Neutral Hydrogen Density Around & Between LAEs in HETDEX

Mahan Mirza Khanlari

Image Credit: NASA/ESA

Overview

Hydrogen:

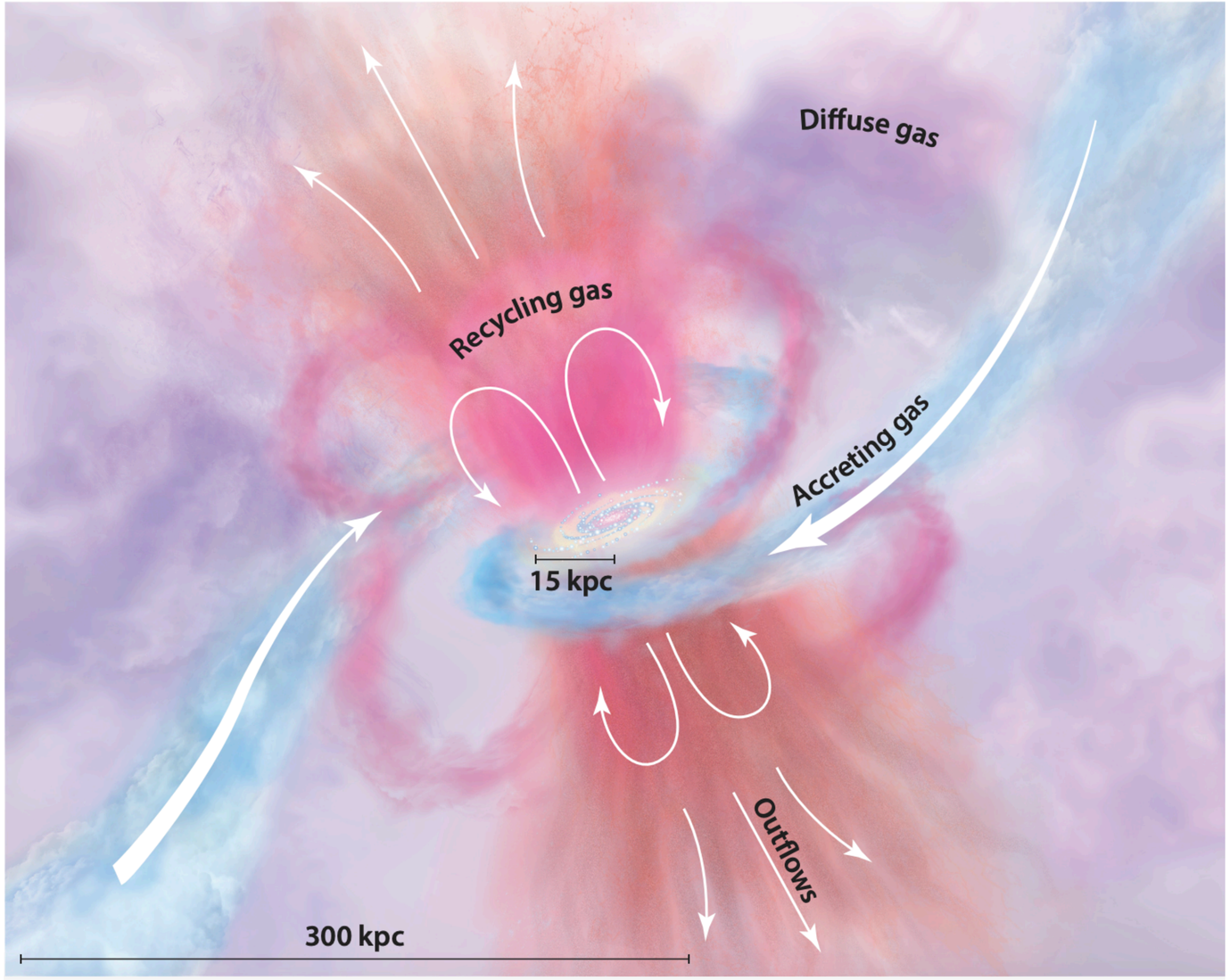
- Abundant and fundamental
- Fuels star formation which lights up our galaxies

Intergalactic Medium (IGM):

- The space between the galaxies
- Mostly made of HII regions

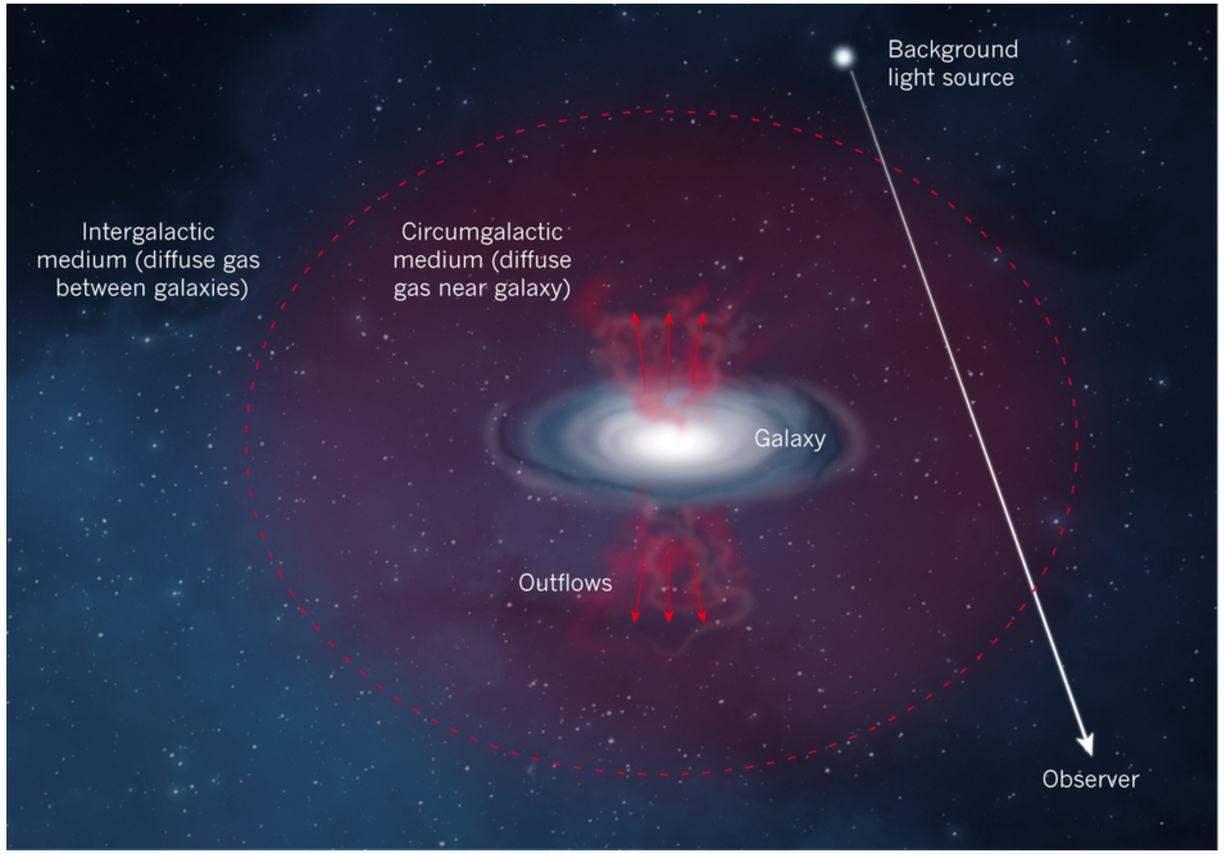
Circumgalactic Medium (CGM):

- The interface between galaxies and the IGM
- Active sites of accretion, feedback
- Multi scale and Multi phase



