The HI picture from the Lyman-α Forest at z~2-3

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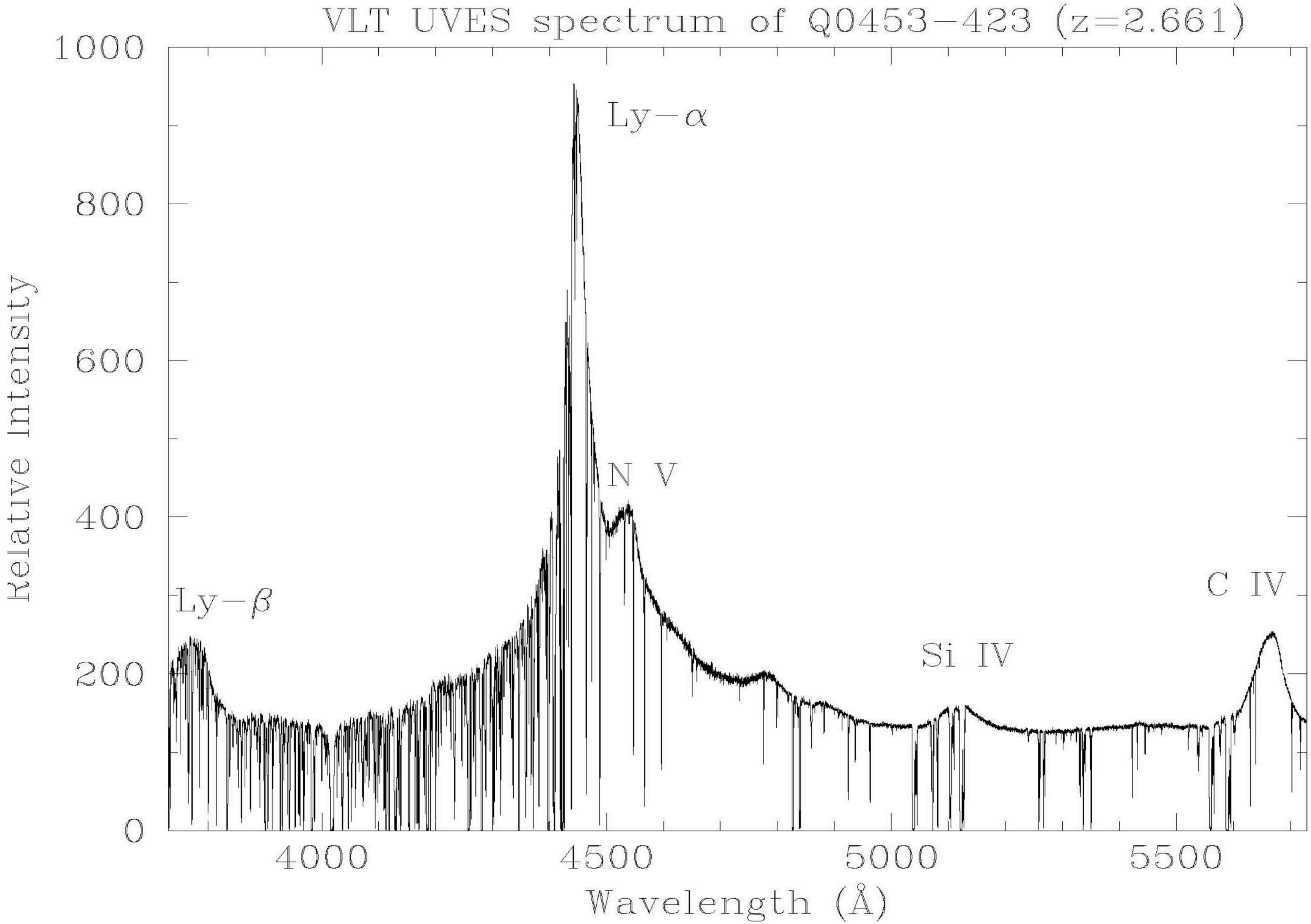
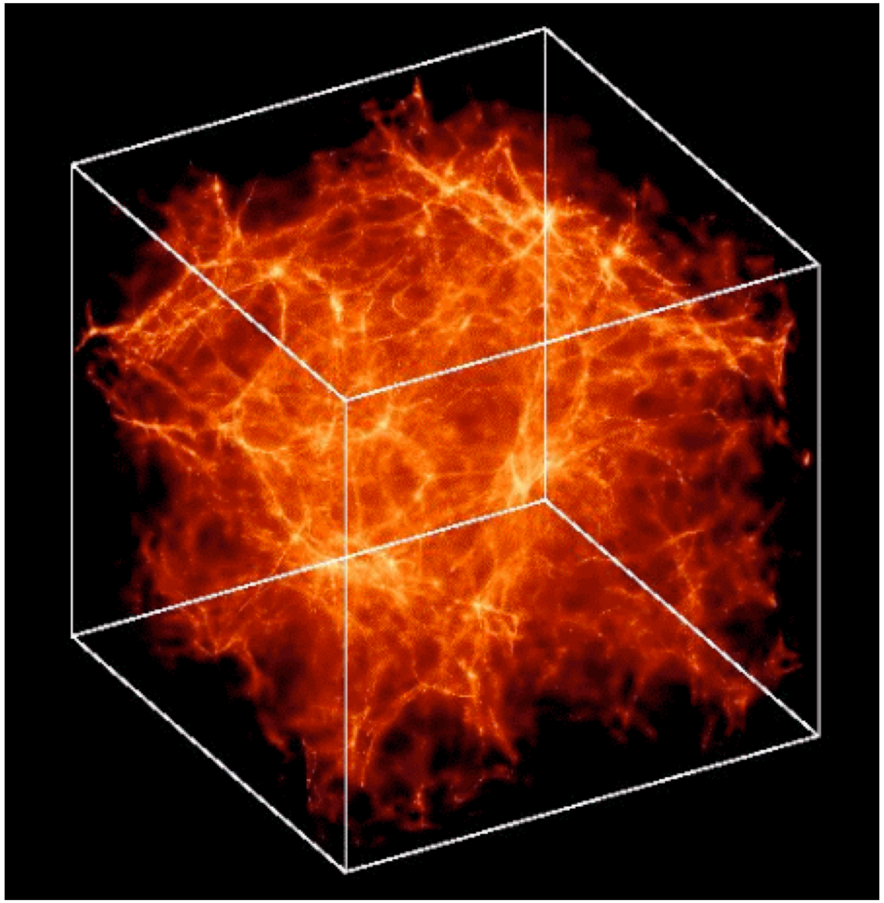
Summary

1. A novel approach to derive the baryonic matter density distribution from the analysis of the Lyman-α forest at $z \sim 2 - 3$;
2. First results: proximity effect, correlation function;
3. Serendipitous detection of a very peculiar metal absorption system at $z \sim 0.45$

The Lyman-α forest



Physical interpretation

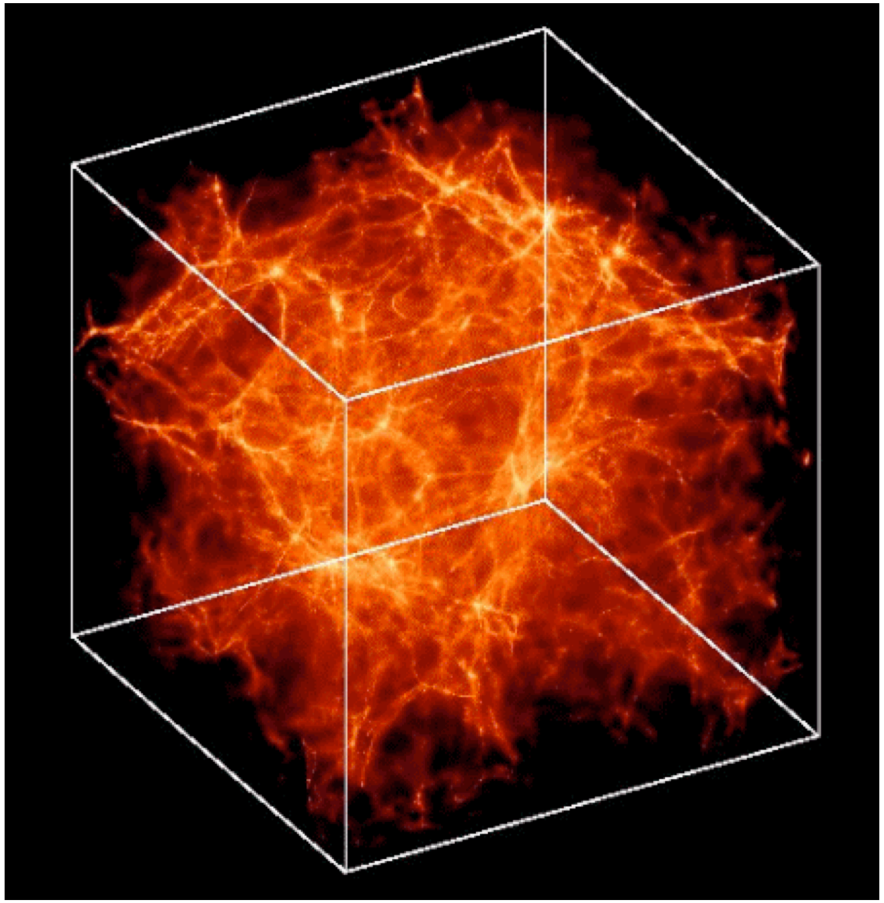


Simulated box of the distribution of baryons at z~2 in a ΛCDM concordance cosmological model (courtesy of Matteo Viel)

