Infrared ELT Spectroscopy and Metal Enrichment in the EoR

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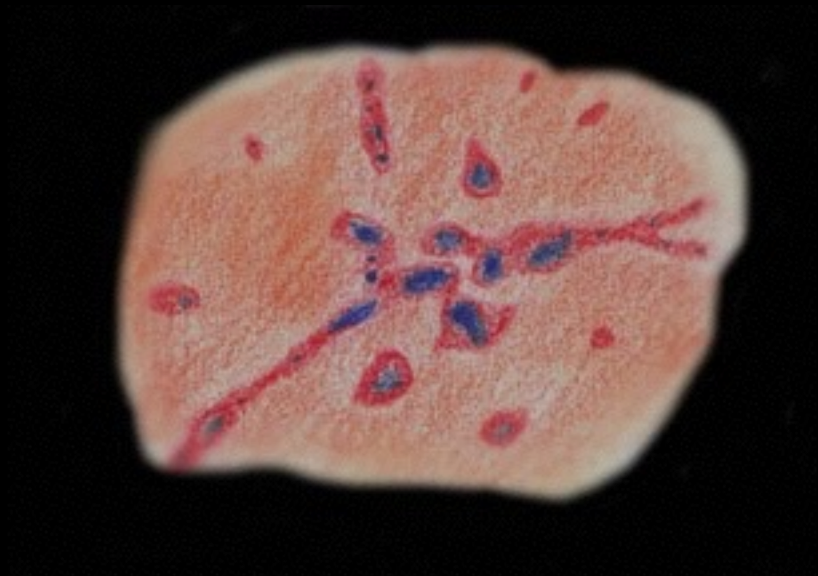
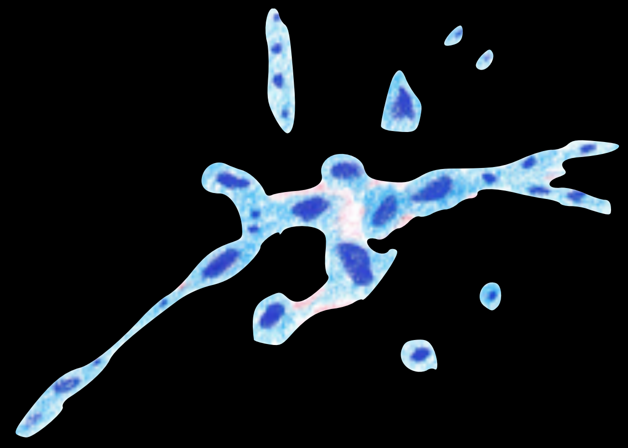
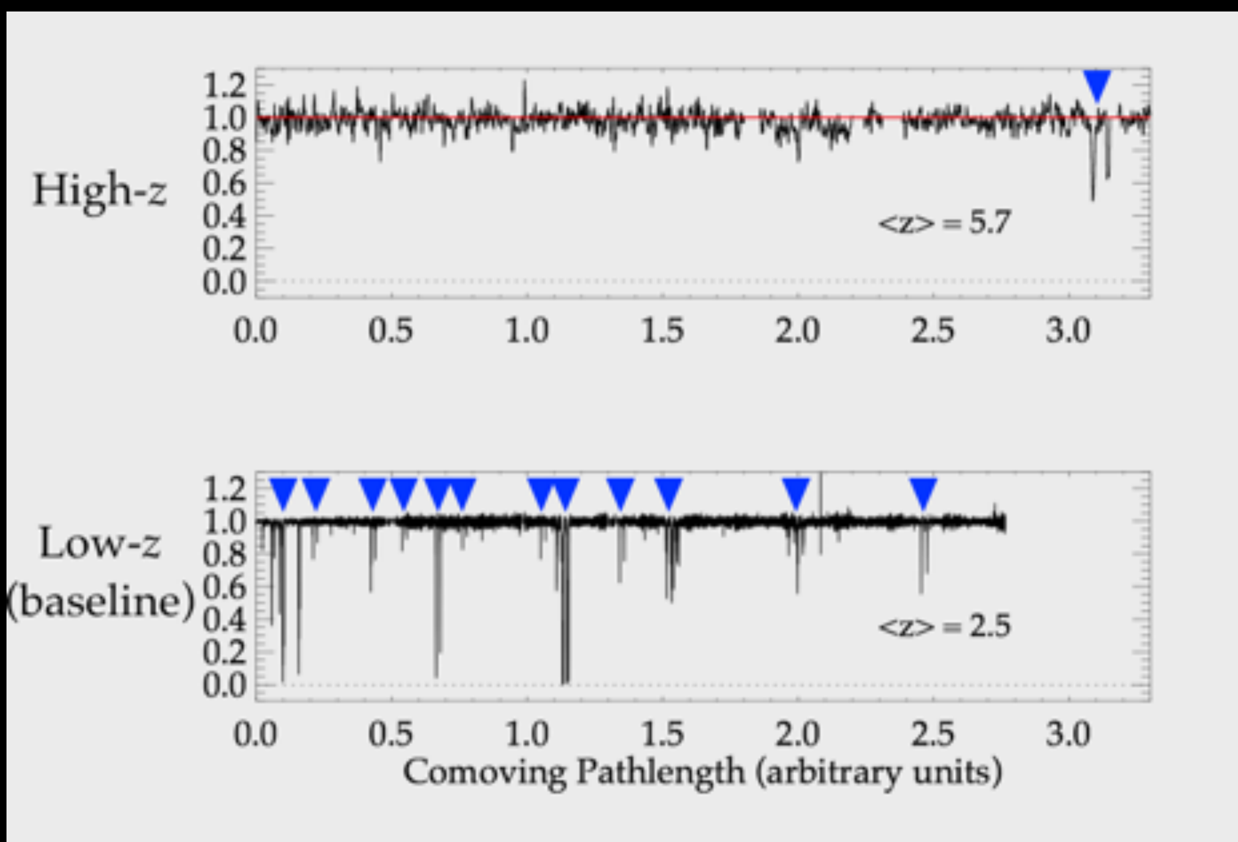


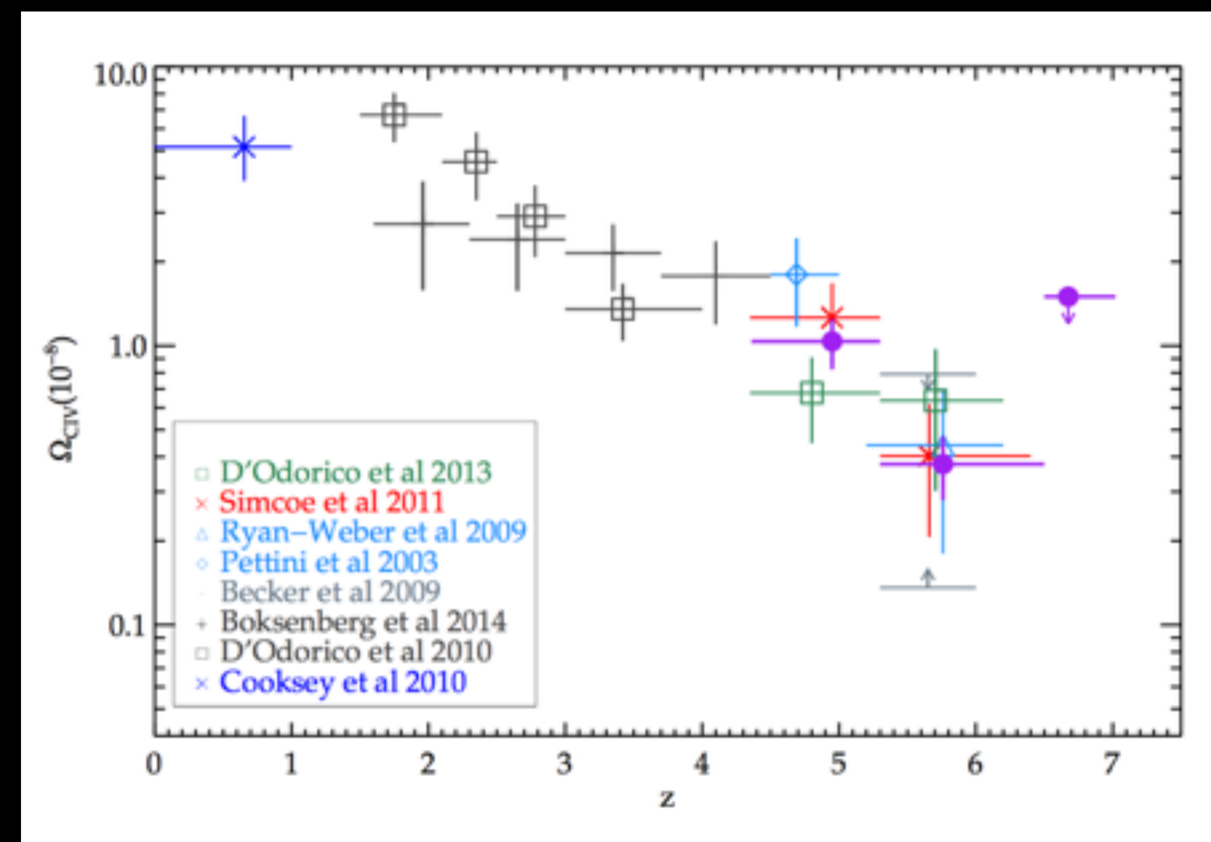


- Surveys of high, low-ionization QSO absorption at z > 6
- Changing signatures of CGM absorption
- Role of IR spectroscopy for the ELTs

