Cosmic Dawn at High Latitudes
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Galaxies as Agents of Cosmic Reionization: Insights from the EIGER Survey

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On behalf of the EIGER team

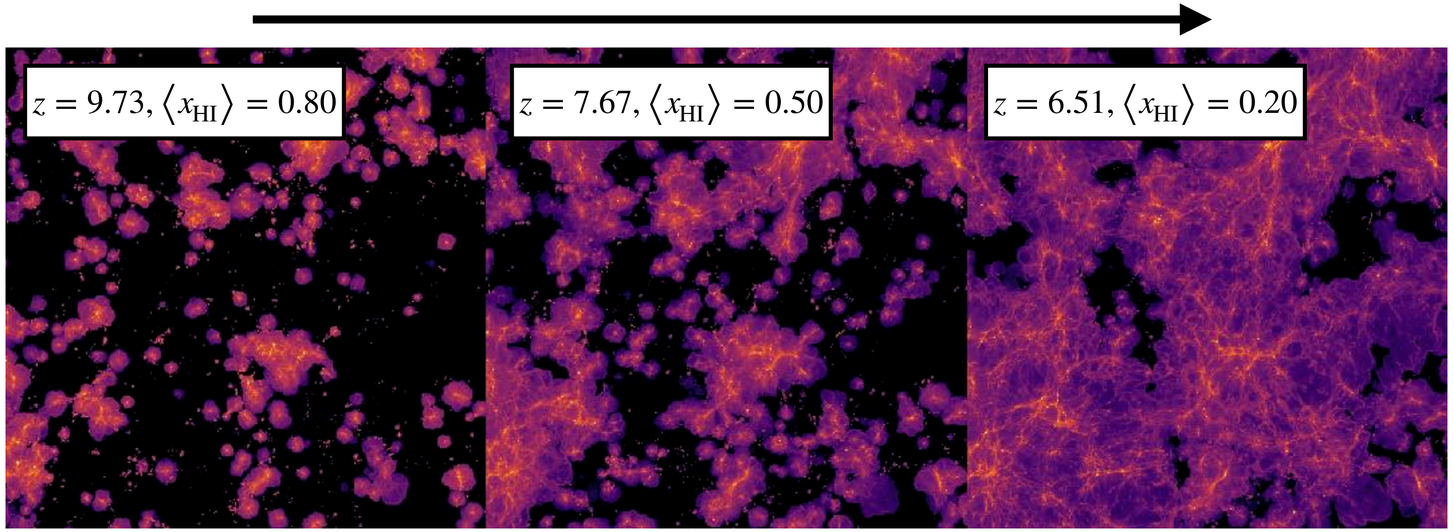
What caused reionization, and how did it proceed?

Star-forming galaxies have long been thought to be main contributors to cosmic reionization.

Lots of efforts have been made to estimate the galactic ionizing photon budget, which involve measurements of number of galaxies (LFs), SFR density, production efficiently and escape fraction of ionizing photons.

Observational evidence supports, or at least, is not inconsistent with the "galaxy scenario."

However, direct evidence has not yet been obtained.



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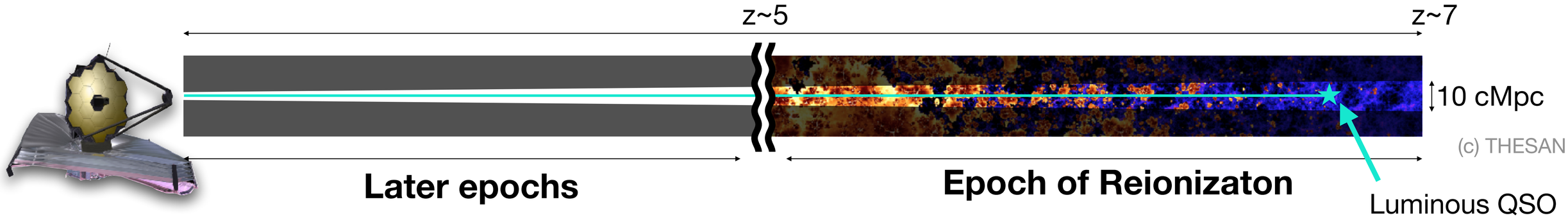
Galaxy scenarios predict that reionization proceeds in a "inside-out" manner, where ionized bubbles form around galaxy overdensities.

➡ The IGM transparency is expected to be systematically higher around galaxies.

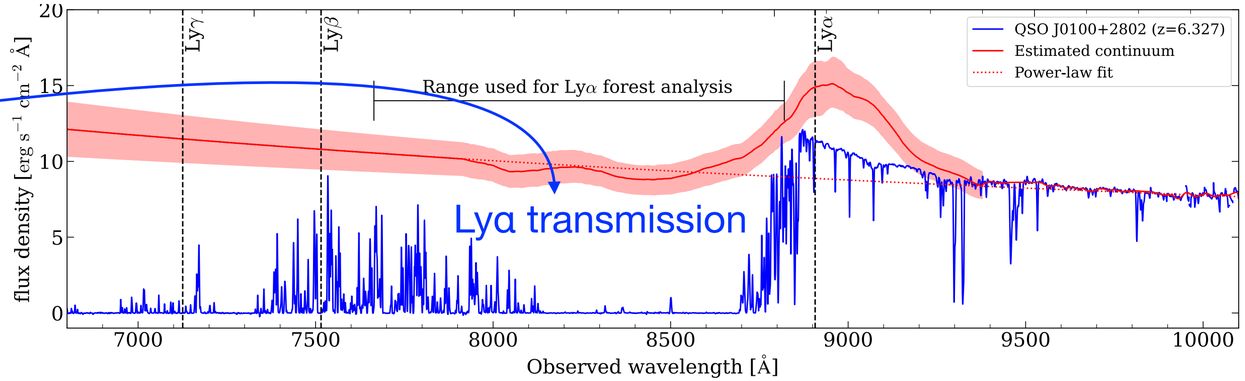
EIGER is about the connection between galaxies and IGM

By looking along the sightline to quasars, we learn about the distribution and state of the gas from the quasar spectrum. JWST tells us about the galaxies surrounding this sightline.

- Reionization - the role of galaxies in reionizing the Universe ➡ *DK+23, DK+in prep*
- CGM and baryon cycle (via identification of absorber host galaxies) ➡ *Bordoloi+24, Simcoe+in prep*
- SMBH, host galaxies, & environments ➡ *Eilers+23, 24, Yue+23, Mckenzie+in prep*
- Large spec-z sample across redshift (via various lines) ➡ *Matthee+23, 24*



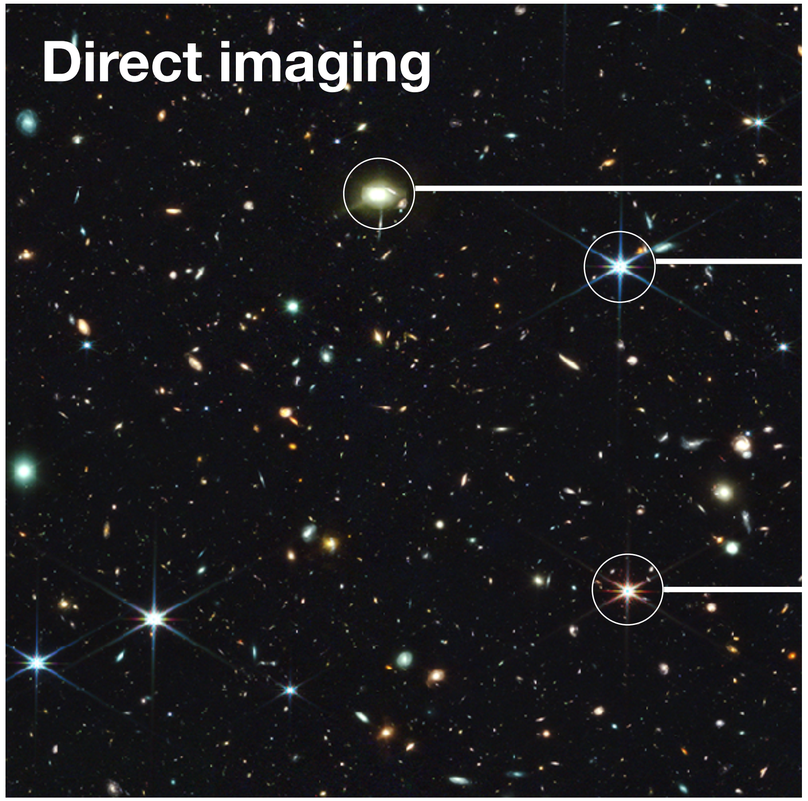
Key concept for reionization studies:
IGM transmission tells us about the amount of HI along the line of sight.

