Emission Line Diagnostics to Identify (SFG) Lyman Continuum Emitters

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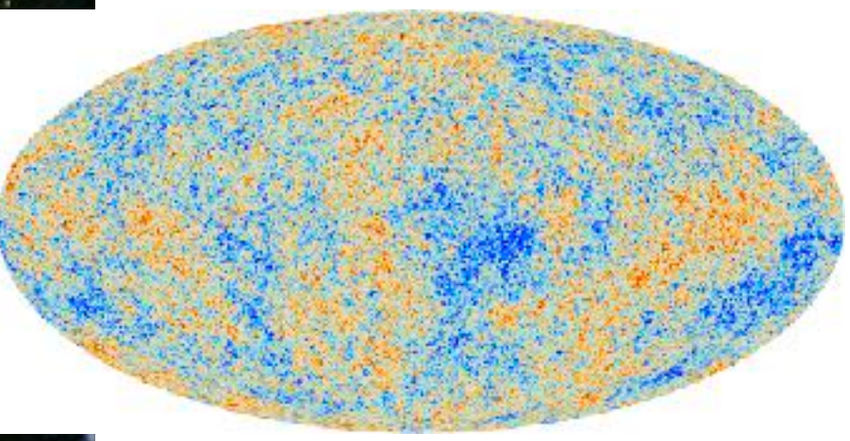
OAC, Crete

Escape of Lyman radiation from galactic labyrinths

2018

Cosmic Reionization



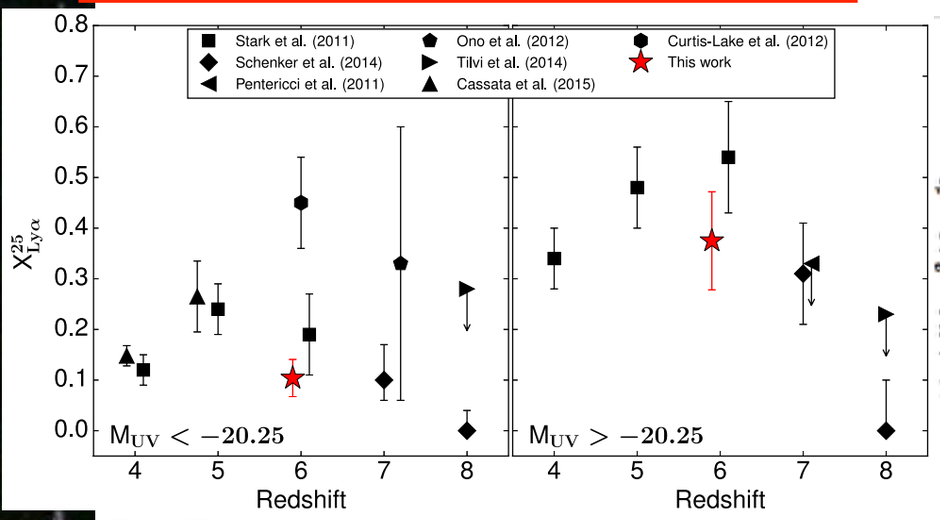
Neutral hydrogen at z~1100

IGM becoming ionized

Today: ionized IGM

When?

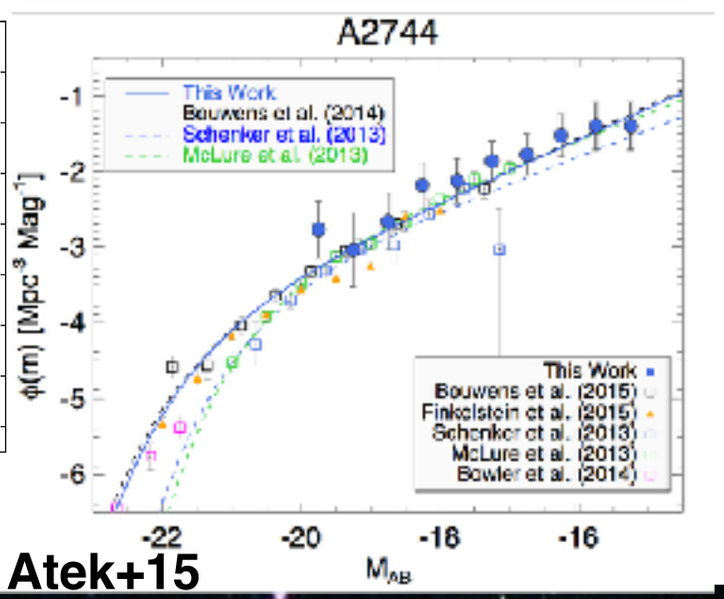
Planck: z~8.8
Drop of LAE fraction at z>6



De Barros+17

Who?

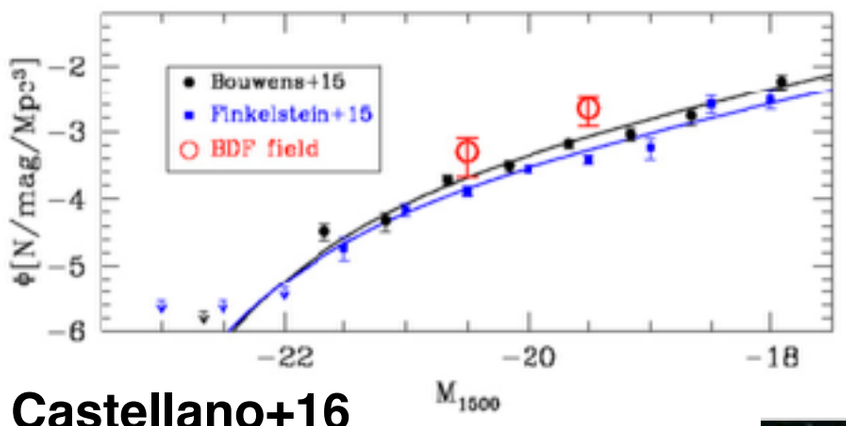
Faint SFGs
AGN contribution?



Atek+15

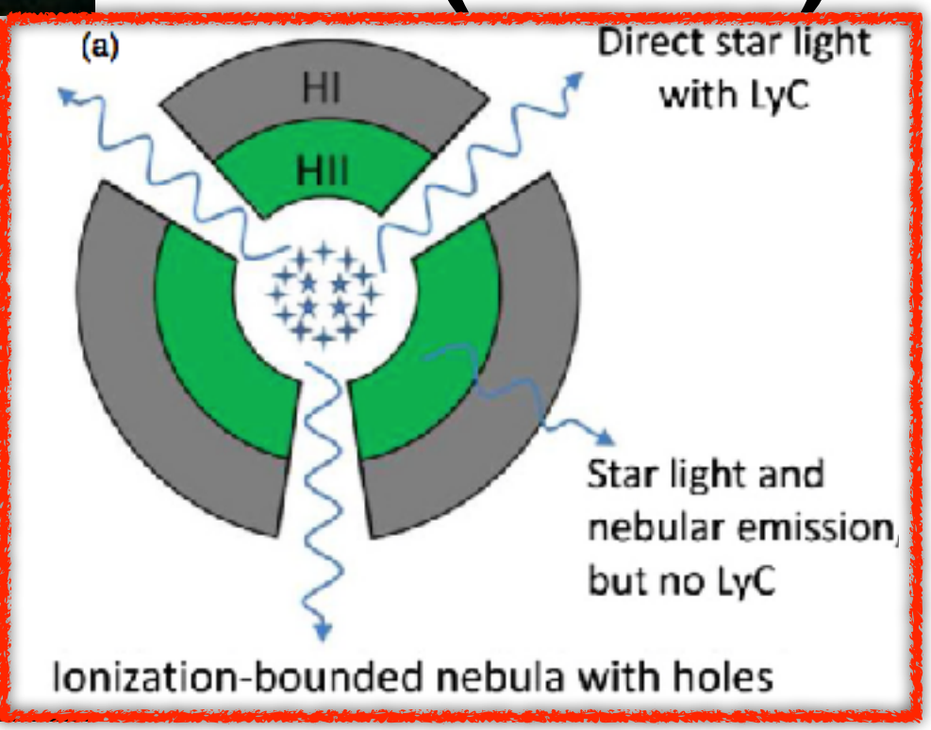
How?

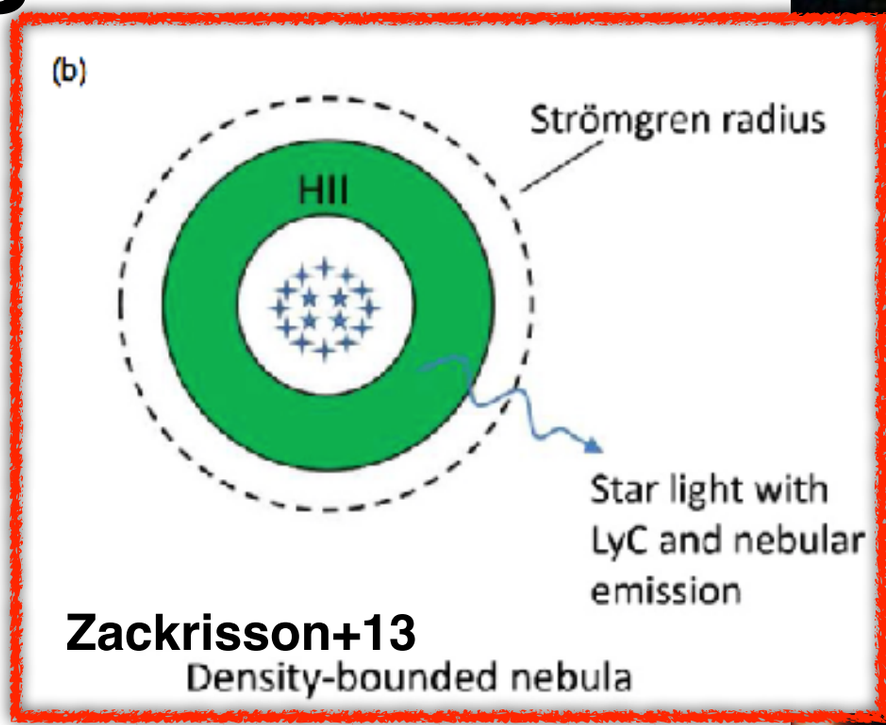
Patchy: ionized bubbles around galaxy overdensities

