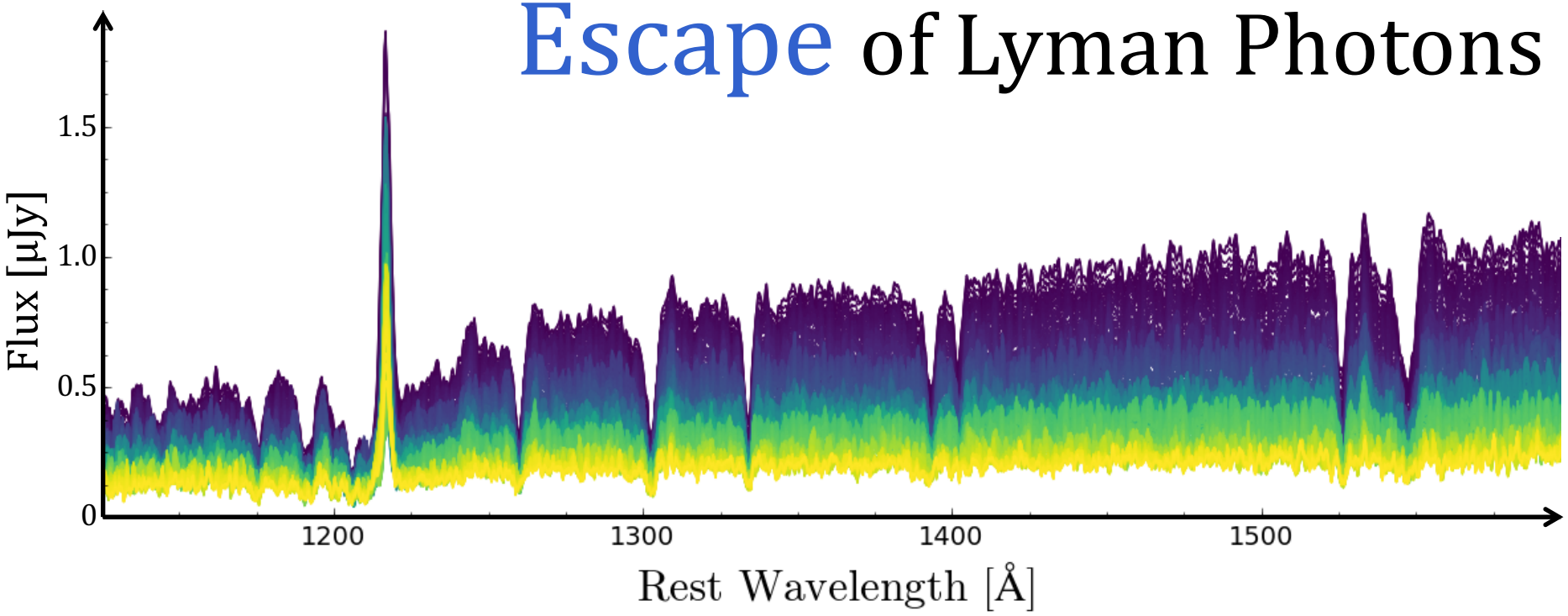
Decoupling the Production and Escape of Lyman Photons



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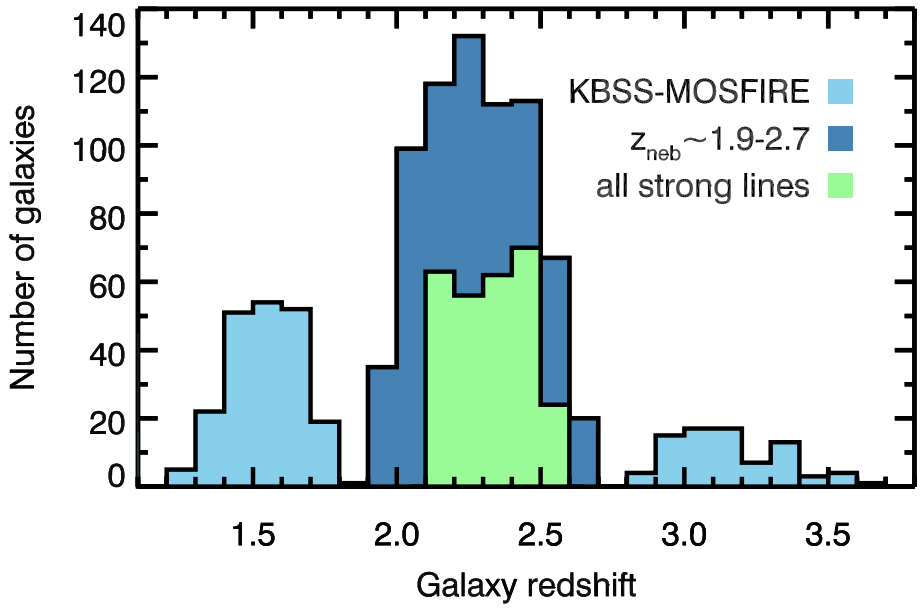
Escape of Lyman radiation from galactic labyrinths
13 September 2018, OAC, Kolymbari, Crete

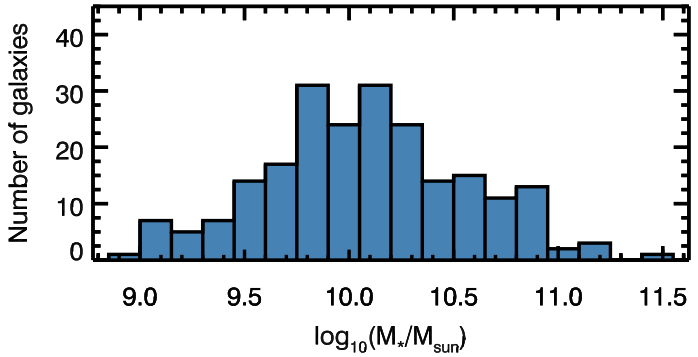
outline

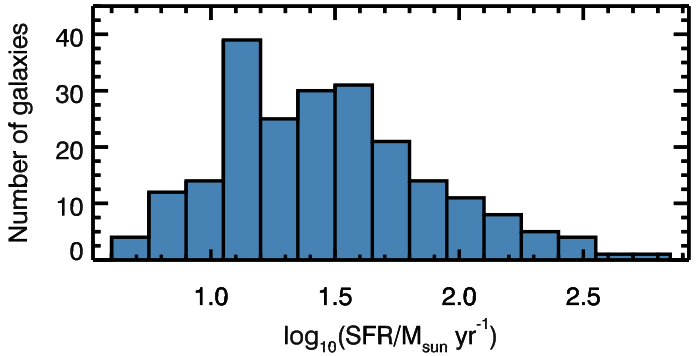
1. Empirical trends of **Lyα** emission vs. proxies for production & escape (8 minutes)
2. **Spatially resolved** Lyα emission (2 minutes)
3. Interpreting ionizing emission from high-z galaxies (4 minutes)

Keck Baryonic Structure Survey

- **KBSS** includes 1000+ LBGs at z ≈ 2-3 with UV+Opt spec
  - $L \approx L_*$ galaxies, log $M_* \approx 9.5$–11.5, $M_{UV} \approx 20.5$
  - Rudie+ 2012; RFT+ 2012; Steidel+ 2014, 2016; **Strom+ 2017**





