Metals at Highish Redshift

From DLAs to Underdense Regions

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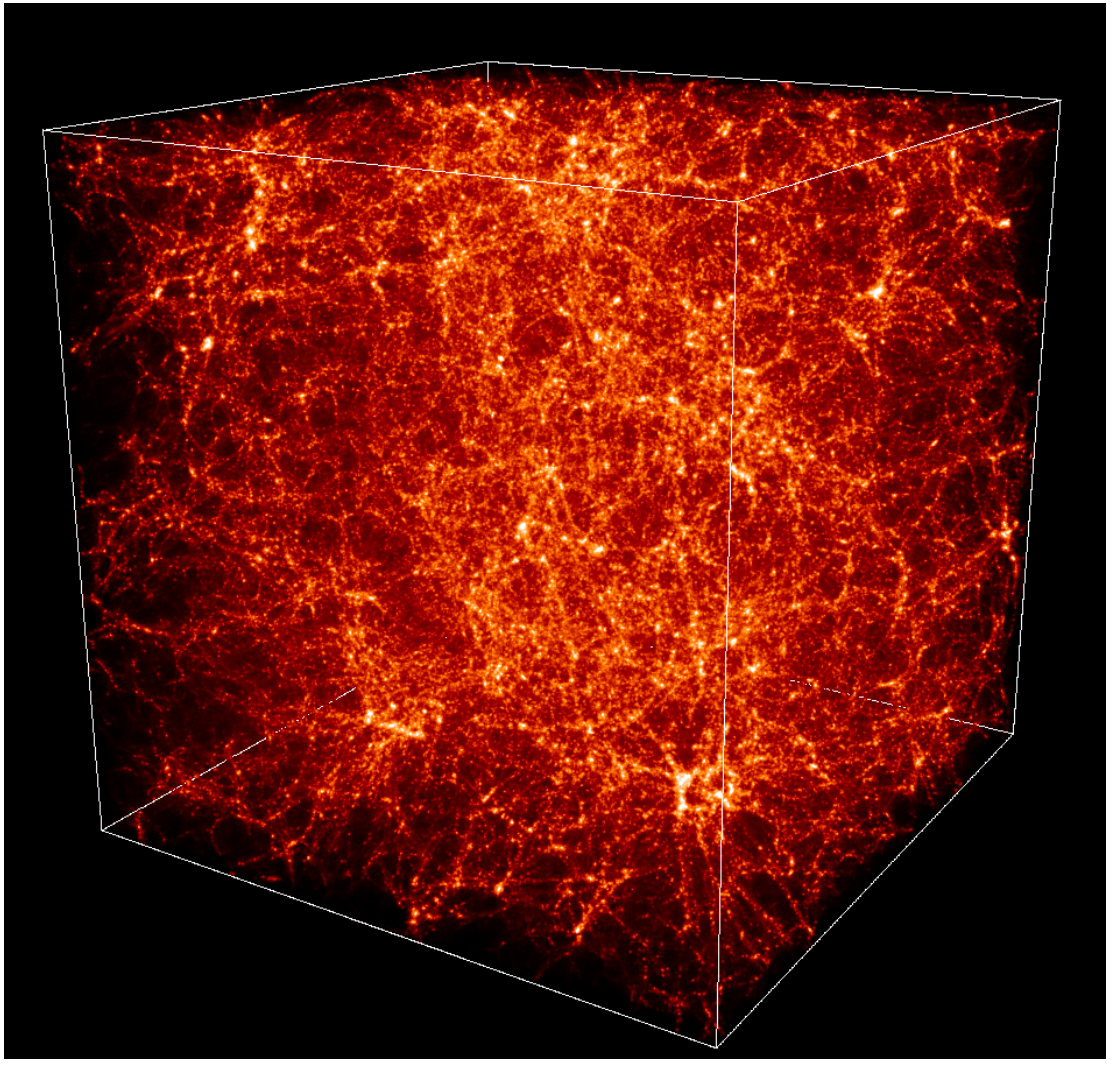
Overall Picture



- Where are the metals ?
- Center of halos
- Expelled from the center of
  Halos -> Winds
- Along filaments
- What about the Voids ?

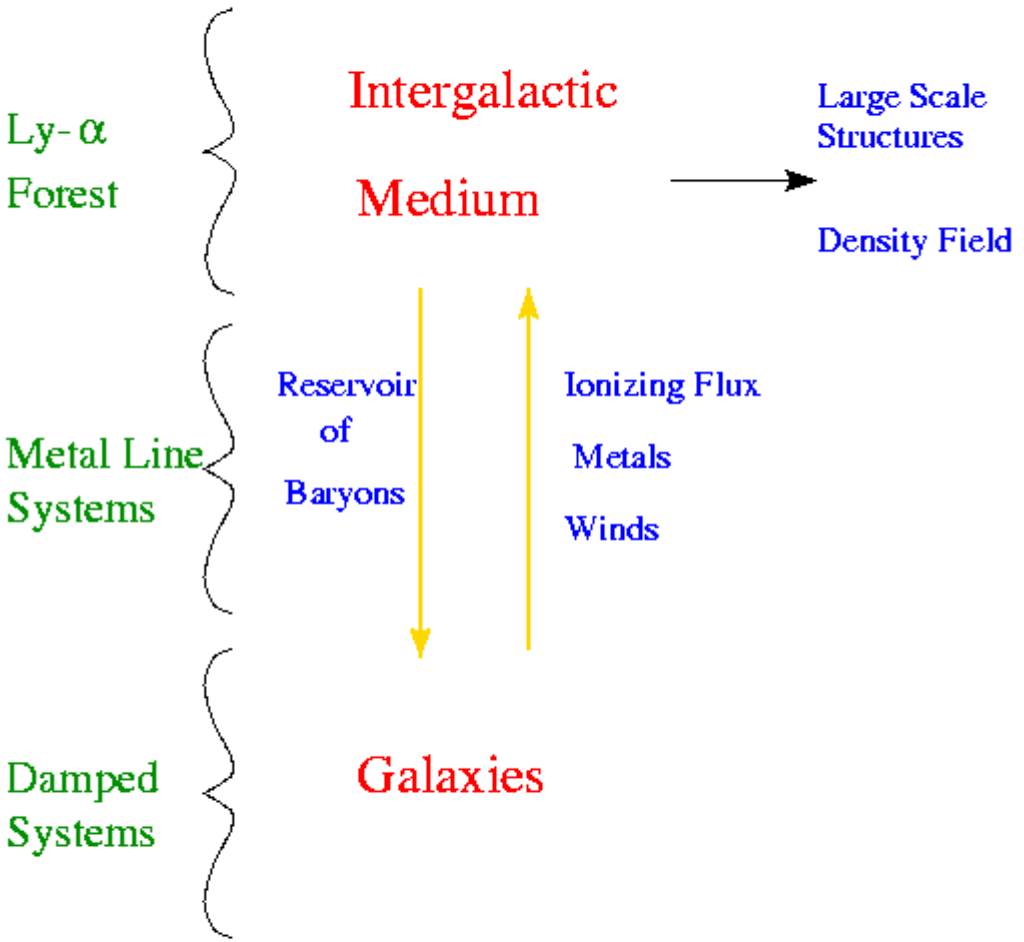
- Metallicities
- Correlations – Clustering

QSO Absorption Lines

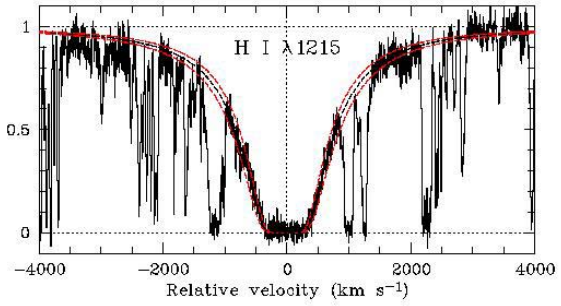
etals in the IGM

ssociation with
alaxies

etallicities and SF



Damped Ly-α Systems

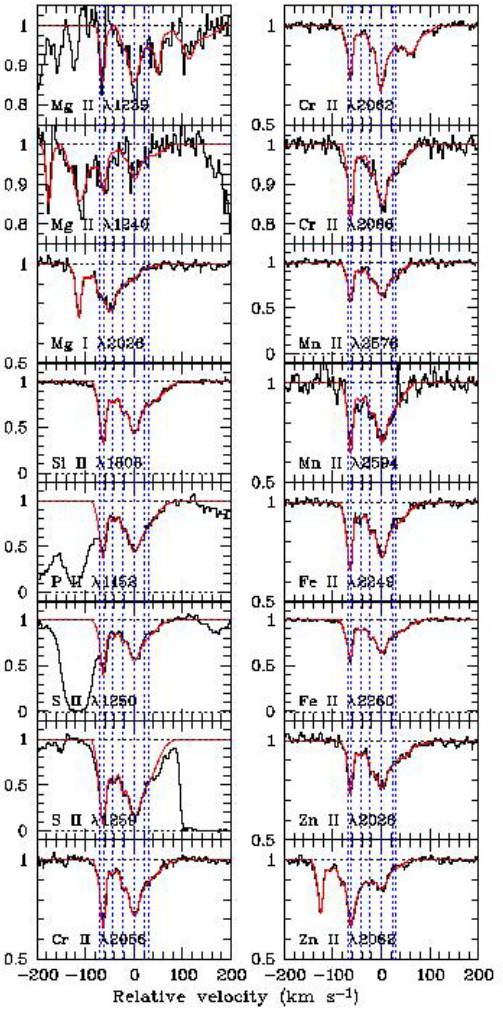


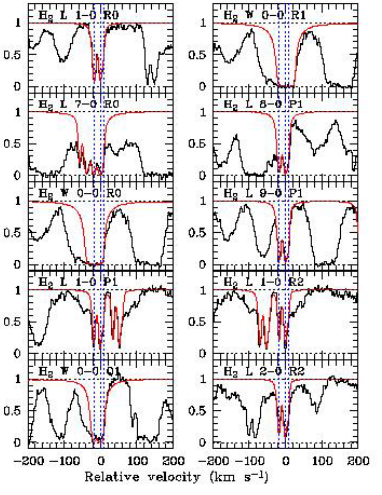
Metals :

