The cold ISM at High Redshift (z>2)

Reionization : 3 < z < 15 - Small galaxies : 'Absorption' - The whole universe

Higher z -> GRBs + radio sources

-> Census of OmegaHI in the SDSS

-> Molecules in high-z DLAs

Patrick Petitjean

Institut d'Astrophysique de Paris

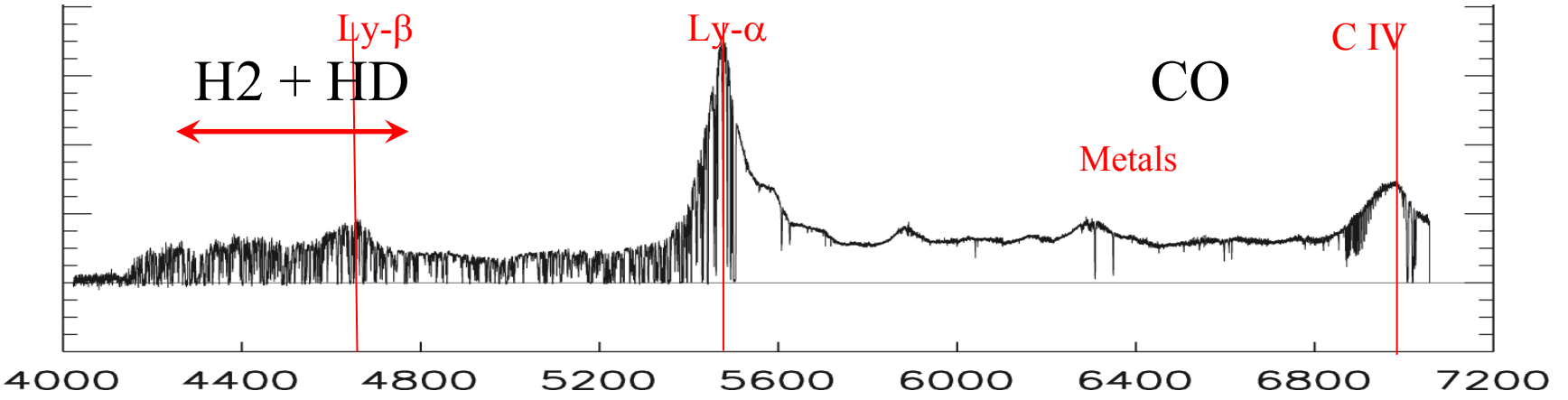
R. Srianand (IUCAA)

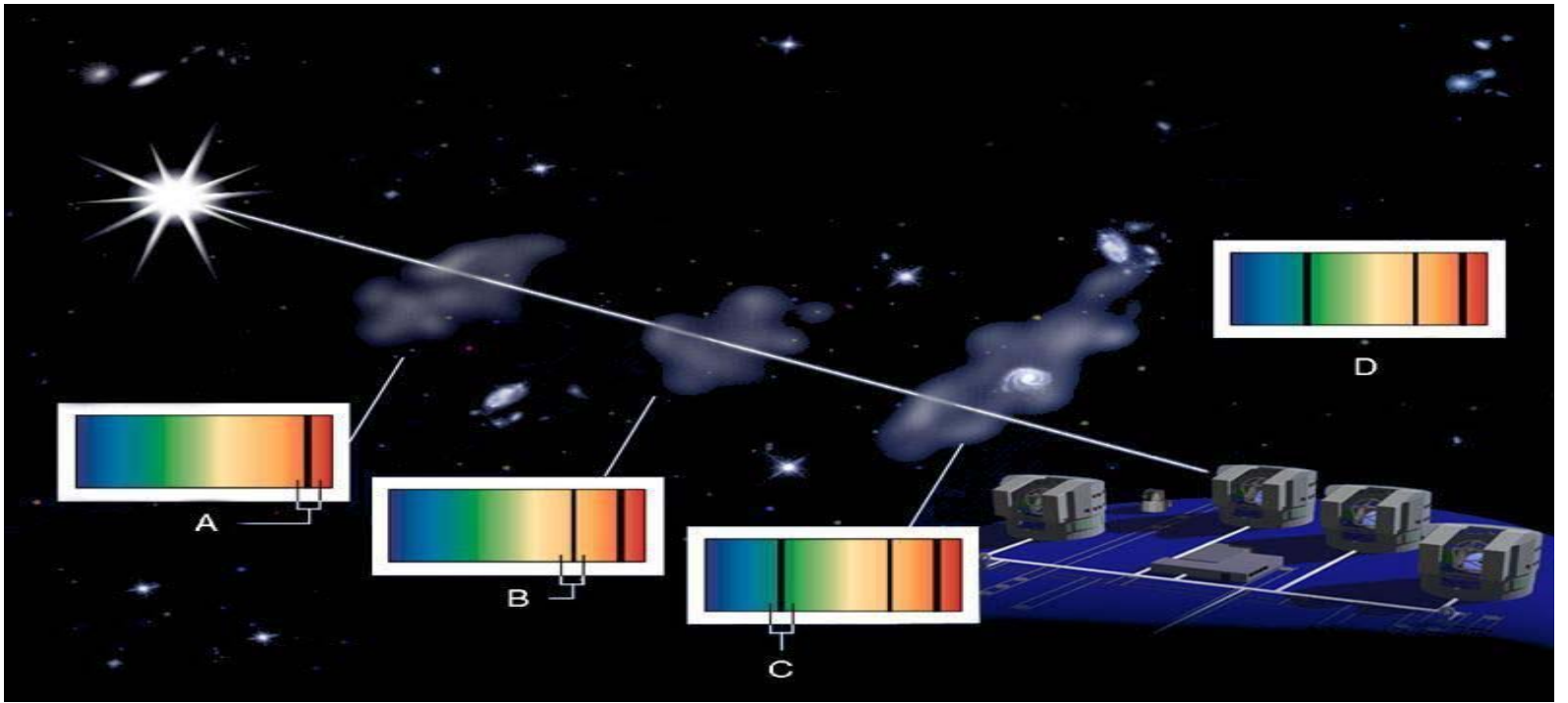
P. Noterdaeme (IUCAA)

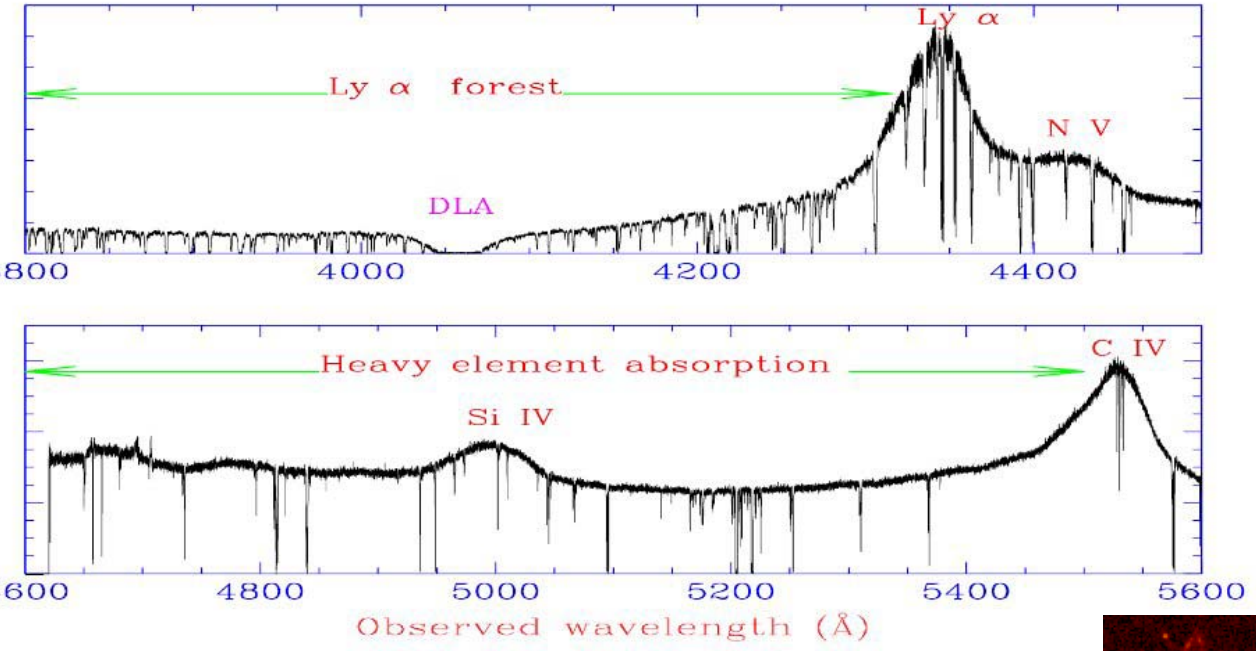
C. Ledoux (ESO)