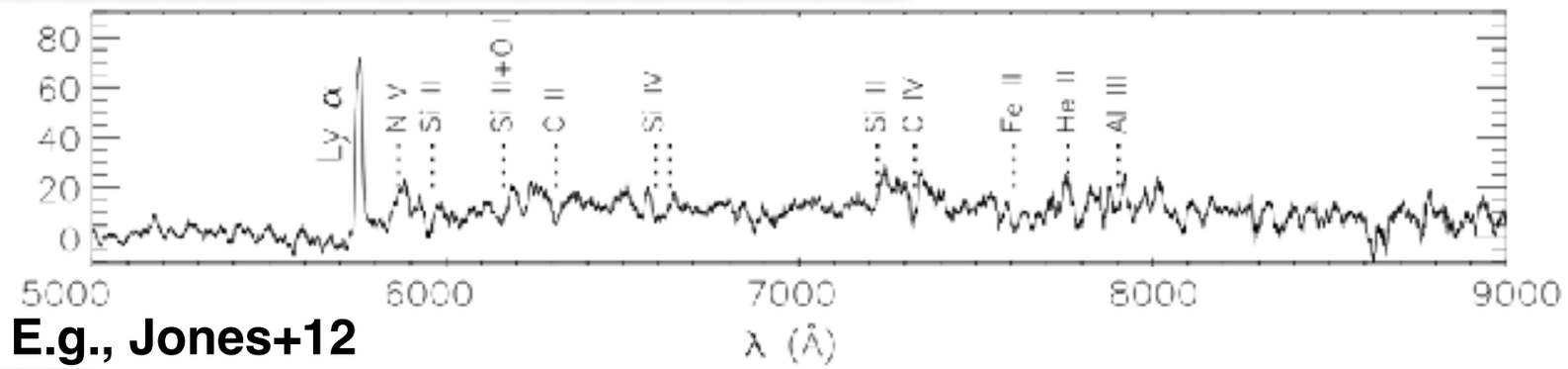


Castellano+16

(Some) Proposed Diagnostics



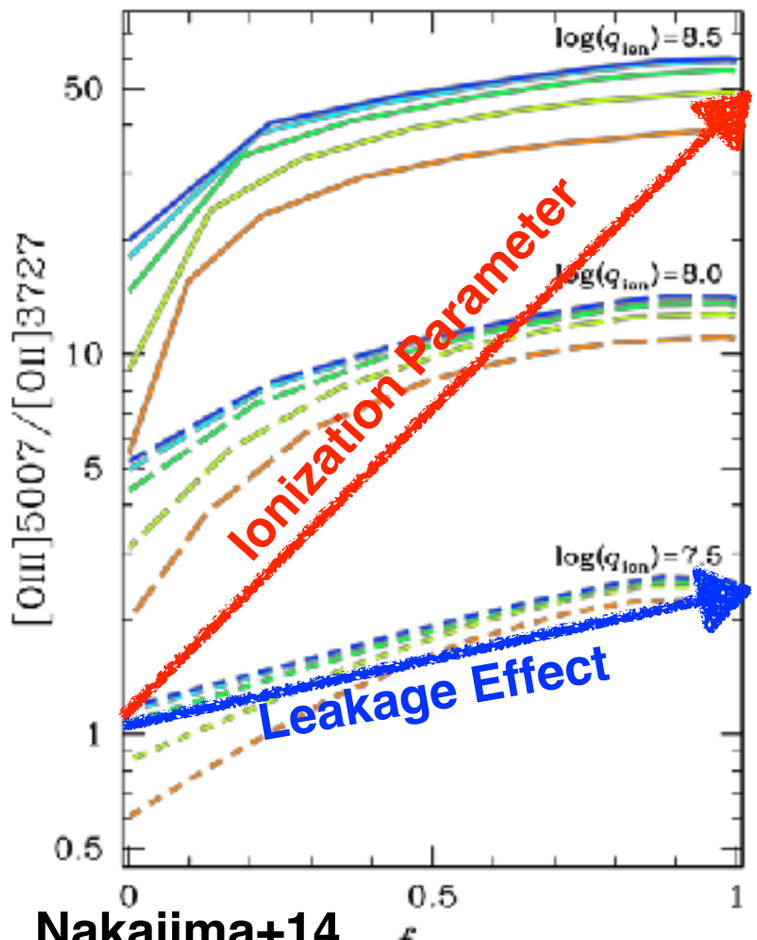




E.g., Jones+12

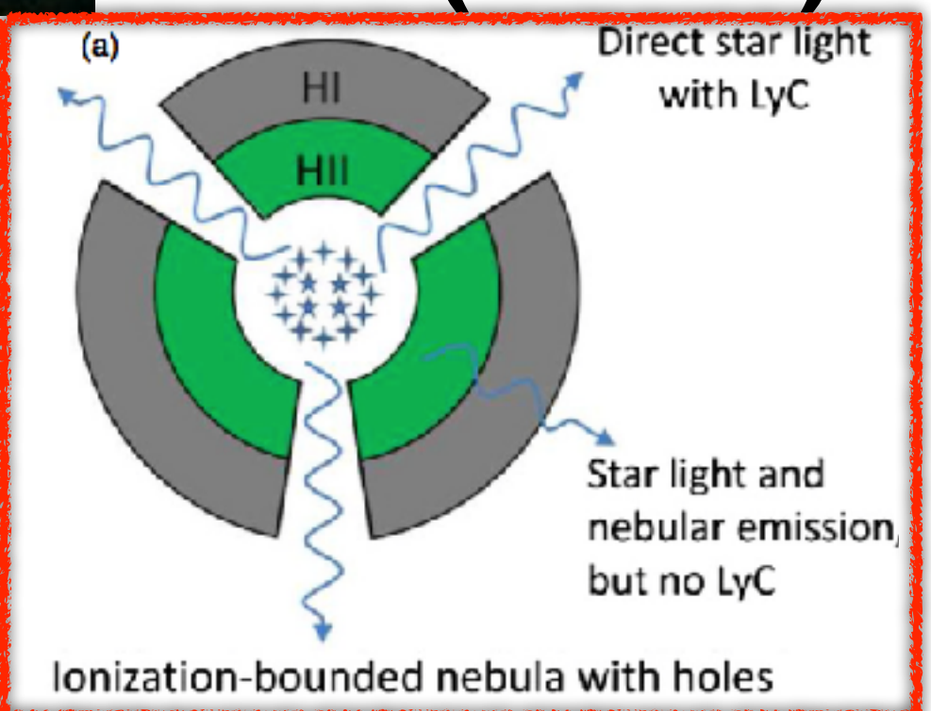
Low-ionization metal absorption lines:
Covering fraction