-> Metallicities

-> Dust

-> Kinematics



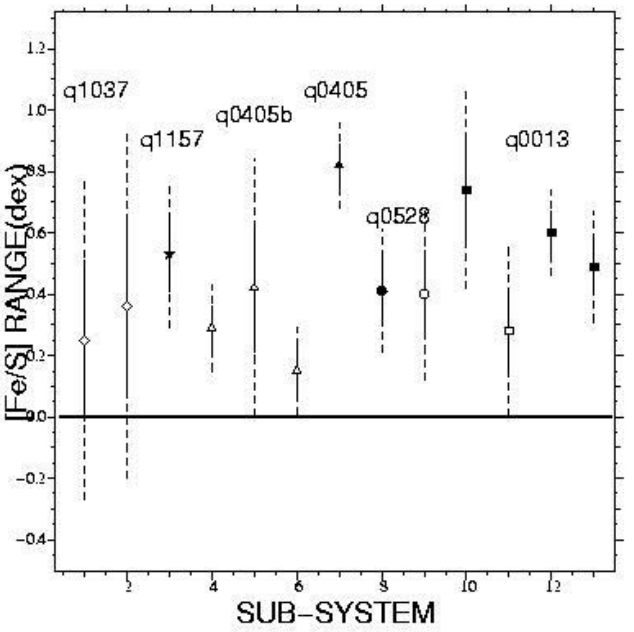


Molecules H2 :

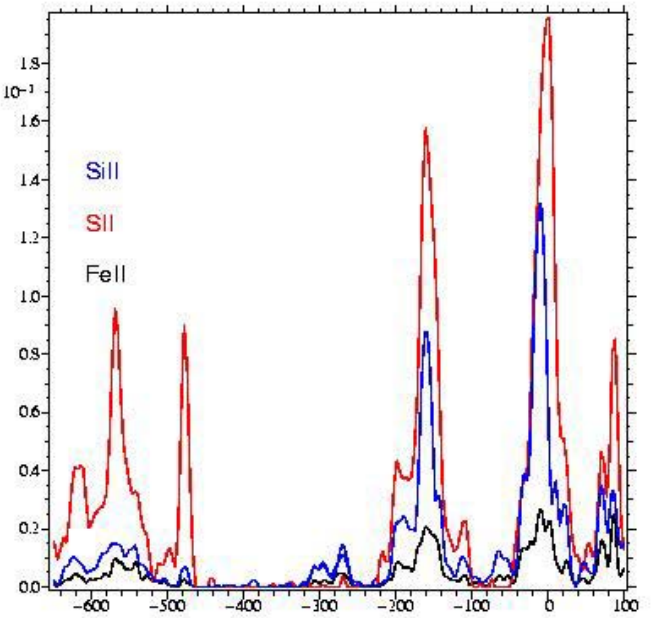
-> Density/Temperature

-> UV flux

Homogeneity



Dispersion



Pixel by pixel metal ratios

Rodriguez et al. 2005, A&A

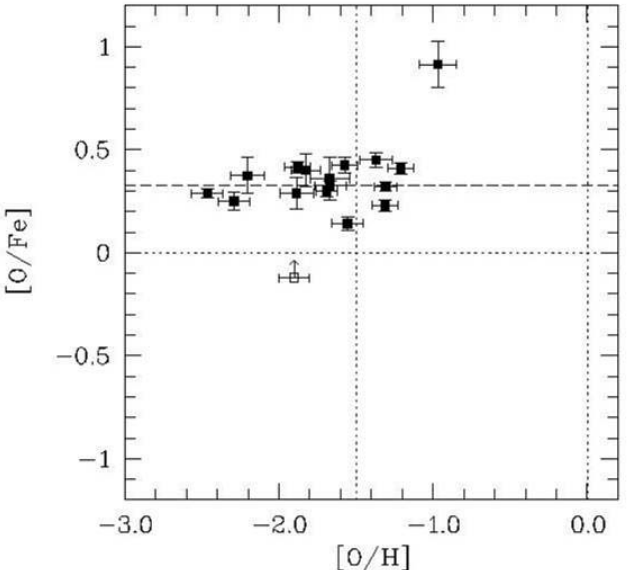
Metallicities in DLA Systems

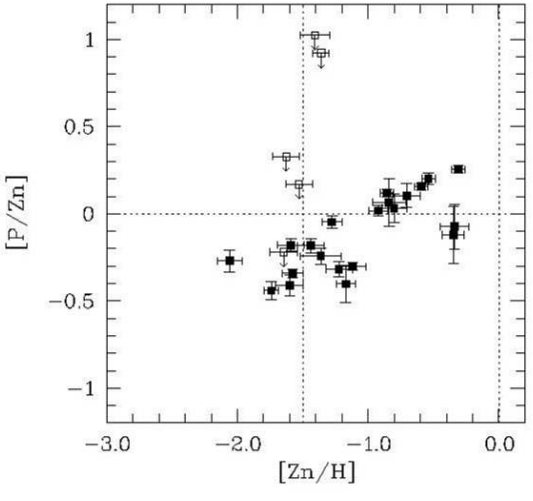
Sample of ~100 DLAs

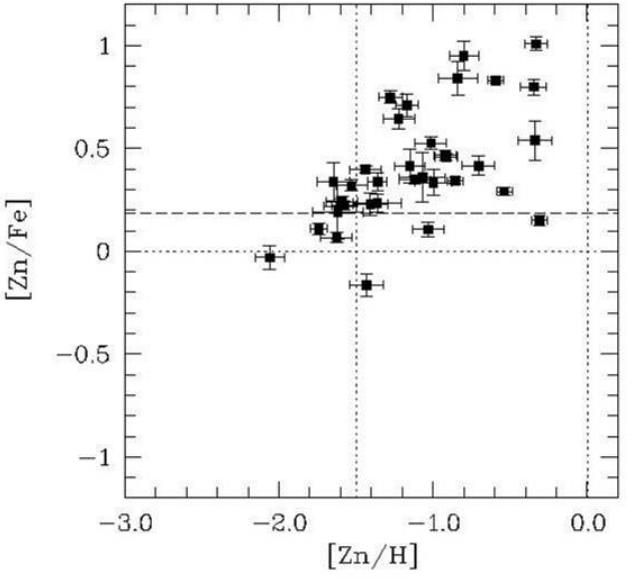
* [O/Fe] ~ 0.35 for -2.6<[O/H]<-1

* Depletion sequence from [Zn/Fe]

* Phosphorus undersolar for [Zn/H]<-1





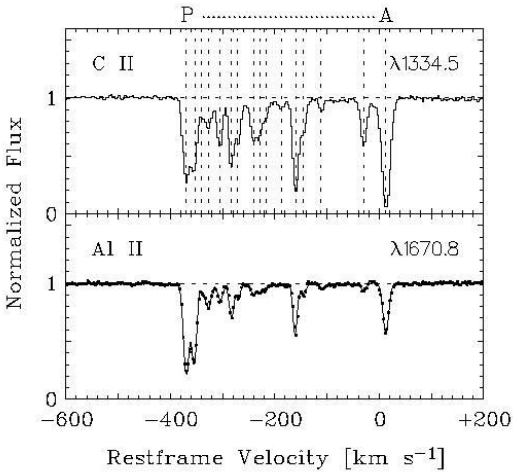


Ledoux et al., in prep.

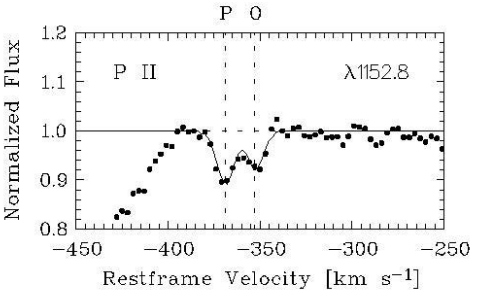
Peculiar Metallicities in DLAs

1. Z=2.19 towards HE0001-2340:

[O/H]=-1.81 [C/H]=-1.76 [N/H]<-3.3 [Fe/H]=-2.12



[P/C] > 1 ?



Richter et al., 2005, astro-ph/0505340

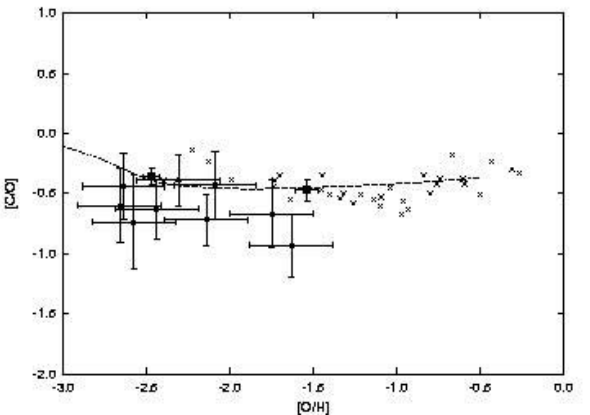
2. Z=2.62 towards Q0913+072:

[O/H]=-2.45 [C/H]=-2.81

[N/H]=-3.83 [Fe/H]=-2.76

-> Metallicity as in the IGM ?

-> IMF 10-50 Msun ?