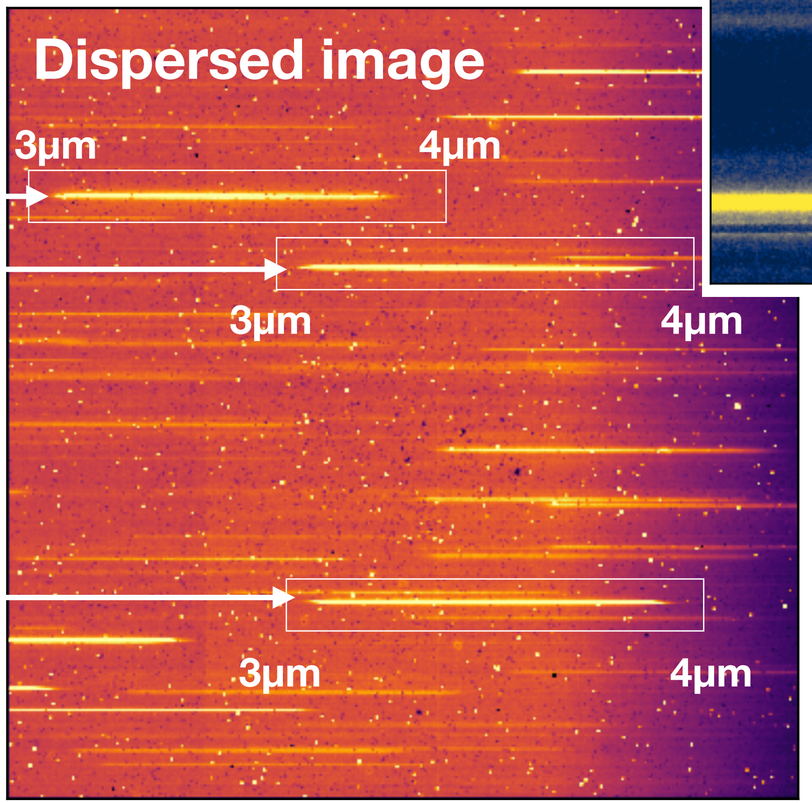


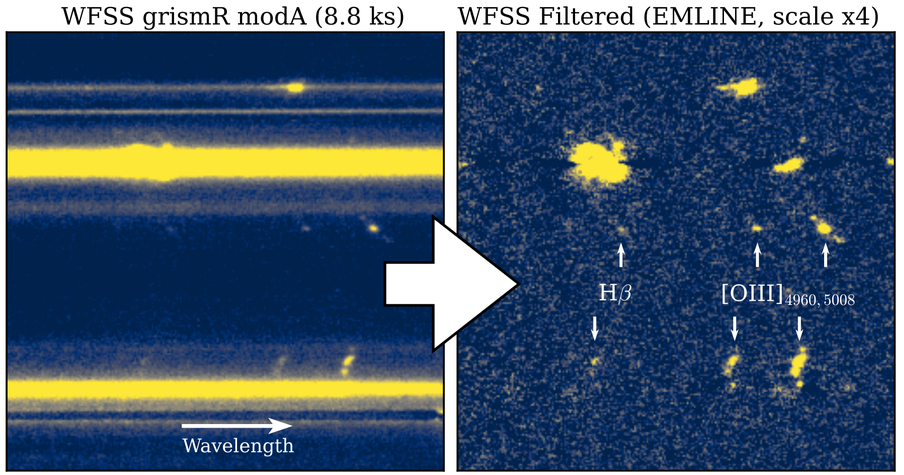
NIRCam WFSS in six quasar fields

WFSS = Get spectra from all objects in the field of view in one observation

- No pre-imaging and configuration of spectrograph
- No bias due to pre-sample selection
- Powerful way to search for strong emission-line galaxies







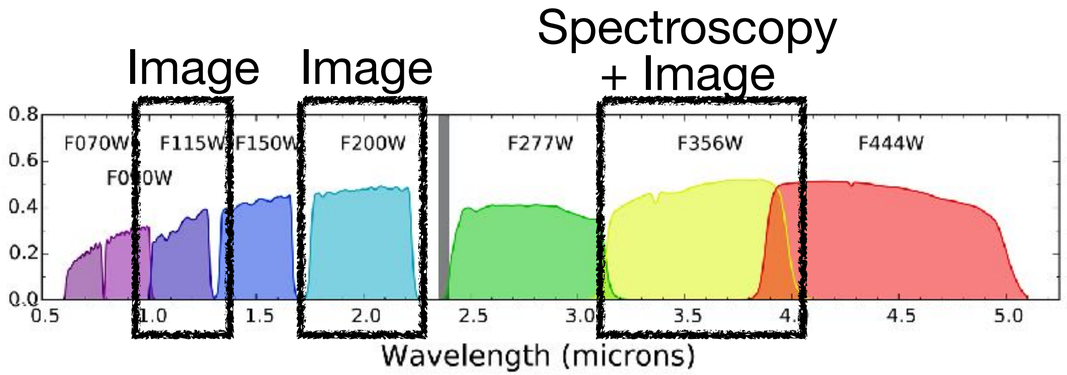
Continuum-subtracted image

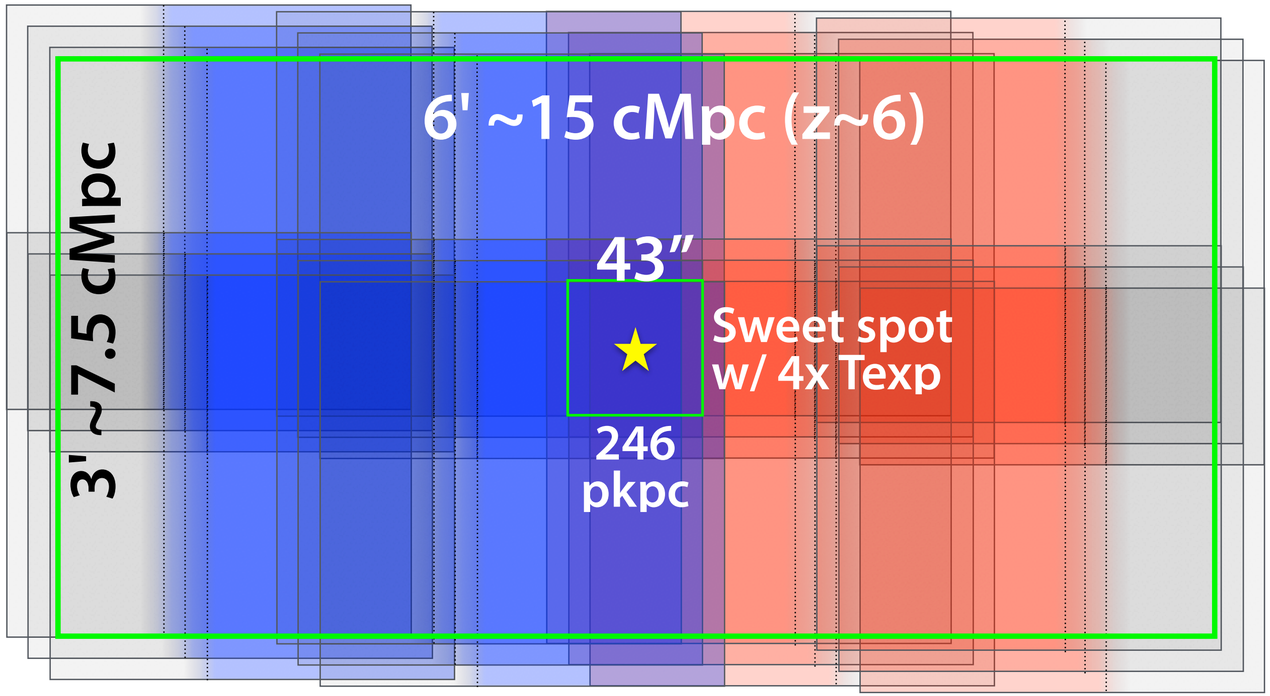
NIRCam WFSS turns JWST into a redshift machine