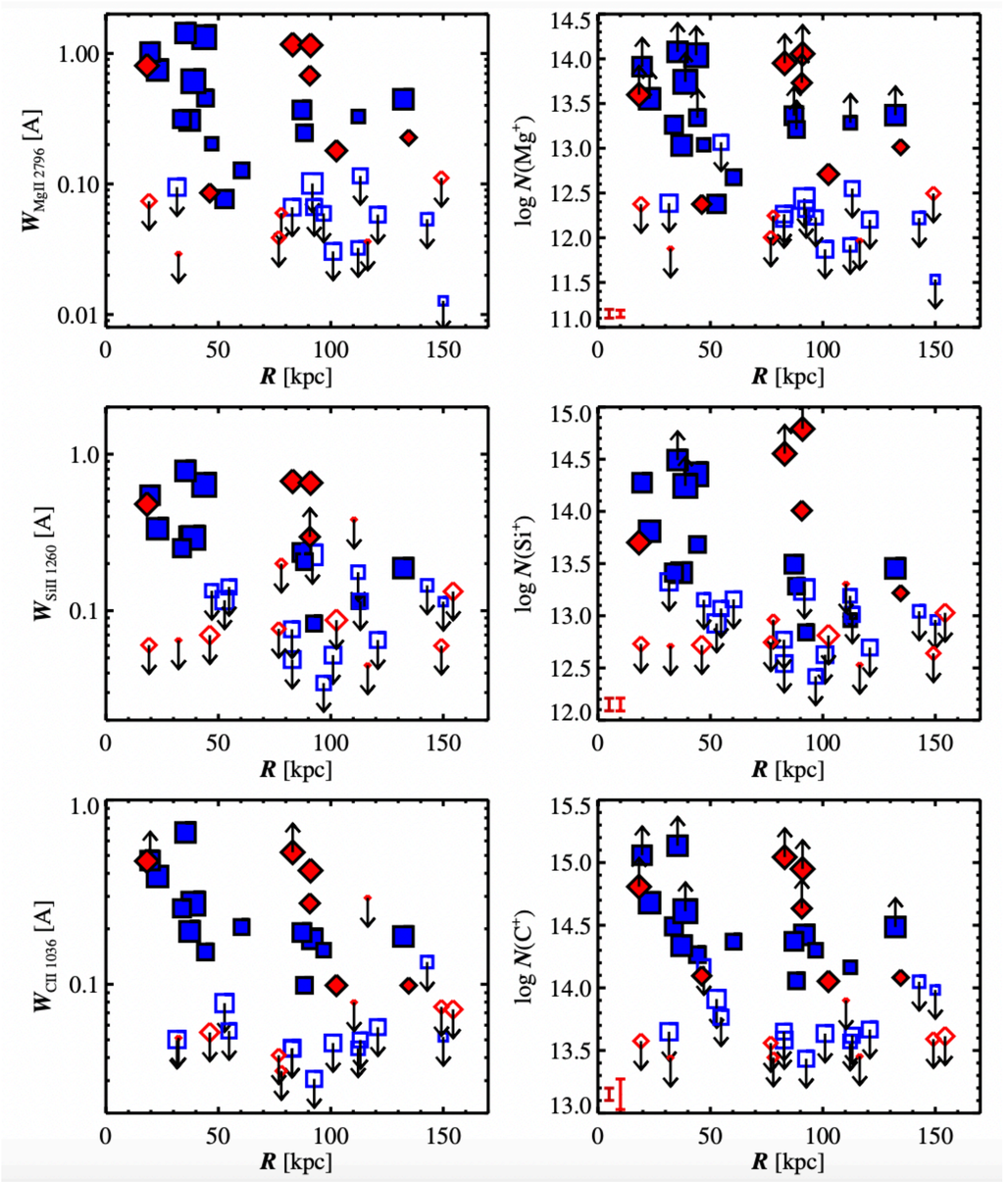
Tumlinson+ 2017

Local/Low-z CGM is quite well studied through absorption lines



Credit: Nikole M. Nielsen

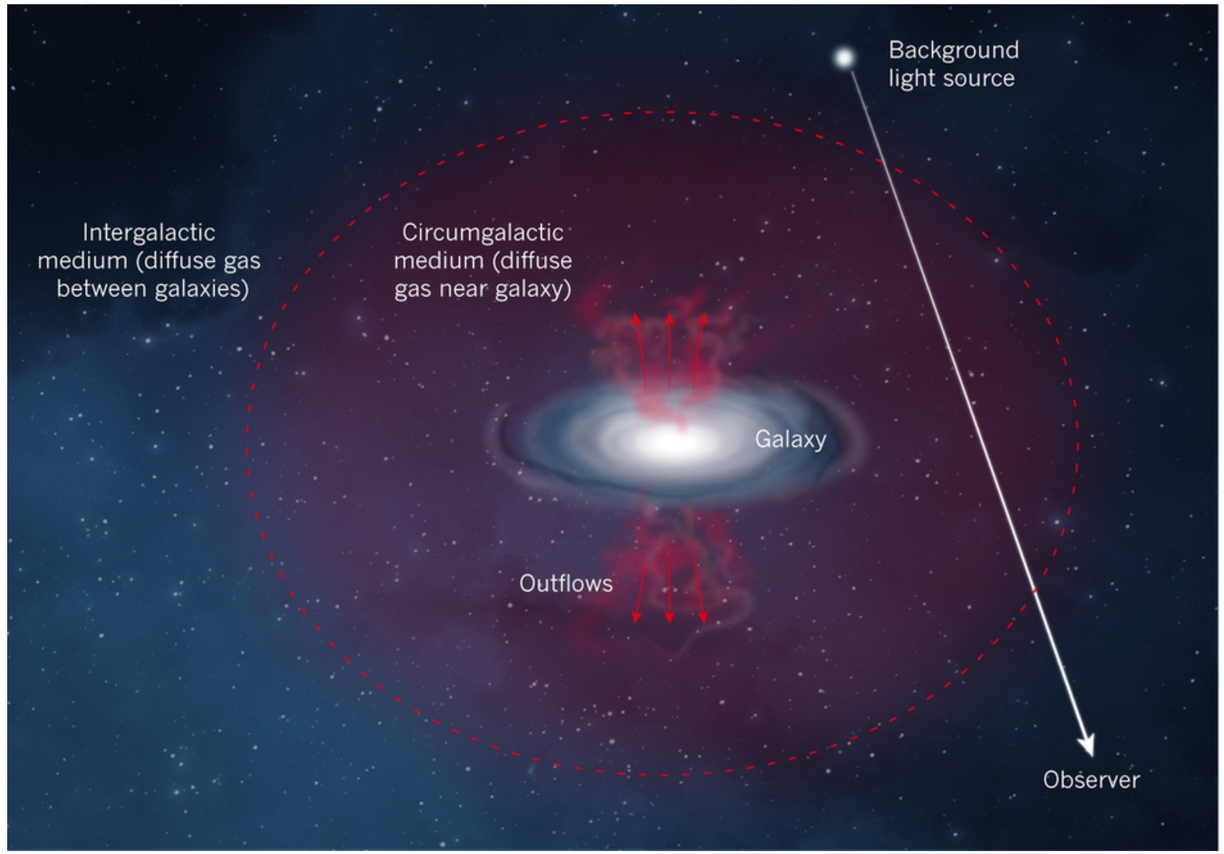
- Metal surface density profile of the CGM
- Ionization fraction of the CGM gas
- CGM's bound to its host galaxy's dark matter halo



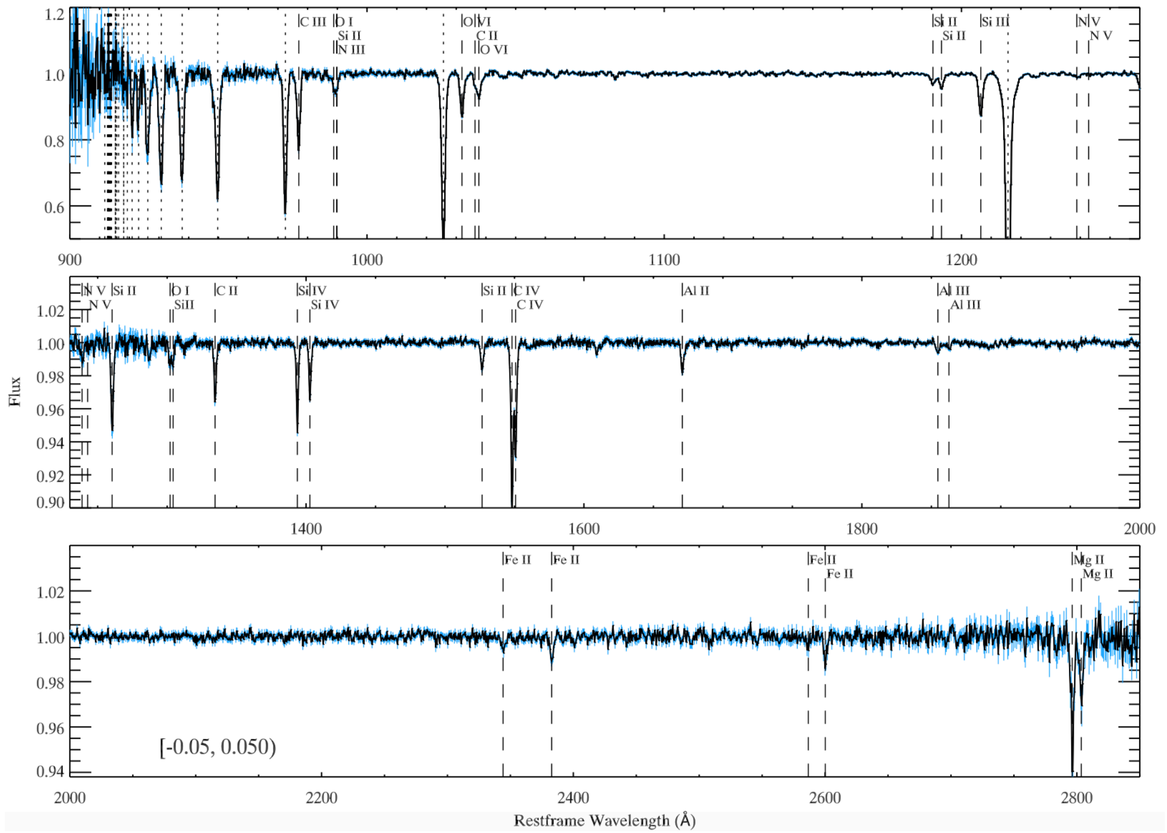
Werk+ 2013

The story is a bit different at high redshift

- High-z CGM studies: still Lyα forest absorbers, not the same resolution
- Alignment with quasars limits the scope of the study



