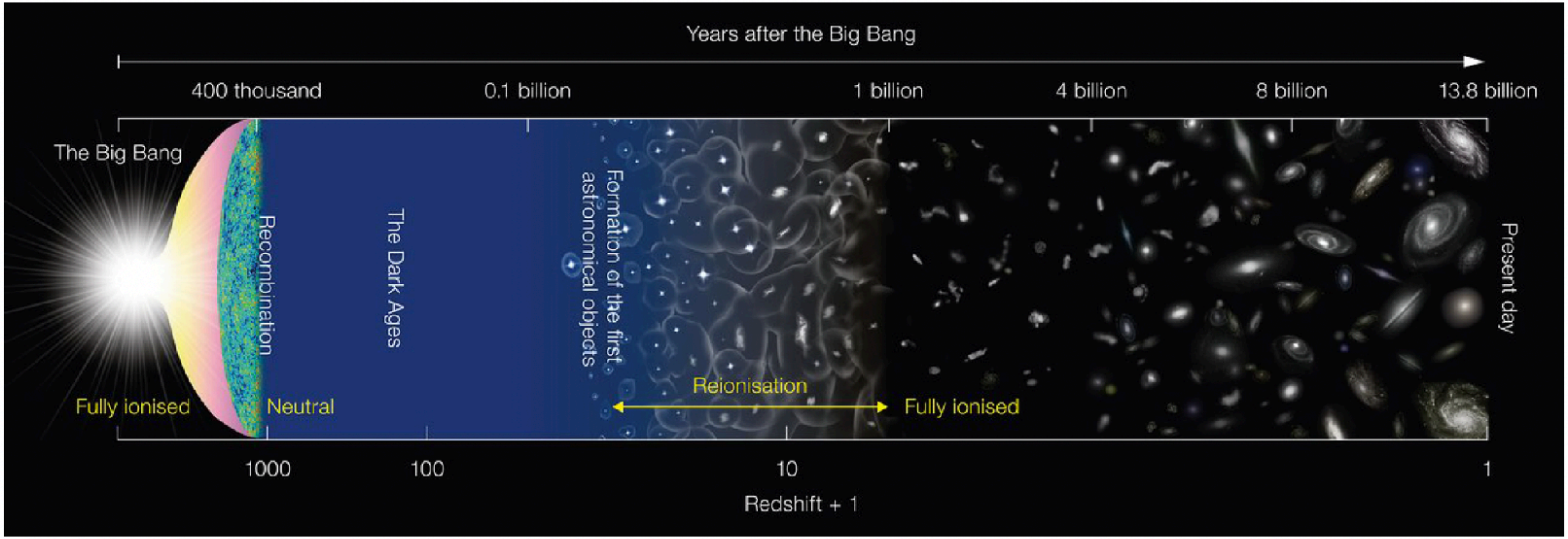
On the escape of LyC from galaxies

The LyC nebular emission contribution

Anne Verhamme, BlueMUSE science meeting, 24.04.2024

What is Reionisation? Why is it important ?



- major phase transition in the history of the Universe
- strong impact on galaxy formation and evolution
- main unknown : the nature of the sources of Reionization

Searching for the sources of Reionisation

Constraints on their LyC spectrum

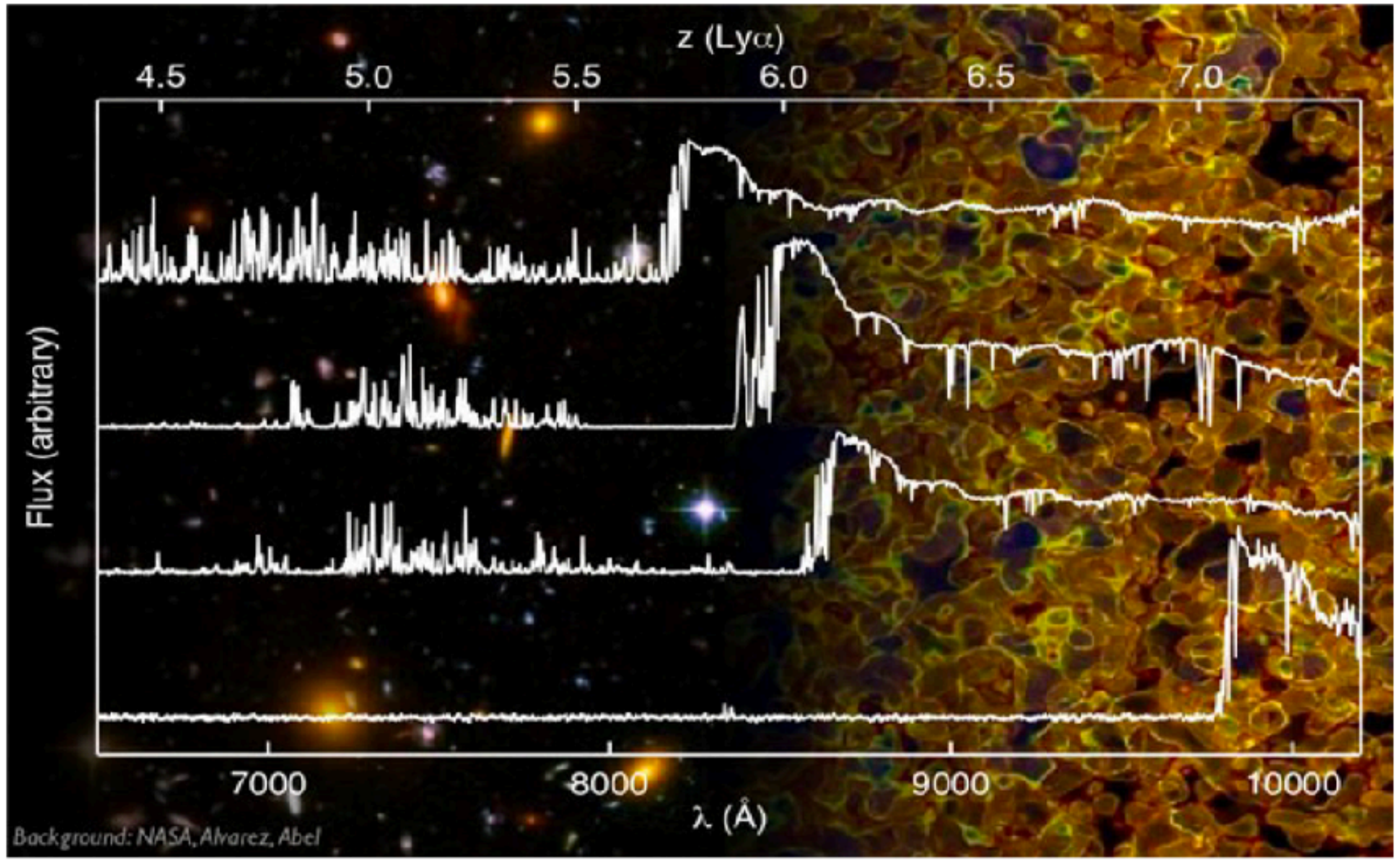
Observations:
impossible to detect LyC at z > 5, due to IGM

z ~ 5.7

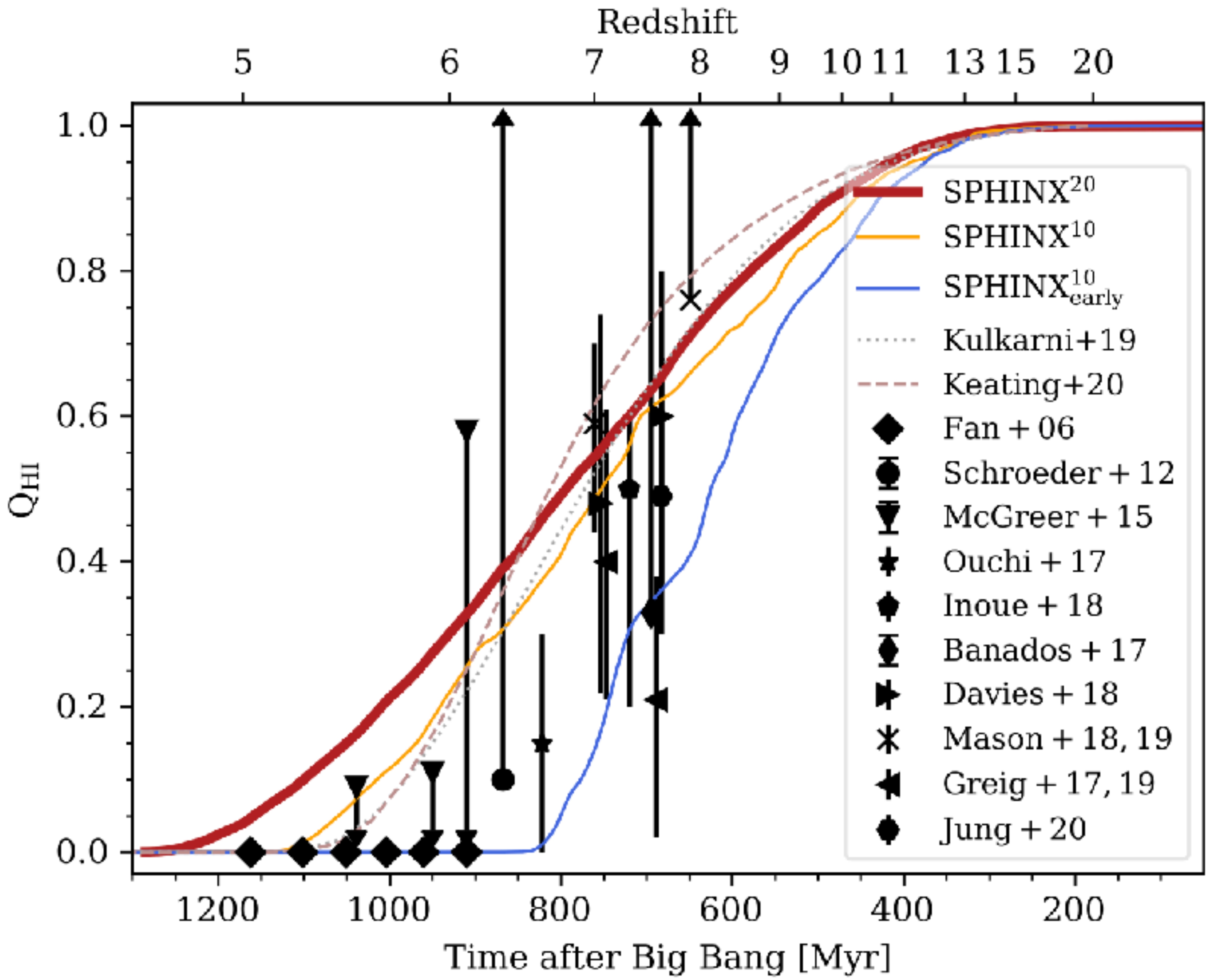
z ~ 5.9

z ~ 6.1

z ~ 7.1



Simulations:
Reionisation timeline depends on LyC



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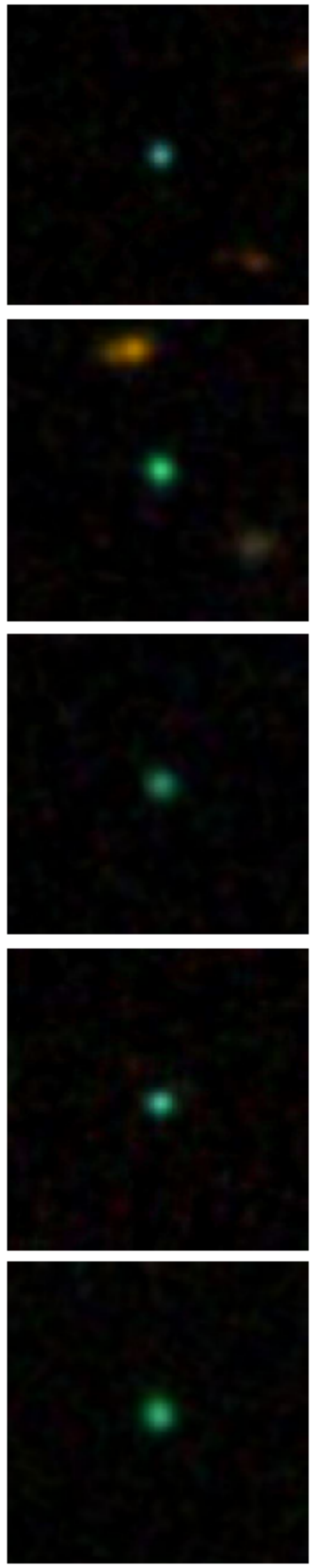
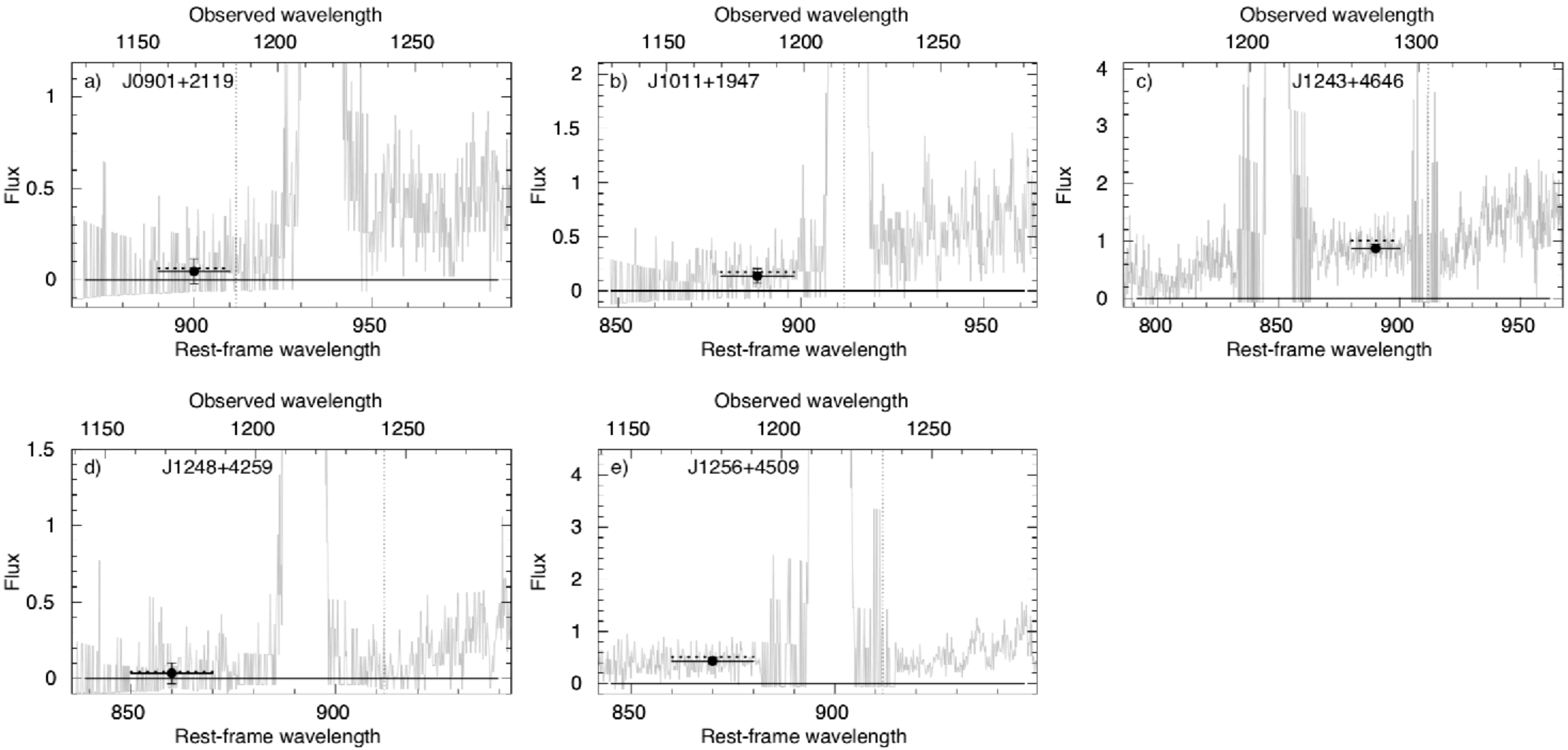
Since 2016, >100 LyC observations



Green Peas: 15/20 LyC Emitters, fesc(LyC) 2-73%

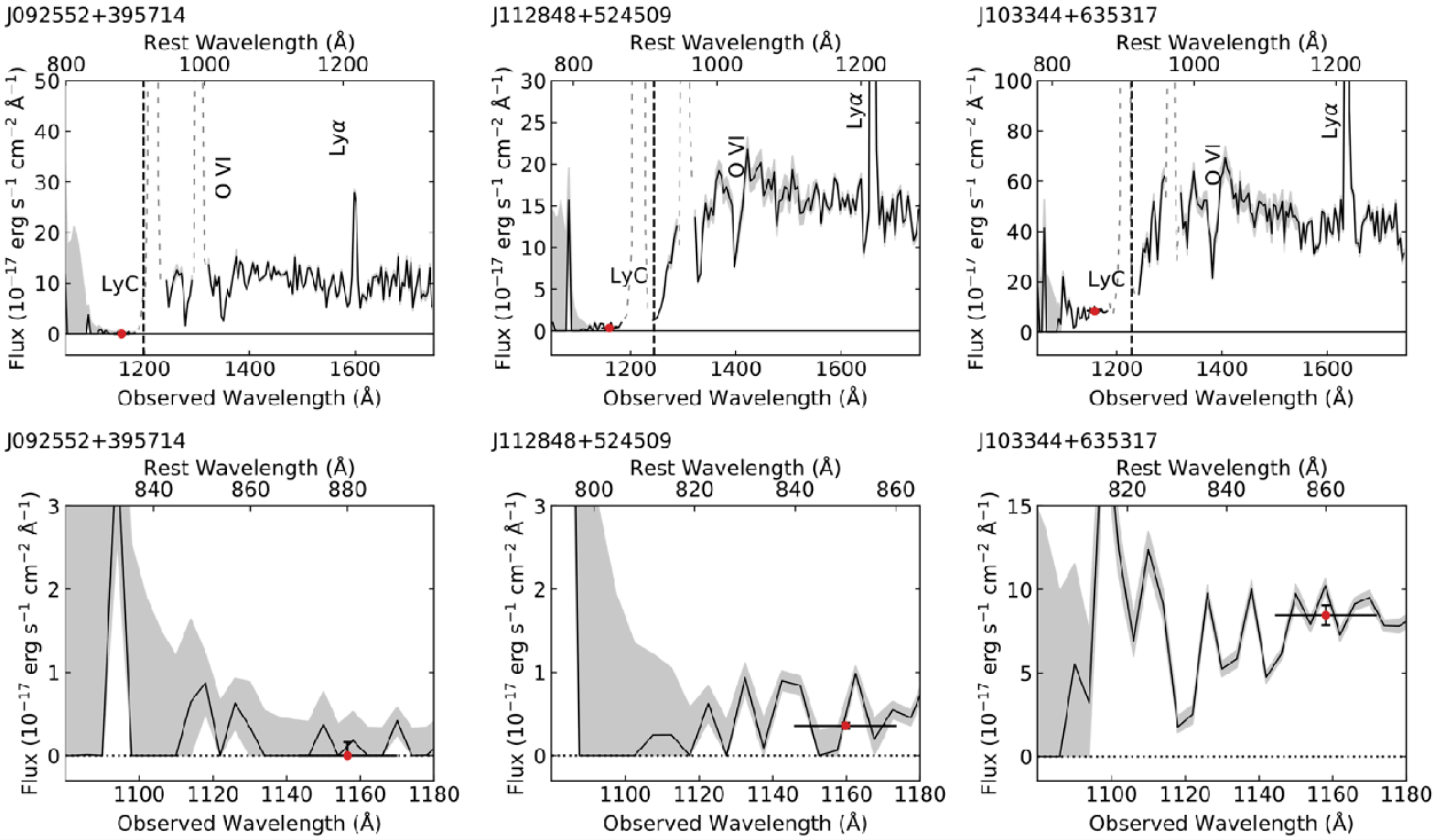
Izotov+16a,b, Schaerer+16, Verhamme+17 Izotov+18a,b, Izotov+21