KEY PROPERTIES

- Contains most of the baryons at z~3;
- Resides in mildly non-linear DM overdensities and on scales larger than L_J traces them quite faithfully;
- Can be described by simple physics (gravitational forces and the Hubble expansion);
- Is in photoionization equilibrium and local hydrostatic equilibrium

Physical interpretation



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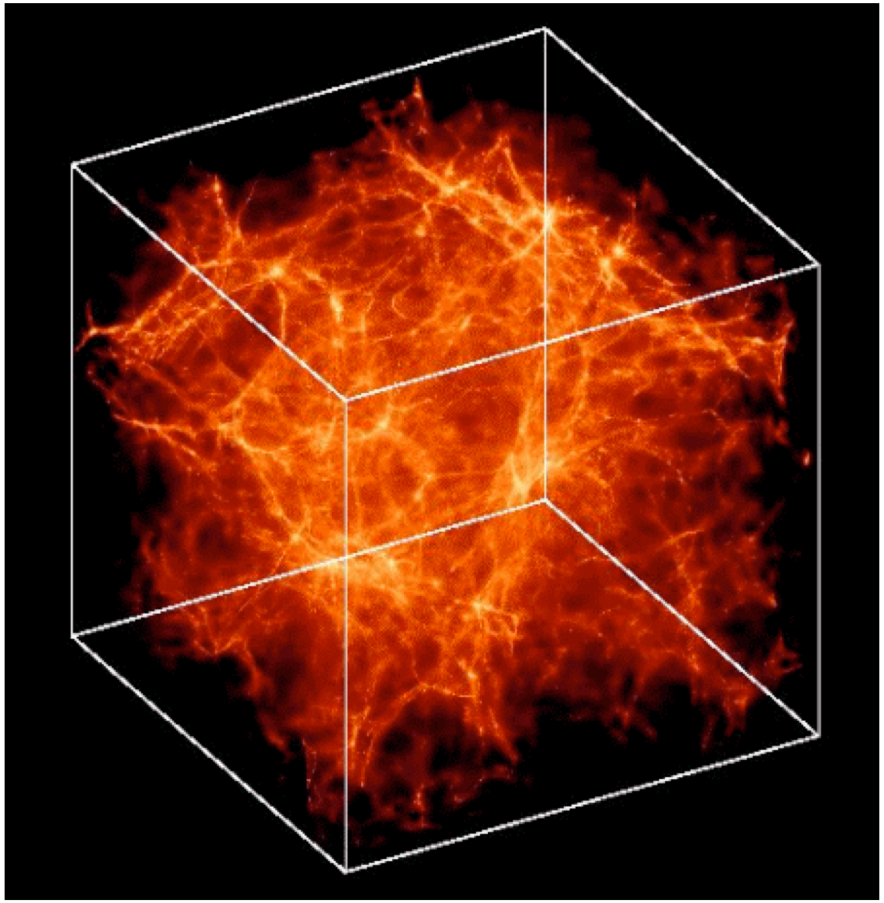

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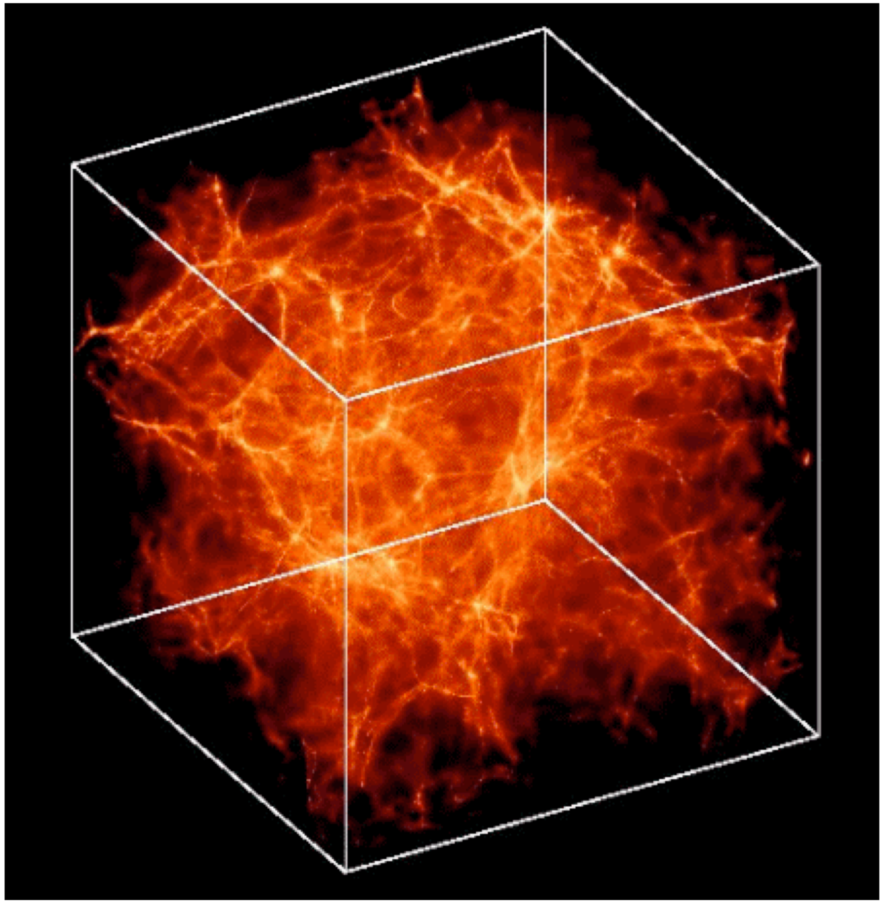

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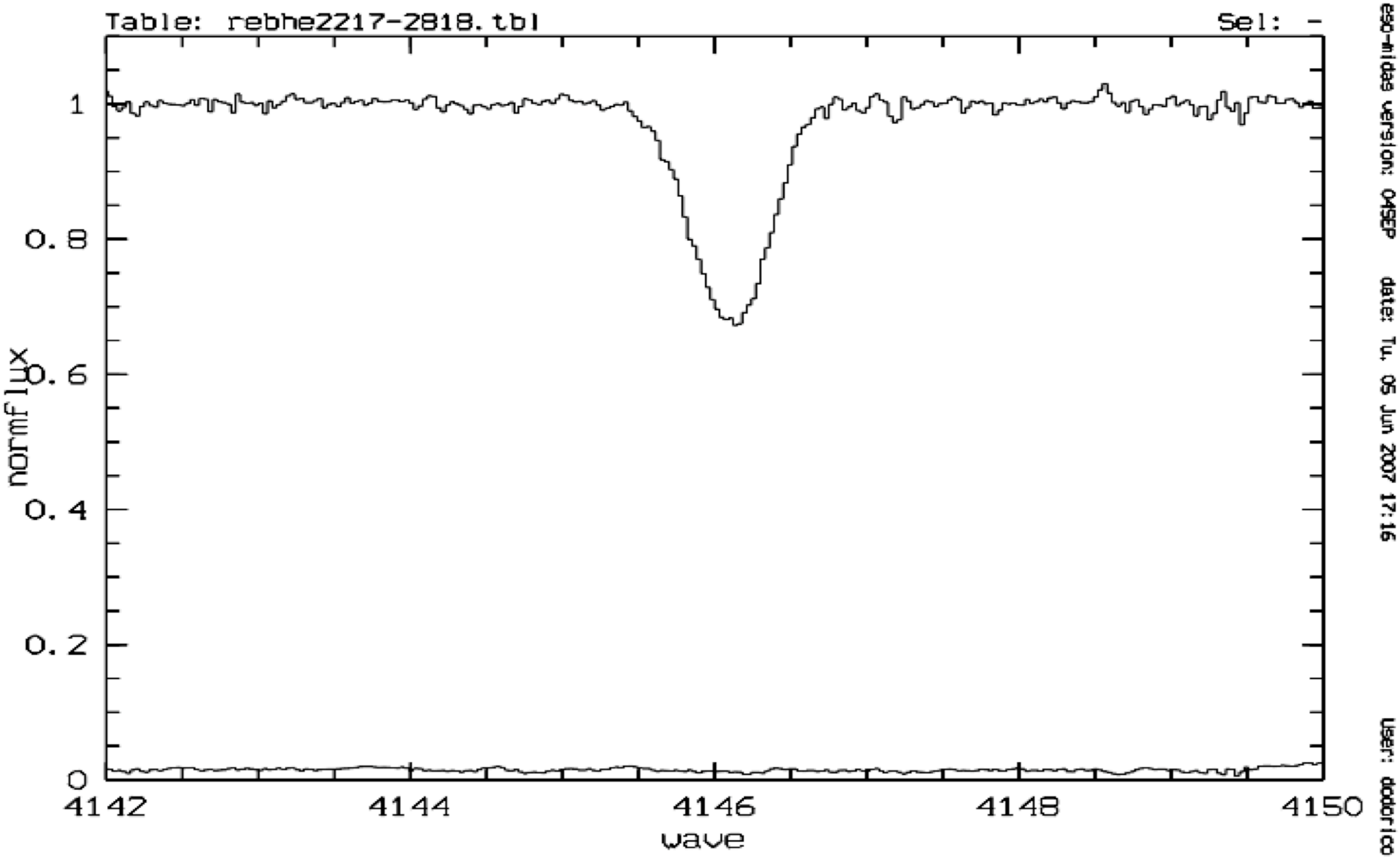
Analysis of observations