Survey design: NIRCam imaging + WFSS

- **Wide-field grism survey in the fields of 6 z>6 quasars**
- Grism in F356W
  - [OIII] doublet (5007, 4960) + Hβ over 5.3<z<7.0
  - Hα over 3.7<z<5.1
- Simultaneous imaging in F115W and F200W

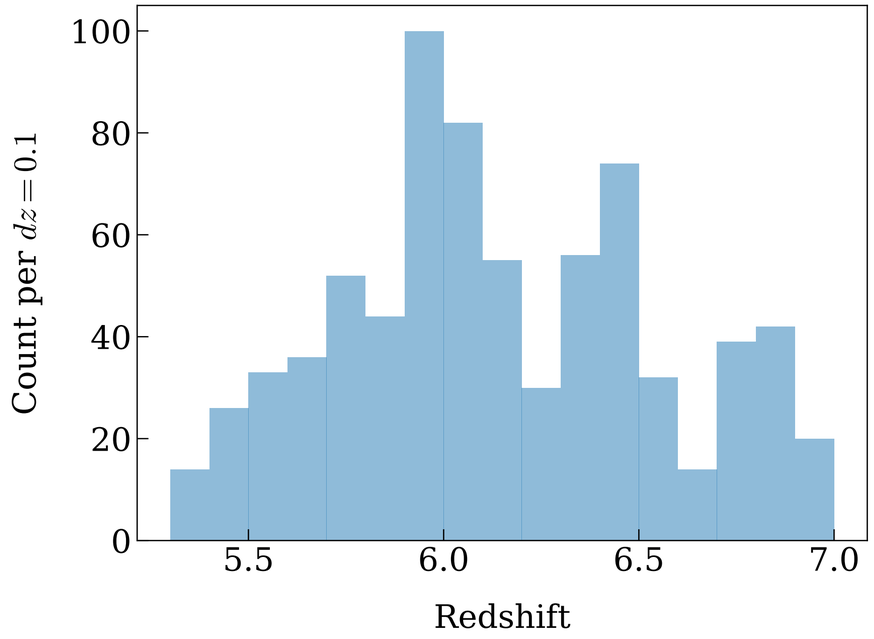
  ➡ Rest-frame FUV for z~6
- 4-Visits mosaic yields ~3' x 6' coverage per quasar field (~7.5 x 15 cMpc at z~6)

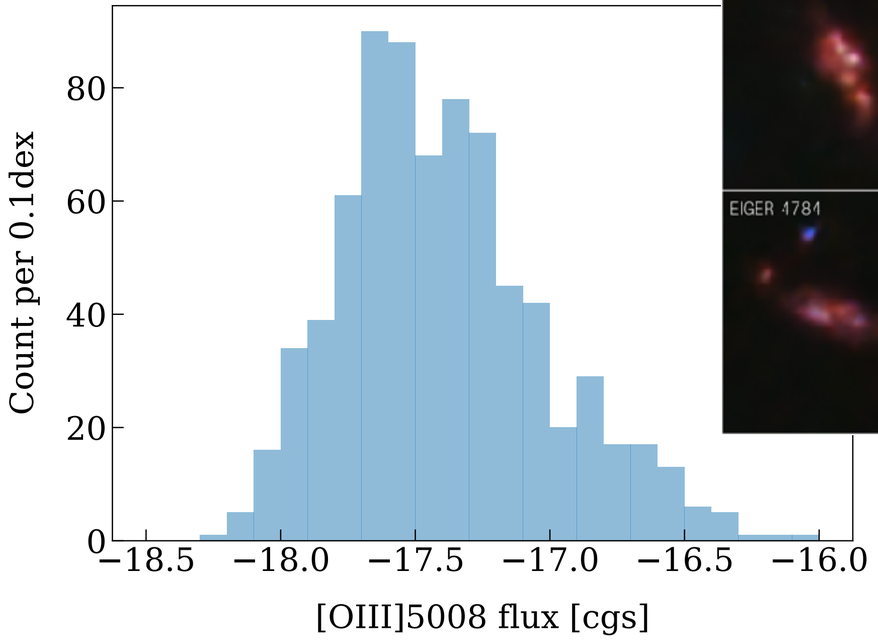


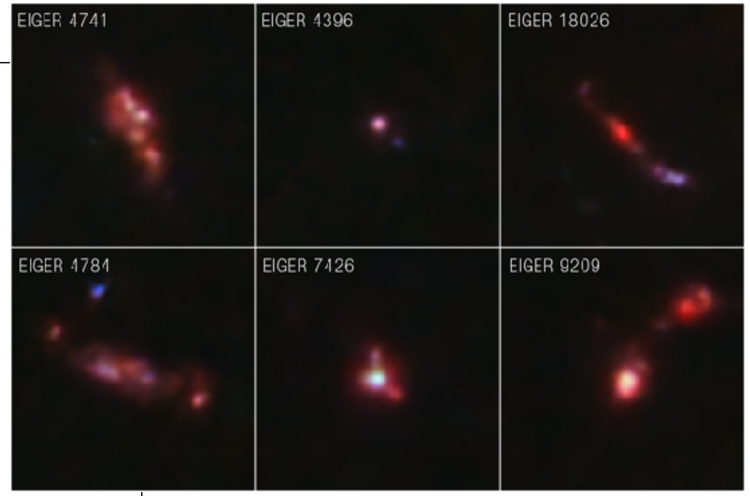


EIGER [OIII]-emitter sample

- All the observations of six quasar fields were completed at the beginning of this month.
- **To date, ~750 unique [OIII]-emitting systems have been identified in five fields over z=5.3–7.0 (the 6th field is being analyzed).**
  - S/N threshold is set to 3 for weaker [OIII]4960
  - Nearby clumps (<2") are merged into a single unique system.
- Limiting [OIII]5008 flux is ~10^-18 erg/s/cm2, or ~4 x 10^41 erg/s in luminosity