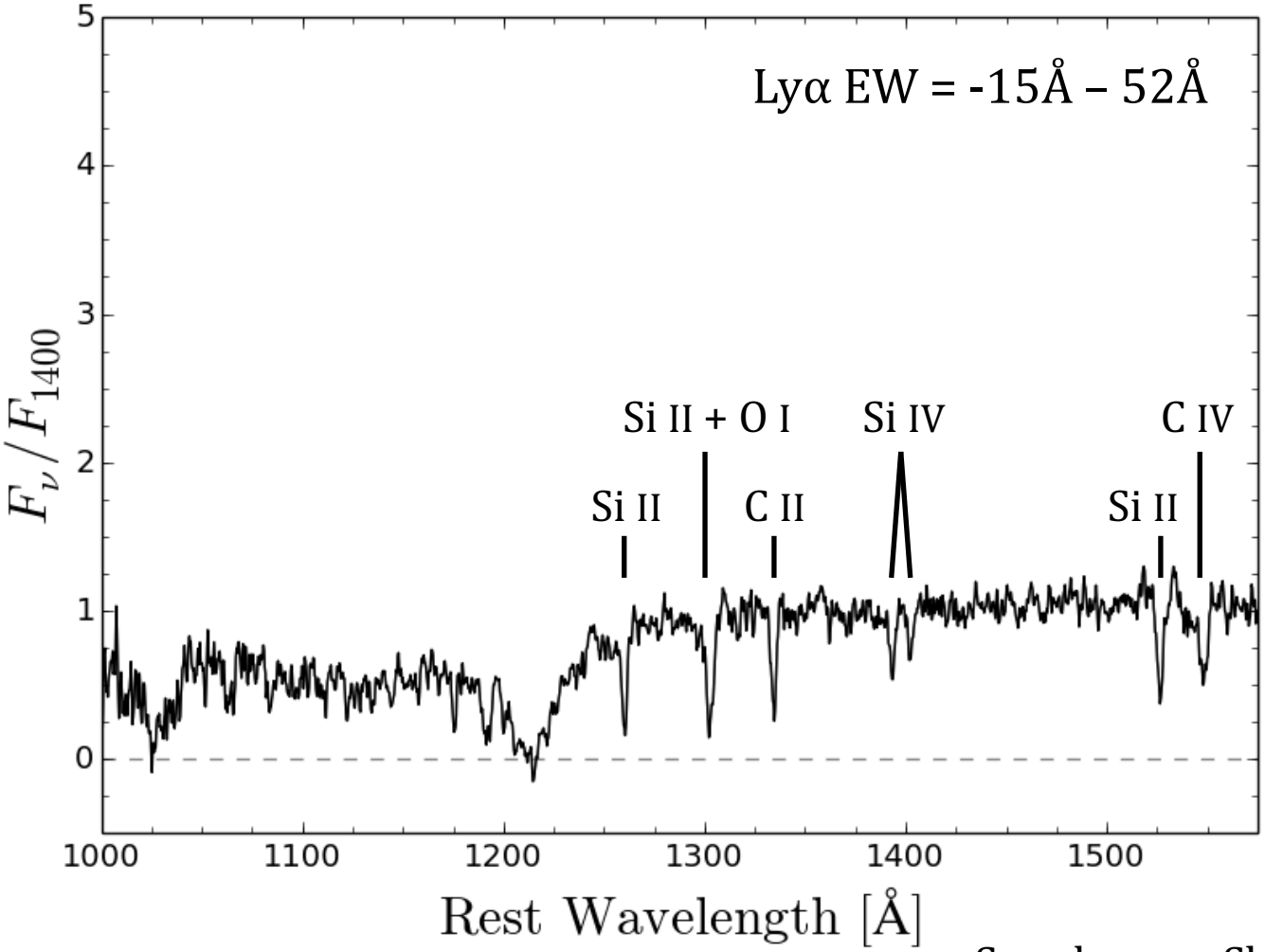


~1000 galaxies with Lyα (LRIS) and rest-optical spectra (MOSFIRE)

Strom+ 2017

LIS absorption suggests ISM porosity

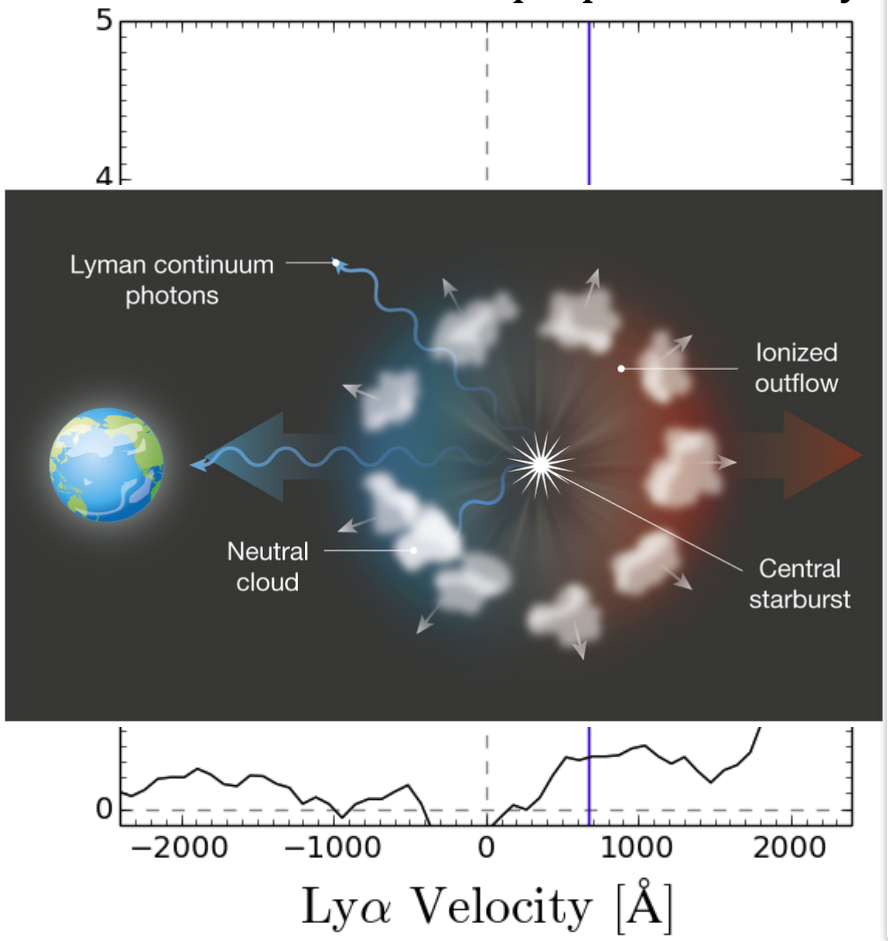
Data from RFT+ in prep, stacks in Lyα EW (50 spectra per frame)