Credit: Nikole M. Nielsen

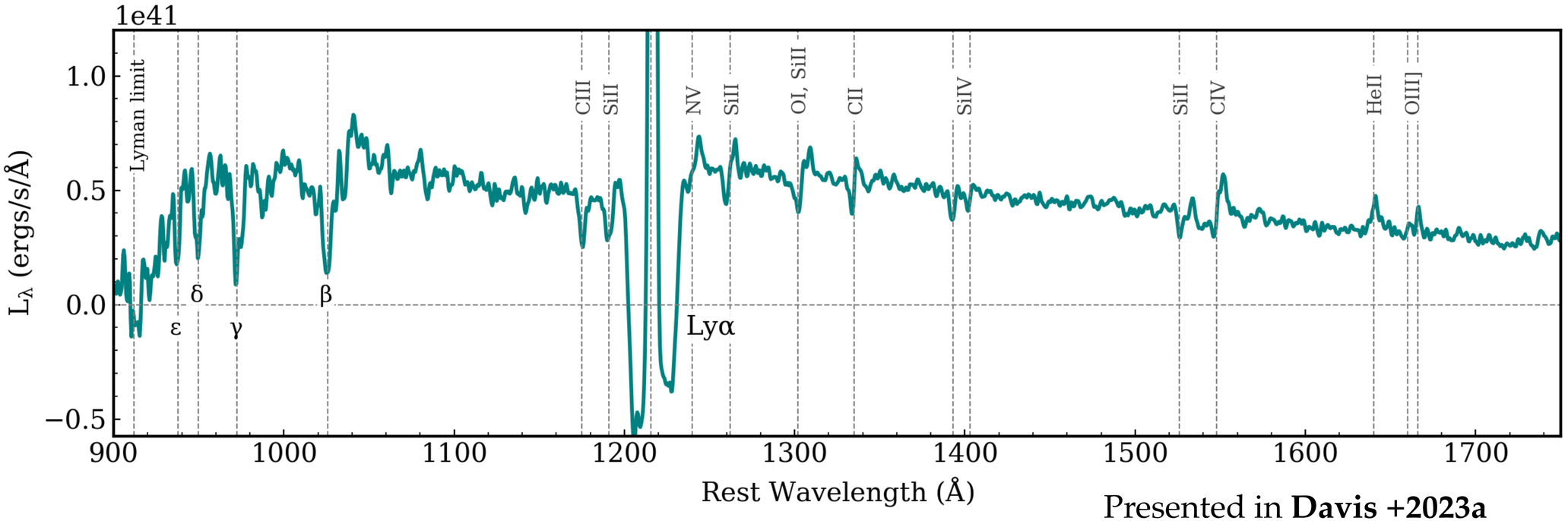


M. M. Pieri+ 2014

- Challenges with this method persist at high z even with stacking
- Difficult to provide a complete statistical view of density profile of galaxies.

Possible solution: Stacking spectra from the environment of galaxies, a LOT of them!

- HETDEX is perfect for this method - 1 Million LAEs
- Background light source: Quasars —-> Extragalactic Background Light (EBL)
- Benefit: No line of sight limitation



Presented in **Davis +2023a**
Troughs explained in **Weiss+ 2024**

Stacking:

- Boosts S/N
- Uncovers lines that are buried in noise

We can stack further from the LAEs…

Idea: HI in the LAE halo will scatter Lyα photons from the EBL in the line of sight

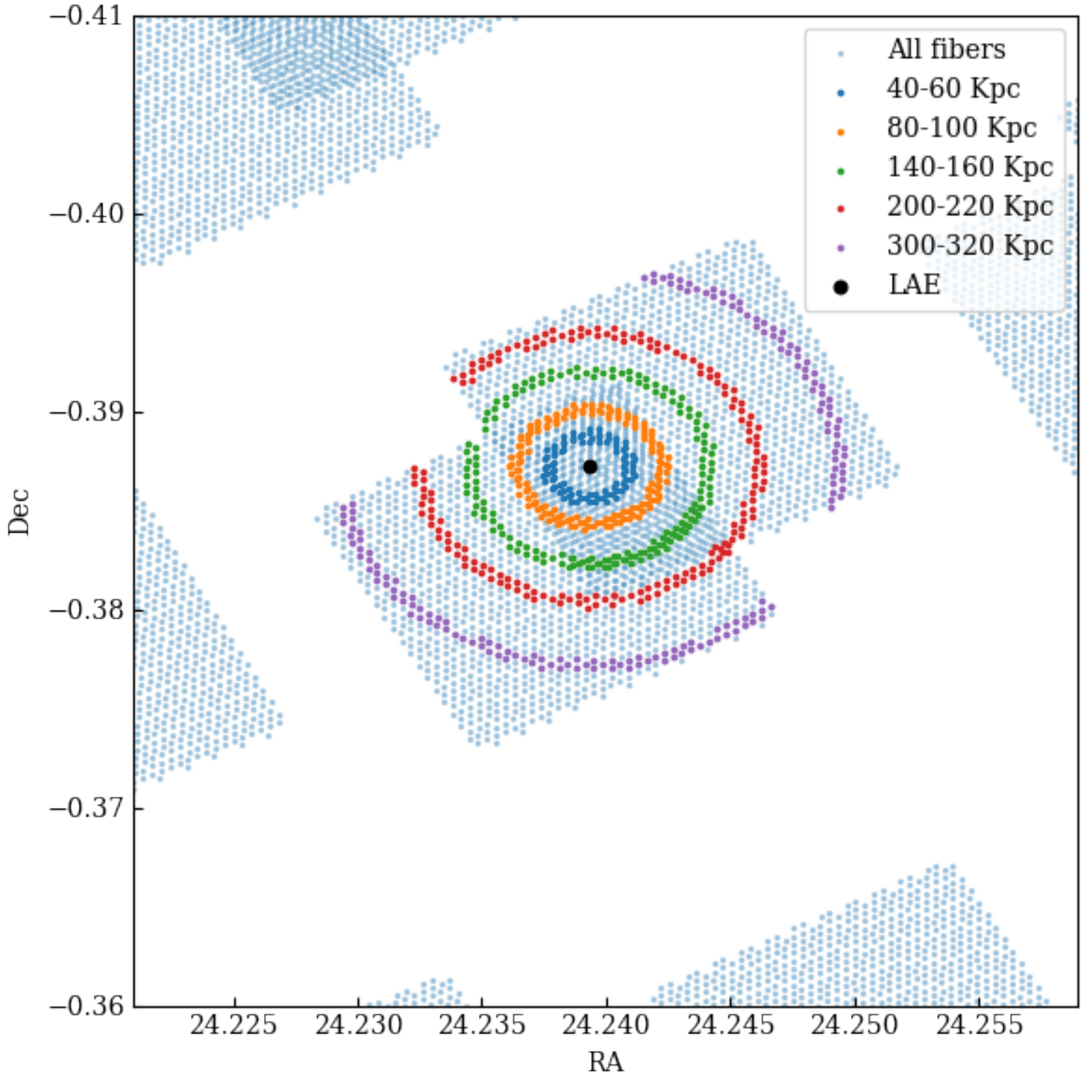
Our LAE sample (55,000):

- HDR 3.0.3
- High Confidence LAEs
- Exclude AGNs
- S/N: 5-10 (~98% of all the high confidence LAEs)

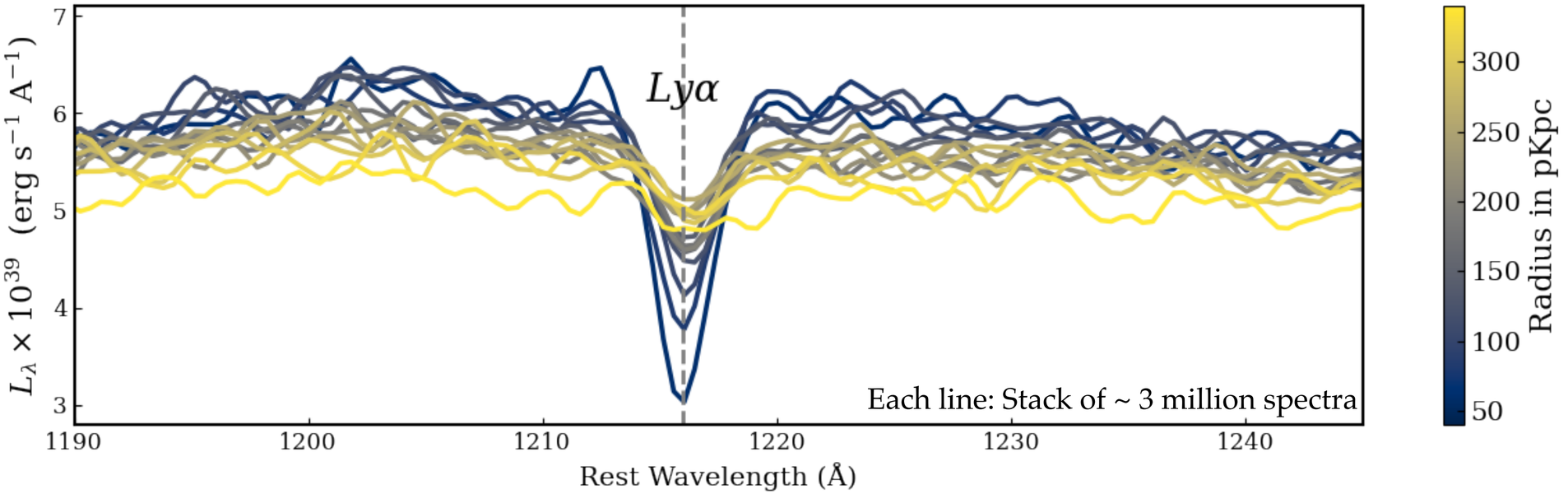
1. Collect the fibers & remove the bad ones
2. Remove the fibers with continuum in them
3. Take a median of the remaining fibers
4. Apply a residual correction
5. Shift to restframe and stack (biweight) **Davis+ 2023b**