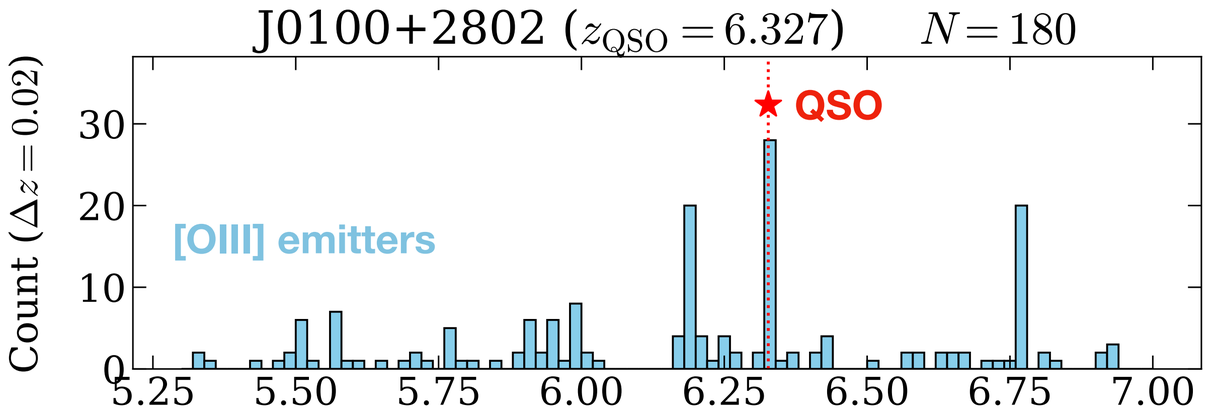


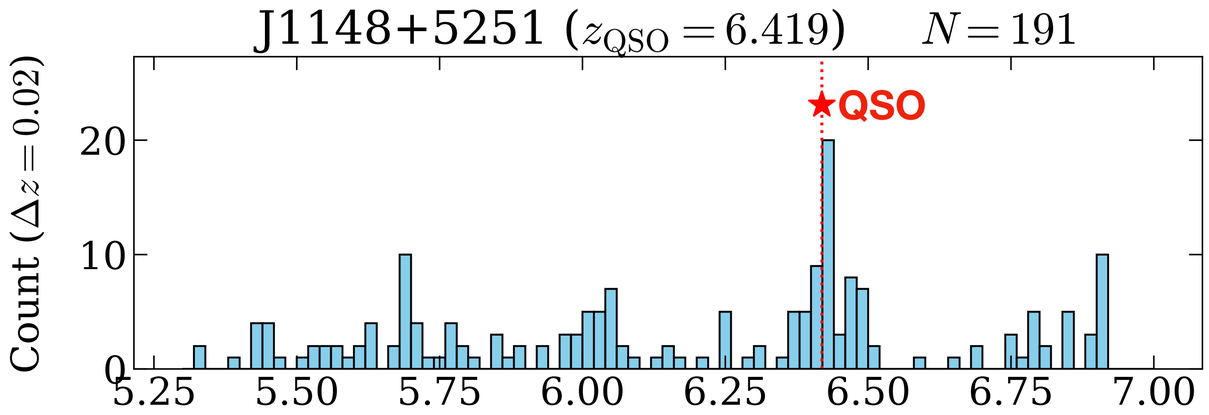


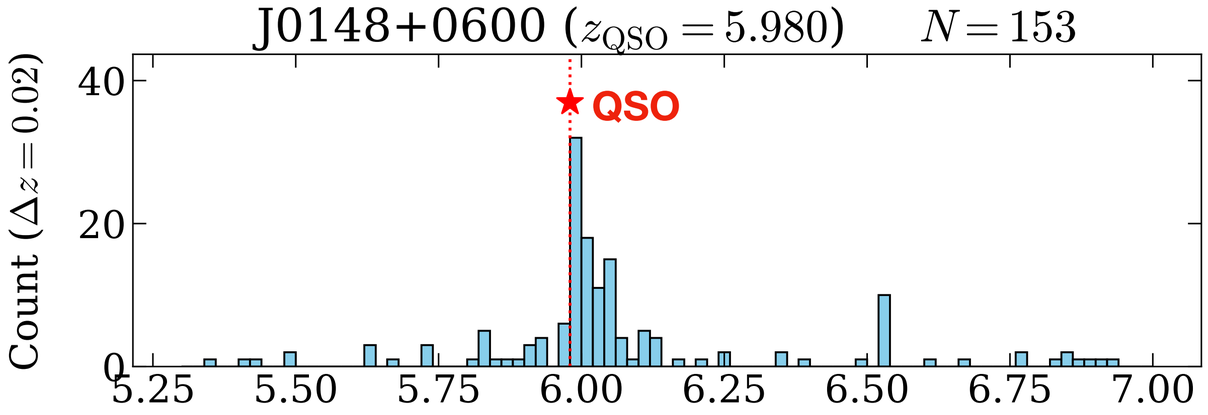


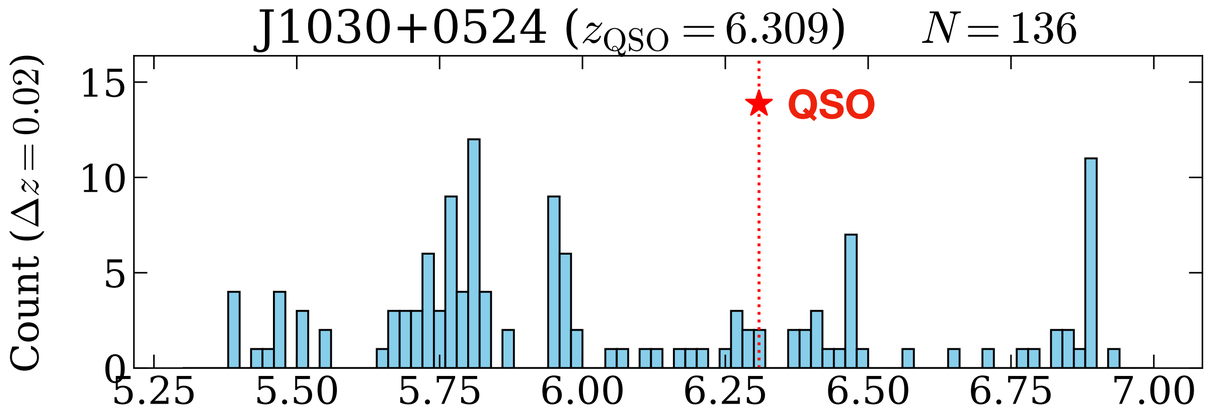
Quasars reside in overdensity?