Since 2016, >100 LyC observations

Low-z Lyman Continuum Survey (LzLCS)

Flury+22a,b, Saldana-Lopez+22, Chisholm+22, Trebitsch+23



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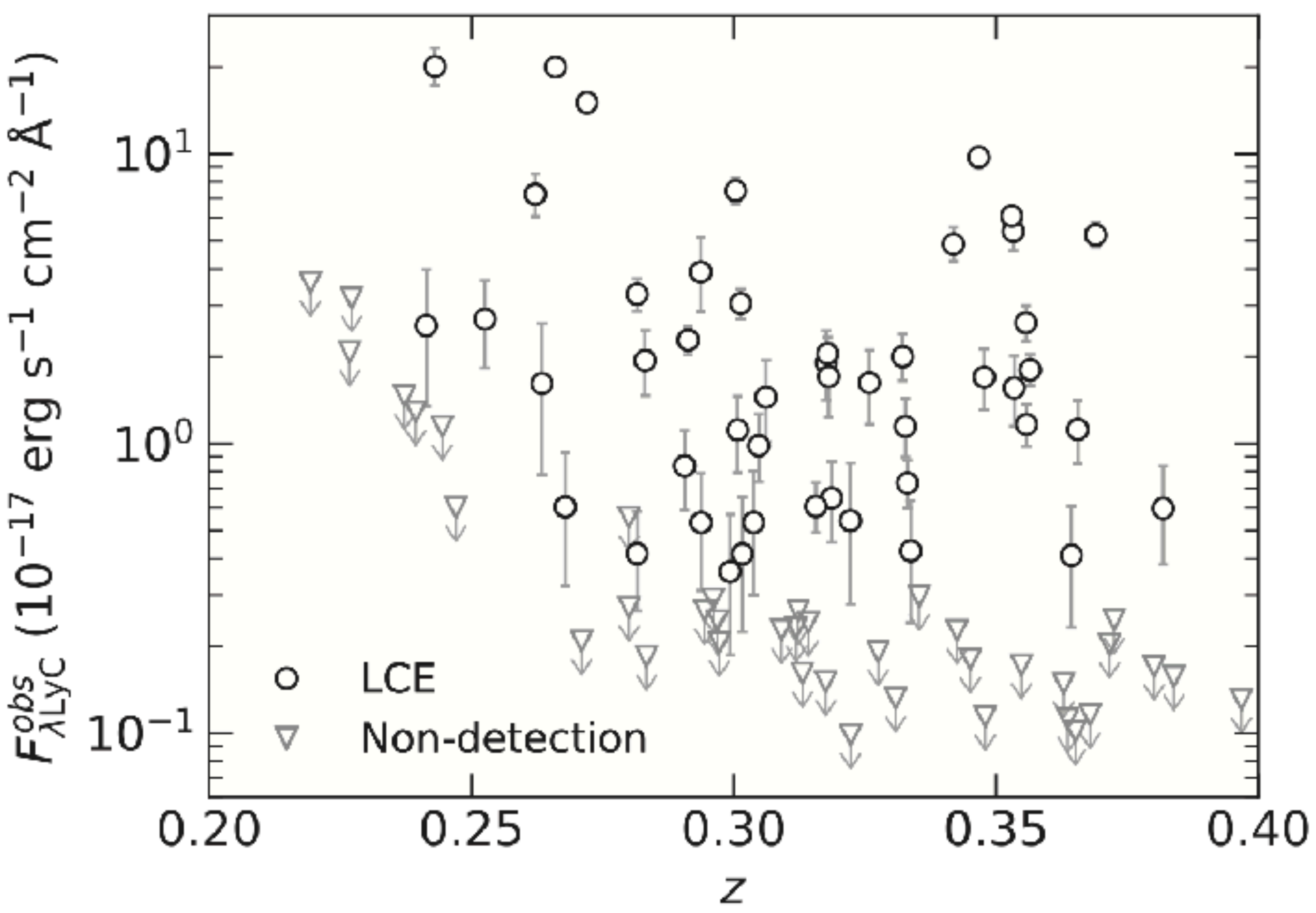
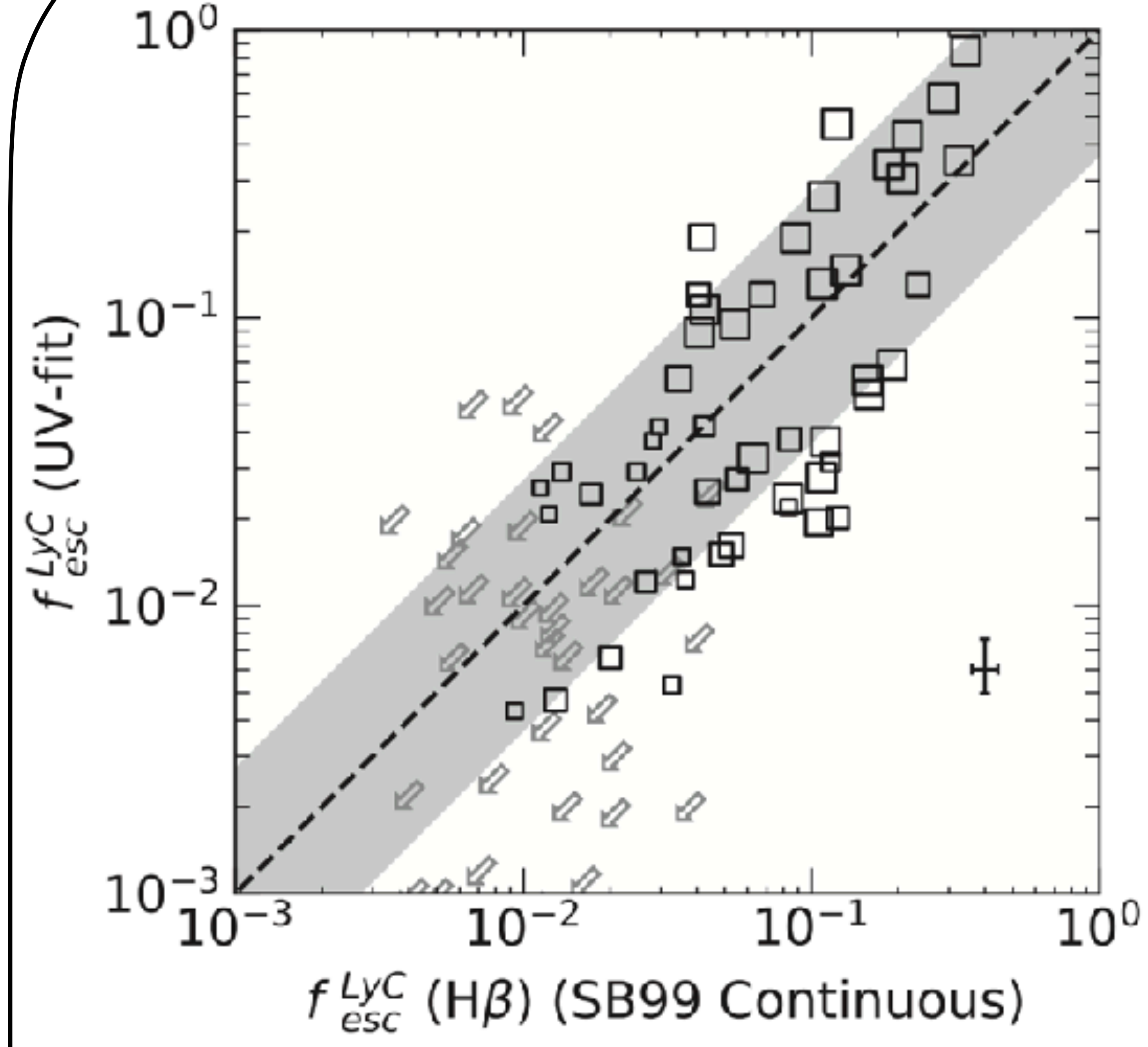
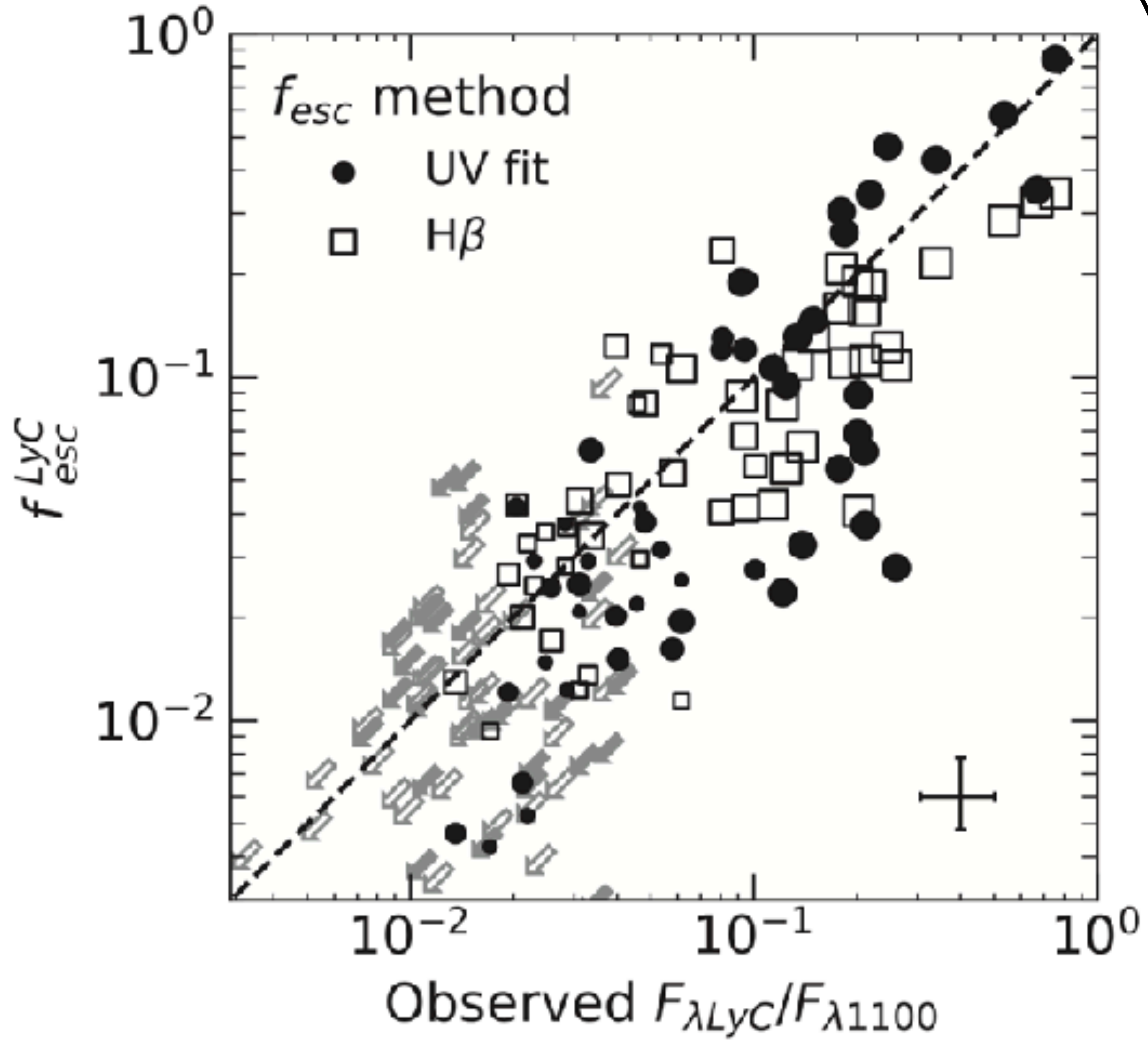


35/66 LyC detections, at z~0.3



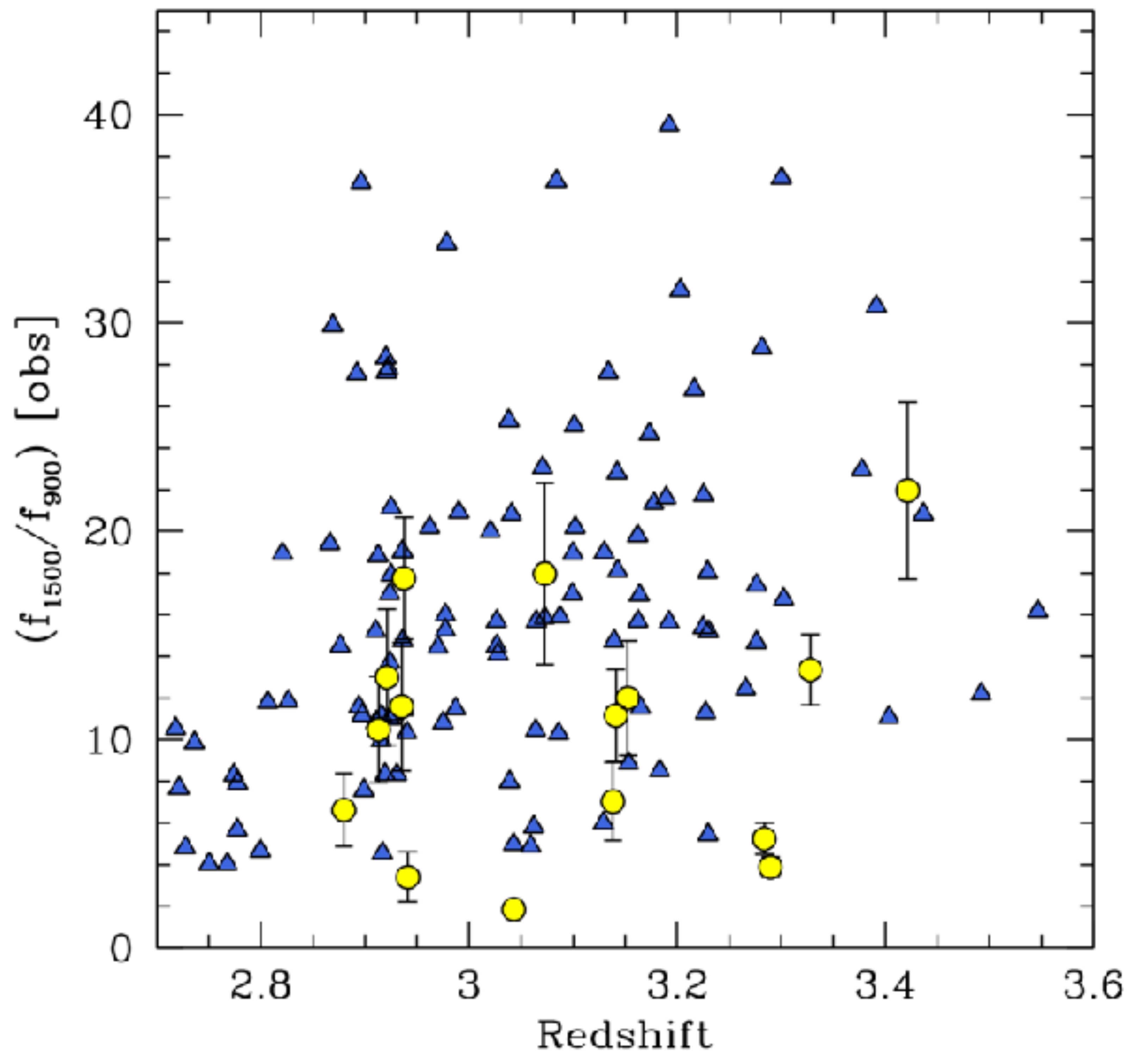


- 12 out of 35 have fesc > 5%, up to 50%
- Fesc estimates depend on model

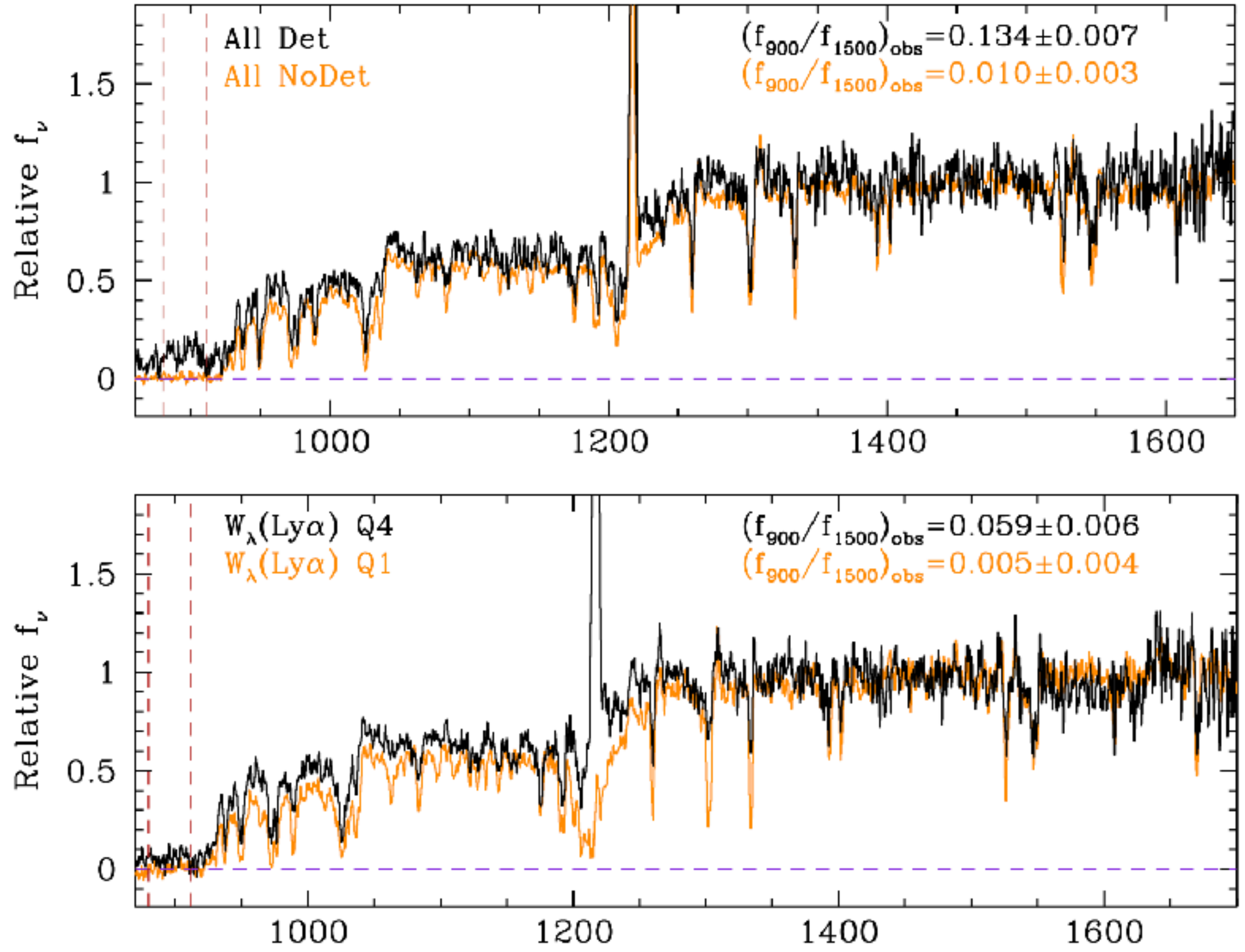
Since 2016, >100 LyC observations

Keck Lyman Continuum Spectroscopic Survey (LzLCS)