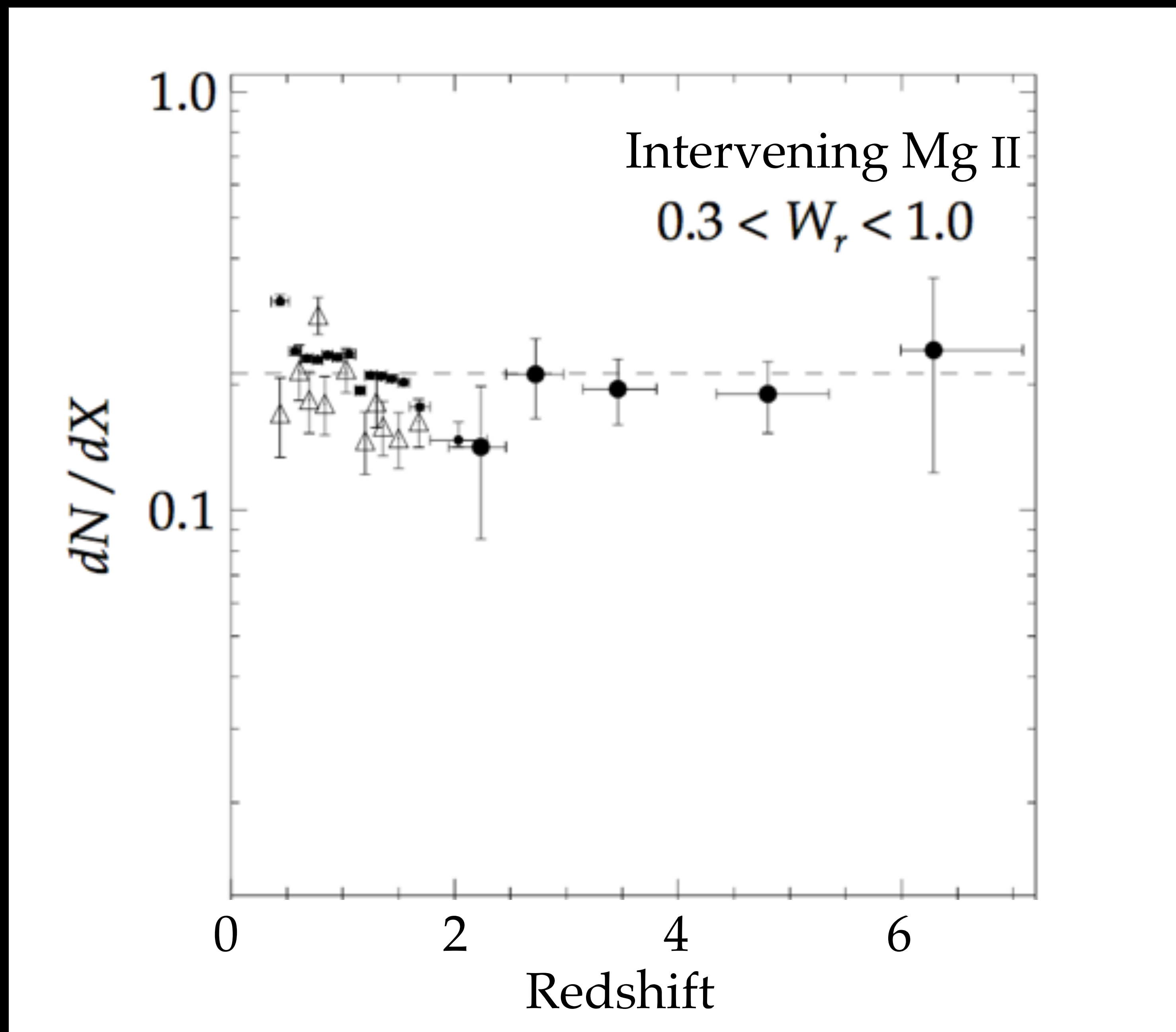
Tom Cooper et al (arxiv/1901.05980)
Stephen Chen et al (2018)
Simcoe et al (2016)

Above z ~ 4, the incidence rate of C IV QSO absorption declines, being very rare at z > 5.5



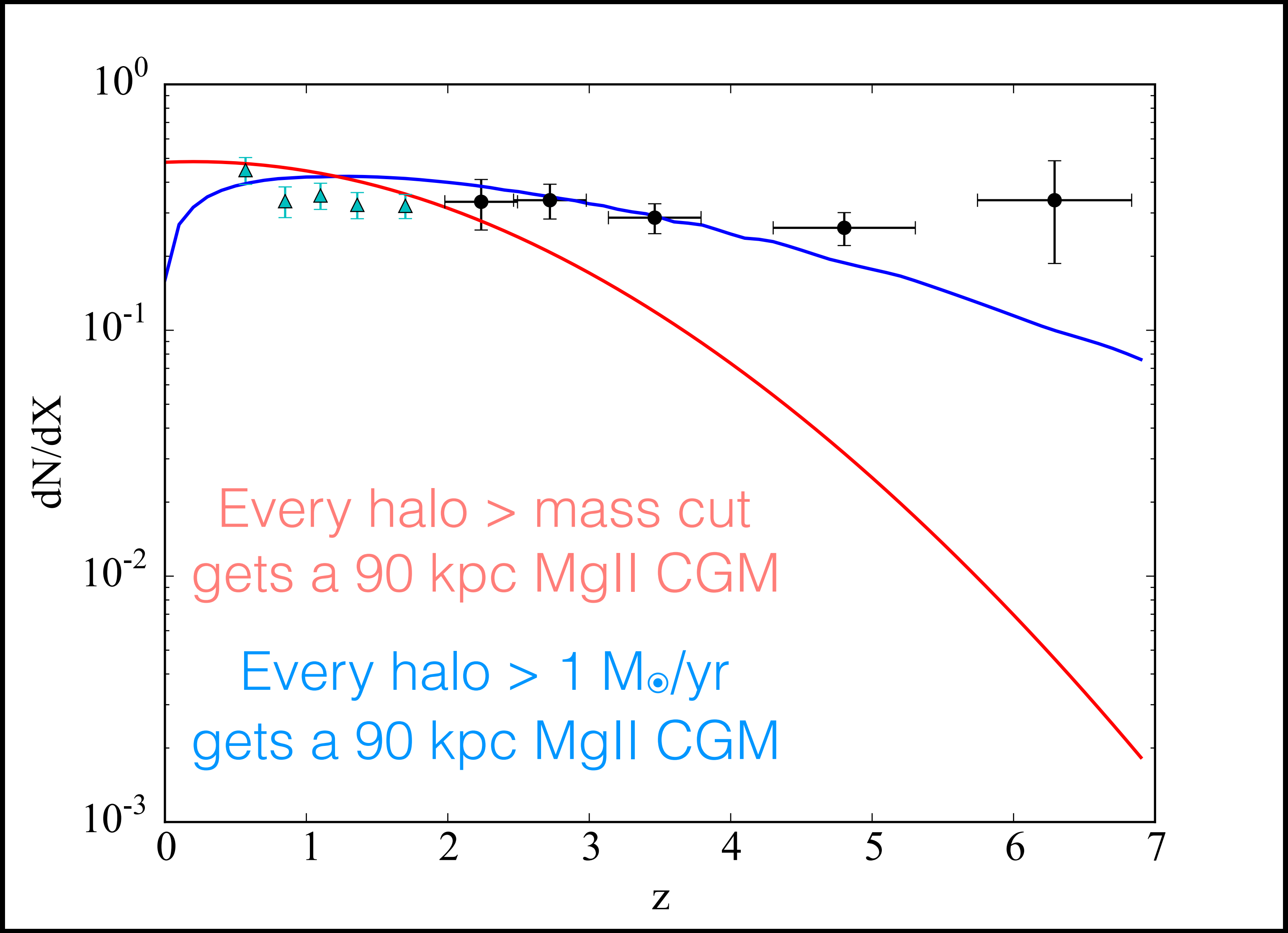


In contrast, the frequency of low-ionization Mg II remains steady to z ~ 7



1. CGM enrichment before L* galaxies are mature
2. At z > 6, must be Mg II systems without C IV

$$dN = n_{\mathrm{comoving,halo}} \cdot \sigma_{\mathrm{abs}} \cdot dX$$



Mg II comoving absorber density (# per unit path)