Molecular Hydrogen in DLA systems at z>2

75 DLAs ; 14 detections

15% of DLAs have H2 - Small H2/HI fraction

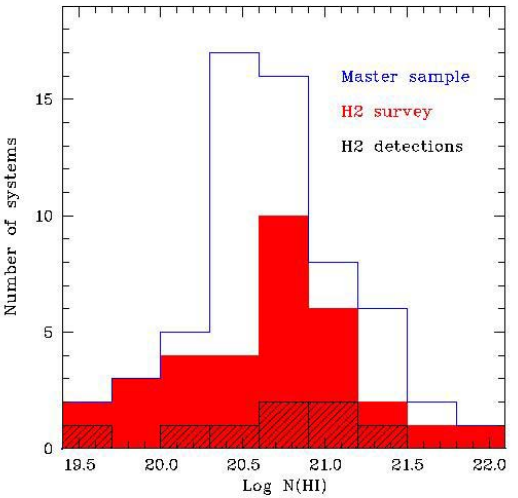
Physical conditions :

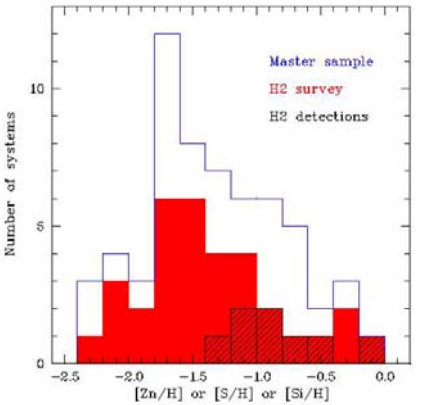
-> Different J levels

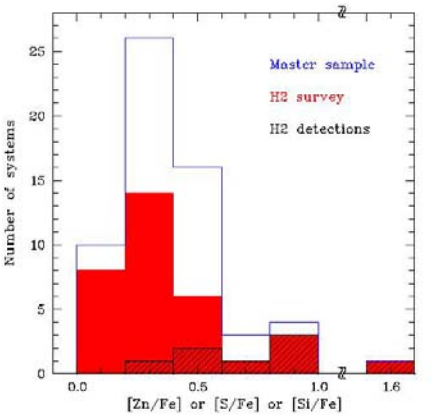
-> CI* ; CII*

T=100 K ; n=10 cm-3

-> Ambiant UV flux is several times that of the Galaxy







Star formation : H2 ; CII* ; Lyα emission

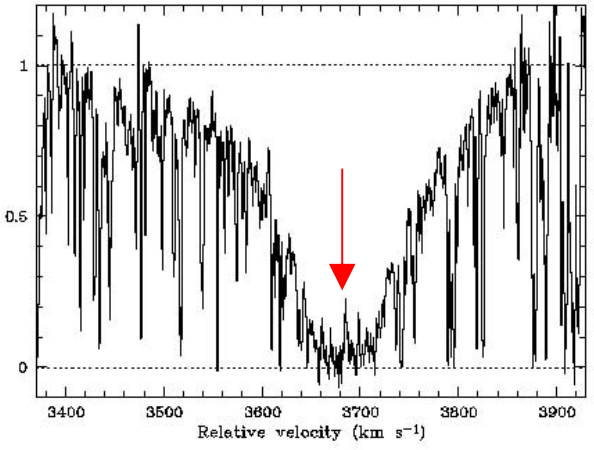
Winds ?

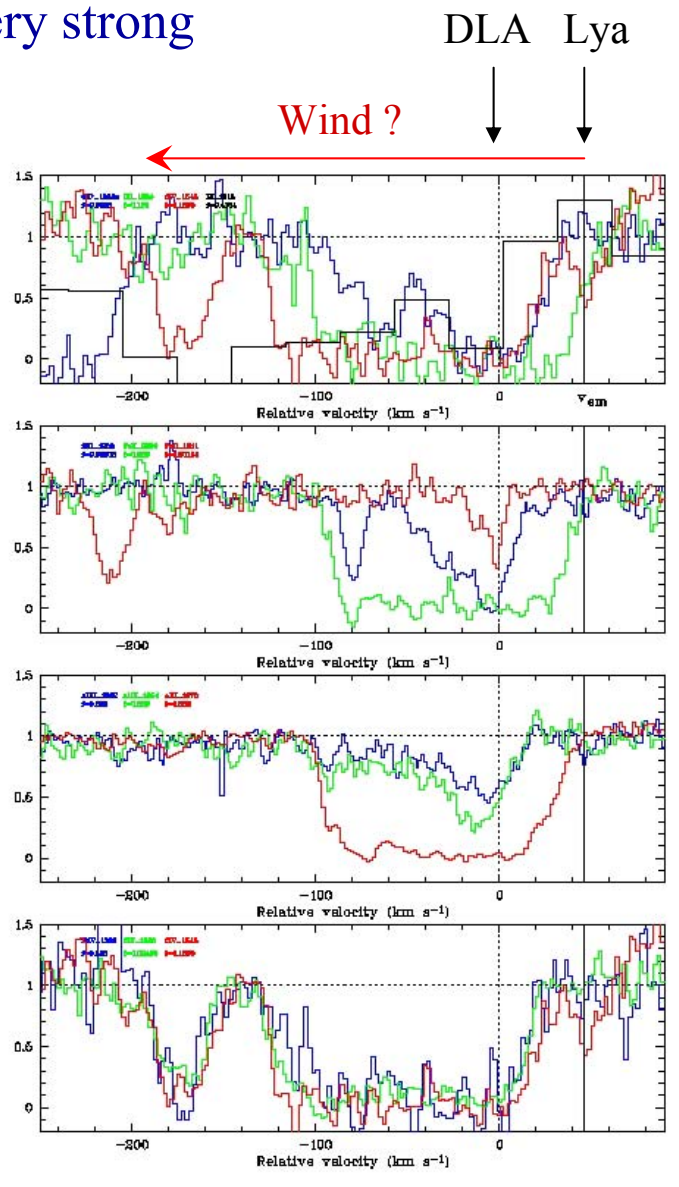
Ledoux et al. 2003, MNRAS, 346, 209

DLA at z=2.09 towards Q0458-02

logNHI = 21.7 - Ly-alpha in emission – CII* very strong

[Zn/H]=-1.22 [Fe/Zn]=-0.65





SFR : Ly-α emission : 1.6 Ms/yr

Consistent with CII*

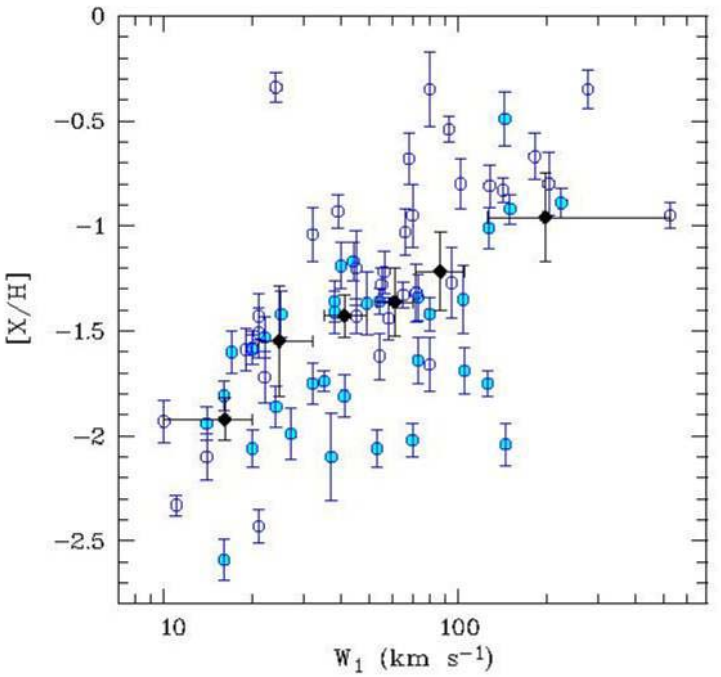
No H2 : UVBG 10x+/Galaxy

Winds are slow…

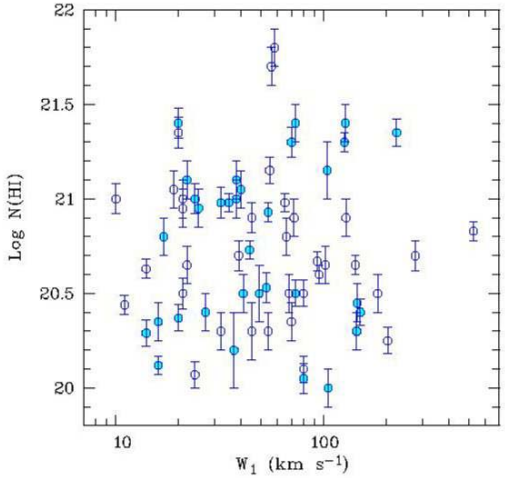
Heinmüller et al. In prep.