A. Ivanchik (Ioffe Univ. St Petersburg)

Quasar (GRB) Absorption Lines -> Diffuse IGM and dense ISM







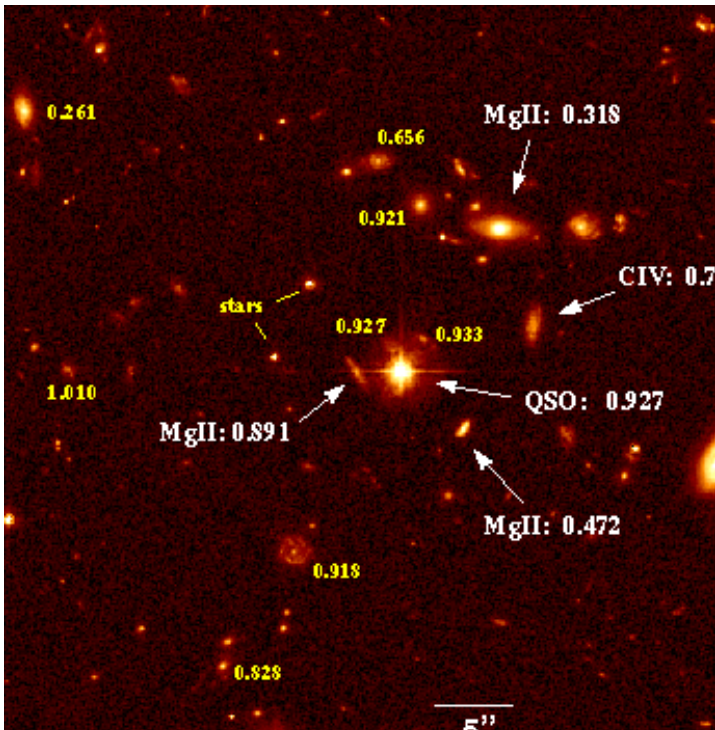
DLA z>1.6

↕

Strong MgII z<1.6

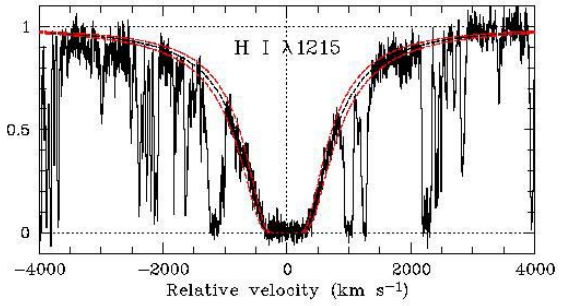
The ISM of (all) high-z galaxies

DLAs-> dwarf galaxies ?



Damped Ly-α Systems

HI :



Metals :

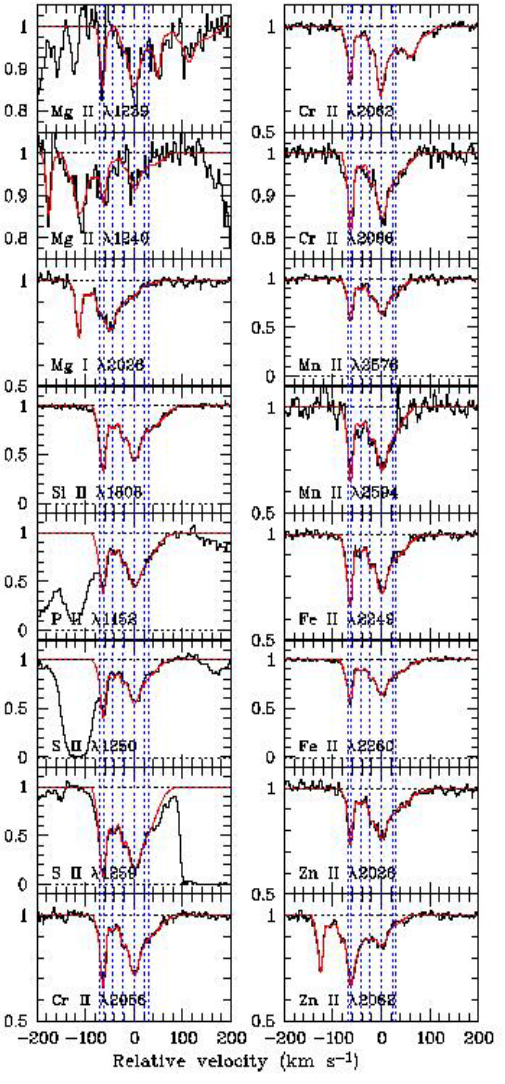
-> Metallicities

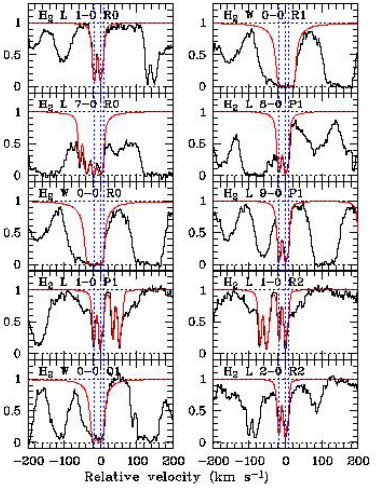
-> Dust content

-> Kinematics

Star- Formation ?

Winds ?





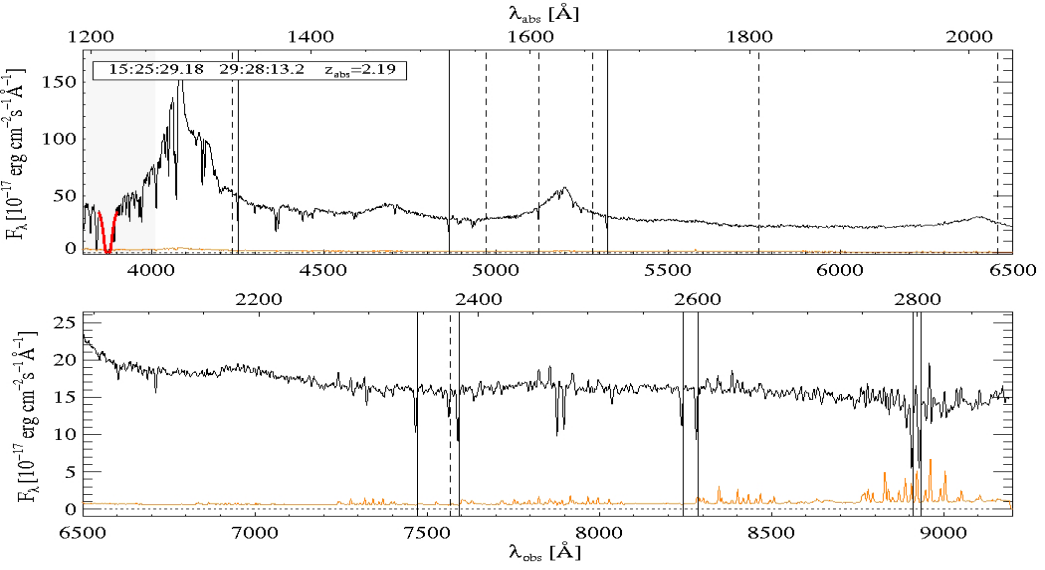
Molecules H2 + CI, CI* :

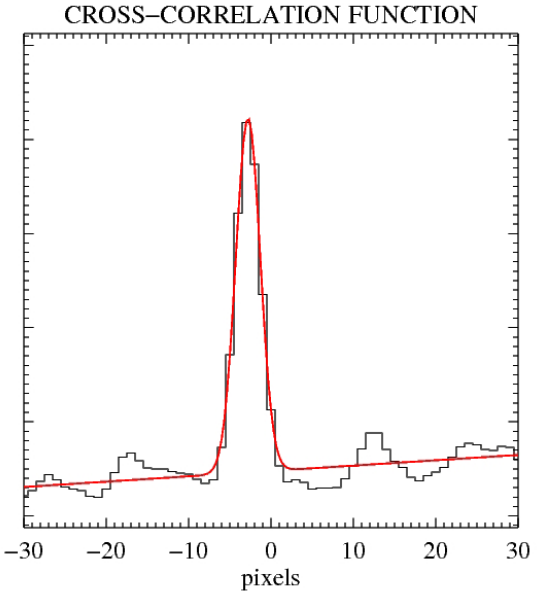
-> Density/Temperature

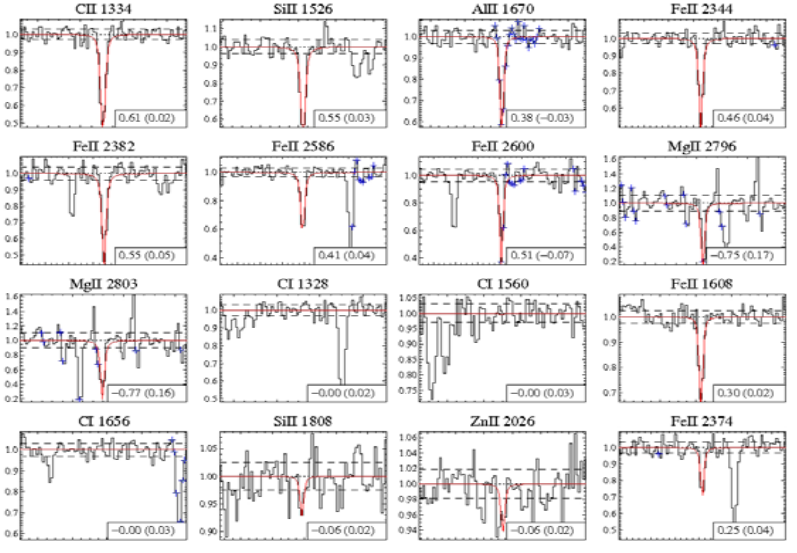
-> UV flux (excitation)