OIII/OII: much more sensitive to ionization parameter

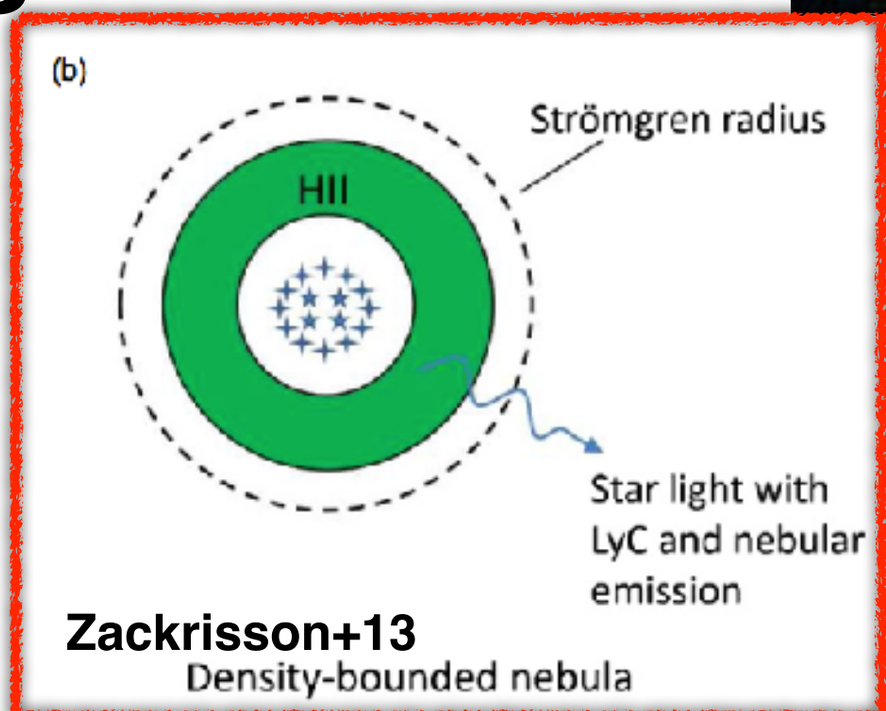


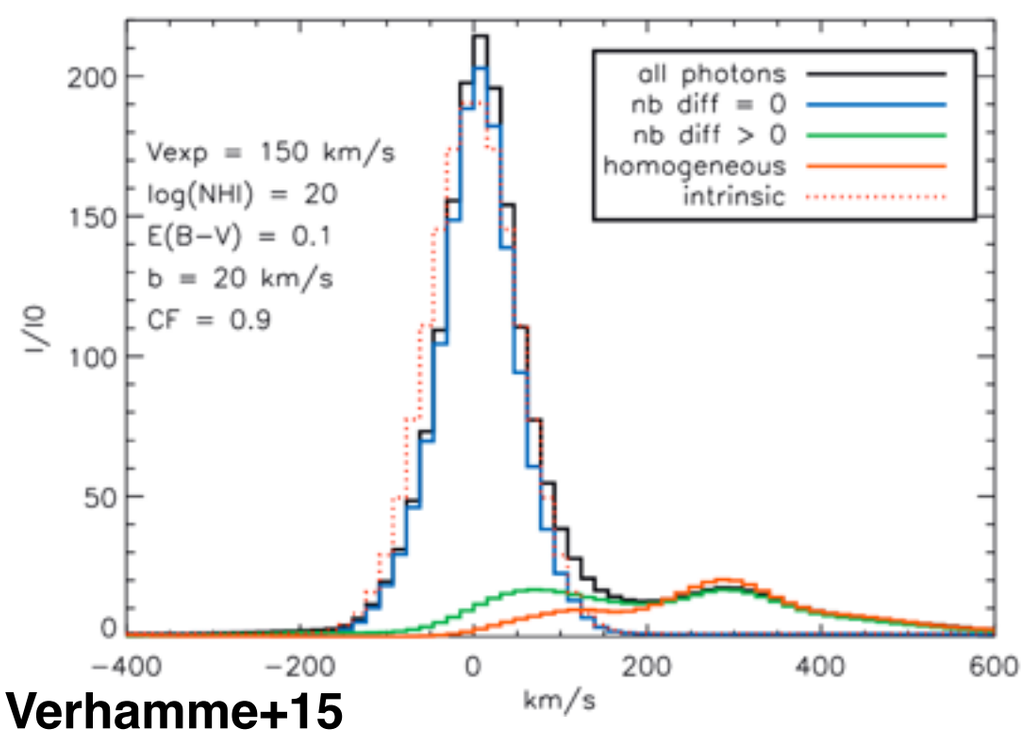
Nakajima+14

(Some) Proposed Diagnostics

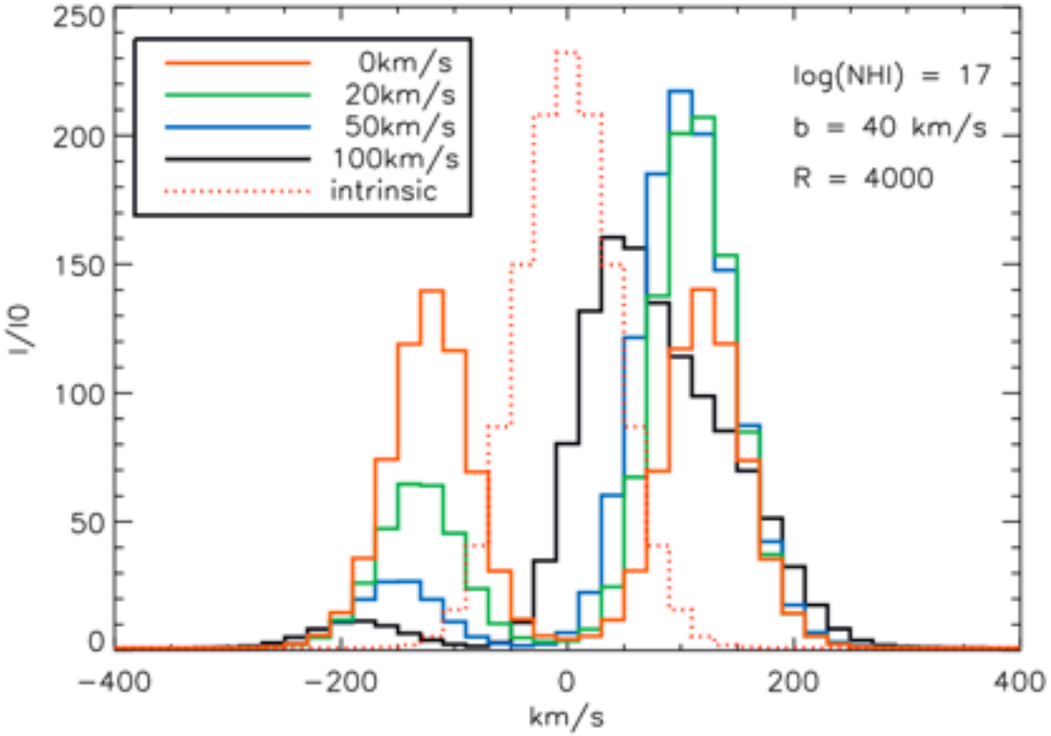


Specific Lya profile for each case



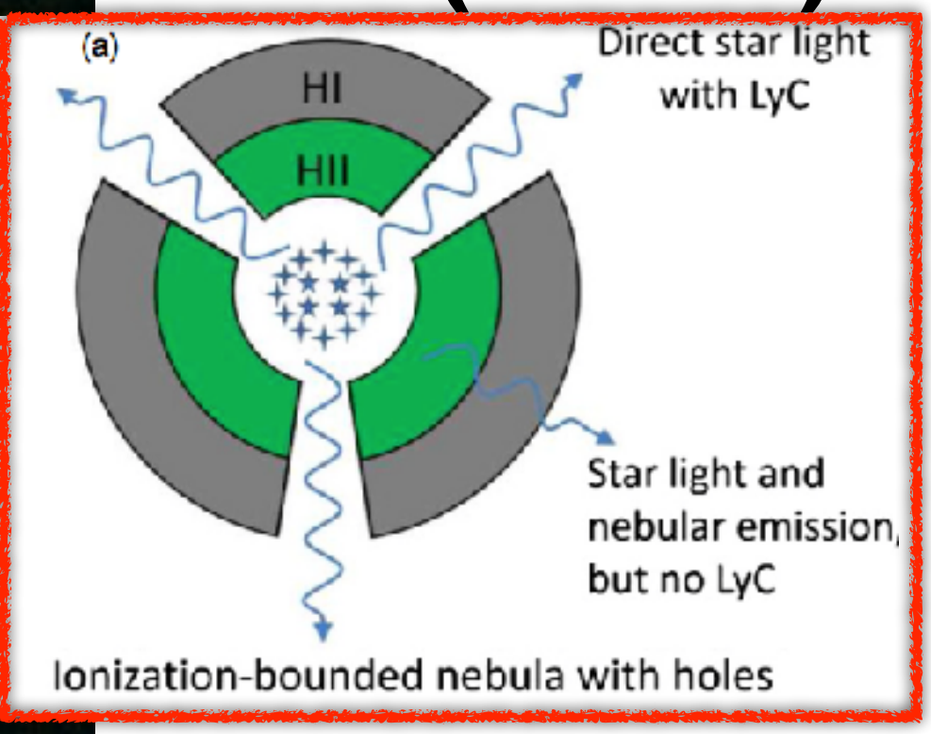


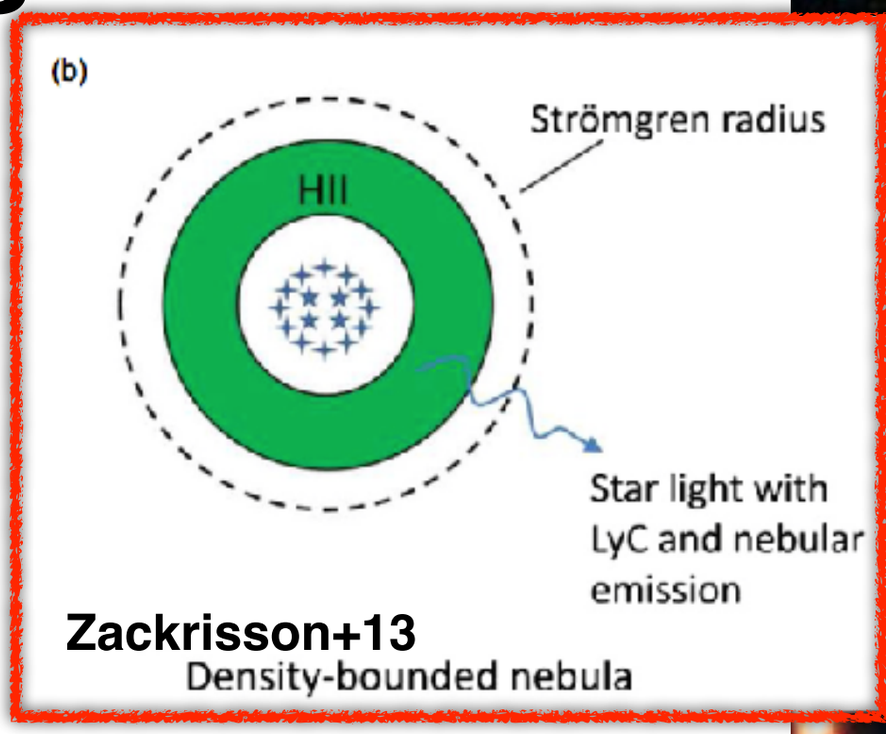
Verhamme+15



Peak separation linked to HI column density

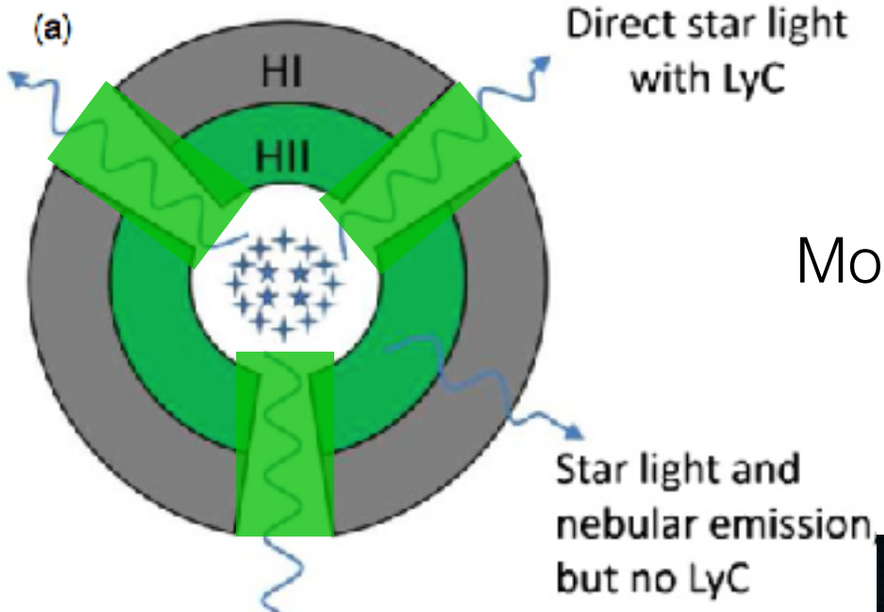
(Some) Proposed Diagnostics





In this framework:
LEAKAGE HAS LITTLE TO NO IMPACT ON NEBULAR LINE RATIOS

In this framework:
LEAKAGE IMPRINTS NEBULAR EMISSION

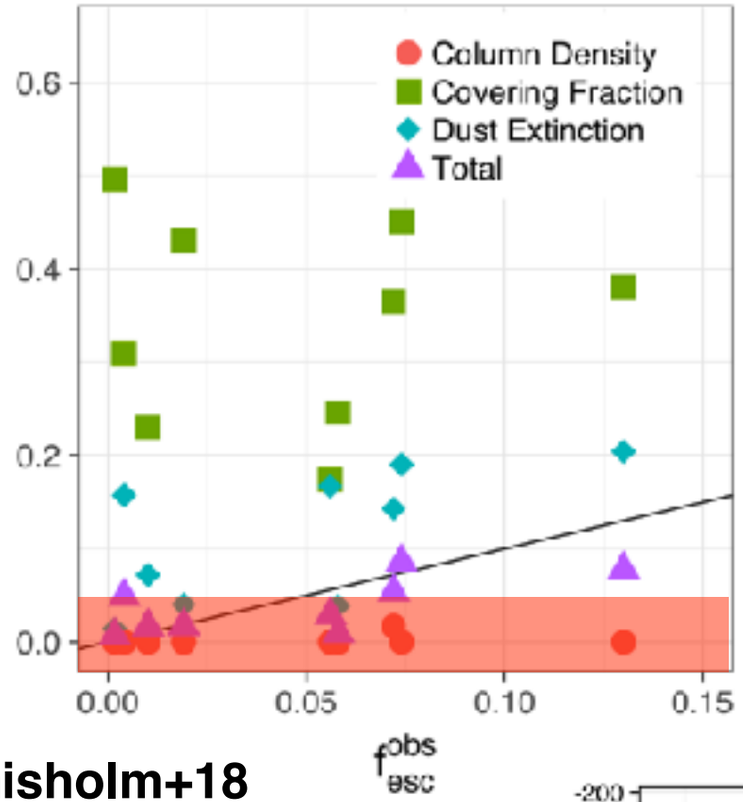


More realistic?

Predictions vs. Observations

Izotov+16,18

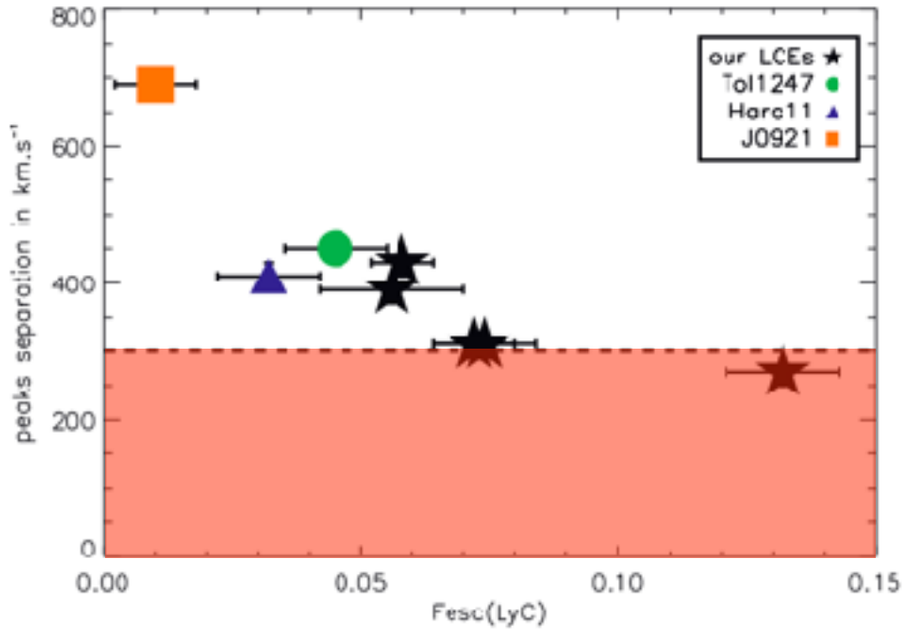
Homogeneous Selection: 11 targets, 100% success rate



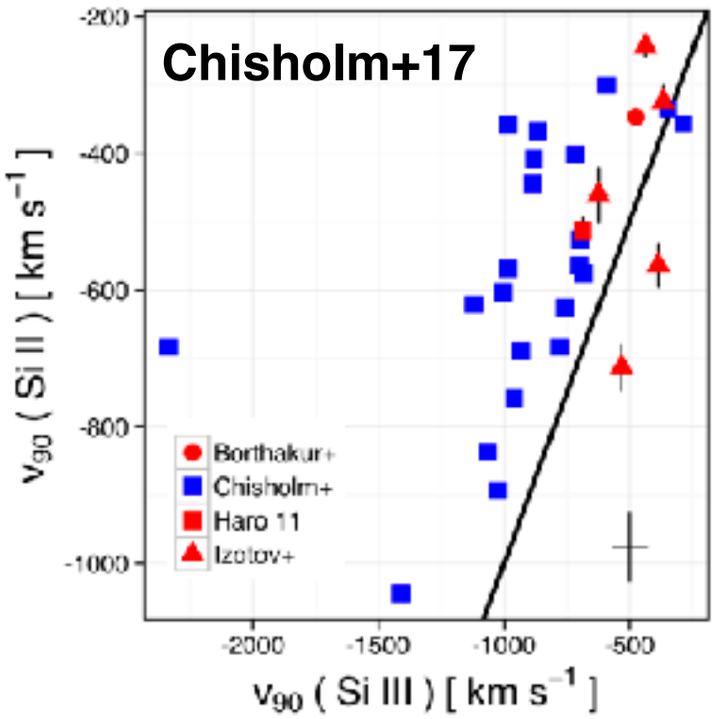
Chisholm+18

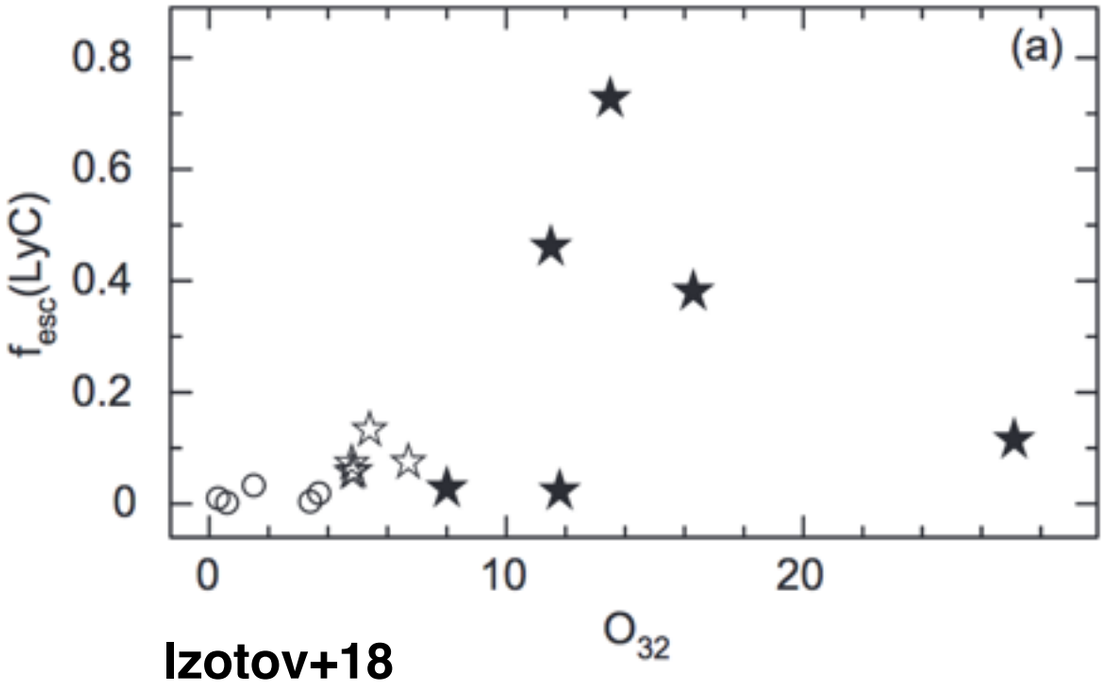
"Holes" scenario favoured?

What about Lya?