Mass-Metallicity Relation

[X/H] : metallicity - W1 : Absorption Width



Ledoux et al. Astro-ph/0504402

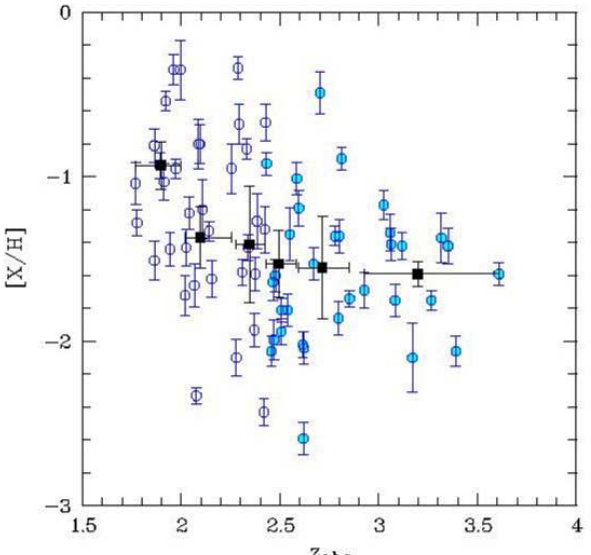


Metal Rich = Massive Galaxy

Evolution with z : For a given mass

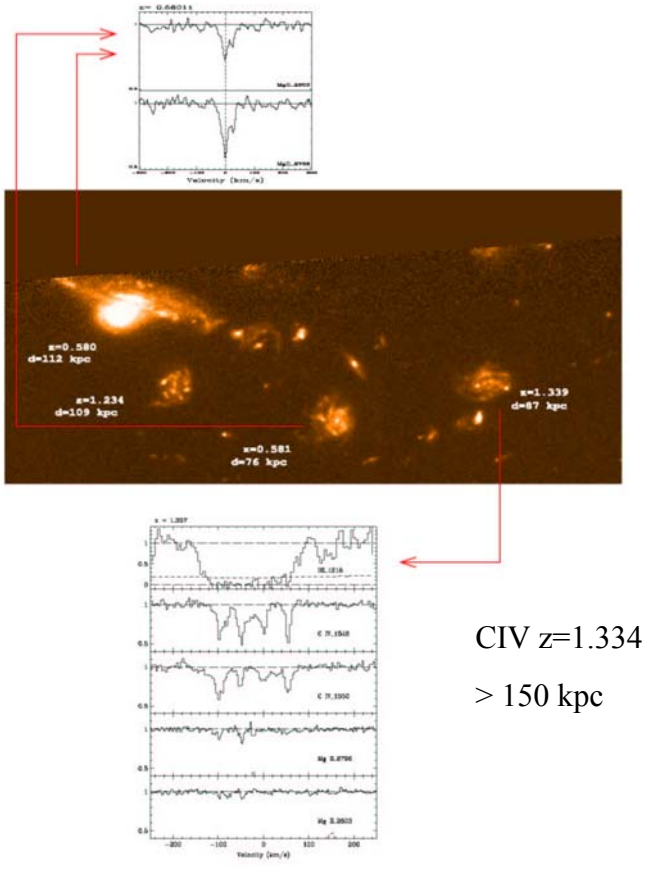
Z increases with time

There is SF ; If winds : not very strong except for massive objects



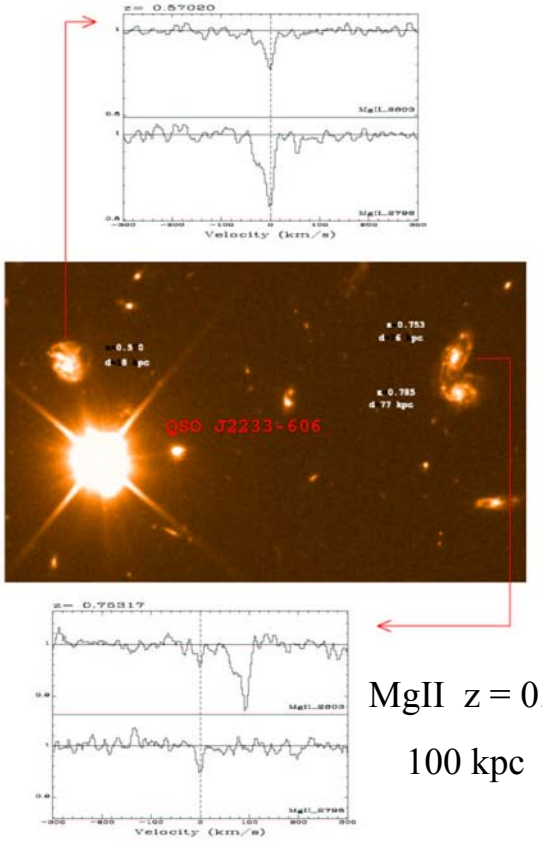
Direct Correlation Galaxy-Absorber

1. MgII Systems (z ~ 1)
   * Broad band imaging and spectroscopic follow-up -> 35 kpc
     Bergeron & Boissé (1991, A&A 243, 344); Steidel (1993)
   * Weak MgII systems ? Churchill et al. (2000) -> > 70 kpc
2. CIV Systems -> Much larger



CIV z=1.334

> 150 kpc

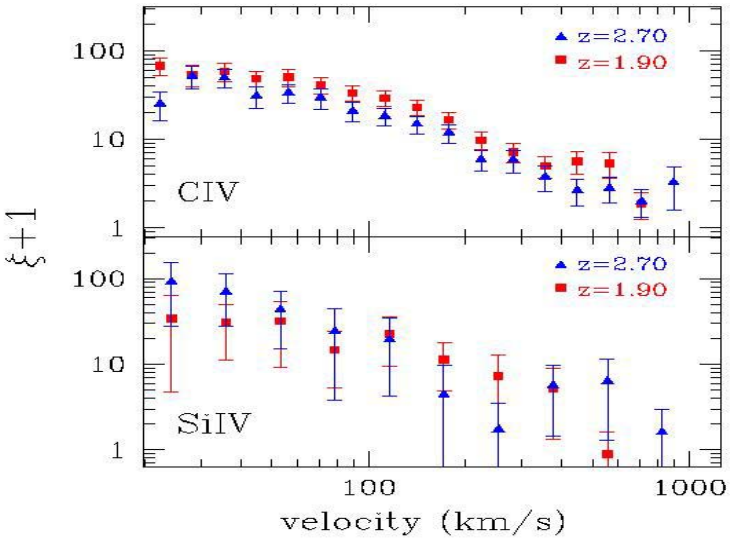


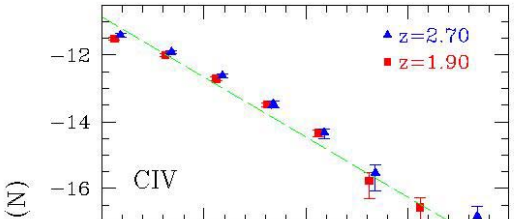
MgII z = 0.73

100 kpc

CIV longitudinal correlation function

Large Programme ESO – 643 CIV systems





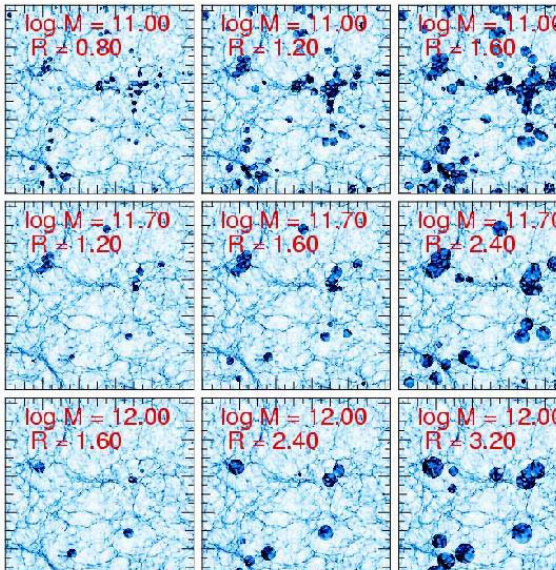
Column density distribution

SPH Simulation :

-Bubbles (radius R_{bubble}) around haloes of mass M_{halo}

- Ionized by the UV background

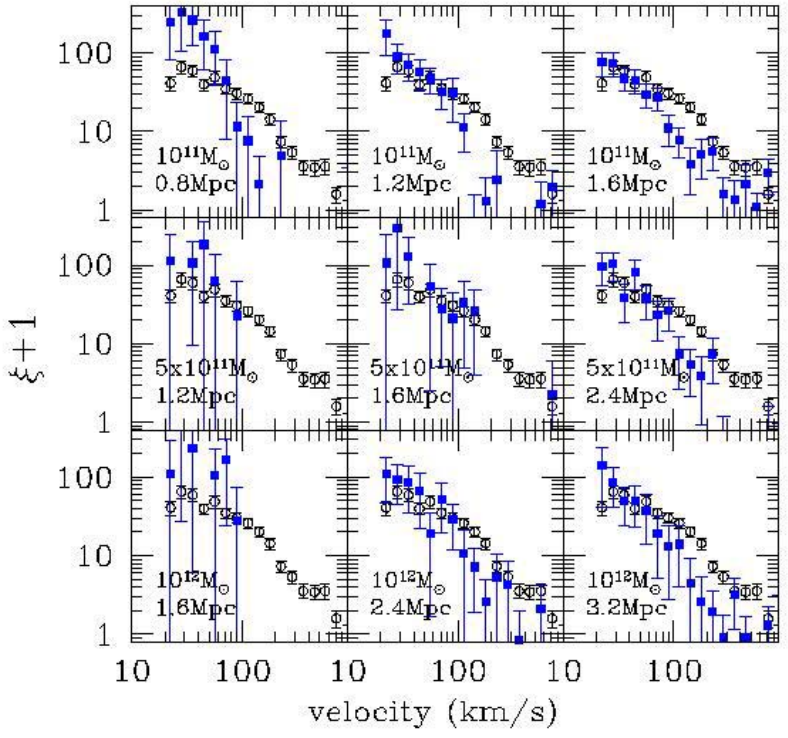
- Simulated los analyzed the same way as data