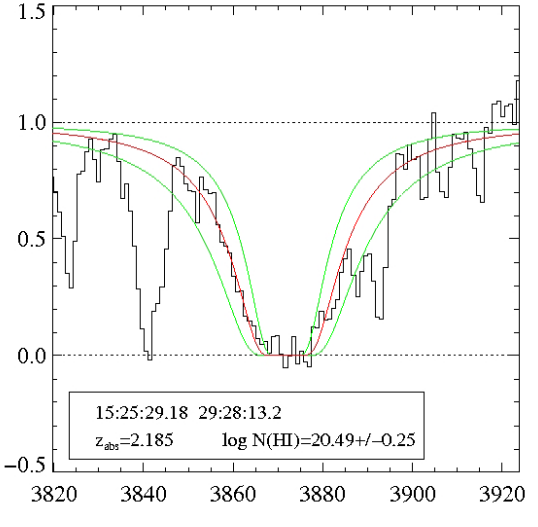
Evolution of the cosmological HI density

- Search the SDSS quasar spectra for DLAs : Fully automatic procedure









Evolution of the cosmological HI density

-About 900 DLAs

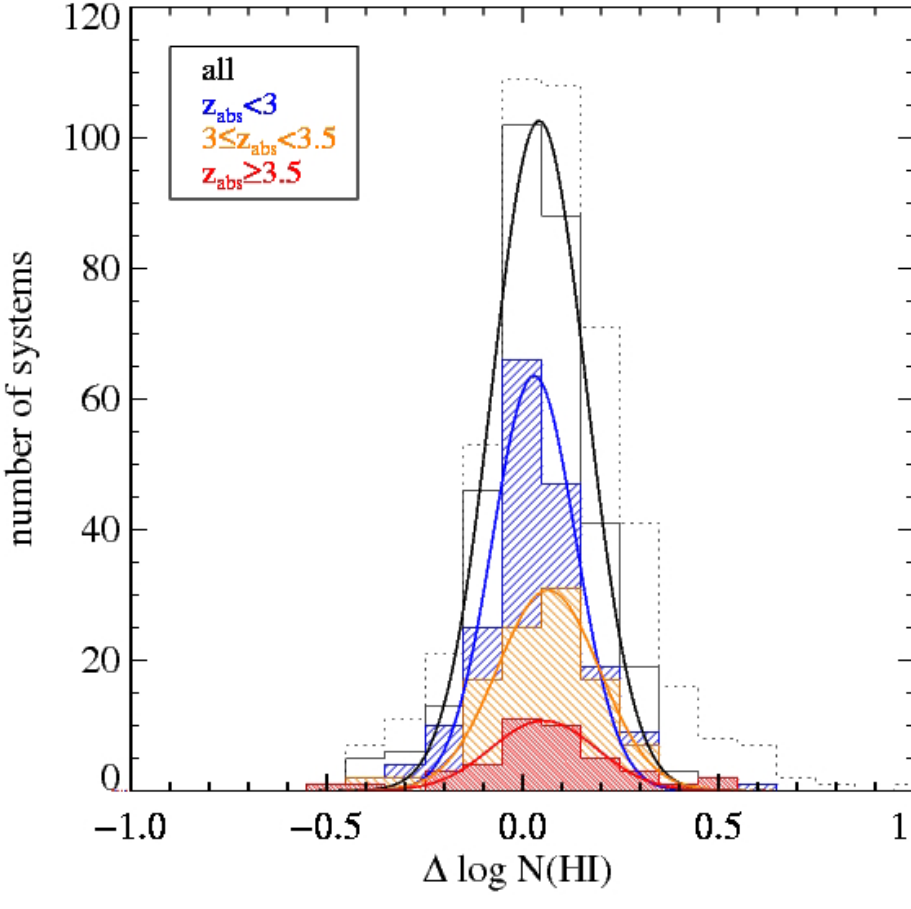
- Comparison with previous searches (Prochaska et al.)

Quite similar results

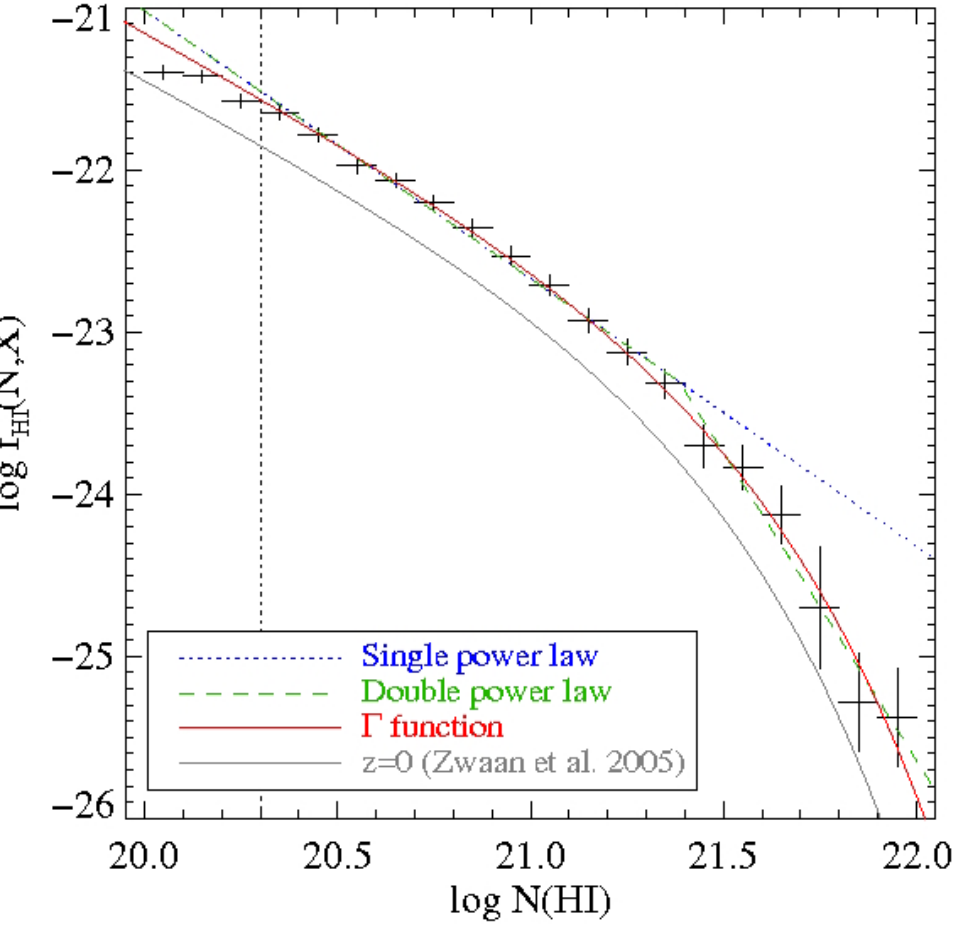
*Difference:

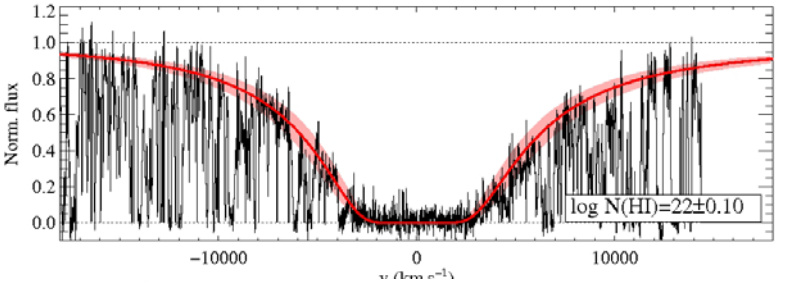
Semi-auto detection and Fits by hand vs fully automatic procedure