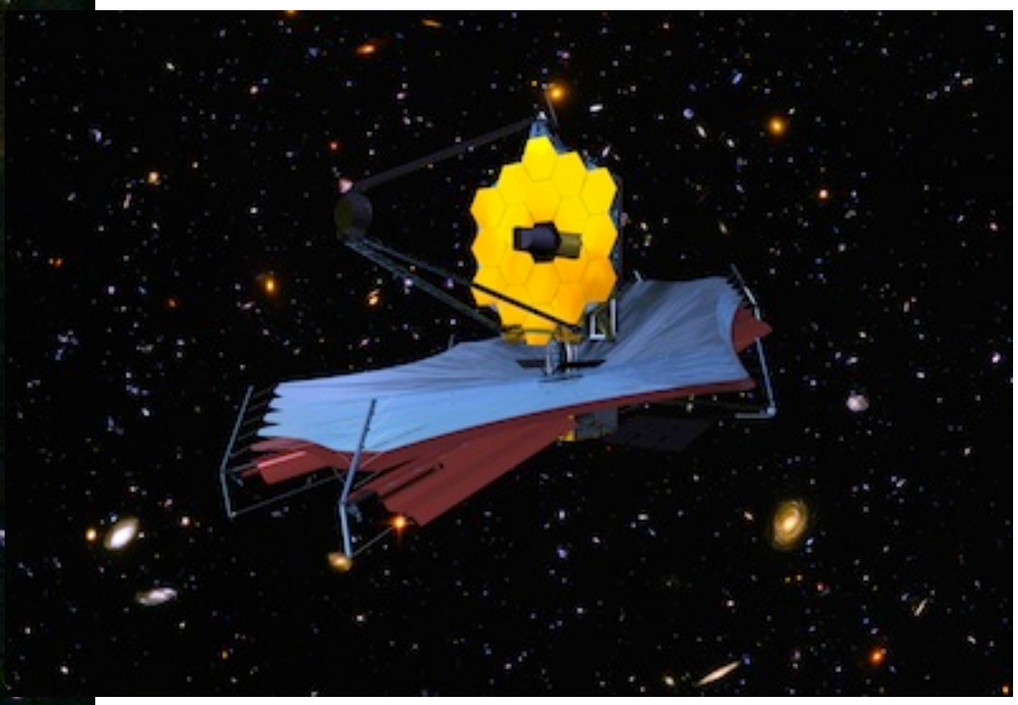
Verhamme+17





Izotov+18

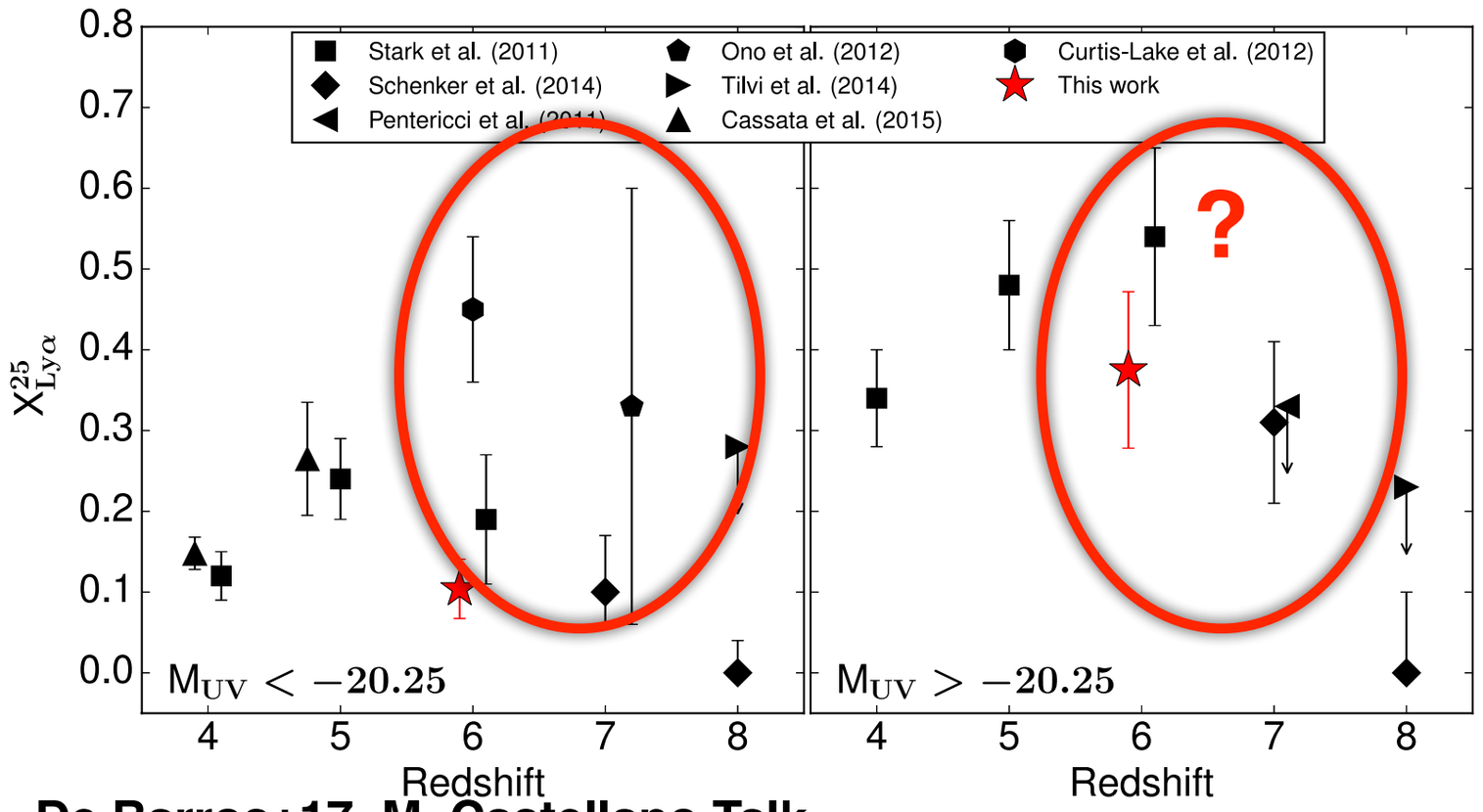
Why (Strong) Nebular Emission Lines?



JWST: Nebular EL of SFGs at z>6

Detect Lya at z>6?
Possible for *some* (?) bright galaxies

Expensive to target LIS (and not feasible for faint sources), same for MgII (A. Henry Talk)



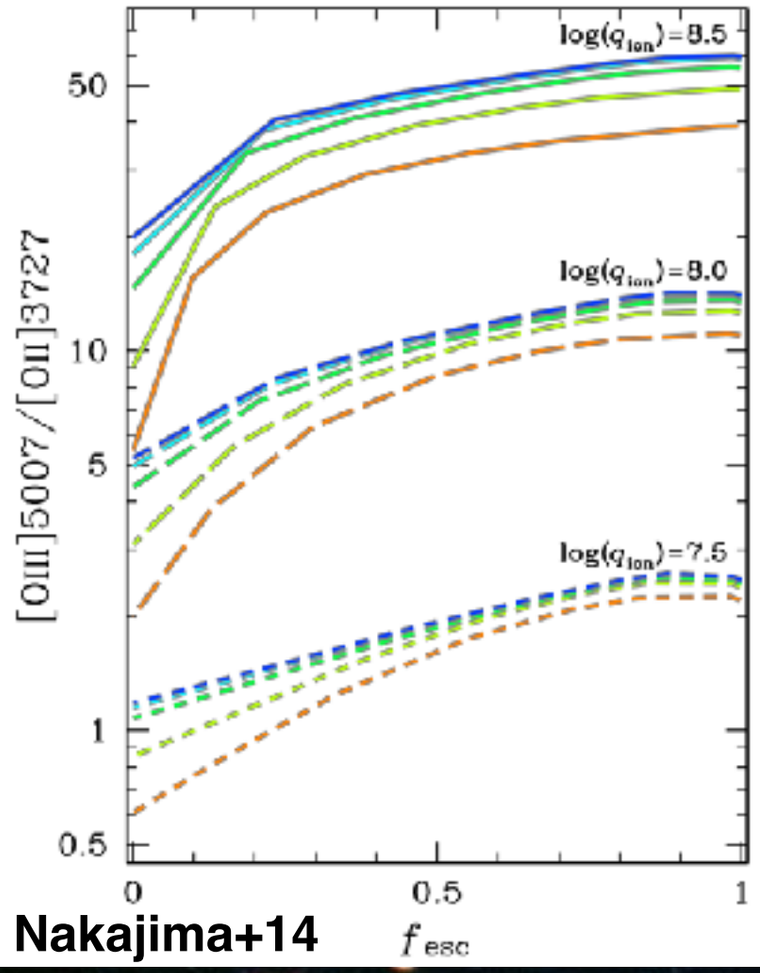
De Barros+17, M. Castellano Talk

Photoionization Grid

CLOUDY (C17, Ferland+17)
BPASSv2.1 (Eldridge+17), Kroupa IMF, 300 Solar Mass cutoff
ISM Abundances, Depletion Factors: Gutkin+16
Free Parameters**:** Z/Z_{gas}, log U, age (SFH=const), n_H, log C/O, **log(NHI)**

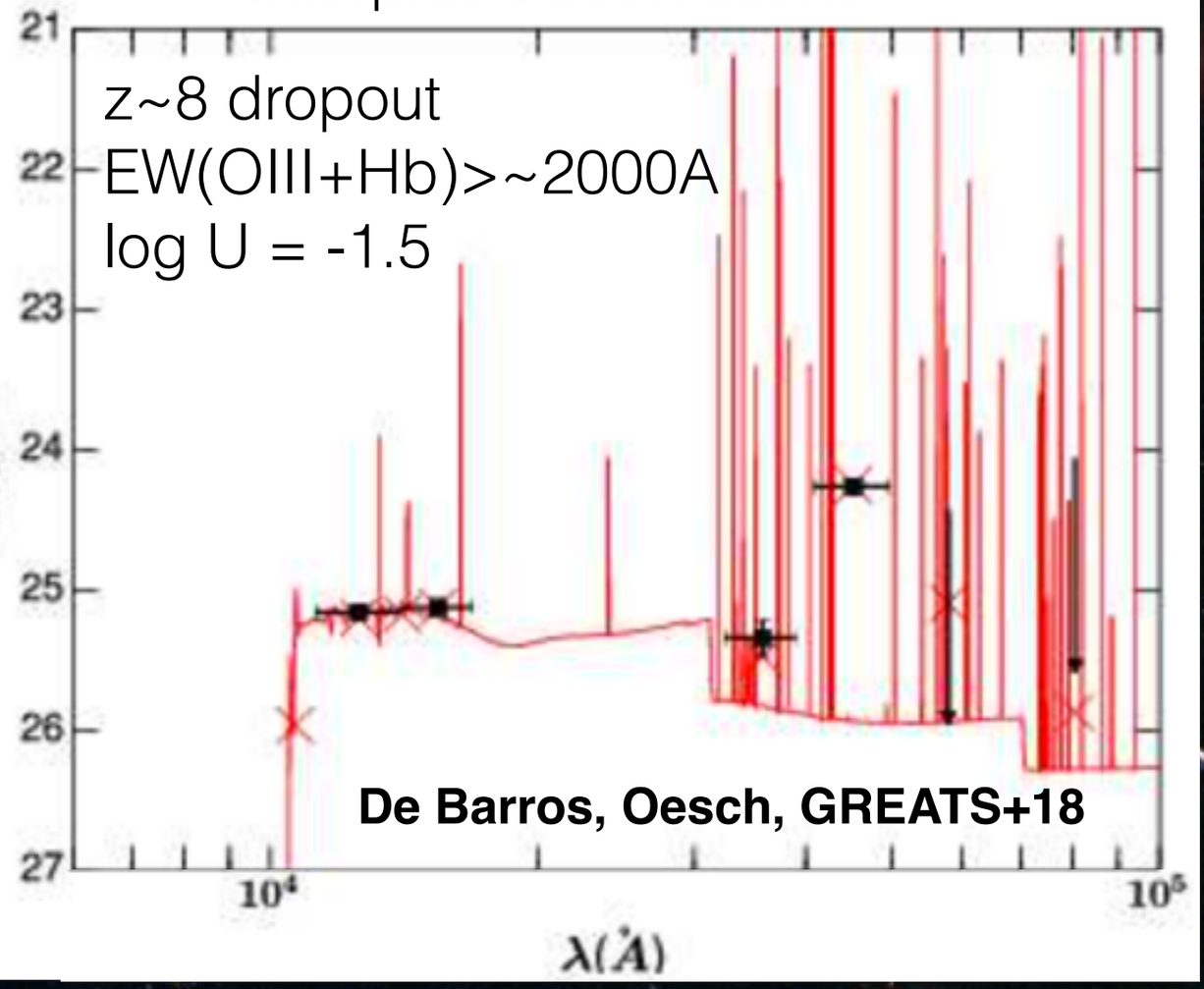
Motivation for density bounded nebulae:
K. Nakajima, A. Inoue, and more, talks