A. Voigt profile fitting



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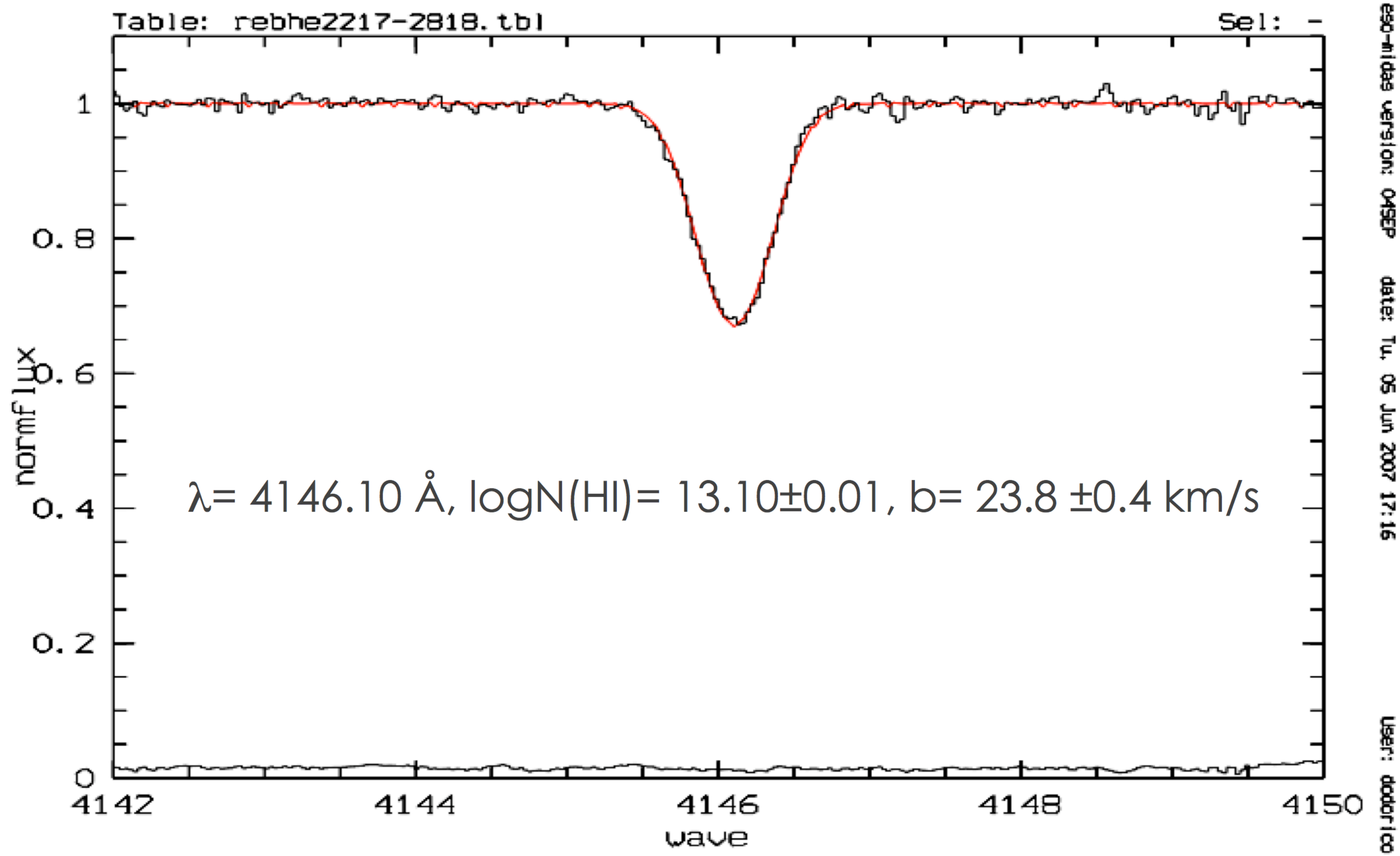

λ= 4146.10 Å, logN(HI)= 13.10±0.01, b= 23.8 ±0.4 km/s

Analysis of observations

A. Voigt profile fitting

- Time consuming operation;
- Every fitted component is counted as an independent object;
- Weak lines are more numerous but their number is more uncertain;
- Complex systems: fitting solutions are not unique but can depend both on software tool and user.

Analysis of observations

A. Voigt profile fitting

B. Transmitted flux - optical depth measurement $f(z) = e^{-\tau(z)}$

   – Uncertainty in the low τ regime due to continuum determination;
   – Uncertainty in the relatively high τ regime due to line saturation;
   – The transformation from f or τ to the density contrast δ strongly depends on the value of the mean flux and is calibrated with simulations.

Our new approach

AIM: overcome the drawbacks of the two previous techniques keeping their positive aspects.

COMPARISON BETWEEN FITTING TOOLS
for complex absorptions

$\Sigma i \neq \Sigma j$ BAD

$\Sigma N(HI)_i = \Sigma N(HI)_j$ GOOD!

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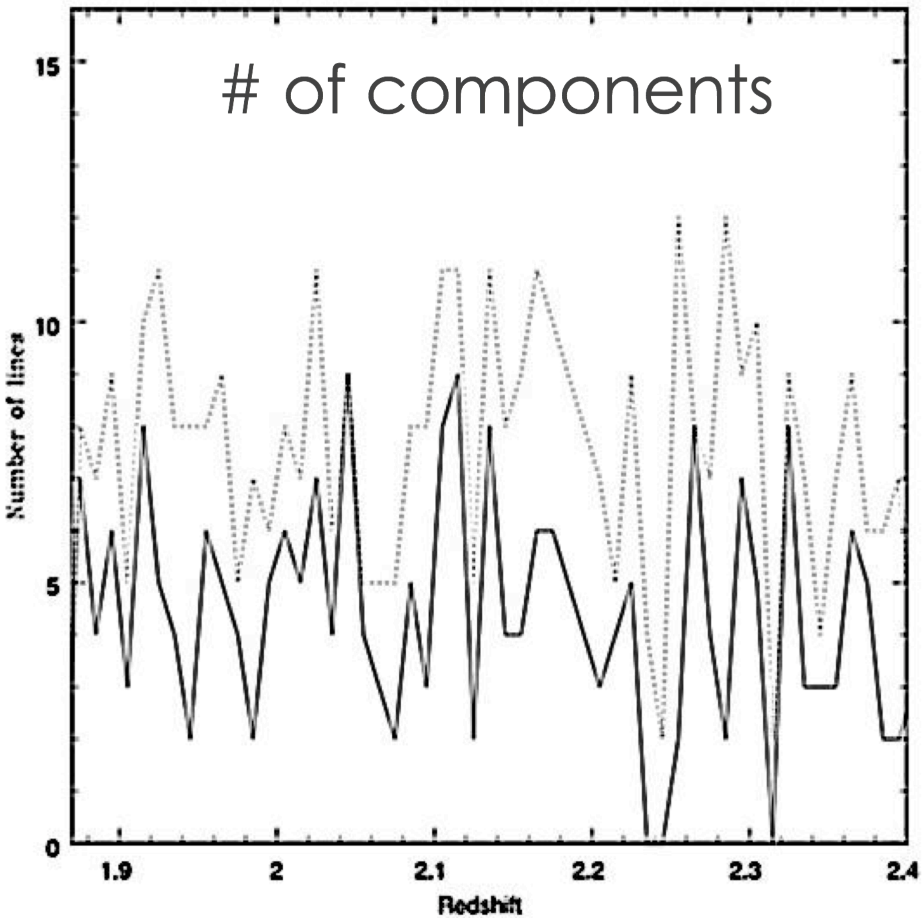
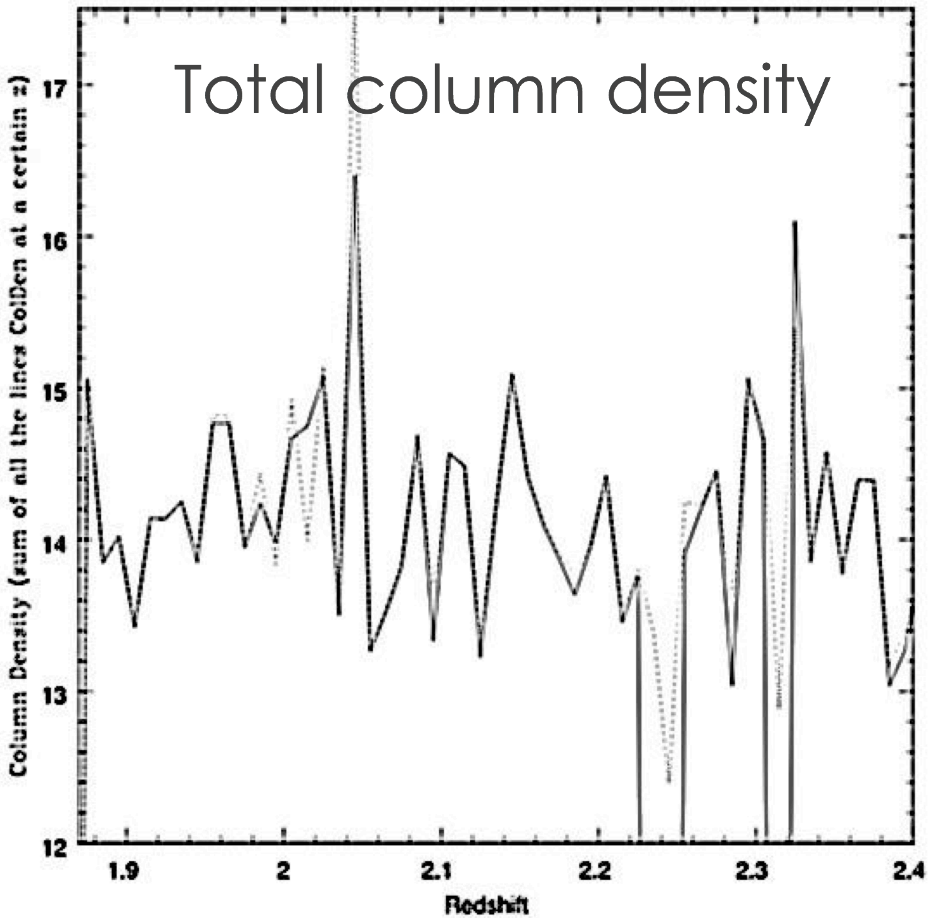