Detailed analysis will be provided in Eilers+24 and Mckenzie+24

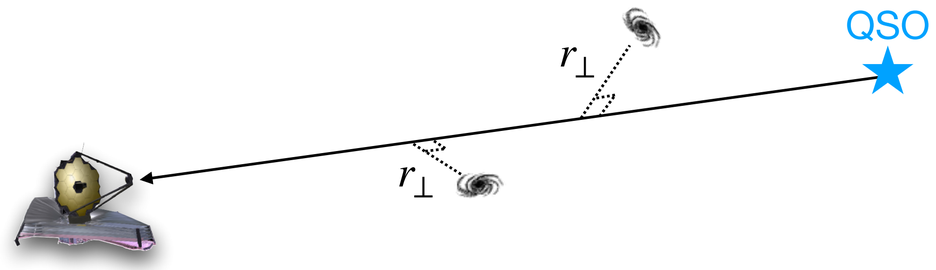




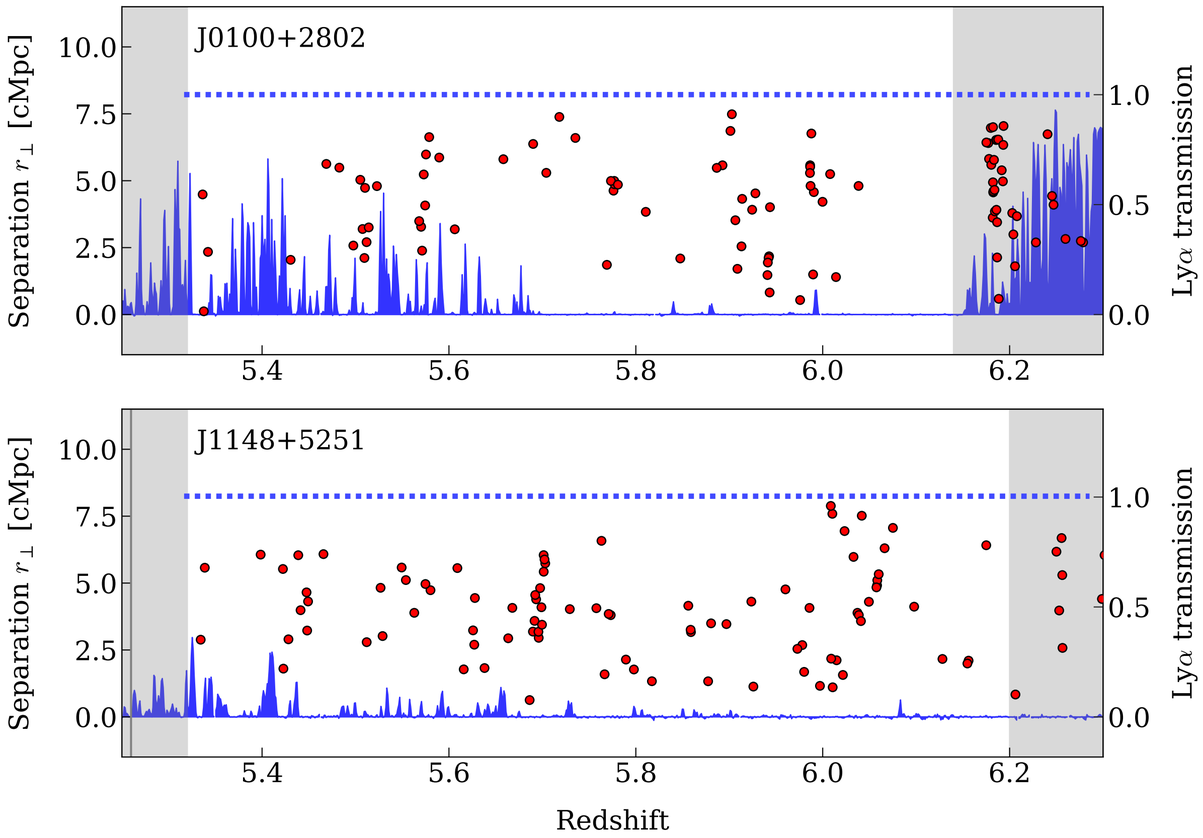


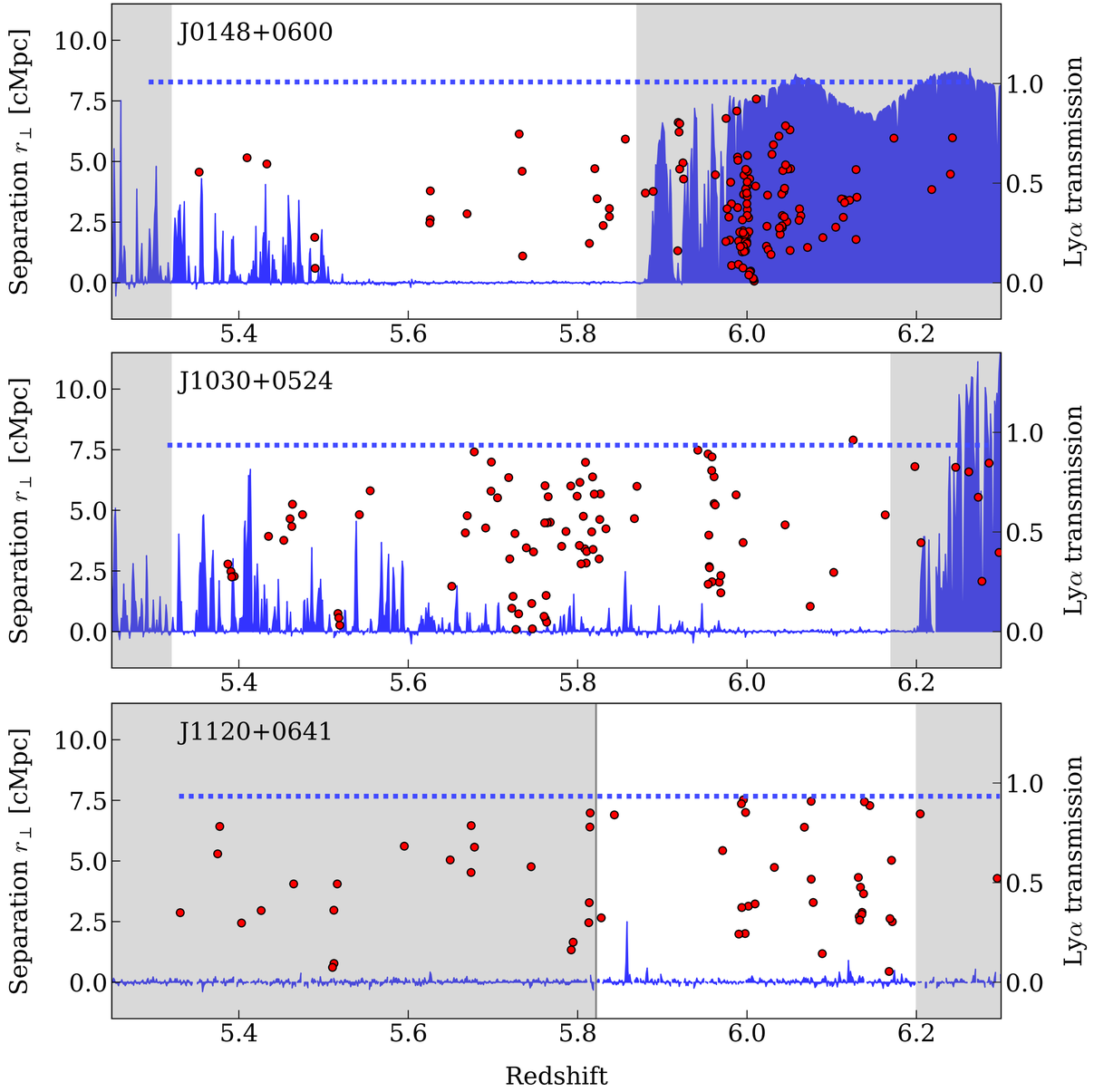


Lyα transmission vs. galaxies in five sightlines

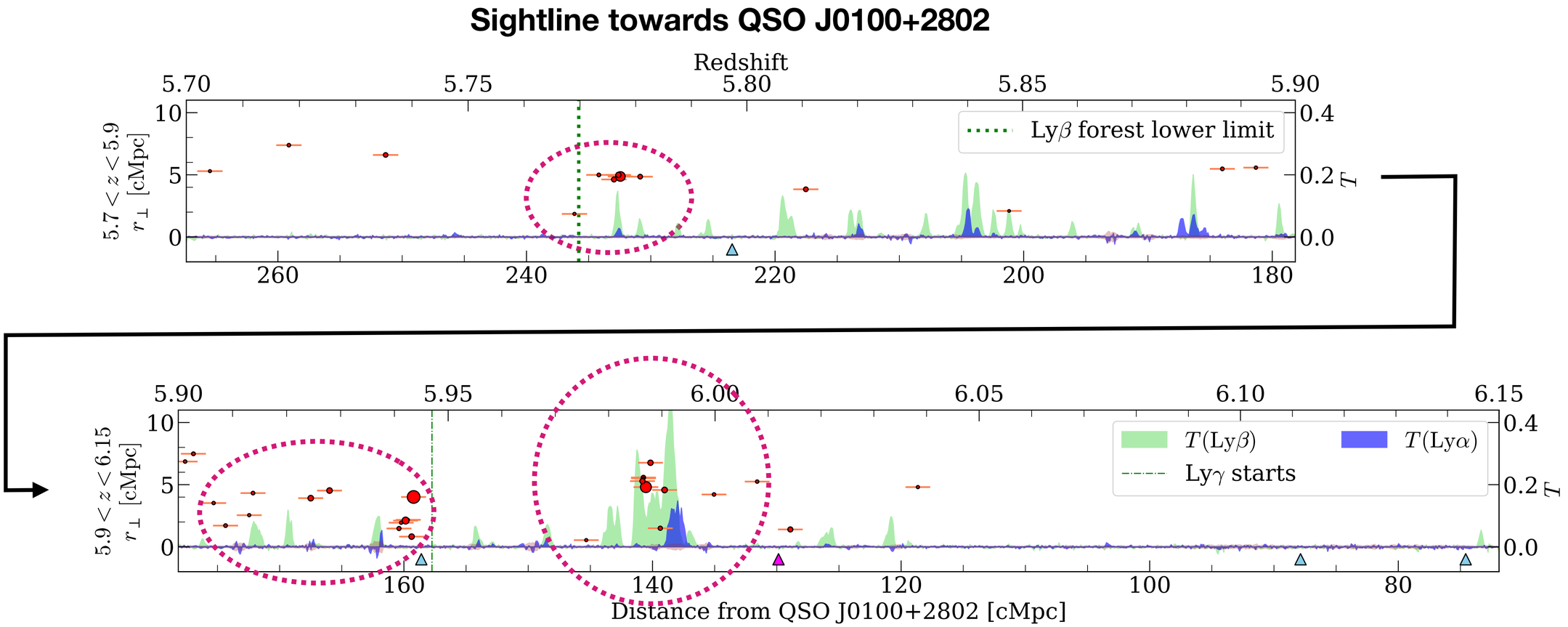


