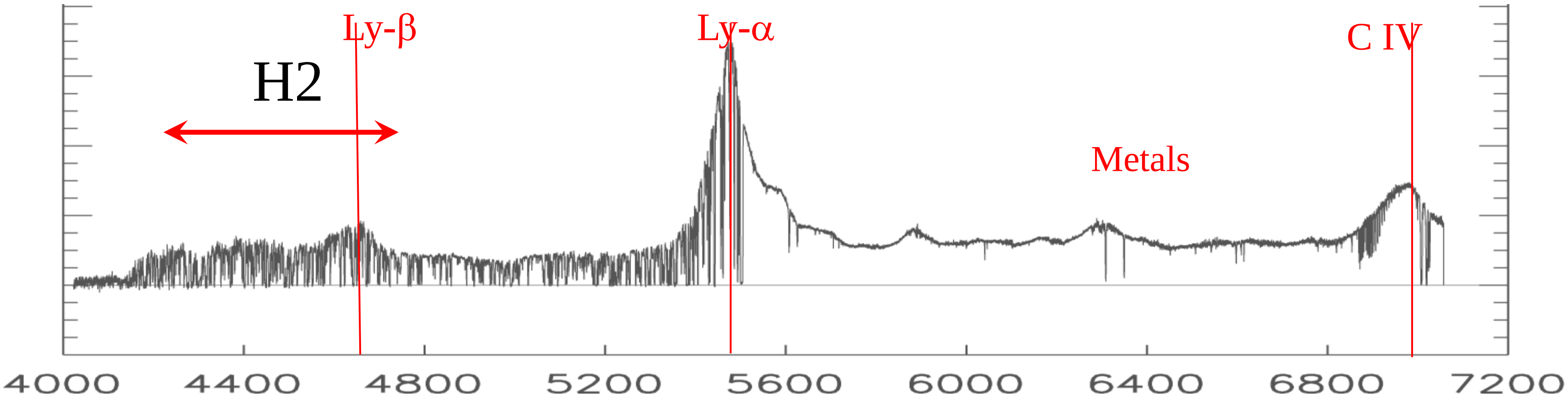
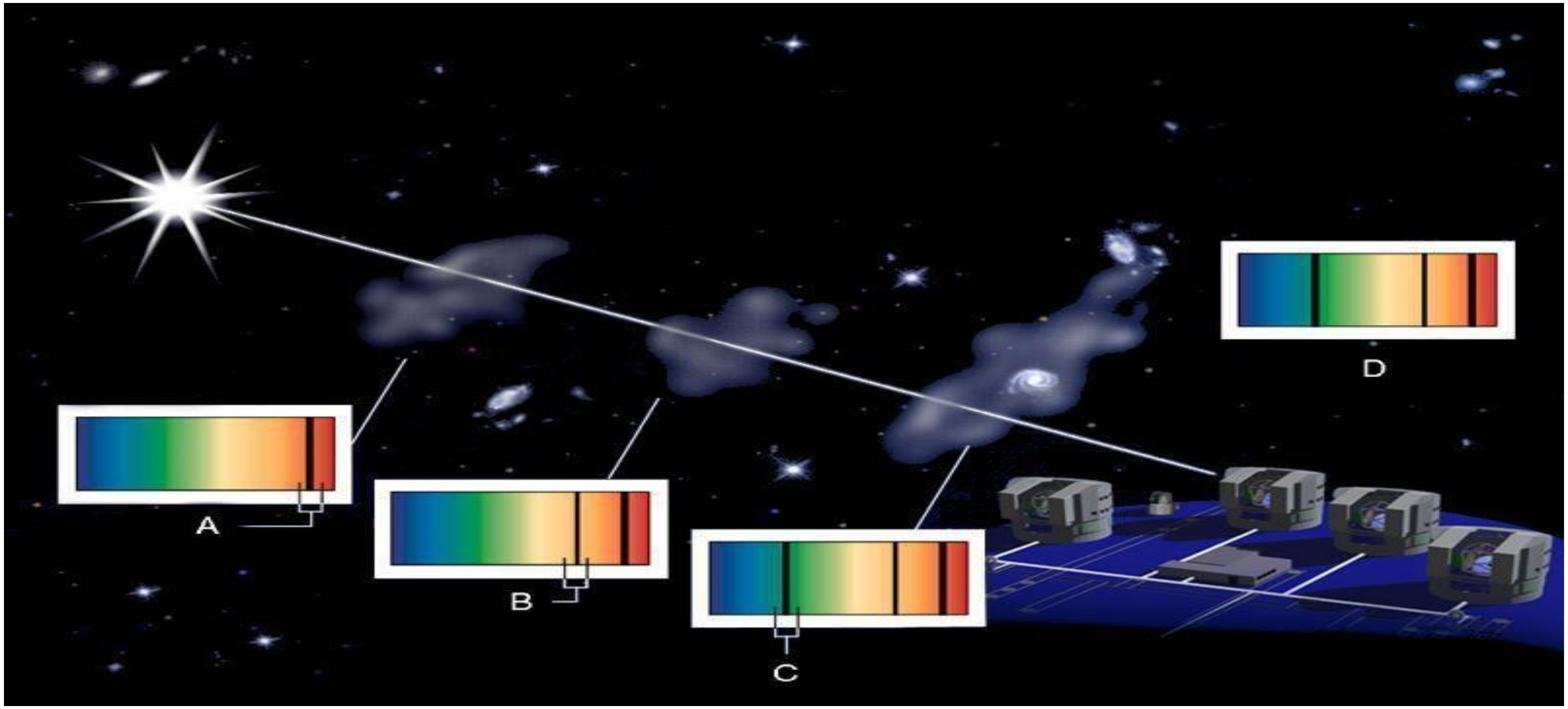
Quasar Absorption Lines -> Diffuse IGM and dense ISM

ESO Blues…





The Universe through absorption lines

Intervening Objects:

The IGM

The ISM of high redshift galaxies

The interplay between galaxies and the IGM

Large scale structures traced by the gas

At the two ends:

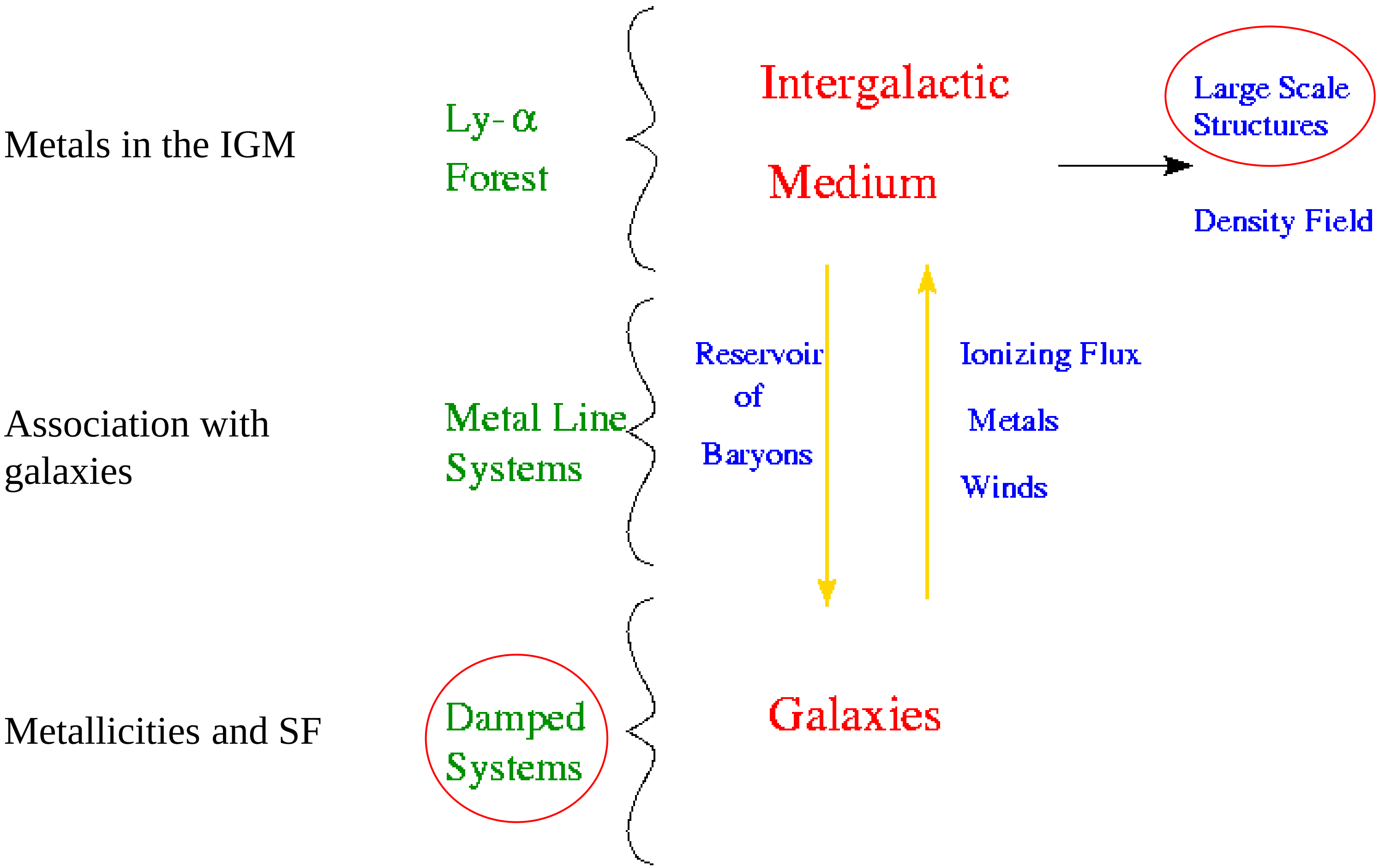
The local universe

Winds from quasars

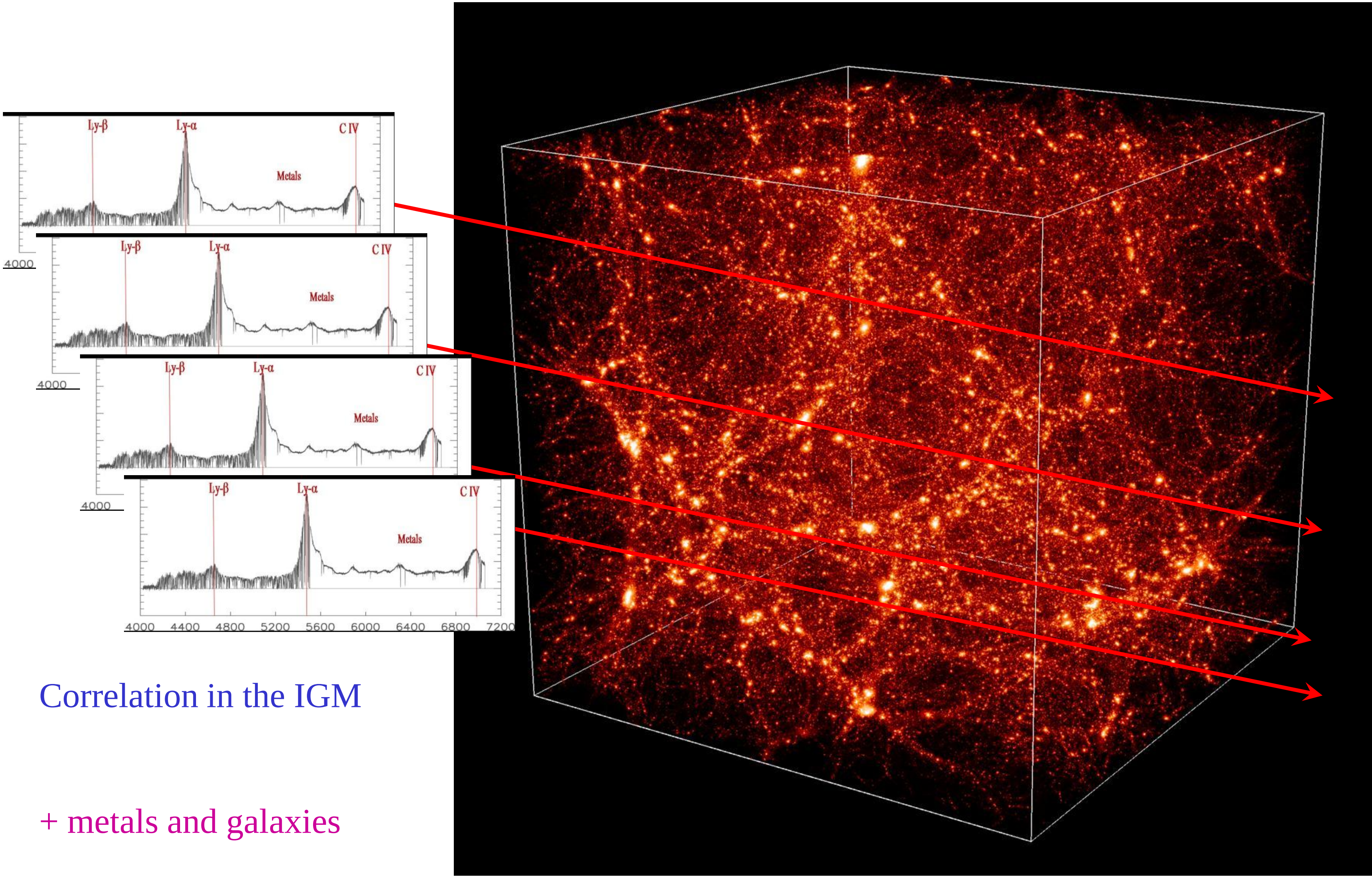
Patrick Petitjean

Institut d'Astrophysique de Paris

QSO (GRBs ?) Absorption Lines



Simulations



Correlation in the IGM

+ metals and galaxies

Fifty years of history

1962: Spectroscopy of the first quasar ; Schmidt, ApJL136, 684

1963: Identification of the redshift, Schmidt and Greenstein & Matthews

1965: Bahcall & Salpeter predict Absorption lines if redshifts are cosmological

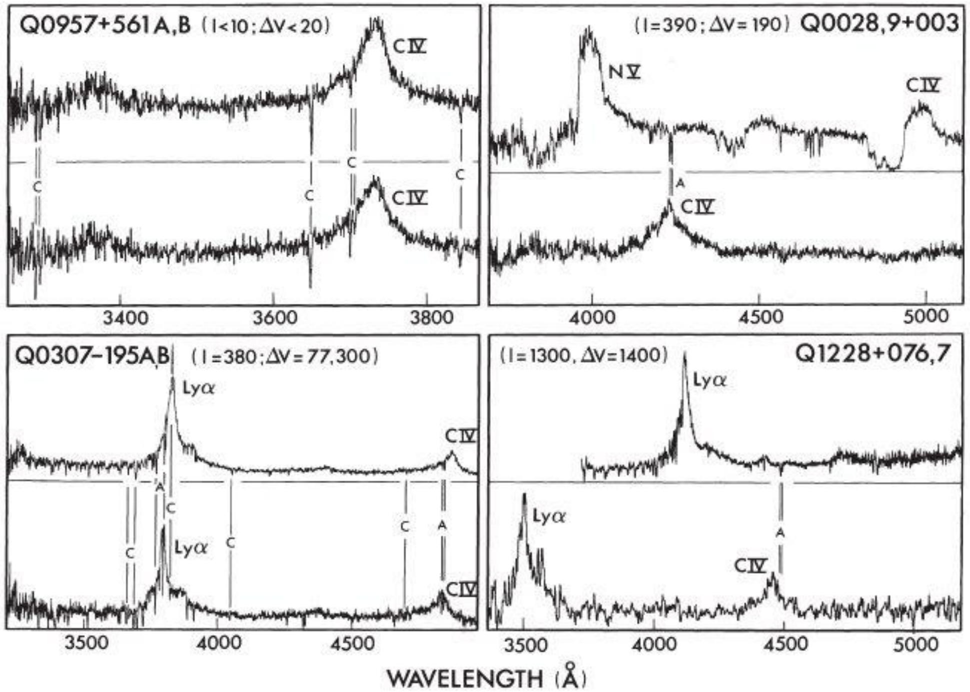
1966: First detection of absorption lines in a QSO spectrum

Gamov, G. Nature, 216,461 (1967) -> Due to intervening galaxies

Burbidge, G+M, Nature, 216, 1092, (1967) -> Associated to the quasar

Twenty years will be needed to definitely settle the problem

QSOAL studies at ESO : an answer



Shaver & Robertson 1983
Messenger 31, 28
IPCS on the 3.6m Telescope

Foreground quasar defined with the associated absorption has a smaller redshift

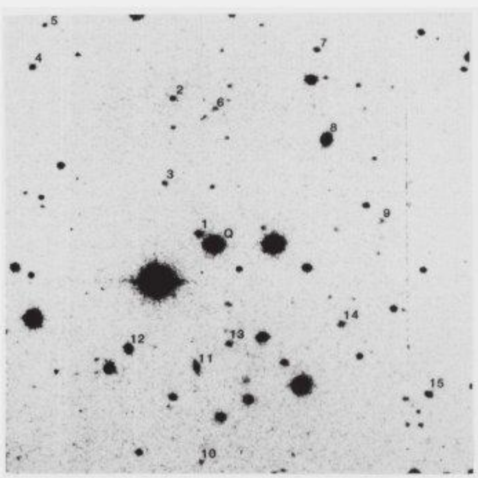


Fig.1. V image of a 216 x 240arcsec^2 field centred on the QSO PKS2128-12. North-east is at the top left corner. The QSO and detected resolved objects are labelled as in Table 1. The spatial resolution is FWHM = 1.6arcsec

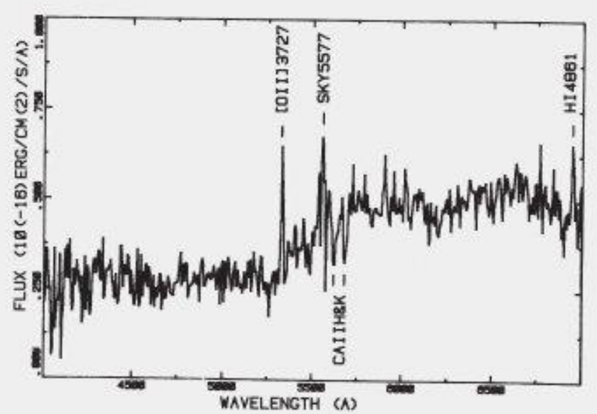
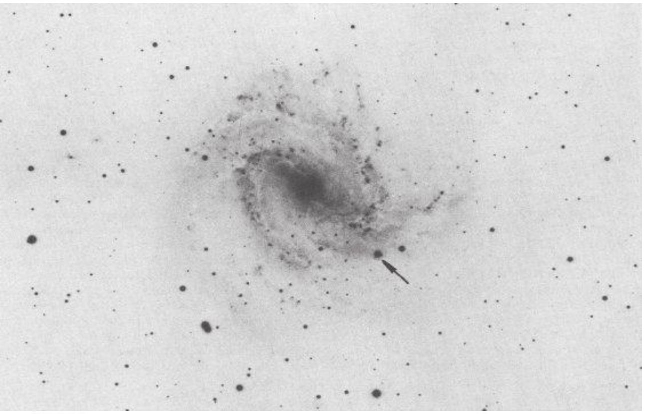