Note that:

A. We go to multiple IFUs
B. Circles are not always perfect



HI halo extends to ~300 pKpc for LAEs in HETDEX



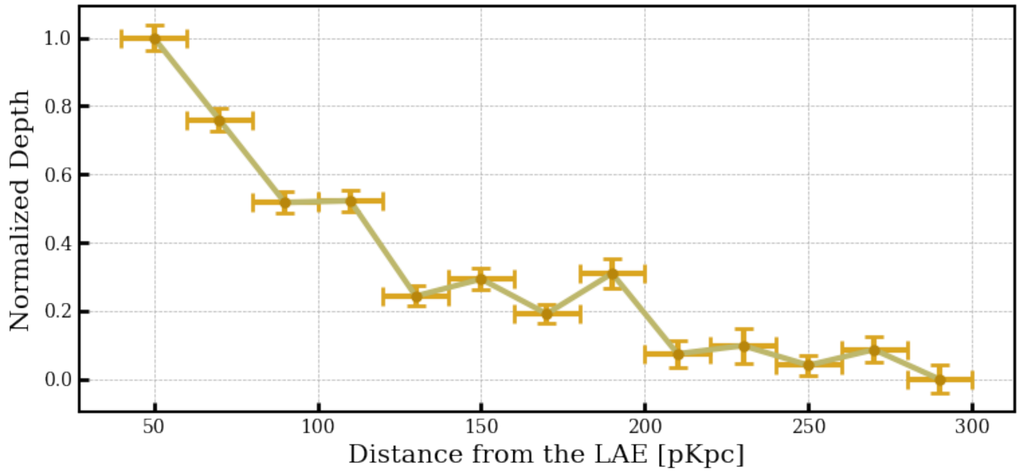
Caveat: Continuum level

- We can only give a relative depth profile and not a density profile, yet!

- Depth: The area under the gaussian fit to the absorption line

Same results with HDR4

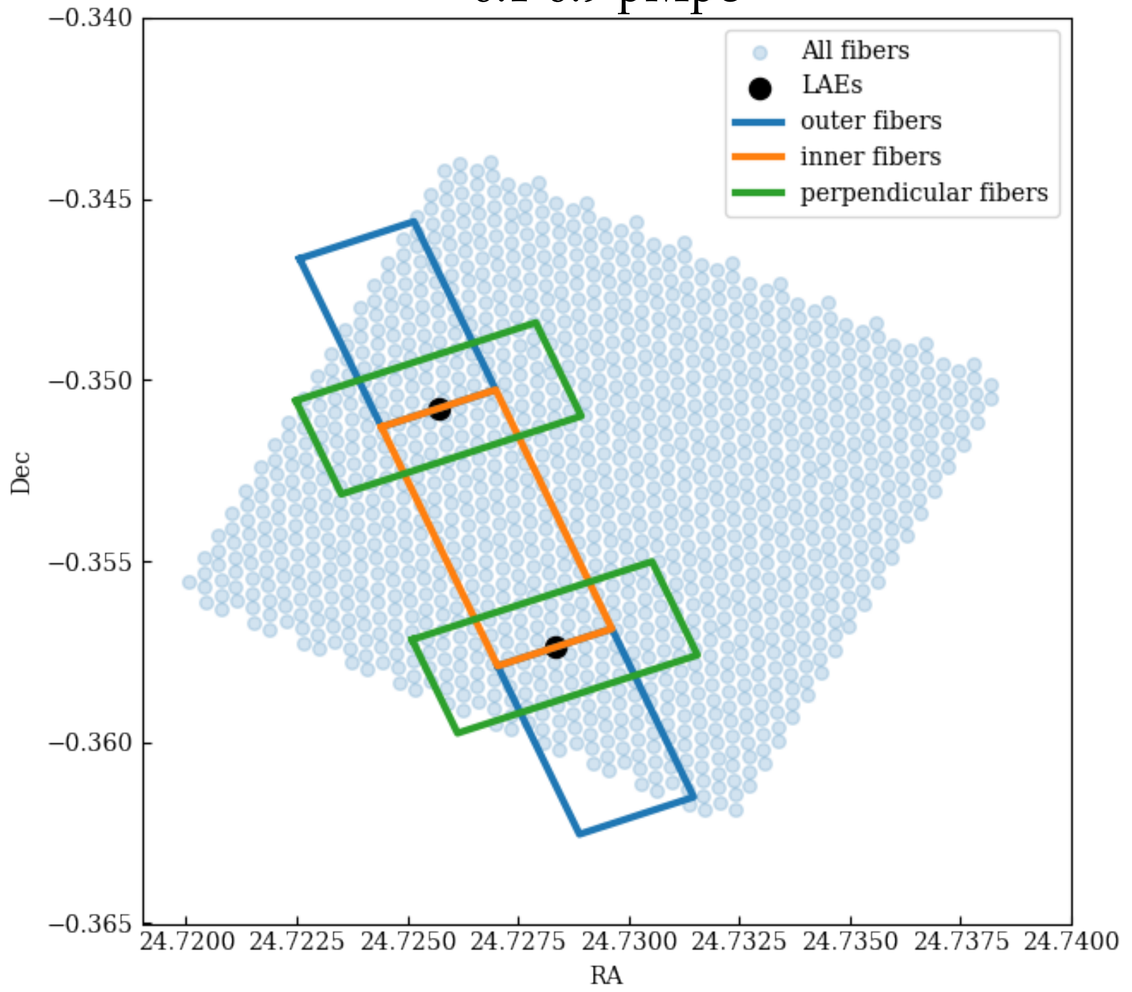
HI depth profile of an average LAE at z~2.5



We can do this with LAE pairs too

Close pairs (1250 pairs)

0.1-0.9 pMpc

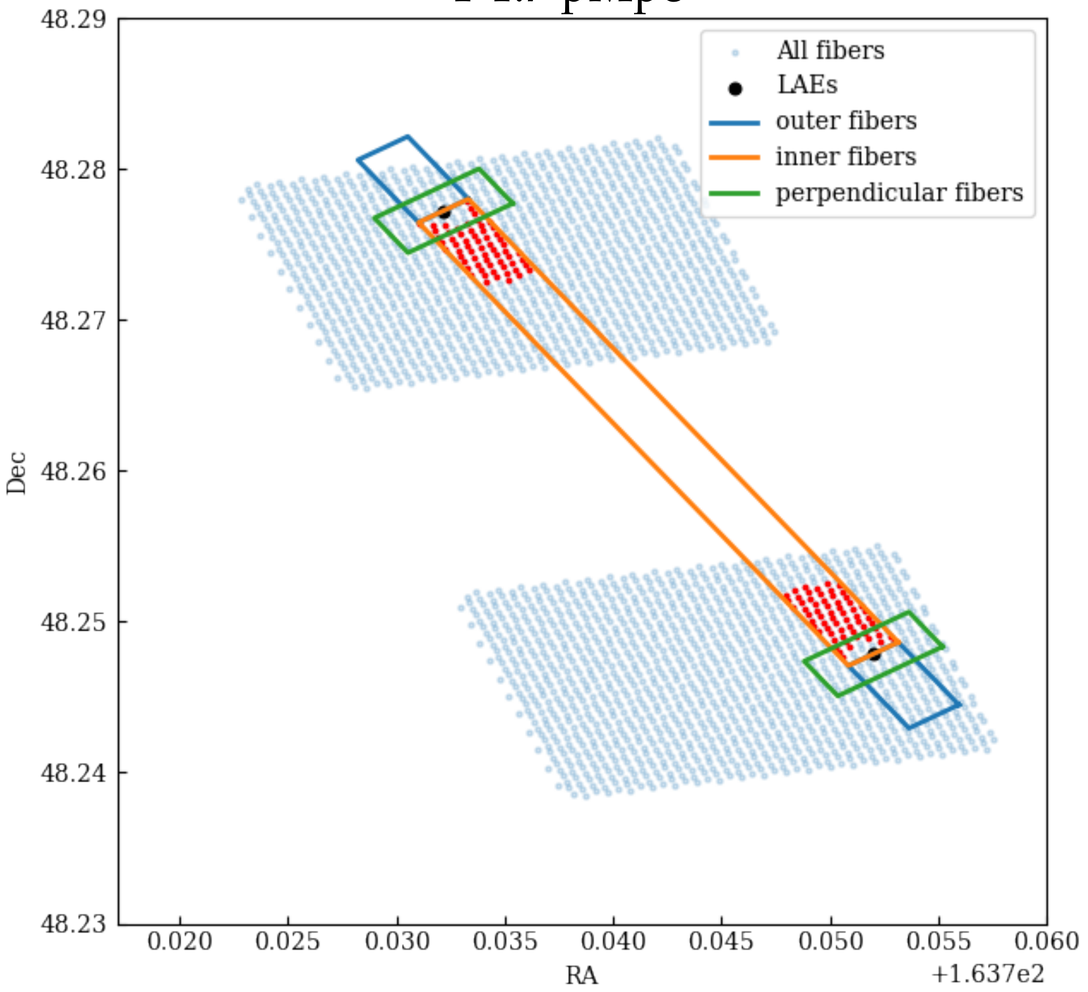


Δz<0.002

10″<Δr<36″

Distant pairs (2500 pairs)