Redshift range used for correlation analysis





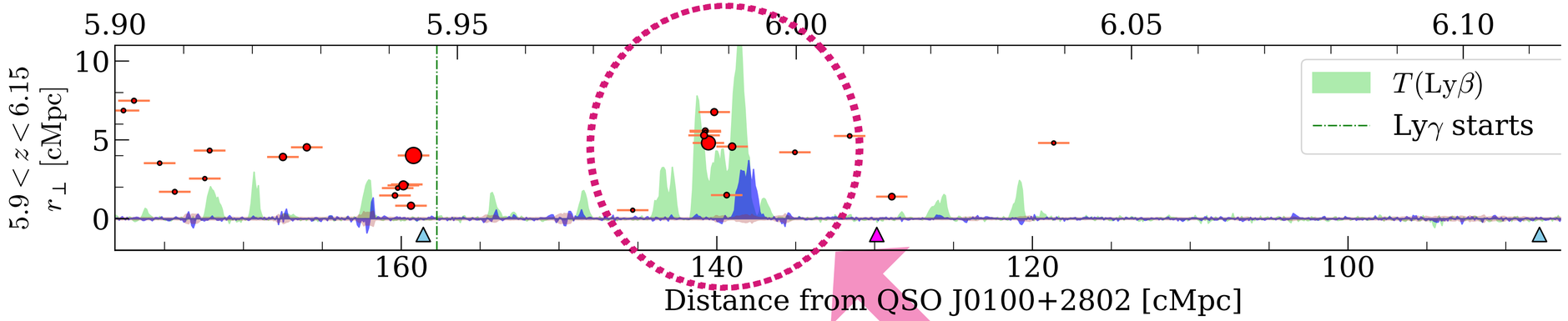
Coincidence between galaxies and spikes

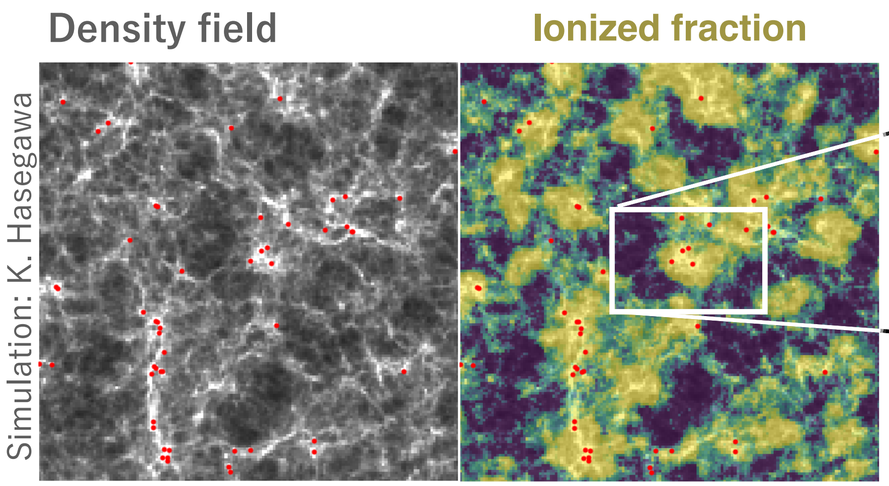


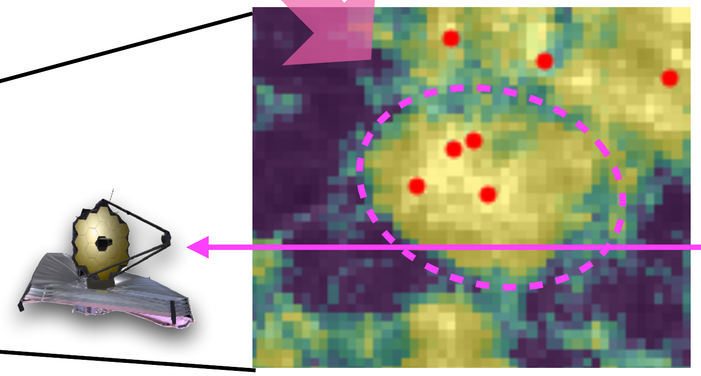
Galaxies tend to be found around Lyα/β transmission spikes!

We are witnessing galaxies ionizing the surrounding IGM!