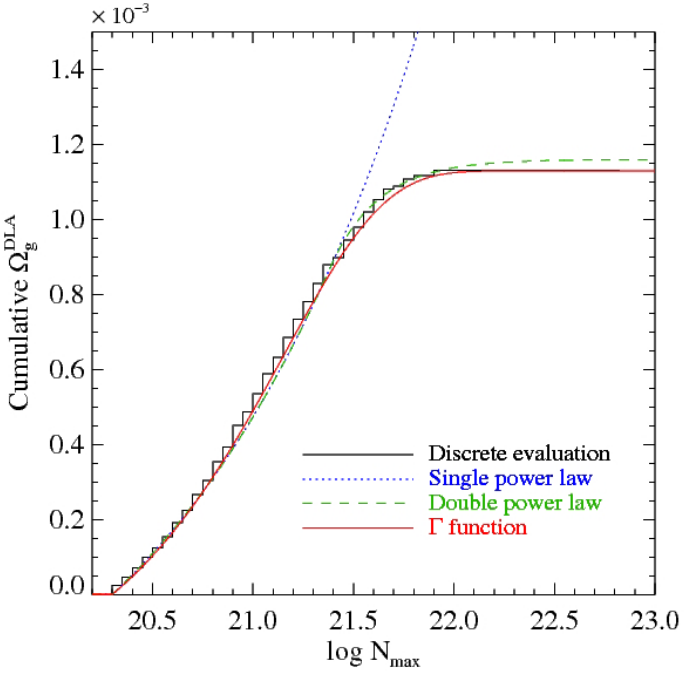
DR7 vs DR5



NHI distribution function

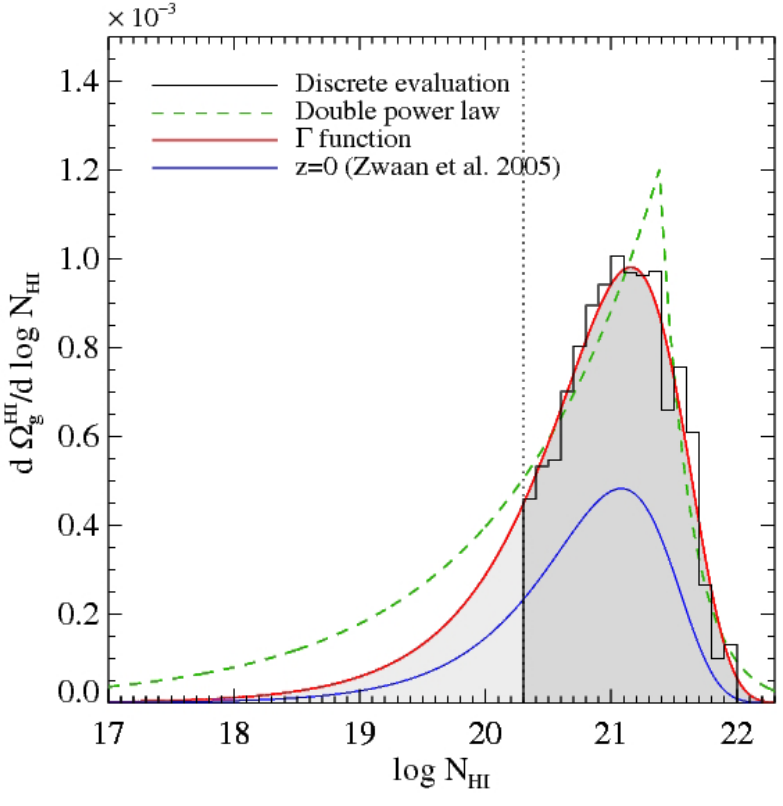






Similar shape at z=0 and z=2.5

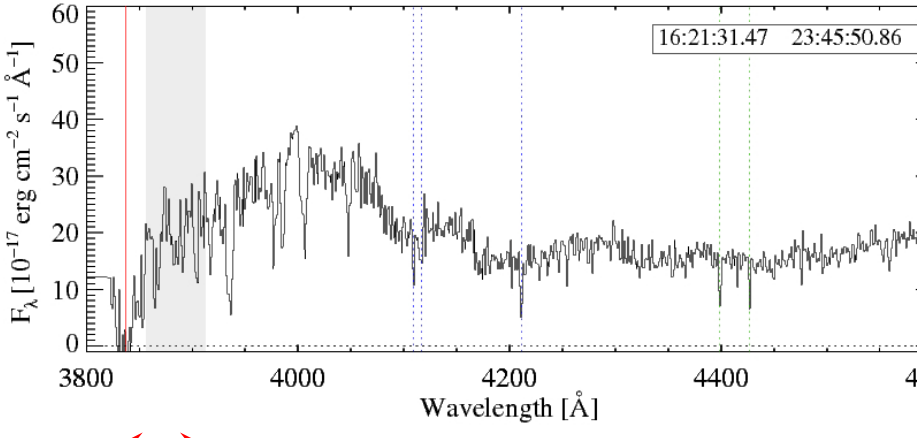
Neutral gas cosmological density



The Big Bias

SNR>4

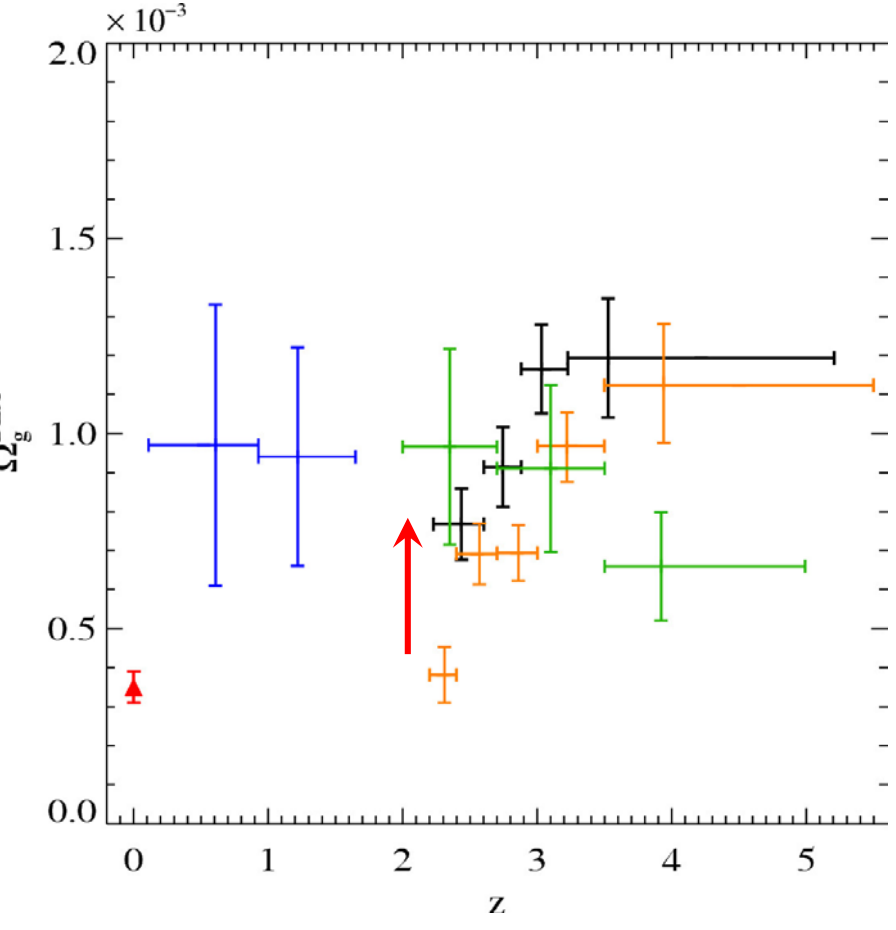
DLAs at the edge (z ~2) are lost

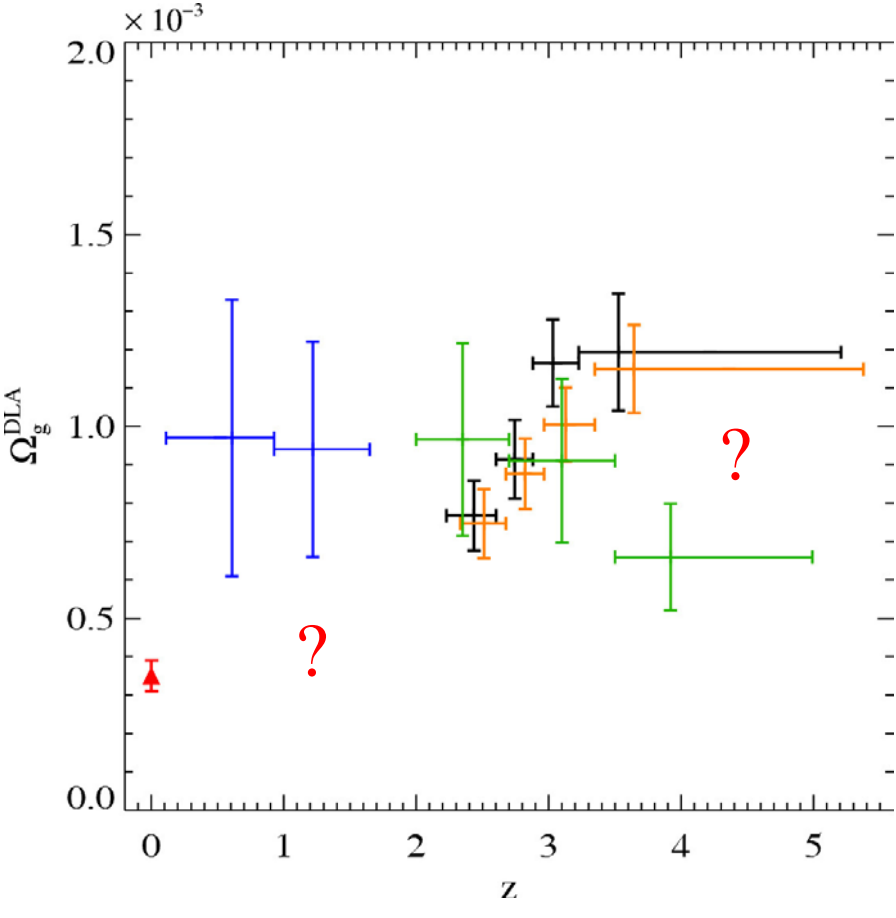


Cut 10000 km/s

Most important contributors around 21

OmegaHI z evolution





Molecules: Why H2 ?

- First molecule to be formed
- Important coolant in the metal free gas -> low-mass halos

- H2 is ubiquitous in star-forming giant clouds and in the diffuse interstellar medium in our Galaxy
- H2 is formed on the surface of dust-grains :What is the role of dust ?
- Excitation of H2 in different rotational levels: Signature of the UV ambient flux + Physical properties of the gas
- Other molecules ? CO, HD
- By-products: variation of μ=me/mp

Two things: * Unbiased survey to learn about the H2-bearing DLA population

* Derive selection criteria -> detailed observations

UVES survey

80 DLAs – sub.DLAs

Spectral resolution R=43000; SNR>20 per pixel

H2 detected in 14 systems (15-20%)

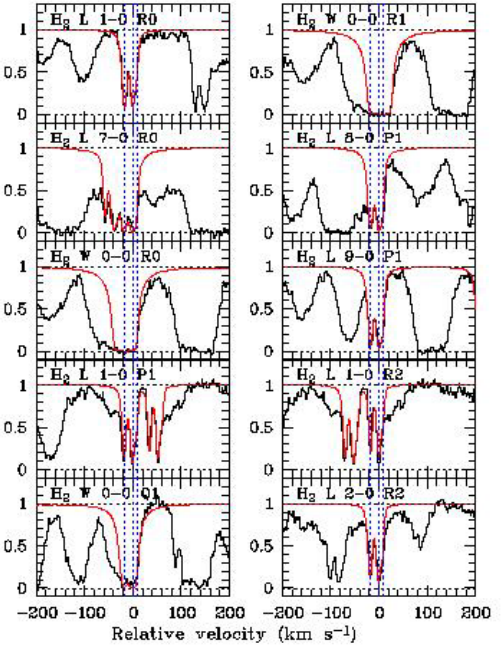
Non detection :

$f = 2xN(H2)/(2xN(H2)+N(HI)) < 10^{-5} - 10^{-7}$

Detection threshold $\sim 10^{14}$ cm^{-2} : 3h exposure time per spectrum for no detection

-> 8h in case of detection.