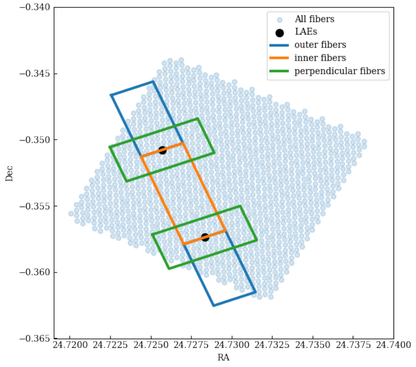
1-1.7 pMpc

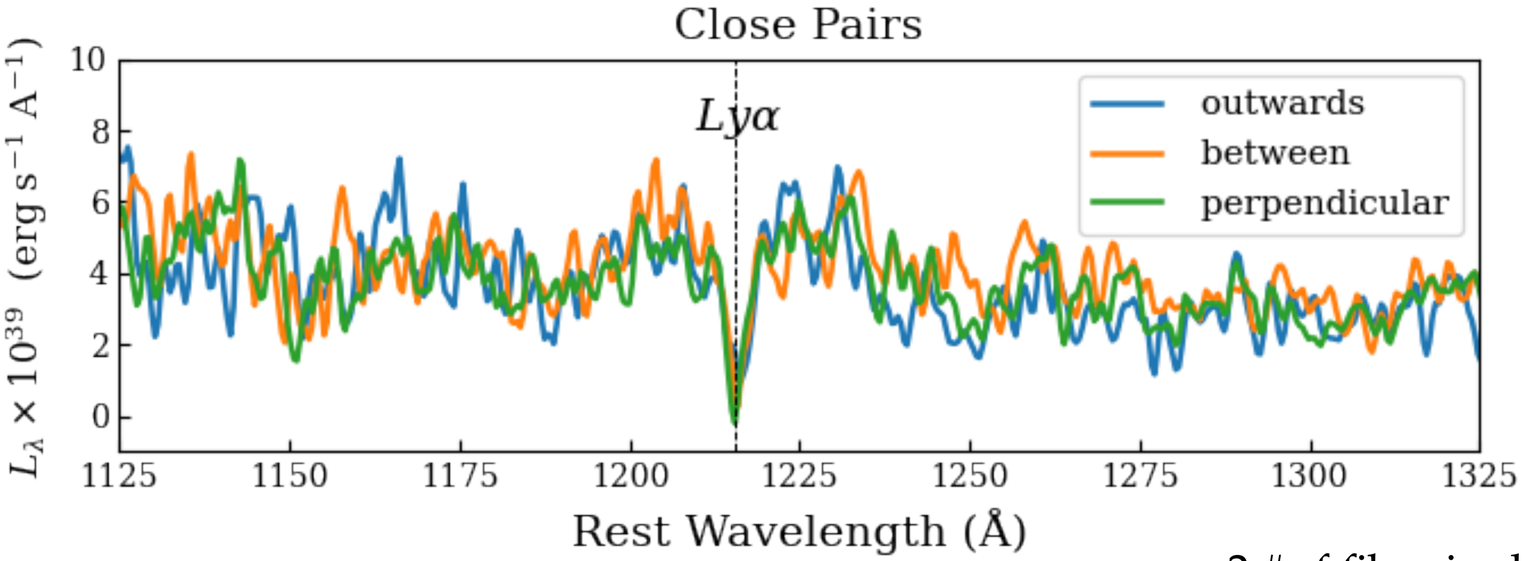


Δz<0.002

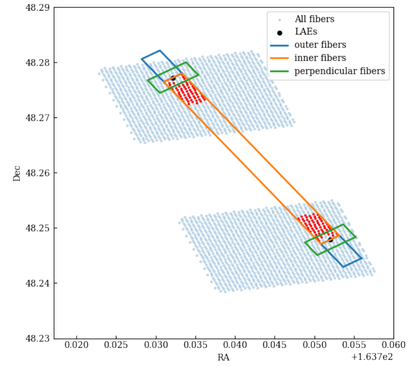
80″<Δr<120″

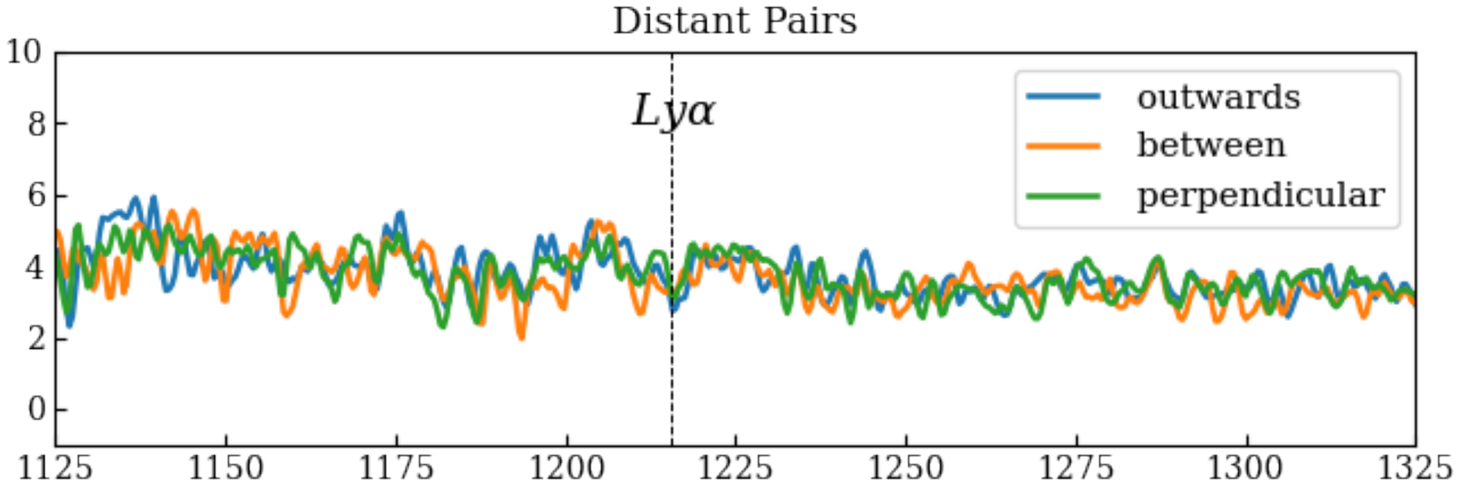
Absorption Strength as a function of density enchancment (sky separation)





