is there any metal out there?

studying the IGM chemical abundances and enrichment mechanism with the ELTs

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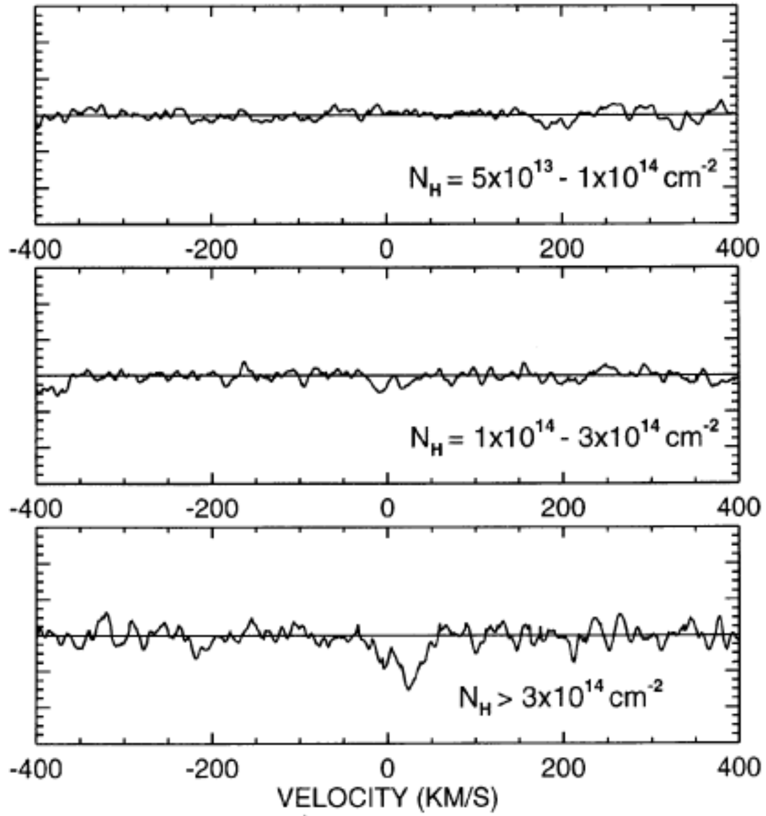
JWST and the ELTs

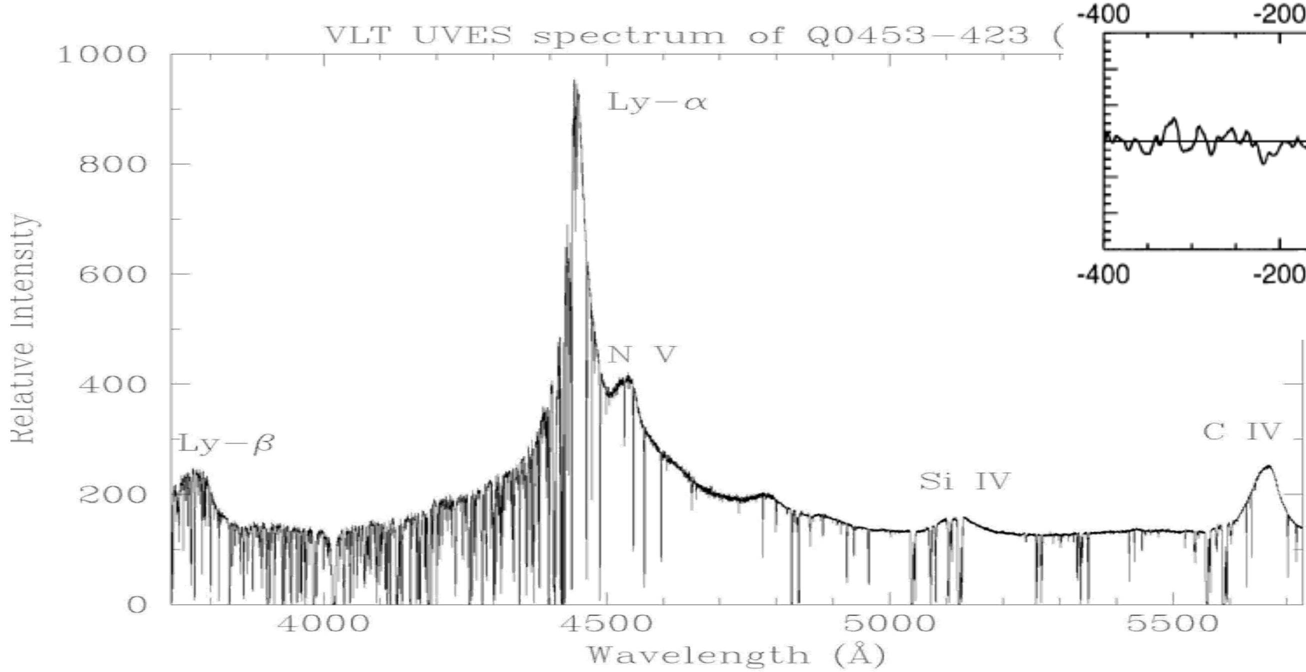
April 14, 2010

the answer is: yes!