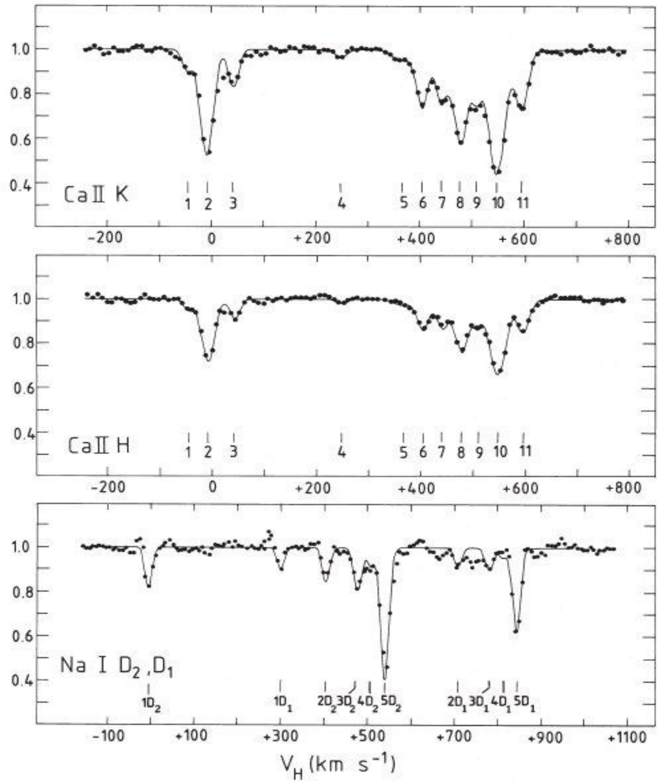
Fig.3. Spectrum of galaxy # 1. It is the sum of two spectra, each of one hour exposure. The spectral resolution is FWHM = 14A. Emission and absorption lines are indicated

Bergeron 1986
A&A, 155, L8
EFOSC on the 3.6m Tel

Direct detection of a galaxy associated with a MgII system at z=0.4299

CASPEC at the 3.6mTelescope and EMMI at the NTT





ISM in M83 from SN1983

D’Odorico et al. (1986)

The Gunn-Peterson effect

Giallong o et al. (1994)

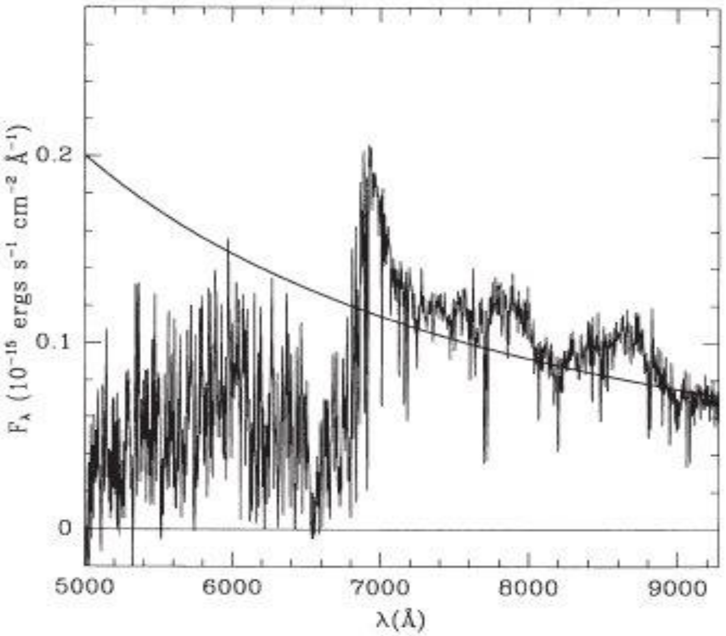


FIG. 1.—Absolute flux distribution of BR 1202−0725 smoothed to FWHM ∼6 Å. The data have not been corrected for slit losses. They are estimated at 20% from the observations of the standard stars. The fitted power-law continuum is also shown. The region between 7600 and 7680 Å has been corrected for atmospheric absorption.

UVES 2000

-> LP « Cosmic Evolution of the IGM » PI: J. Bergeron
Best data on 21 QSOs at $z<3$ available to the community over the past ten years (SNR=40-80 at $R>45{,}000$)

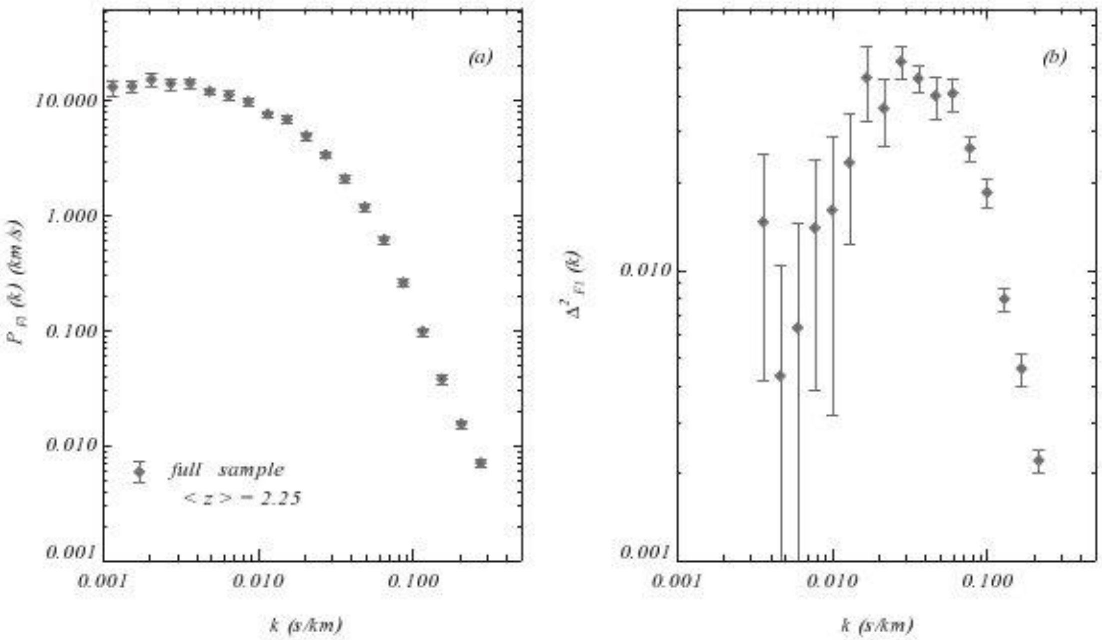
-> Metals in the IGM

-> The ISM of high redshift galaxies : studies of DLAs

-> Broad Absorption lines in quasars

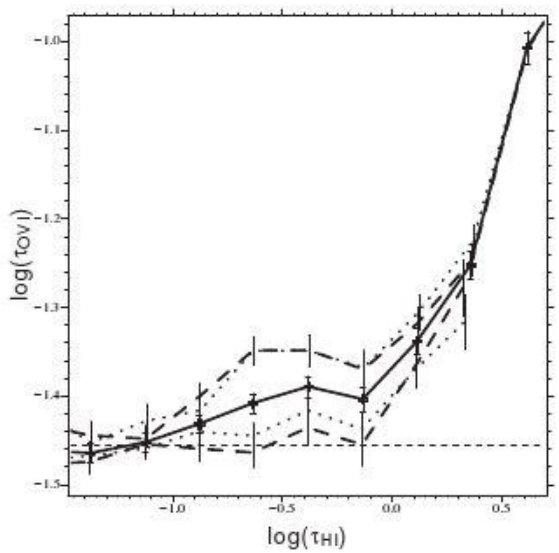
-> Constraints on the variations of fundamental constants (LP PI: P. Molaro) -> M. Murphy talk

IGM



Flux power spectrum ->
Density power spectrum

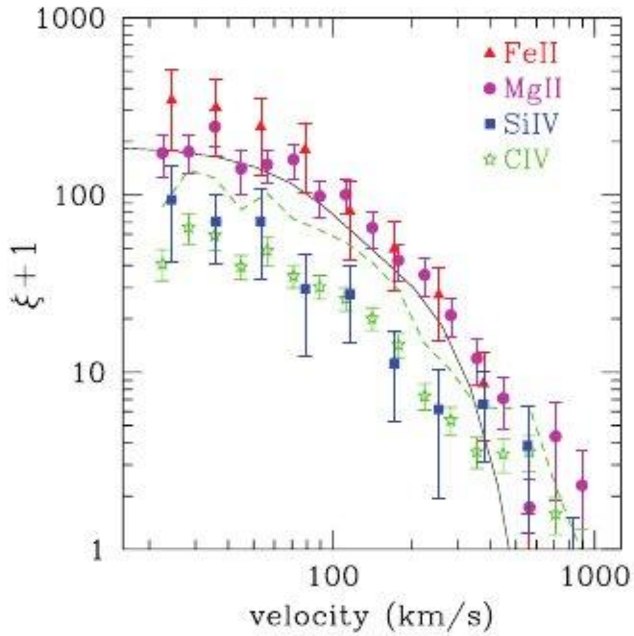
Kim et al. (2003)
Large set of data of very good quality
-> S. Cristiani talk