Steidel+18



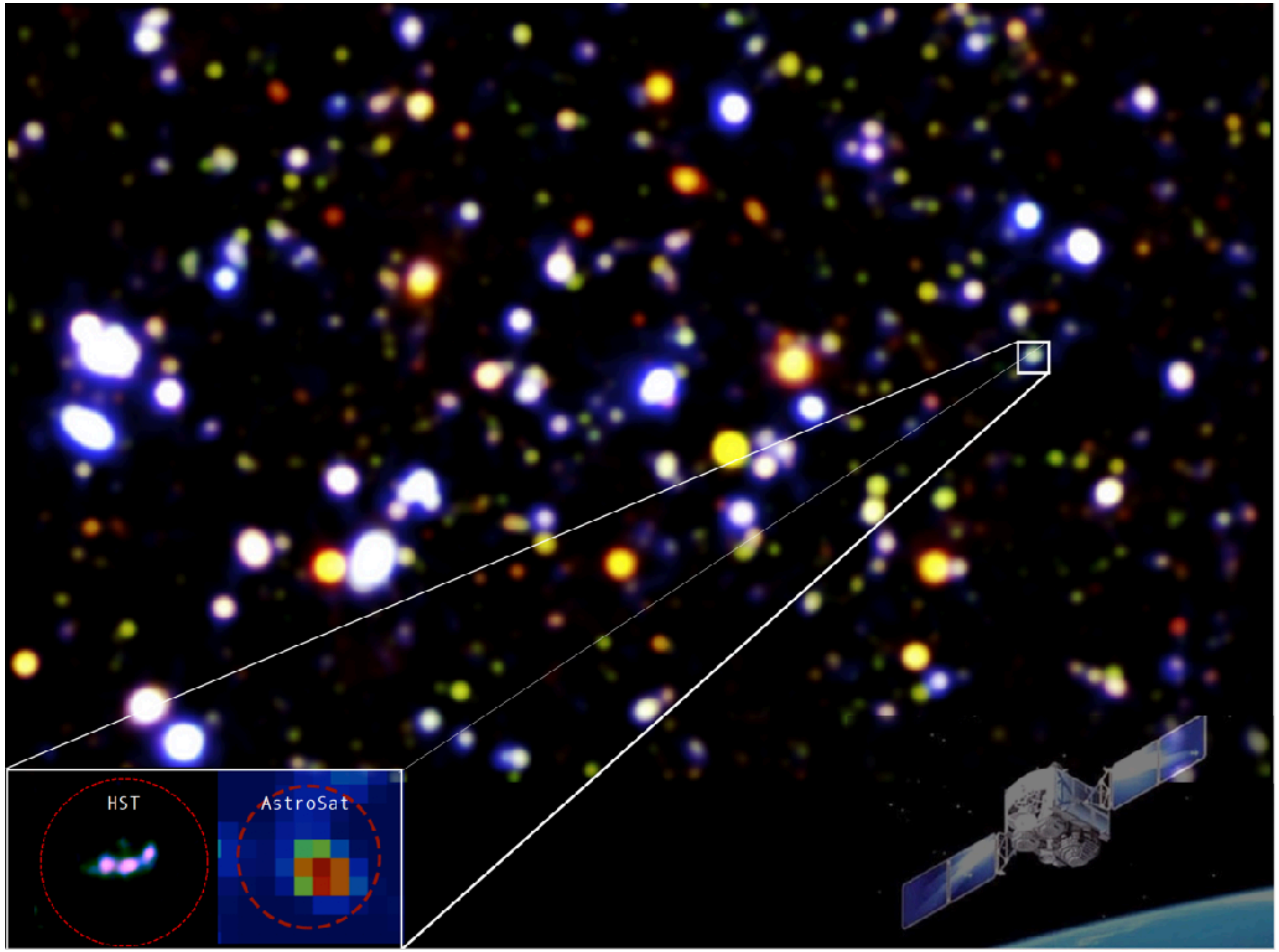
15/124 LyC detections, at z~3



Stacked UV Keck spectra, shape of LyC emission

First LyC detection at 600 angstrom

From a galaxy at z~1.42 with AstroSat, Saha+20



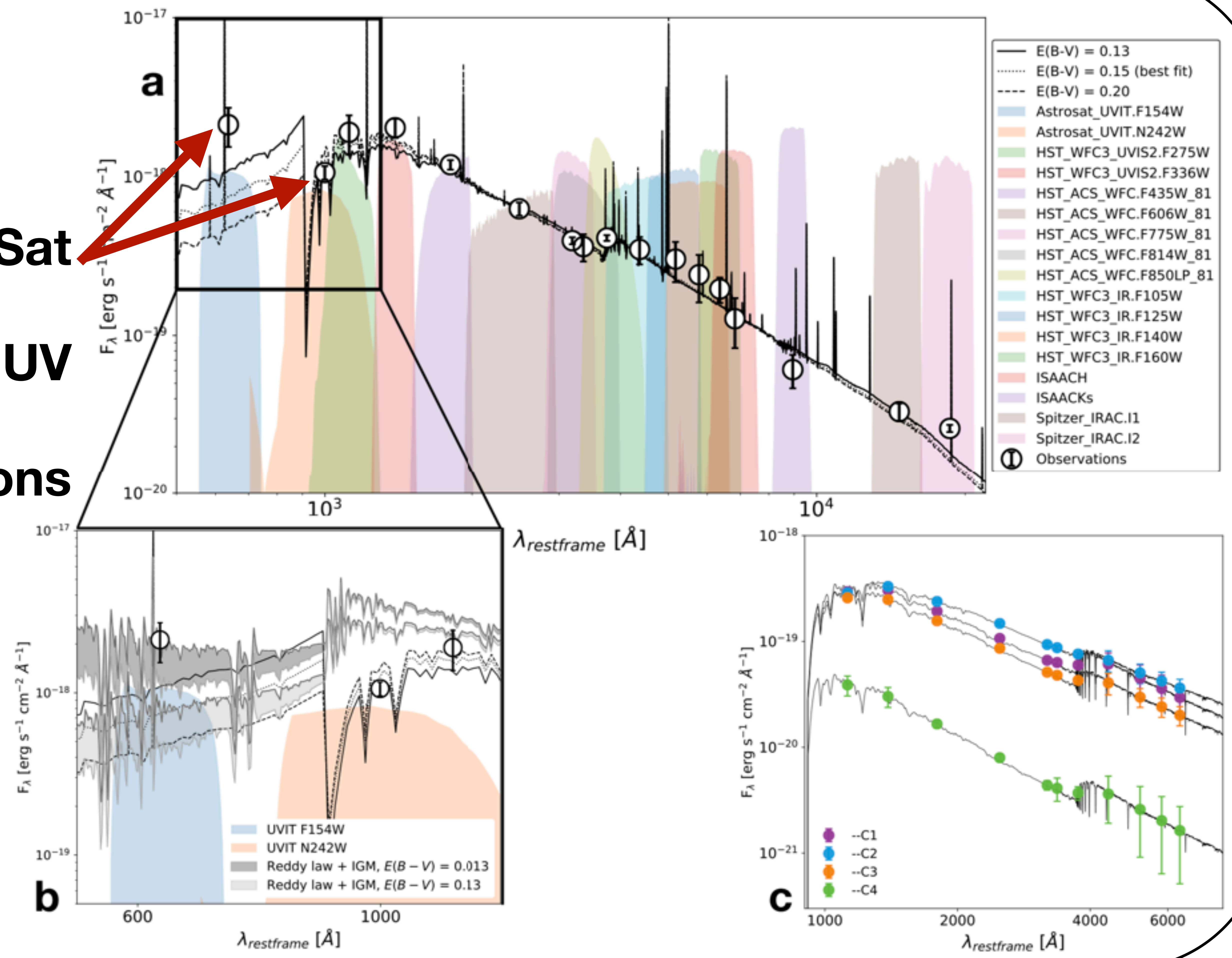
First LyC detection at 600 angstrom

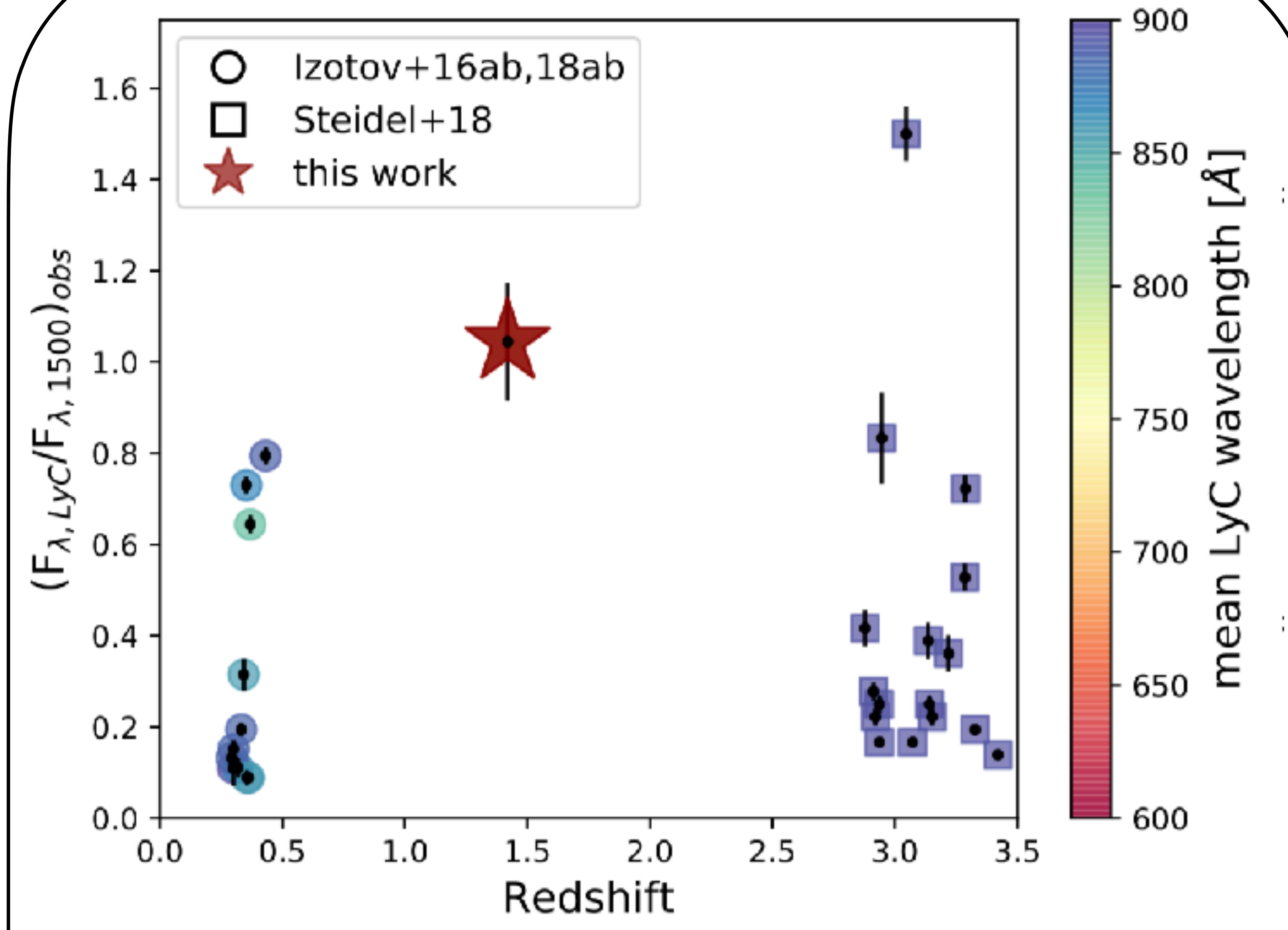
From a galaxy at z~1.42 with AstroSat, Saha+20