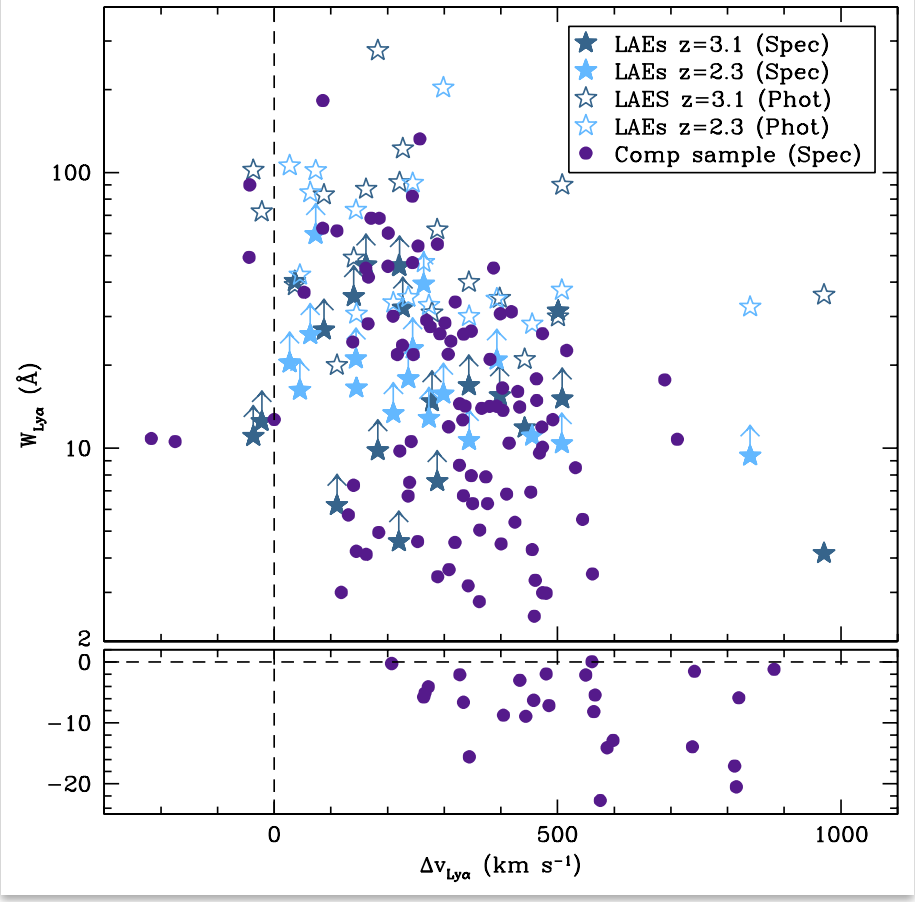
See also e.g., Shapley+ 2003

LIS absorption suggests ISM porosity

Data from RFT+ in prep, stacks in Lya

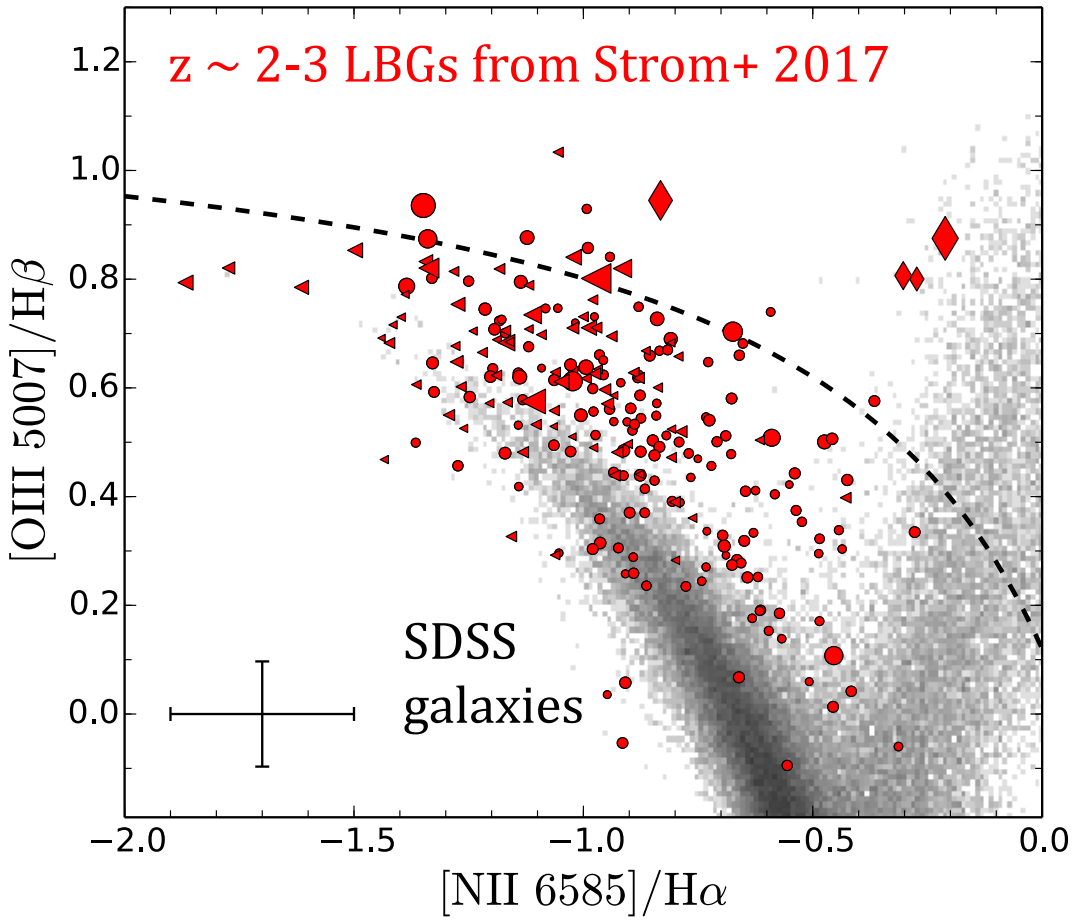


Erb, Steidel, RFT+ 2014



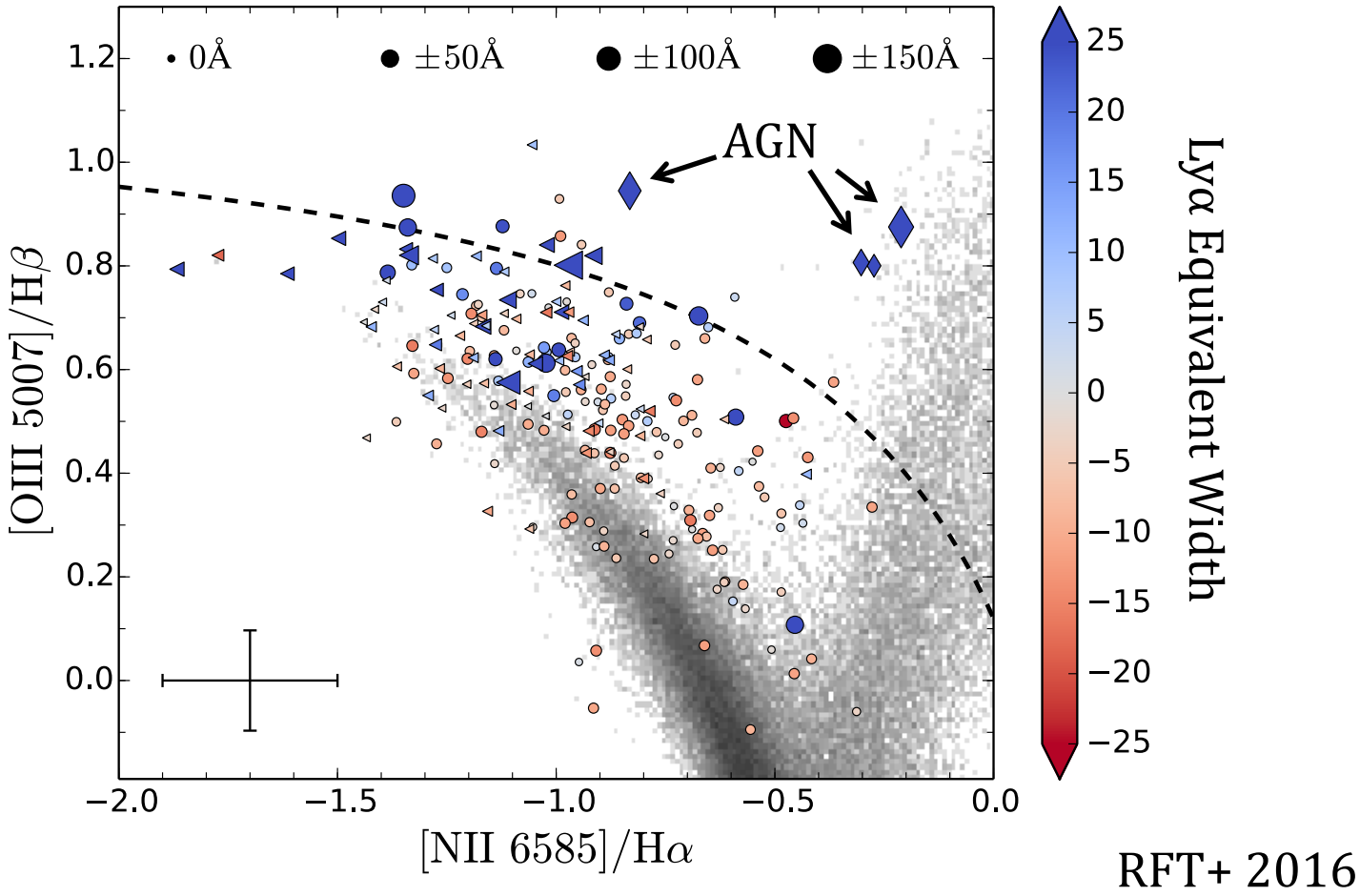
See also e.g., Shapley+ 2003; Steidel+ 2010; Erb, Steidel, RFT+ 2014; c.f. Henry+ 2015

BPT-Lyα relation



See also: Steidel+ 2014, Shapley+ 2015, Sanders+ 2015

BPT-Lyα relation

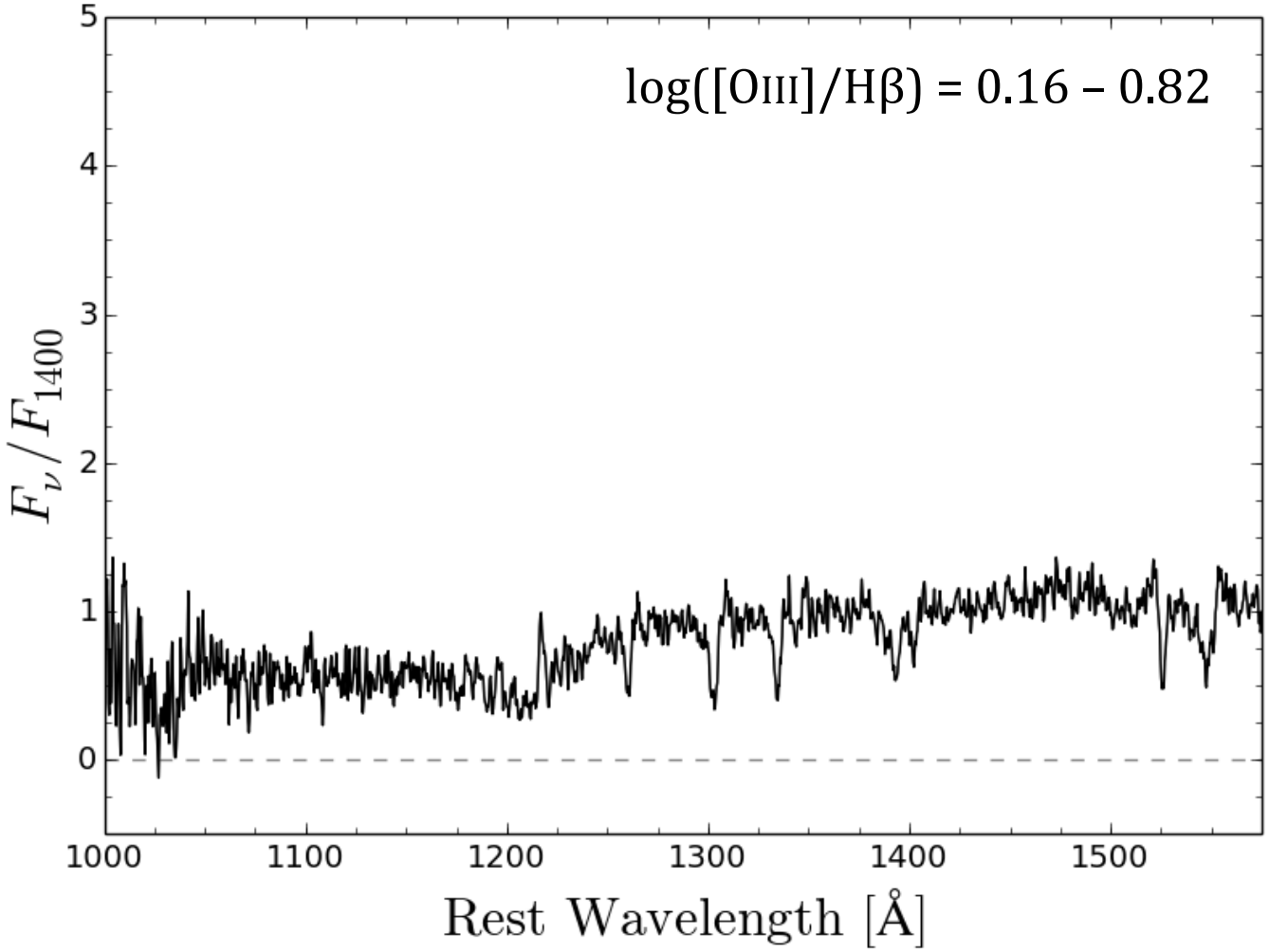


RFT+ 2016

See also: Hagen+2016, Erb+ 2016, Nakajima+2013

Lyα tracks [OIII]/Hβ (nebular excitation)