Metals outside galaxies detected by their absorption lines in high-z QSO spectra, thanks to the advent of **8-10m class telescopes** and **high res spectrographs** (HIRES, UVES)



CIV 1548 for stacked Lya forest lines (Cowie et al. 1995)



enrichment of the igm:
two paradigms

early enrichment by z >> 6 galaxies

- Evidence: re-ionization
- Scenario:
  - Outflows from the sources responsible of the re-ionization process: protogalaxies/Pop. III.
  - Small potential wells easier to escape from.
  - Low outflow velocities ➔ little heating.
  - IGM has time to "recover"
- Prediction:metals are sprinkled in

late enrichment by $2 < z < 6$ galaxies

- Evidence:
  - $z \sim 3$ galaxies drive strong winds like low-z starbursts.
  - Most of cosmic star formation at $z < 5$.
- Scenario:
  - Heating of IGM (less with momentum driven winds)
  - strong feedback as require by galaxy formation theory
- Prediction: metals in the outskirts of galaxies

enrichment of the igm:

status of observations

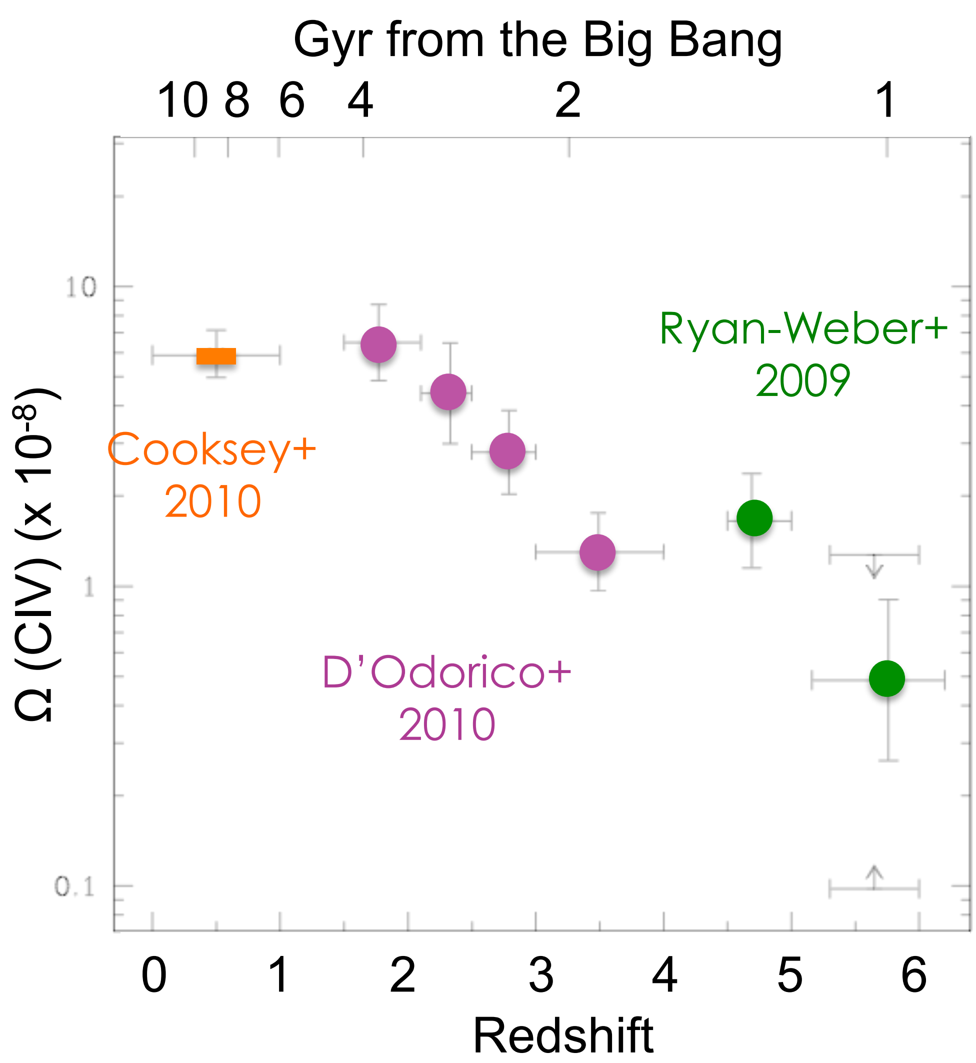
direct detection and fit of metal lines

Correlation with the position of galaxies in the field (Adelberger et al. 2003, 2005)

Alternative analysis with fitted lines and upper limits (Simcoe et al. 2004): z~2.5 median [C,O/H]=-2.82

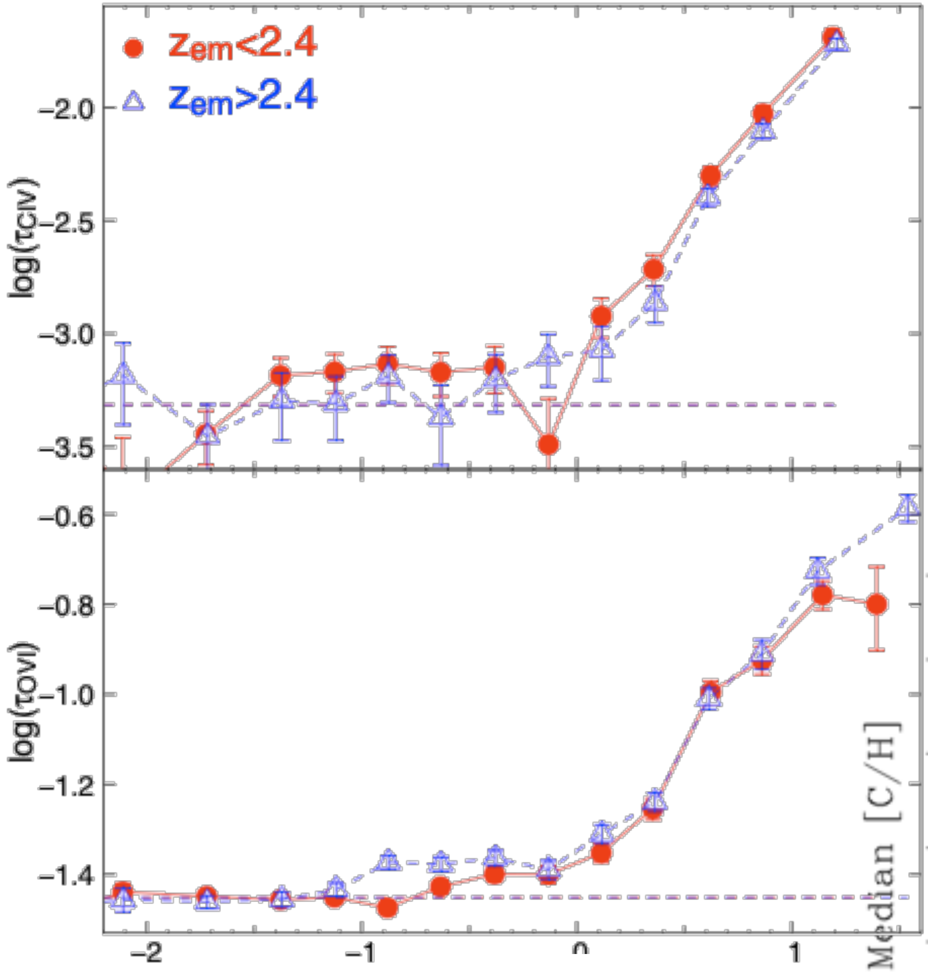
Simulations mainly by Oppenheimer and Dave' (momentum driven winds)