AstroSat

FUV / NUV

detections



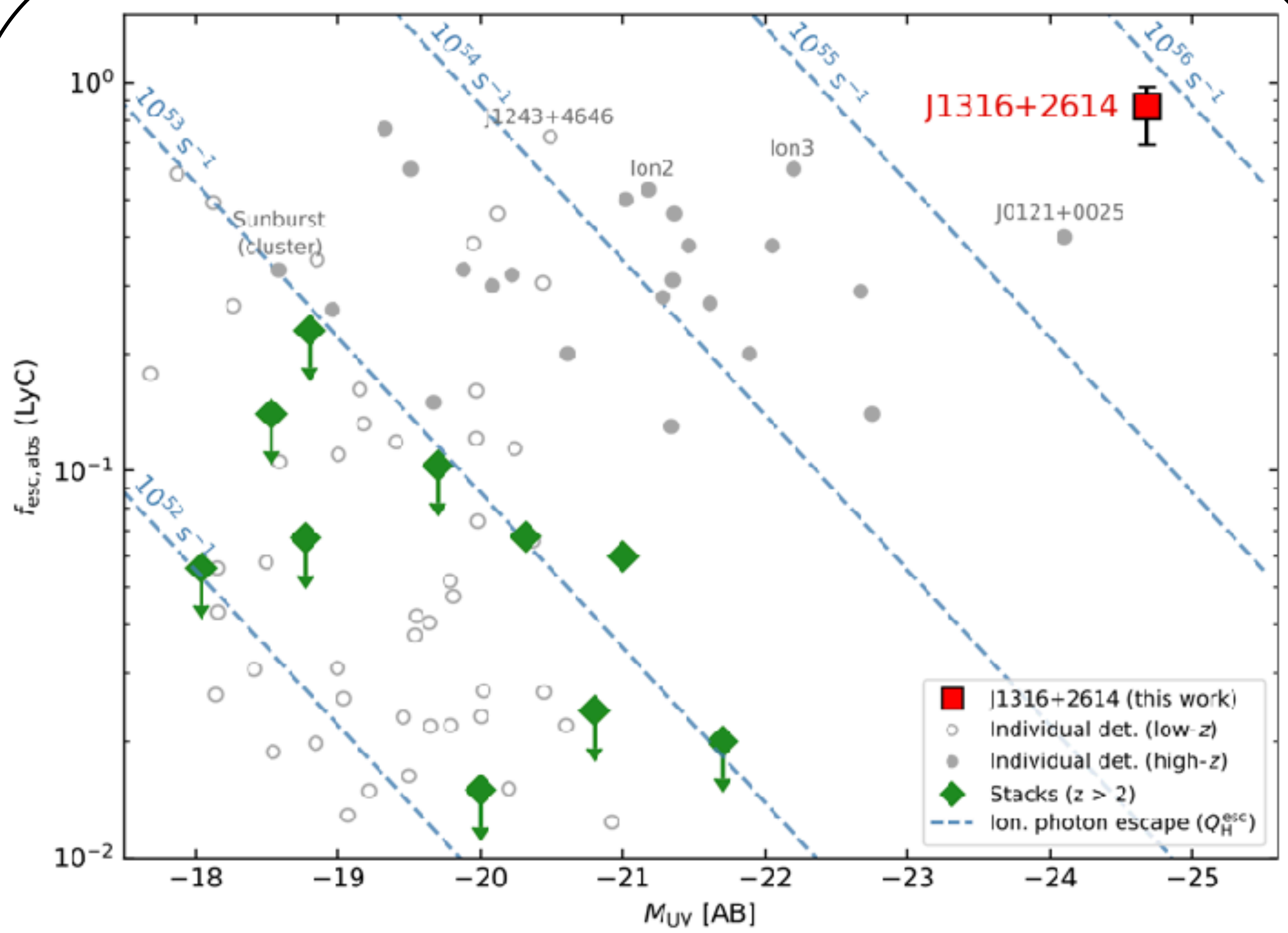


Uniqueness of AstroSat

See also Dhiwar+24

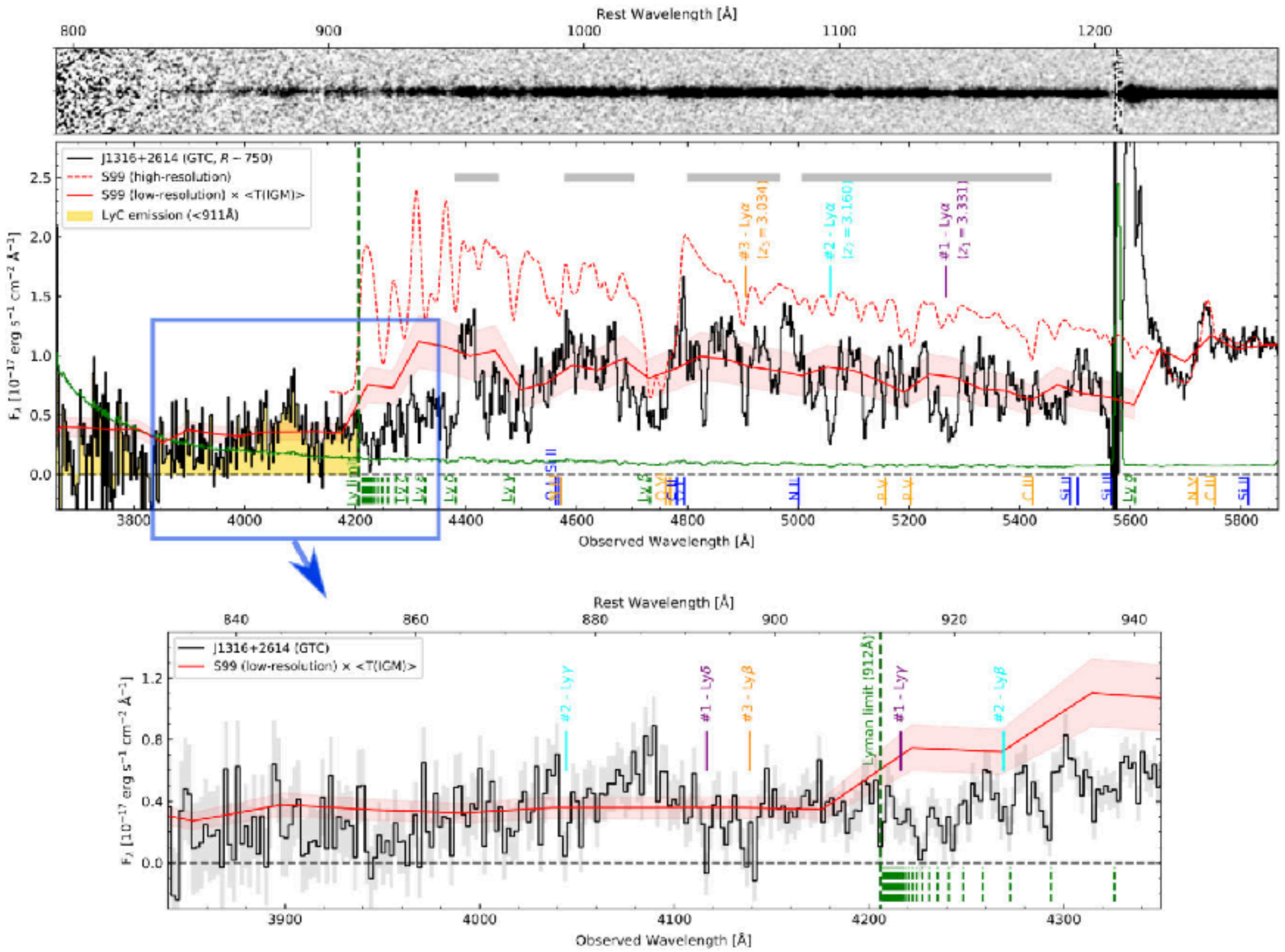
LyC at z~2-3 from LyC monsters

Chavez-Marques+21,22



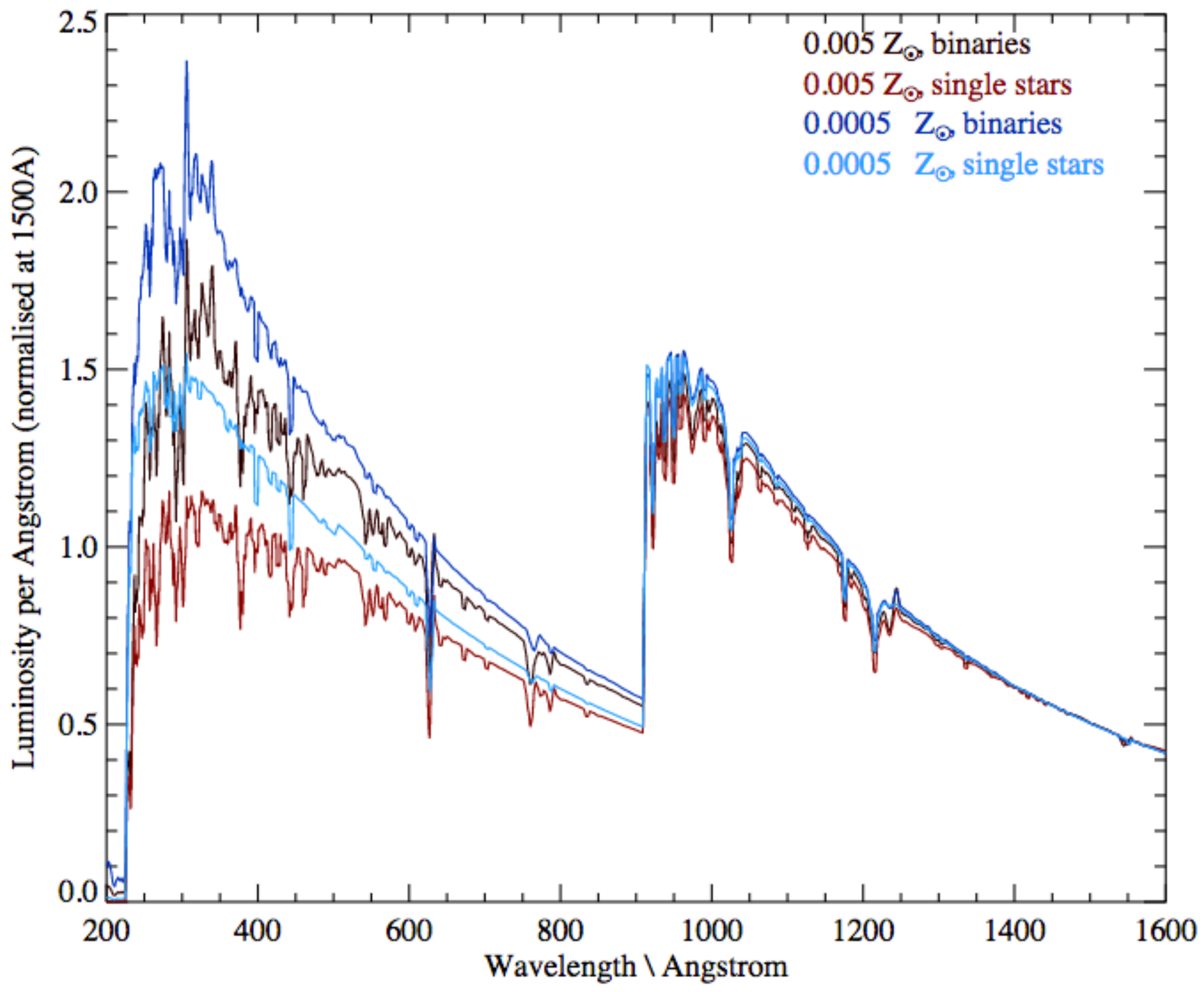
Emits more ionising photons

than all detected leakers so far…

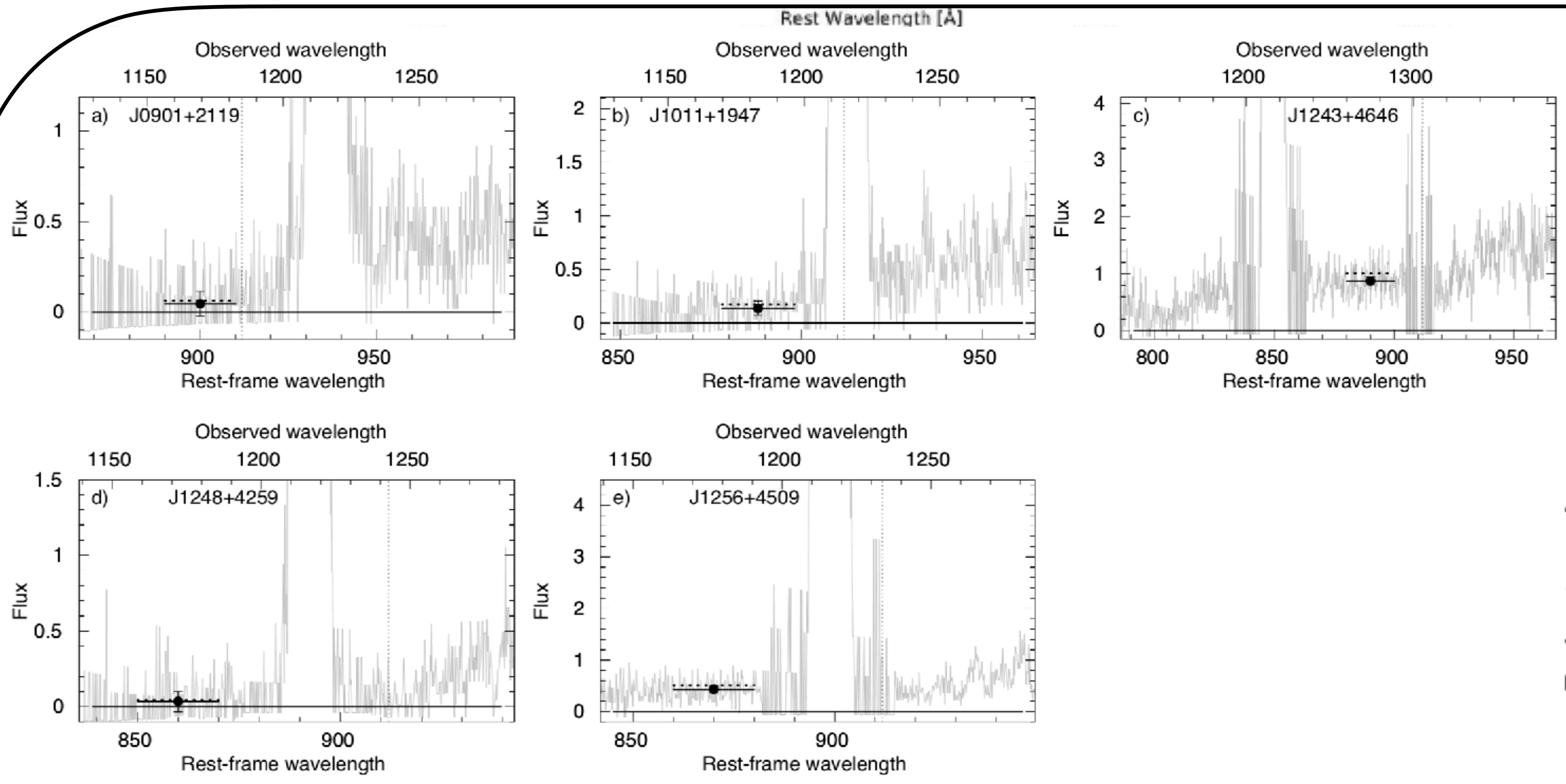


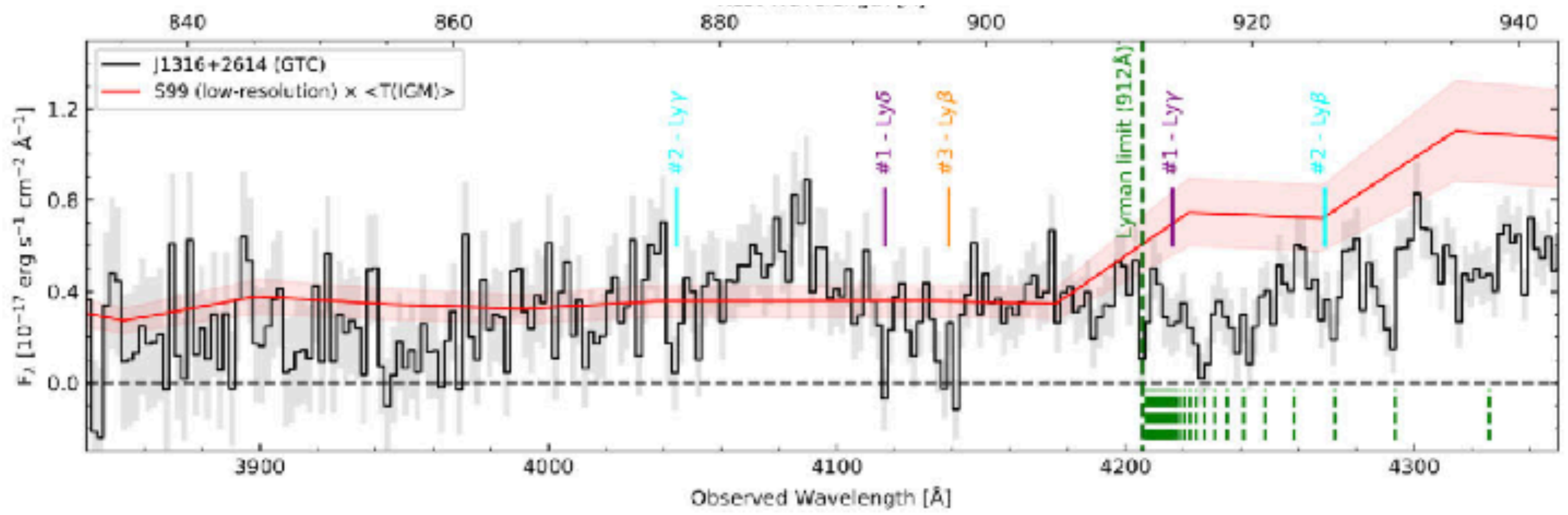
No LyC break…

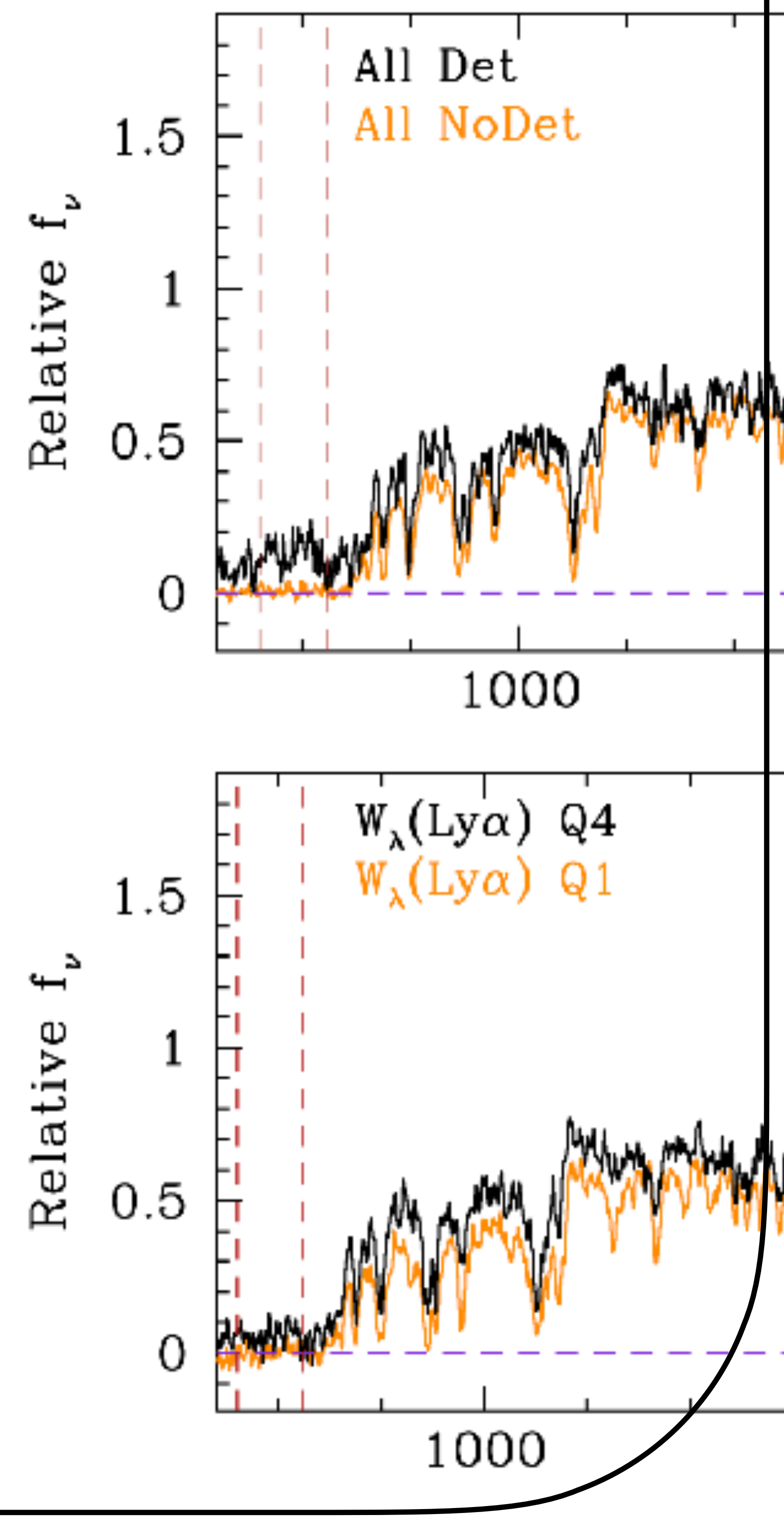
Observed LyC spectral distributions look different from attenuated stellar LyC



BPASS stellar LyC templates



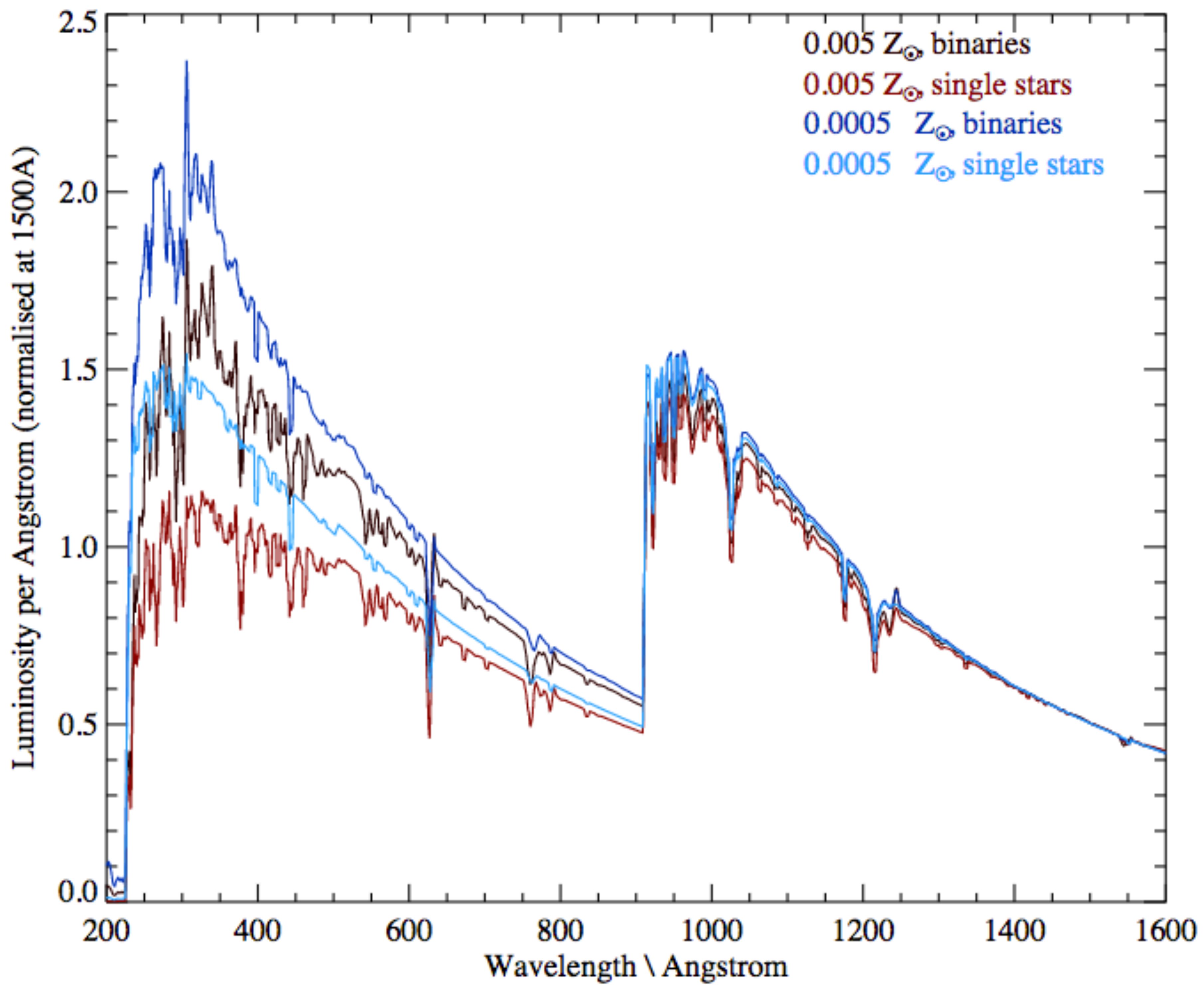




No LyC break…

Observed LyC spectral distributions look different from attenuated stellar LyC

LyC nebular emission ?



