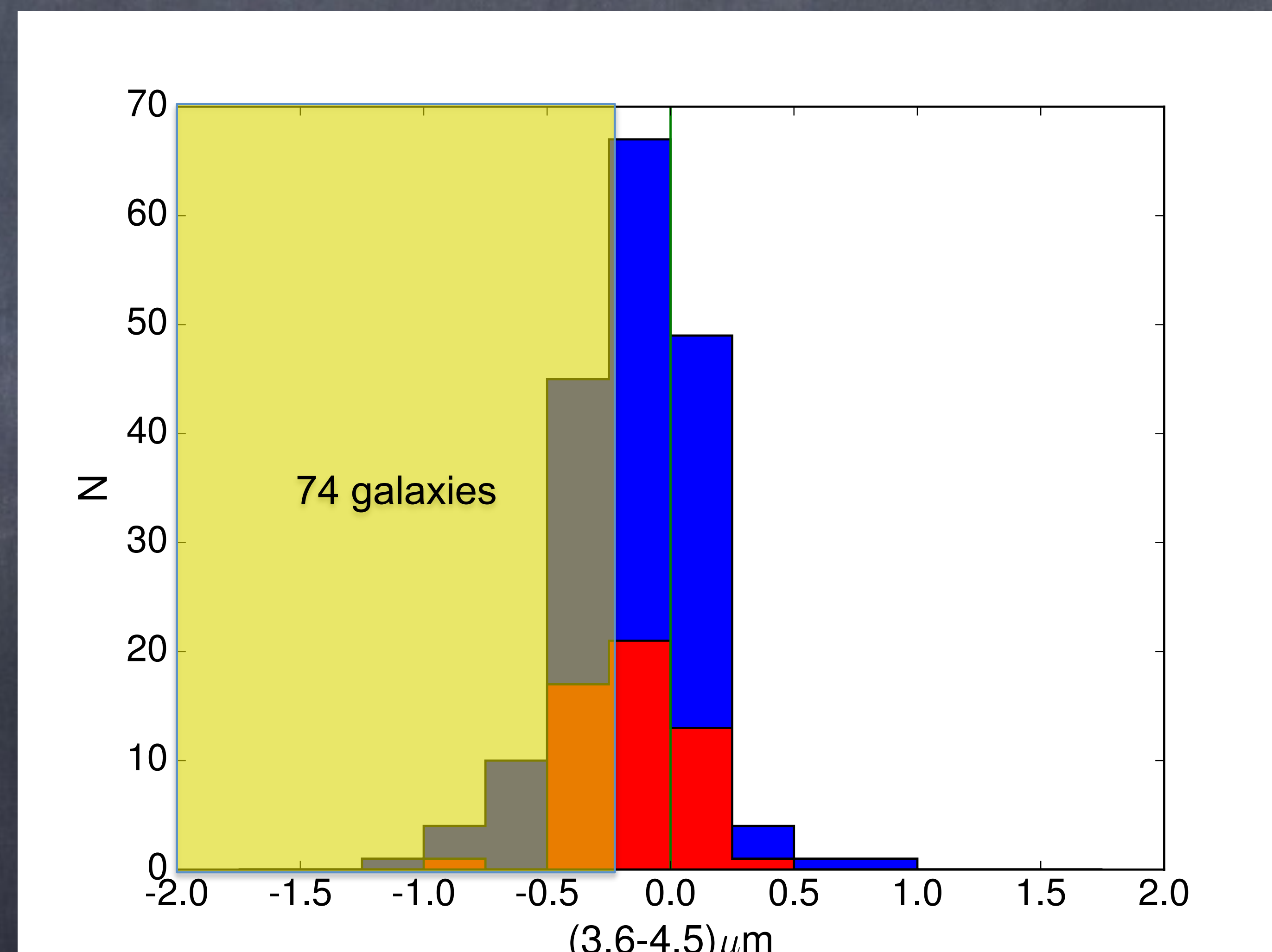

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