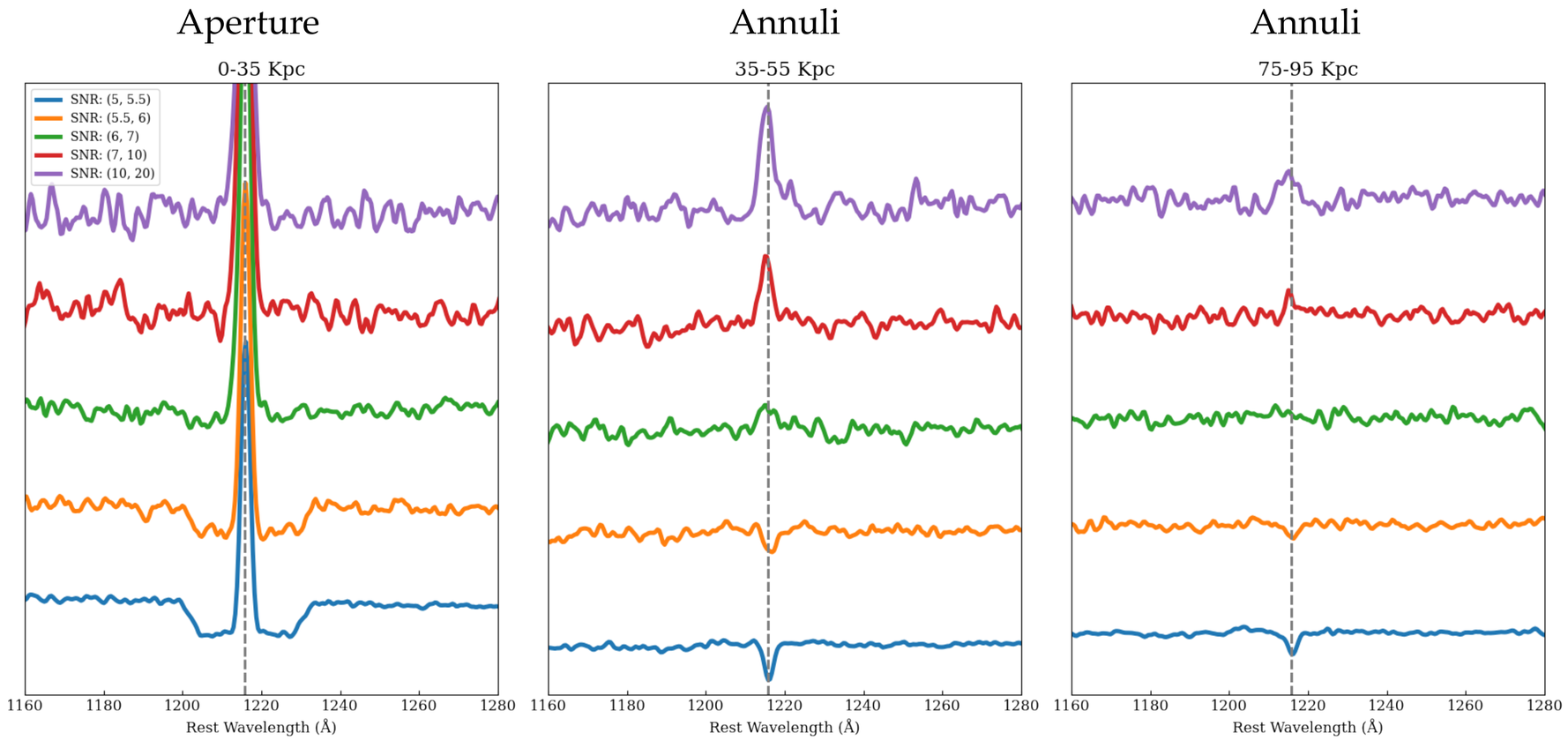
x2 #of fiber in distant pair regions

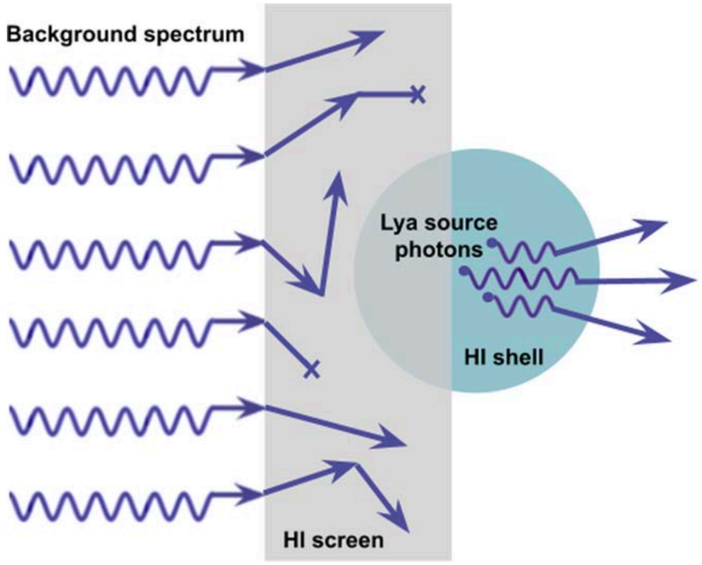




Same results with HDR4

Physical Model of the absorption





Weiss+ 2024

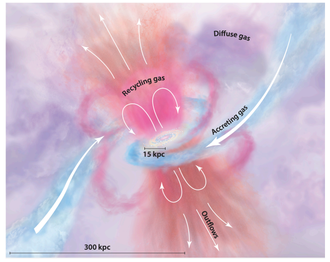
- LAE is partially embedded in an HI screen or filament
- The degree of embedding in the filament inversely correlates with the observed signal

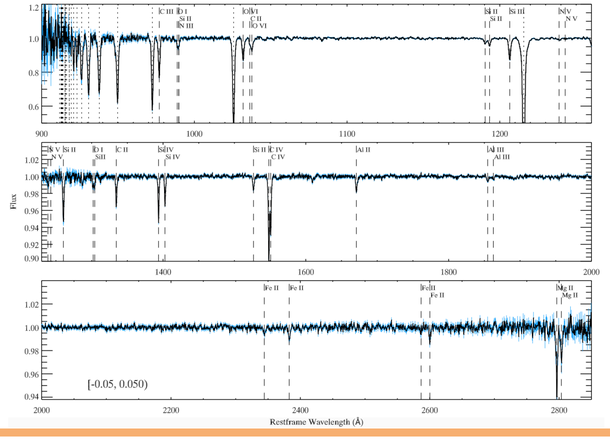
(1) the LAE in an overdense region,
(2) More Lya photons in the background than in the foreground
(3) LAE more embedded in the HI screen
(4) Stacking reveals this subtle absorption

Takeaways

CGM:

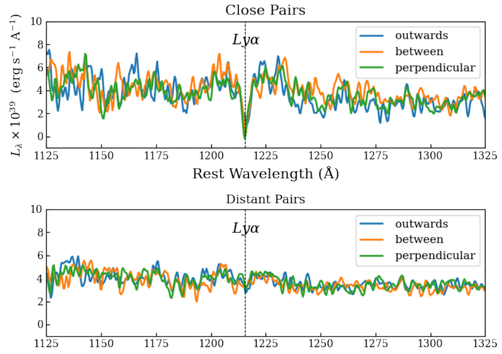
- Multi phase & multi scale
- Well studied locally
- Hard to provide a complete statistical view at high z

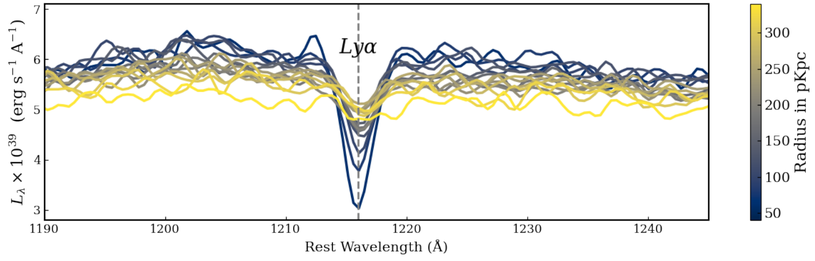


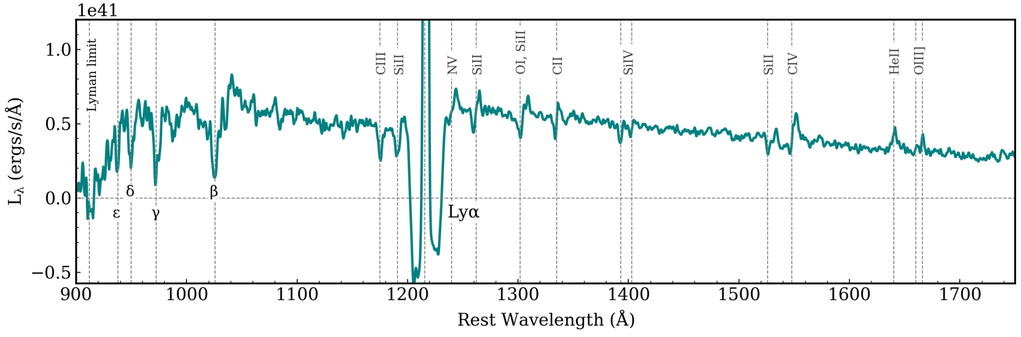


HETDEX LAEs (z~2.5):

- HI halo extents out to ~ 300 pKpc
- Lyα absorption strength can be used as a proxy of local density enhancements

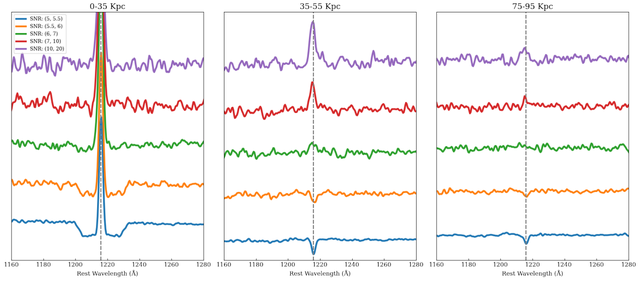






- Stacking lots of spectra from can provide a complete statistical view
- We stack spectra from the environment around & between LAEs

(1) the LAE in an overdense region,
(2) More Lya photons in the background than in the foreground
(3) LAE more embedded in a filament
(4) Stacking reveals this subtle absorption