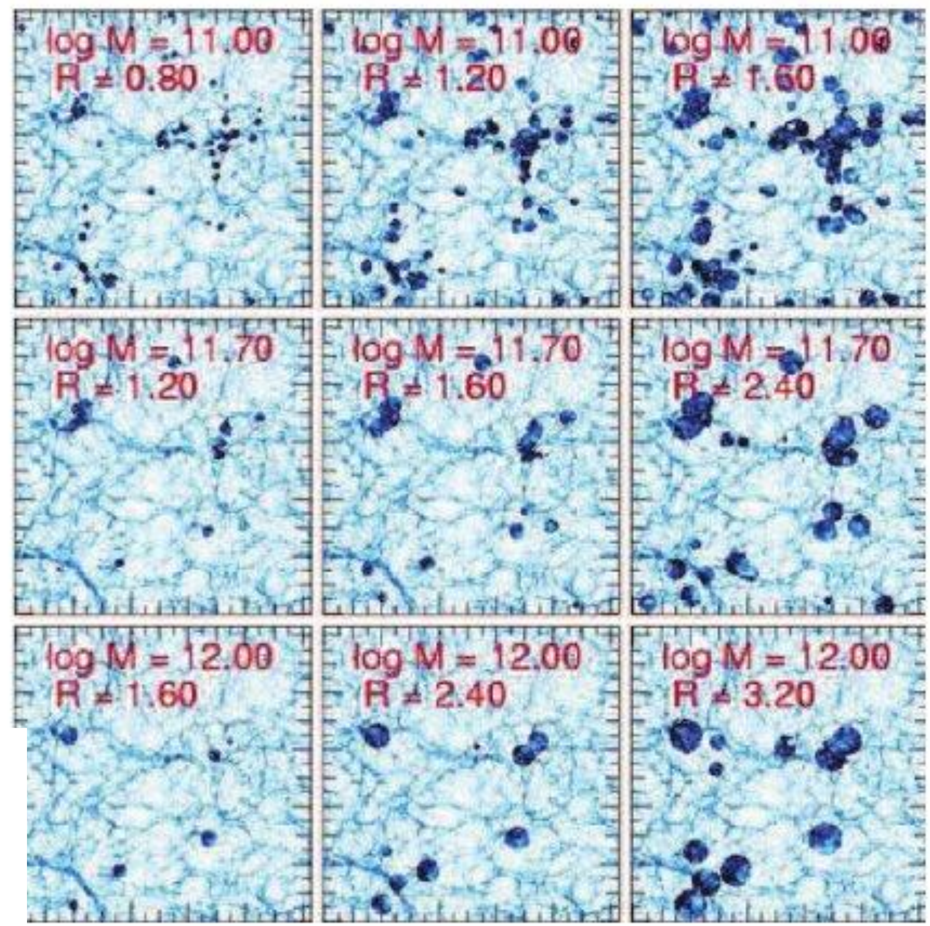


Metals in the IGM (20% of the volume)
Stacking pixels

Aracil et al. (2004)
The blue

Spatial distribution of metals



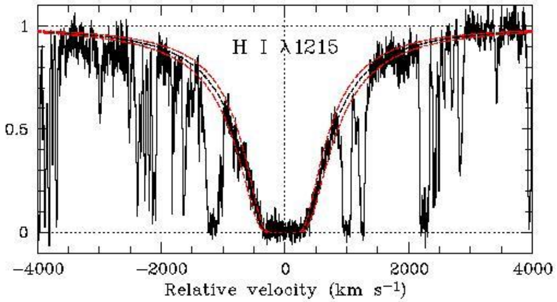


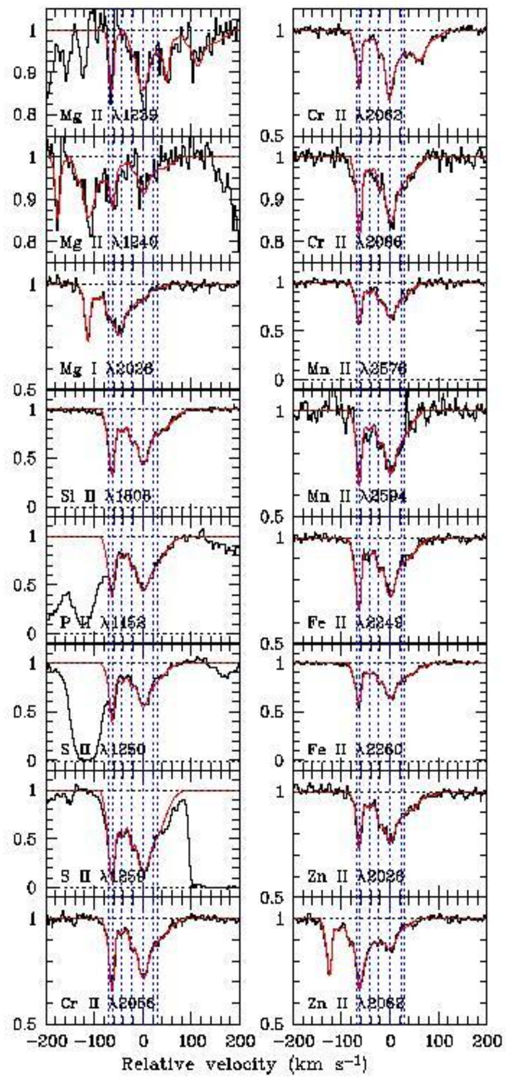
Comparison of the spatial distribution of metals in simulations and the correlation function in the data
-> Massive halos (same for DLAs)

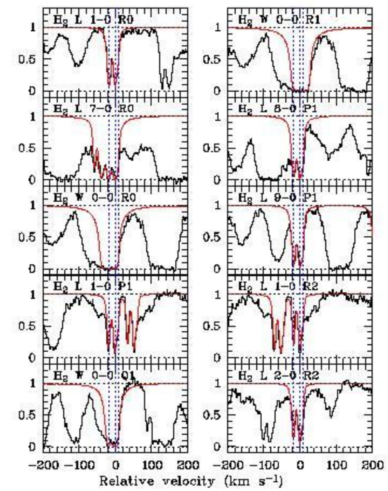
Scannapieco et al. (2006)

Damped Ly-α Systems: The ISM of high-z galaxies

HI :







Metals :

-> Metallicities

-> Dust content

-> Kinematics

Star- Formation ?

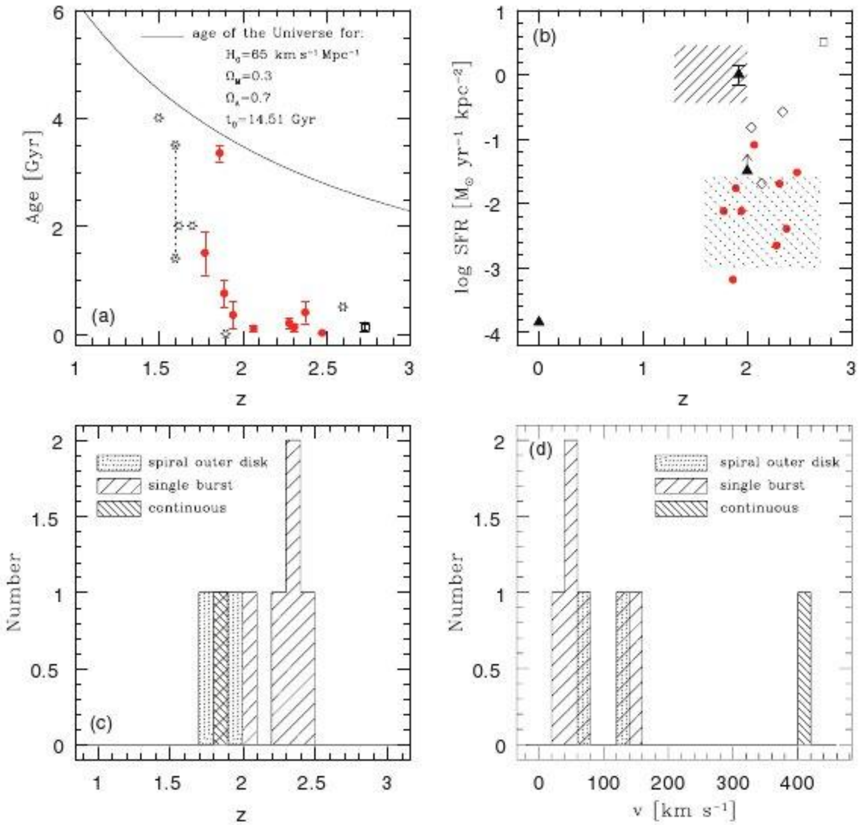
Winds ?

Molecules H2 + CI, CI* :

-> Density/Temperature

-> UV flux (excitation)

Chemical evolution



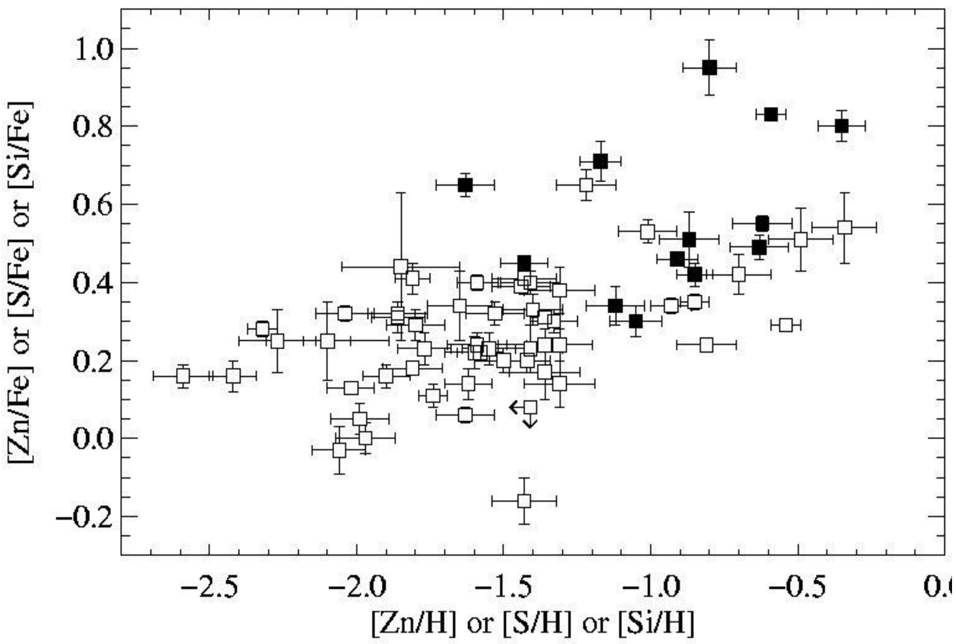
Analytical Models of chemical evolution

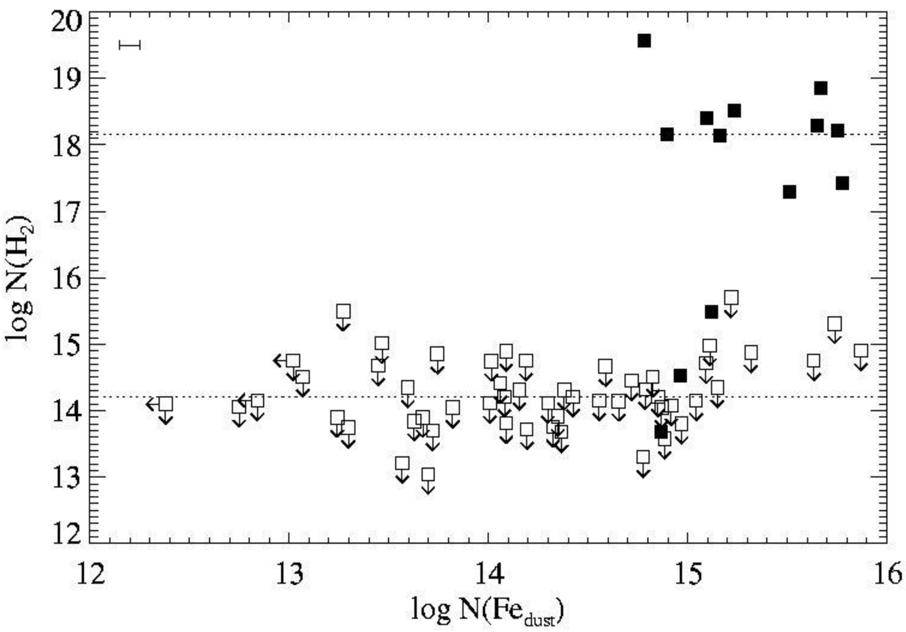
Dessauges-Zavadsky et al. (2007)