Data from RFT+ 2016, stacks in OIII/Hβ (50 spectra per frame)



Lyα tracks [OIII]/Hβ (nebular excitation)

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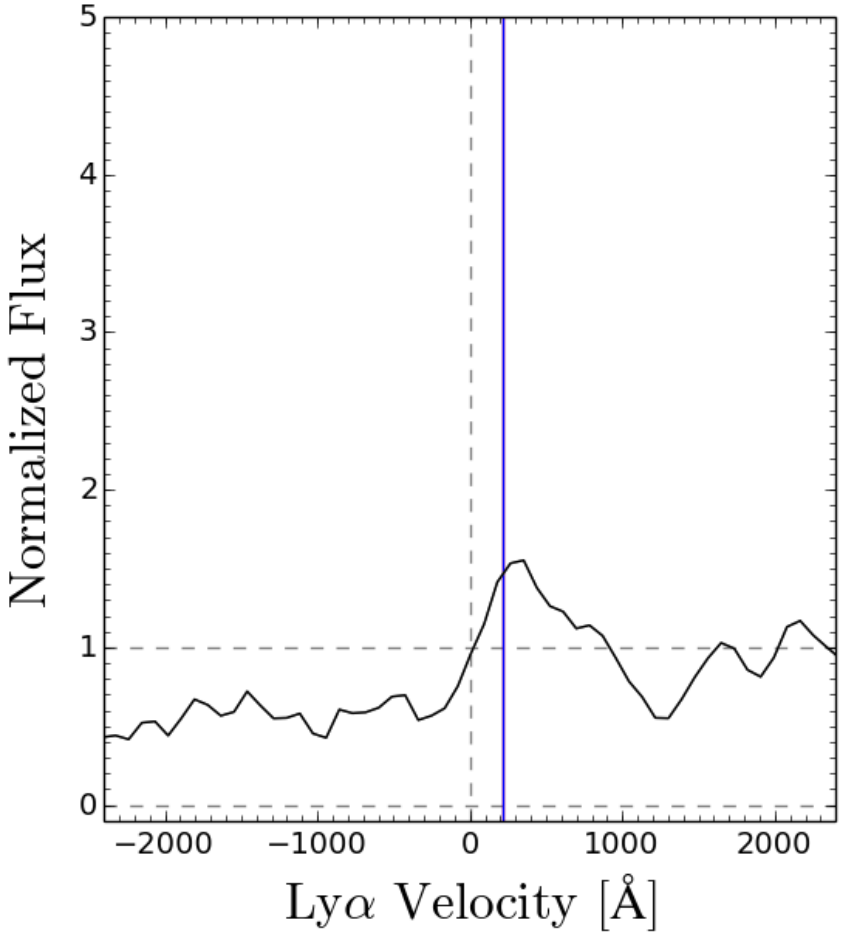
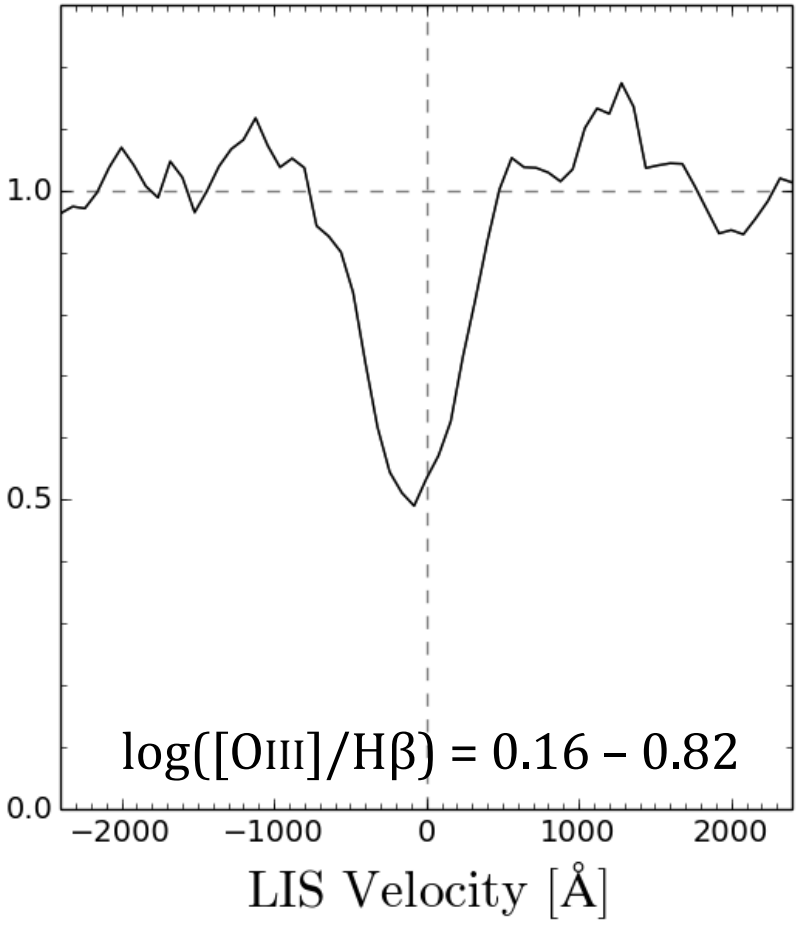
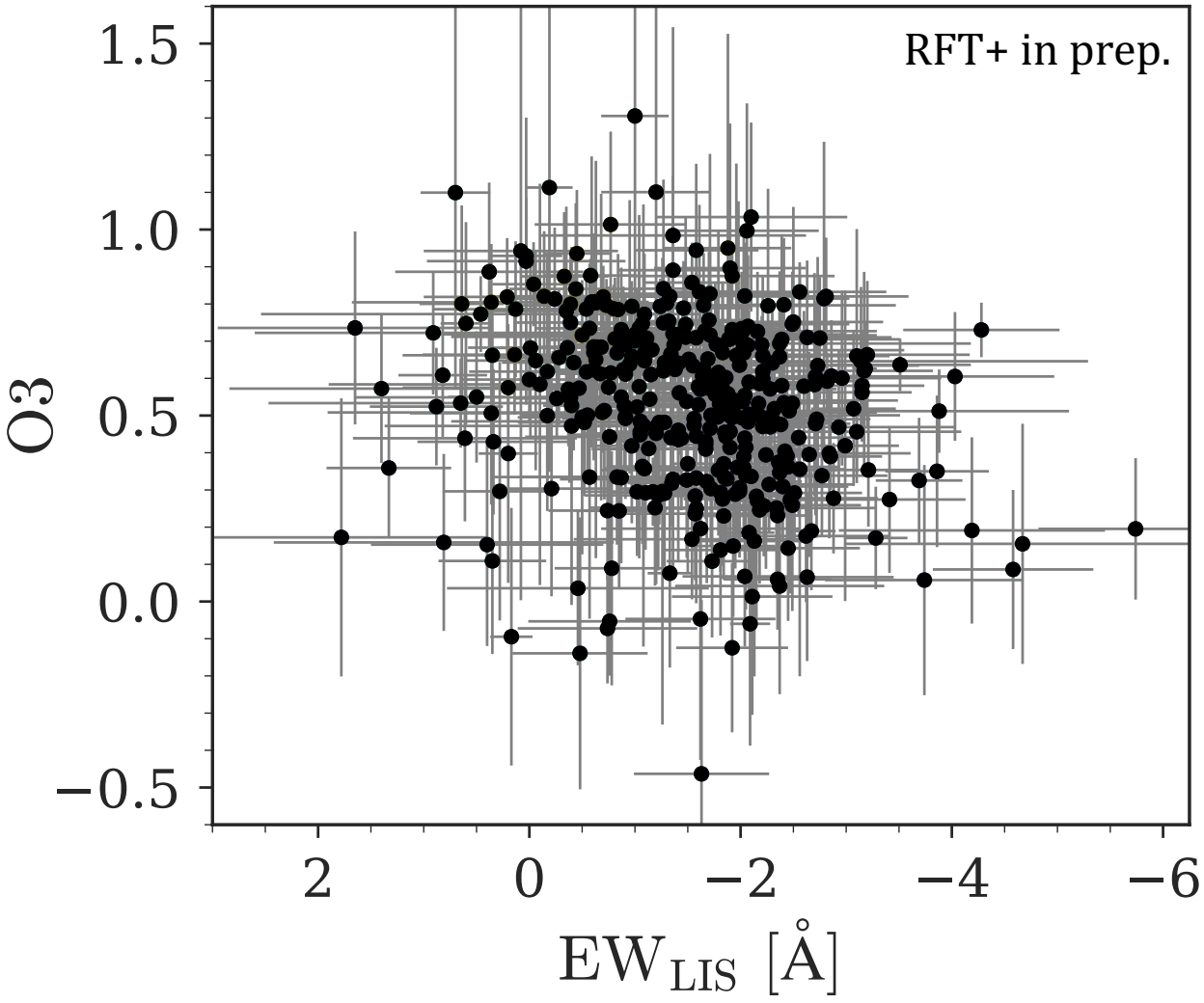