Make Predictions



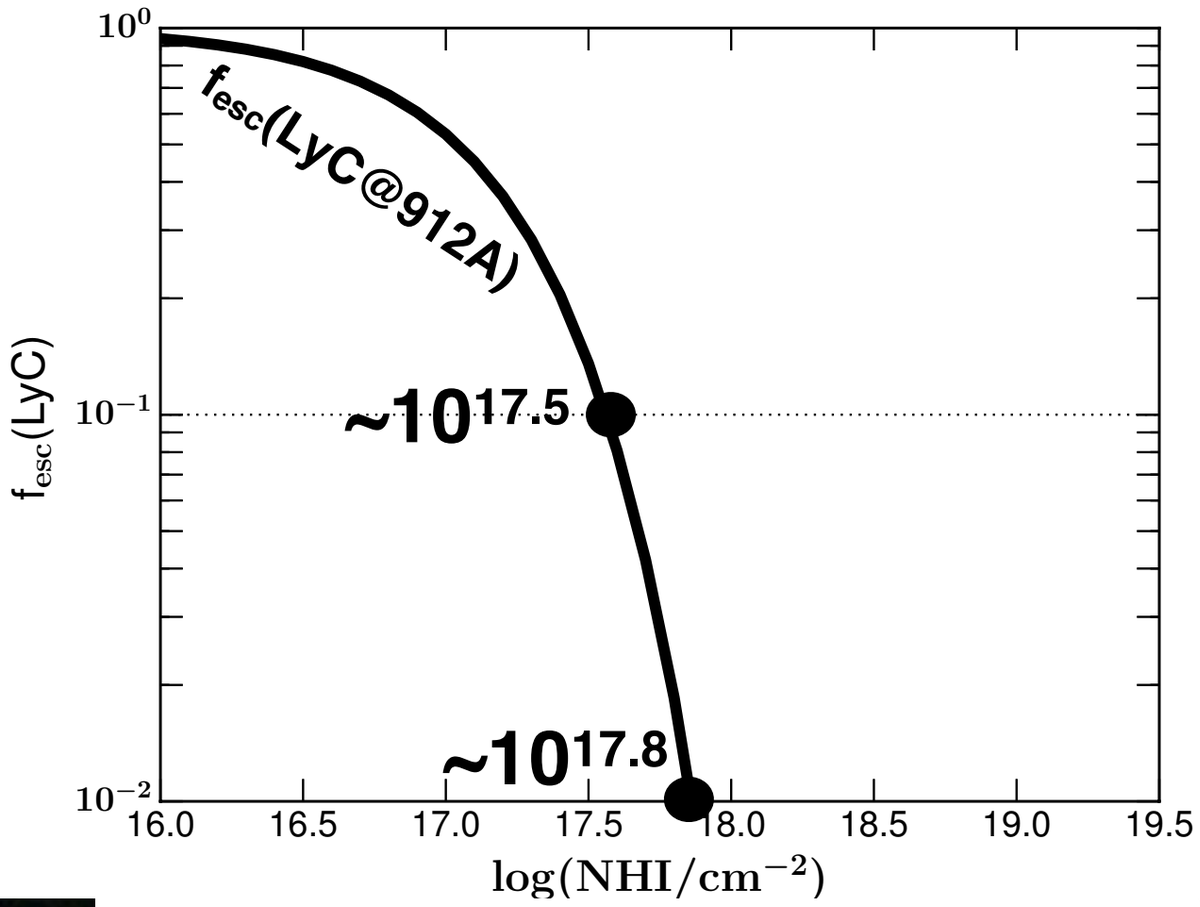
Nakajima+14

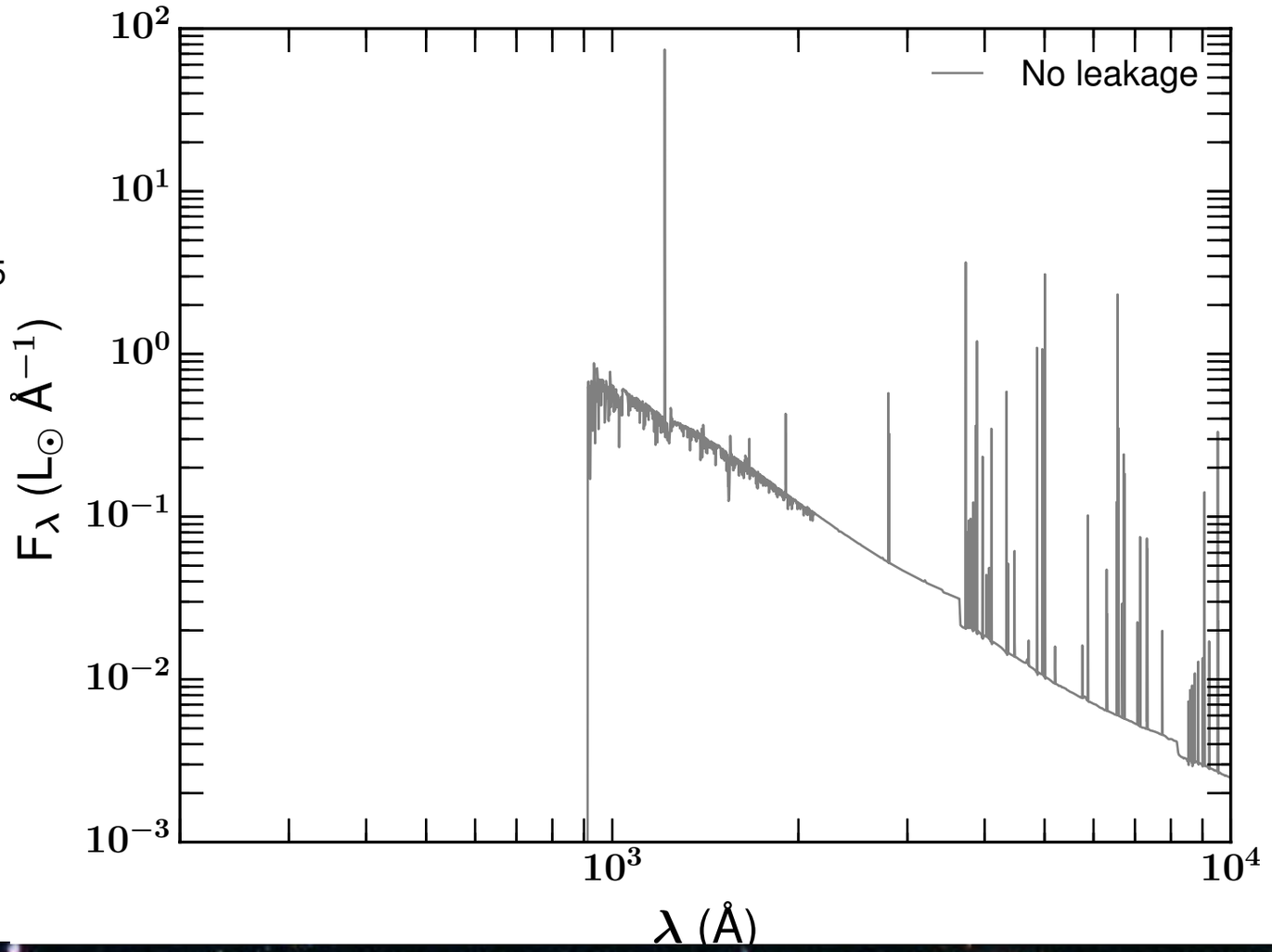
Interpret Observations



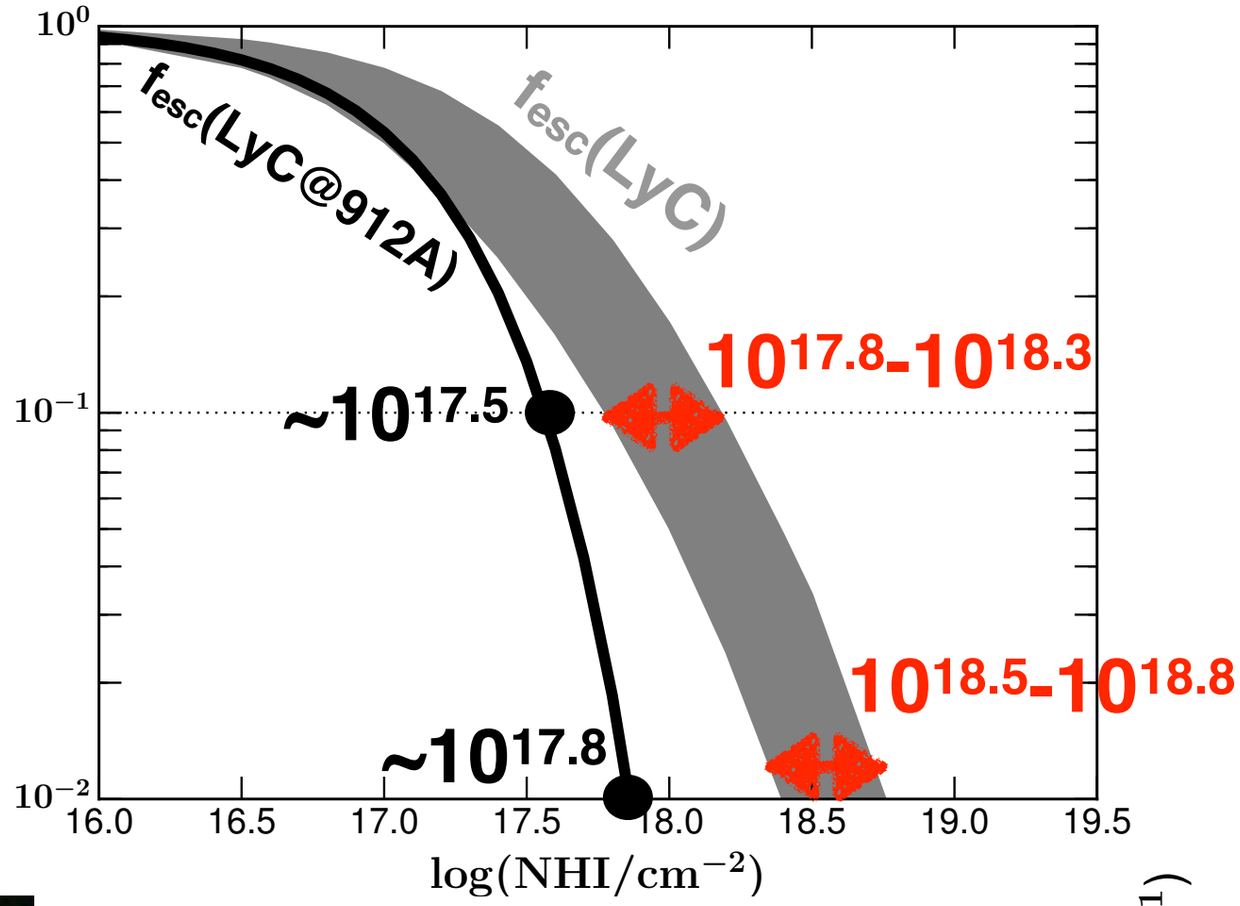
De Barros, Oesch, GREATS+18

Revisiting log(NHI) vs. f_{esc}(LyC)



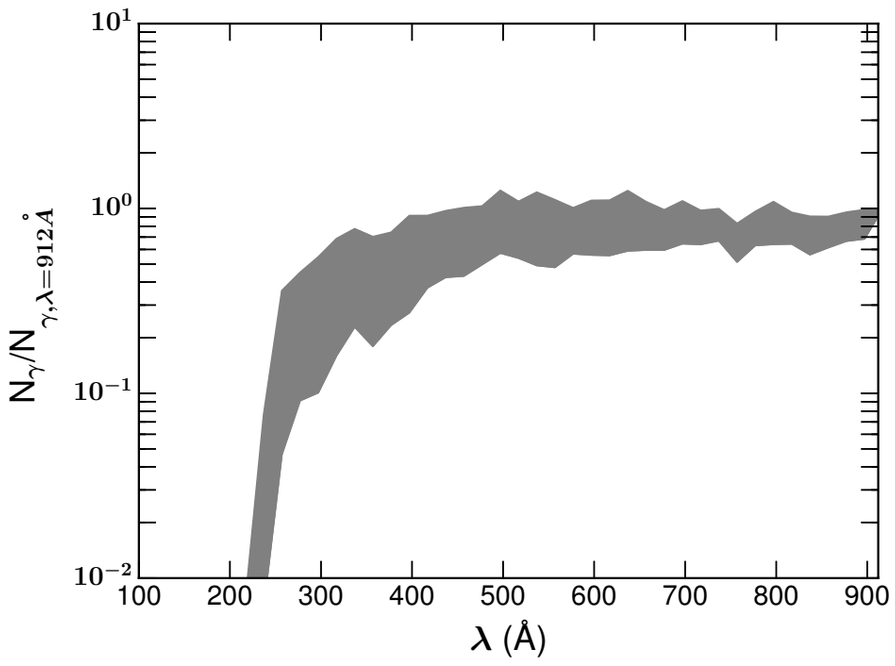


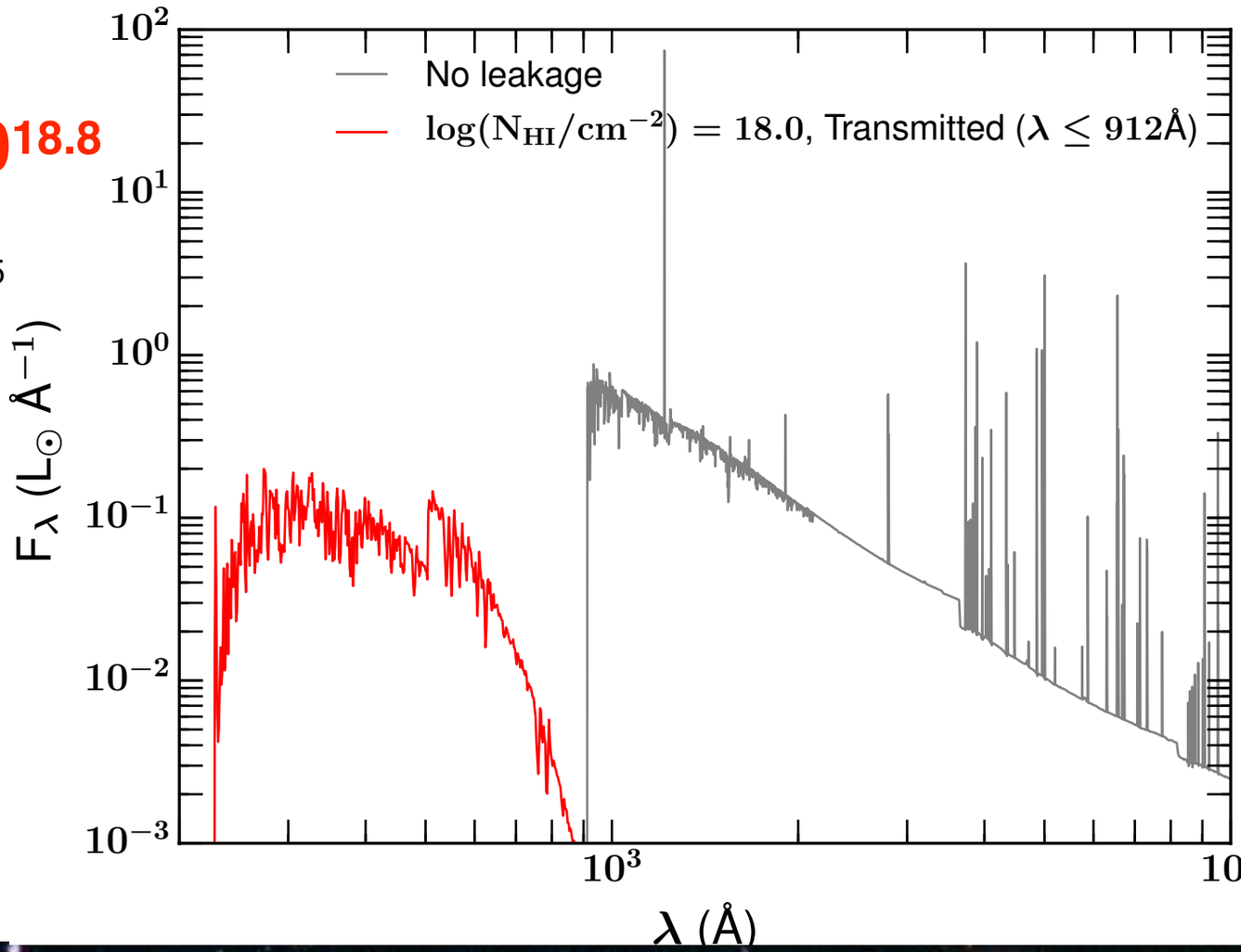
Revisiting log(NHI) vs. f_{esc}(LyC)