Exact nature is still unclear

Molecules: Cold gas with small covering factor
ESO survey for H2 : < 10% =>most DLAs are warm

Presence of dust



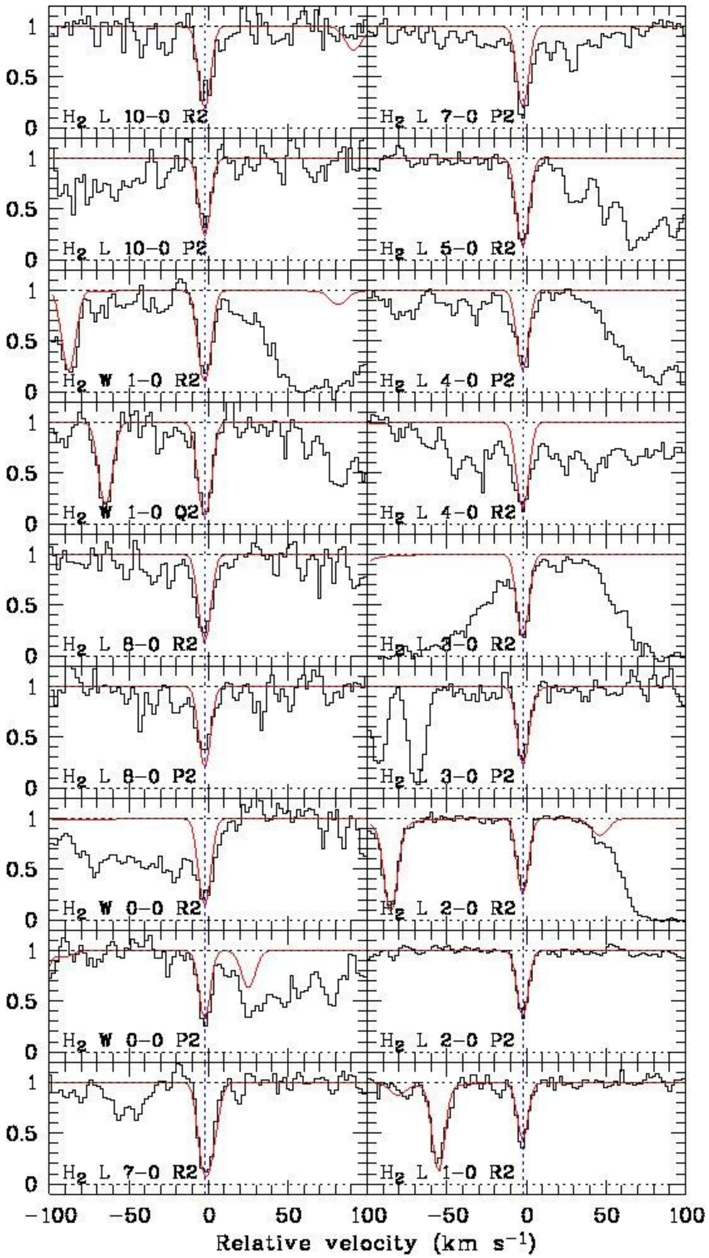


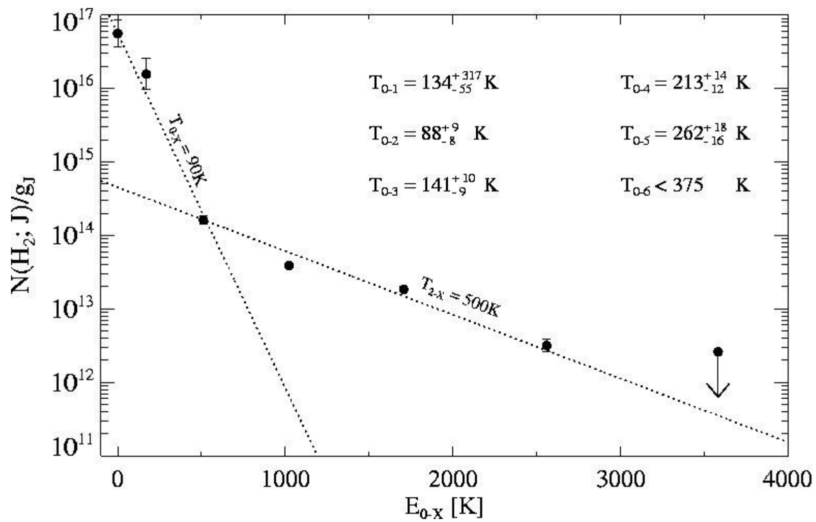
- Correlation Depletion ([Zn/Fe]) vs Metallicity ([Zn/H])

- Presence of H2 related to the dust column density

(Ledoux et al. 2003, 2006, 2012)