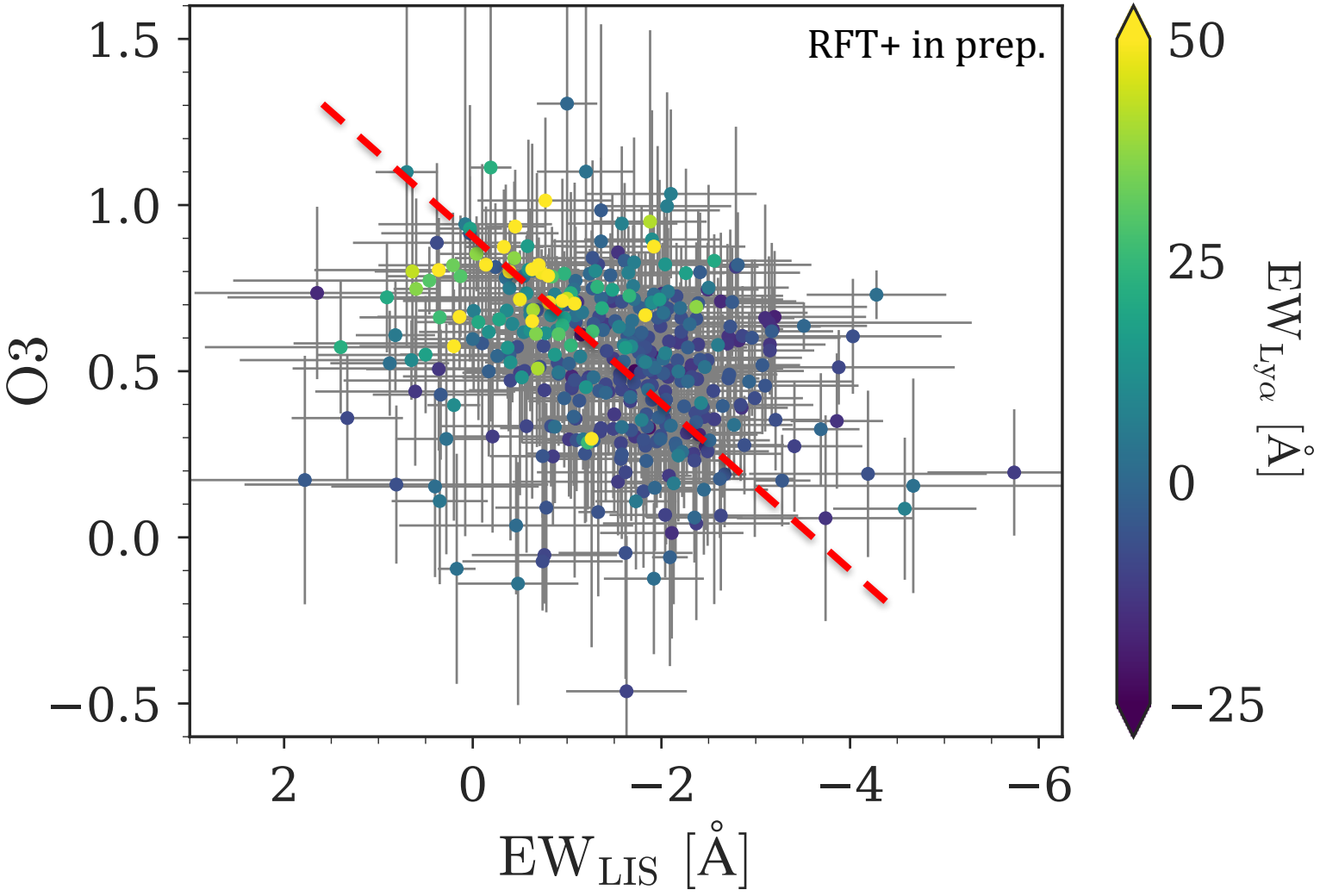


See discussion in RFT+ 2016

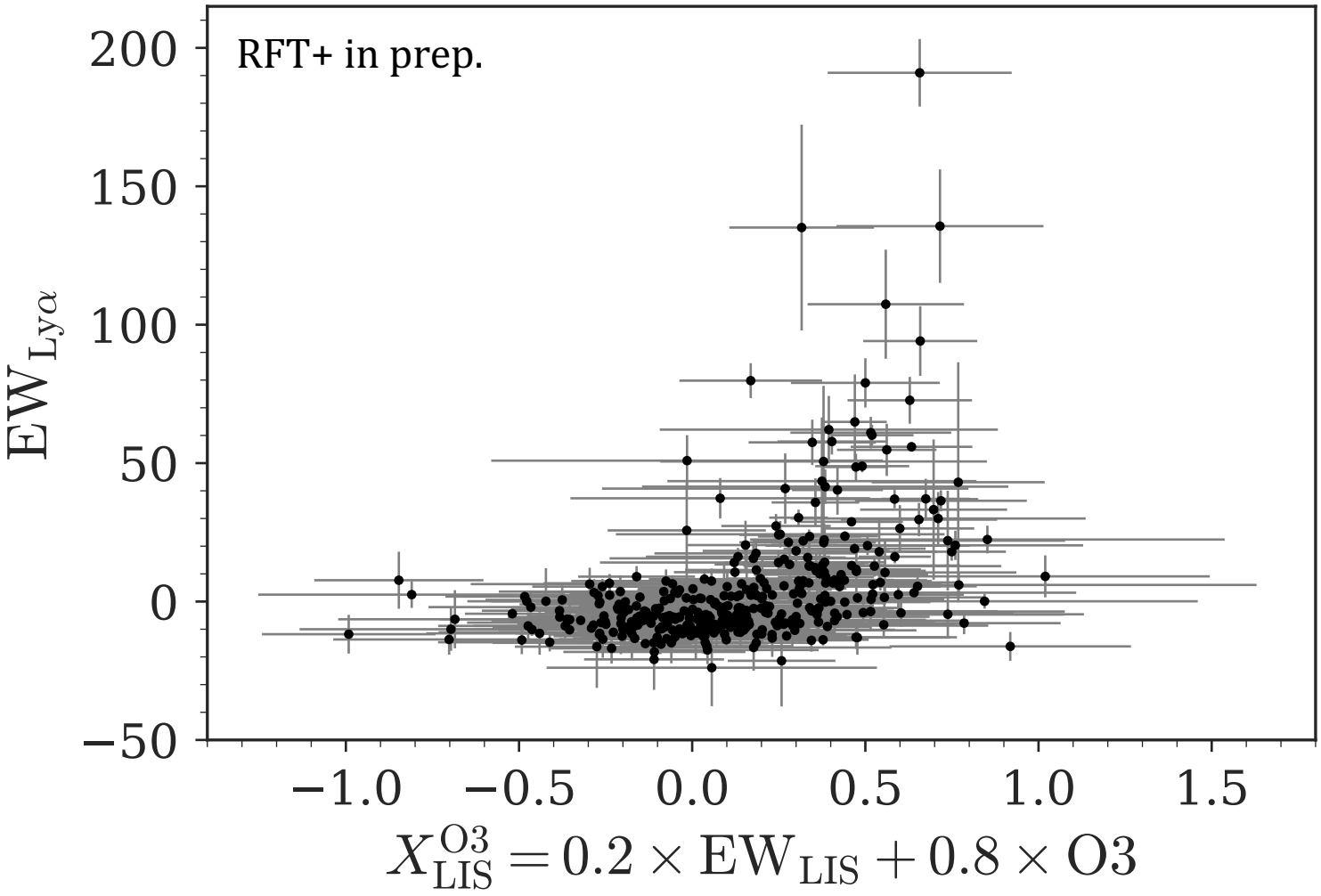
production vs. escape



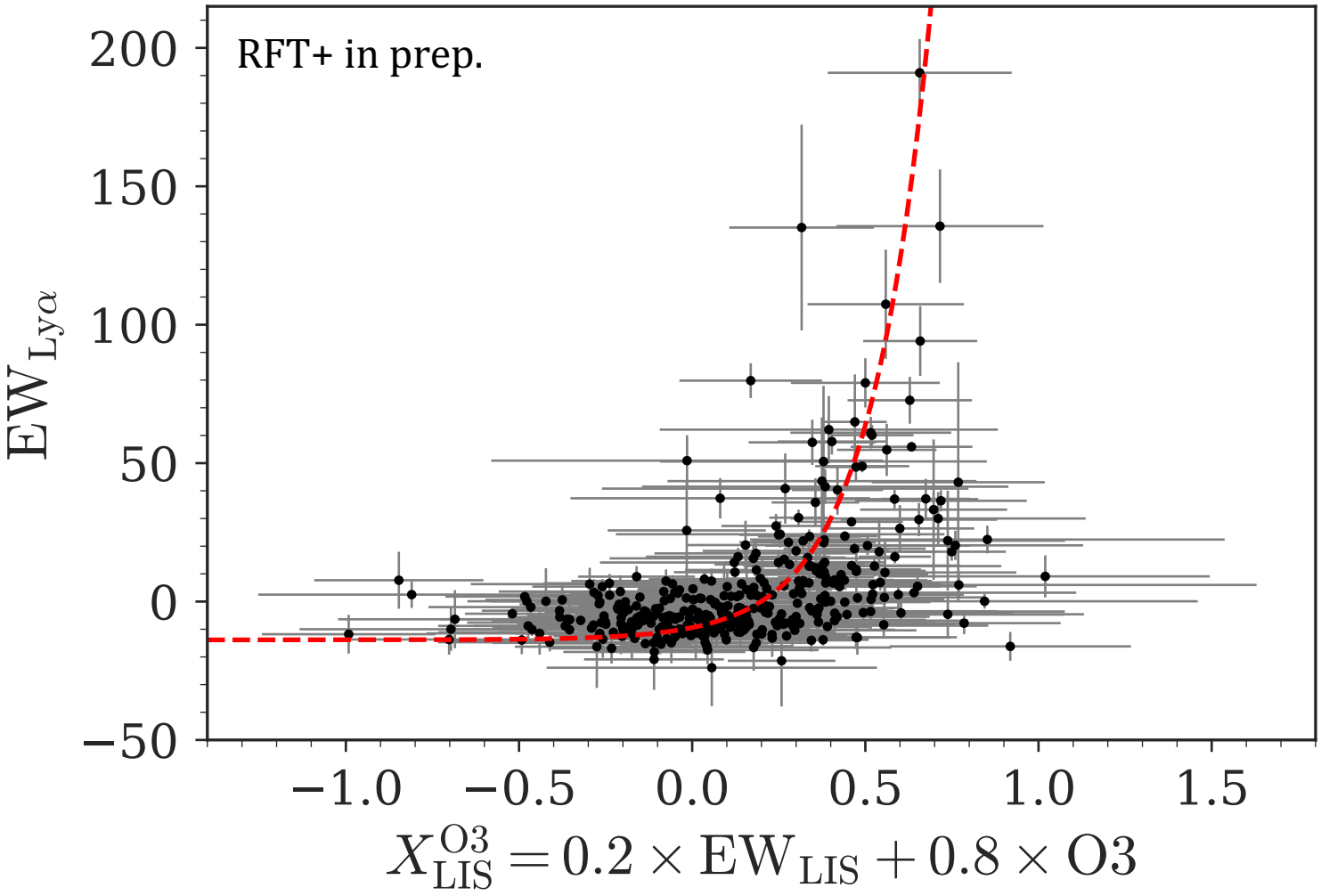
production vs. escape



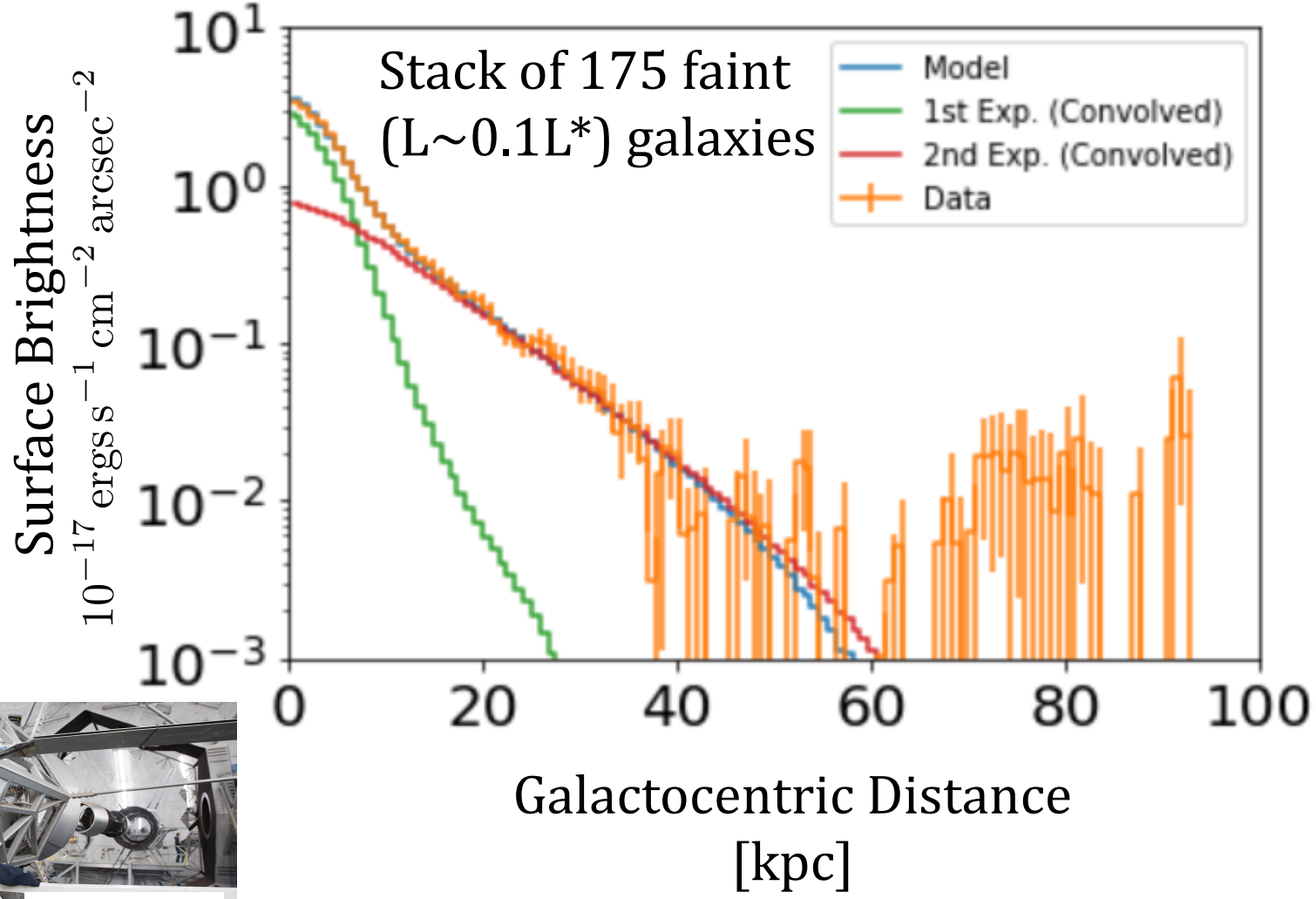
Lyα vs. production+escape

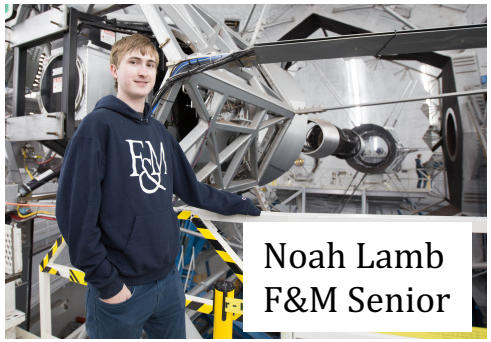