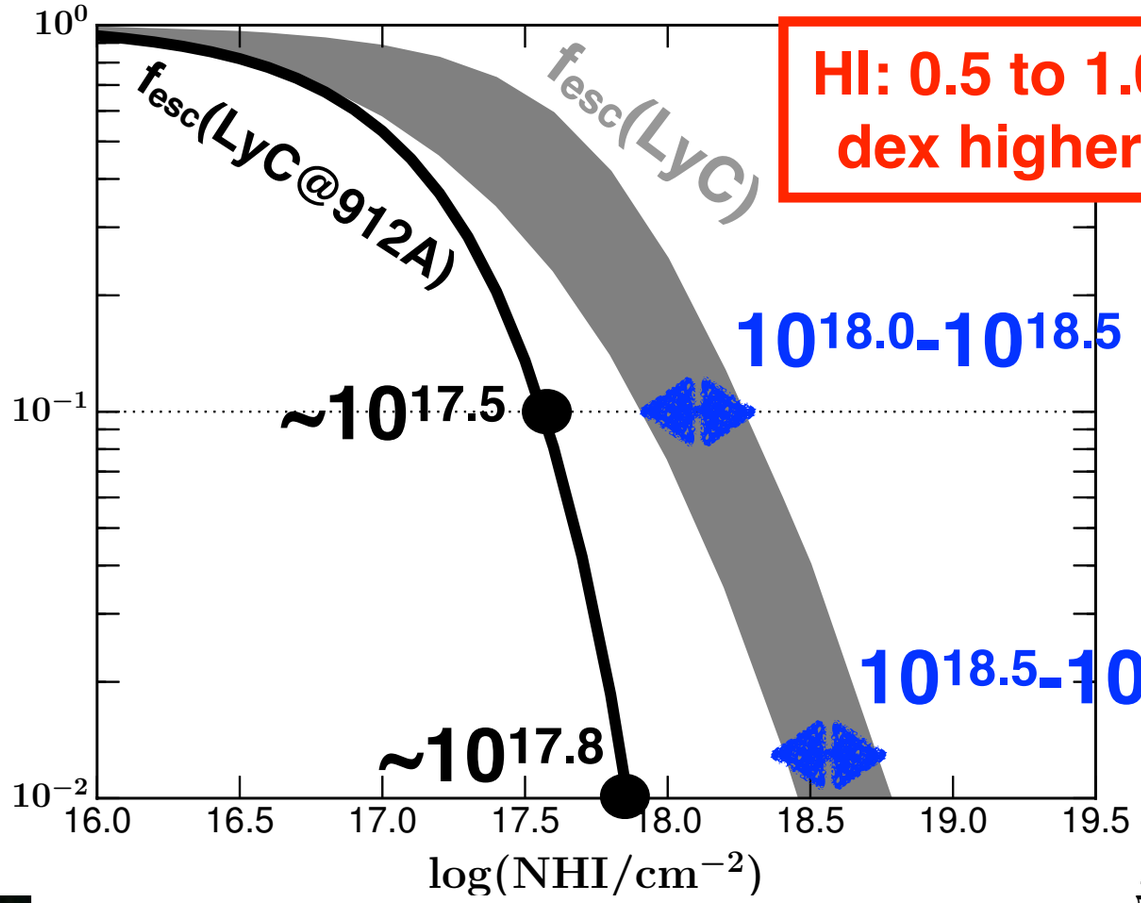
Possible to observe?
K. Saha Talk

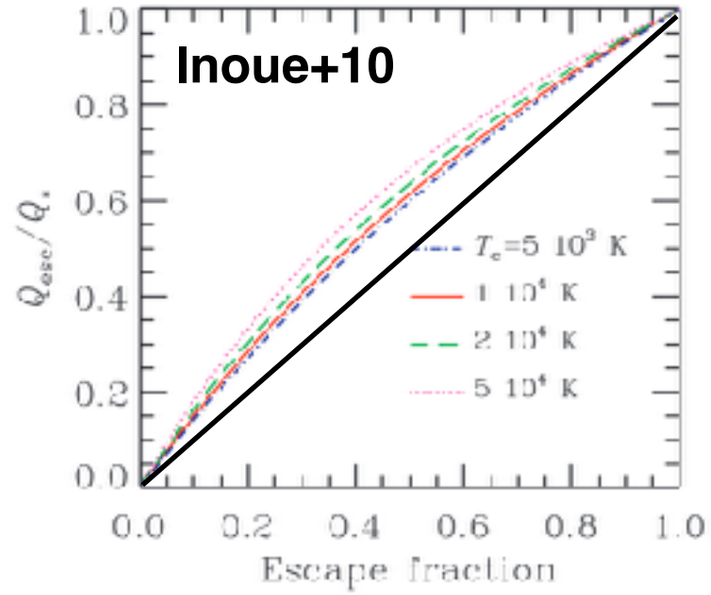
McCandliss+17 (M. Hayes Talk)

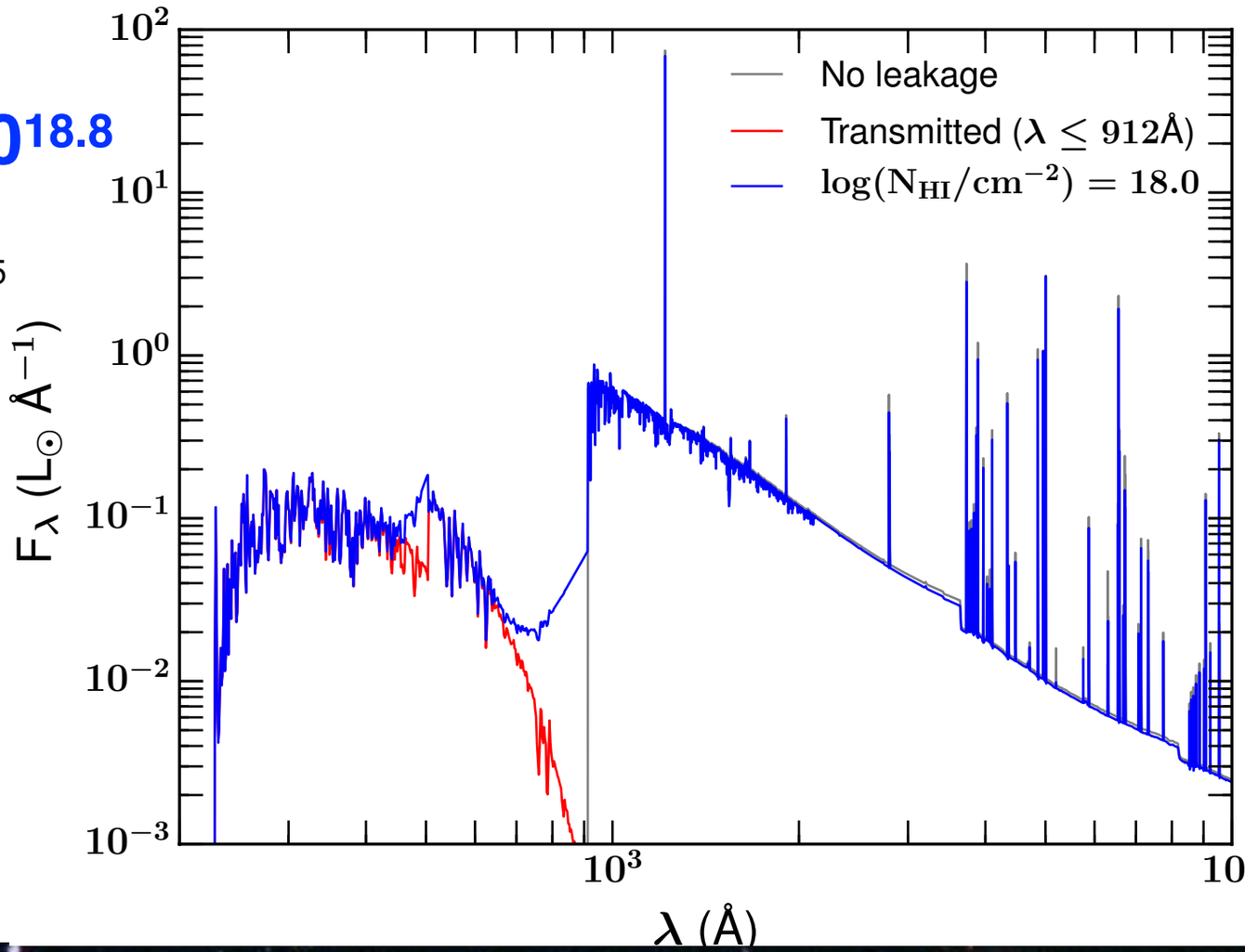




Revisiting log(NHI) vs. f_{esc}(LyC)







"On-the-spot" approximation: underestimates "effective" f_{esc}(LyC) (G. Östlin talk)

Revisiting log(NHI) vs. f_{esc}(LyC)

Steidel+18

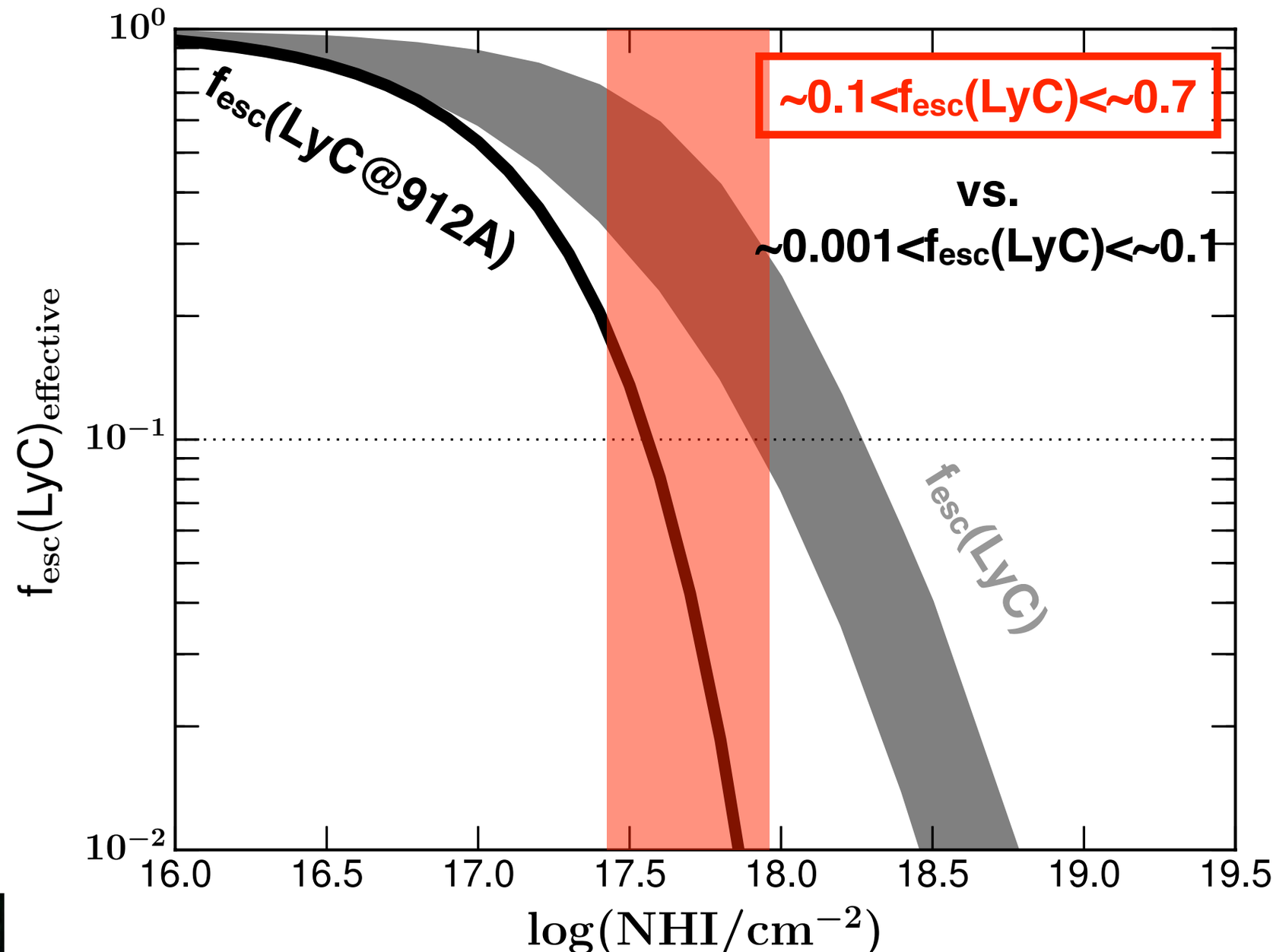
Table 9
ISM Fit Results: Screen Model[a]

Sample	Att.	E(B-V)	log(N_{HI}) (cm^{-2})	f_c[b]	$f_{esc,abs}$[c]
All	R16	0.129	20.61	0.70	0.12 ± 0.02
All, detected[d]	SMC	0.045	(17.41)	0.47	0.69 ± 0.04
All, not detected	R16	0.135	20.65	0.75	0.05 ± 0.01

No Lya damping wings +/-0.75

Table 10
ISM Fit Results: Holes Model[a]