The CIV cosmic density



D'Odorico et al. 2010

pixel optical depth of metals vs HI

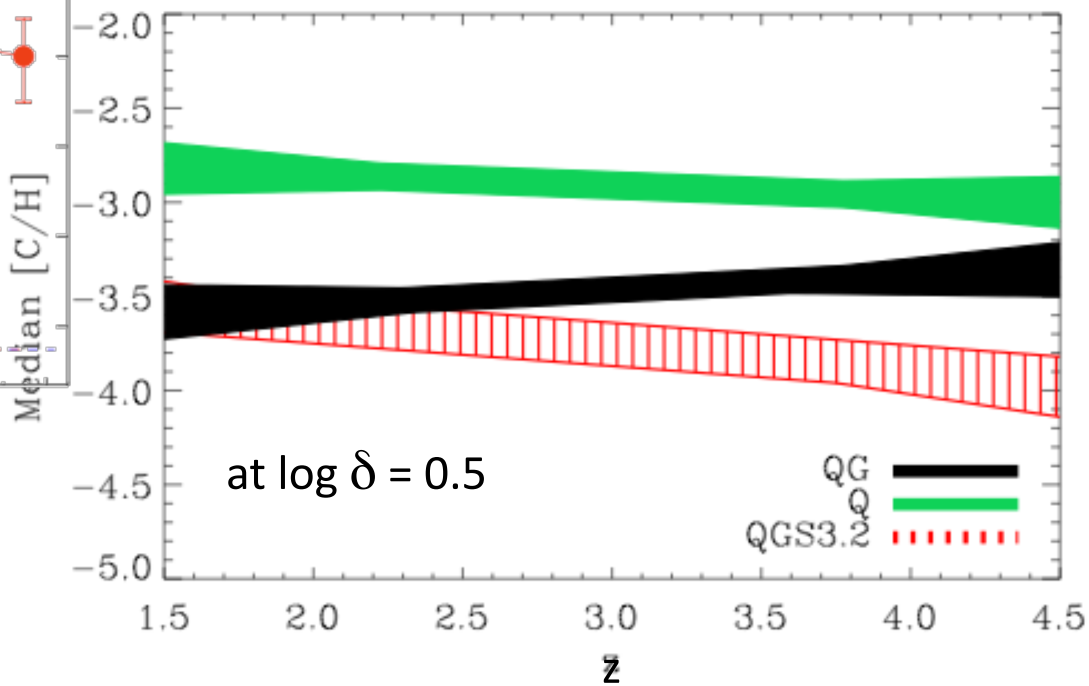


OVI is a better tracer of low density IGM (Aracil et al. 2004)

statistical approach

Mean density not reached
Probing less than 5% of the volume of the Universe
(Pieri & Haehnelt 2004)

Schaye et al. 2003



problems, limitations, needs

- Weaker lines ➔ S/N and resolution of the spectra ☺
- Higher redshift ➔ extend wvl range to IR ☺
- Ionization corrections (CIV/SiIV vs. T, O VI) ➔ extended wavelength range 😐
- HI contamination ☹
- Spectral shape of the UV BKG 😐
- Simulations 😐