Lyα vs. production+escape

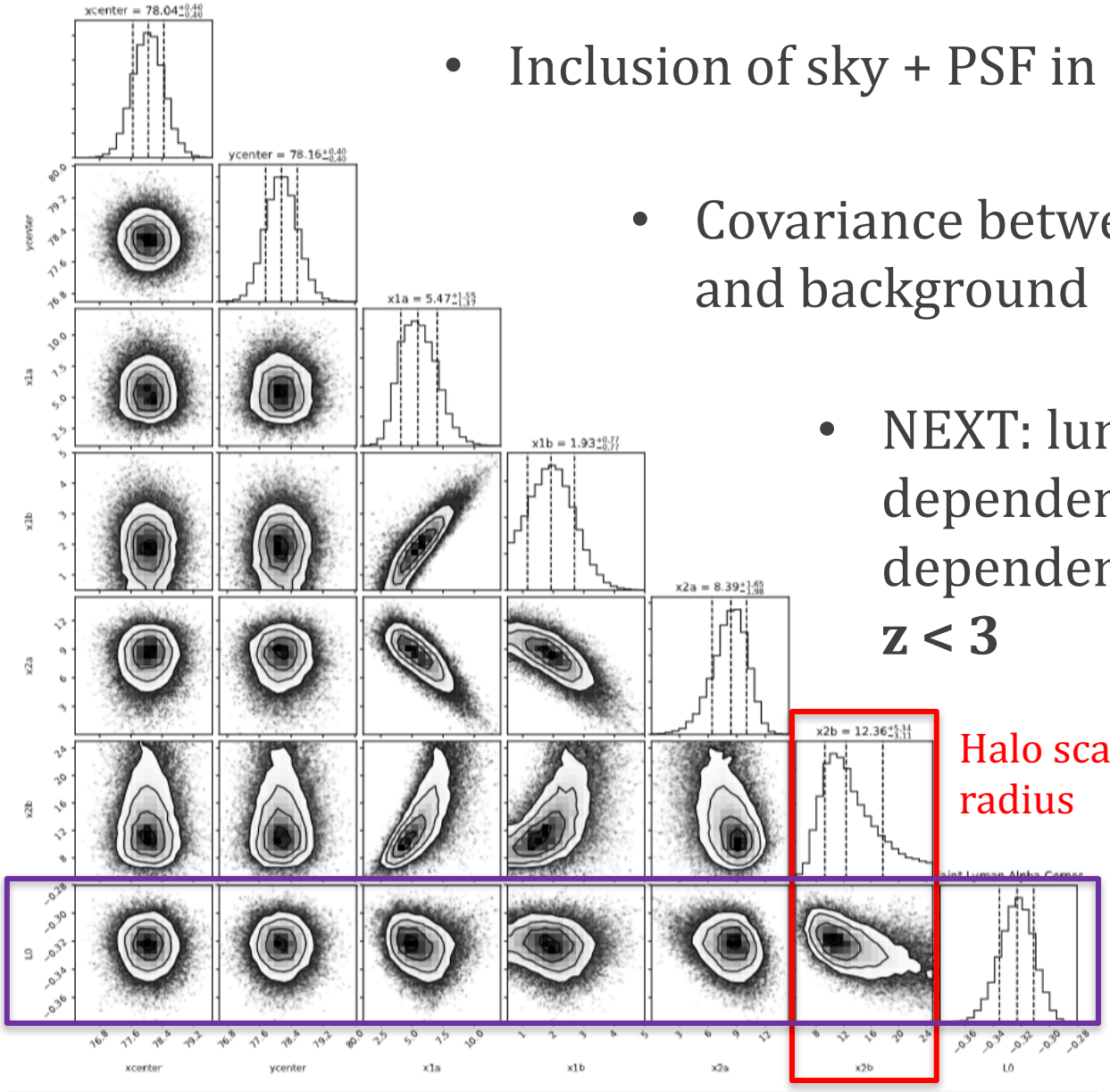


fitting Lyα halos in stacks





fitting Lyα halos via MCMC



- Inclusion of sky + PSF in halo fitting
- Covariance between scale radius and background
- NEXT: luminosity dependence, environmental dependence, QSO proximity, **z < 3**