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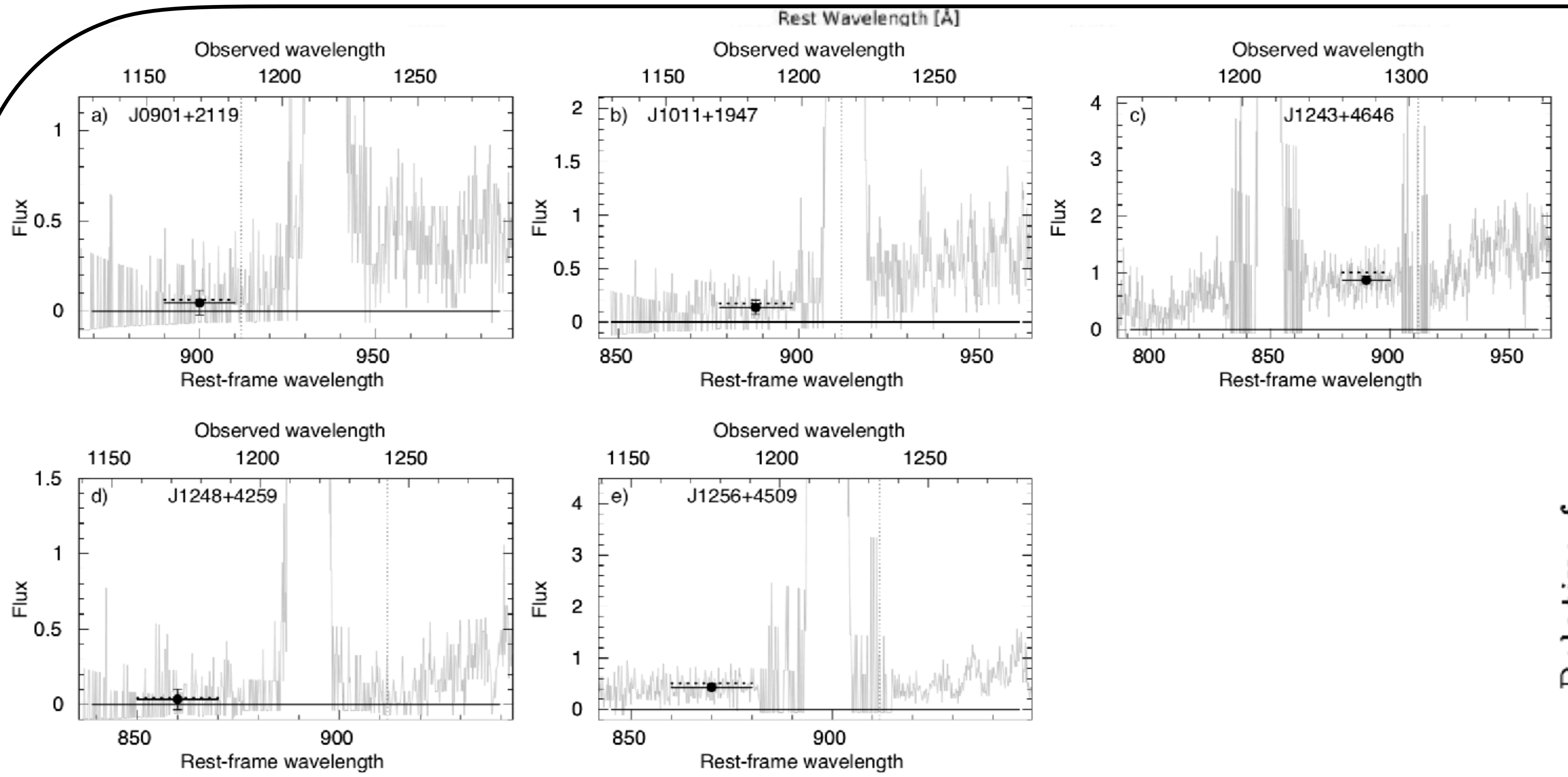

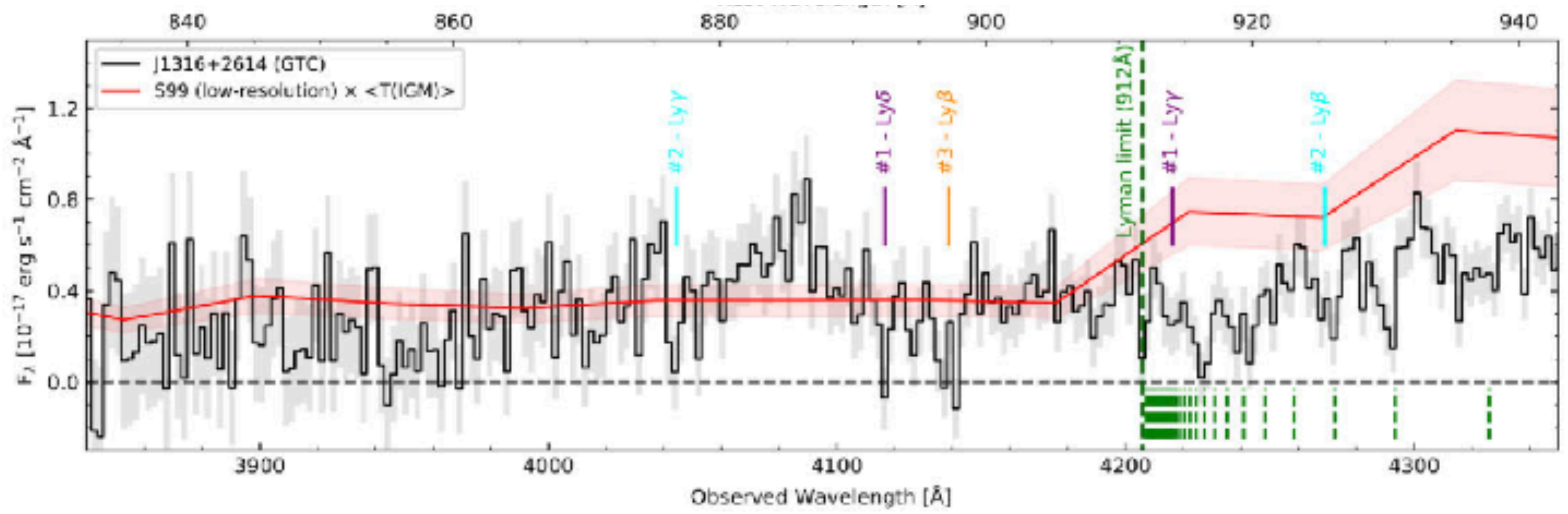

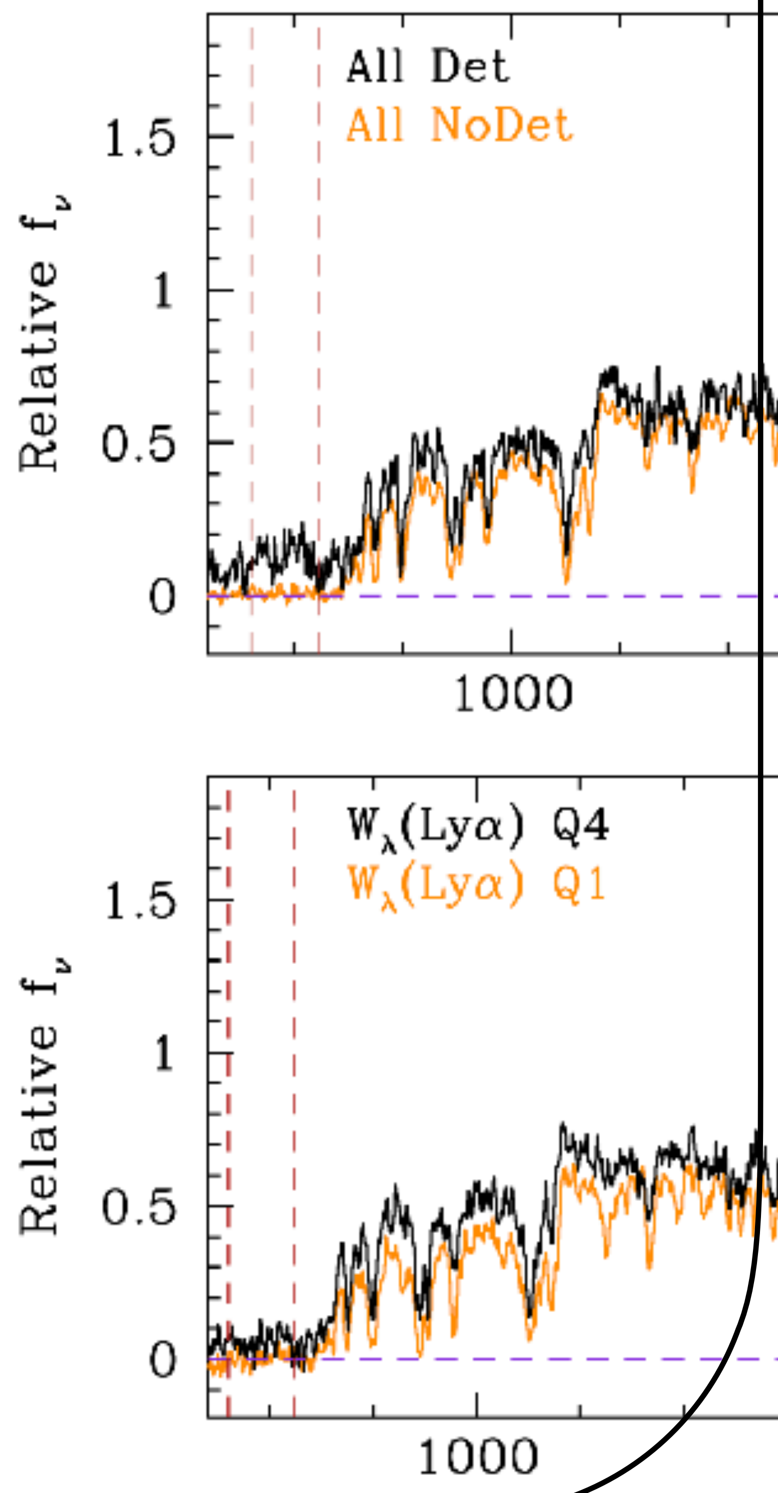

No LyC break…

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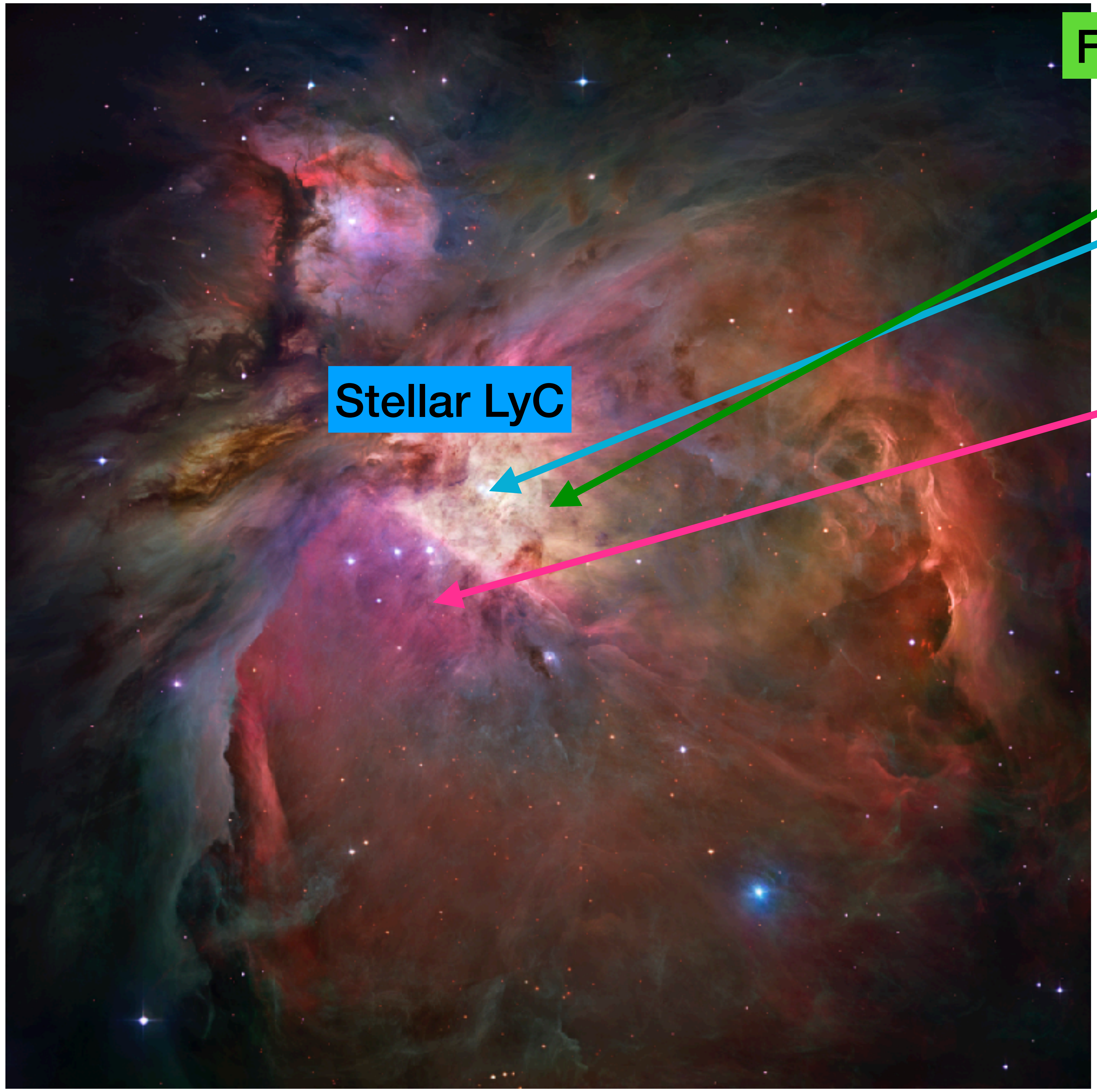
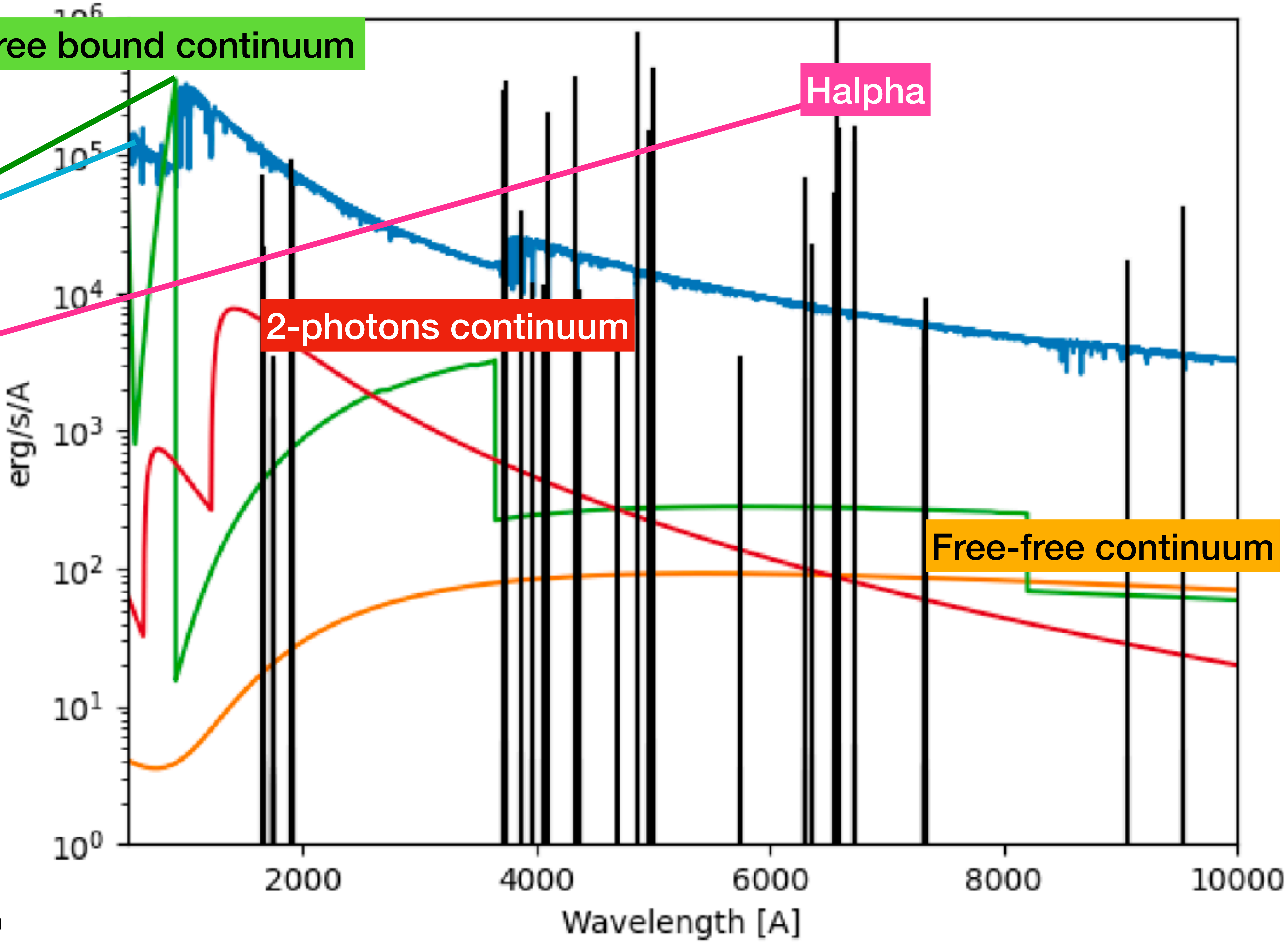
LyC nebular emission