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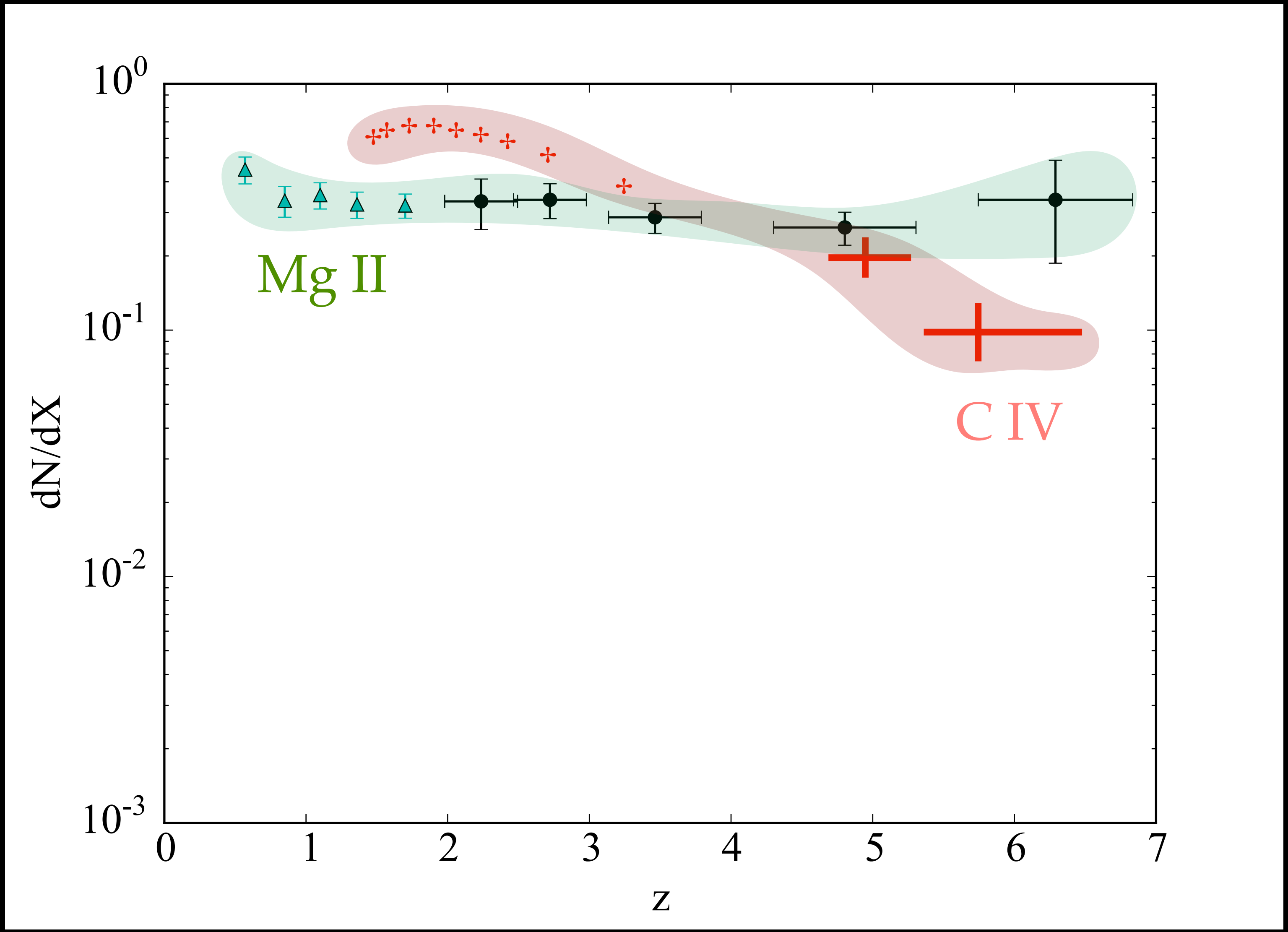
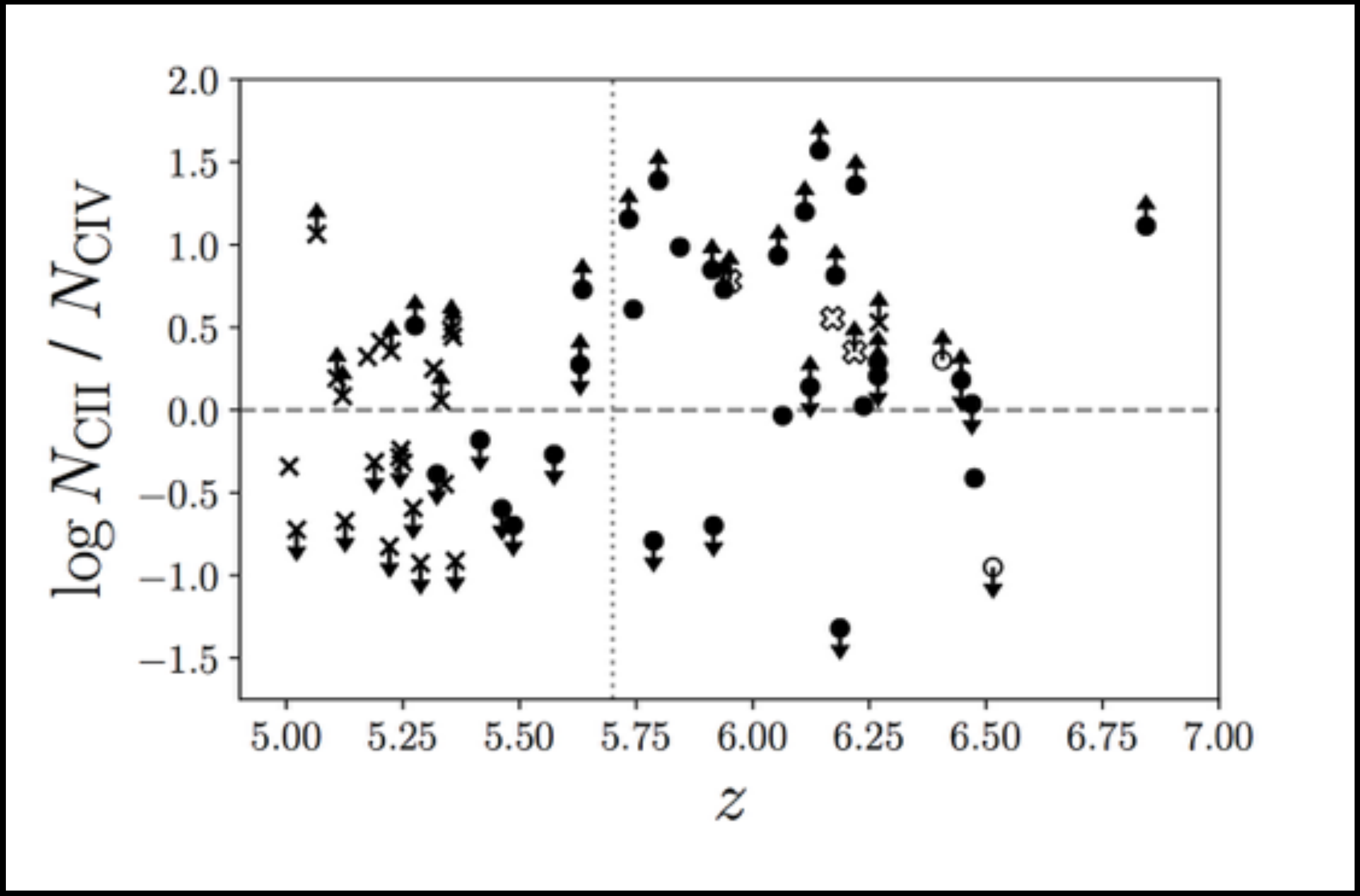


Mg II or CIV comoving absorber density (# per unit path)

Above z ~ 5.7, QSO absorbers commonly invert their ratio to $N_{CII} > N_{CIV}$

noted by Becker et al 2006, 2011



47 quasars above z = 5.7
69 absorbers, 16 new at z > 6

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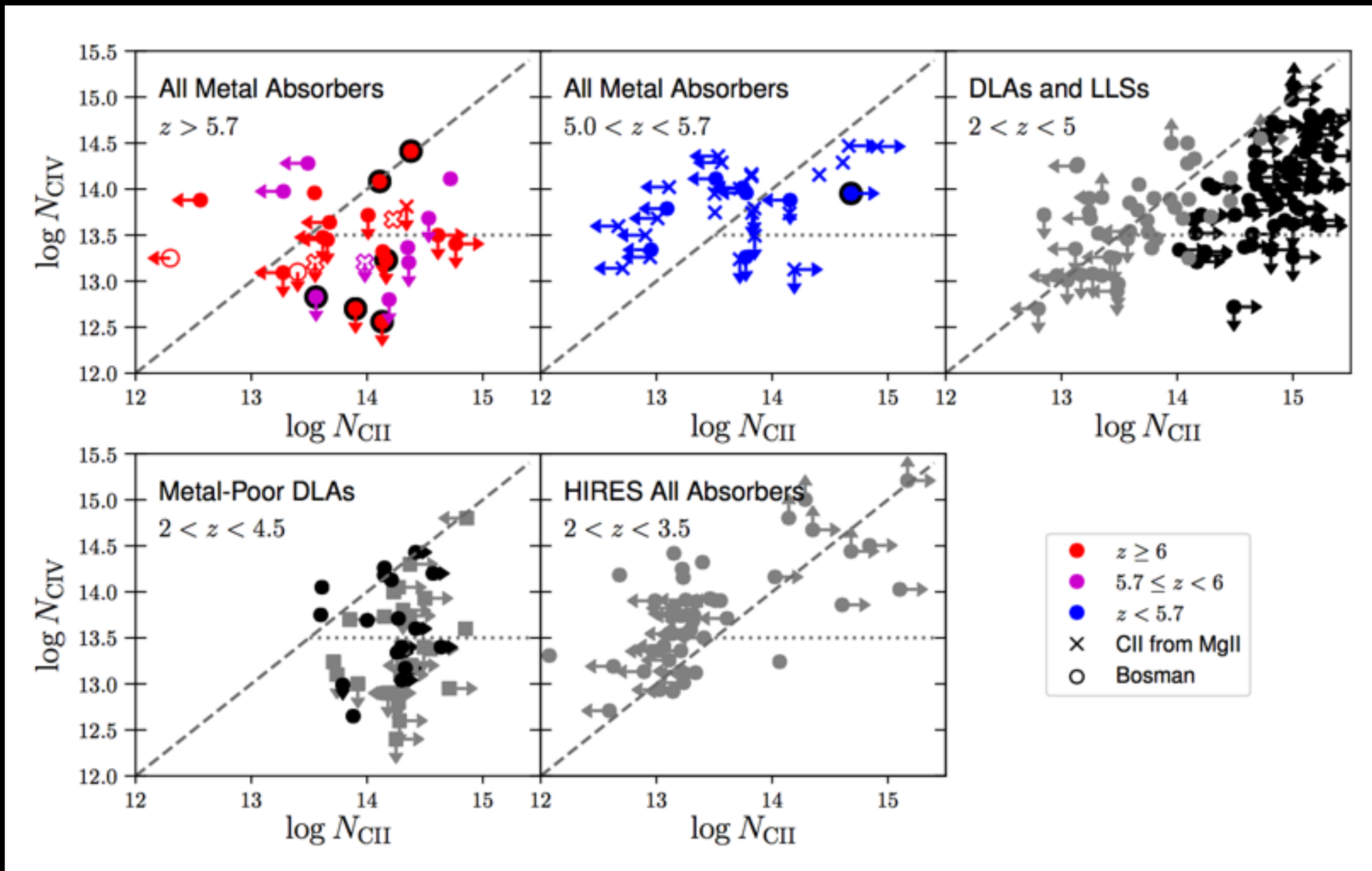
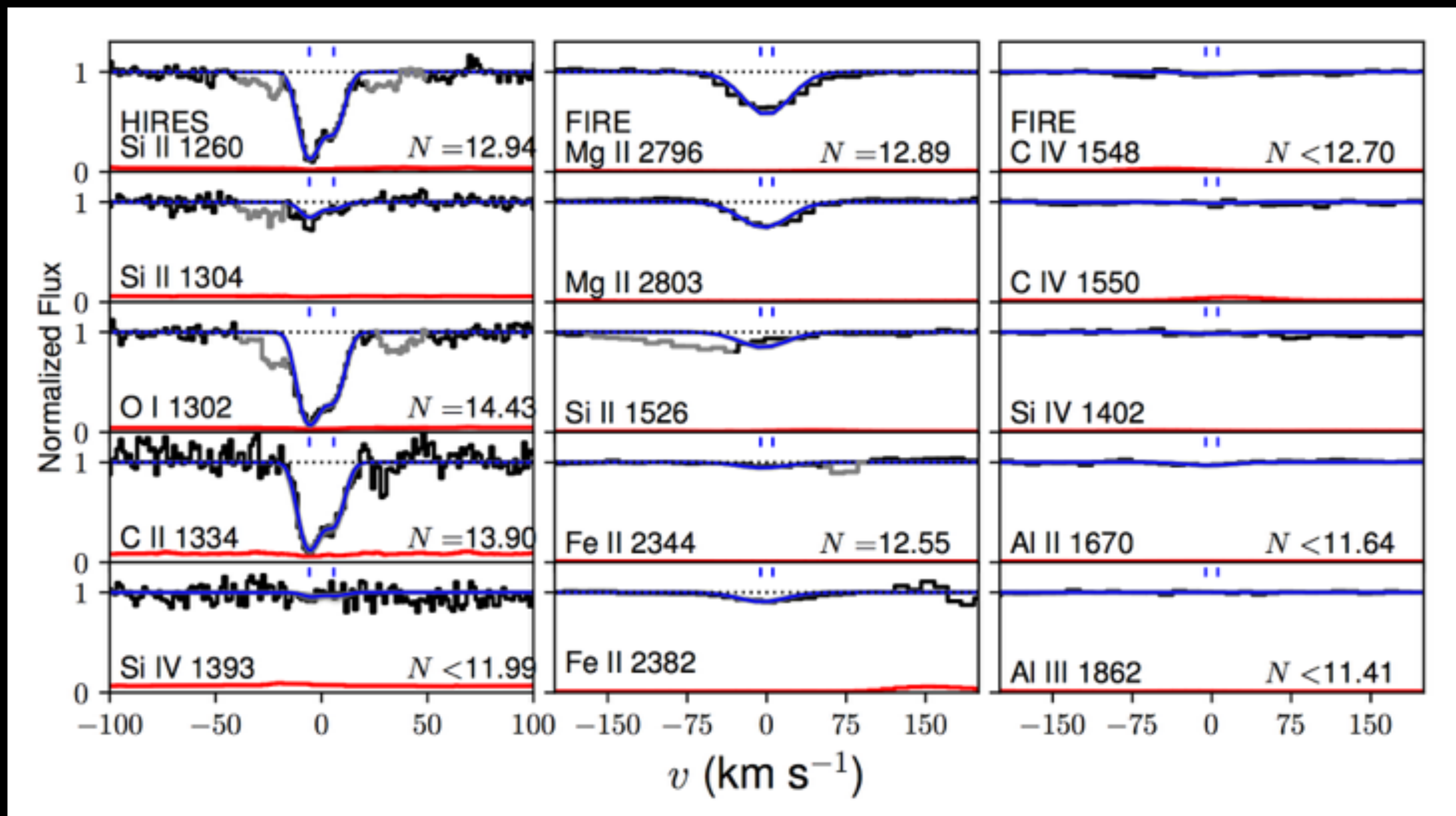