Halo scale radius

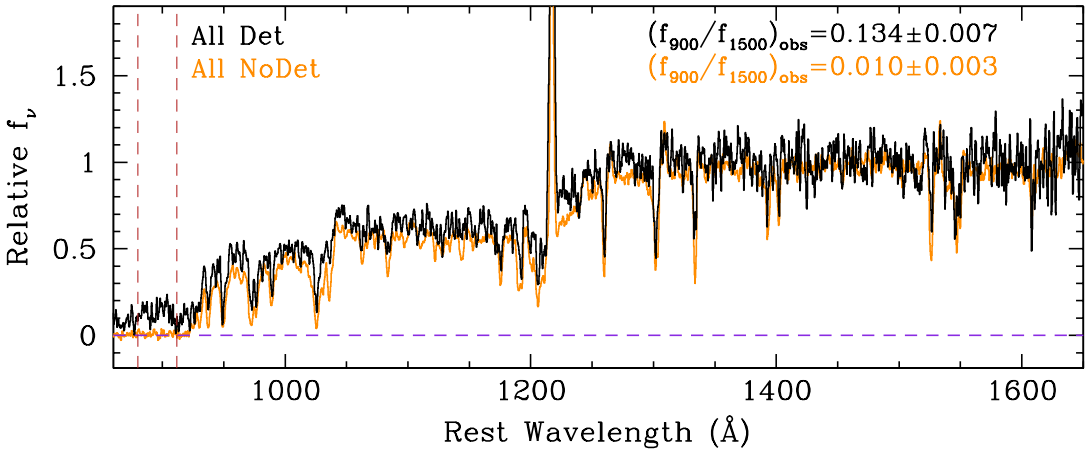
Zero-order sky background

KLCS sample (z ~ 3)

Keck Lyman Continuum Survey

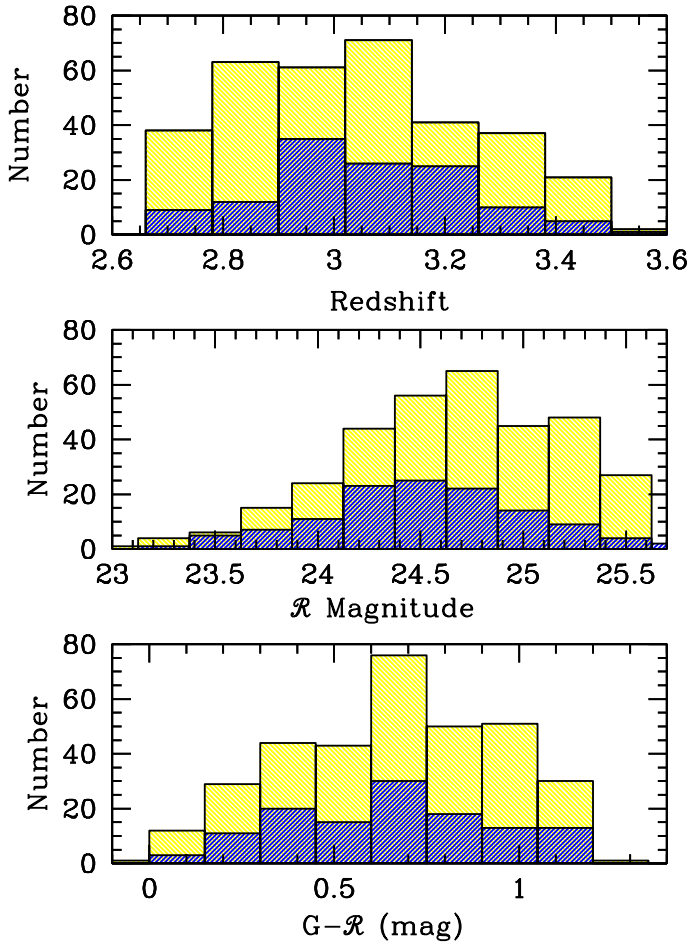
see Shapley+2016, **Steidel+2018**

- 124 galaxies over 9 fields
  - "typical" LBGs
- $-19.5 > M_{UV} > 22.1$
- Rest-frame spectra:
  $880\,\text{Å} < \lambda_0 < 1750\,\text{Å}$



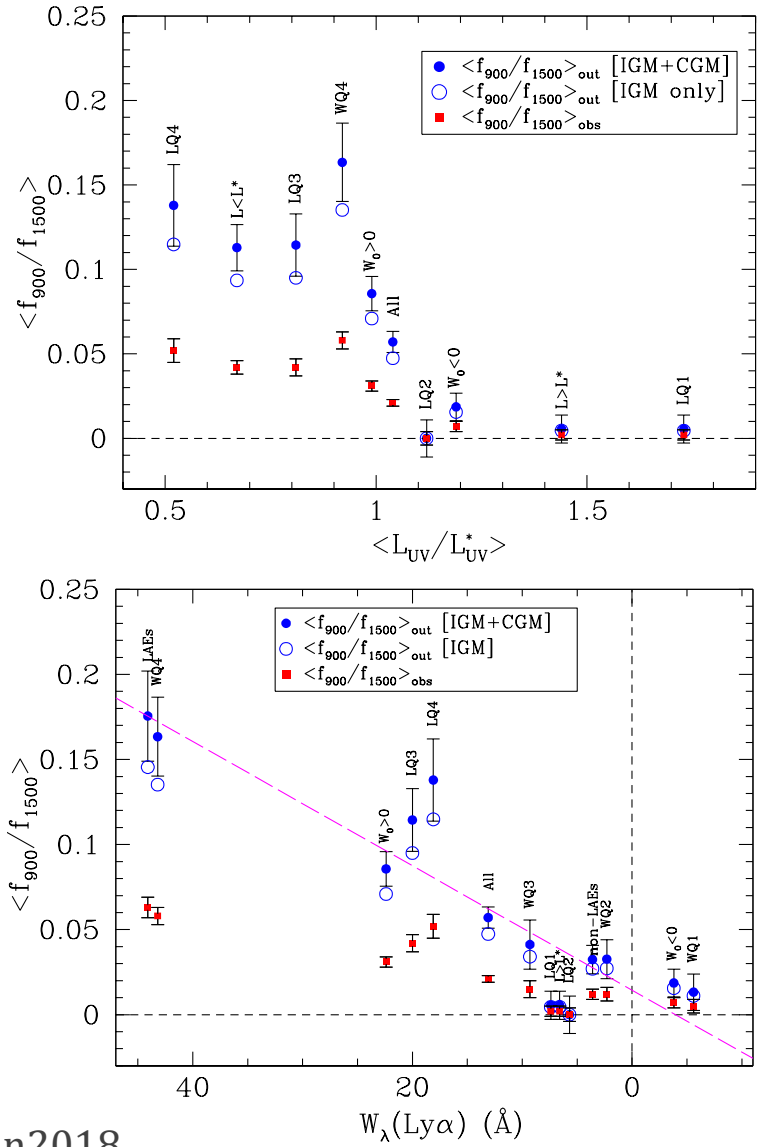
Parent Population

Spectroscopic Sample

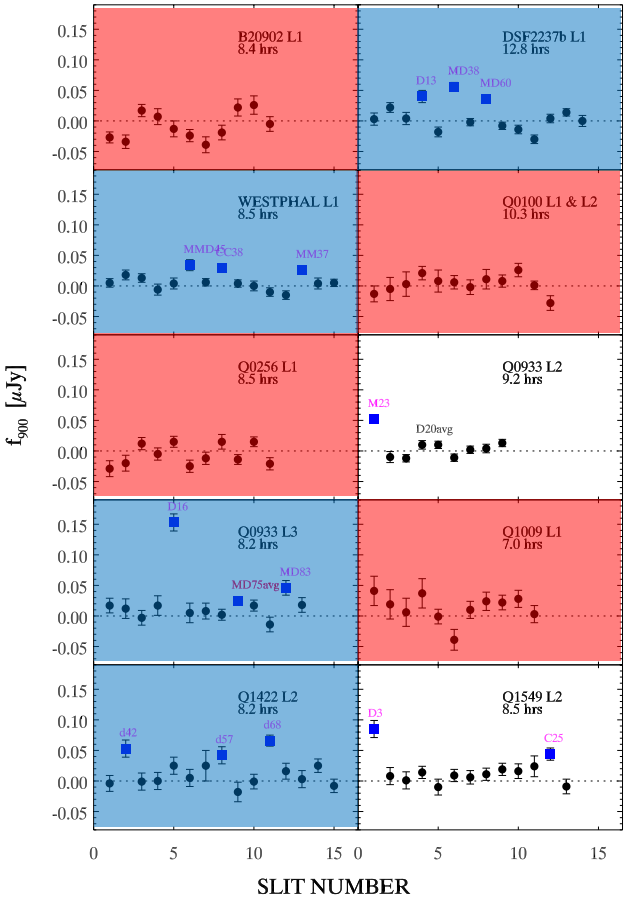


faint galaxies and LAEs are LCEs

- Average "escape fraction" of 9%
  - Model dependent!!
- Variation in stacks: 0% to 50%+
- L > L* don't emit LyC
- Strong function of $W_{Ly\alpha}$ (LAEs emit strongly)