=> More than 350 hours observations



Highest redshift

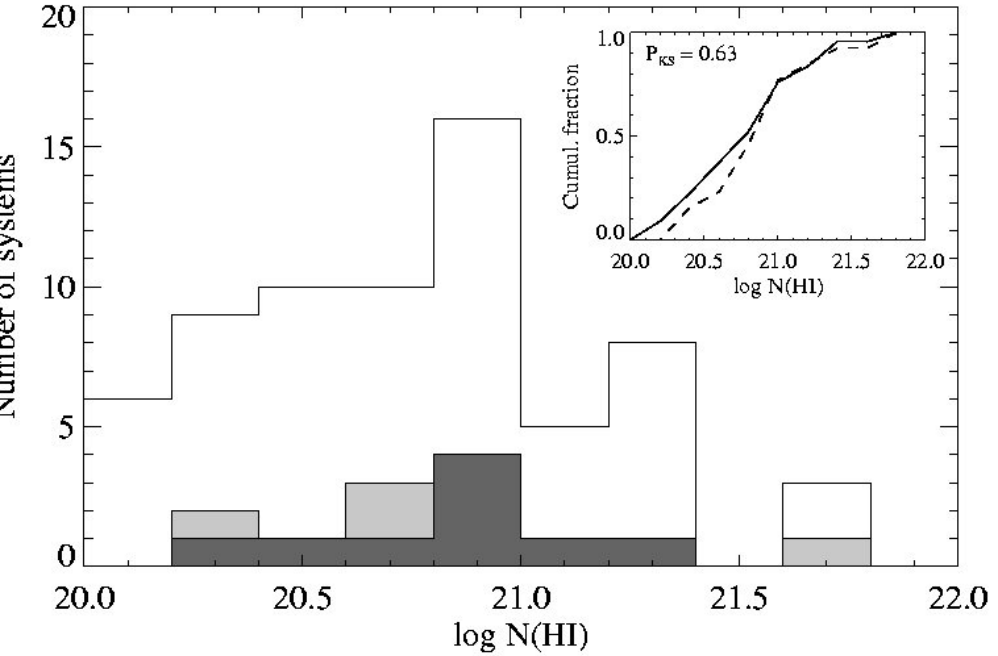
J1443+2724 z = 4.224

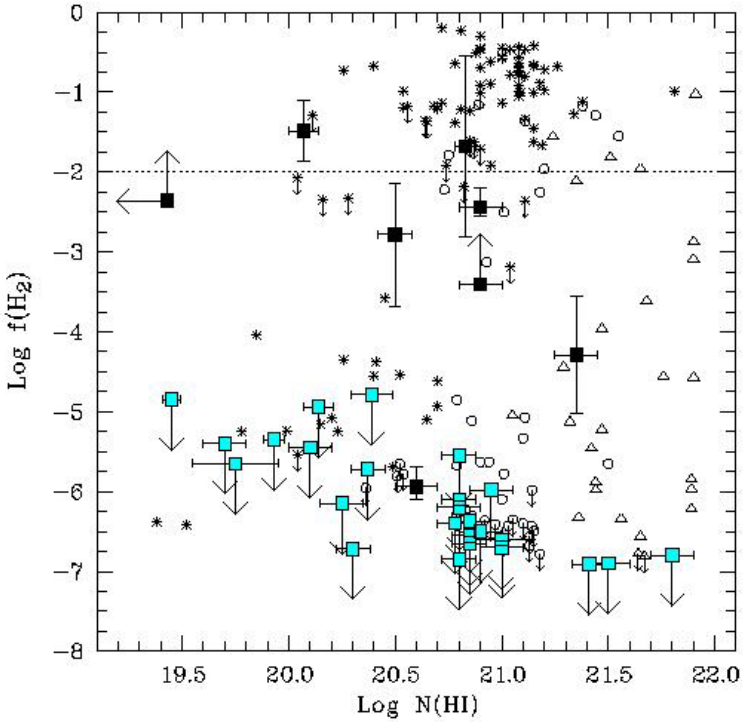
Petitjean et al. (2000), A&A, 364, L26

Ledoux et al. (2003), MNRAS, 346, 209

Noterdaeme et al. (2008), A&A, 481, 327

HI Column density



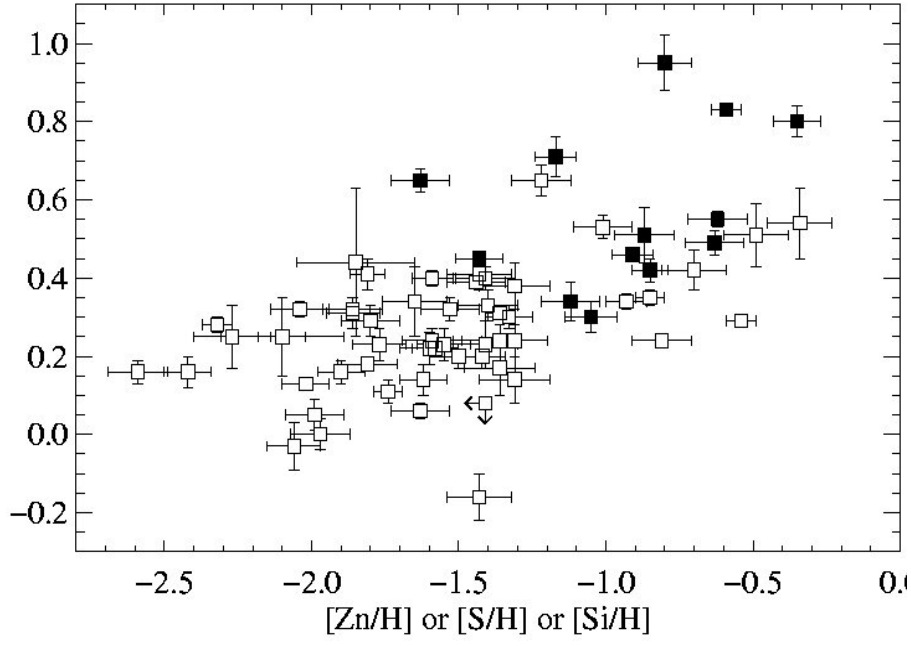


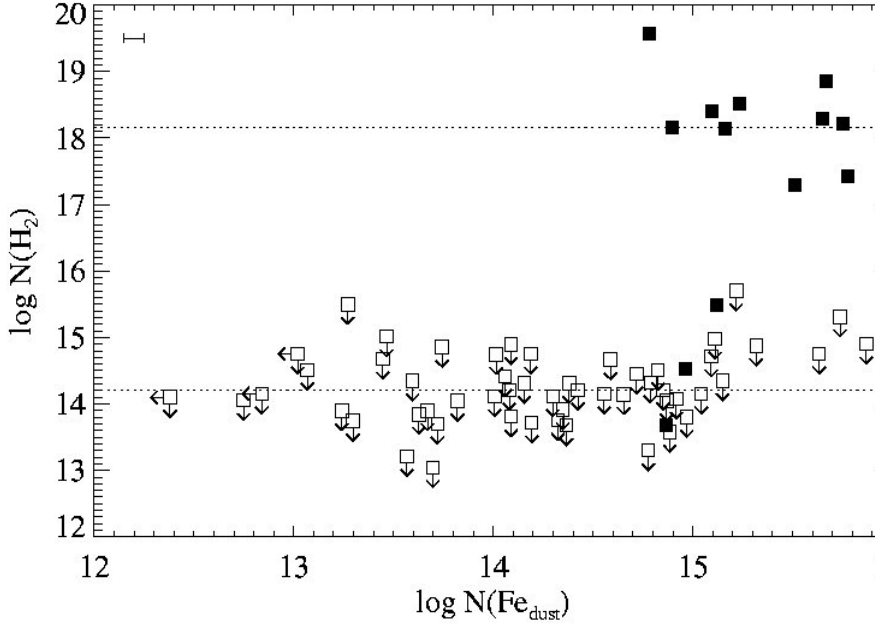
-Presence of H2 is independent of N(HI)

- Molecular fraction, f, smaller than in the Galactic disk