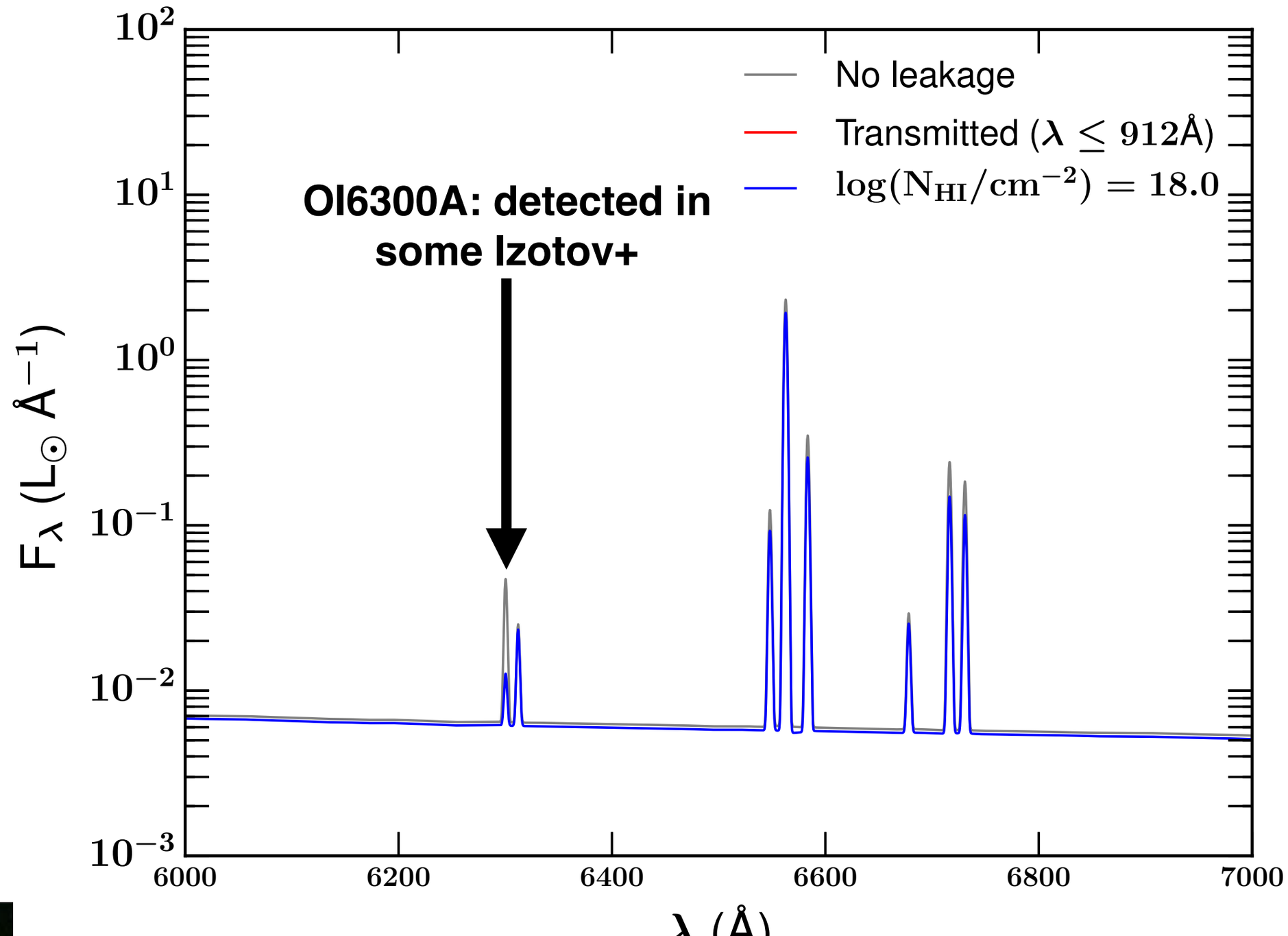
Sample	Att	E(B-V)$_{cov}$	log(N_{HI}) (cm^{-2})	f_c[b]	$f_{esc,abs}$[c]
All	SMC	0.068	20.57	0.91	0.09 ± 0.01
All, detected[d]	SMC	0.085	(17.9)	0.80	0.31 ± 0.03
All, not detected	R16	0.163	20.60	0.95	0.05 ± 0.01



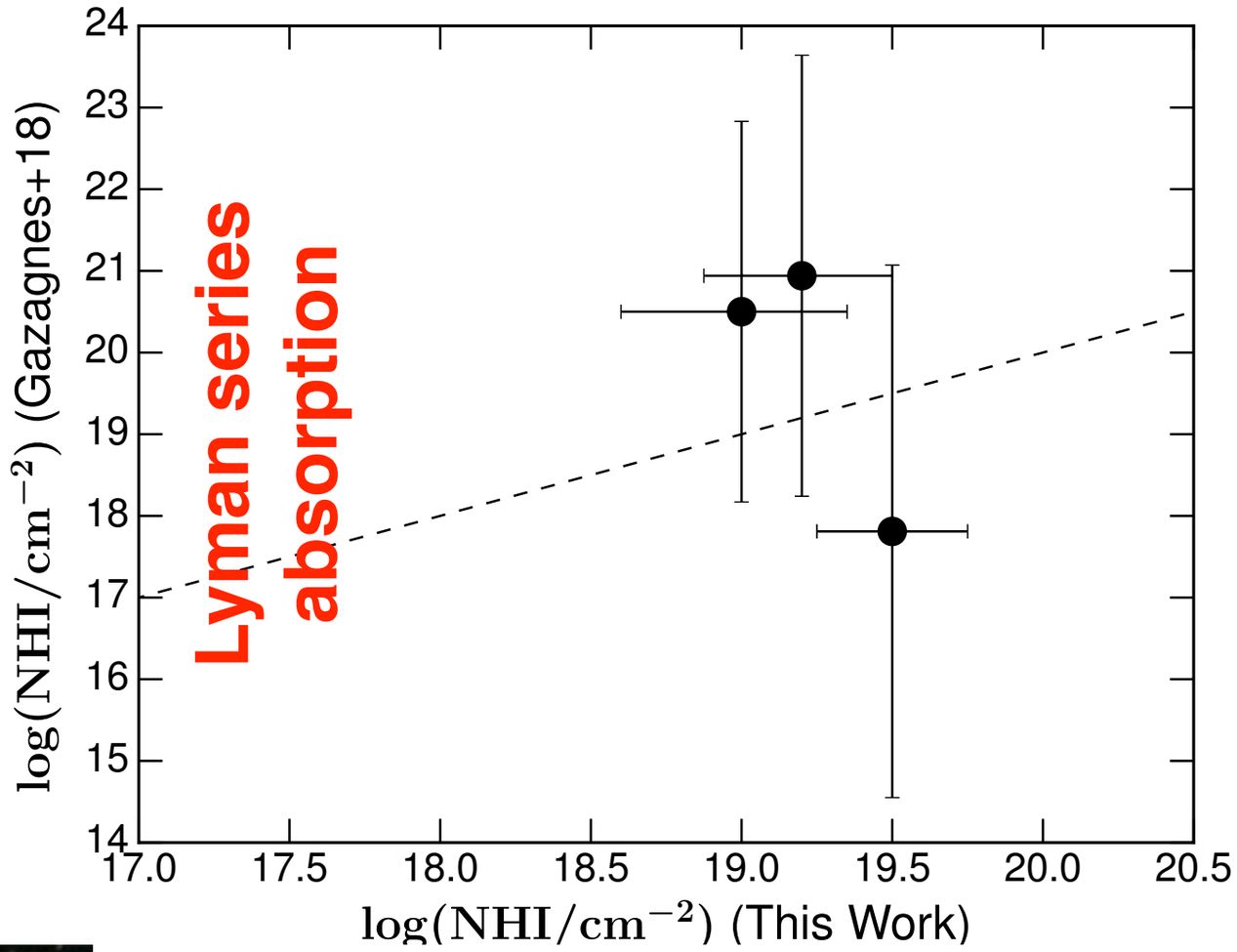
HI Column Density From Nebular Lines

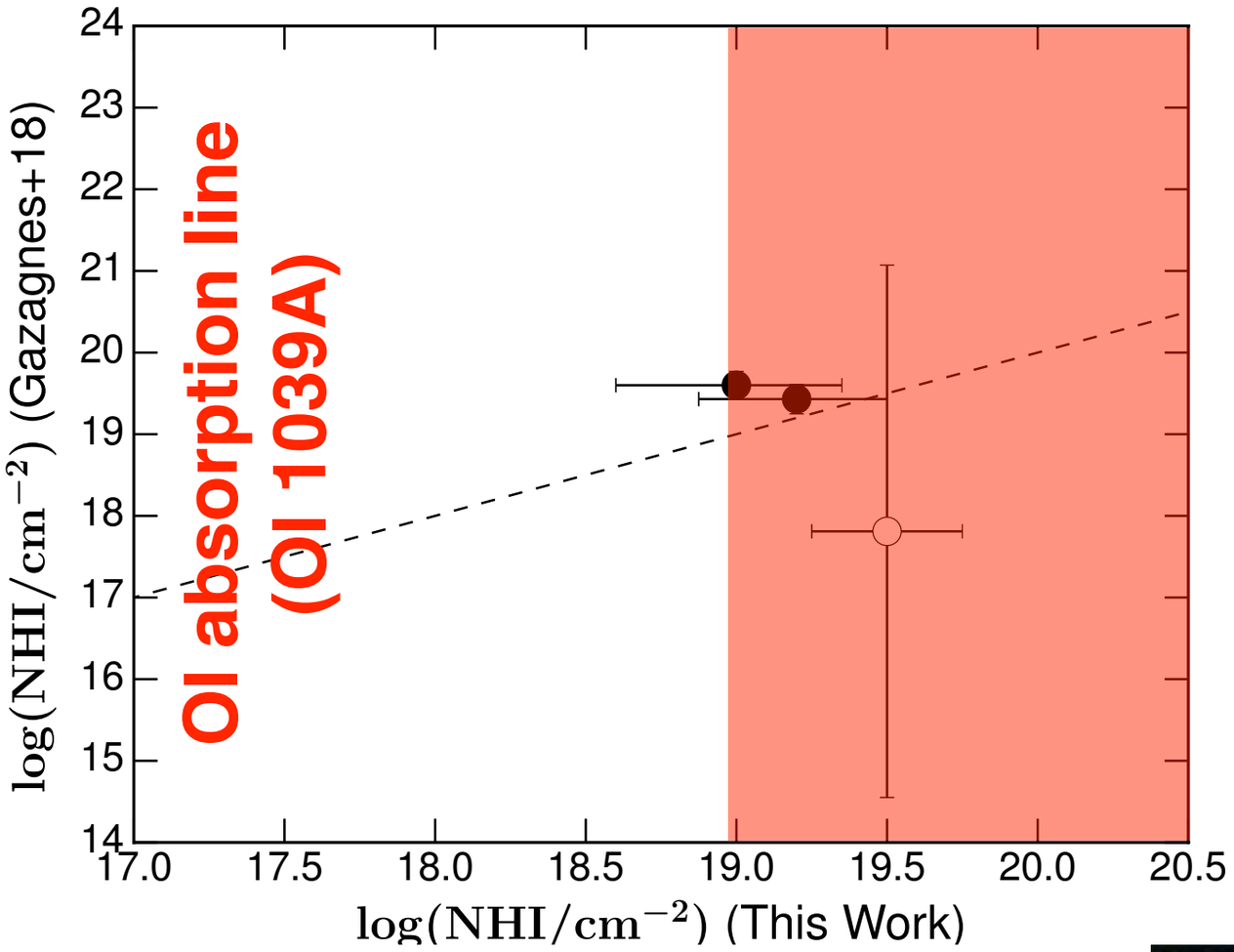
We use a “HII-CHI-MISTRY” like approach (Perez-Montero 2014):

- Use all nebular emission lines available
- Chi2 minimisation over the entire photoionization grid