Our new approach

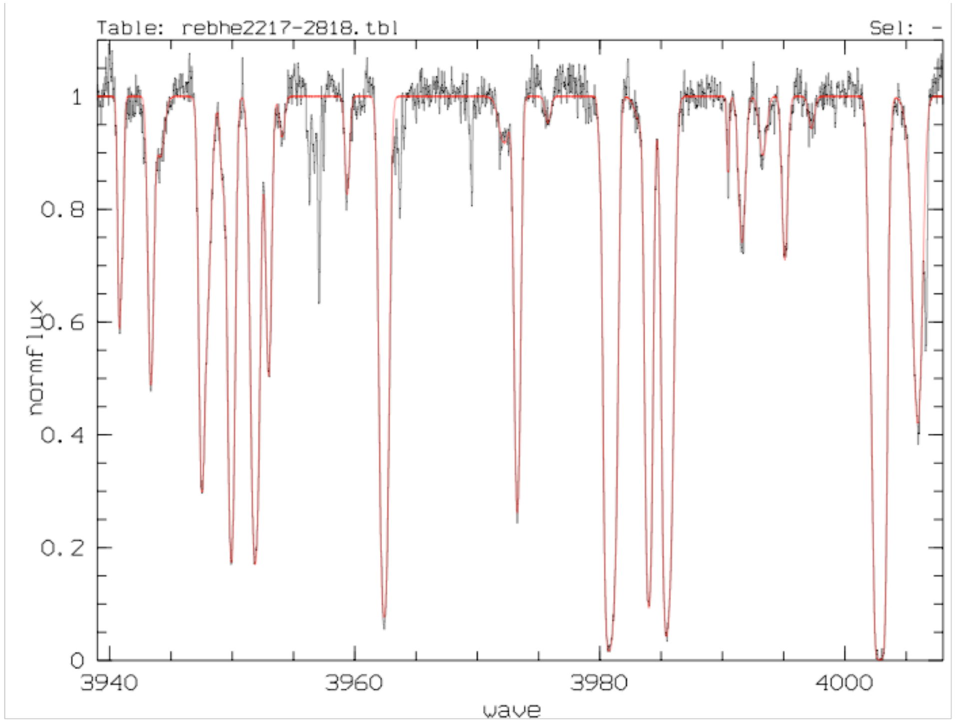
MAIN HYPOTHESIS: L_J is the characteristic smoothing scale of the IGM traced by the Ly-α forest (Schaye 2001).

From the KEY PROPERTIES and numerical simulation results (Hui & Gnedin 1997):