the promise of ELTs: a detailed description of the IGM enrichment

CODEX and SIMPLE at the E-ELT

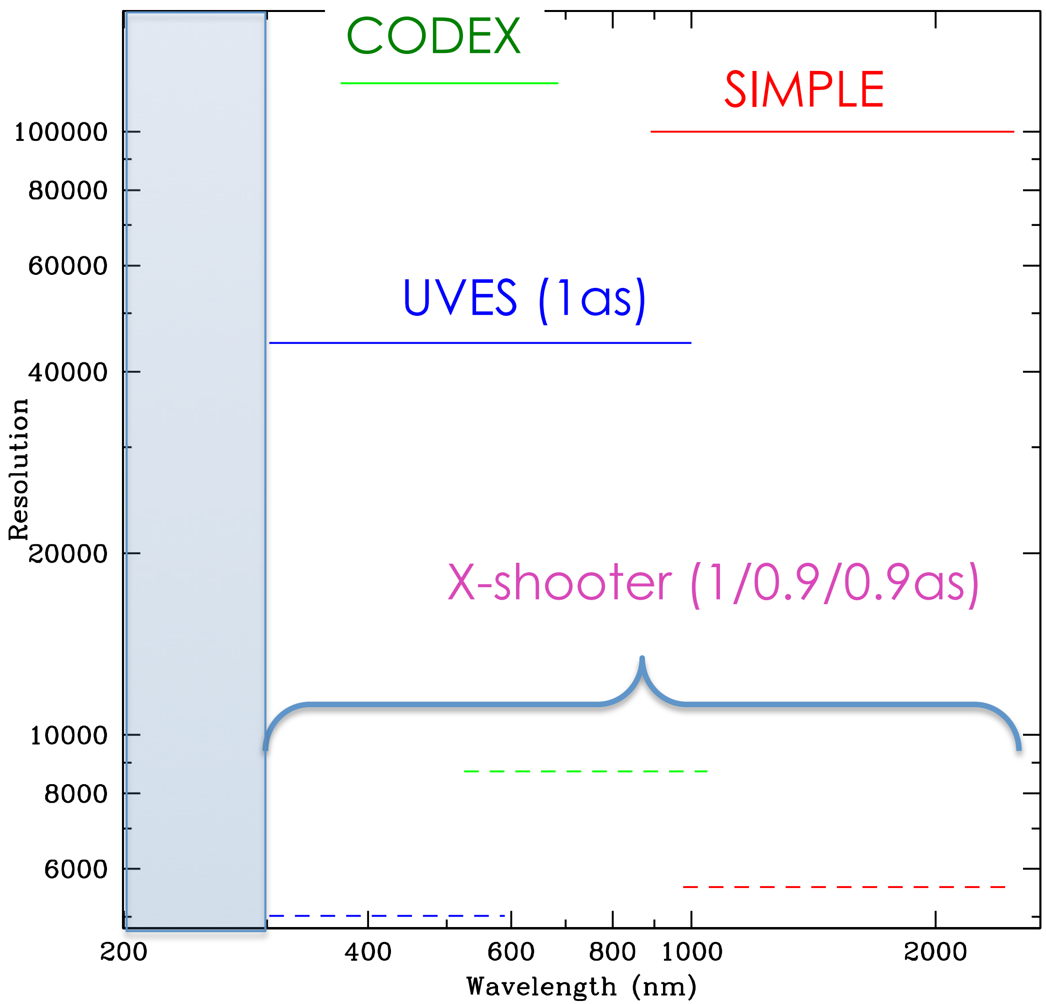
COsmic Dynamics and EXo-earths experiment (P.I. L. Pasquini)

- Very high resolution
- Exceptional stability (2cm/s)
- Fiber input
- Seeing limited

SIMPLE (P.I. L. Origlia)

- Very high resolution
- NIR coverage
- 4 slit apertures
- AO assisted

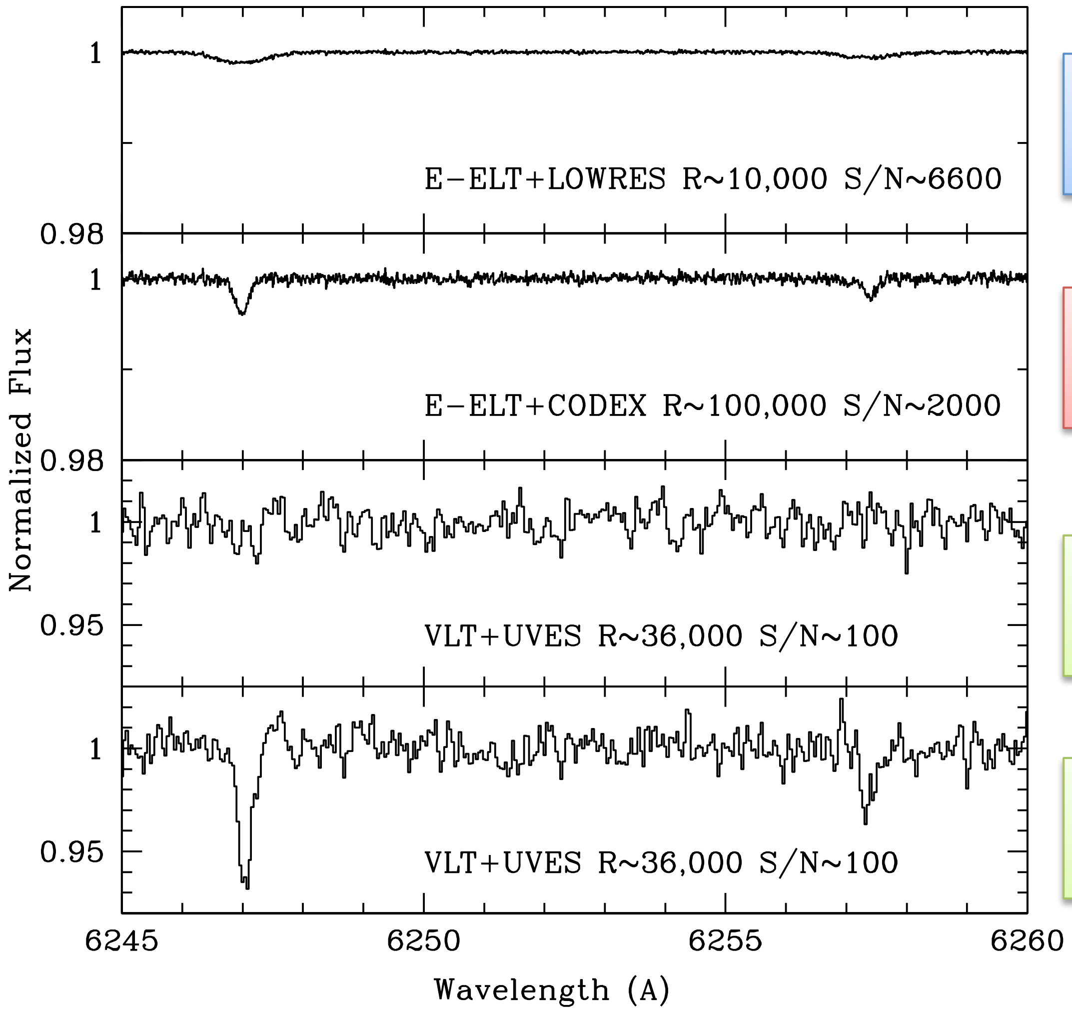
ESO biased view of most performing spectrographs