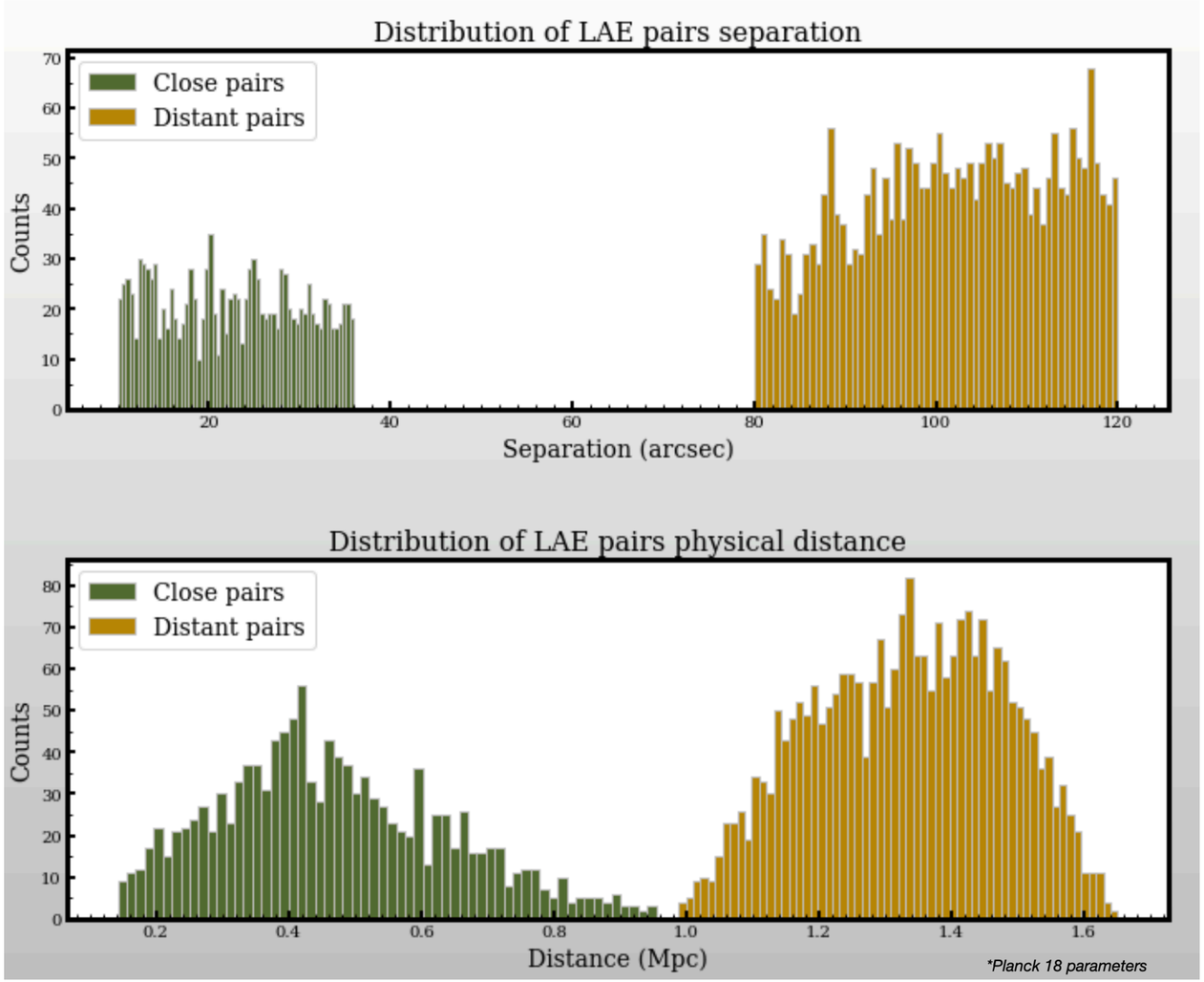
The goal is to quantify the extent and column density of HI as a function of redshift, size, density enhancements, and Lya luminosity.

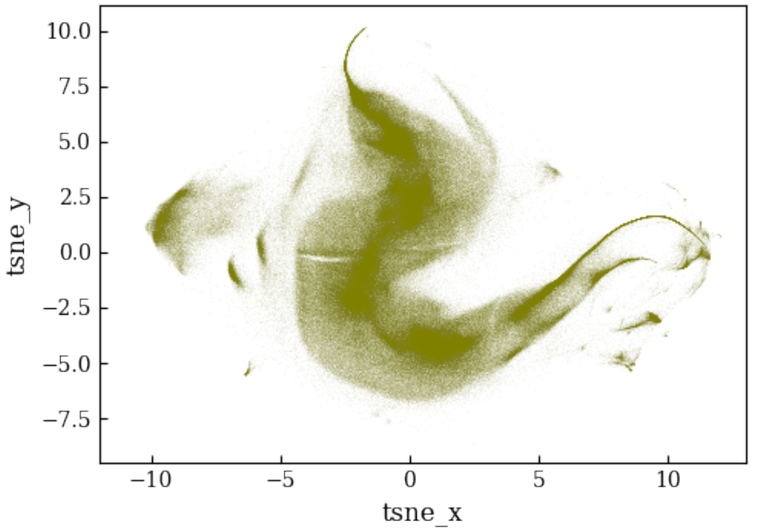
Paper is submitted to the collaboration!

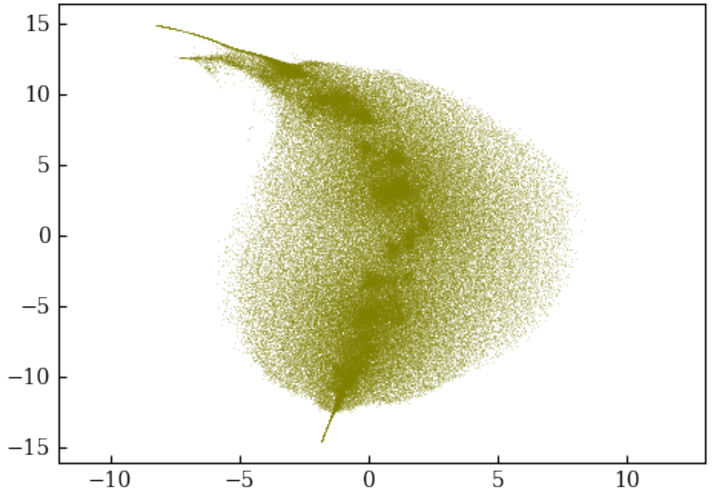
https://github.com/mahanmkh

Thank You!

Extra Plots

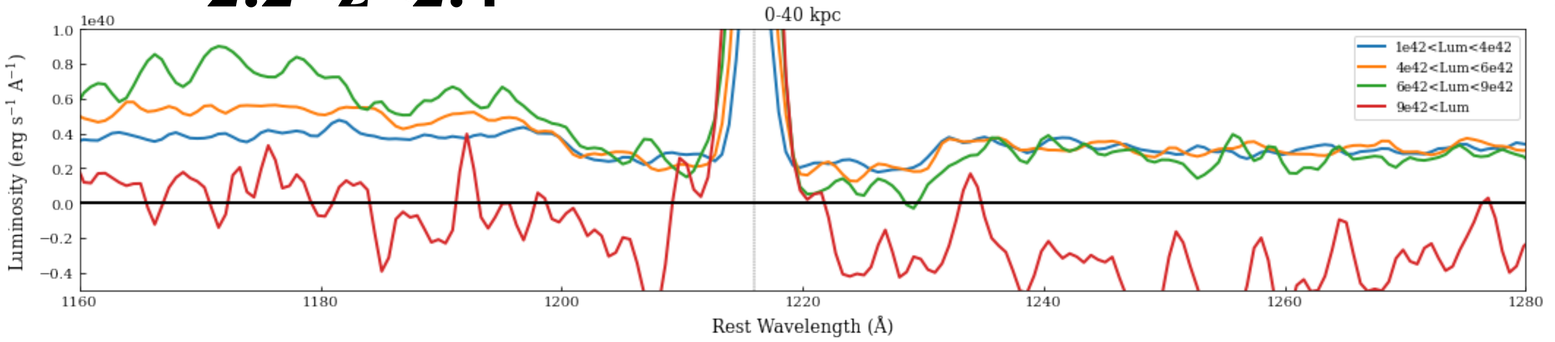

Distribution of LAE pairs separation
Close pairs
Distant pairs
Counts
Separation (arcsec)
Distribution of LAE pairs physical distance
Close pairs
Distant pairs
Counts
Distance (Mpc)
*Planck 18 parameters