$$N(HI) \propto (1+\delta)^{1.5-0.26(\gamma-1)} (1+z)^{9/2} \Gamma^{-1}{}_{12}$$

Our new approach

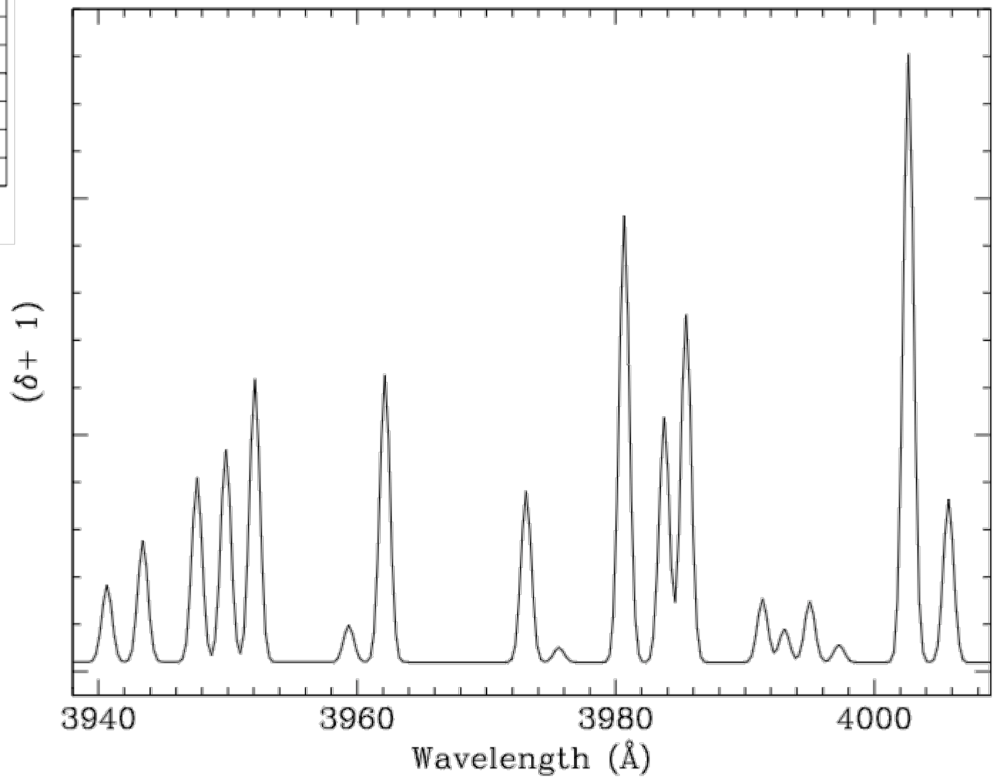
Our new approach



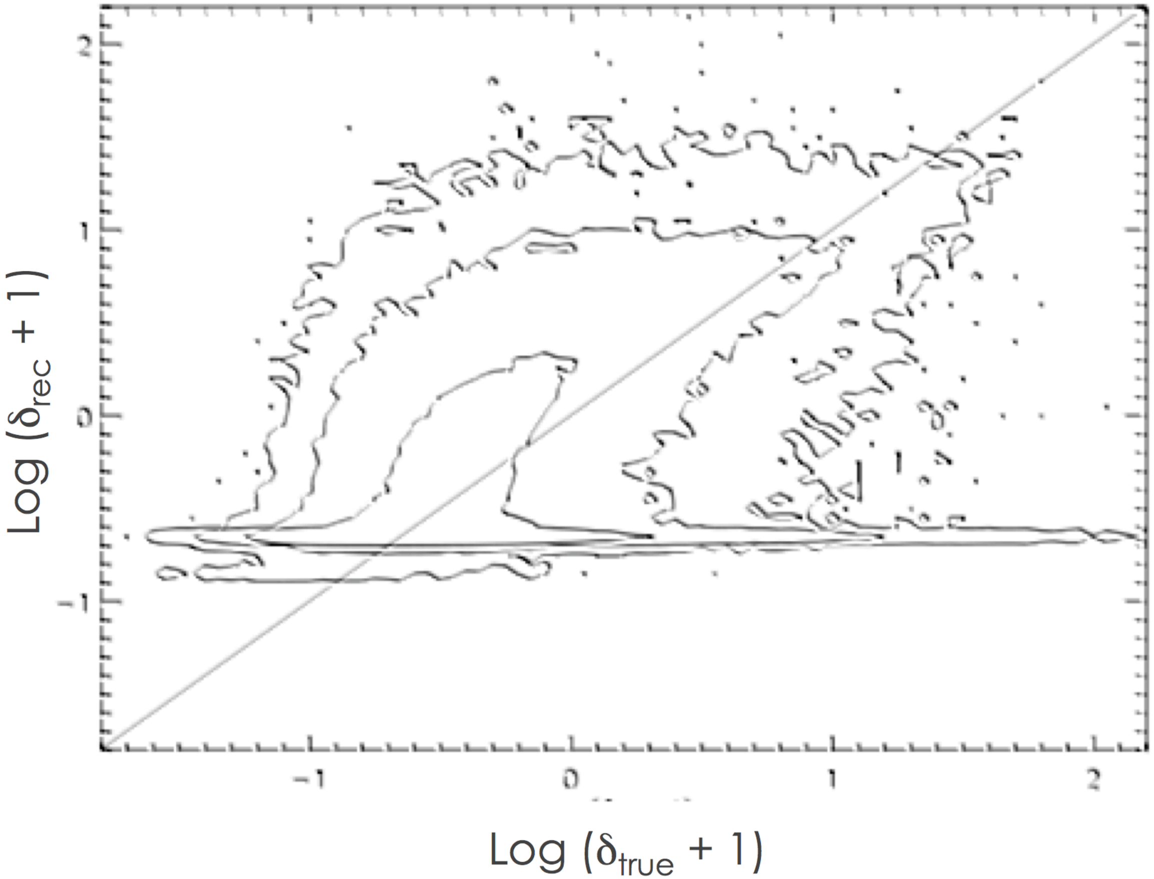
Lines fitted with Voigt profiles

- ➪ List of N(HI) vs. z
- ➪ List of delta vs. z

Smoothed over one Jeans length



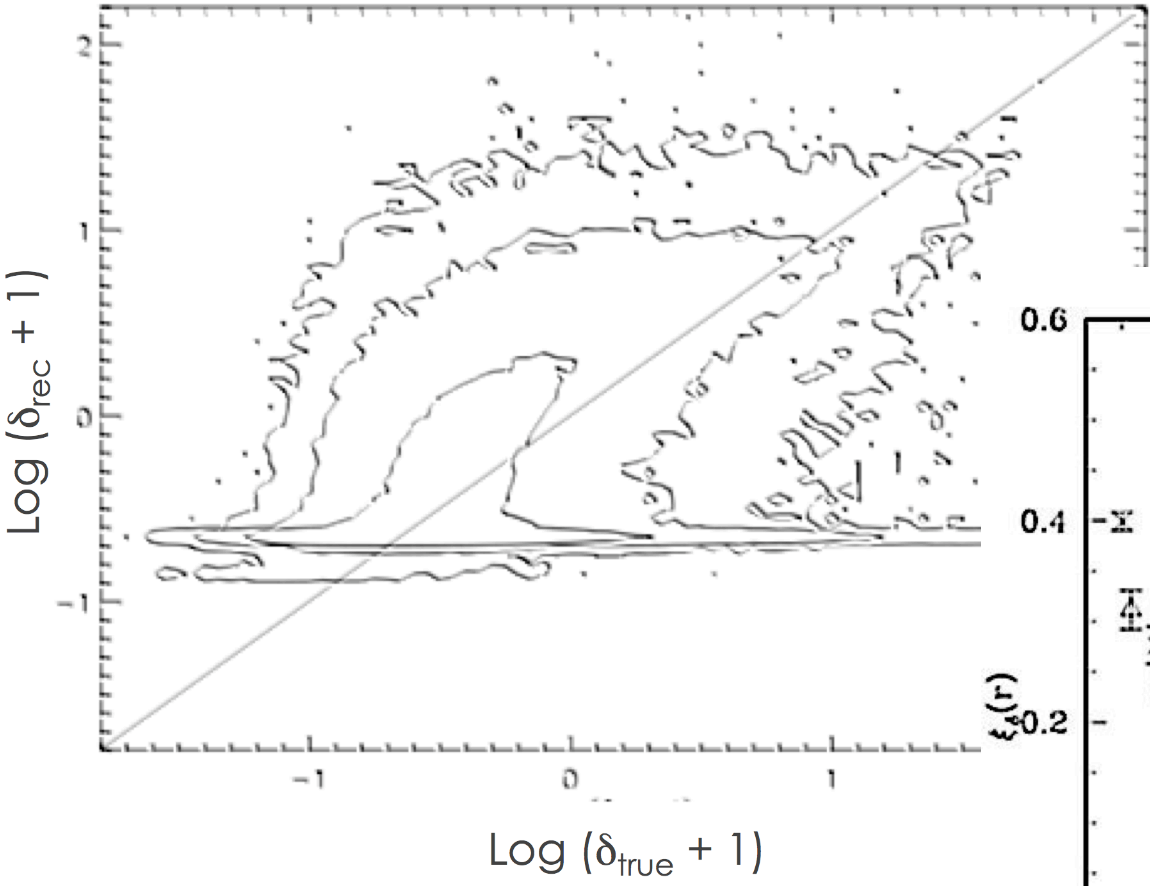
Tested against simulations



364 simulated lines of sight from a box of 120 h^{-1} comoving Mpc.

Fitted with VPFIT

Tested against simulations



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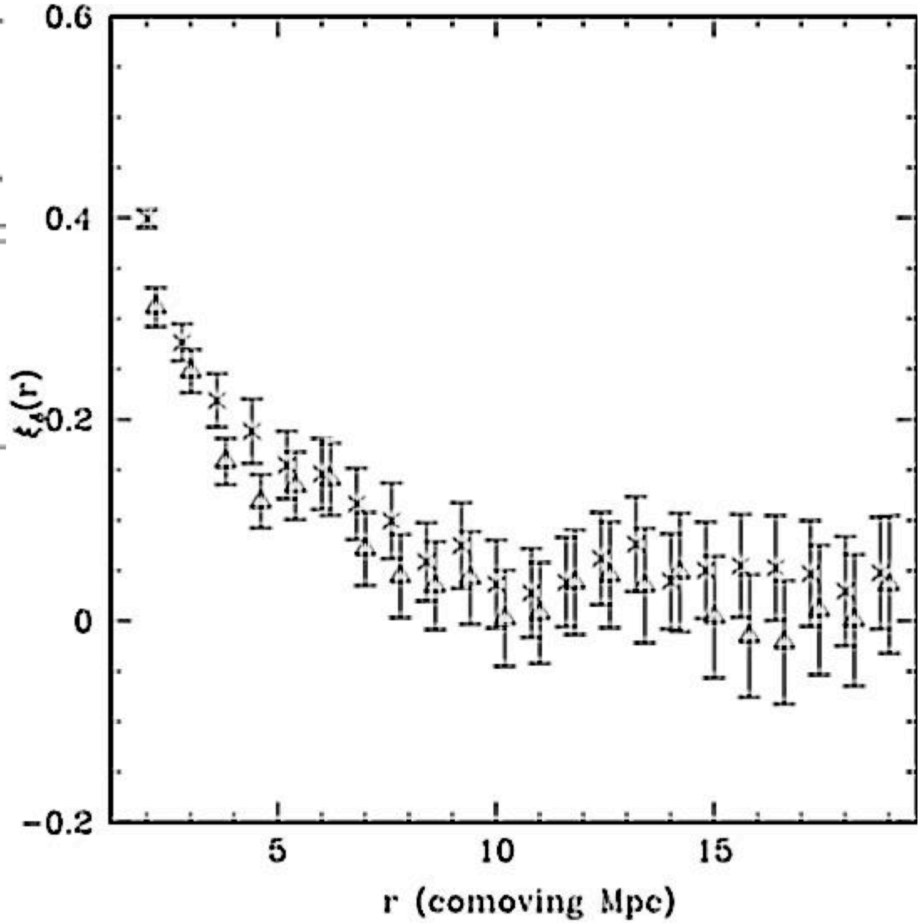
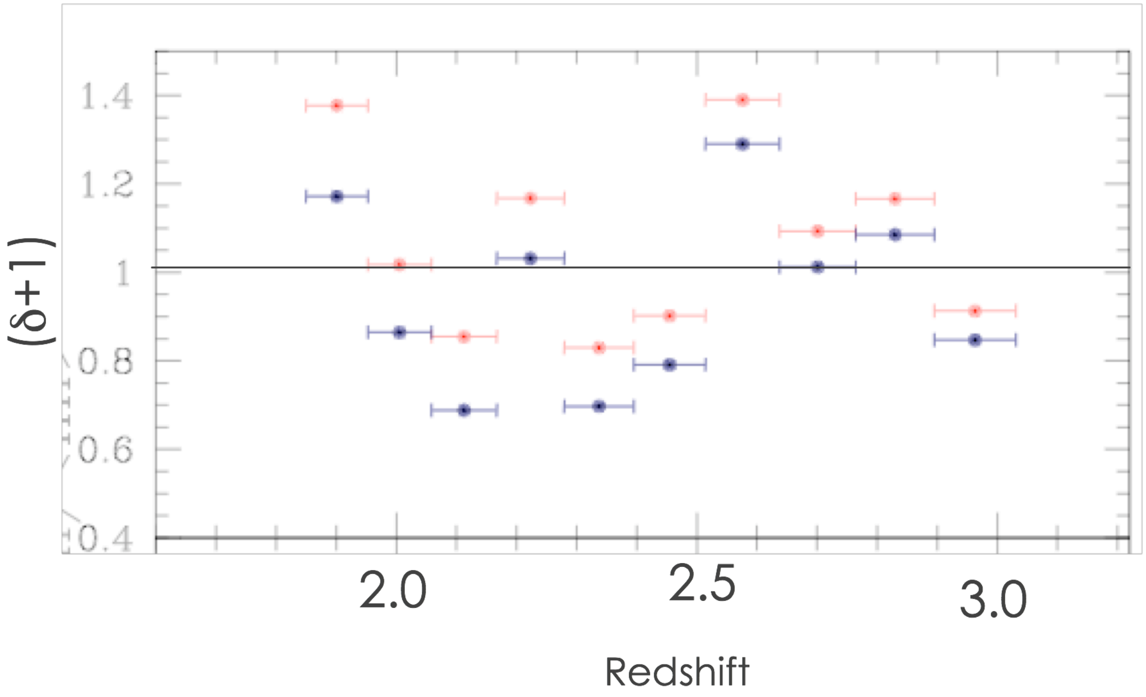