probing low density with CODEX

CODEX Science Report

Redshift z=3



Same observing time at ELT but lower resolution

Scaled to the mean density observed with CODEX

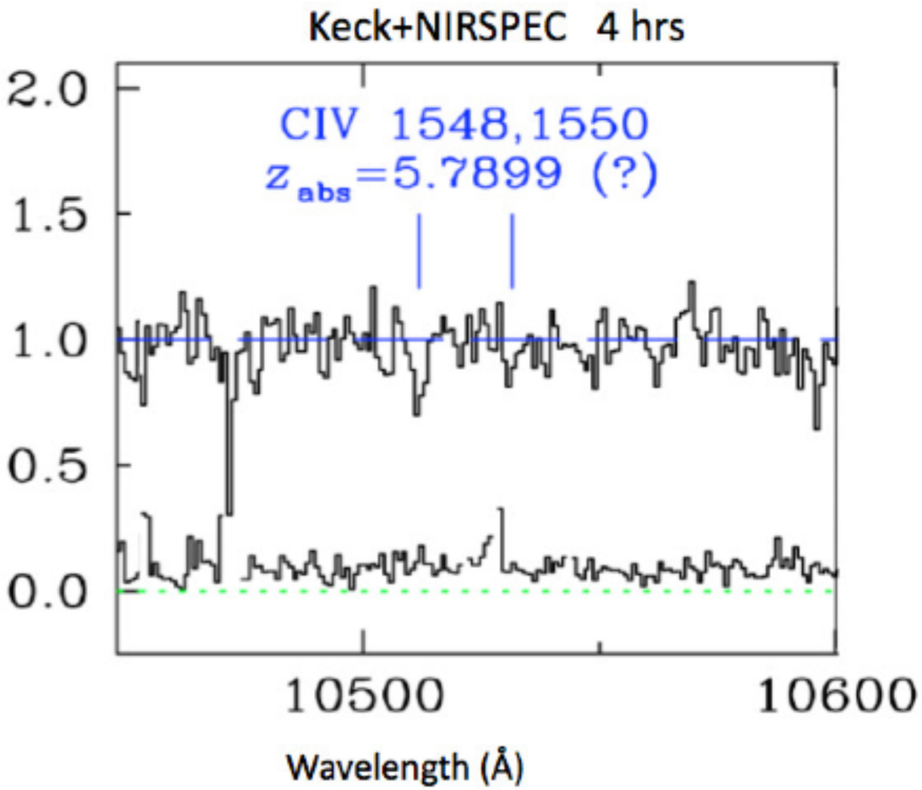
Scaled to the mean density log N(CIV) ~ 11

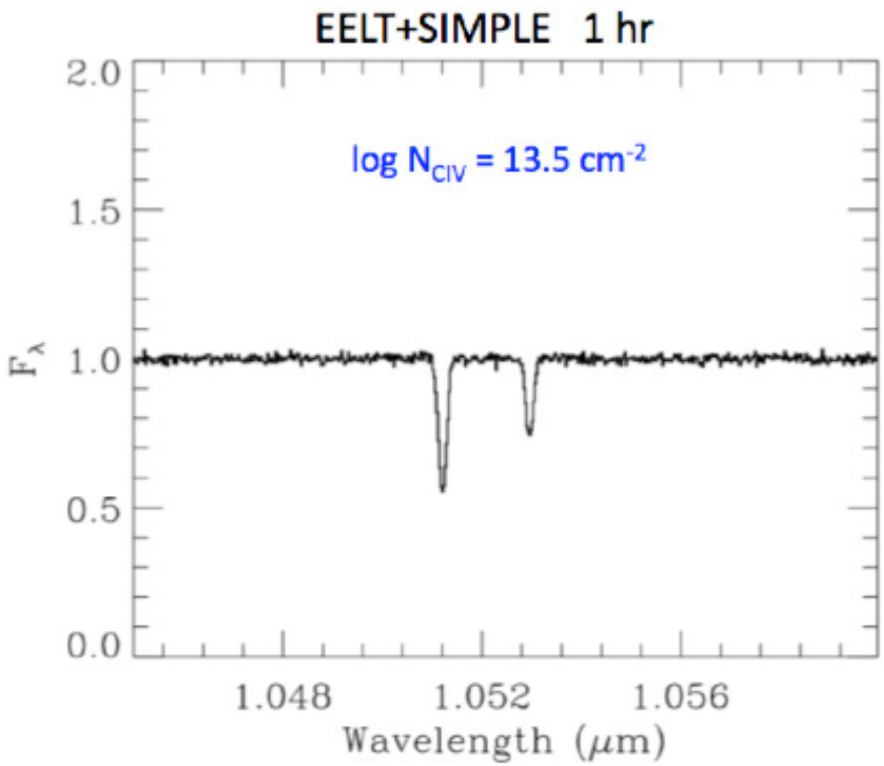
Limit of present observations: log N(CIV) = 12 ➔ δ ~ 5-10