We see this trend broadly, including our best individual specimens, and in population stacks



z = 6.1117; Keck/HIRES + Magellan/FIRE
SDSS J0100+2802

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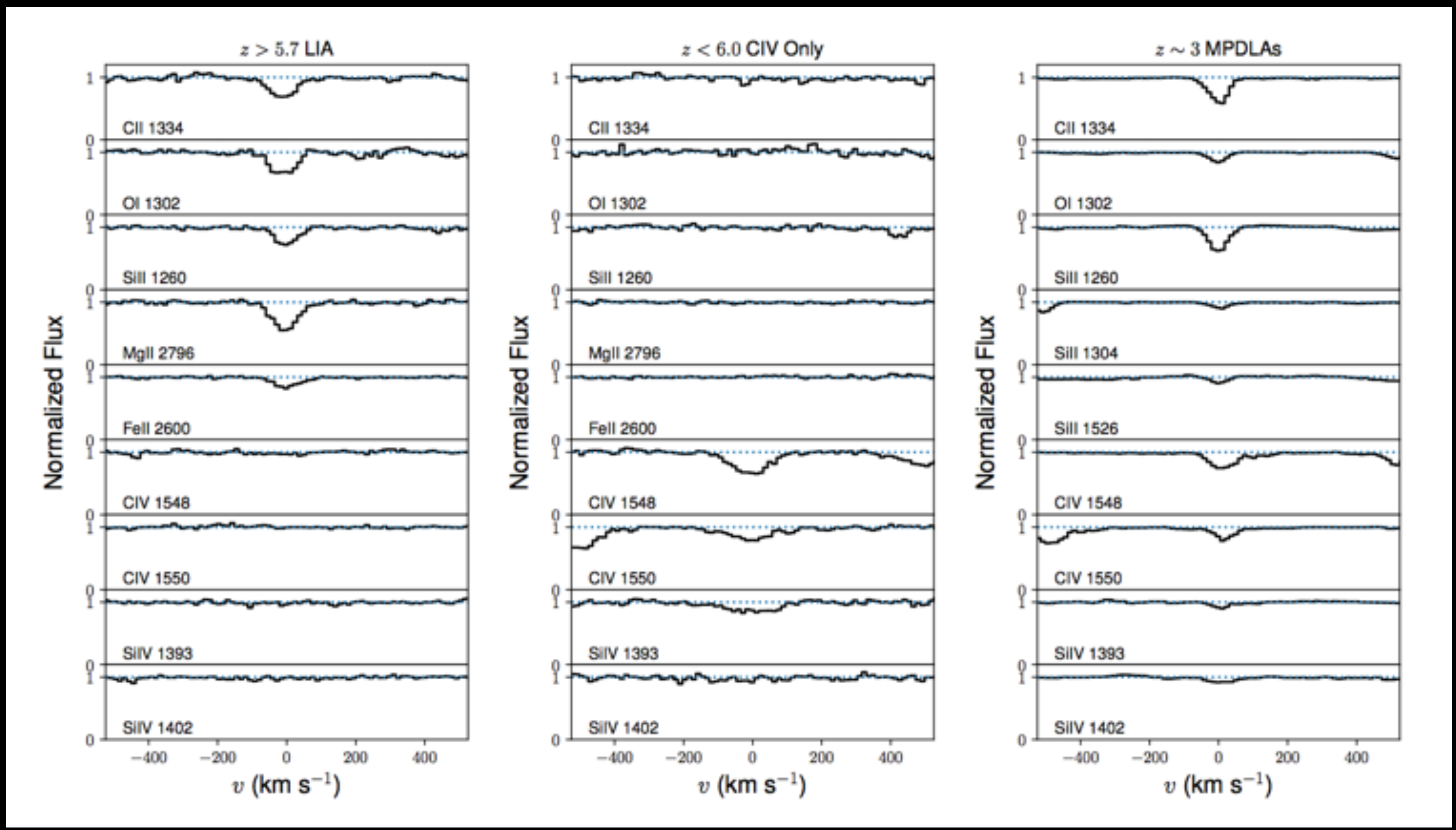
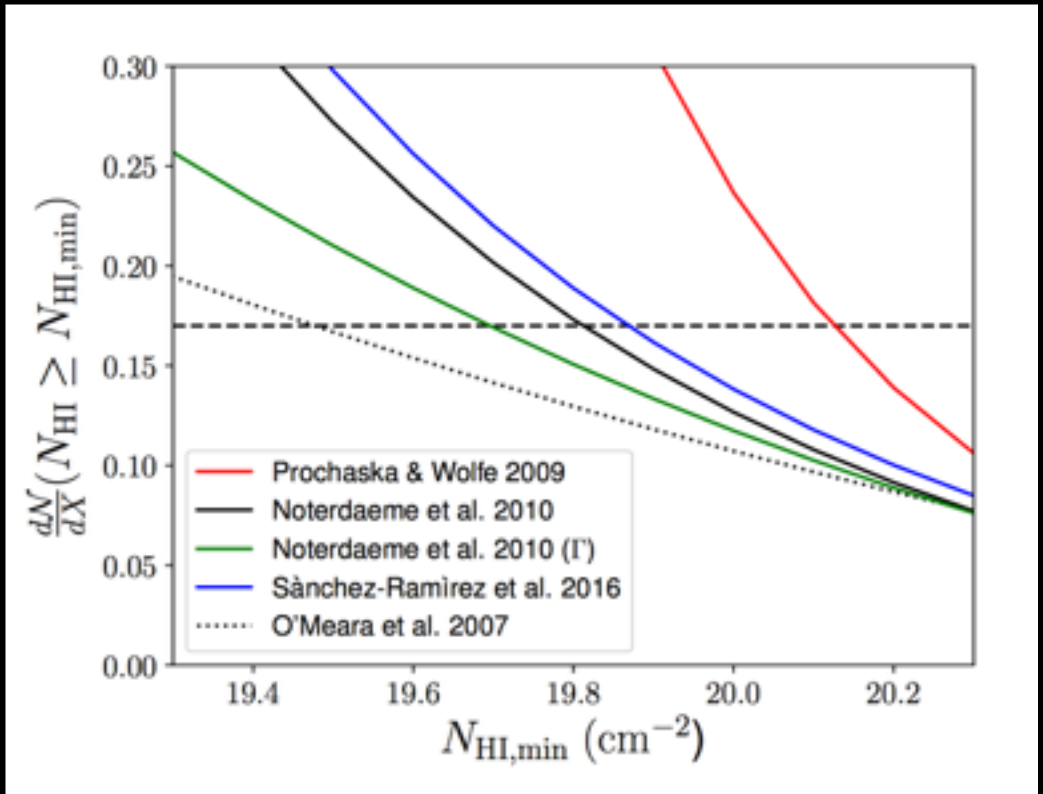