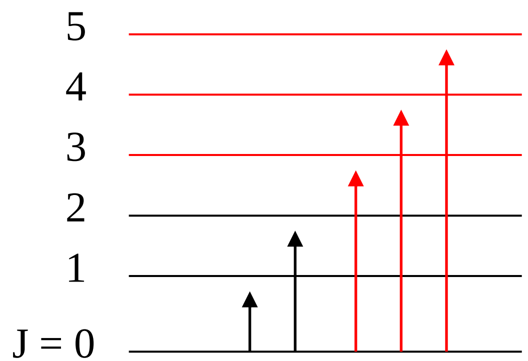
Heating processes: Molecular excitation





Two temperatures

No velocity shift



Fluorescence -> UV flux

Collisions -> Tk, density

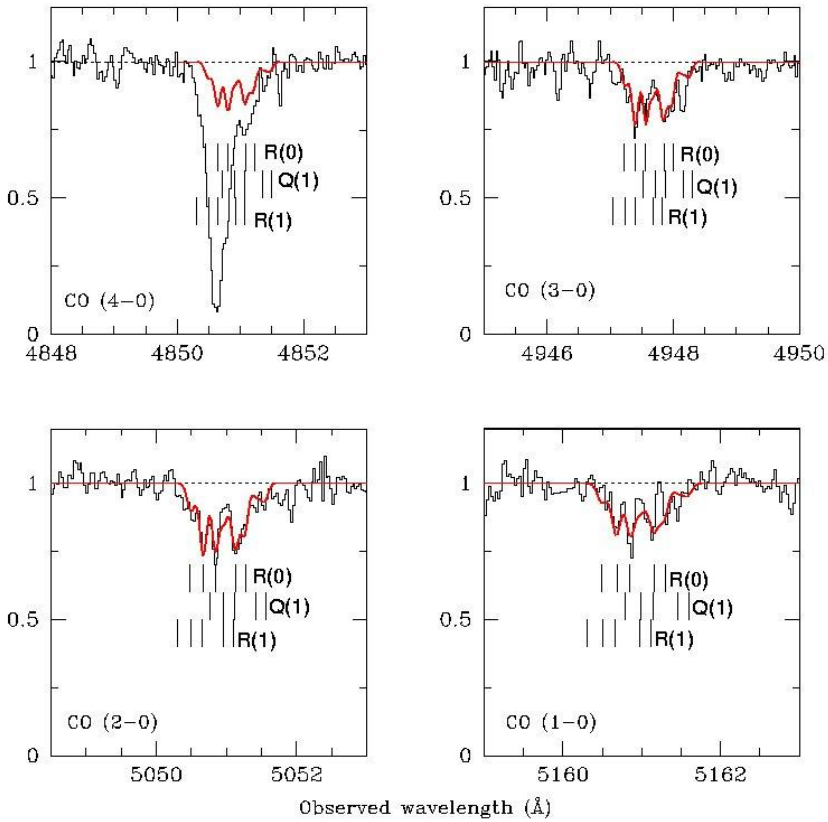
CI+ CI*

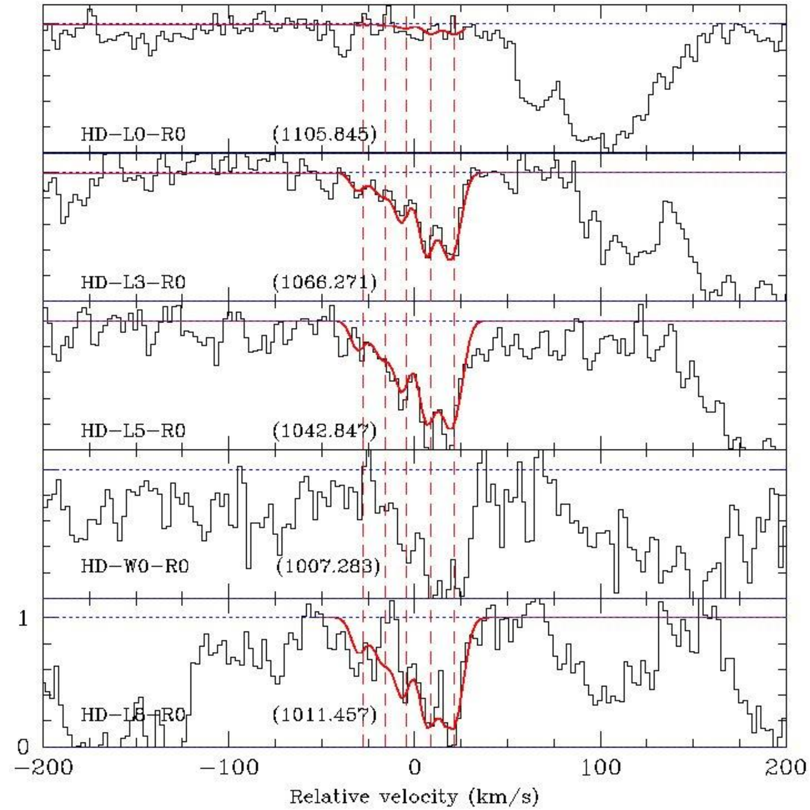
Doppler parameter increases with J

n_H=30-100 cm^{-3} (3-10pc)   T=70-150 K

UV flux 10xGal

CO and HD





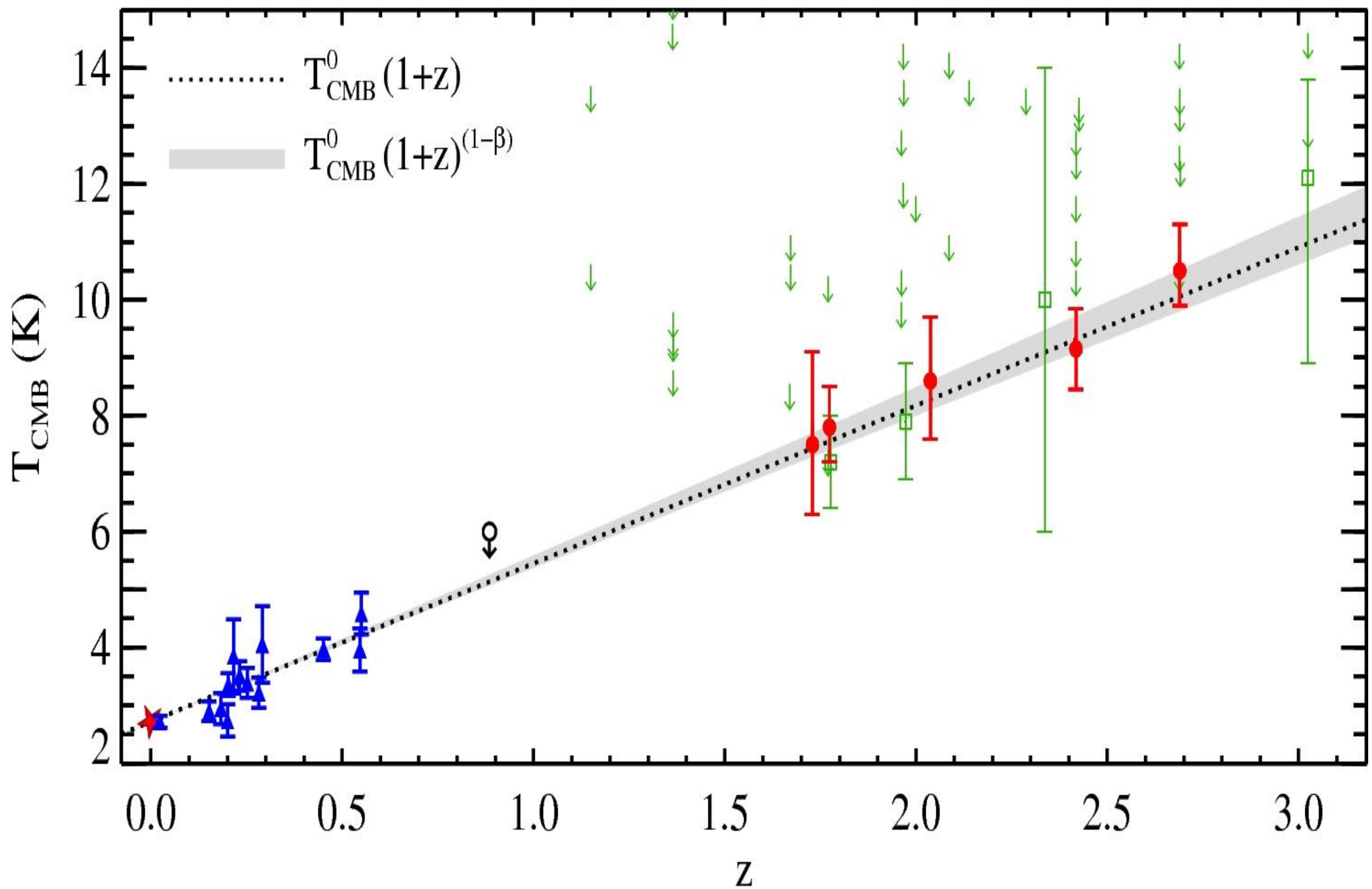
First detection of CO (elusive for 25 years) : Object selected amongst 10 000 QSOs

=> HD/2H2 = > The galaxy is formed with strong accretion of gas

HD/2H2 = 2.1x10-5 Log(f) = -0.3 (highest in DLAs) ; CO/H2 = 3x10-6

Srianand et al. (2008) A&A, 482, L39 - Noterdaeme et al. (2008) A&A, 491, 397

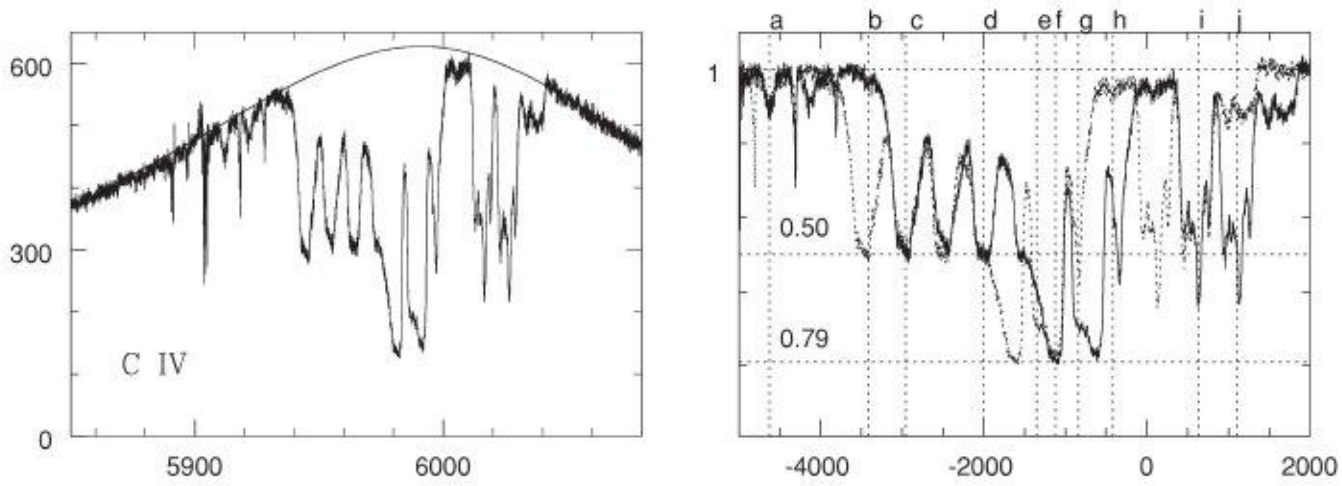
Excitation of CO: Redshift evolution of T_{CMB}



$\beta = 0.007 \pm 0.027$ (we've tried…)

Broad Absorption Lines – Quasar winds

Small scale to large scales ?



Organised flow : small covering factor and line locking

Clouds are small and flow is radiatively driven

-> Variability

Srianand et al. (2002)

New claims for variations of constants

Webb et al., 2010, astroph/1008.3907
2011, PRL 107.191101

UVES data : All data: no significant variation

$z < 1.8$ $-0.06 \pm 0.16 \times 10^{-5}$

$z \sim 1.5$ $0.01 \pm 0.15 \times 10^{-5}$ Srianand et al., 2007, PRL, 99, 239002

The two groups agree

$z > 1.8$ $+0.61 \pm 0.20 \times 10^{-5}$ 3σ

+ Keck $-0.74 \pm 0.17 \times 10^{-5}$ 4σ

Spatial Variations ?