Use the QSO spectra of the redshift drift experiment

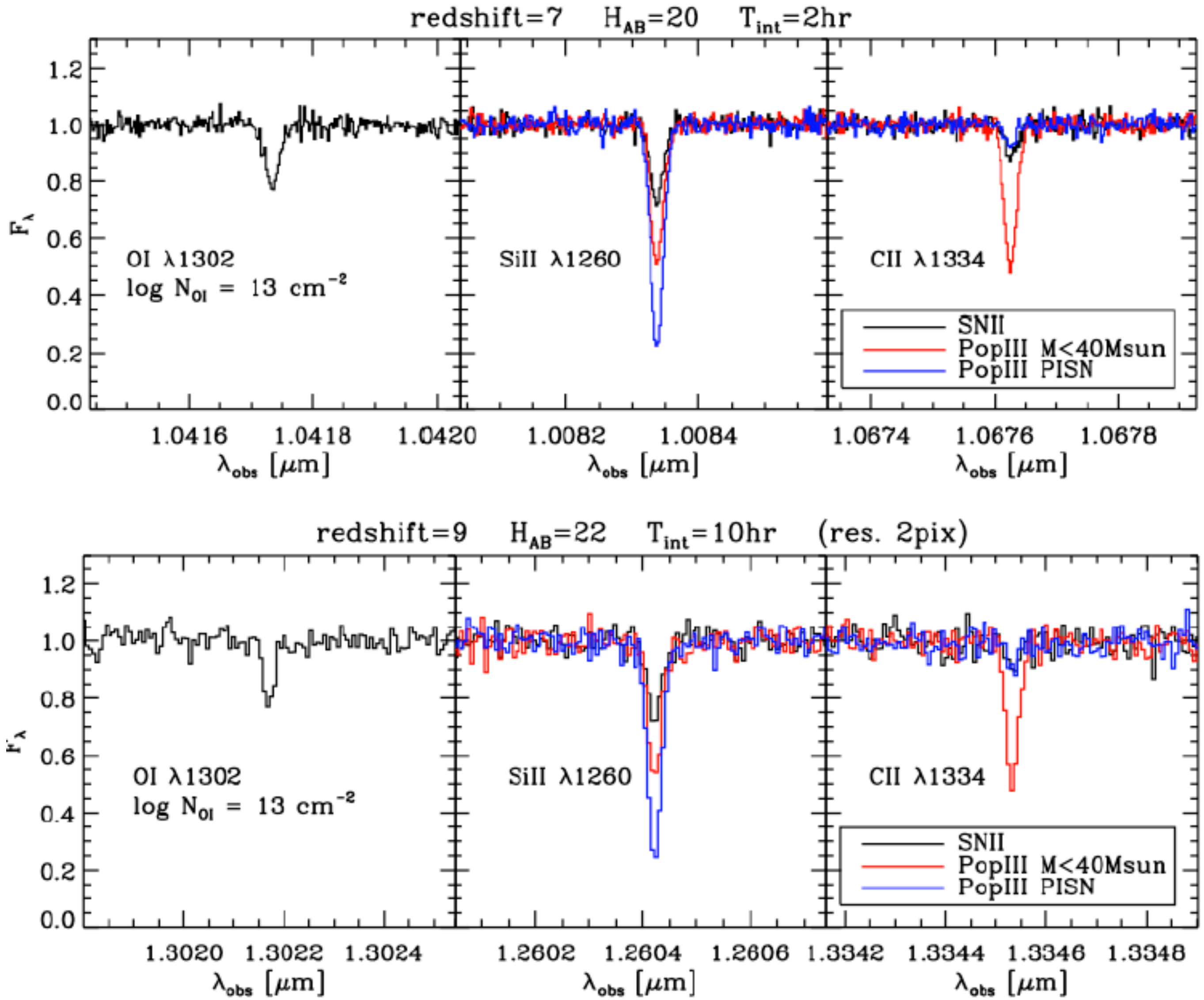
probing high redshift with SIMPLE

CIV cosmic density at z~6





probing high redshift with SIMPLE



Pop. III abundance signatures

z=7
T_{exp} = 2 h

z=9
T_{exp} = 10 h

conclusions

• IGM metal enrichment is a key tool to characterize physical mechanisms like galactic winds and more, generally, feedback;

• metals outside galaxies do exist, now we need to know the details;

• high resolution spectrographs at an ELT covering a large wavelength range are the answer;