First direct evidence for local ionization of the IGM by galaxies



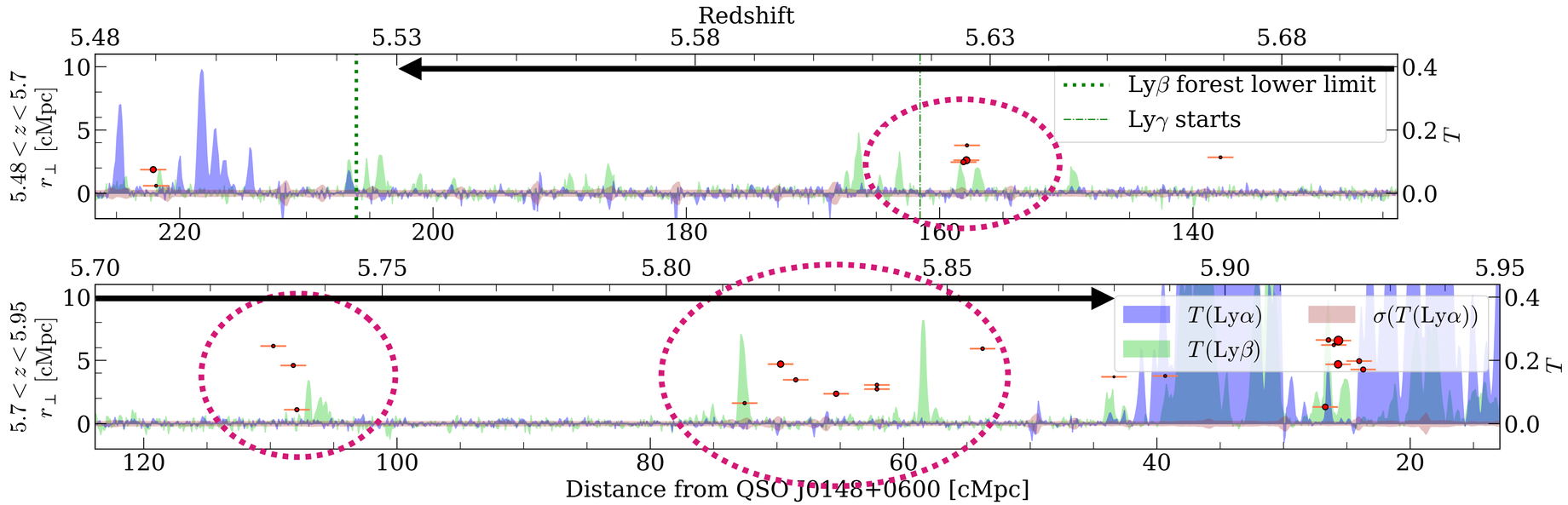




QSO sightline is passing through a "local" ionized bubble around galaxies

Local ionization allows Lyβ to transmit in the deep Lyα trough

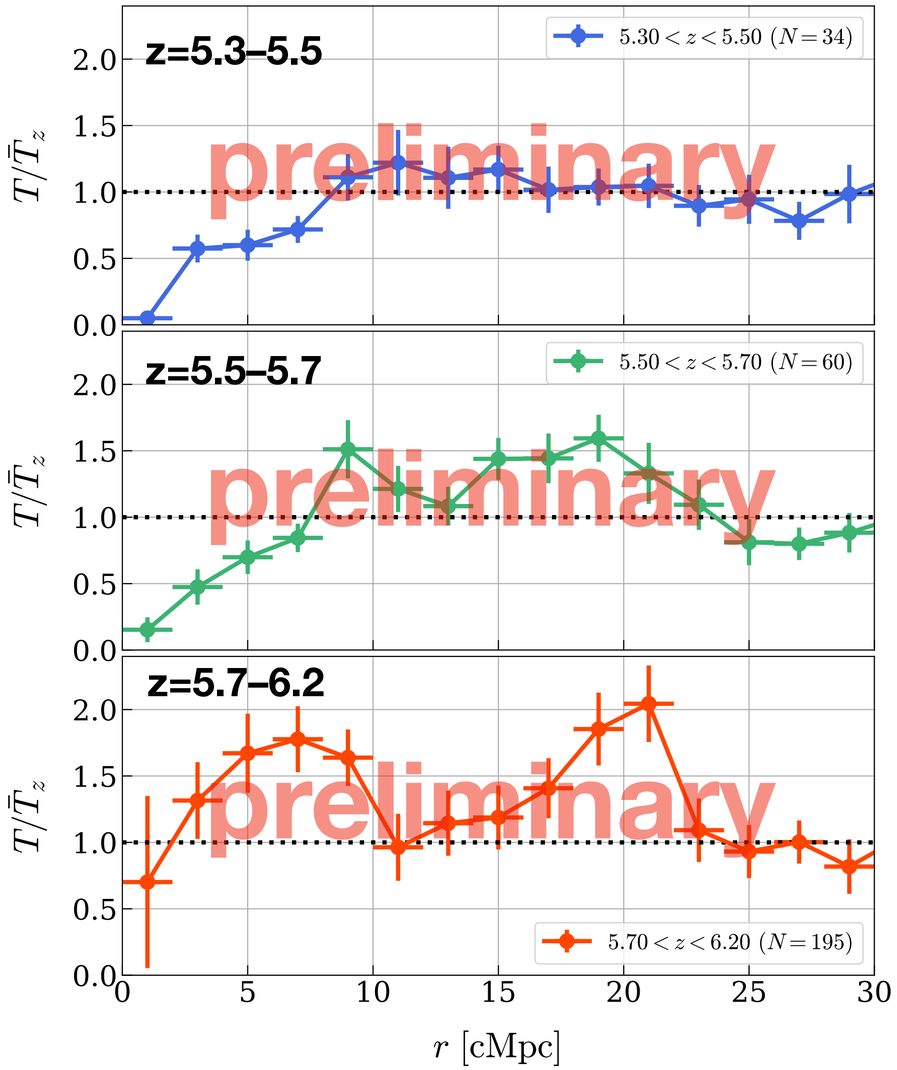
Sightline towards QSO J0148+0600 with a famous long Lyα trough over z=5.53–5.88

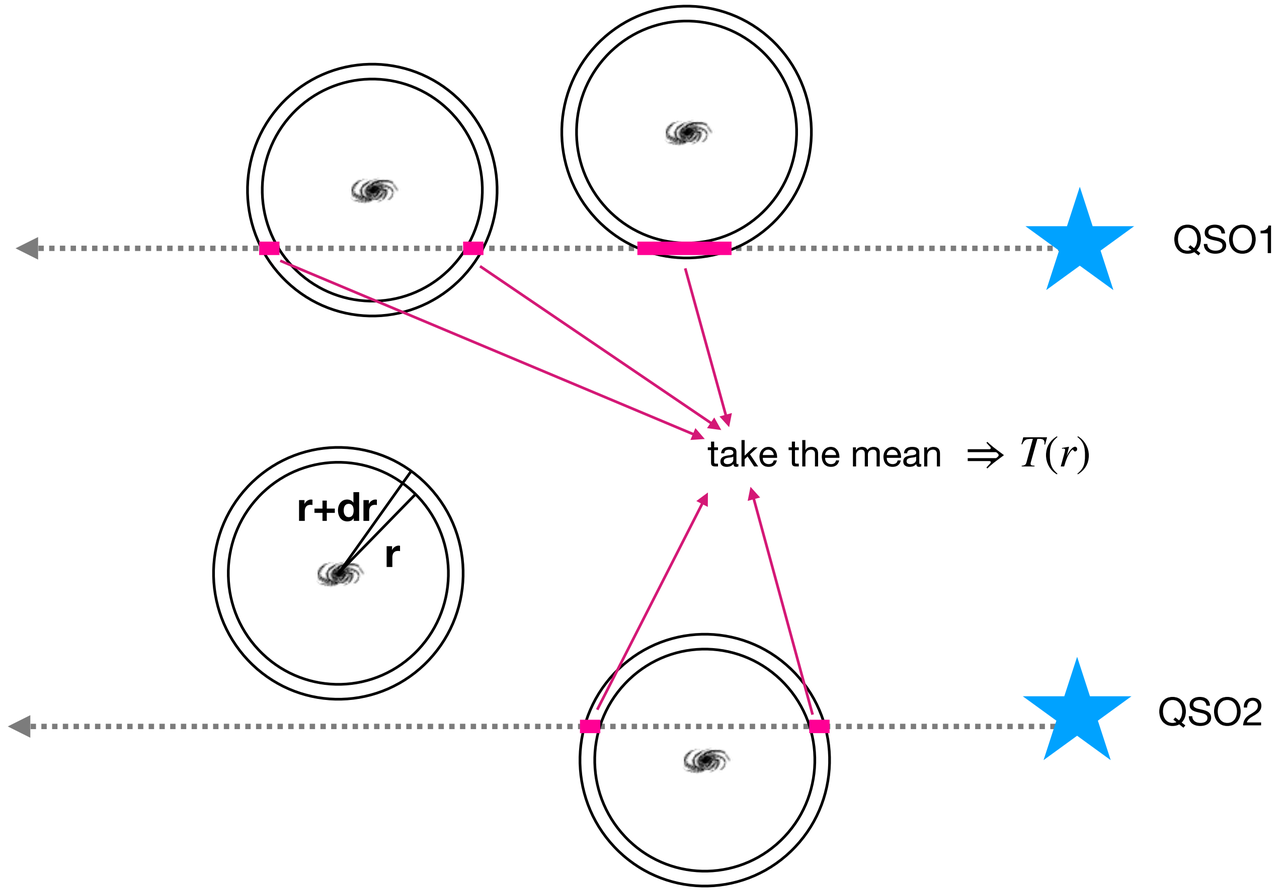


Even in the "trough", Lyβ transmits somewhere, indicating the presence of ionized regions.
We then found that (Faint) galaxies exist near such Lyβ transmission!