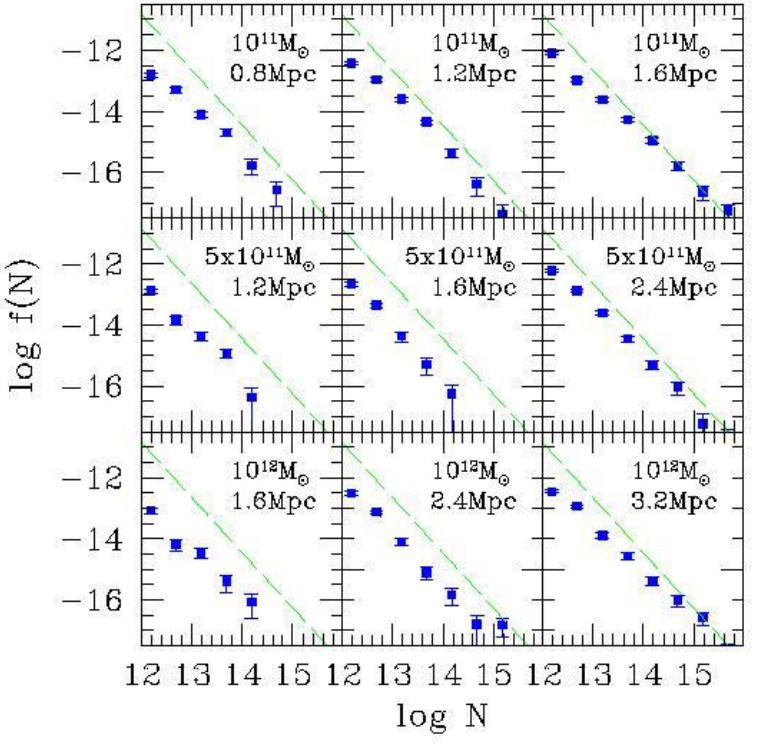


Fitting the CIV longitudinal correlation function

Fitting the column density distribution and the correlation function

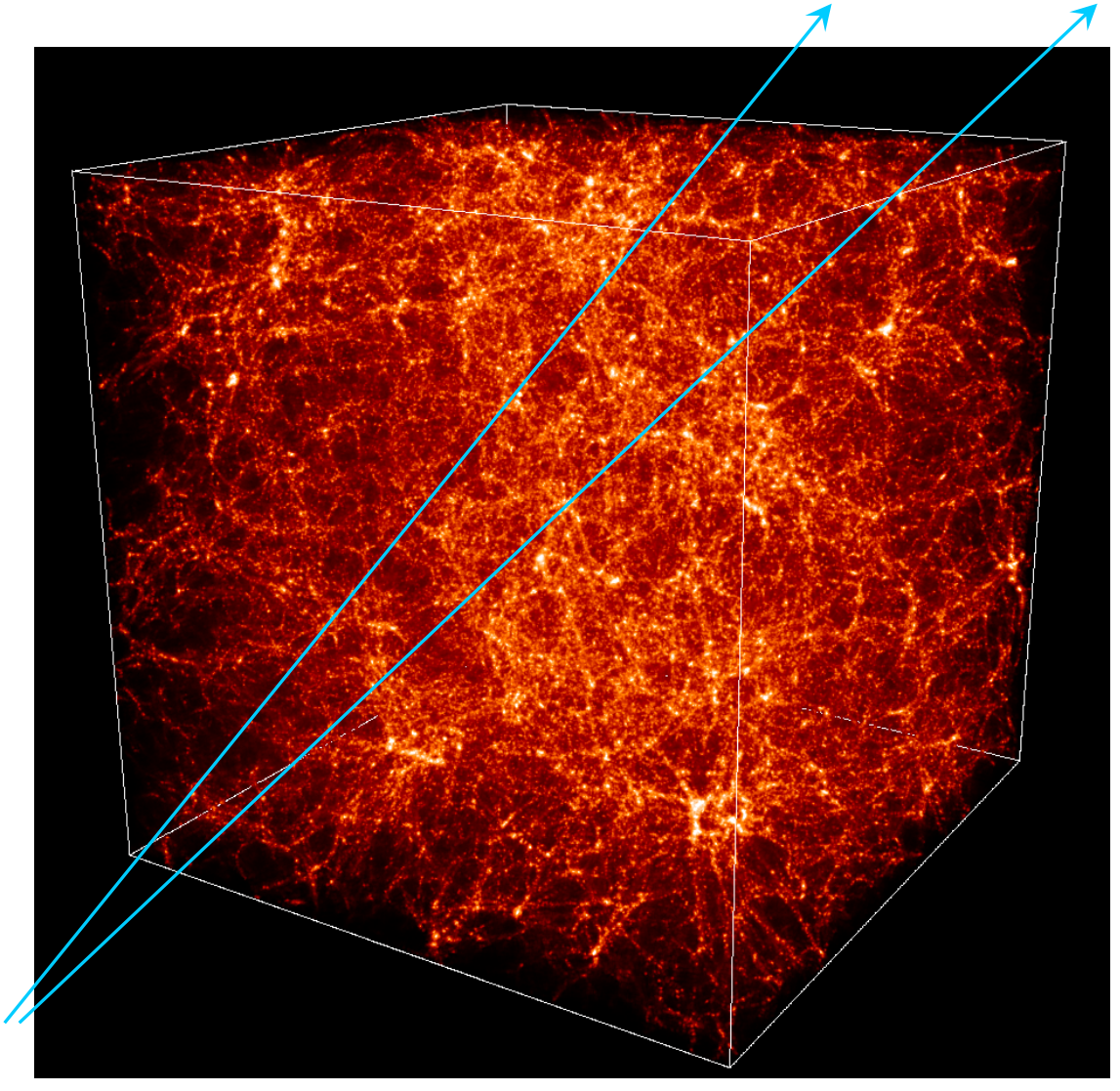
=> M_{halo} = 5x10^{11} M_{sun} and R_{bubble} = 2.5 Mpc Filling factor : ~10%





Scannapieco et al., 2005, astro-ph/0503001

The Third Dimension



- Where are the metals ?
- Expelled from the center of Halos -> Winds
- Along filaments
- What about the Voids ?
- The IGM

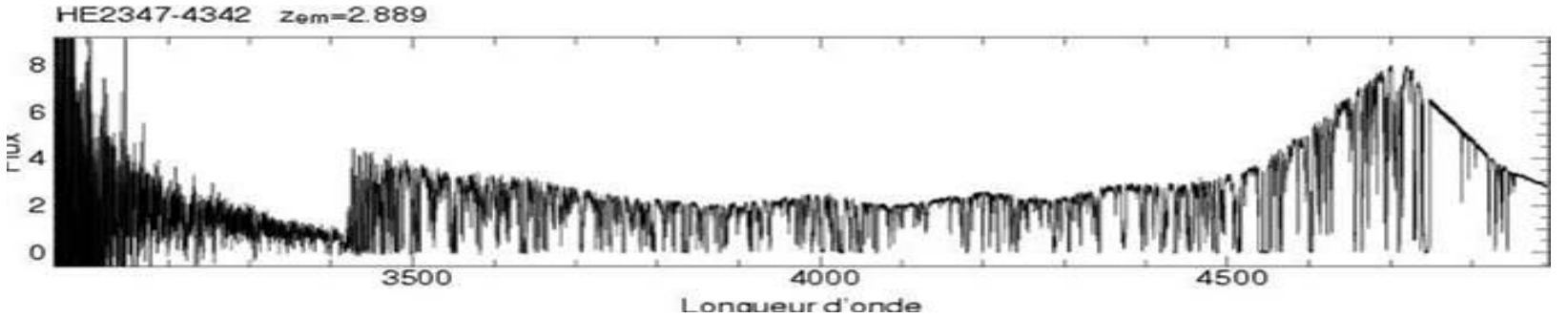
•Correlations

Along the los -> Big Sample

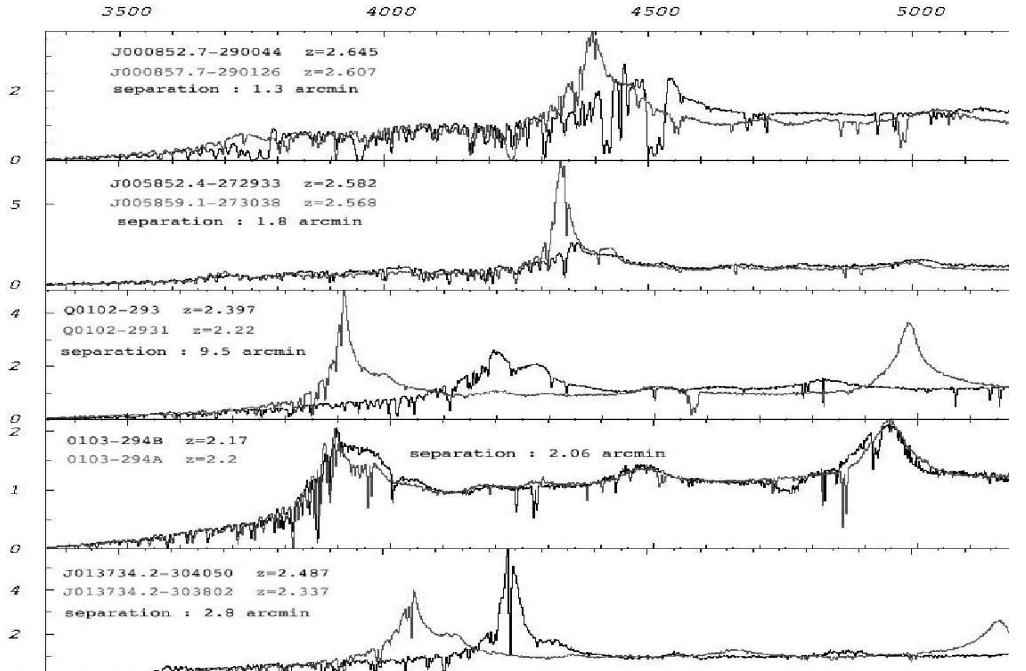
Transverse -> Pairs or groups

Transverse Correlation in the Lyman-α forest and the metals

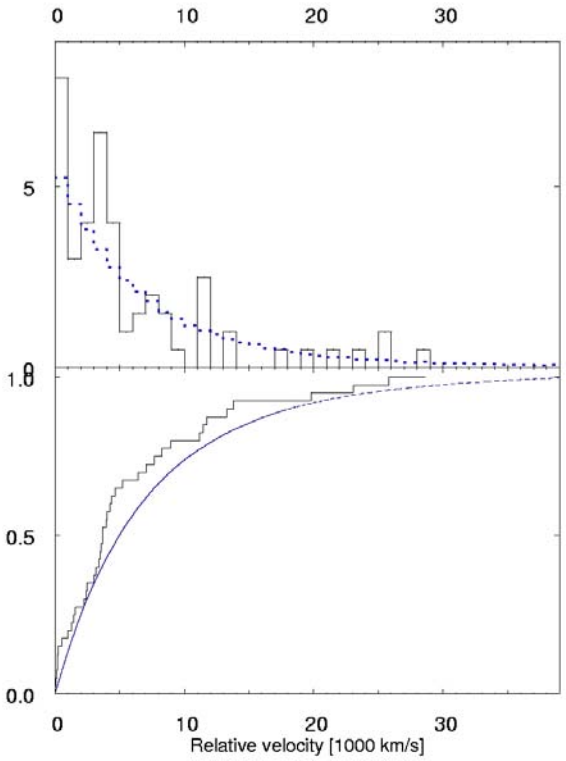
Longitudinal : Large Programme ESO : 20 LOS UVES R=45000 S/N=40-100



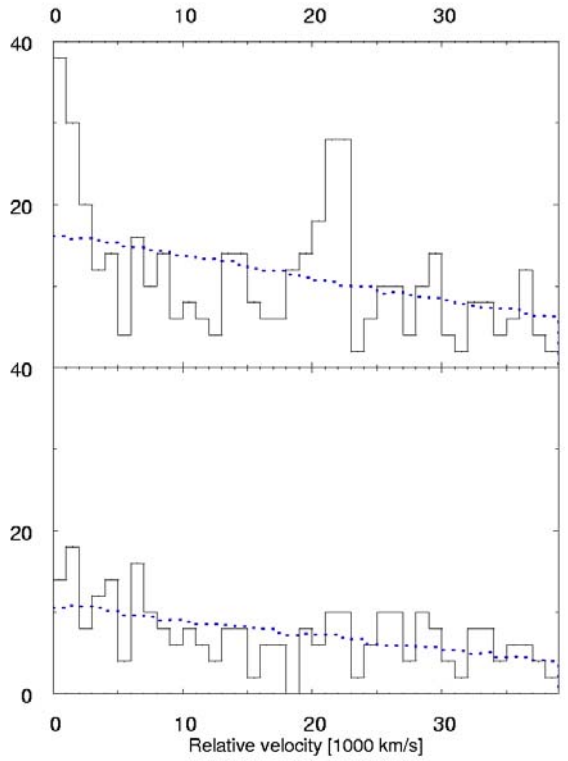
Transverse : 33 pairs 1-3 arcmin observed with FORS - z ~ 2.1