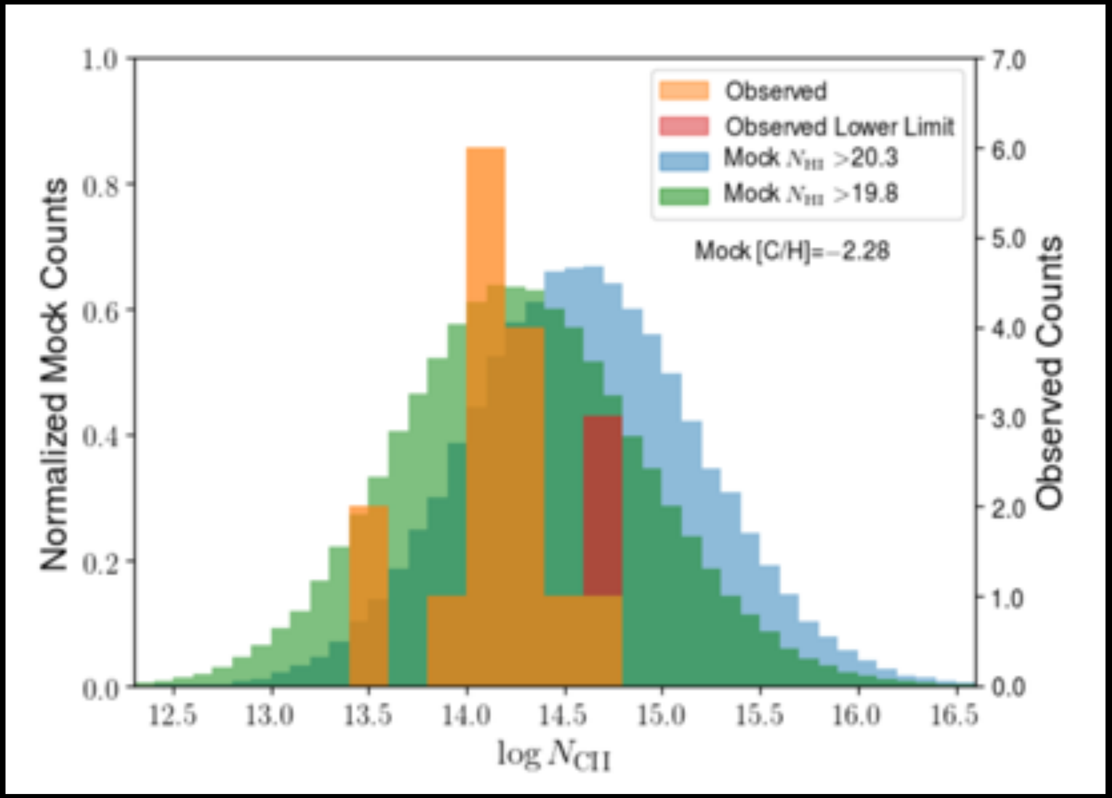
Unweighted Median Stacks

Some interpretations can be weighed, even when measuring N_{HI} is impossible

- Gas is likely to be substantially neutral
  - O I is generally observed when accessible
- Heavy element abundance likely low
  - Si II 1260 usually unsaturated

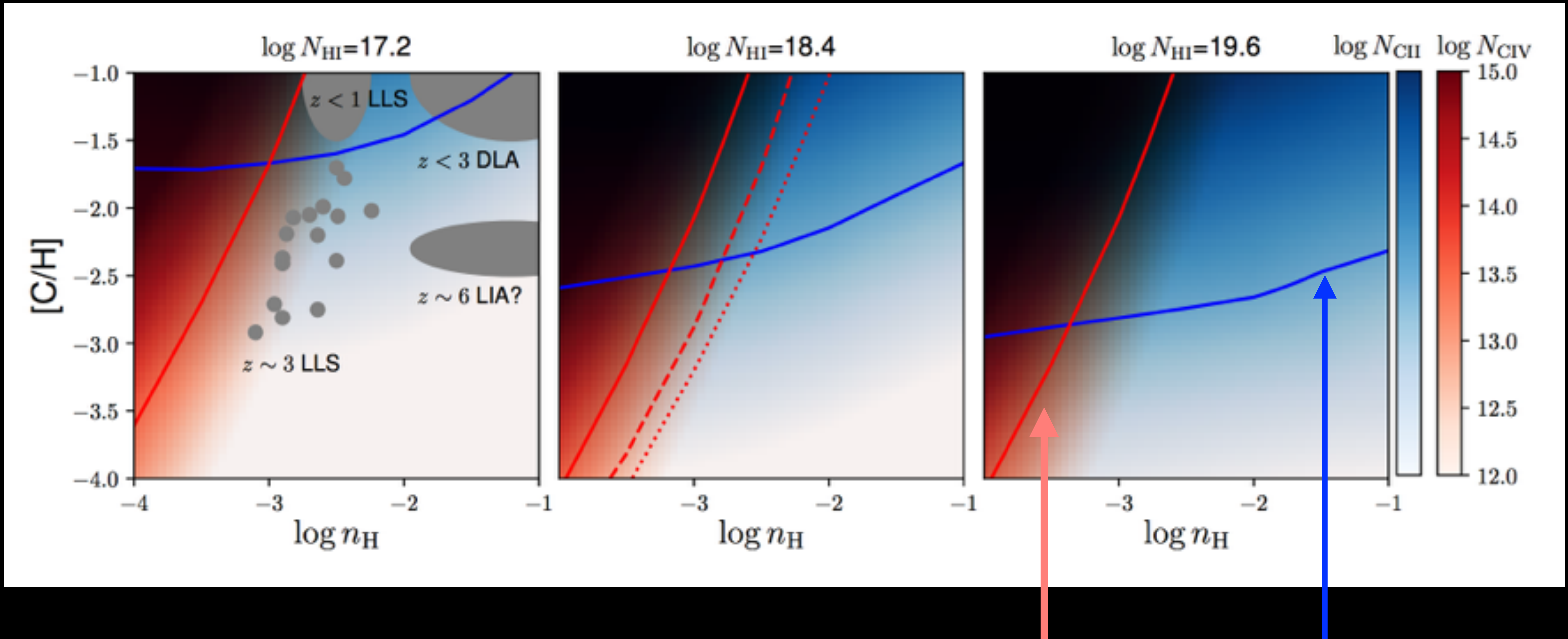
Number counts suggest these are metal-poor (sub) DLAs with no ionized+enriched CGM





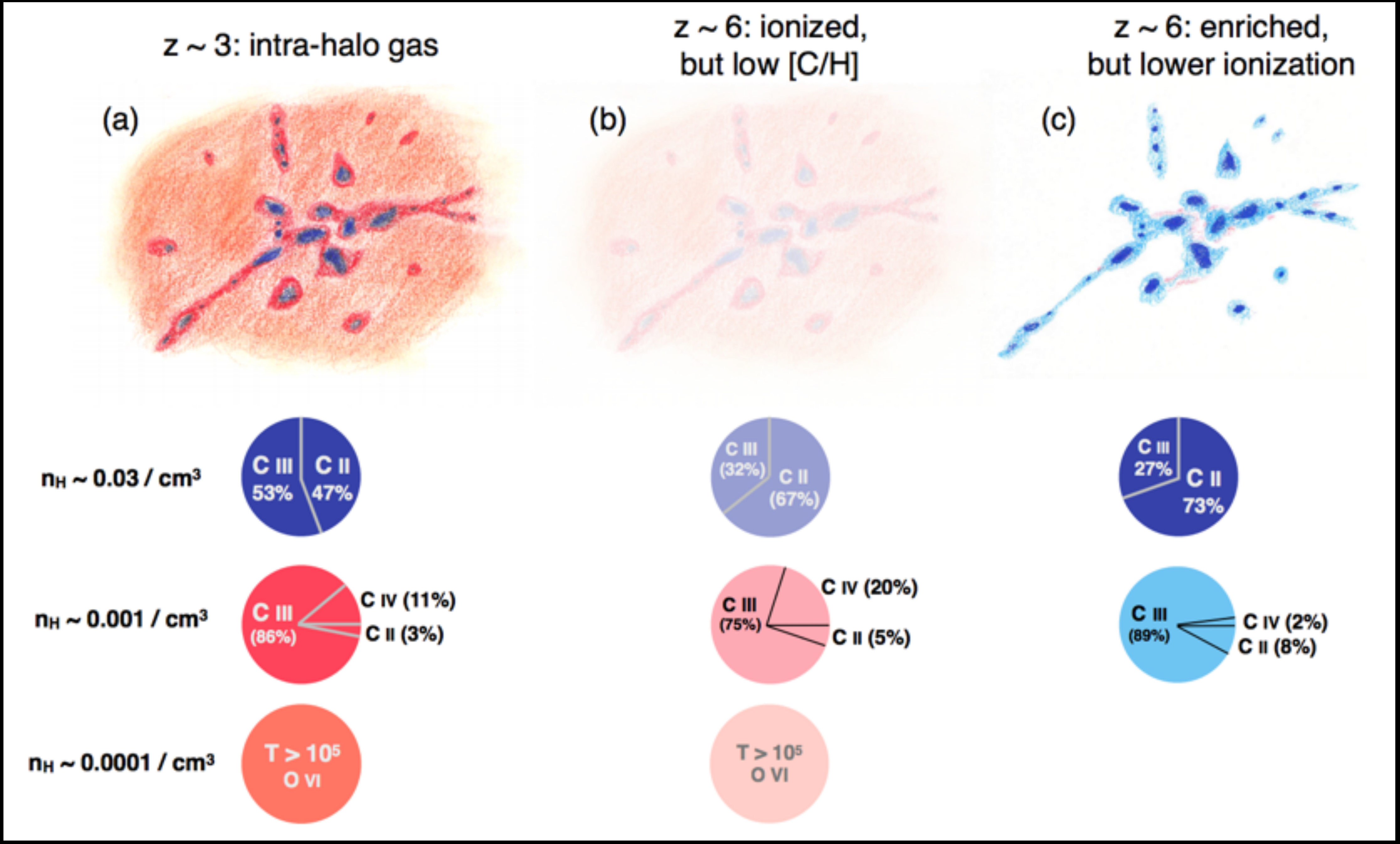
Lyman limit systems are too numerous

Why don't we see the tenuous CGM in C IV?
Softer UV background and/or lower [C/H]