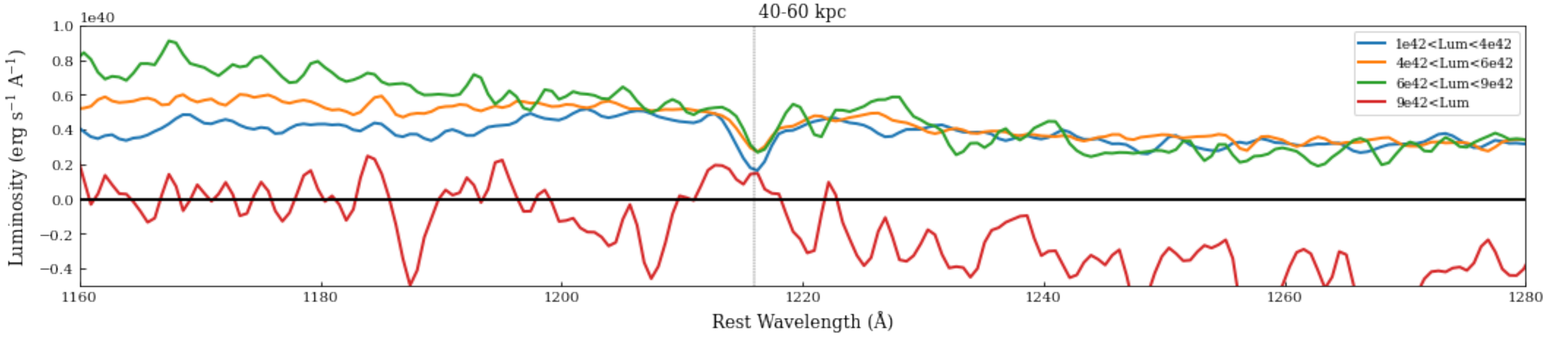

tsne_y
tsne_x

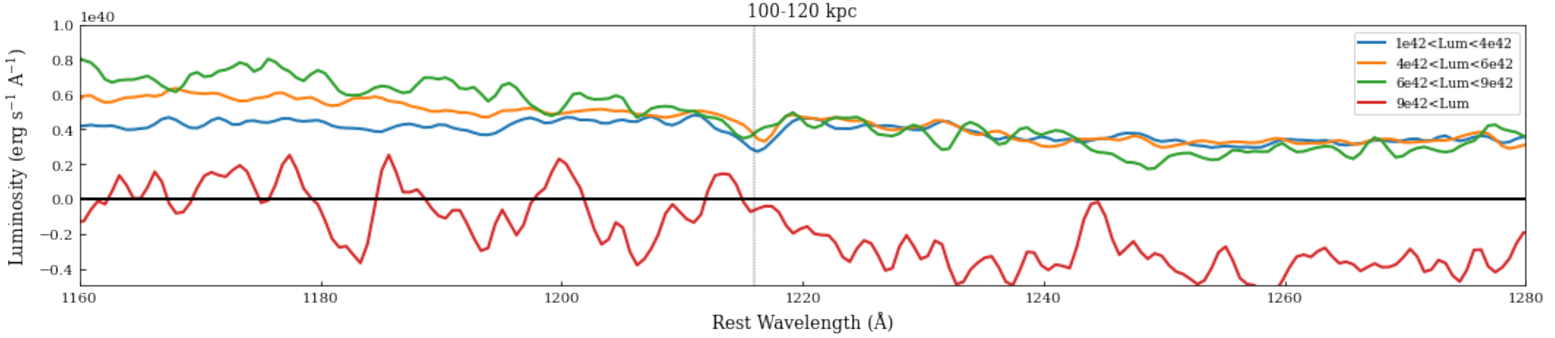


Luminosity Binning

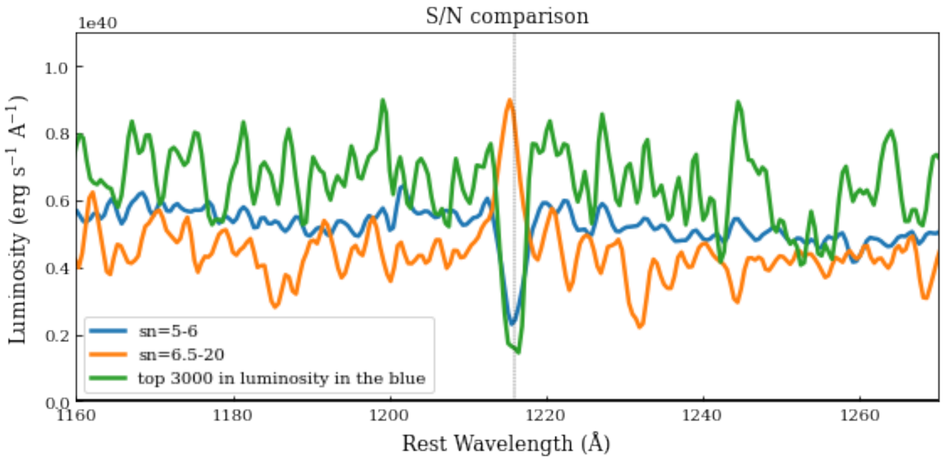
2.2<z<2.4



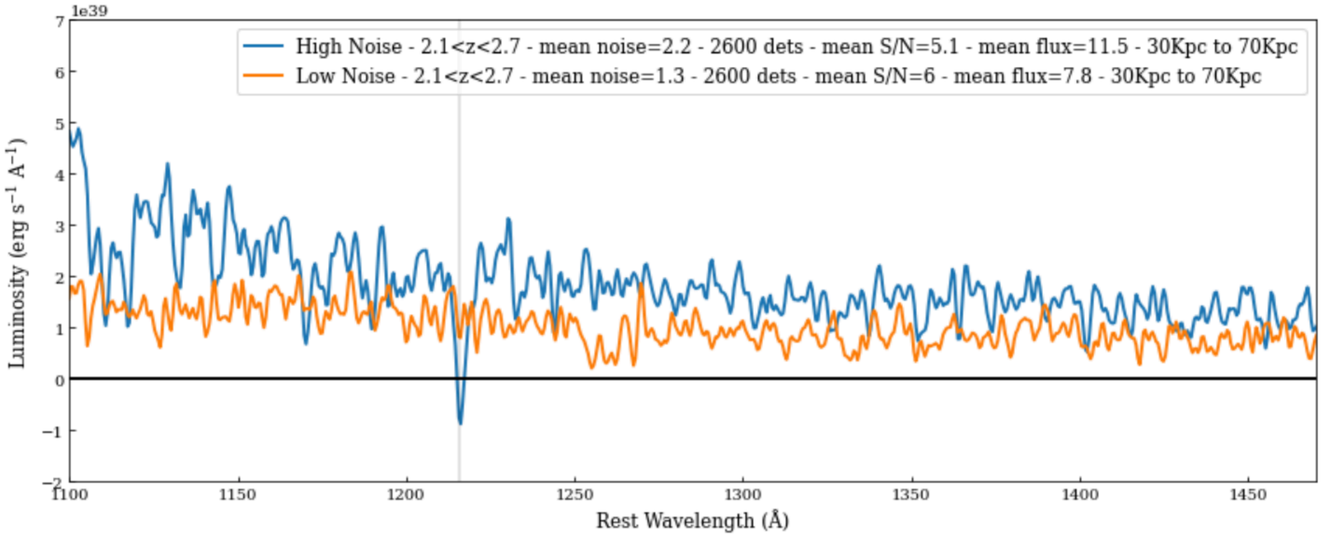


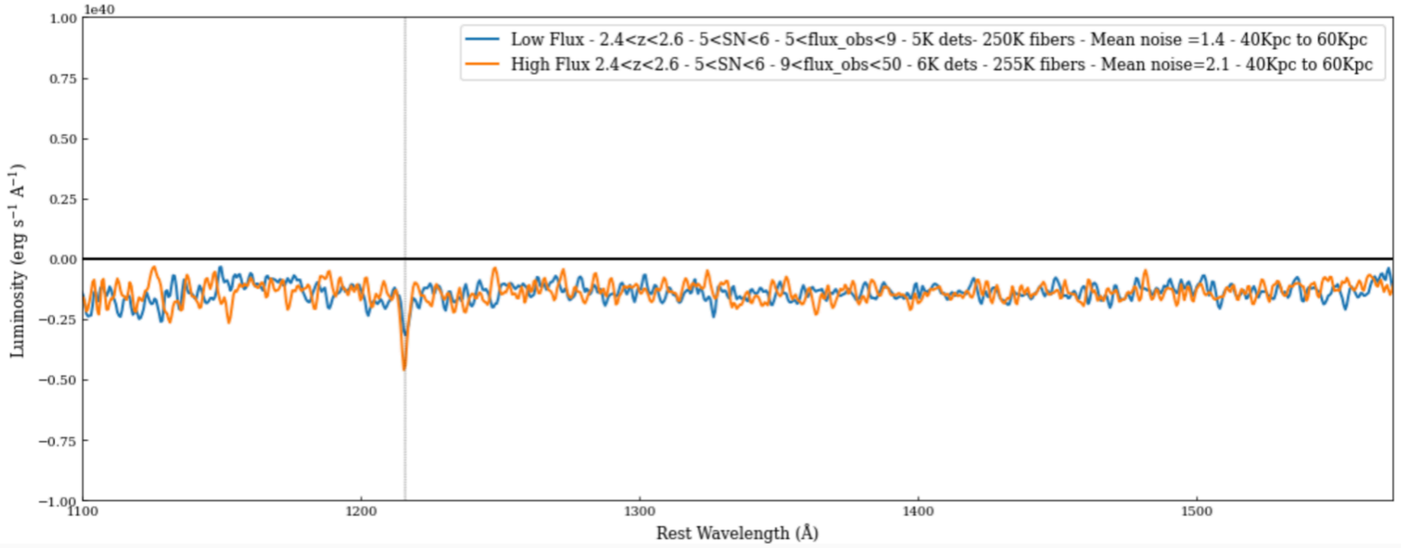


Extra Plots



Extra Plots


1e39
High Noise - 2.1<z<2.7 - mean noise=2.2 - 2600 dets - mean S/N=5.1 - mean flux=11.5 - 30Kpc to 70Kpc
Low Noise - 2.1<z<2.7 - mean noise=1.3 - 2600 dets - mean S/N=6 - mean flux=7.8 - 30Kpc to 70Kpc
Luminosity (erg s^{-1} A^{-1})
Rest Wavelength (Å)


1e40
Low Flux - 2.4<z<2.6 - 5<SN<6 - 5<flux_obs<9 - 5K dets- 250K fibers - Mean noise =1.4 - 40Kpc to 60Kpc
High Flux 2.4<z<2.6 - 5<SN<6 - 9<flux_obs<50 - 6K dets - 255K fibers - Mean noise=2.1 - 40Kpc to 60Kpc
Luminosity (erg s^{-1} A^{-1})
Rest Wavelength (Å)