Cooling emission from ionised gas that recombines





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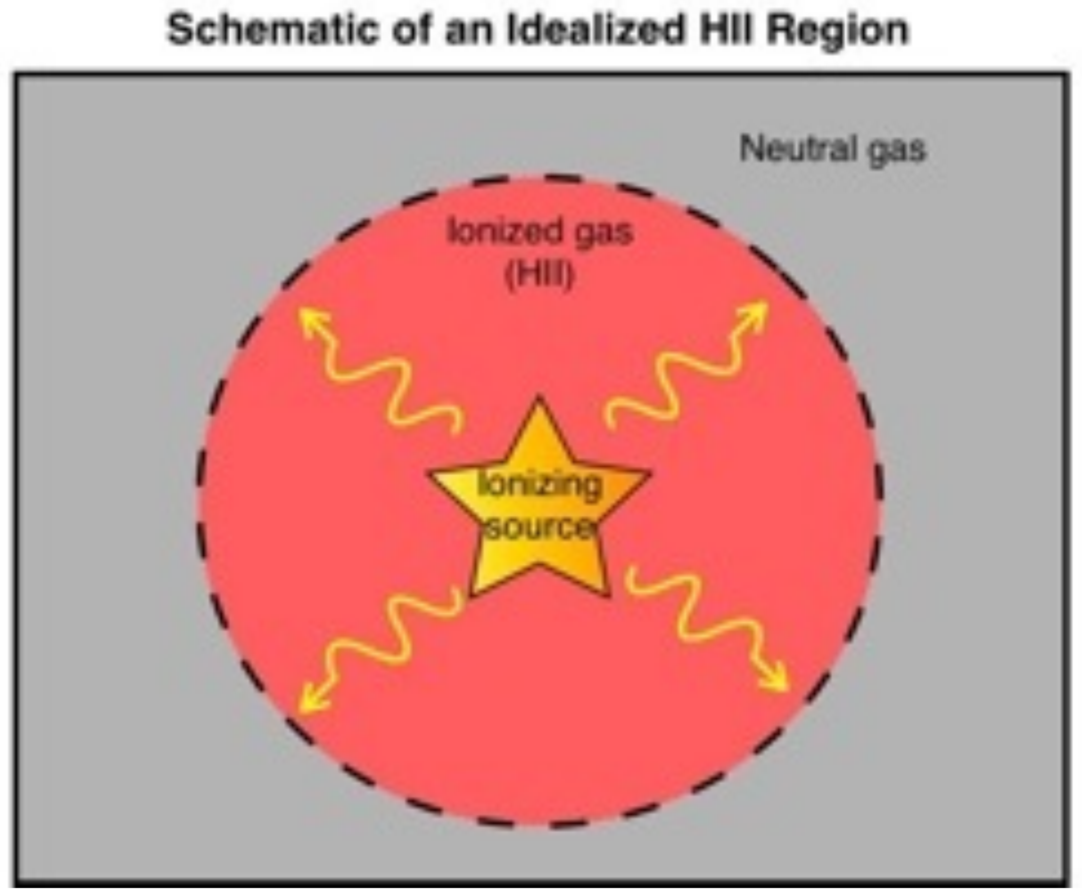
LyC nebular emission

Simmonds, Verhamme et al accepted

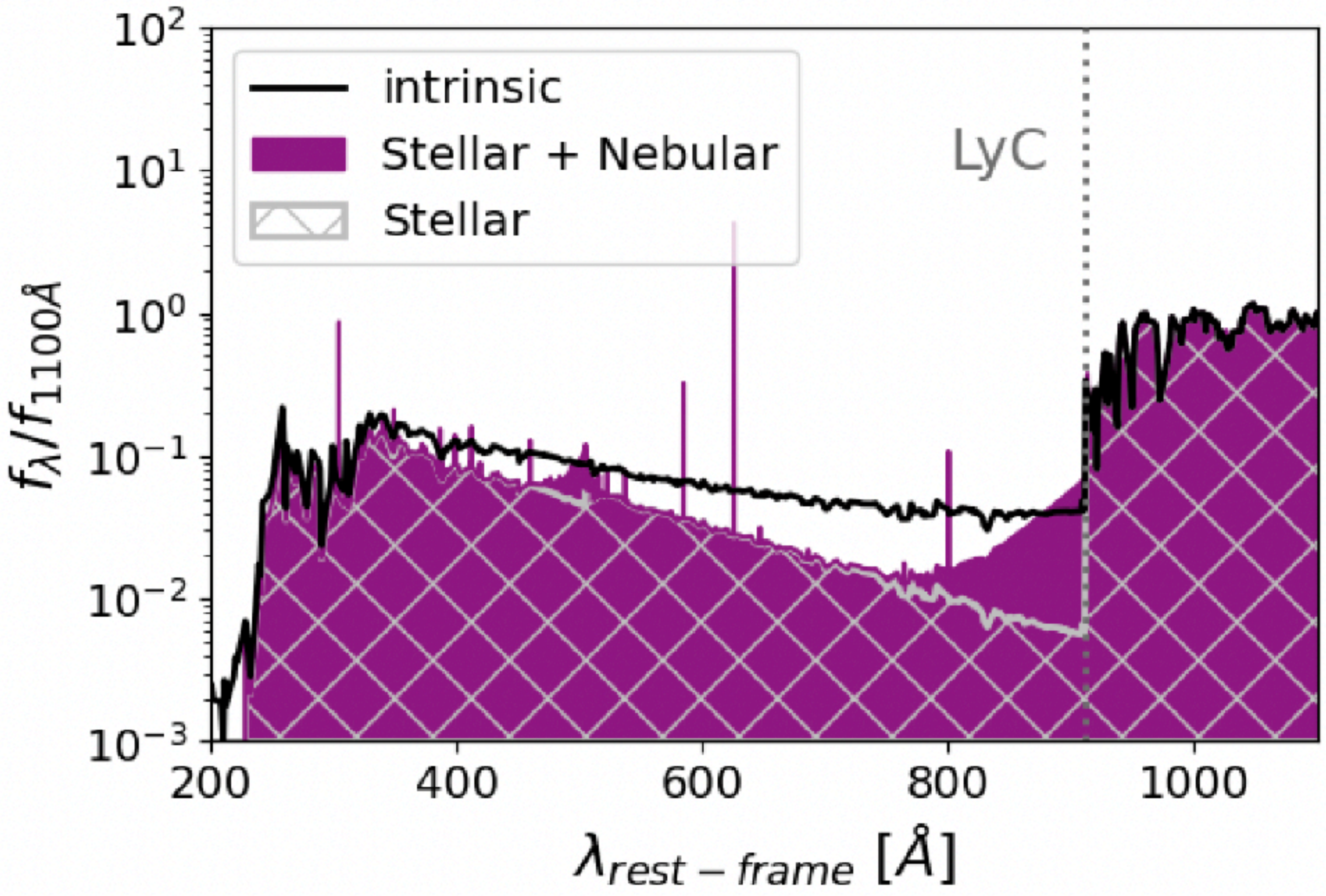


CLOUDY models:

Ionising source: BPASS spectra

Cloud gas: ‘ISM’ metals+ dust

16 < log(NHI) < 19

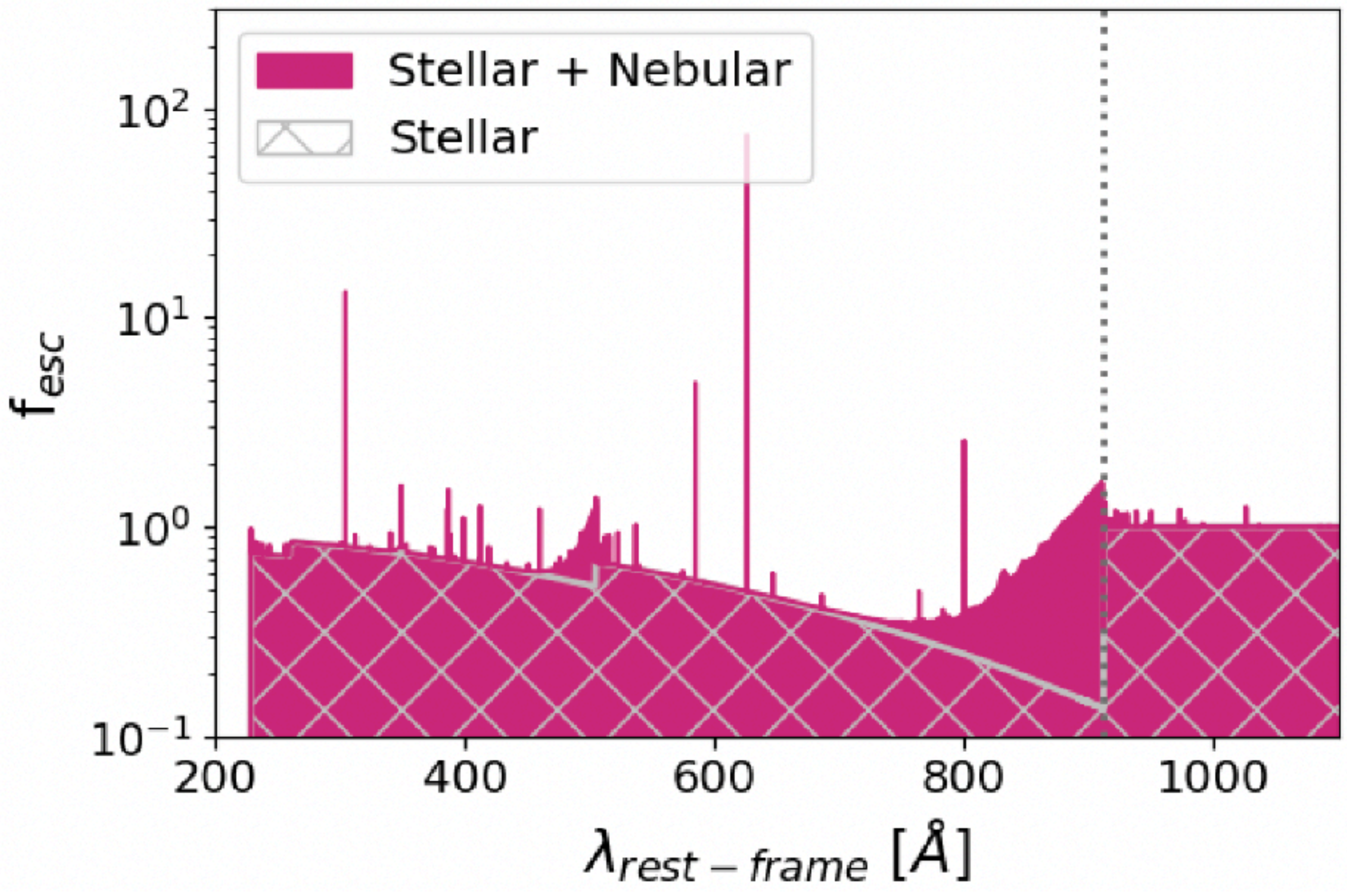


Fiducial model, log(NHI) = 17.5

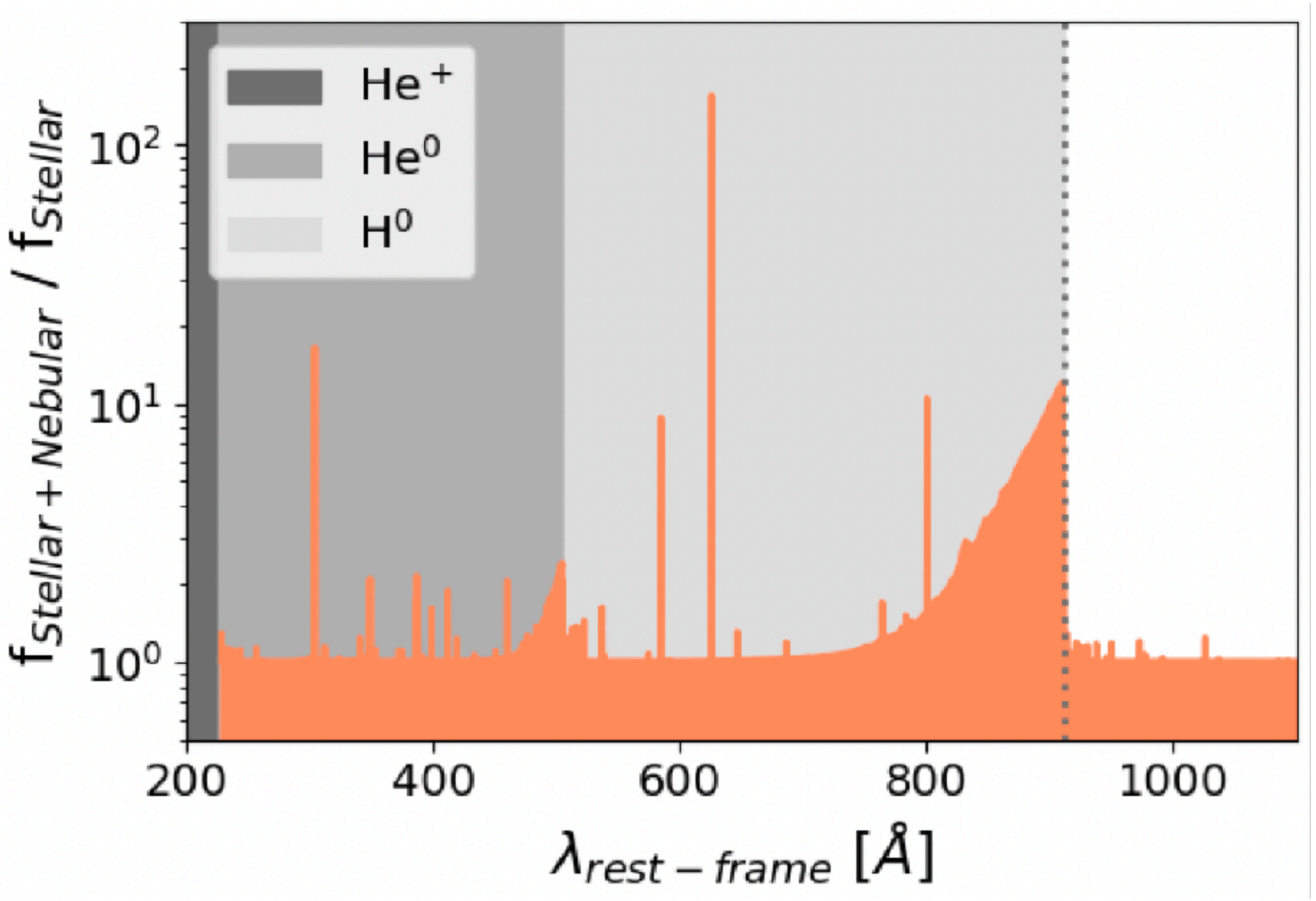
LyC nebular emission

Simmonds, Verhamme et al accepted

Monochromatic escape fractions



Monochromatic luminosity boost



LyC escape fractions with nebular emission

Purple -> stellar + nebular photons, grey -> stellar only photons

Evolution of fesc with NHI:
At extreme regimes (log(NHI) = 16, fesc = 1 or log(NHI) = 19, fesc = 0), the contribution of LyC nebular emission is negligible, it counts at intermediate regimes, 0 < fesc <1

Integrated escape fractions not much affected, but fesc(800 < lambda <912) more, and fesc(900) extremely