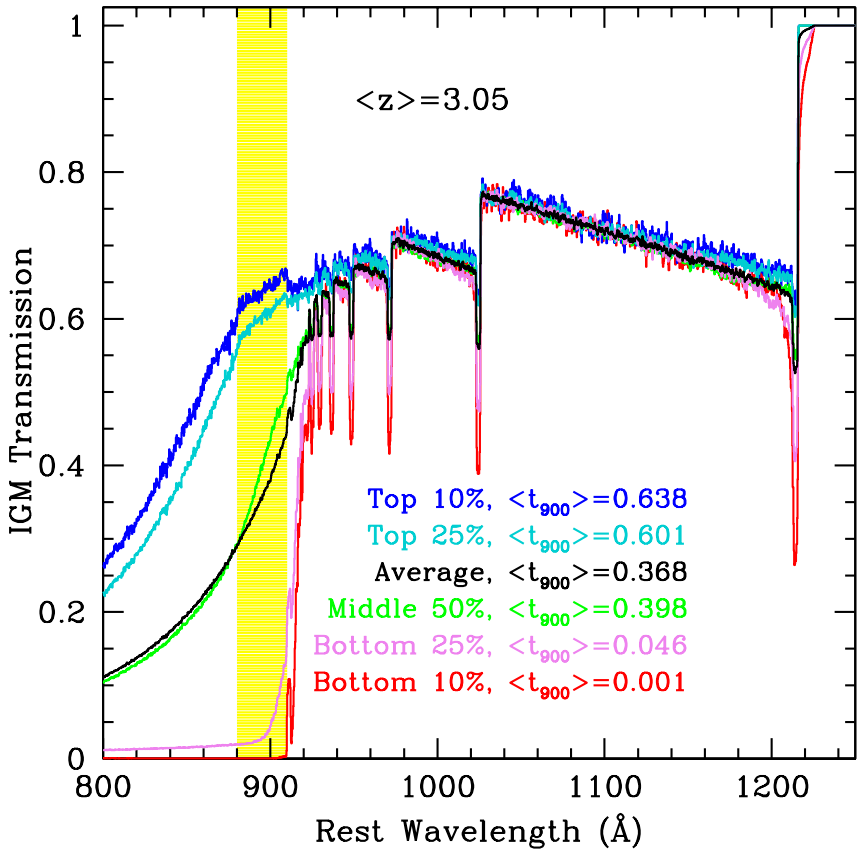


significant (spatially-correlated) variation in sightlines



Steidel+2018

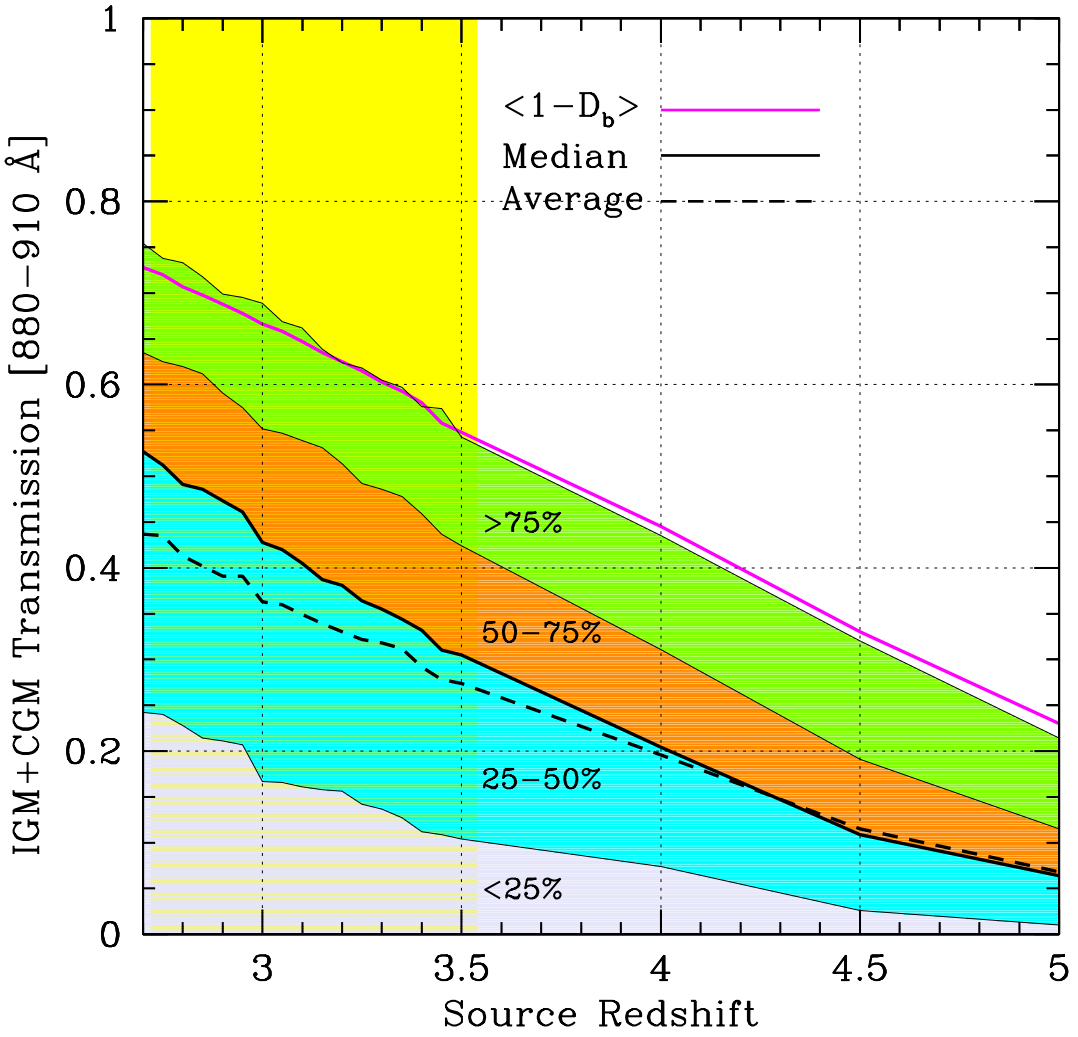
# of detections per field is bimodal

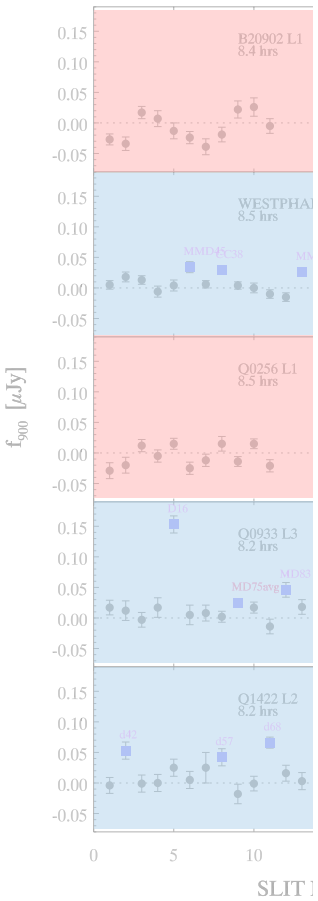


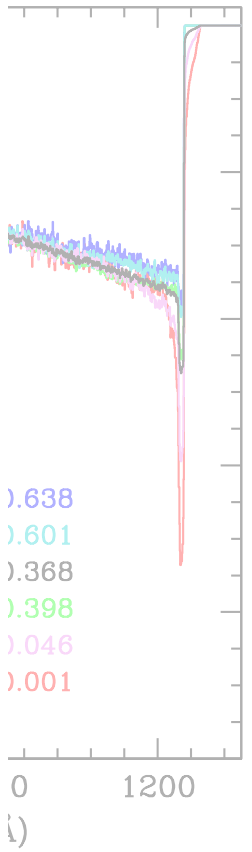
Steidel+2018

IGM to a galaxy may be 100% opaque or 20% opaque

significant (spatially-correlated)







Steidel+2018

# of detect
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Minimum opacity is a strong function of redshift

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summary

- Lyman radiation depends on galaxy properties
  - Porosity of ISM

    (example probe: absorption lines)
  - Photon production and local escape

    (example probe: emission lines)

- **Observed** Lyman radiation depends on galaxy properties **+ CGM + IGM** (with large variation)
  - **Large** (N $\gtrsim$ 30), **representative** samples are required to average over IGM and establish trends

- The trends look good for galaxies + reionization