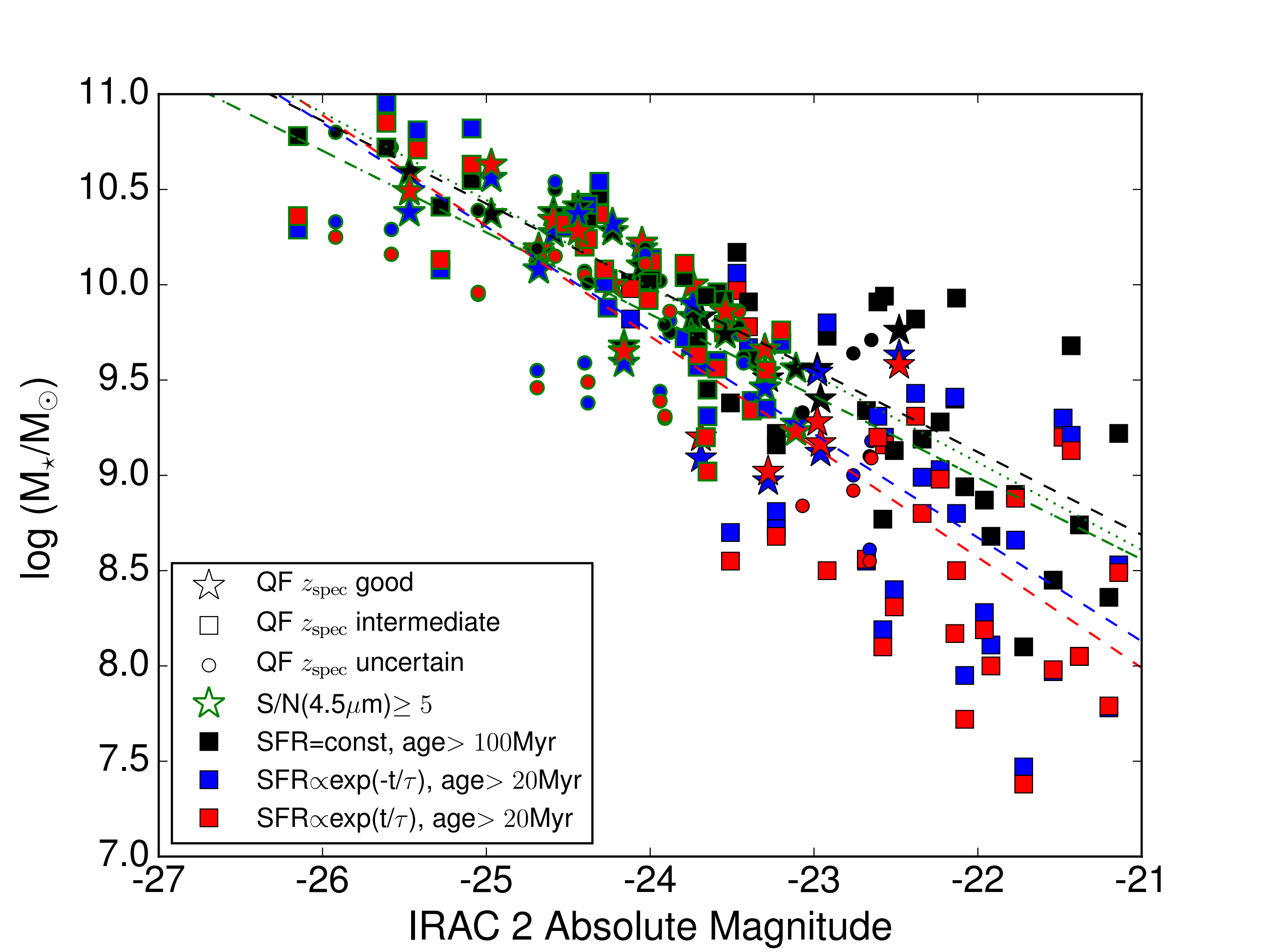
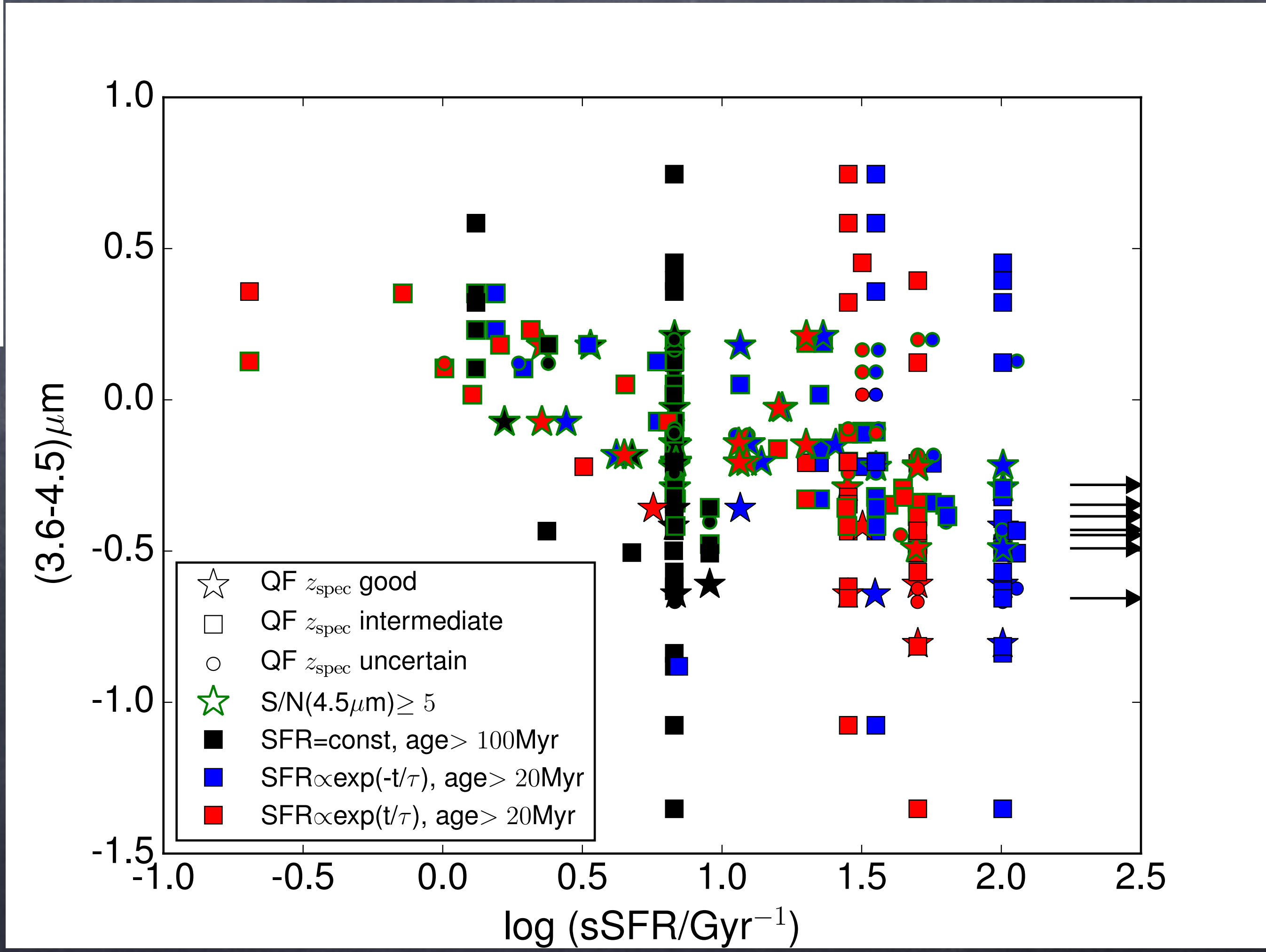
Theoretical predictions based on several assumptions (ISM physical conditions, stellar populations models, …)

Empirical method to derive stellar mass and sSFR (or EW(Ha)) at z=4





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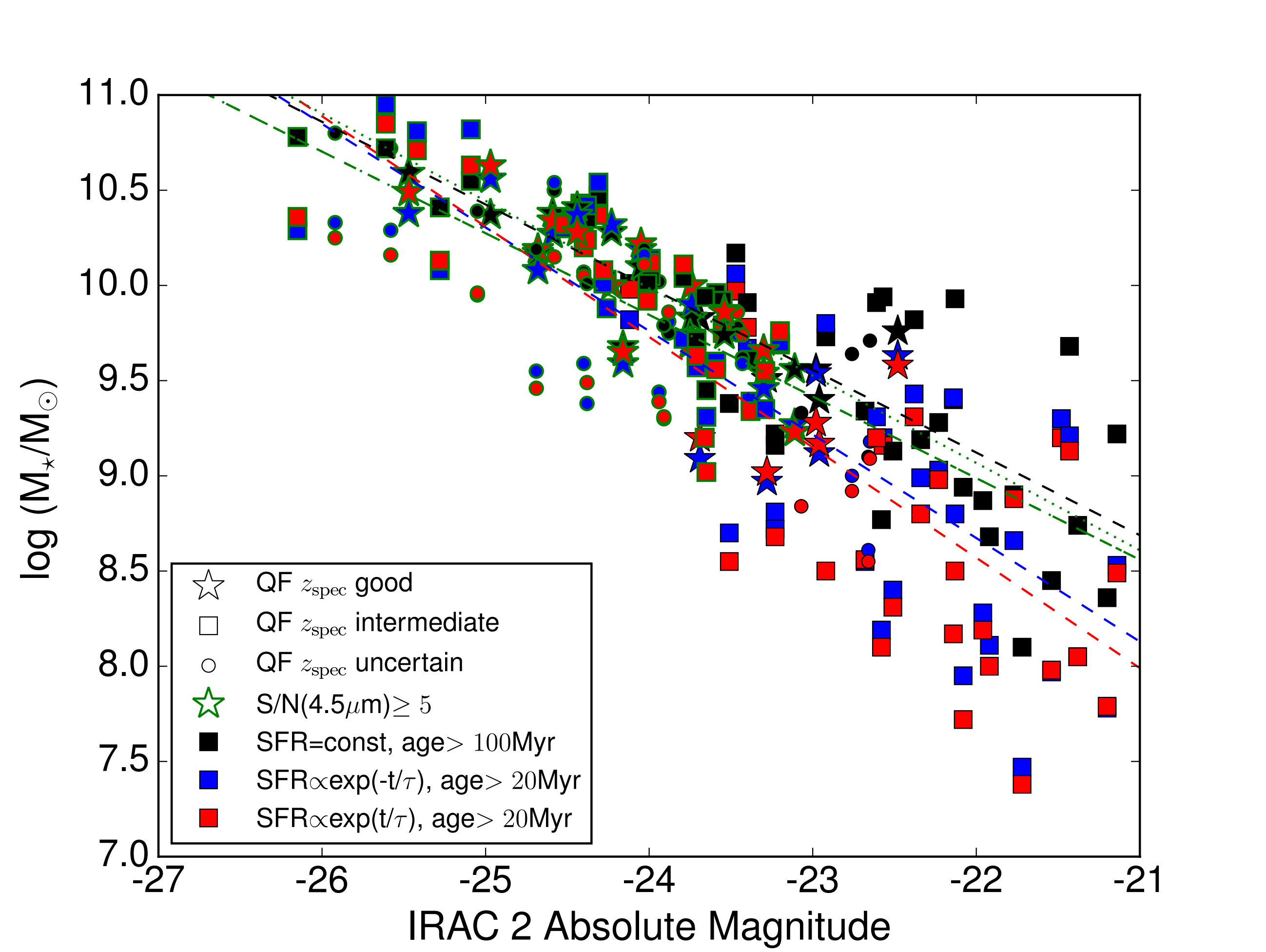