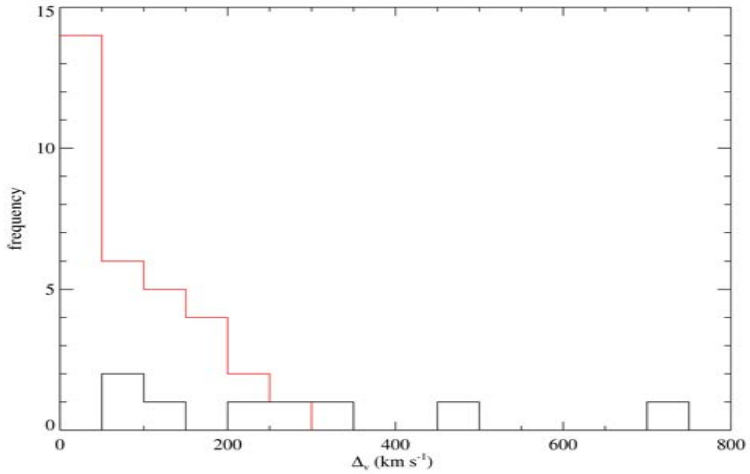
  - > Magellanic clouds or halo diffuse clouds

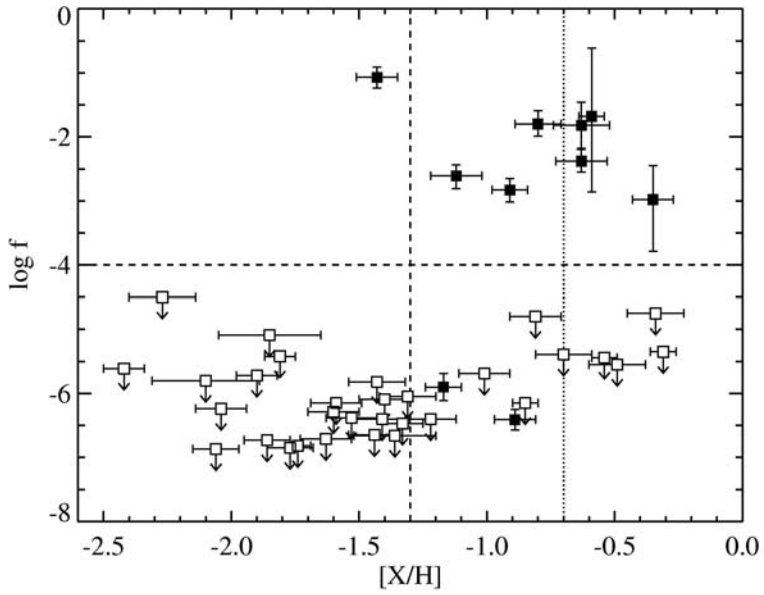
Presence of dust





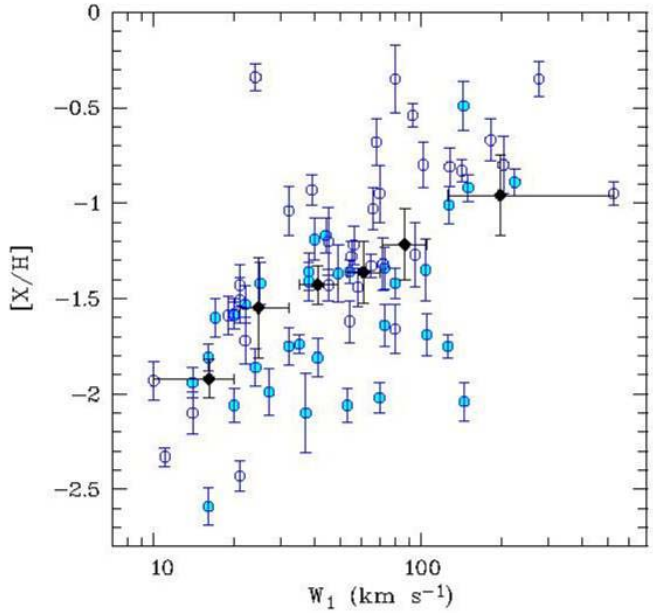
- Correlation Depletion ([Zn/Fe]) vs Metallicity ([Zn/H])
- Presence of H2 related to the dust column density





Presence of H2 for High metallicities

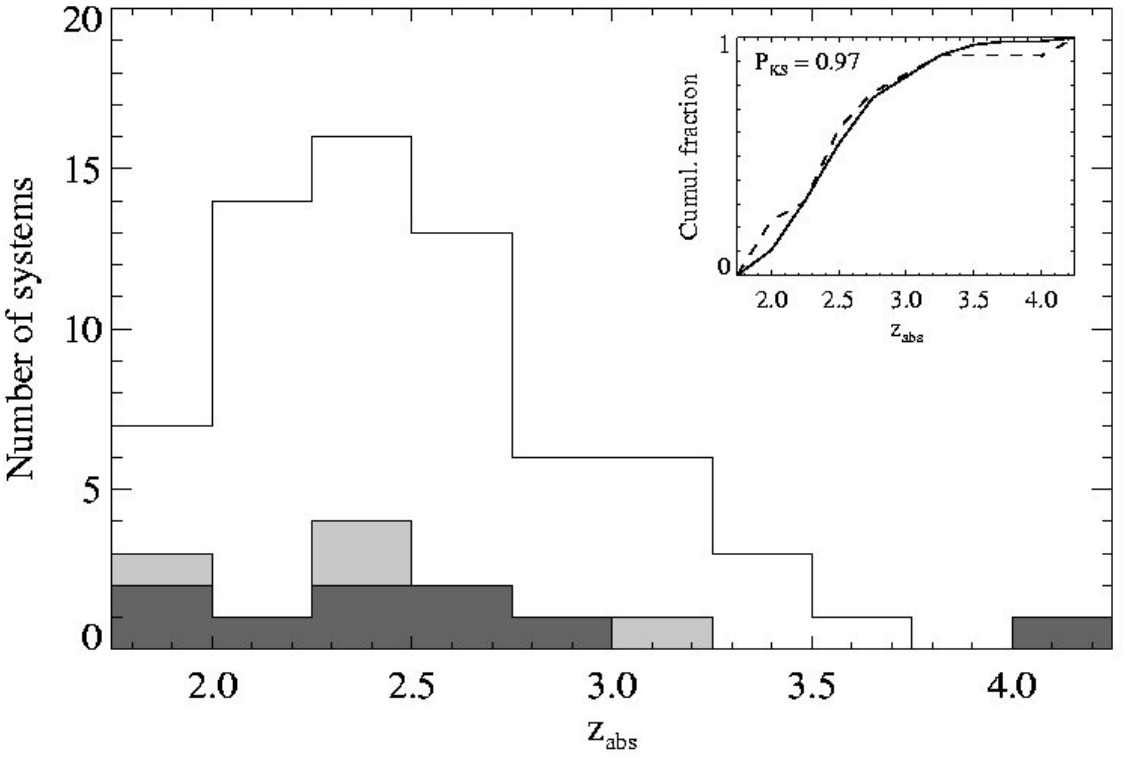
AND high velocity width



H2 = Metal Rich = Massive Galaxies ?