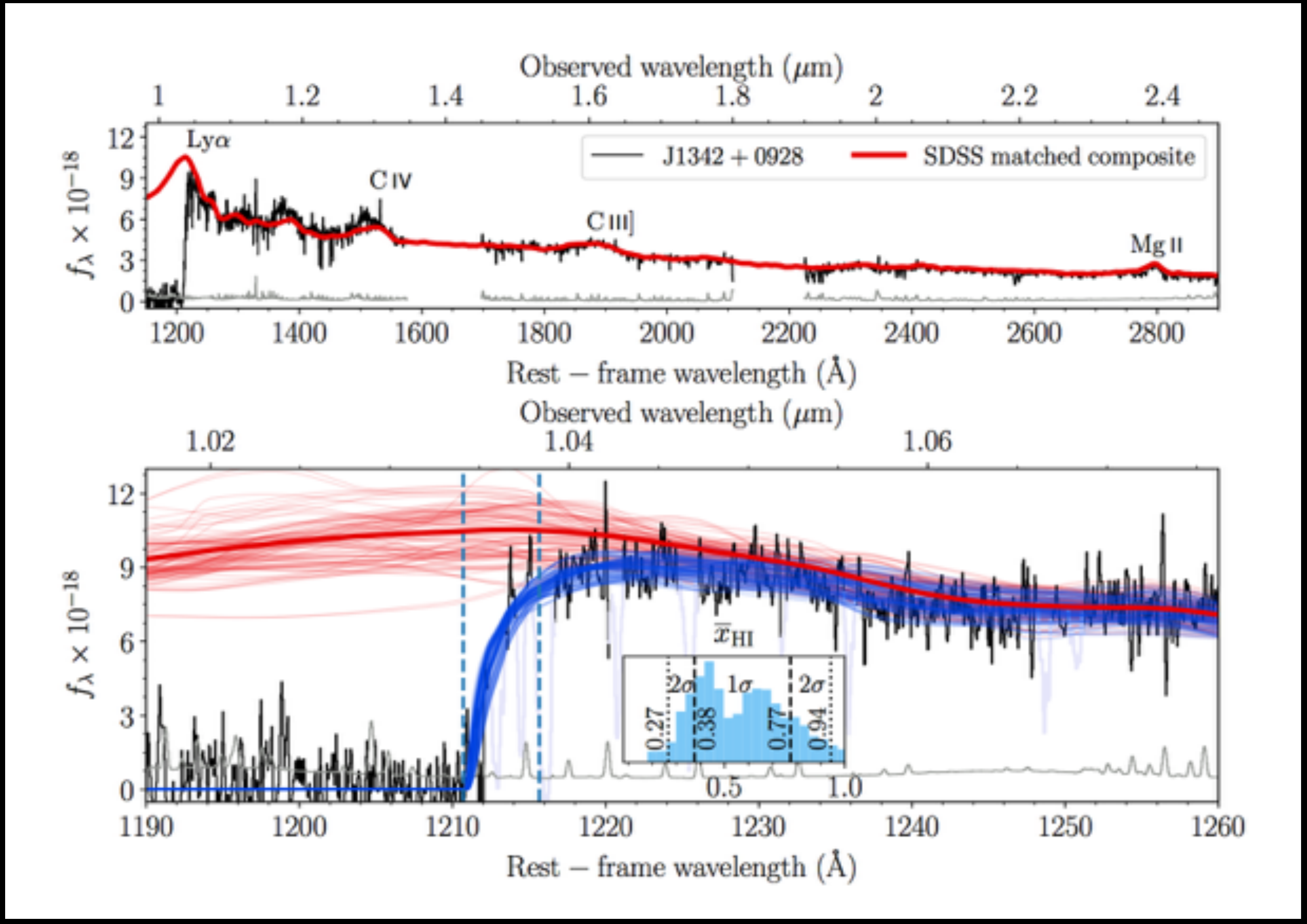


$N_{CIV} = 10^{13.5}$ $N_{CII} = 10^{13.5}$
(approx. detection limits)

An heuristic picture of the CGM at $t_{\rm H}$ ~ 1 Gyr as galaxies are assembling

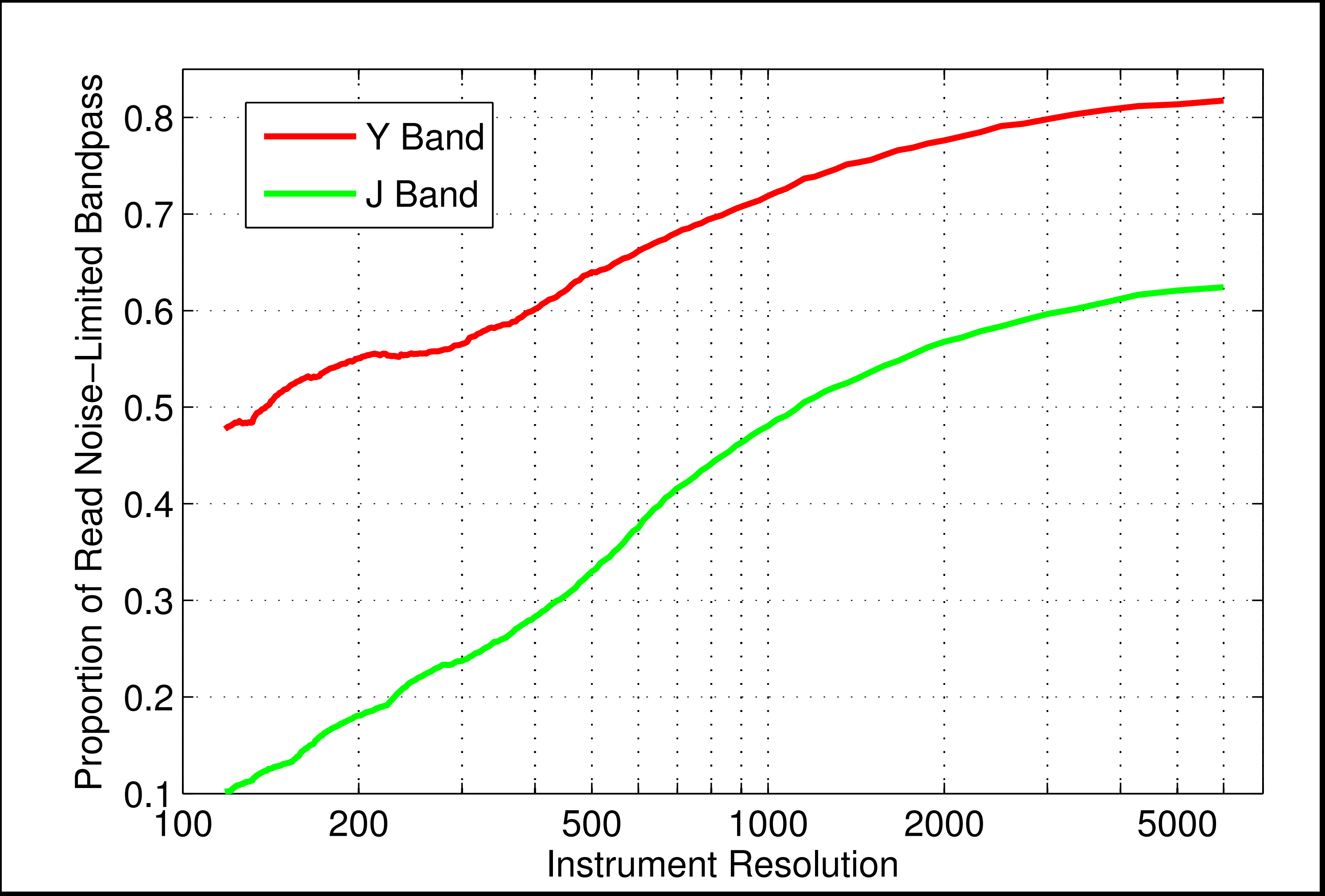


Near-IR quasar spectra deliver quantitative astrophysical measurements of EoR conditions



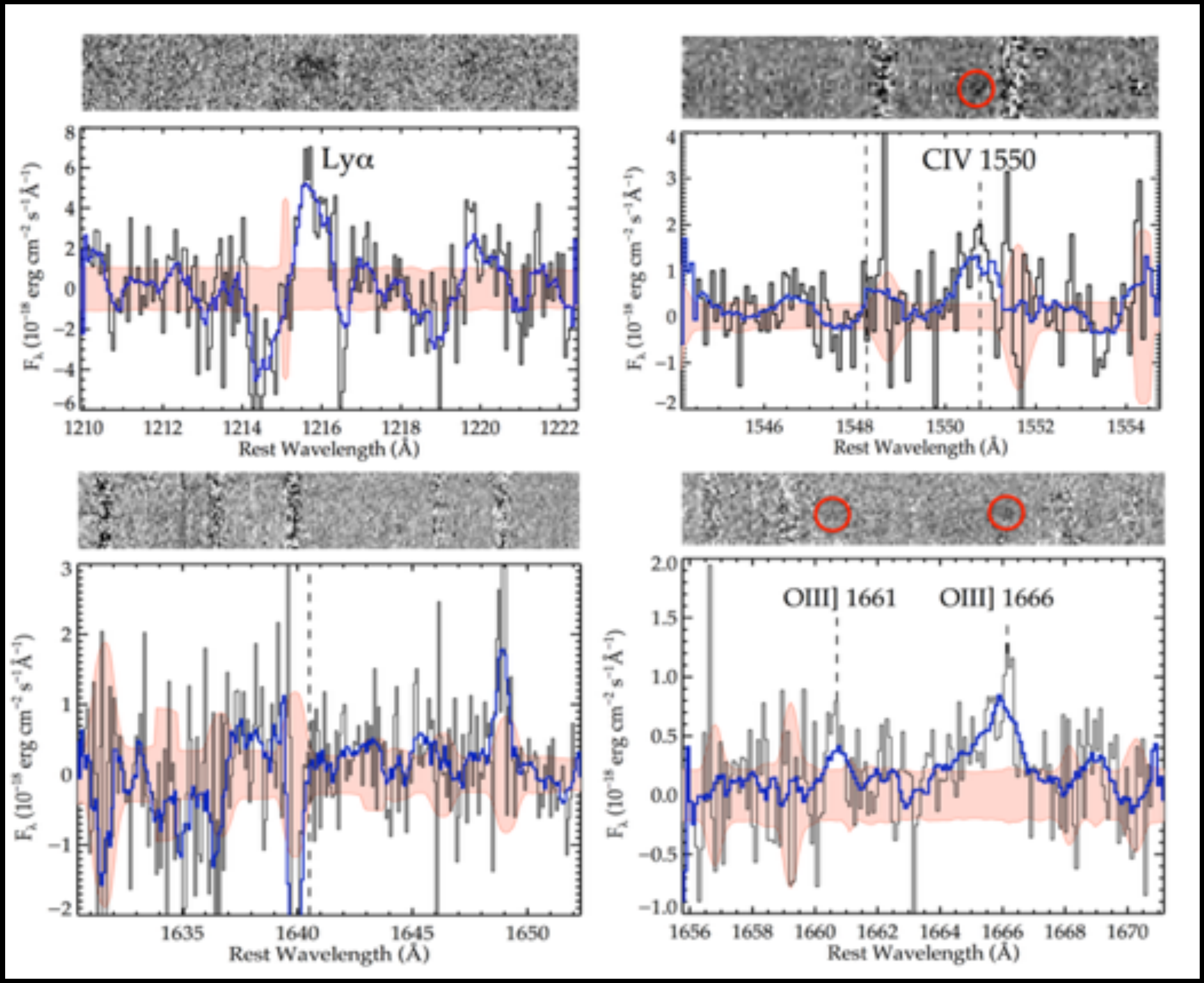
Banados et al 2018

ELTs can overcome the read noise limit for high-R near-IR spectrographs on today's telescopes