Correlation Functions for CIV



Transverse Correlation



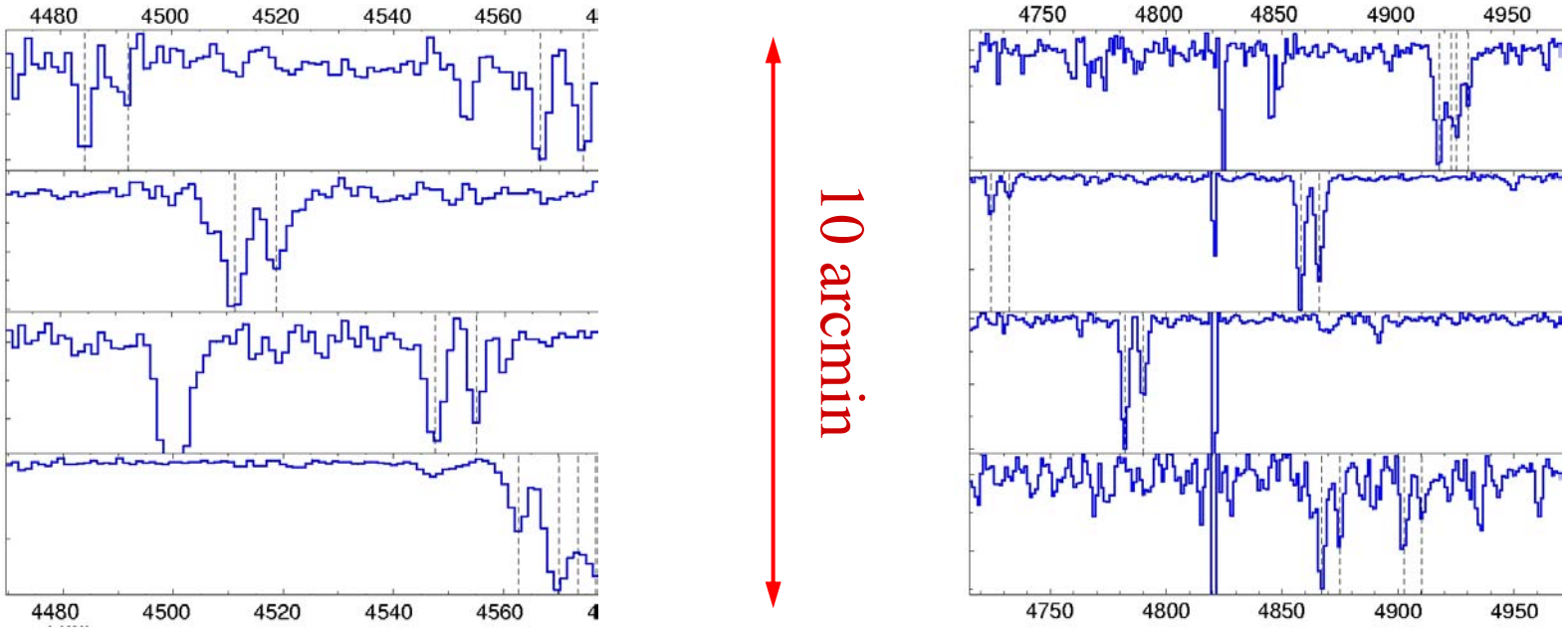
Longitudinal Correlation

All together

Without a quartet of QSO

Coppolani et al. 2005, subm

A quartet of QSOs within 10 arcmin

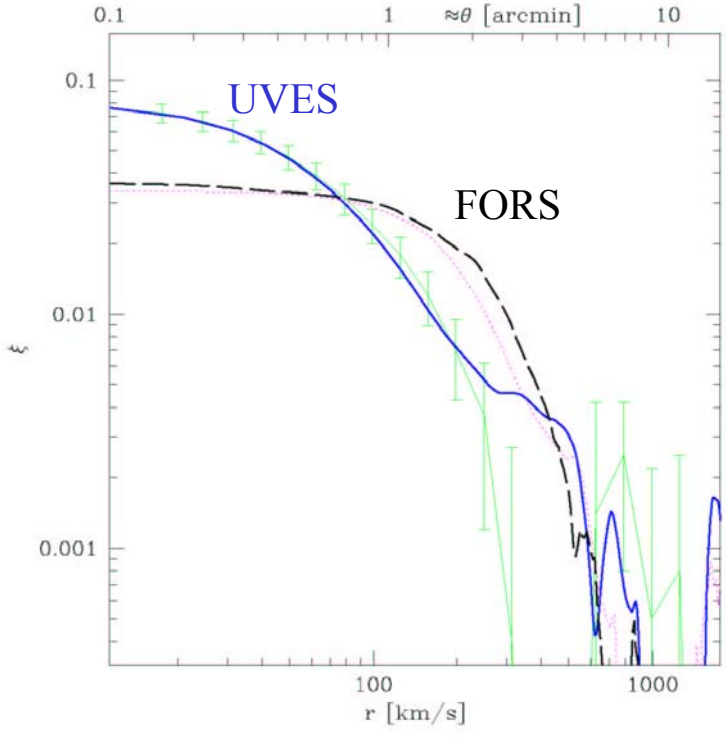


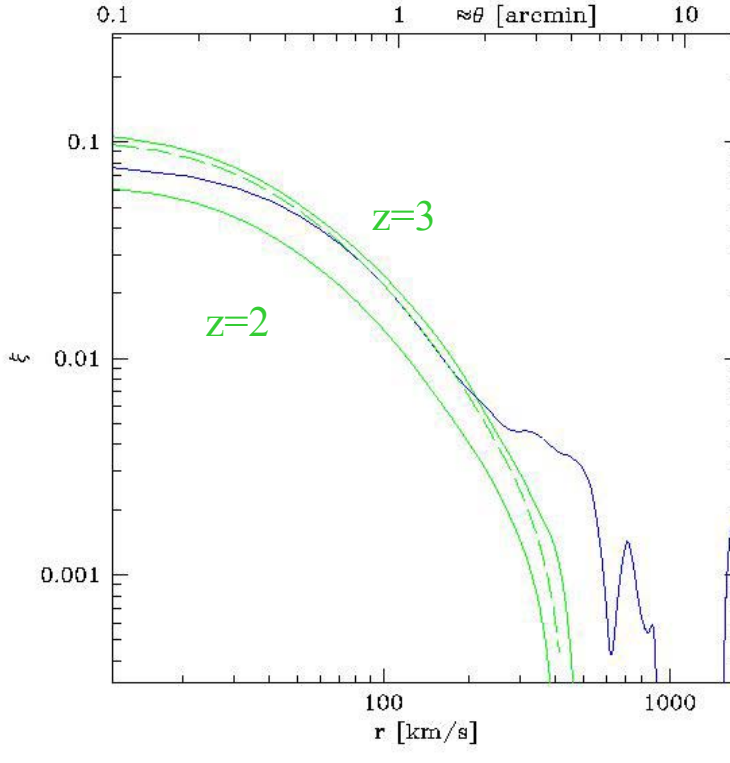
$1.5 < z < 2.2$

-> Tol 1037-27

Correlation in the Lyman-α Forest
Longitudinal correlation function

Observed versus Simulated correlation functions



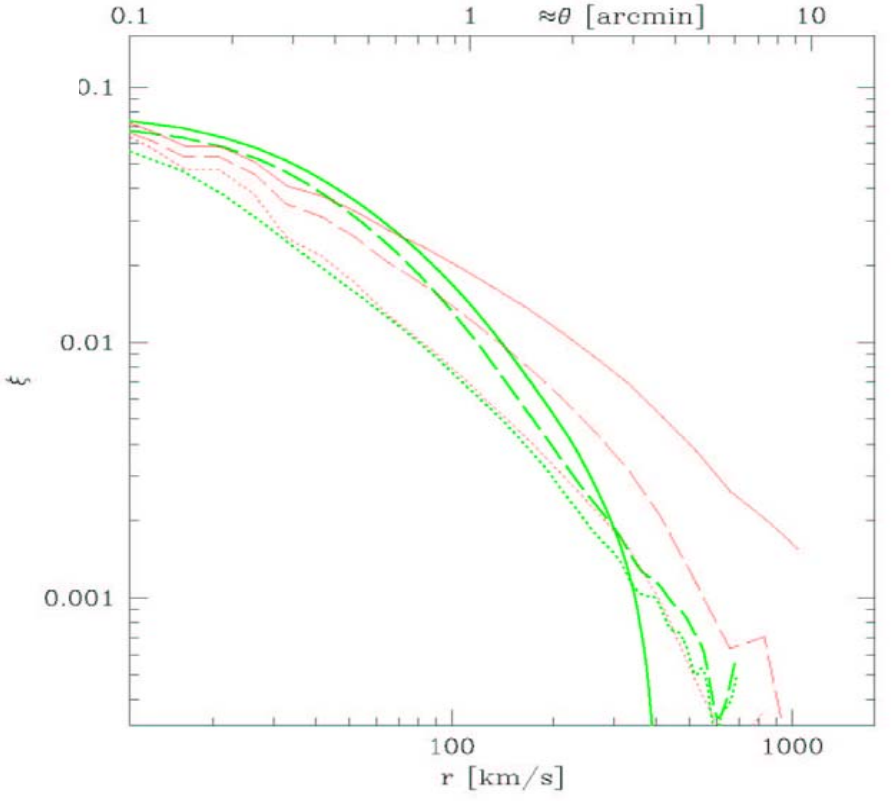


Simulated correlation functions

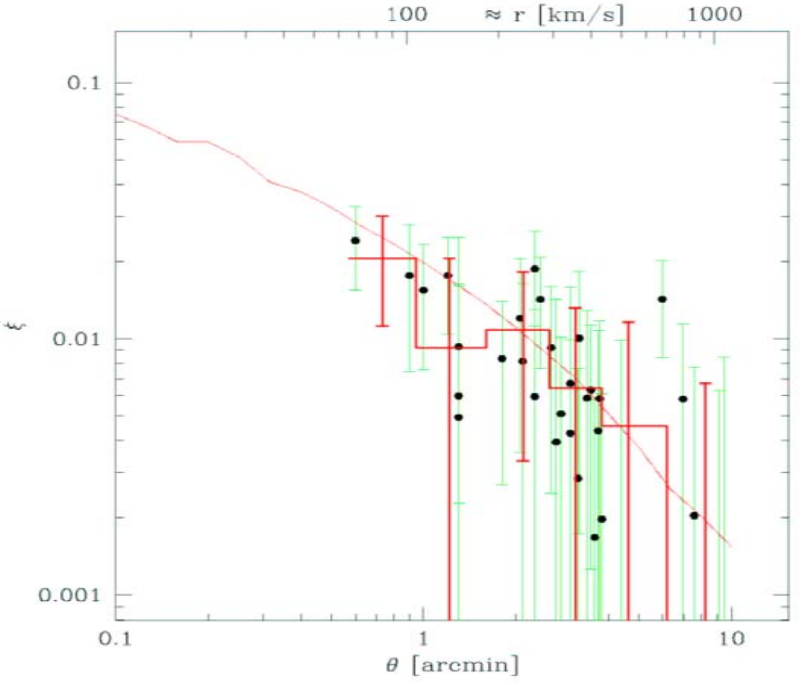
- Hydro simulations in a 100 Mpc simulation
- Effect of temperature and peculiar velocities on longitudinal and transverse correlation functions