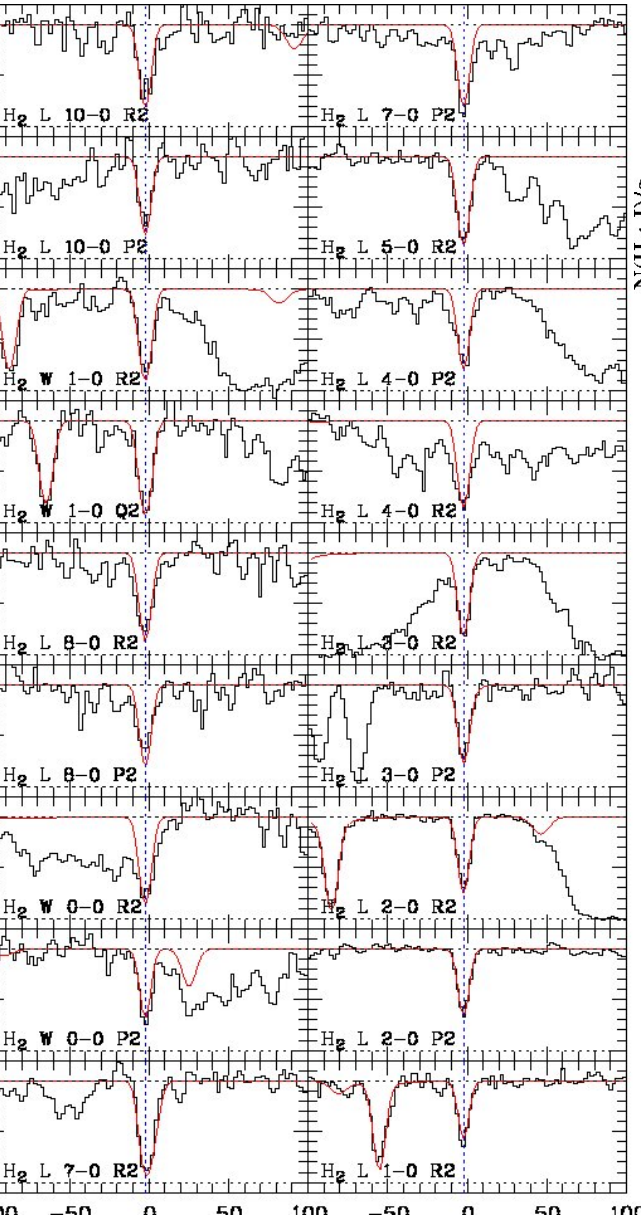
[X/H] : metallicity W1 : Absorption Width