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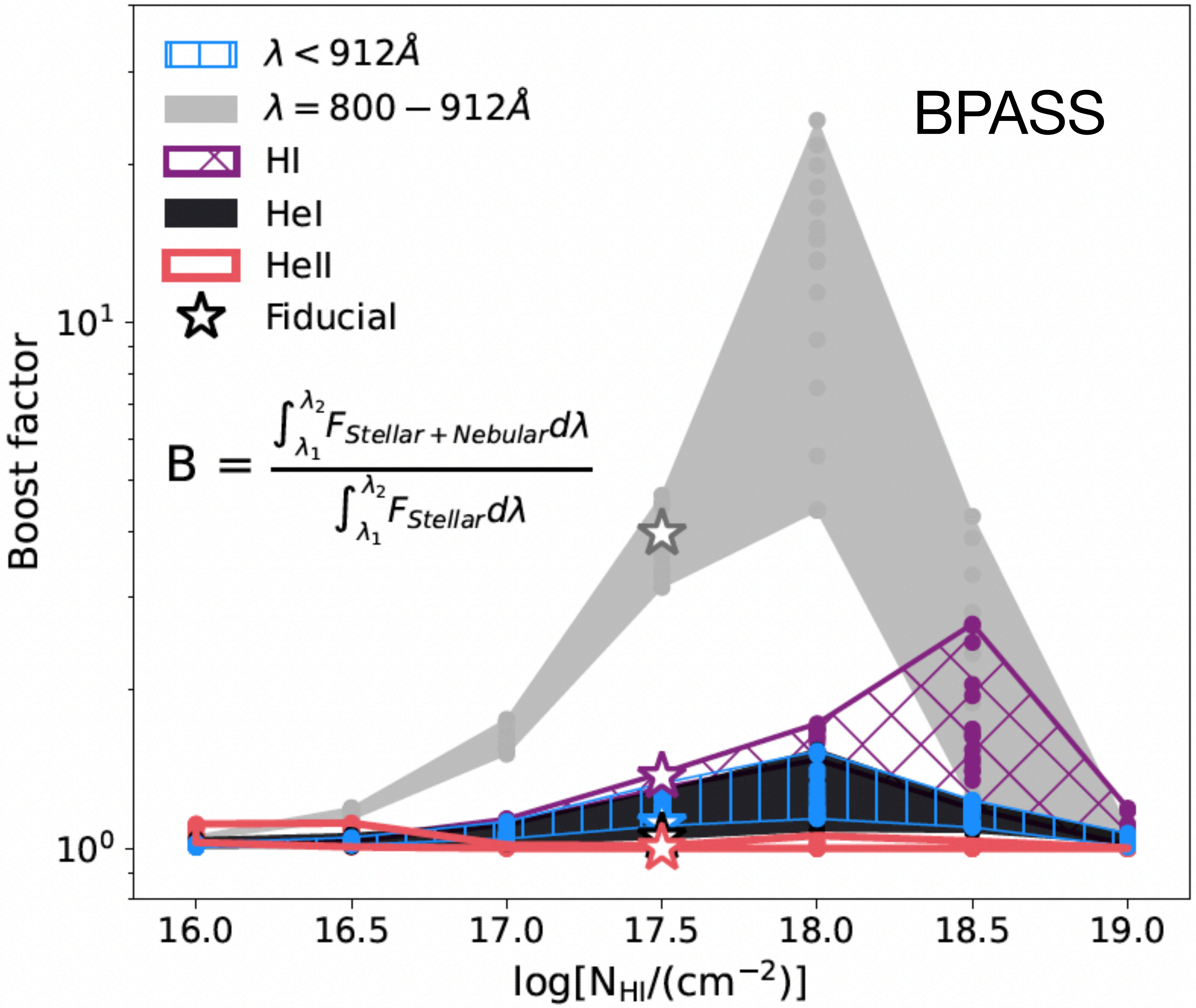
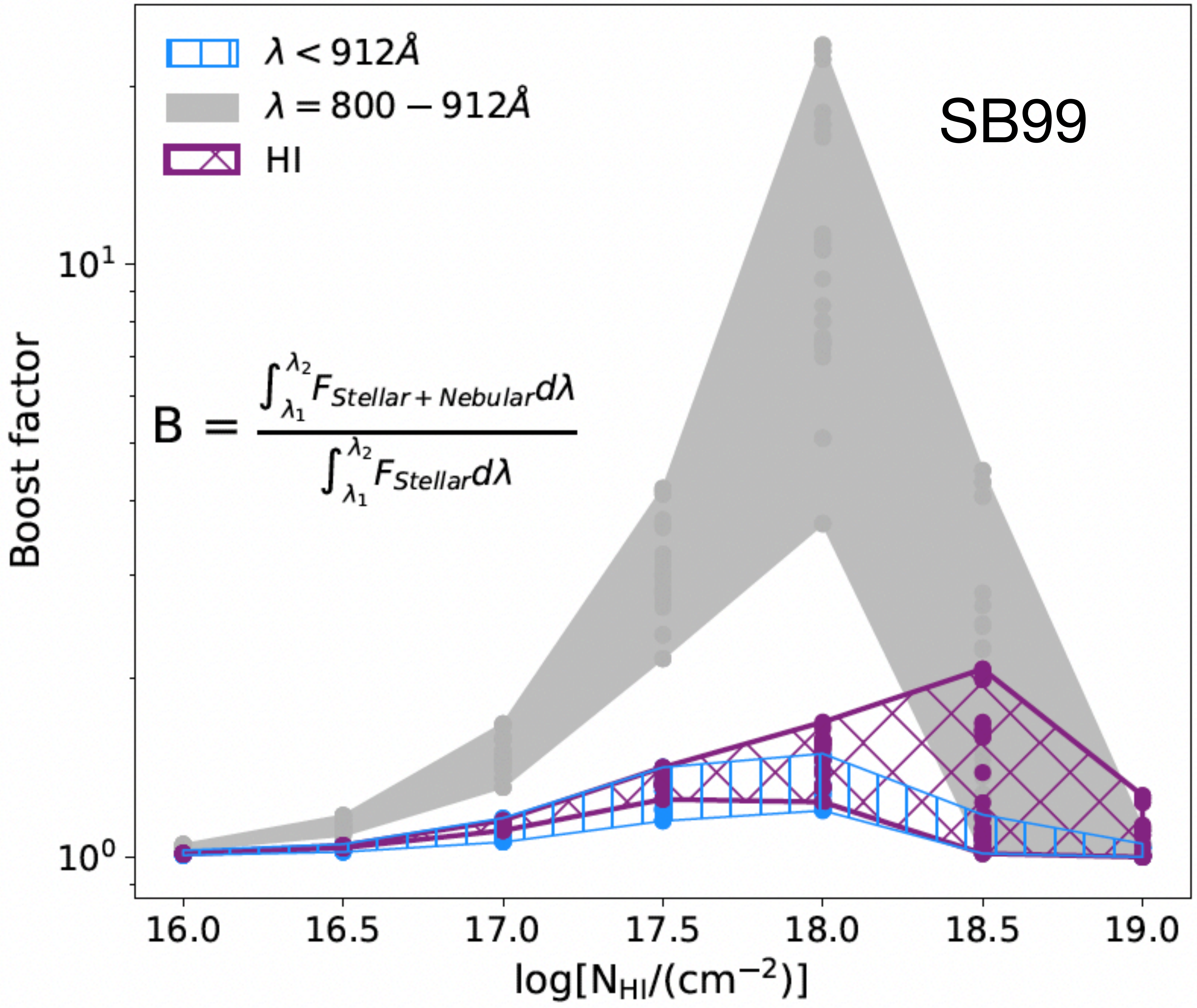
LyC boost in luminosity





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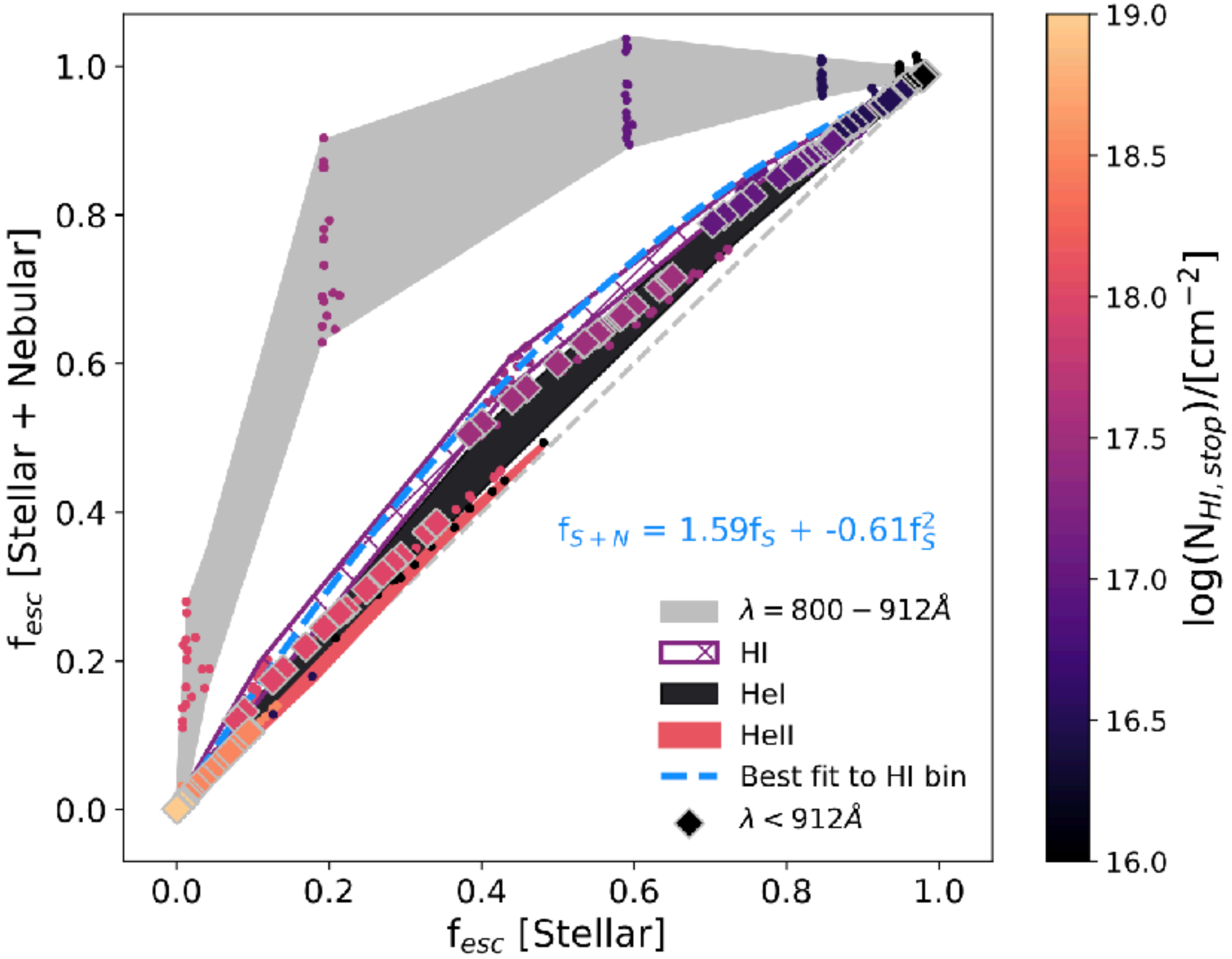
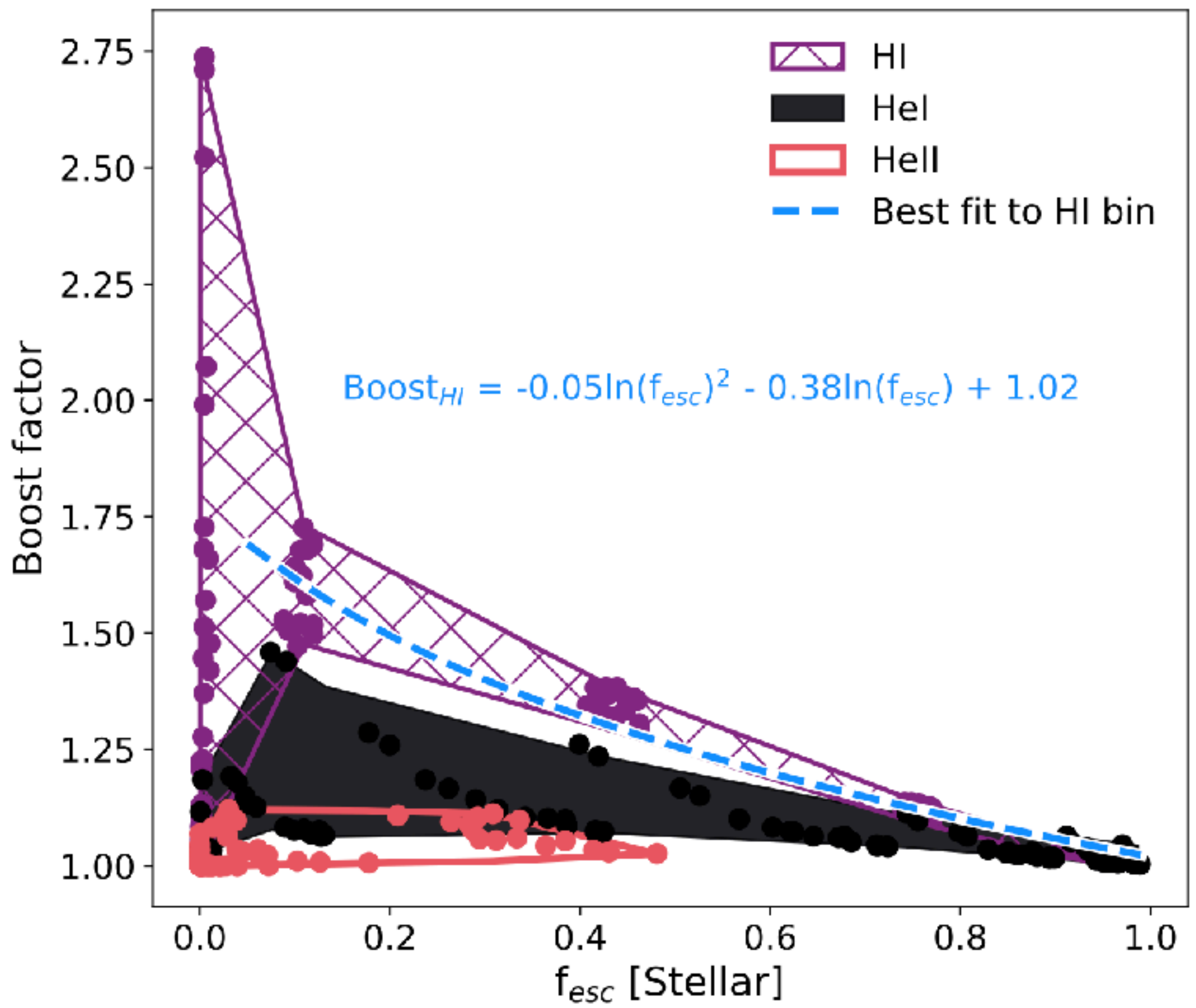
Implications on the simulations side





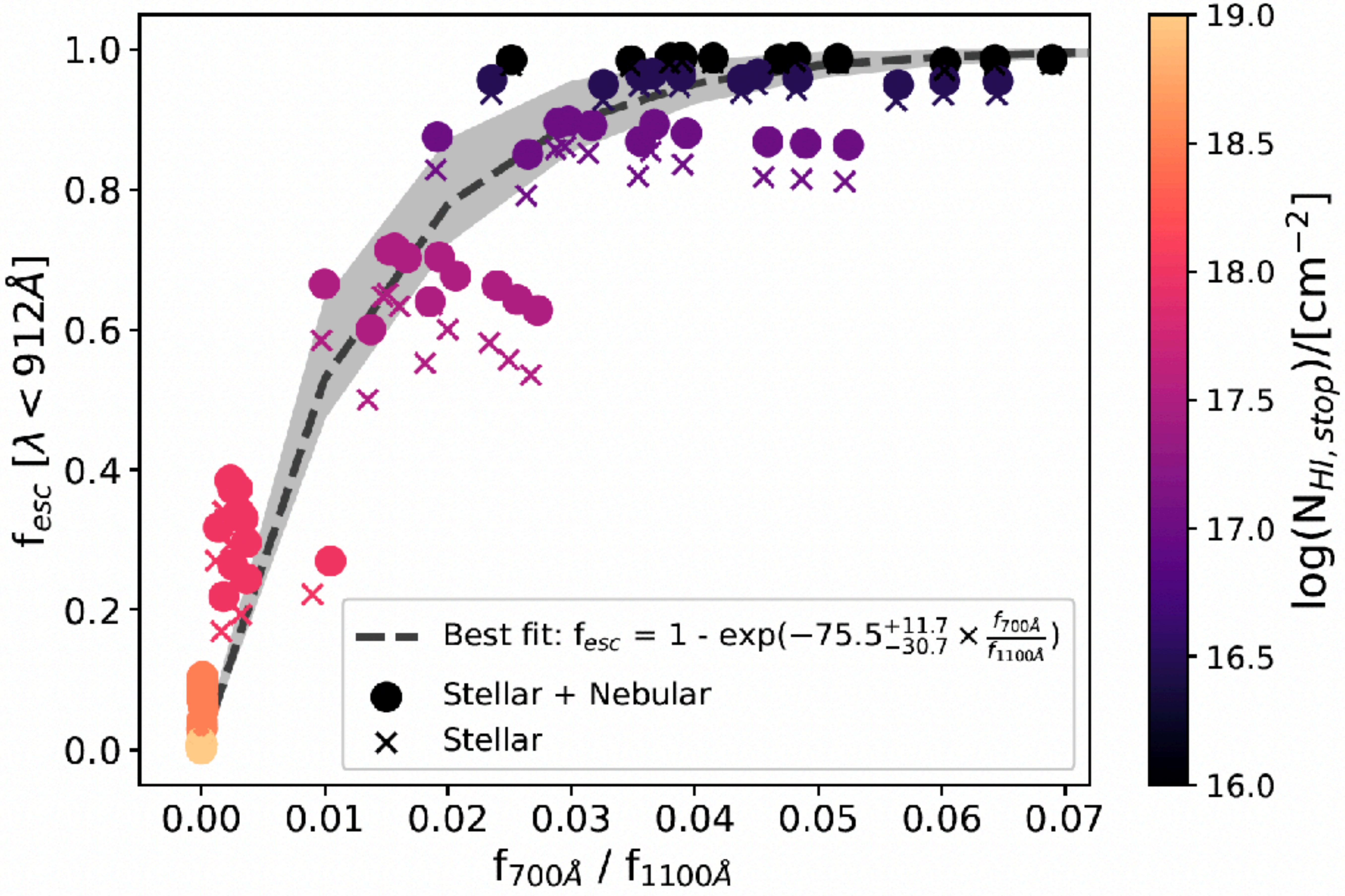
Fesc and boost integrated over the three bins of ionising photons: HI, HeI, HeII

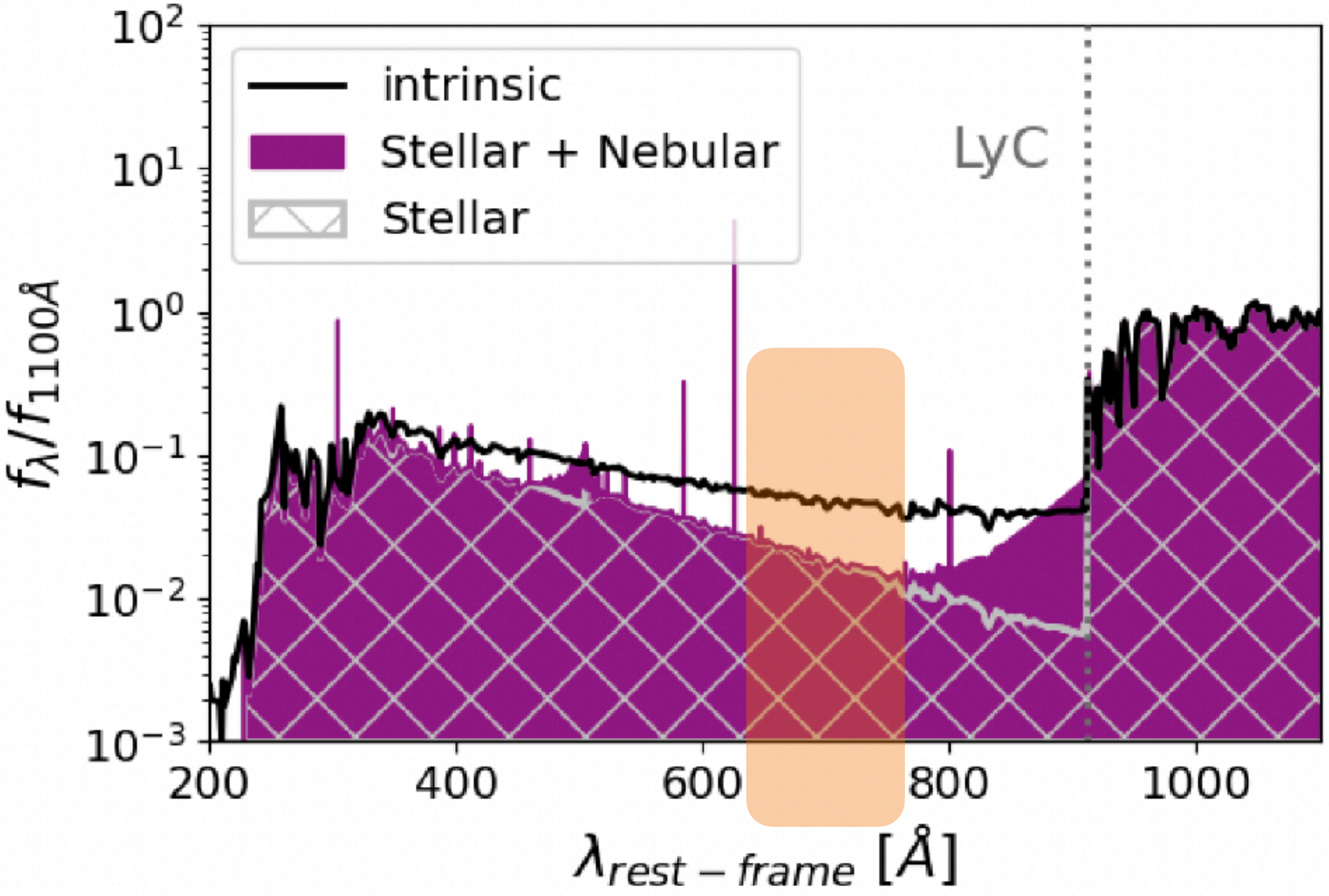
Negligeable effects on 2 high-energy bins, important for HI bin