Longitudinal

Transverse



Transverse correlation function
Alcock & Paczynski test



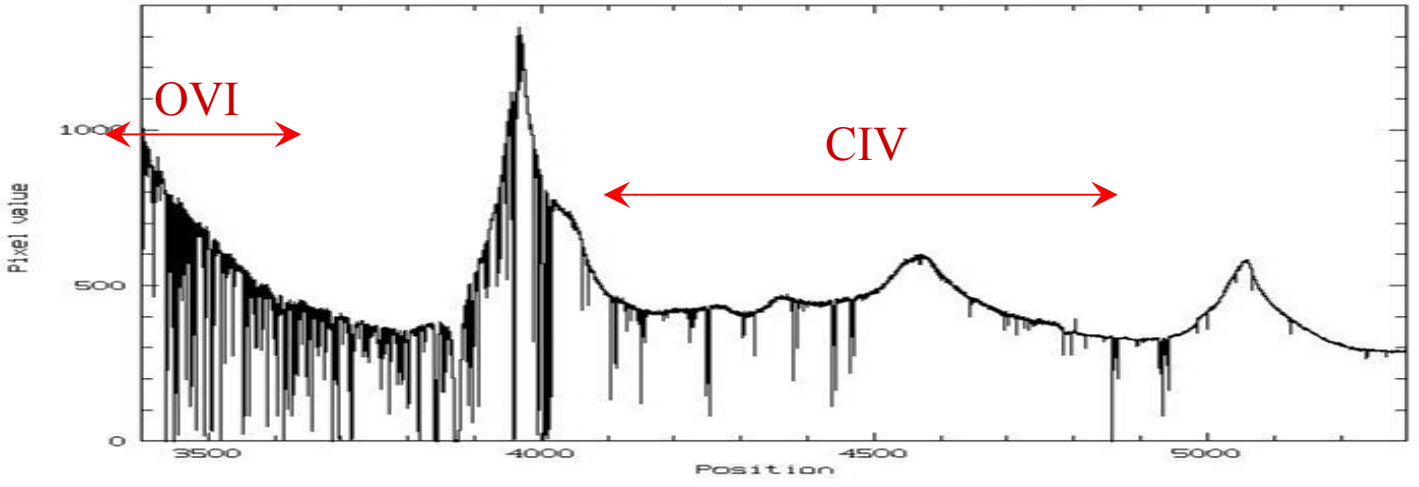
-> Sample should be increased to derive Ωλ

-> Very good prospect for further investigation

-> Groups of QSOs

Metals in Underdense Regions

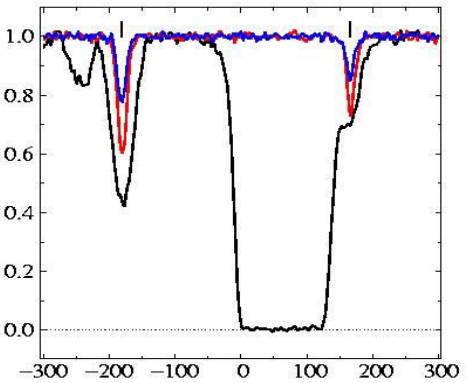
Large Programme ESO : R=45000 S/N>70 20 LOS



1. IGM is Very Inhomogeneous

2. Metallicity small : [C/H] < -2.5

Pixel analysis: <τ(CIV)> vs τ(HI)

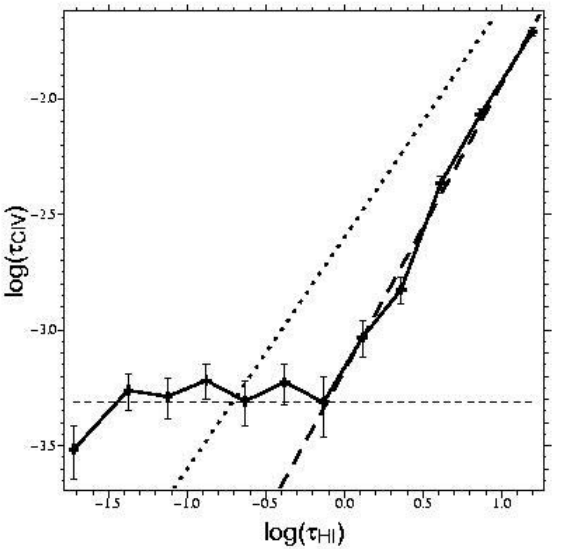


Aracil et al. 2004, A&A 419, 811

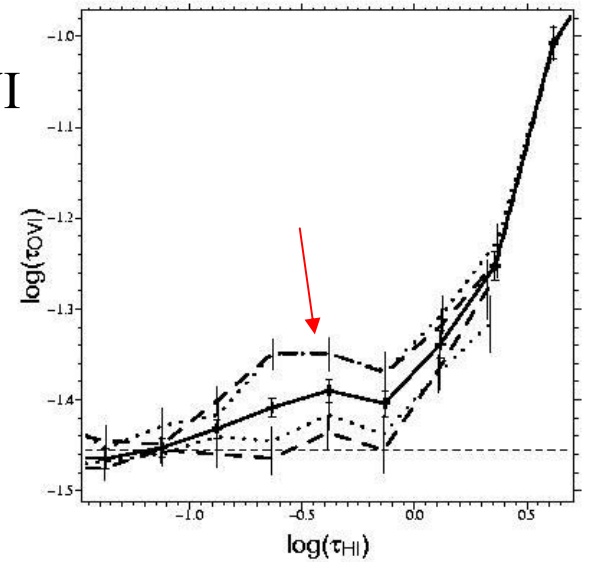
Metals in Underdense Regions

CIV and OVI are present for $\tau(HI)>1$

CIV



OVI



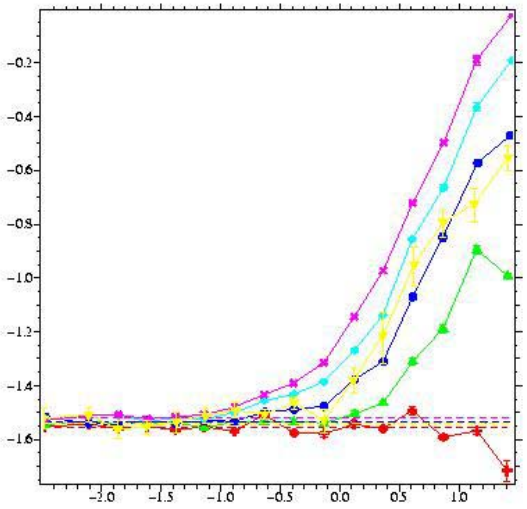
Log CIV/HI ~ -3 and log OVI/HI ~ -1.8 for $\tau(HI)>1$ or $\delta \sim 2$ for z=2.5

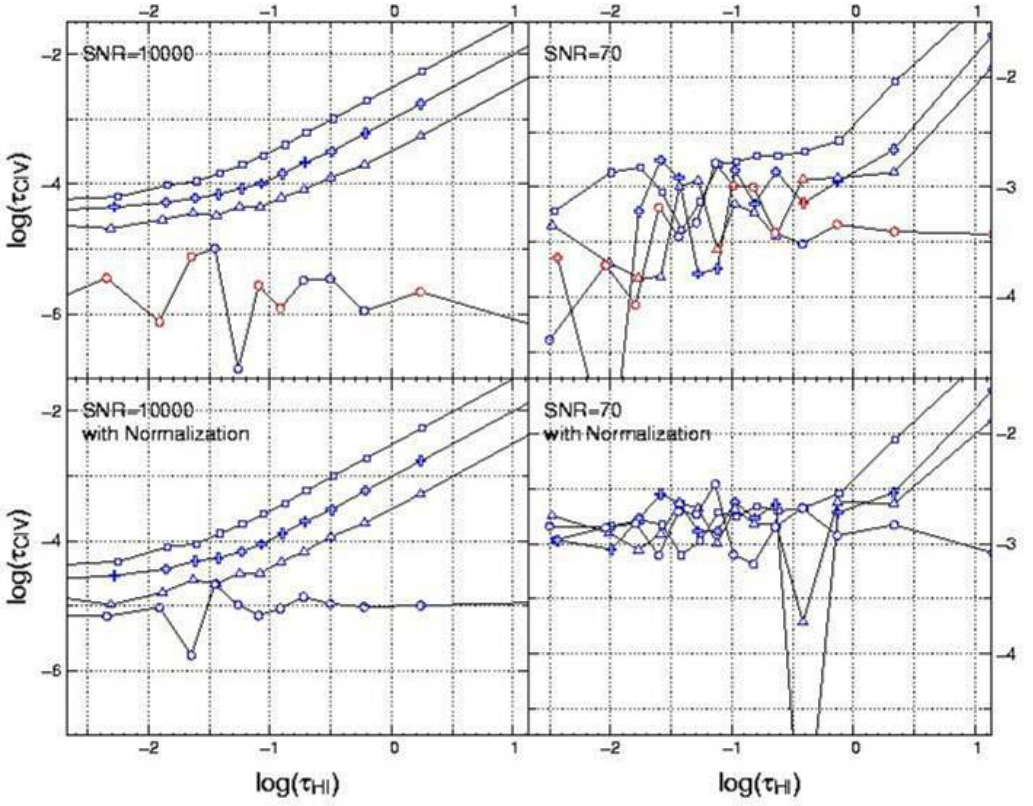
Excess of OVI in the vicinity of overdensities -> Winds ?