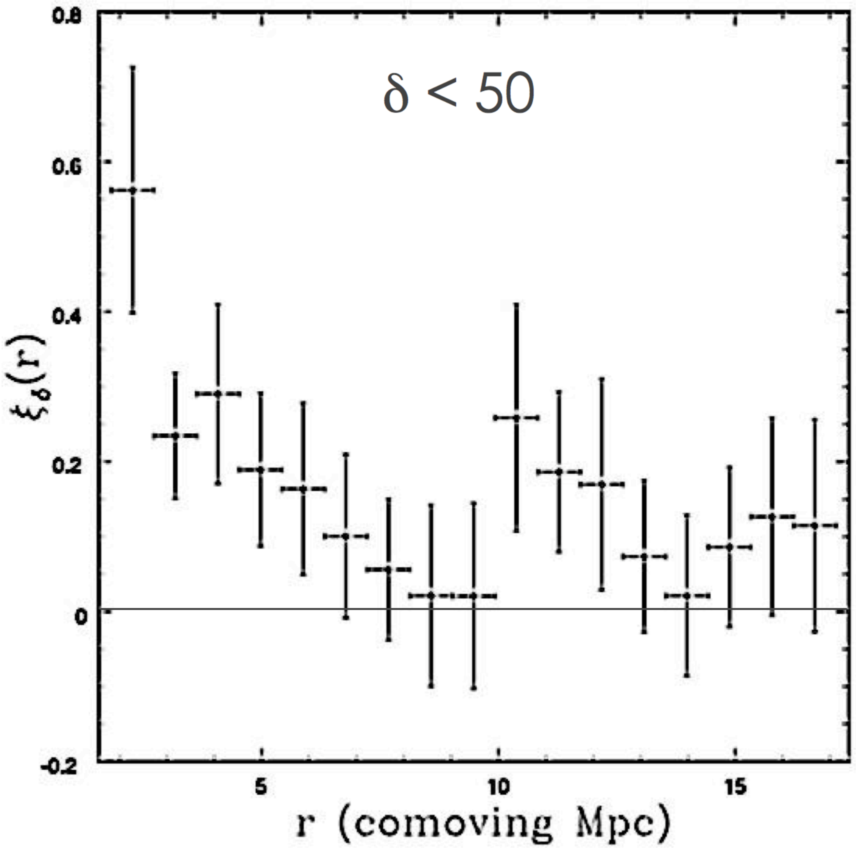
Correlation function of density contrast, true and recovered