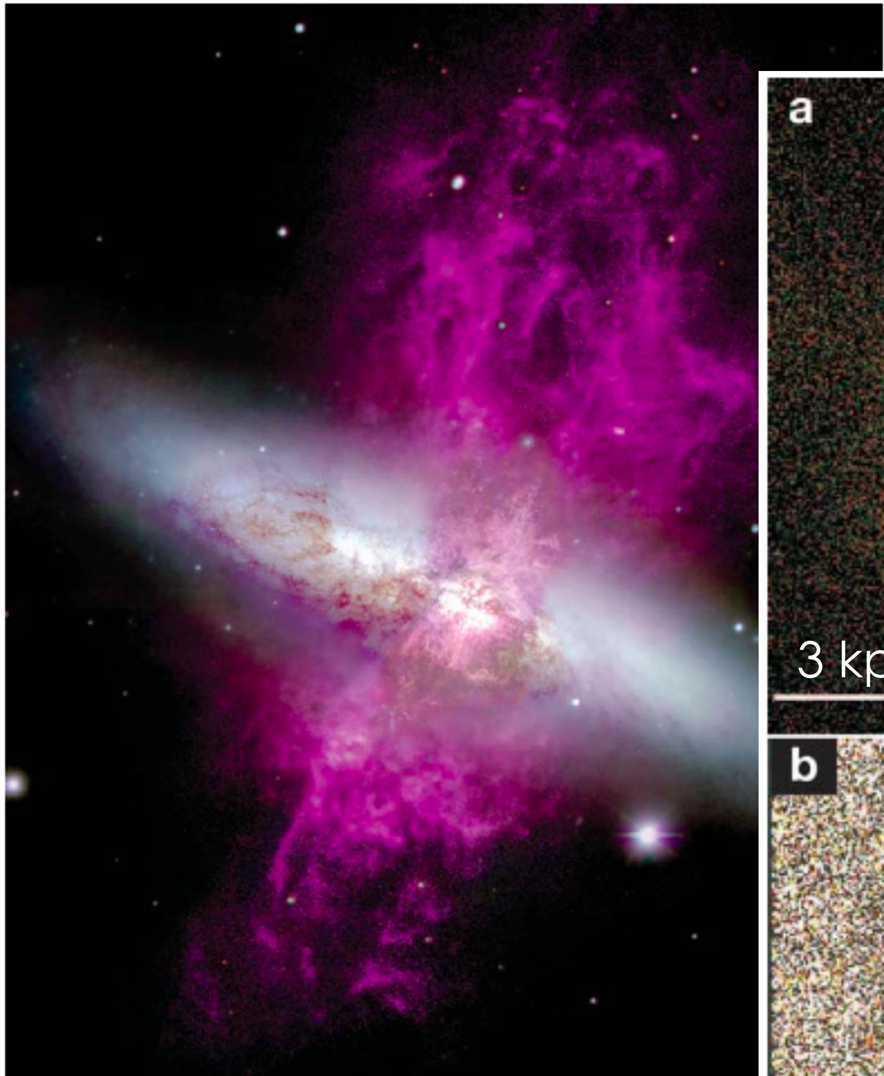
CODEX to probe tenuous gas

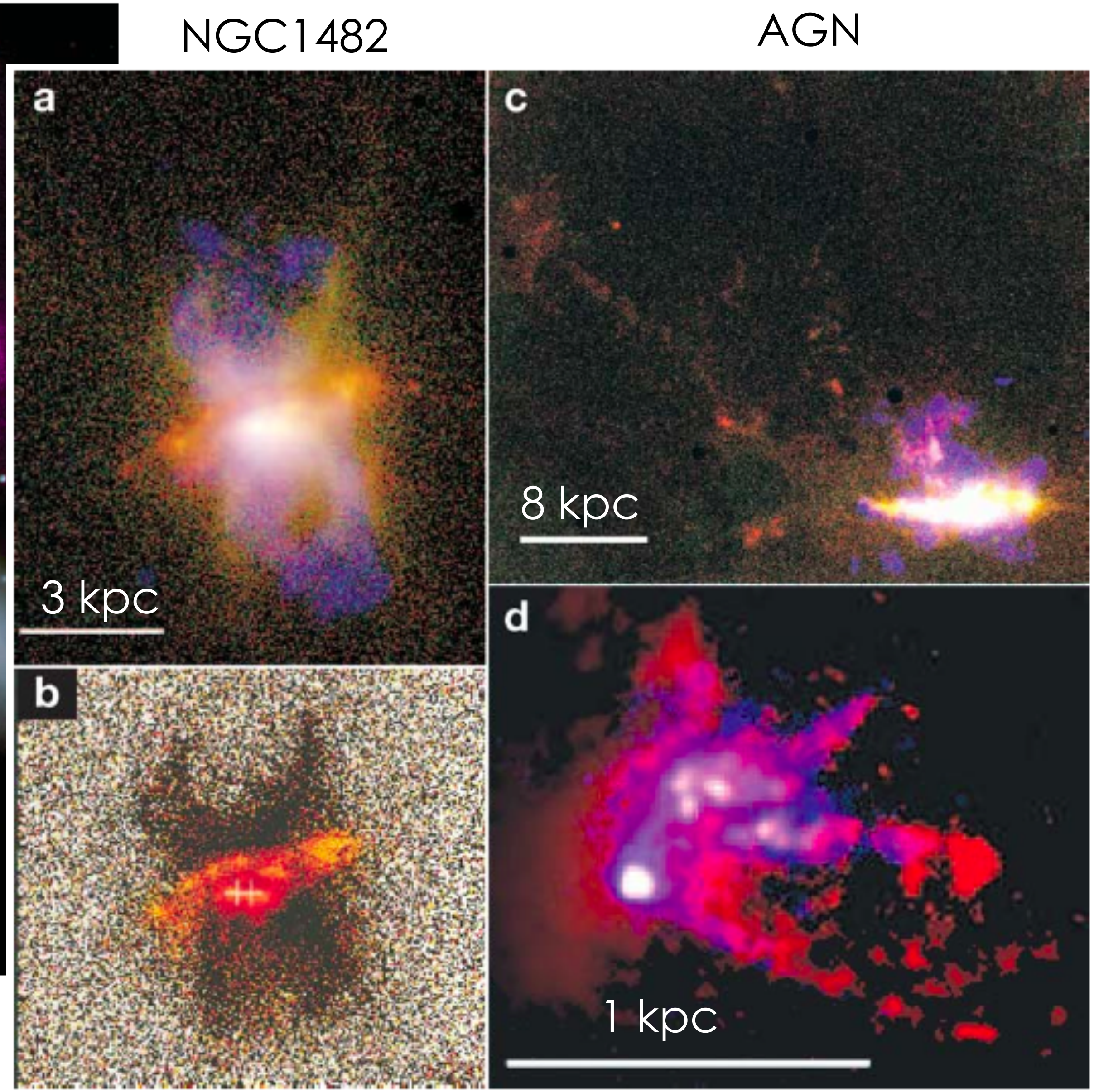
SIMPLE to probe early pollution

…and the synergy with JWST?