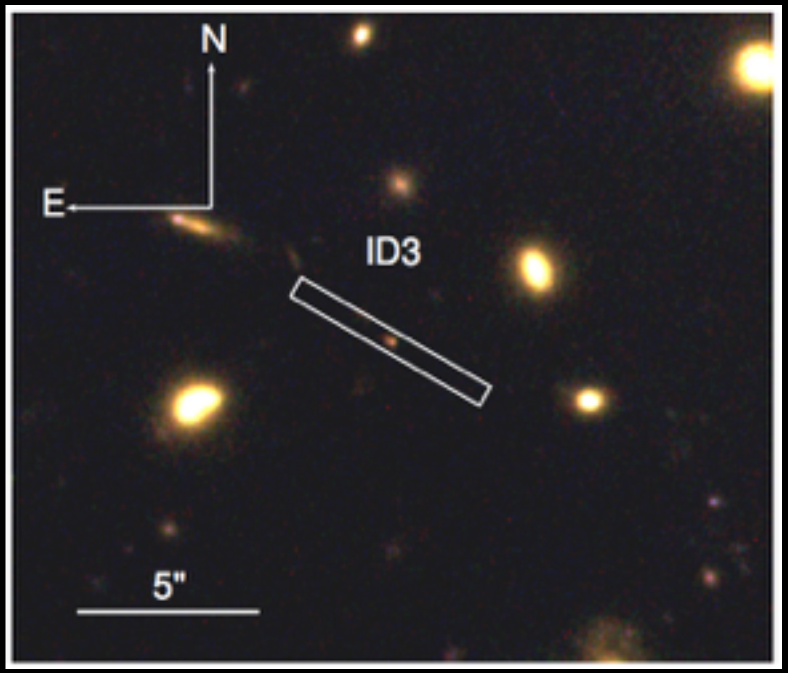


Prime motivation why all three ELTs have AO-fed near-IR IFUs: > D^2 SNR scaling

Working in the read noise with time-variable sky is painful



Mainali et al 2016

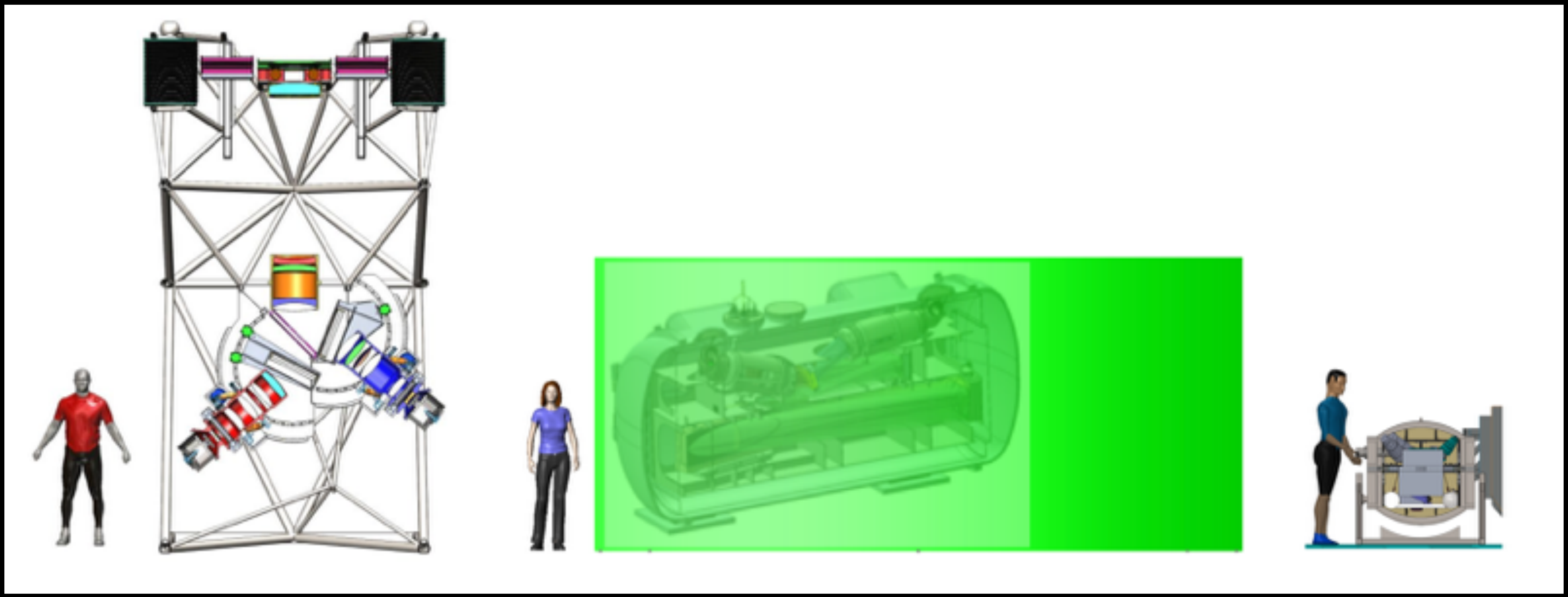


J = 25.0

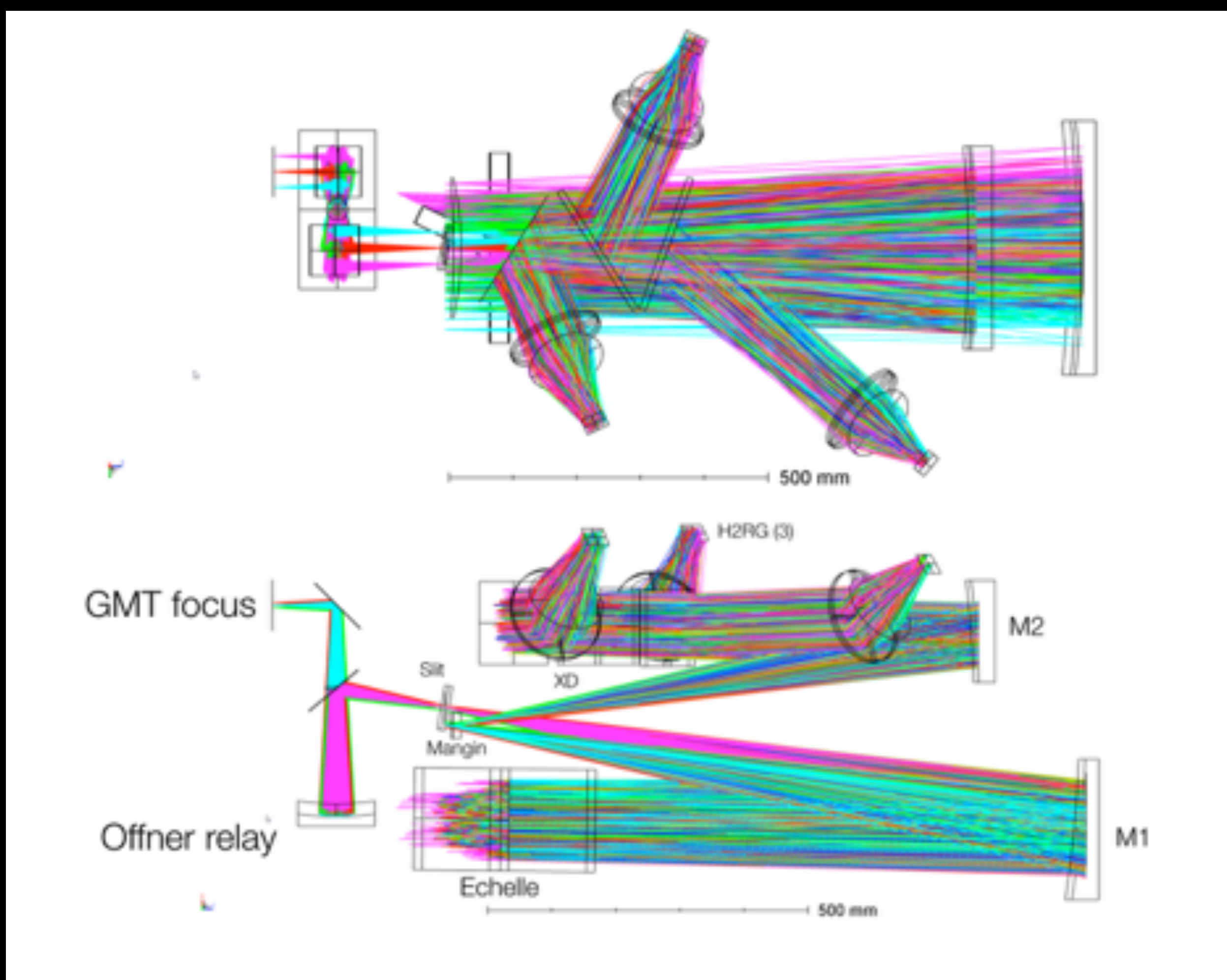
8.5x lens mag

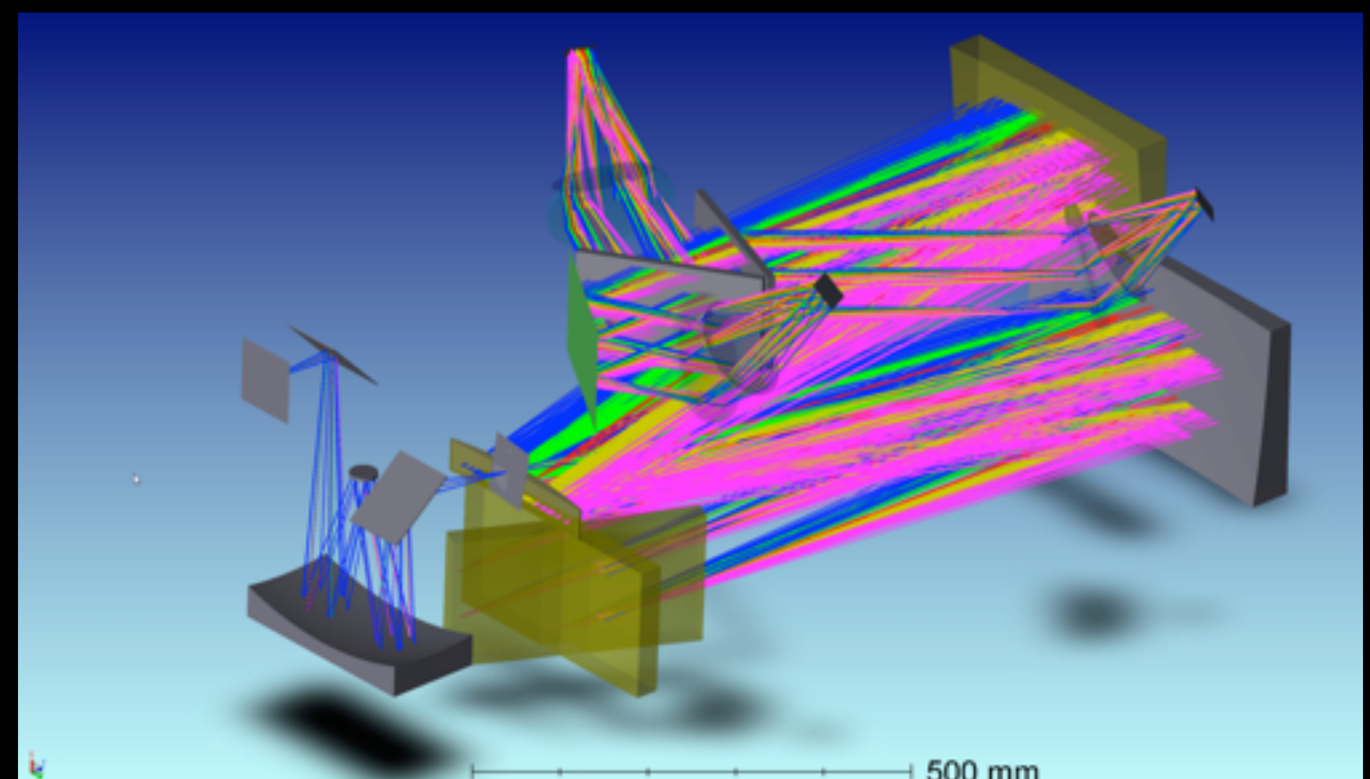
9 hours, 0.4″ seeing

Design study: a simple seeing-limited IR echelle, responding to schedule, funding pressures



Three-armed white-pupil R2 echelle; 130mm beam, H2RG sensors, all “TRL-6+”





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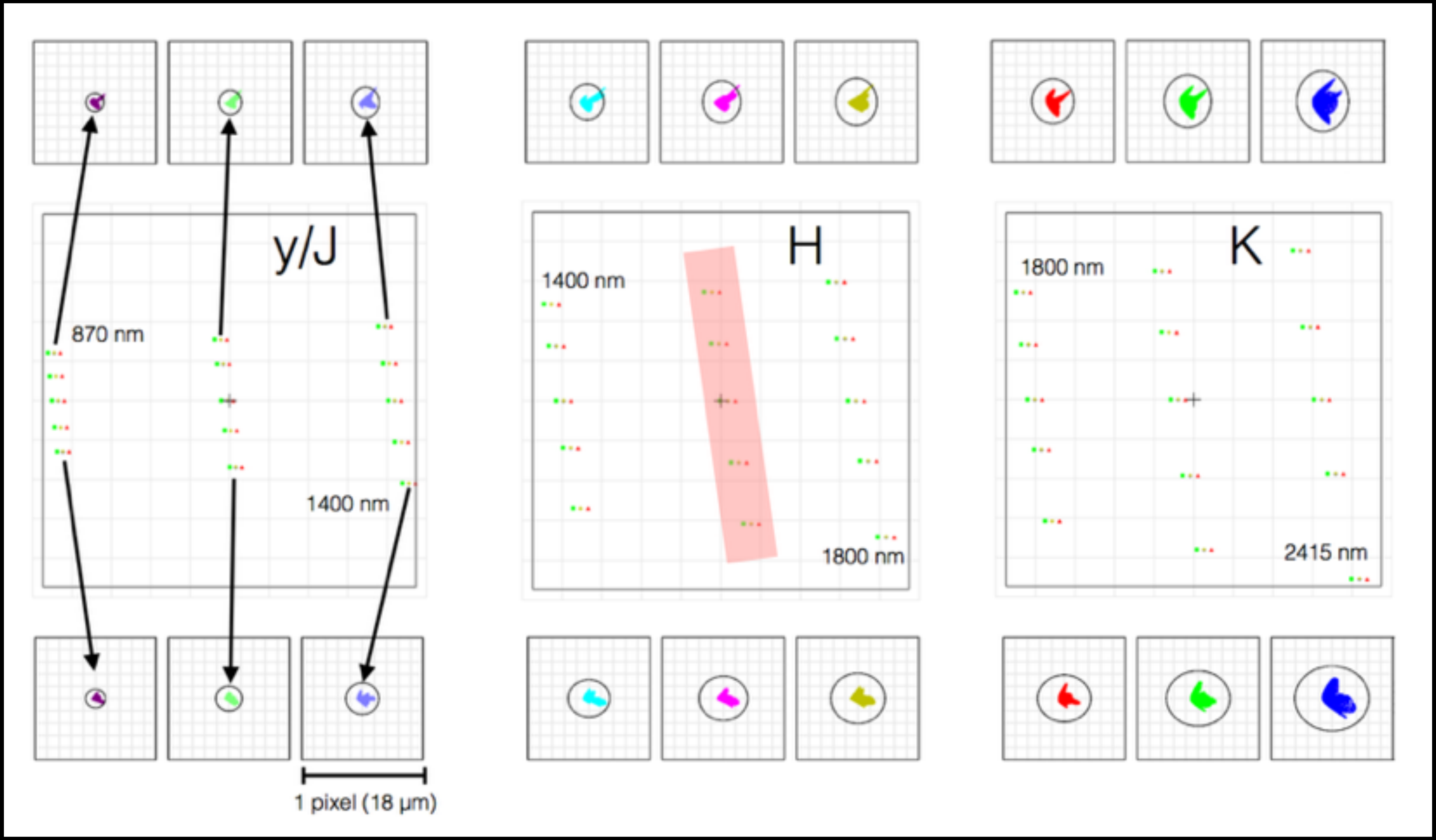
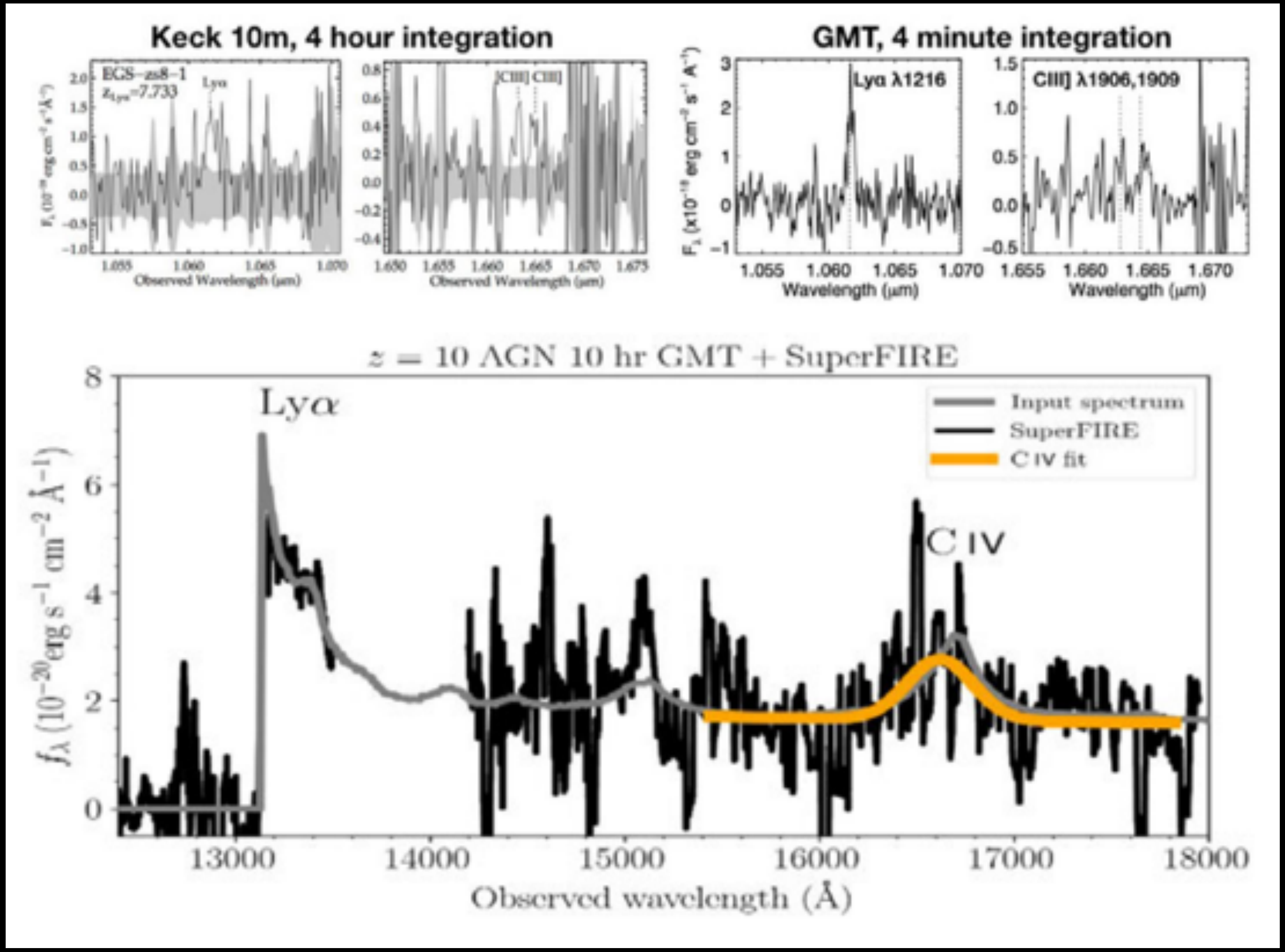


EoR quasars are out there, ELTs, JWST, ALMA together exploit their full physical info content

- zyJHK, single setup
- R = 6000 or 850
- 0.7” x 7” slit
- +3 mags, natural seeing



Infrared ELT Spectroscopy and Metal Enrichment in the EoR

- Heavy-element absorbers appear to experience a qualitative change around z~6
- Ionized CGM (as seen in CIV) falls off, but enriched neutral clumps persist to highest surveyed redshifts
- We speculate these are metal-poor DLAs, but N_{HI} cannot be measured
- More tenuous CGM not detected - either lower abundances, or softer ionizing background fails to produce CIV
- All conclusions drawn from near-IR spectra, where the ELTs will shine relative to current facilities and JWST
- Currently-envisioned IR spectrographs are totally dependent on AO to reach EoR sensitivities, but will then be spectacular
- It is possible to build seeing-limited versions that are compelling