Average transmission profile around galaxies

Mean transmission as a function of distance from galaxies using 5 quasar sightlines

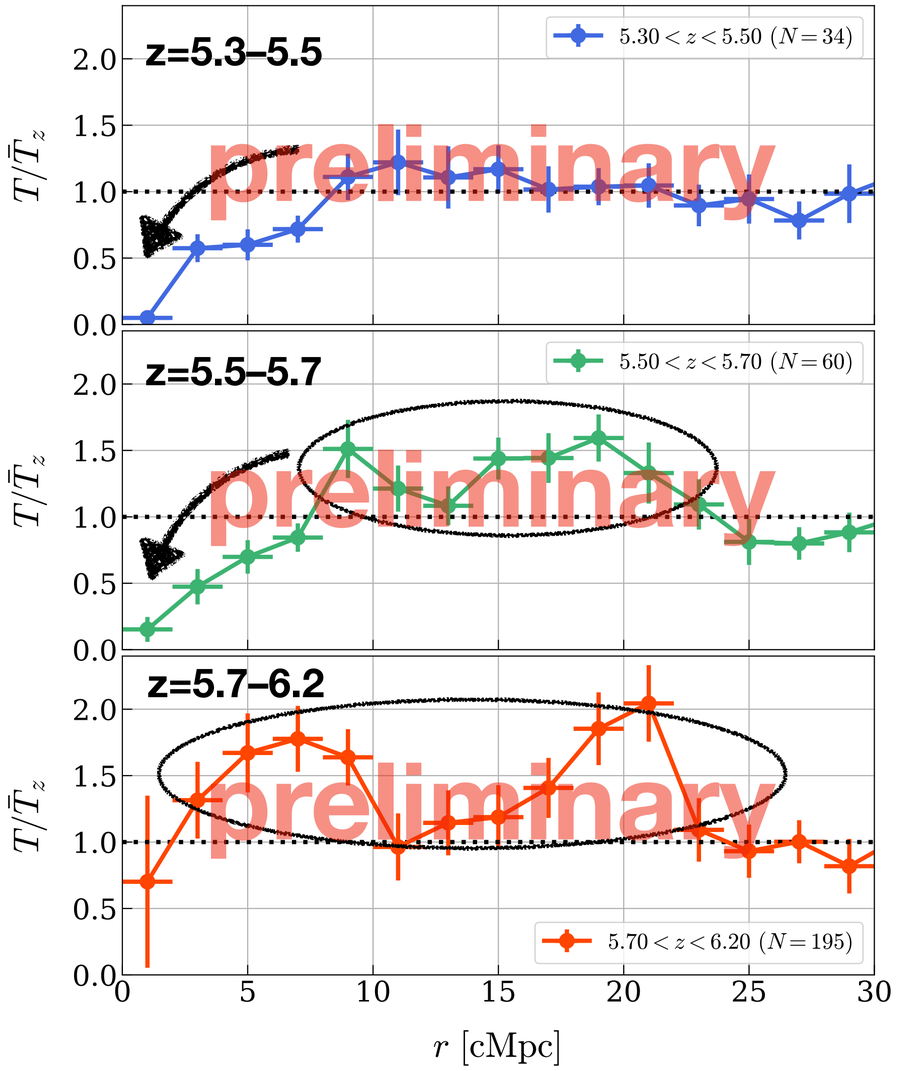




Average transmission profile around galaxies

preliminary

Mean transmission as a function of distance from galaxies using 5 quasar sightlines



Three (arbitrary) redshift regimes:

- At redshifts below z~5.7, transmission is more suppressed (or strongly absorbed) nearer to the galaxies.
  - This should be reflecting overdensity around galaxies
- At the intermediate redshift (z~5.6), some excess transmission seems to exist over r~10-20 cMpc.
- At the highest redshift regime (z=5.7–6.2), stronger transmission excess is seen over r~5--20 cMpc.
  - Evidence of local reionization of the IGM around galaxies.

Comparison with THESAN

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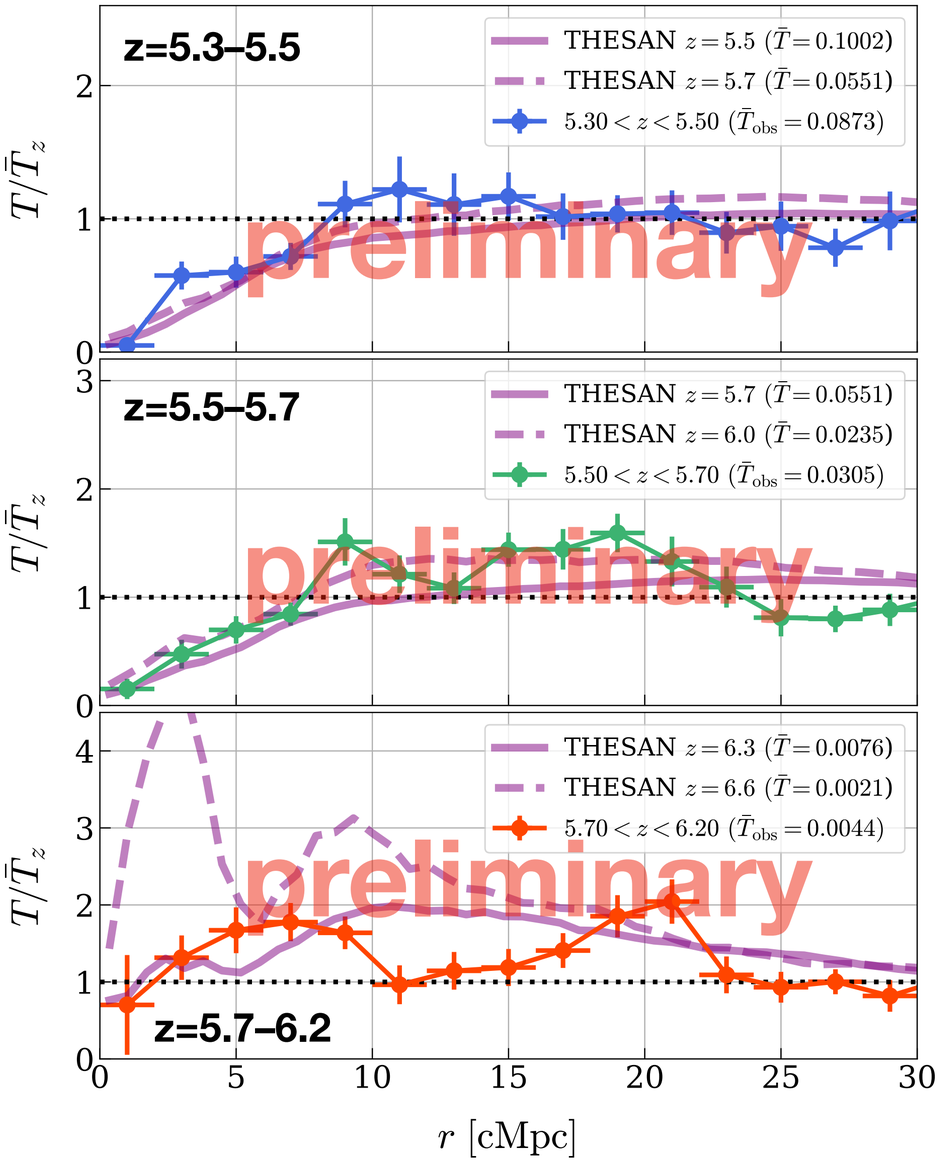

Compared with the THESAN simulations (Garaldi+22).

(The snapshots are selected based on similar volume-averaged transmission value, rather than redshifts)

- The suppression (absorption) toward r=0 (in the two lower redshift bins) is in good agreement!
- Excess transmission at the intermediate bin is also similarly reproduced in THESAN.
- At the highest-z regime, the level of transmission excess is more or less in agreement, though the detailed shape is not very similar.

Summary

- Our **EIGER** sample now contains ~750 [OIII]-emitting galaxies over z=5.3–7.0 in the five fields, and ~150 is expected to be newly identified in the last, sixth field.
- We find direct evidence for local ionization of the IGM around galaxies.
- Our observations strongly supports the inside-out reionization, powered by galaxies.

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