Implications on the observations side

Neither the wavelength integrated boost nor fesc correlate with f900/f1100

Implications on the observations side





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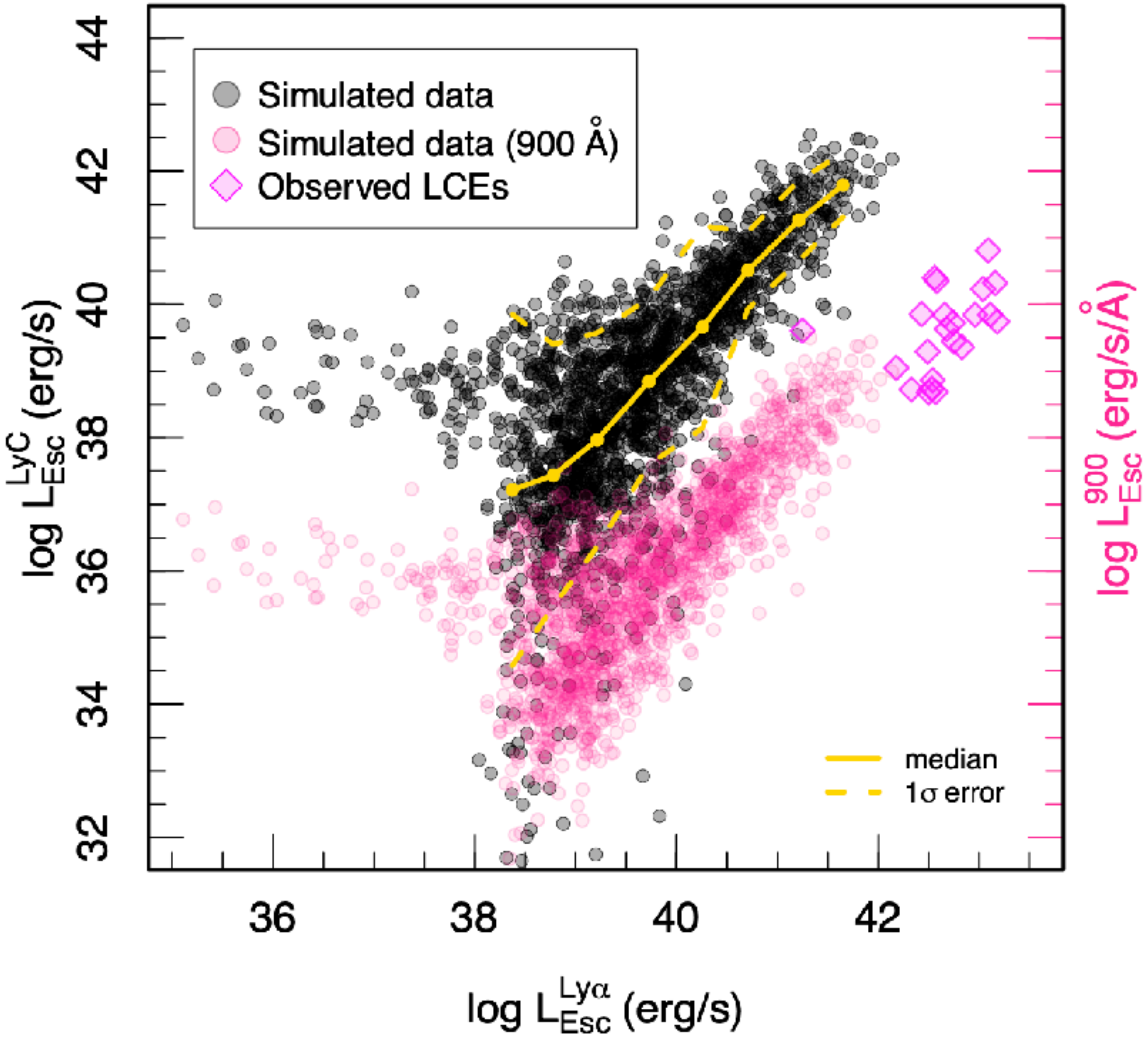
Conclusions on LyC nebular contribution

- In LyC leaking galaxies, LyC nebular emission will also escape, see Inoue 2010, 2011 Lyman bump predictions
- This nebular emission has a complex spectral distribution (free-bound + lines), dependent on the intrinsic stellar LyC distribution and the physical conditions in the gas of the galaxy
- As a consequence, escape fraction measurements strongly depend on wavelength
- Cosmologically relevant wavelength integrated boosts and escape fractions are not increased dramatically by adding this nebular contribution. Still, boost of 1.5 for the HI bin for galaxies with ~10% stellar escape)
- LyC observations at ~900 A are most likely dominated by nebular LyC photons, and not stellar, depending on log(NHI)
- We propose to measure the f700/f1100 ratio to recover wavelength integrated escape fractions from observations

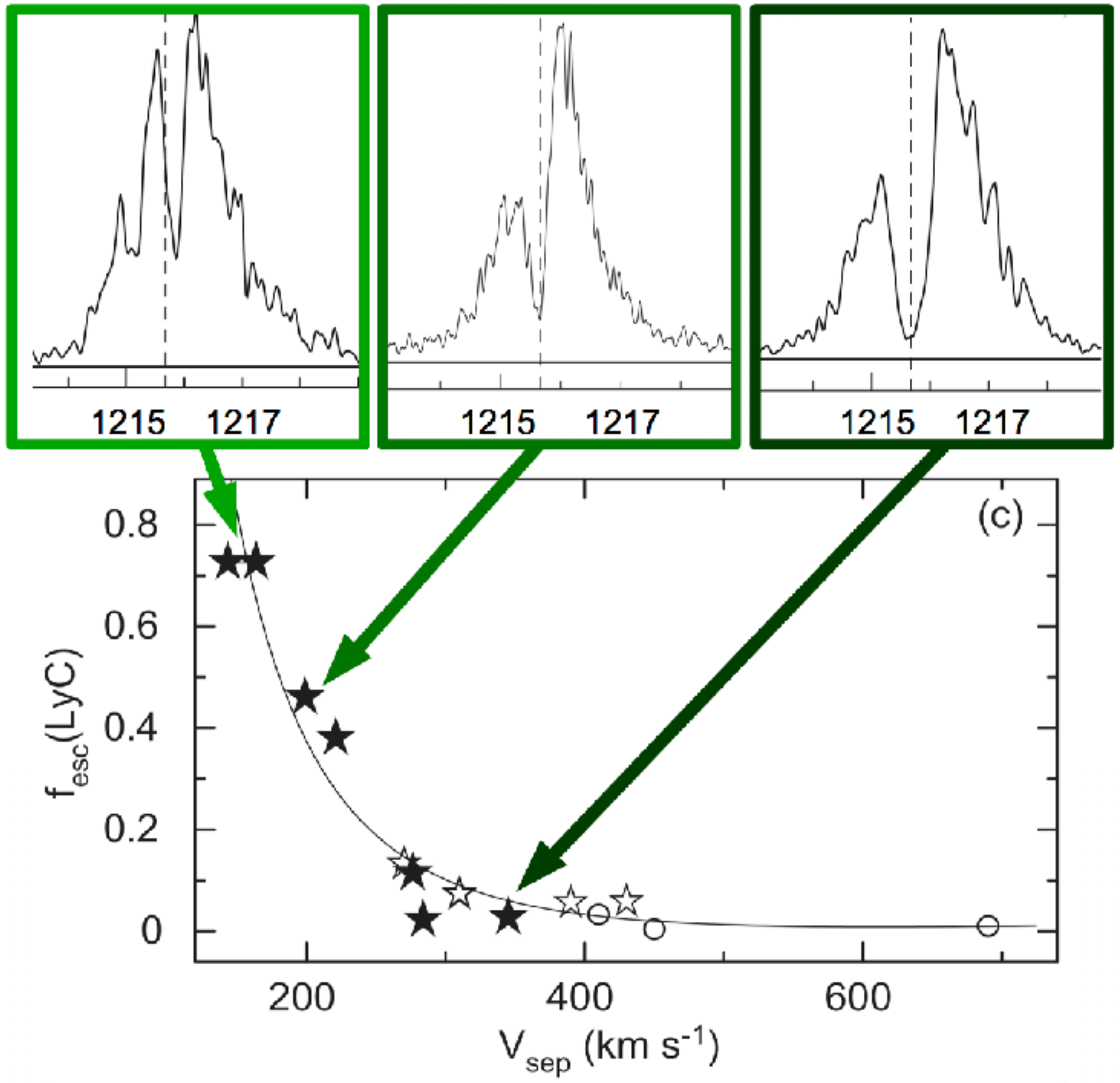
Observing LyC leakers with BlueMUSE

LyC emitters are Lya bright, their Lya peaks separation correlates with fesc(LyC)

Maji et al, 2022



Richard et al, 2019



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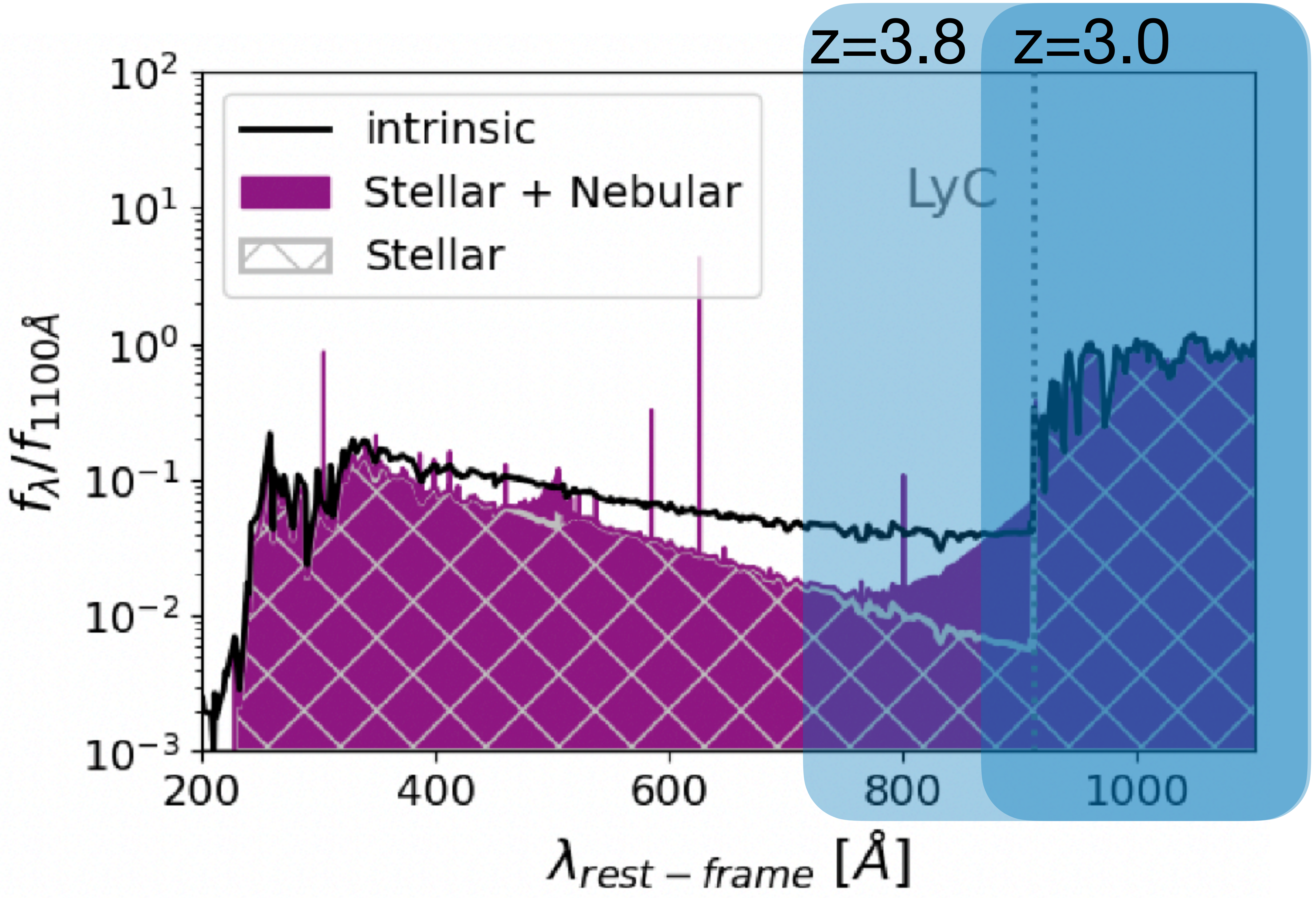
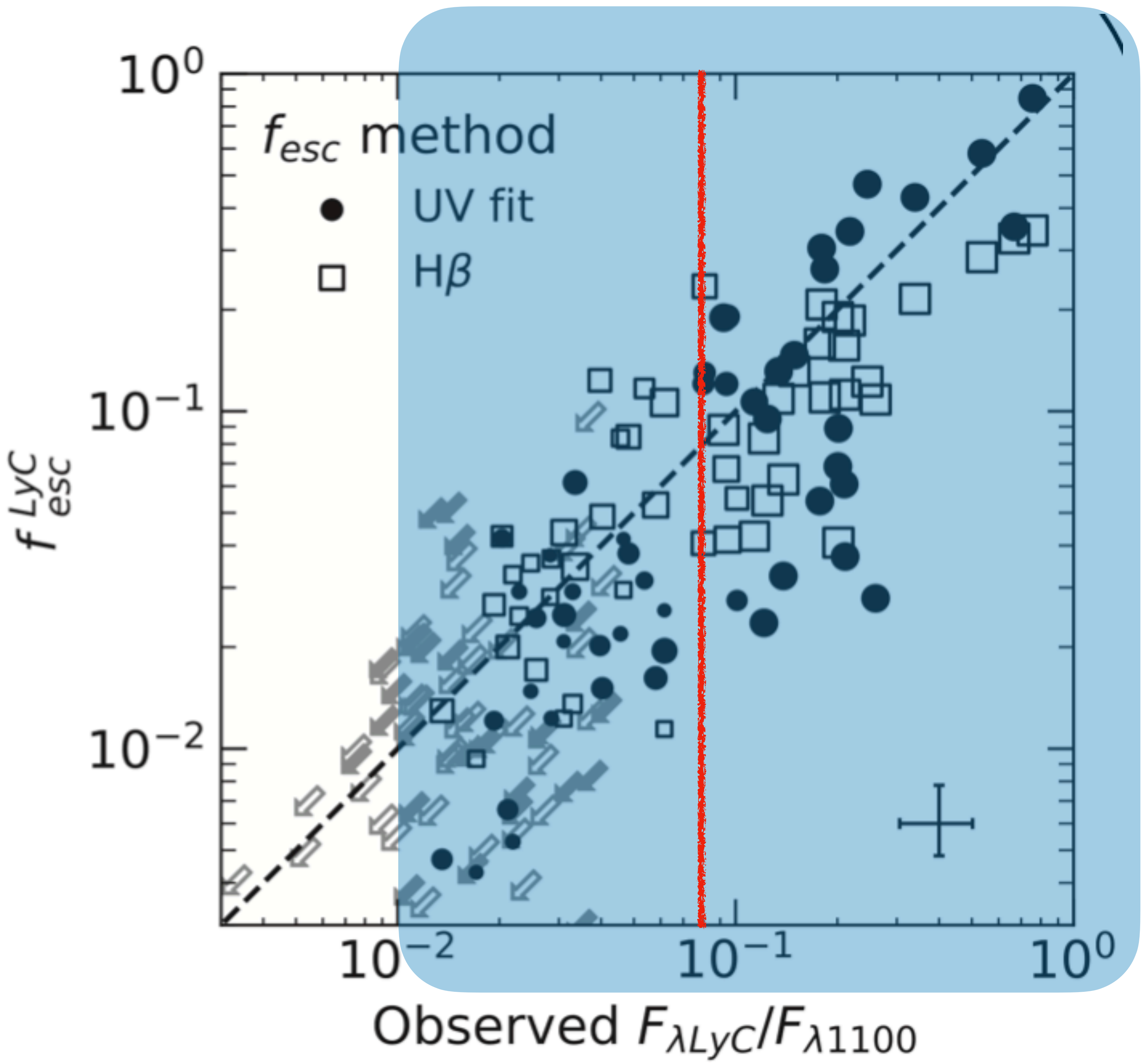
Observing LyC leakers with BlueMUSE

- Lya + LyC observable with BlueMUSE at 3 < z < 3.8, the bluest observable ionising wavelength goes from 875A at z=3 to 730A at z=3.8

- Observed F900/F1100 span a broad range, from 0.01 to ~1, most at 0.1-0.2





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Perspectives, next steps

- Use BlueMUSE ETC to estimate the necessary observational time to detect LyC,

knowing Muv, and assuming different fLyC/f1100 ratios

- Use UV LFs to determine the number of galaxies brighter than Muv per FoV
- Use IGM attenuation simulations ?
- Assume a fraction of leakers, 10% as in Steidel+18 ?, to decide a survey strategy:
  - Only extreme deep fields will allow individual detections
  - Stacks of all medium deep data
  - Target crowded fields ? Rui's objects ? Lensed fields ?