thank you

galactic winds: local Universe

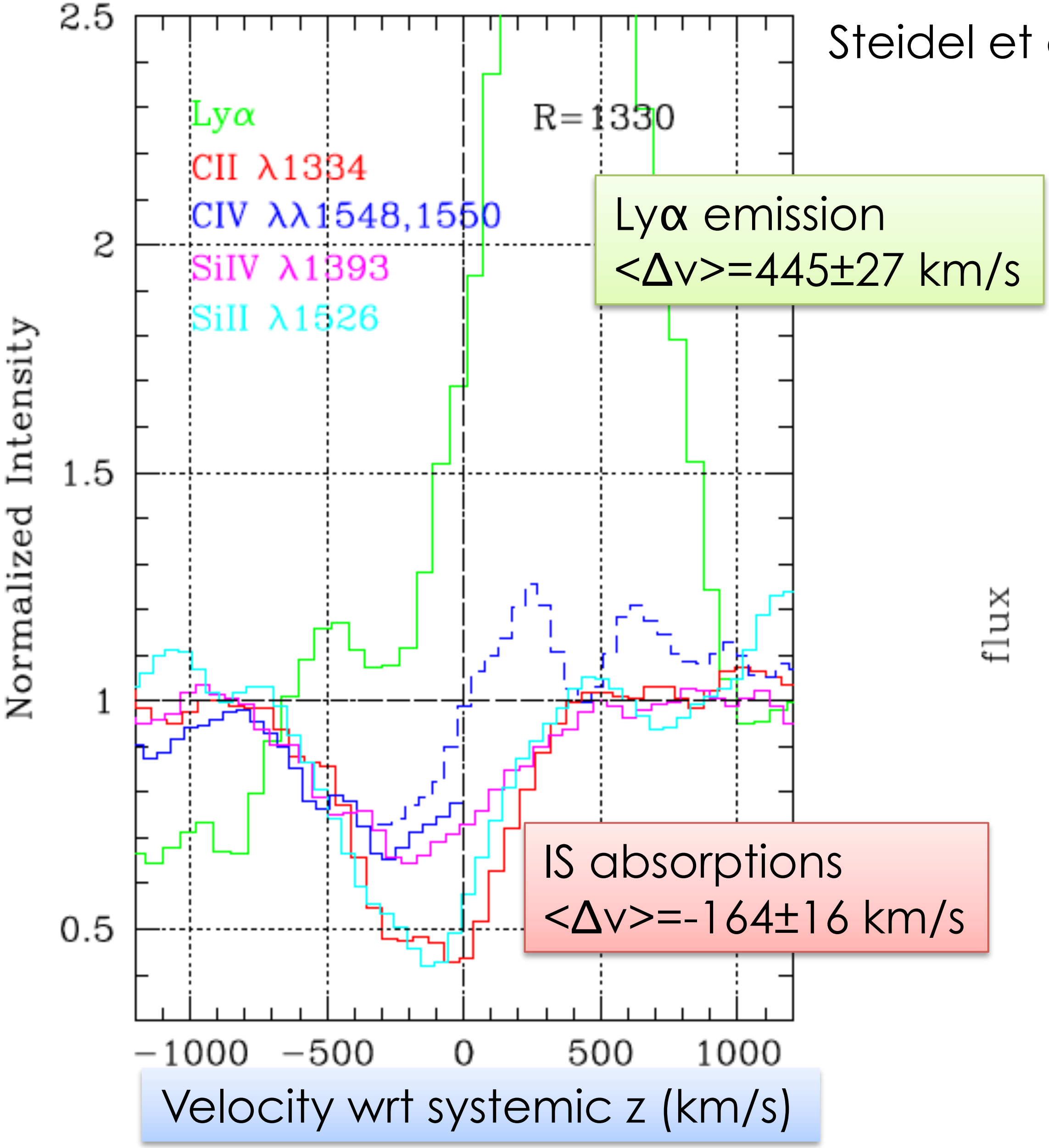




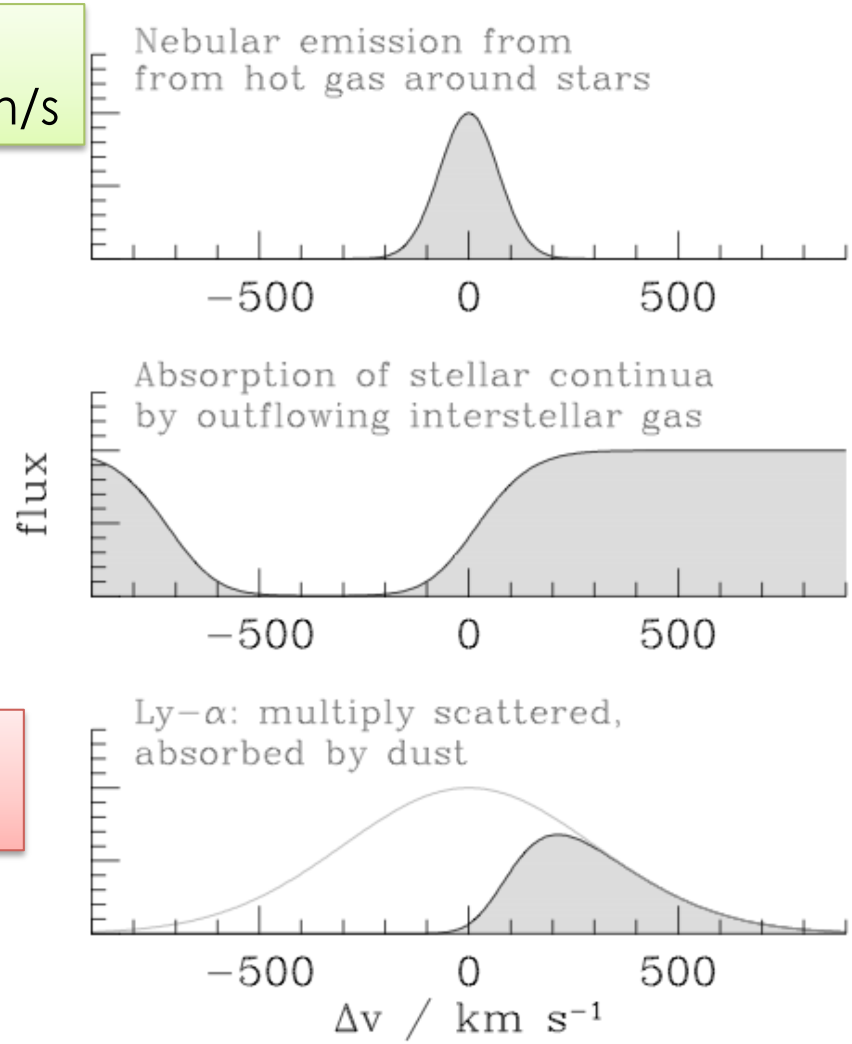
Veilleux et al. ARAA 2005

galactic winds: distant Universe

Steidel et al. 2010



Adelberger et al. 2003



ubiquitous feedback

The cessation of star formation in massive galaxies at high redshift;

The small number of low-mass galaxies relative to the dark matter halo mass function predicted by the otherwise successful CDM cosmology;

The correlation between galaxy spheroid mass and the mass of central super-massive black holes;

The general absence of cooling flows in clusters of galaxies;

The metal enrichment of intracluster gas.