-> M. Murphy Talk

The Future: The questions

-IGM : Derive the power spectrum better (simulations)
Metals at lower tauHI

-IGM : The acceleration of the universe from the Lya forest

- IGM : Correlations in pairs (or groups) of quasars
(A. Smette et al. 1995)

- ISM : Physical conditions vs Z (need to go fainter at HR)

- Galaxy – IGM interactions <- <- <-

-Broad Absorption Lines and the AGN properties
Variability and covering factors (several cases from H2)

The Future: The instruments

-> Xshooter :

LP for 100 los at z>3 PI: S. Lopez : IGM properties and zQSO

Legacy value

-> CUBES : Keep the blue with very high throughput

R=10,000-20,000

-> Espresso : Very high resolution and precision but fixed set-up

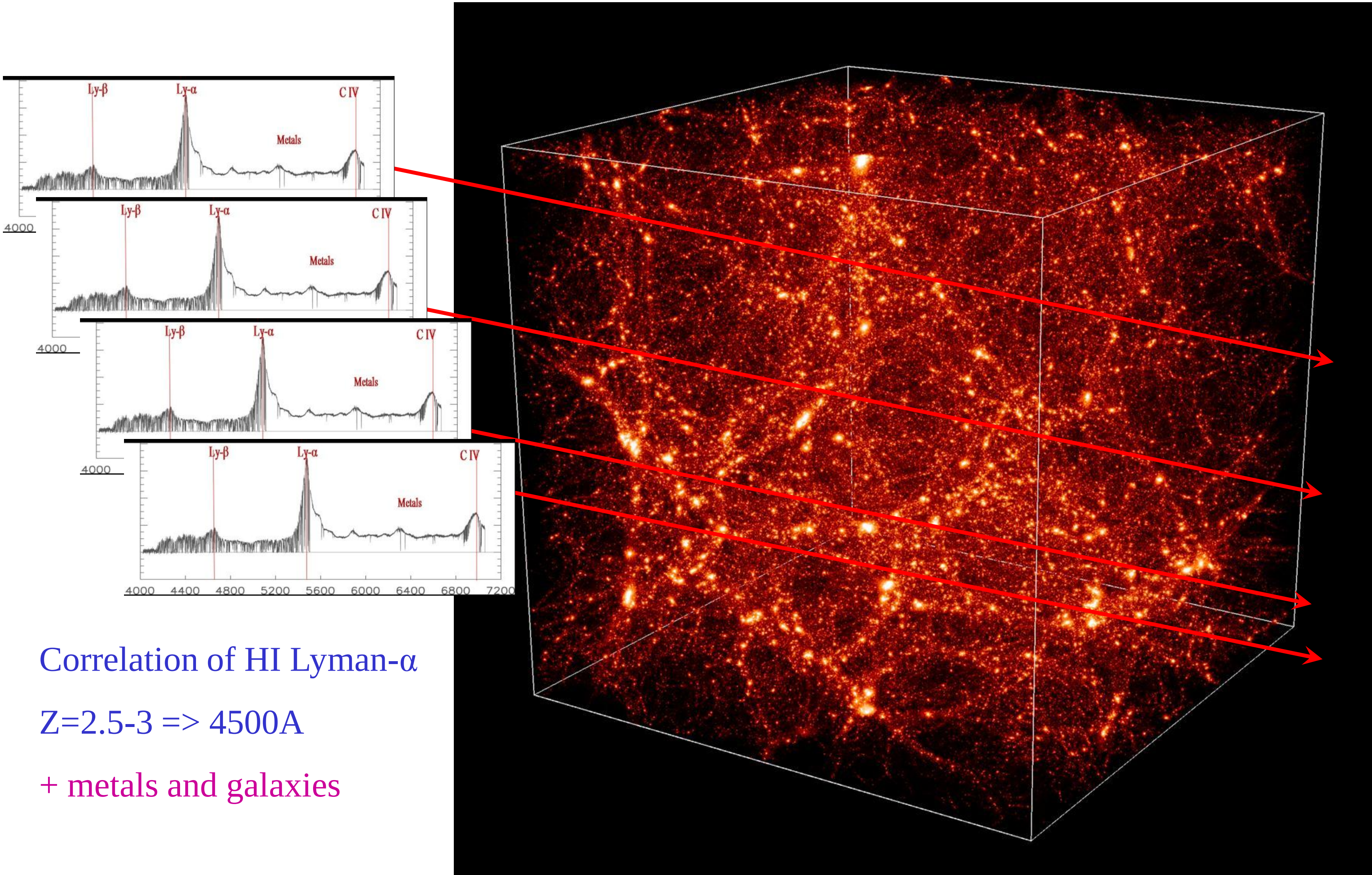
(variation of constants)

-> High resolution spectrograph on E-ELT obviously needed

Boss will discover over 150,000 z>2 QSO at g=21 !