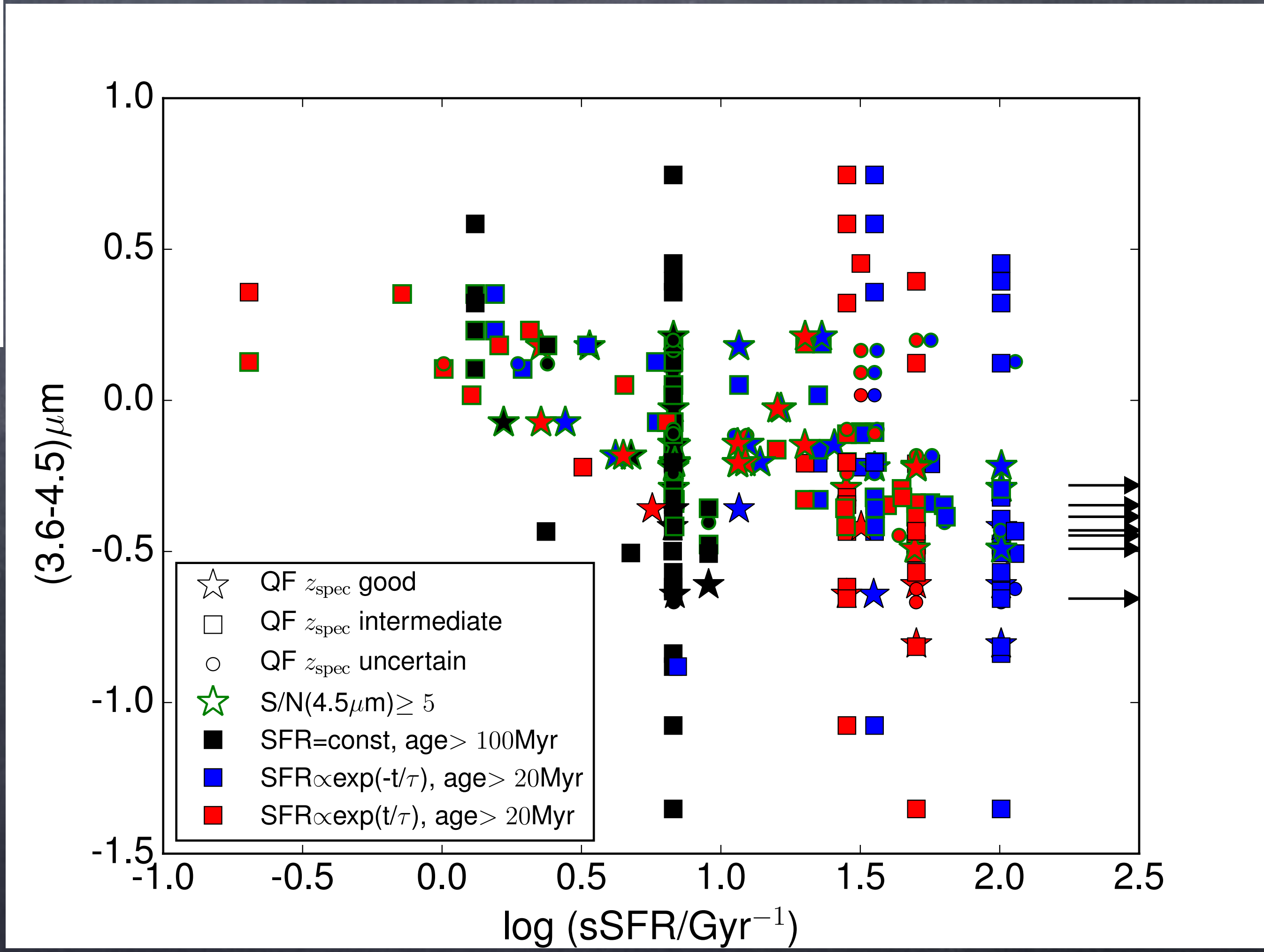

JWST will be able to measure directly Ha fluxes!

Thank you... again!