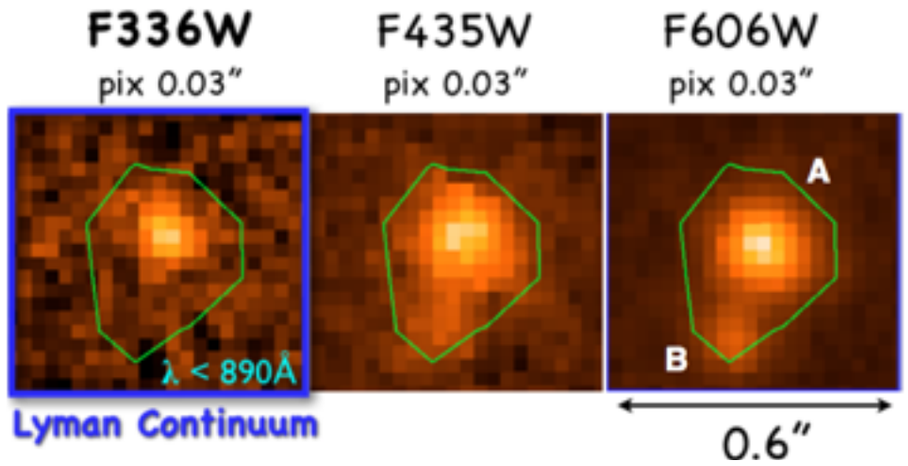
HI Column Density From Nebular Lines



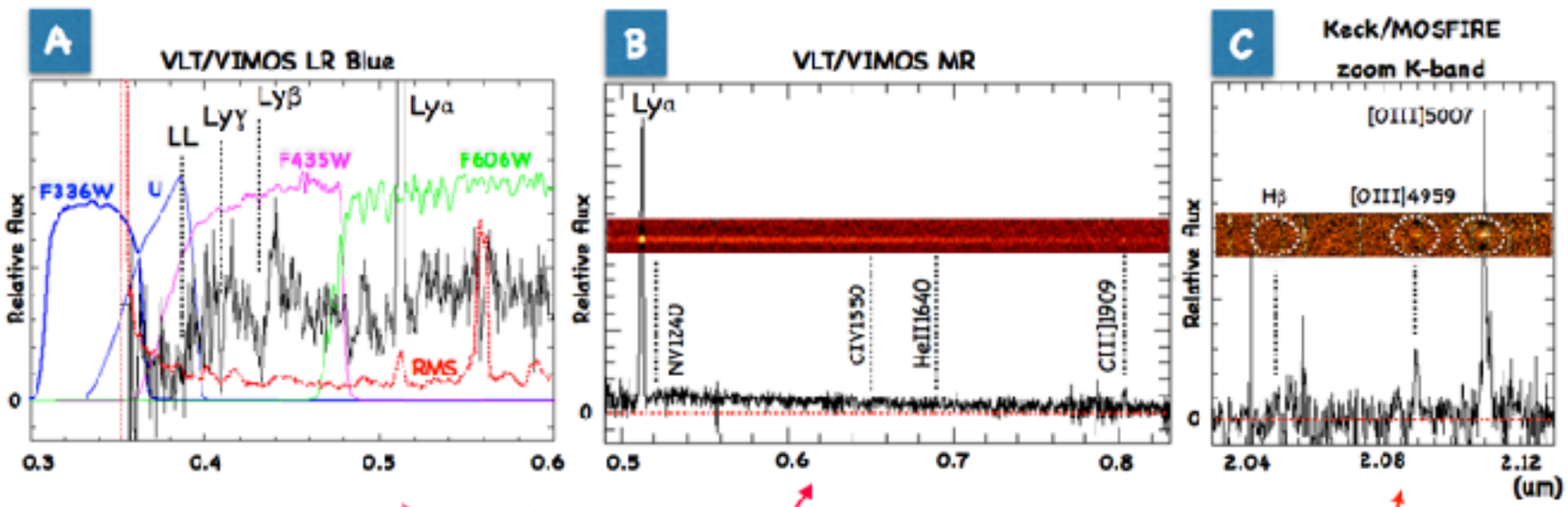


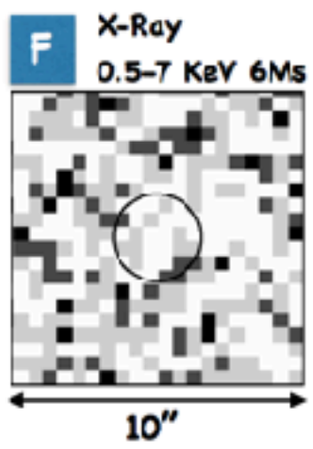
OIII/OII ratio fitted simultaneously…
No link to density bounded nebulae

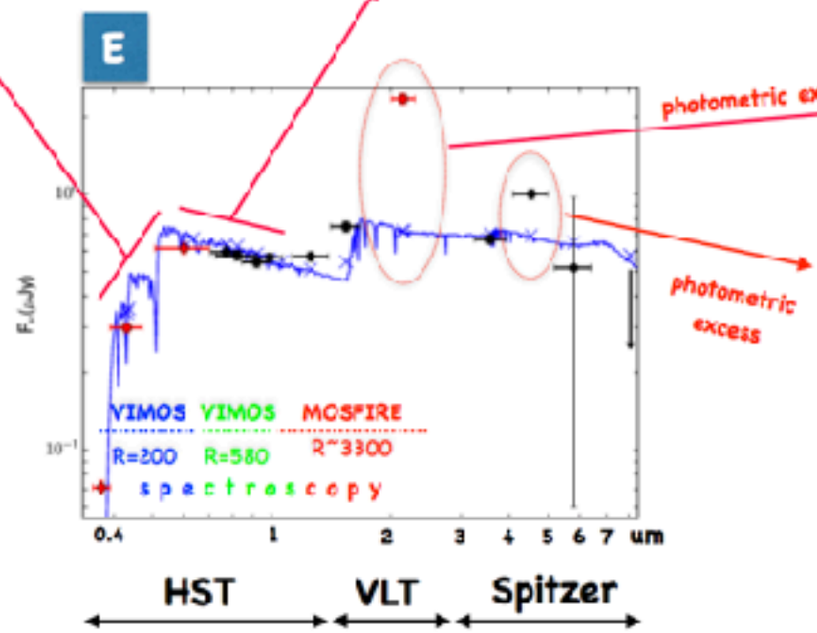
HI Column Density From Nebular Lines



Ion2, z=3.2
Lya, CIII, <CIV, Hb, OIII/OII…
No constraints on HI… yet
X-Shooter in few weeks







D

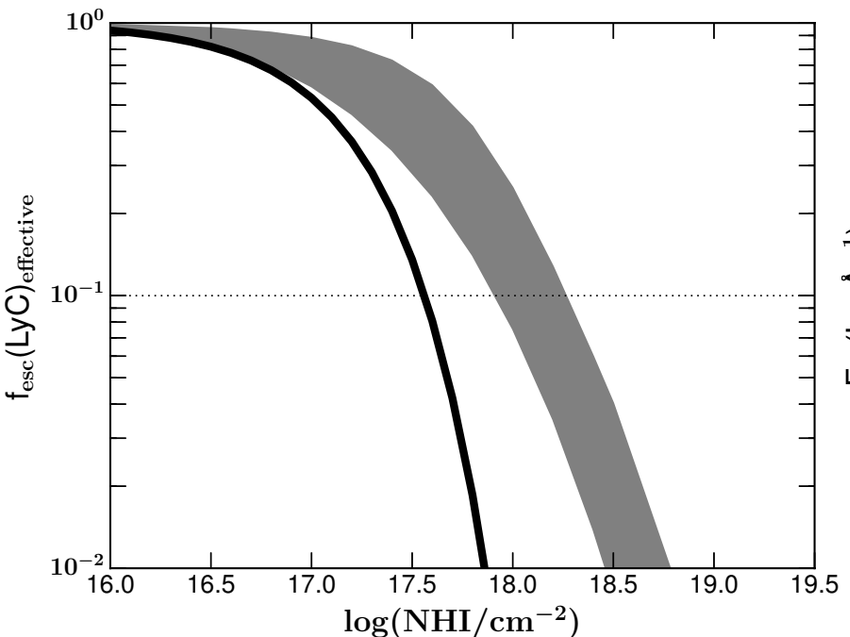
JWST
will capture Ha and HeI

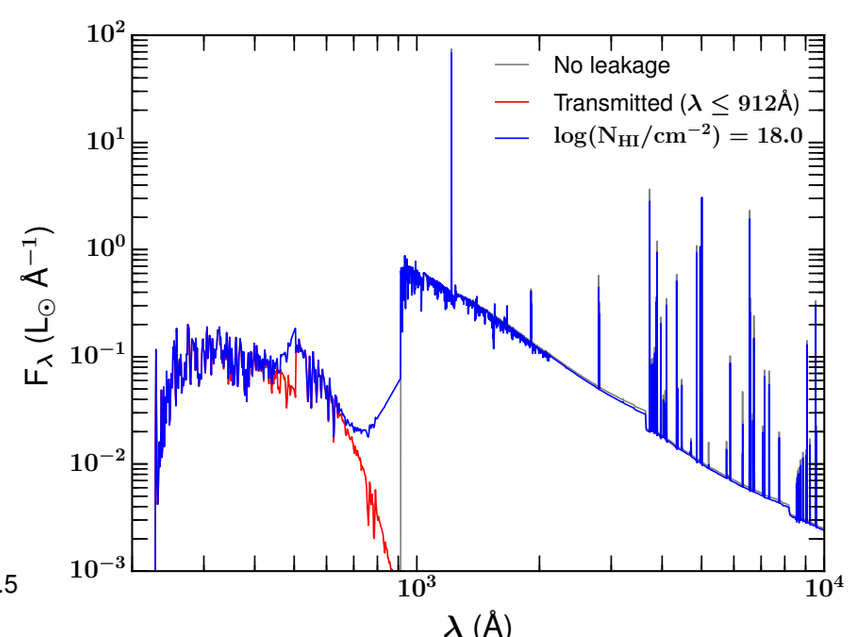
HeI 10830 + Pγ @ 4.5um ?

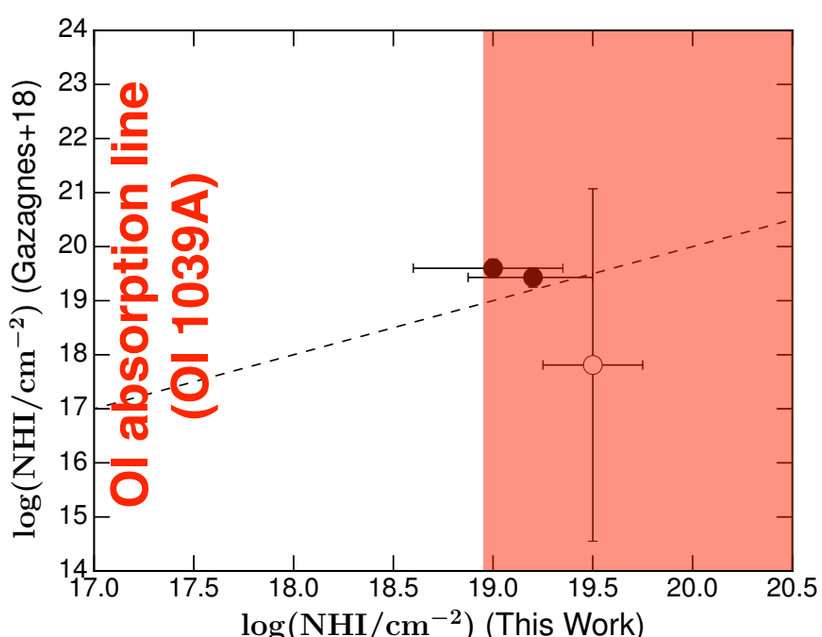
Vanzella+15,16
De Barros+16

Summary

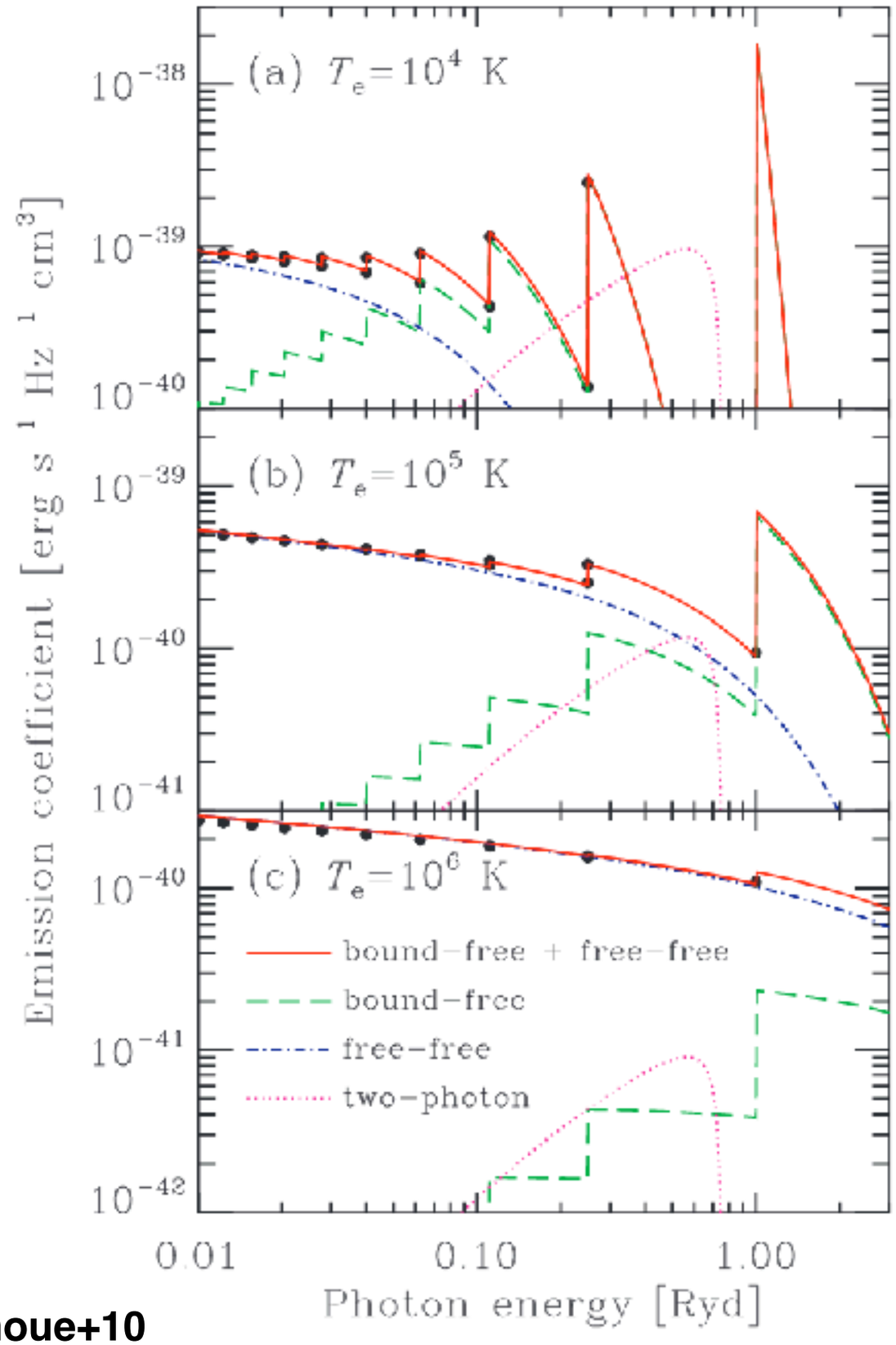
- Diagnostics not consistent with simple frameworks
- “High” HI column density can allow some ionizing photons to escape
- Possible to derive HI column density from nebular lines with OI6300A: results consistent with Gazagnes+18, Chisholm+18
- Large OIII/OII not related to density bounded nebulae? Indirect link? Any hope to find diagnostic for JWST to apply to faint galaxies?







Cloud Emission: Energy Distribution



Inoue+10

Bound-free + free-free: range of possible energy >13.6eV