A MOS on ELT

Large Scales: Direct reconstruction of the IGM at z=3

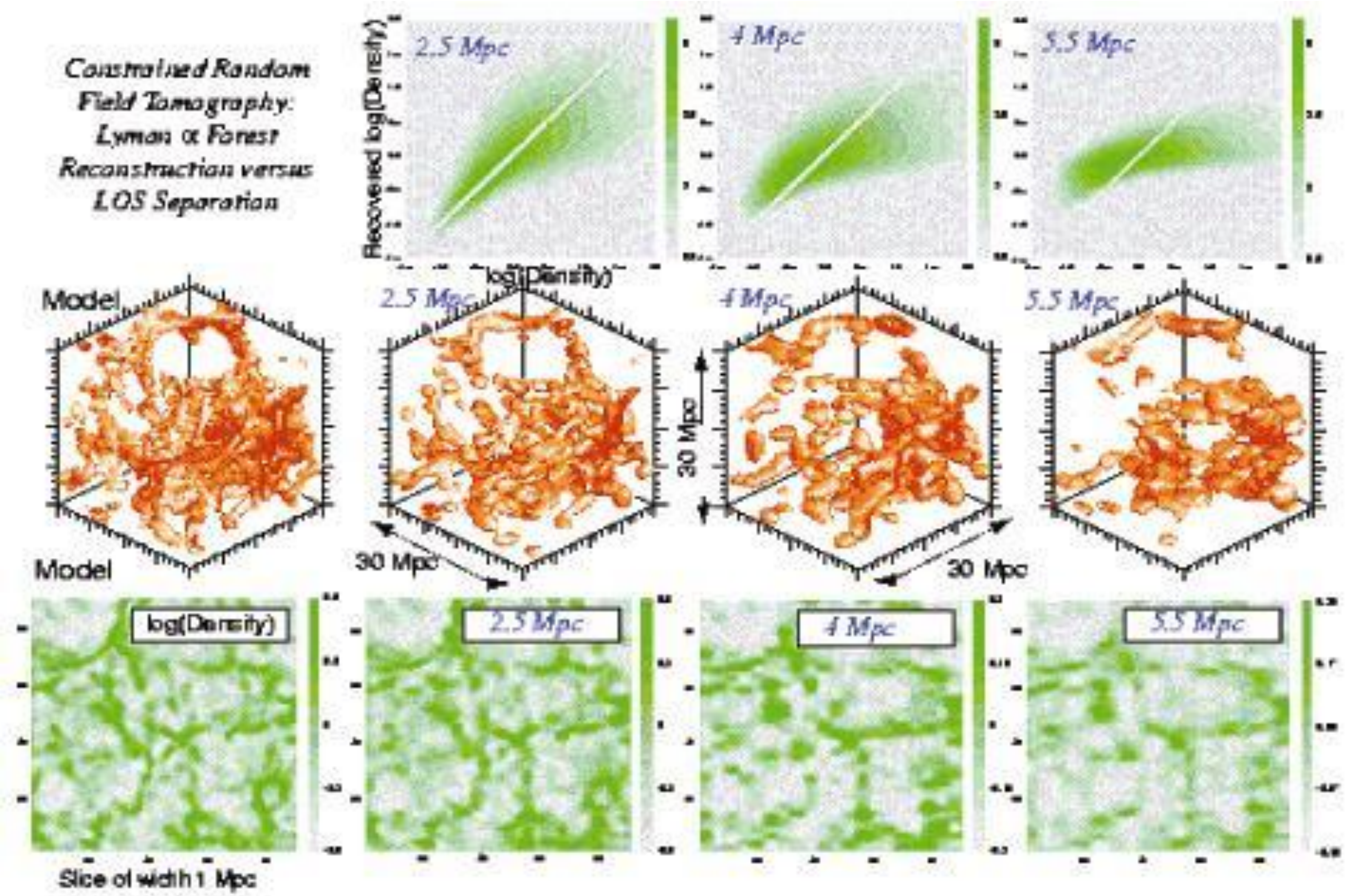


Correlation of HI Lyman-α

Z=2.5-3 => 4500A

+ metals and galaxies

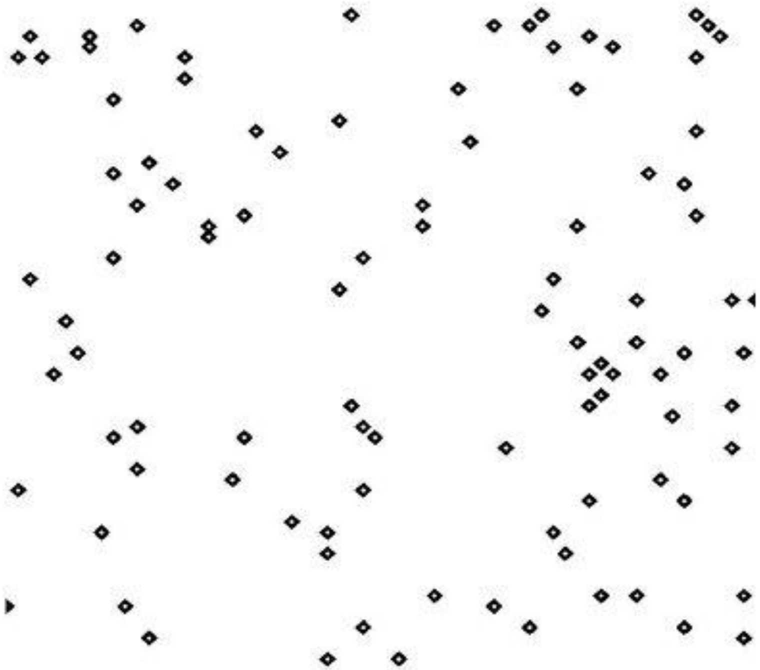
Pichon et al. 2001, MNRAS, 326, 597

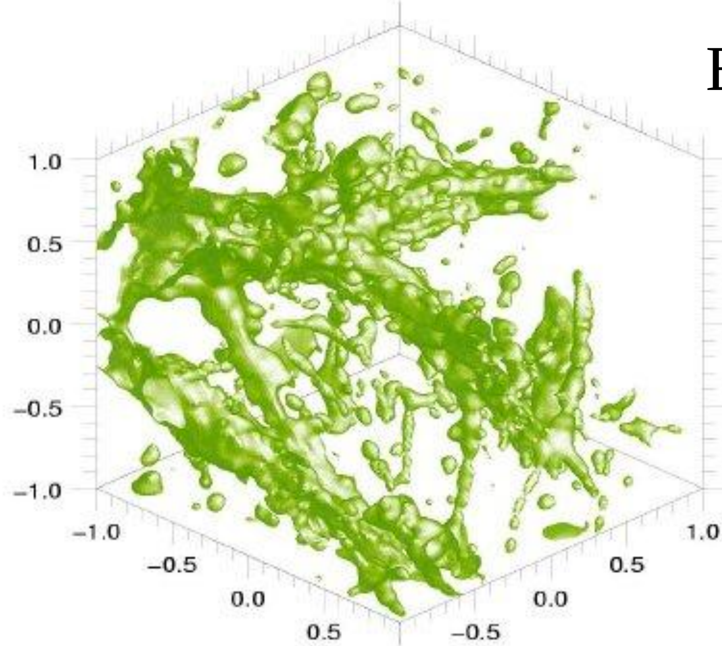


900 400 150

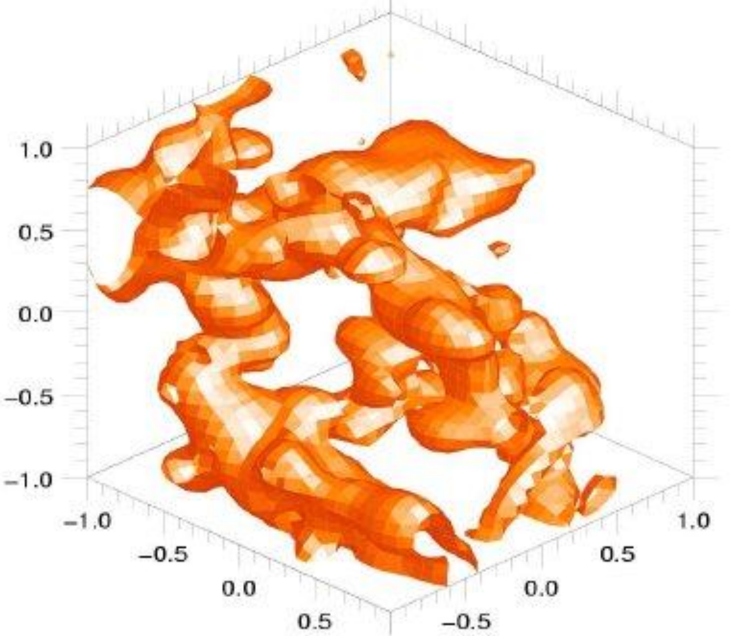
QSOs -> 100 / sqdeg not enough

With LBGs => Density field will be recovered





ELT-MOS



Inversion methods tested : density of sources:

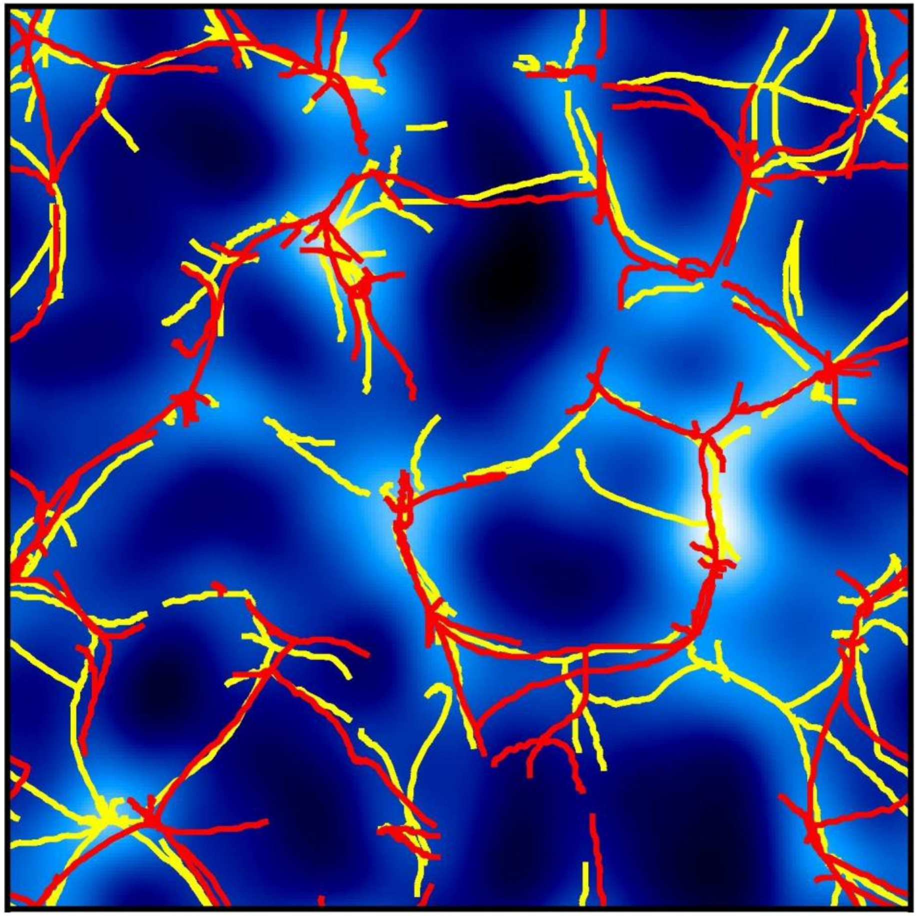
LBGs: about 900 sources/sq degree at r=24.8

QSOs: only 100 sources/sq degree

Topology of the IGM (cosmological parameters; growth of structures)

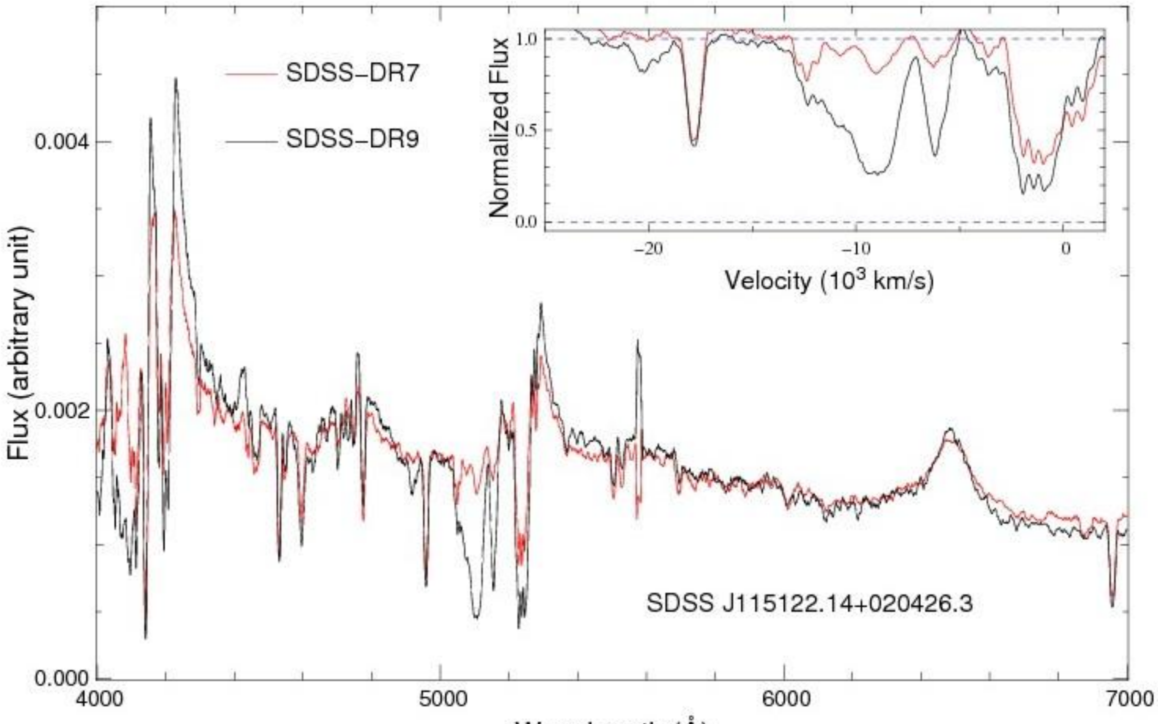
Correlation IGM-galaxies: winds; metal enrichment; infall

Caucci et al. 2008, MNRAS, 386, 211



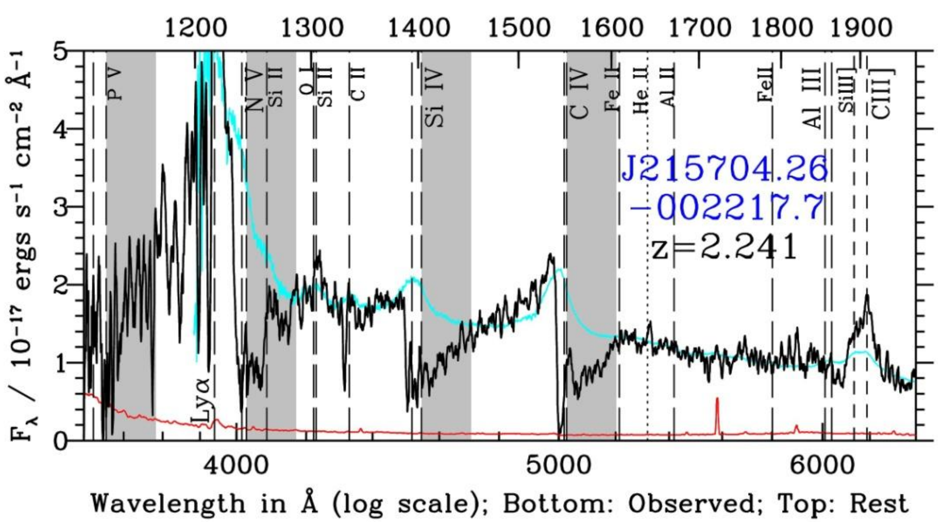
Skeleton

Variability



And a lot of strange things !

The boomerang outflow



Thank you !

to all these people running the telescopes