Simulations : [C/H]=-3 filling factor : 20% (Schaye & Aguirre)

Aracil et al. 2004, A&A, 419, 811

OVI in the IGM





Conclusions

Metals detected directly – CIV:

=> $M_{halo} = 5x10^{11} M_{sun}$ and $R_{bubble} = 2.5$ Mpc Filling factor : ~10%

There is SF in DLAs :

* H2 in 15% of DLAs
* Metallicity – Mass Relation => Metals come from the most massive objects
* Difficult to estimate the SFR (Lyα emission and CII*)
  Winds are not fast ?

Transverse Correlation:

* No signal in strong CIV at 2 arcmin and z=2
* Strong signal in the Lyα forest up to 5 armin

Metals in Underdense regions :

* CIV is present in at least 20% of the volume
* Excess of OVI within 300 km/s from overdensities -> Winds ?

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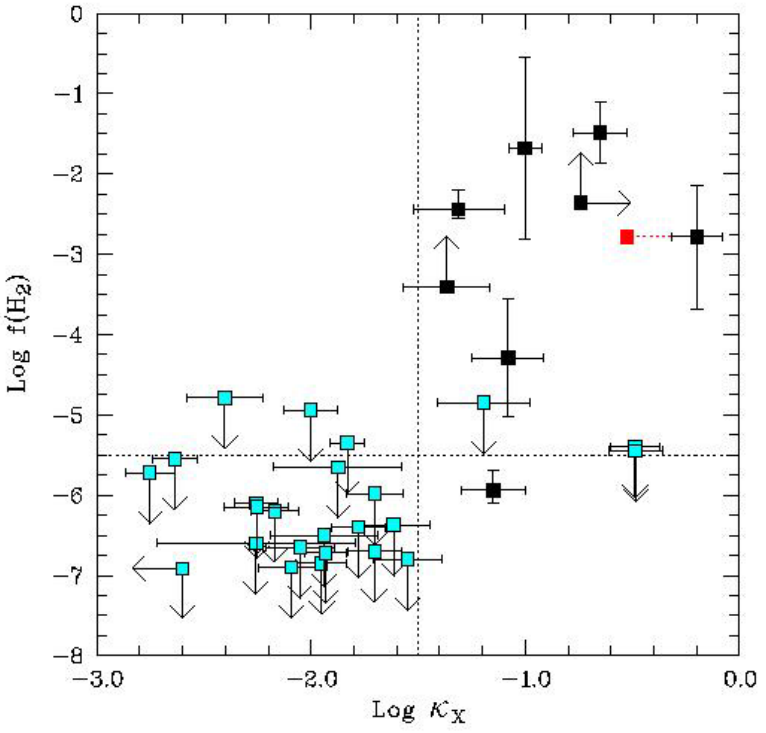
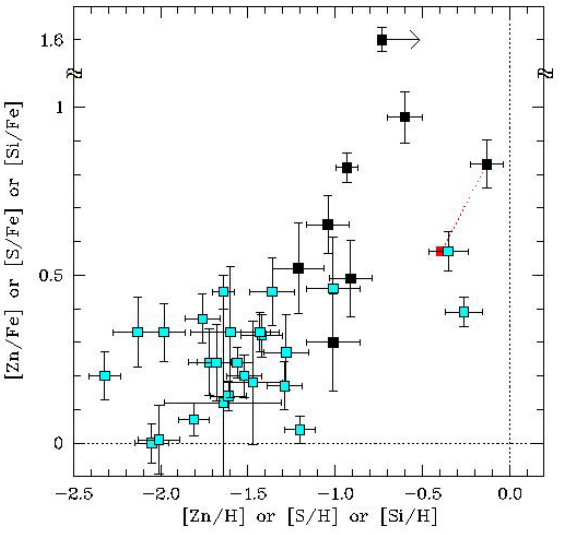
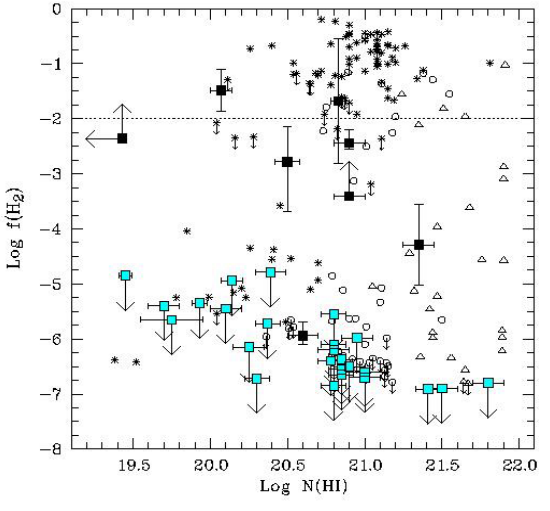
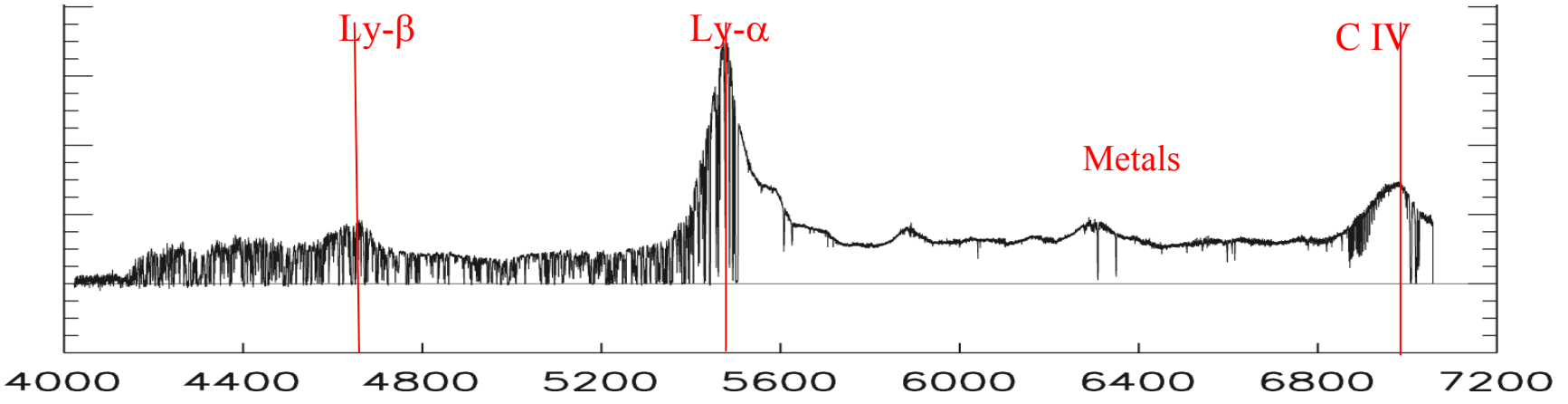
Molecular Hydrogen at High Redshift

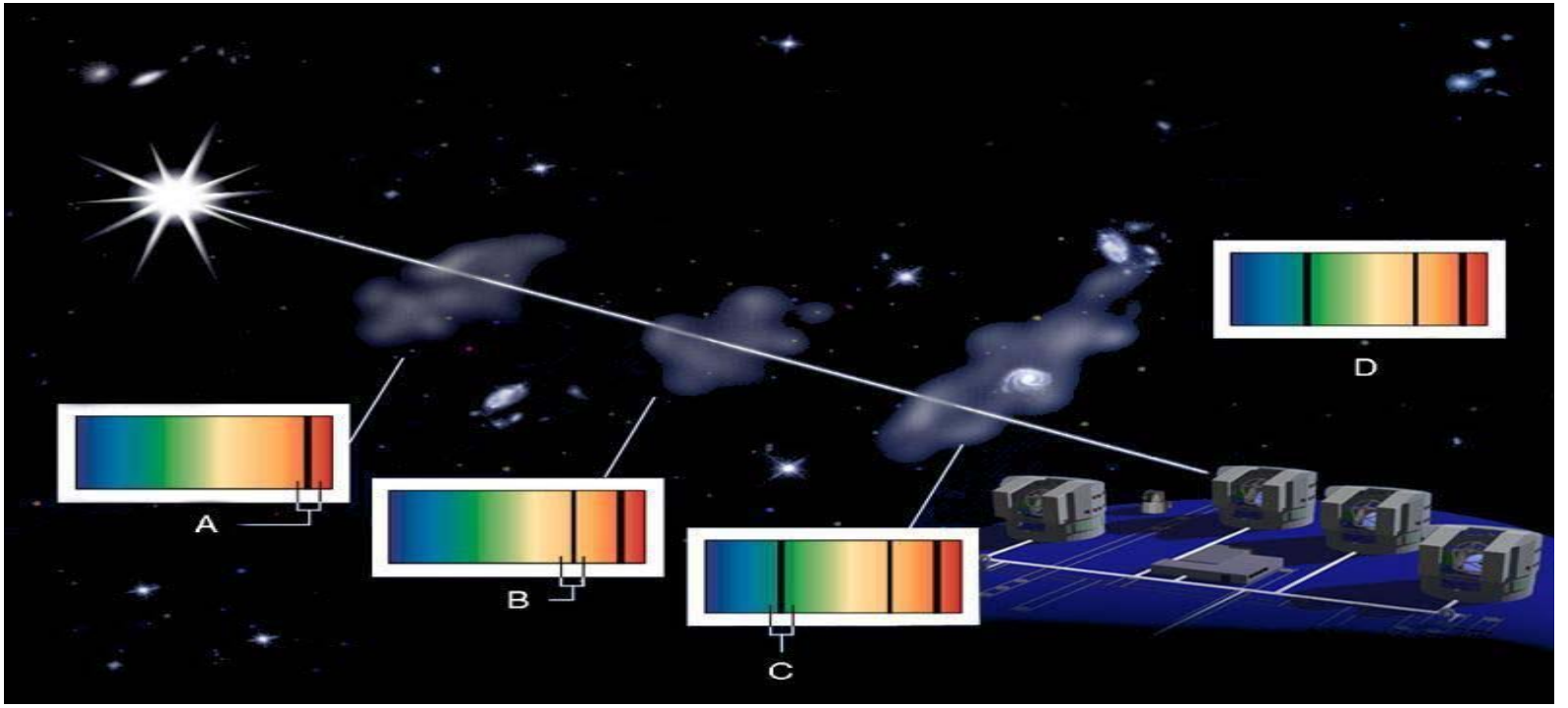






QSO Spectra


Ly-β
Ly-α
C IV
Metals
4000
4400
4800
5200
5600
6000
6400
6800
7200


A
B
C
D