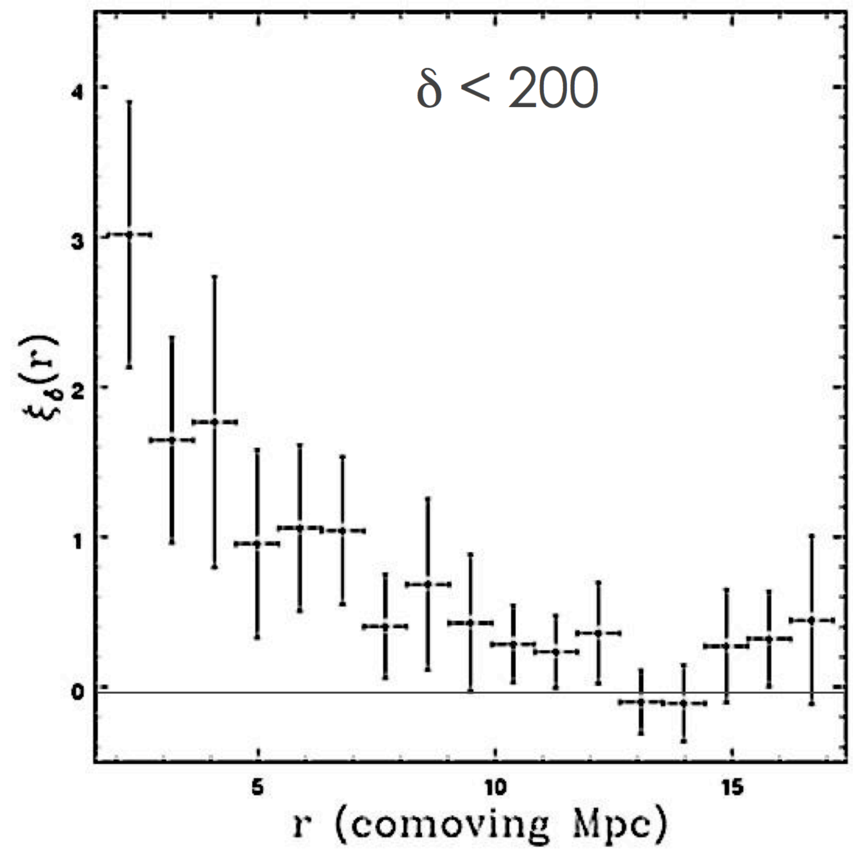
First results: 19 UVES spectra



The density contrast derived from the Lyman-α forest QSOs

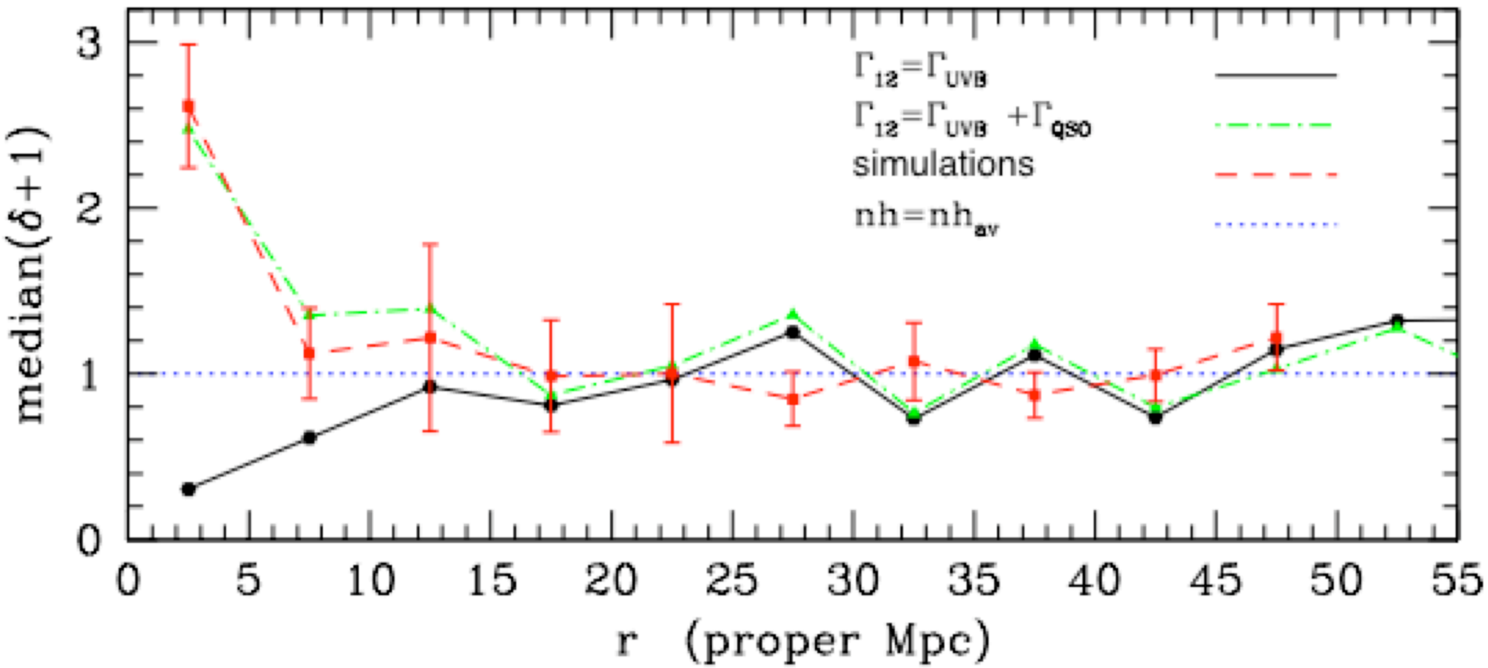
First results: 19 UVES spectra





First results: 19 UVES spectra

Density distribution in the proximity of QSOs



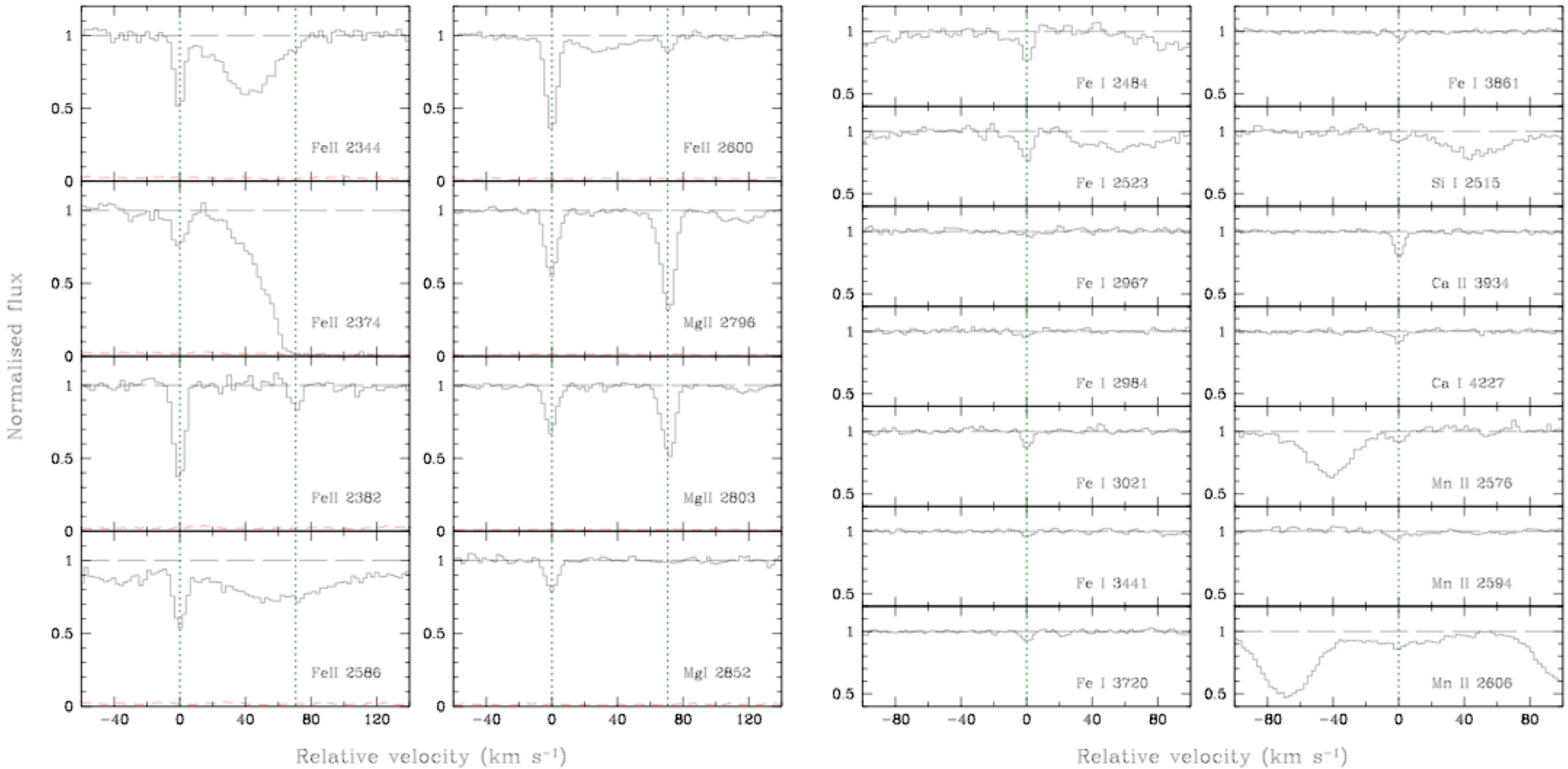
See poster by M. Bruscoli !

More will come…

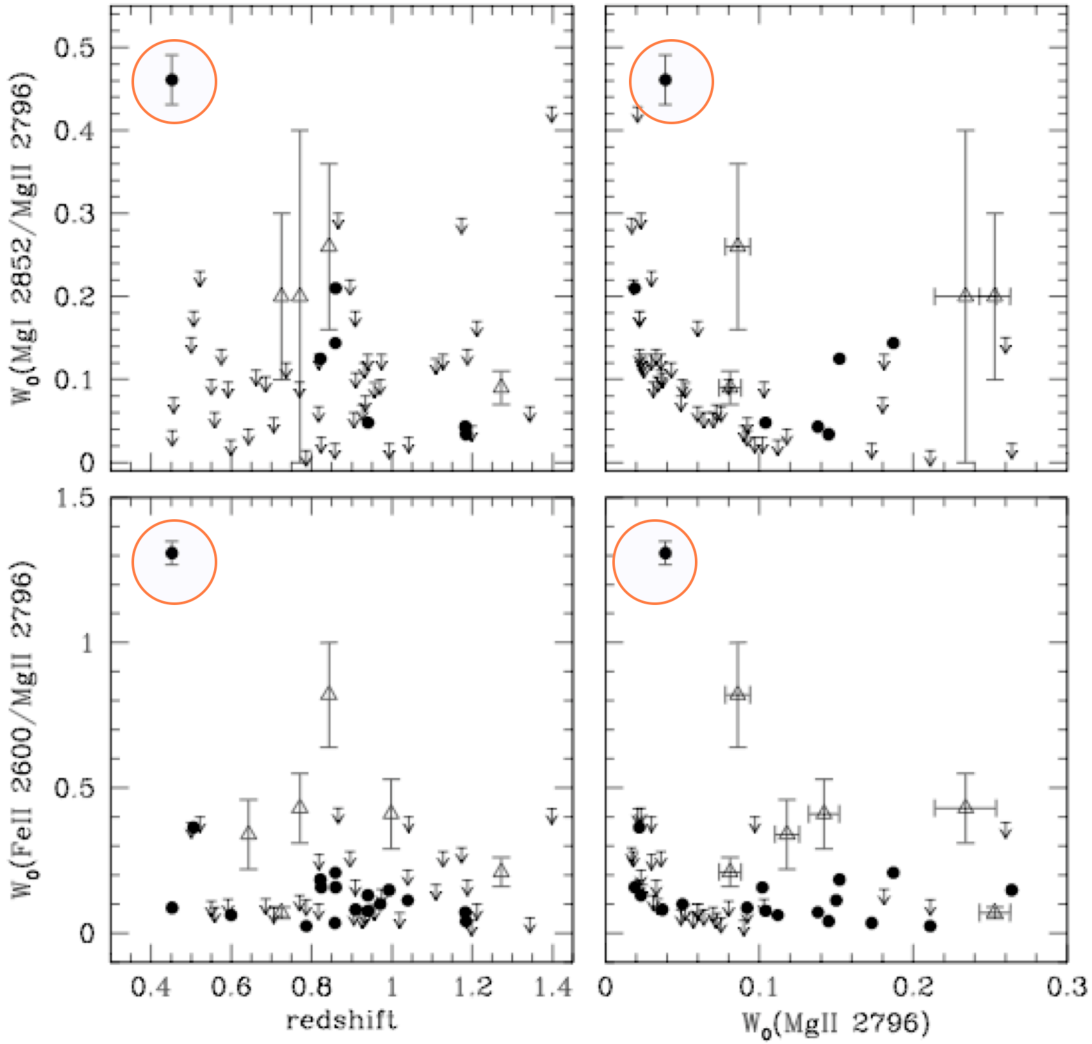
M. Bruscoli, V.D., et al.

F. Saitta, V.D., et al.

A single, metal poor, cold cloud at z ~ 0.45: first detection of Fe I, Si I, and Ca I in a QSO absorber



Comparison with other classes of absorbers



Mg II rest equivalent width classifies it as a: WEAK MgII SYSTEM

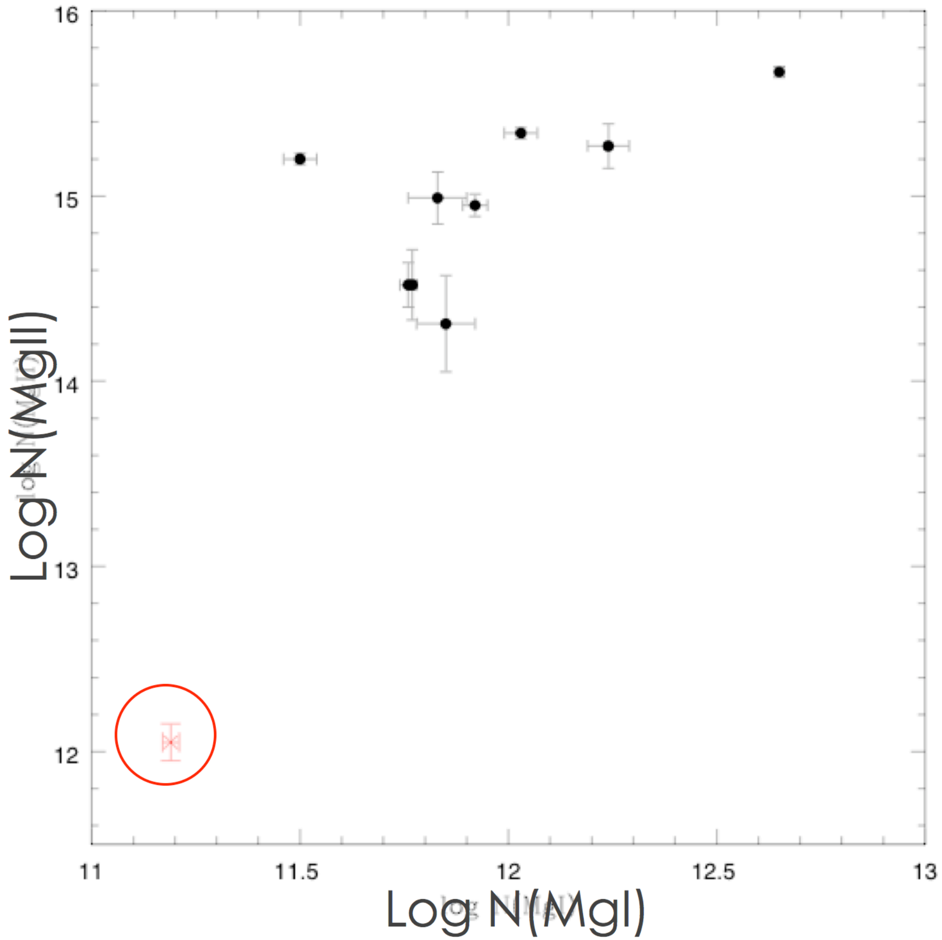
Comparison with other classes of absorbers

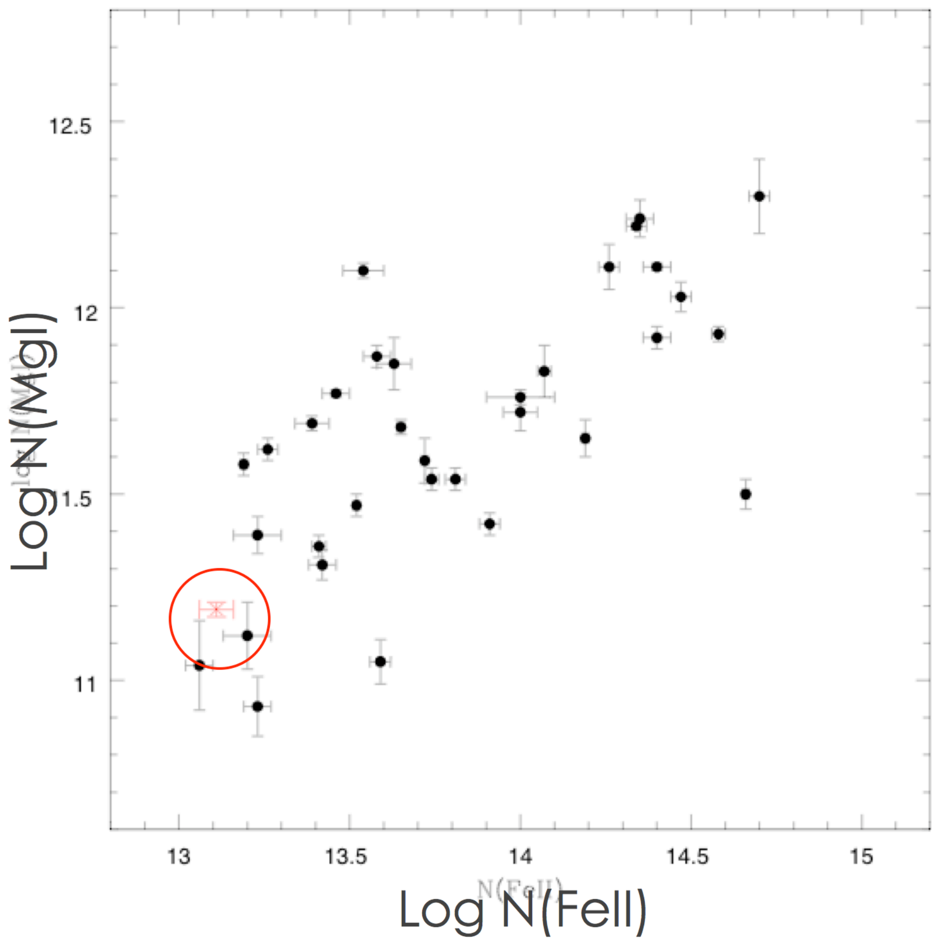
Damped Lyman-α systems

(data by Dessauges-Zavadski et al. 2006)

[Mg/Fe] = -1.05±0.05

DLA: [Mg/Fe] = 0.7 ±0.4

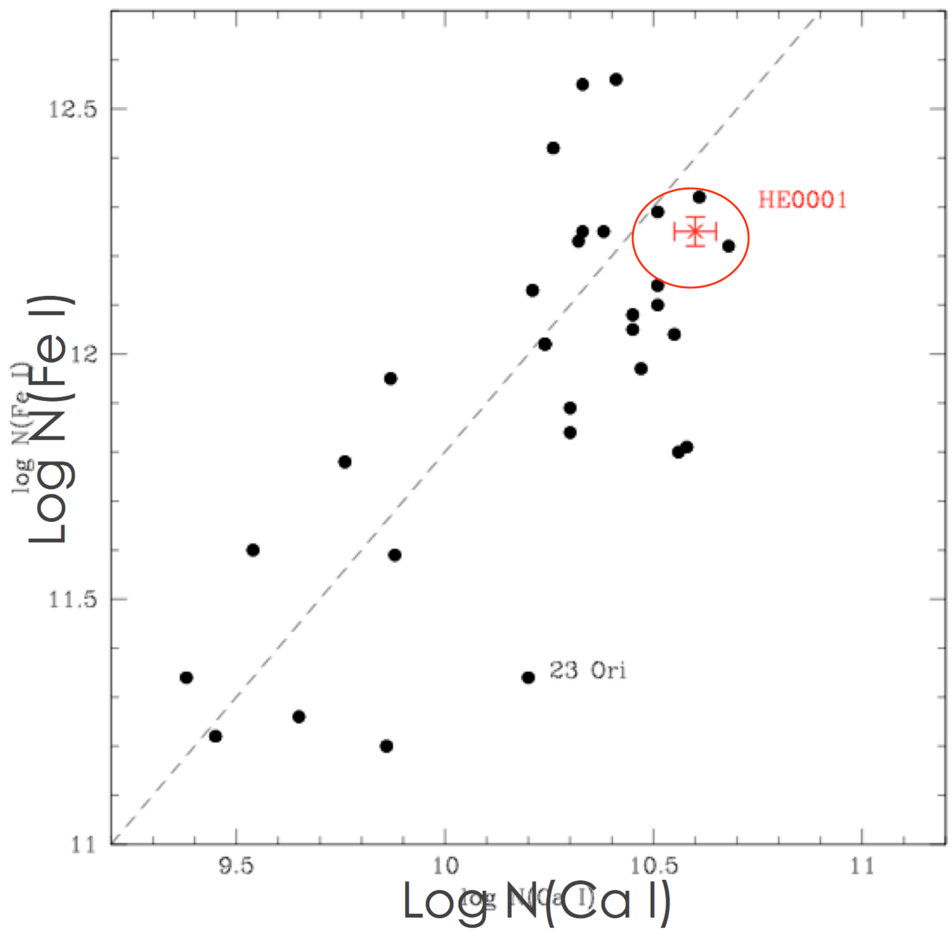


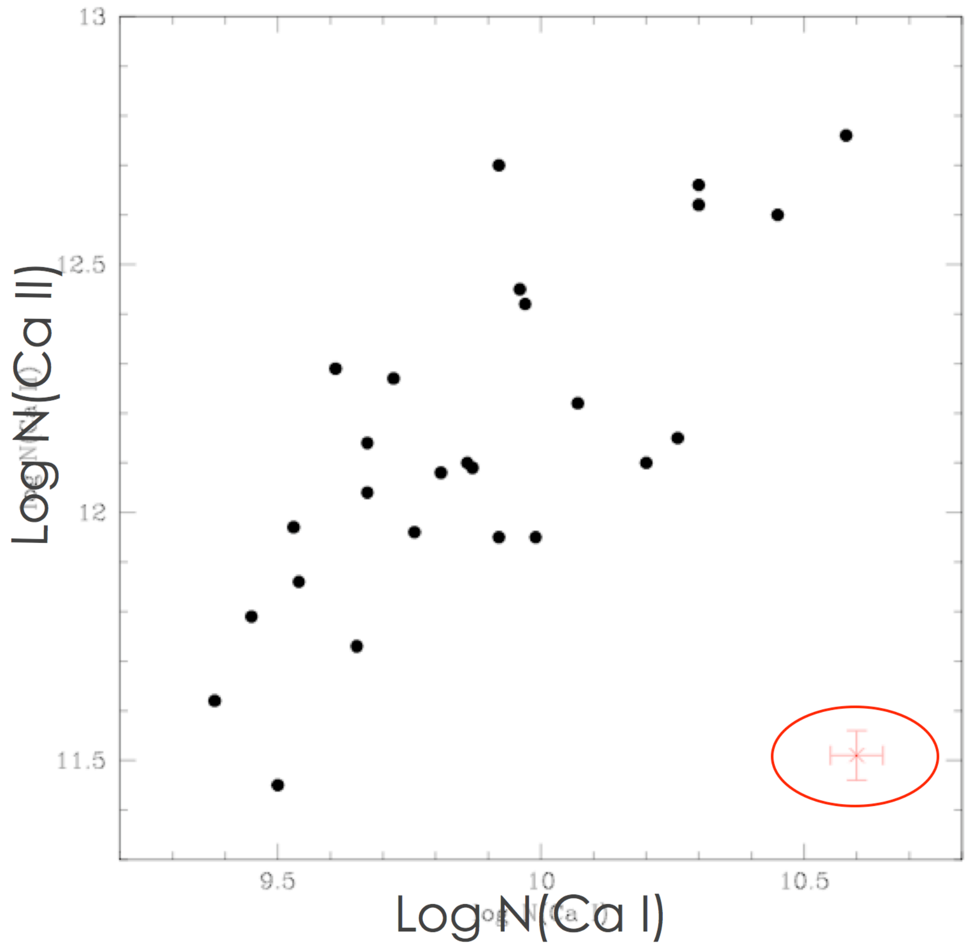


Comparison with other classes of absorbers

Local interstellar clouds
(data by Welty et al. 2003)

Metallicity
-2.78 < [Fe/H] < -3.78





Conclusions

Photoionization models with Cloudy: It is not possible to recover the observed Mg I/Mg II, Ca I/Ca II, and Fe I/Fe II column density ratios with a single gas slab of constant density.

A complex density structure is strongly suggested by the data to explain the observed ionic abundances.

The probability of intersecting such a cloud is $P \approx 0.03$. We observed one over 34 single Mg II components.

What is this the nature of this very rare absorber ?

- UV observations would be needed to confirm the predicted high HI and, likely, H2 content;
- (maybe) more example could be found with the next generation of very high resolution (> 100,000) spectrographs

Definitions

Lyman-α forest ➡ hundreds of absorption lines observed in near-UV/optical spectra of QSOs at $z > 1.5$-2 due to the Lyman-α resonant transition in HI atoms intercepted along the line of sight.