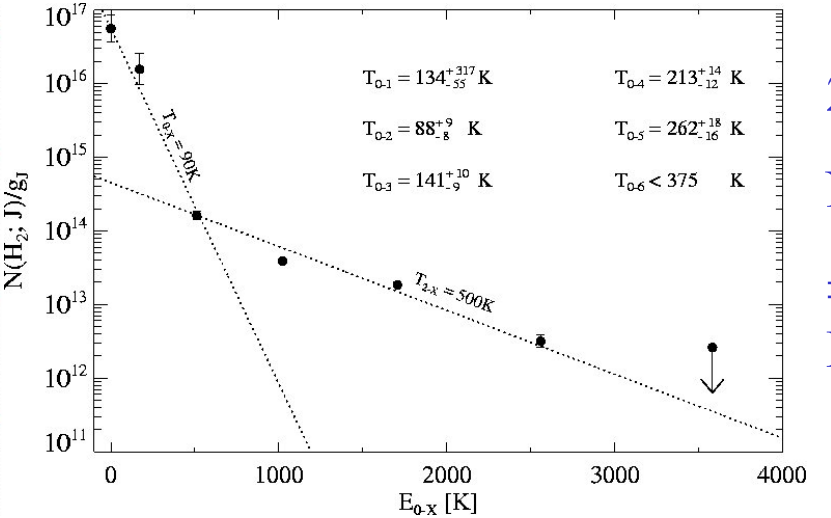
No redshift evolution

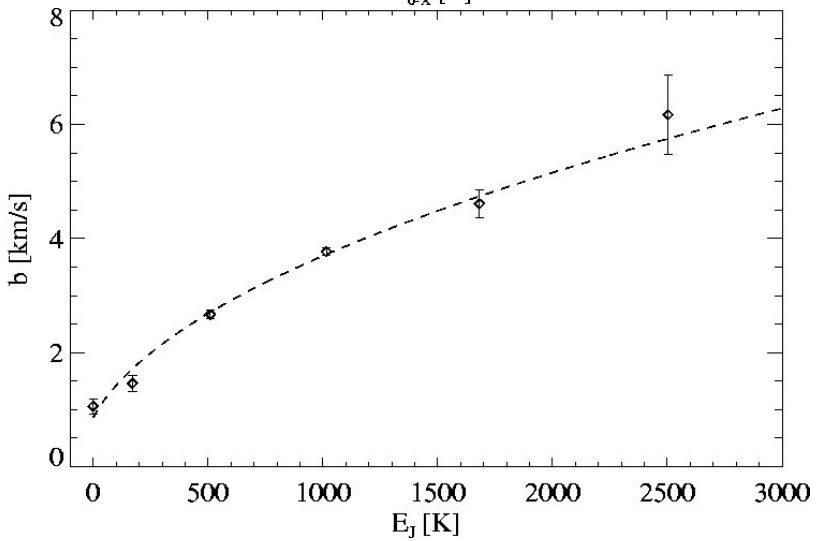


Survey -> Selection -> detailed studies

Heating processes







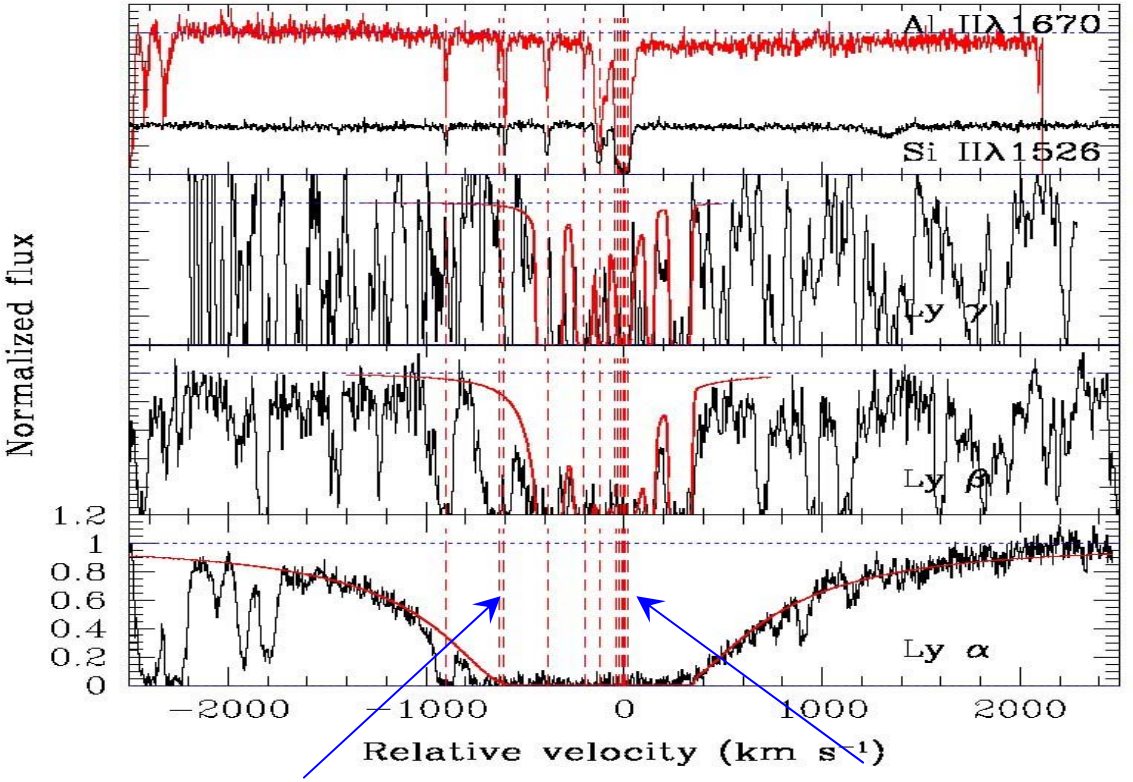
2 T components

No shift

⇒New Heating Process

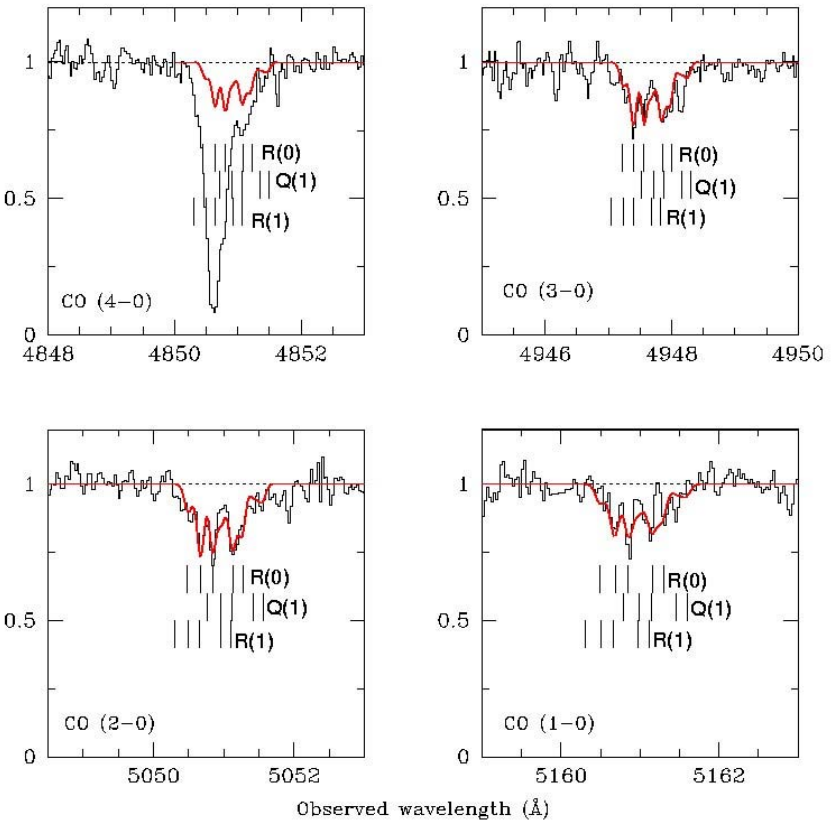
Doppler parameter increases with J

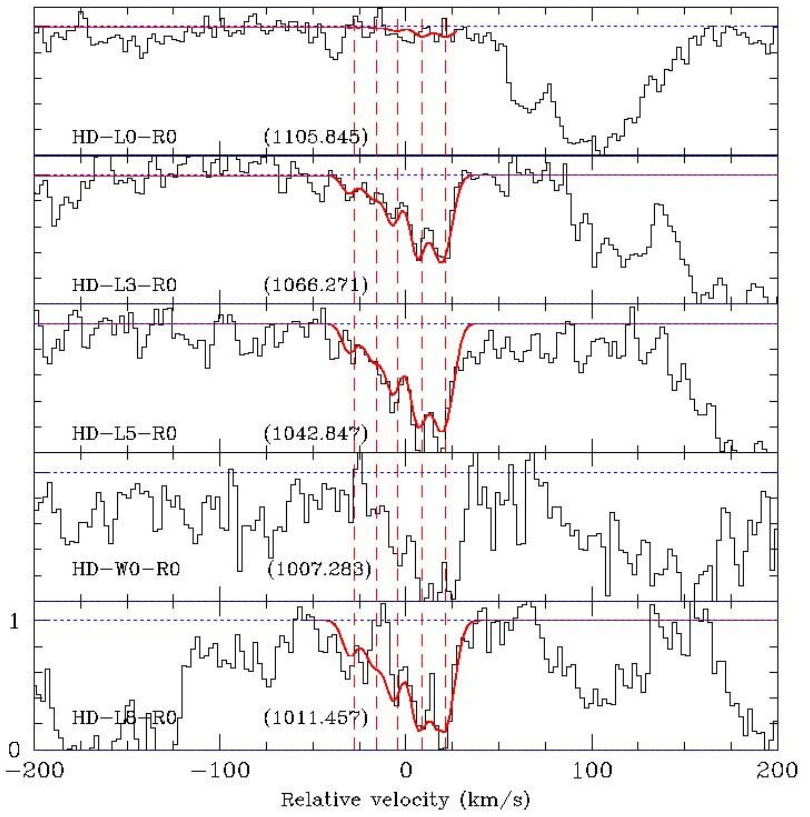
Other Molecules-> Selection: Dust, Metallicity, CI



Two sub-DLAs ; z=2.42 ; [S/H]=-0.07; [Fe/S]=-1.33

CO and HD





Log(f) = -0.3 (highest in DLAs) ; CO/H2 = 3×10^{-6}

HD/2H2 = 1.9×10^{-5}

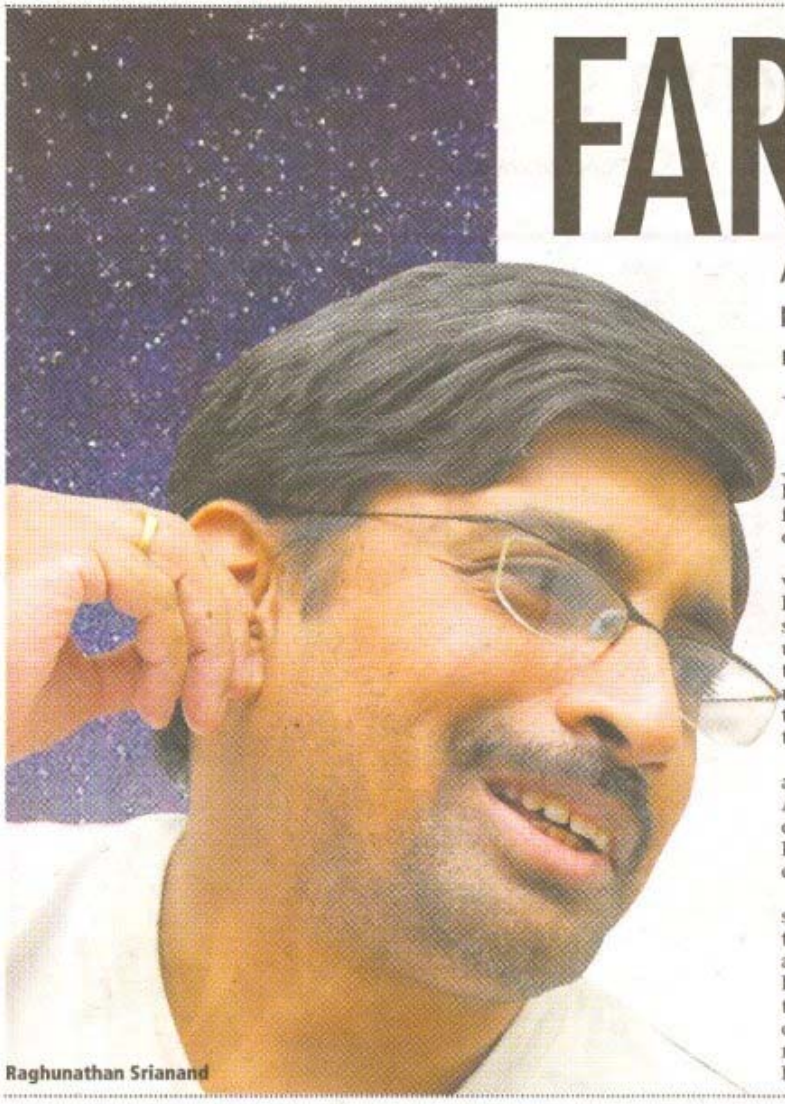
Srianand et al. (2008) A&A, 482, L39 - Noterdaeme et al. (2008) A&A, 491, 397

« Times of India » …

FAR TOO CO-OL!

A professor from Pune has been successful in detecting a carbon monoxide molecule in a galaxy located 11 billion light years away

DEVIDAS DESHPANDE



Raghunathan Srianand

Here is one more achievement that scientific institutions in the city can lay claim to. A city scientist has led a team of researchers in detecting the carbon monoxide (CO) molecule in a galaxy located almost 11 billion light-years away. This is a big feat considering the fact that research was being carried out in this field for the past 25 years.

Raghunathan Srianand, a professor with the Inter University Centre for Astronomy and Astrophysics (IUCCA), led a team of scientists from the European Southern Observatory for this project. The astronomers have made use of ESO's Very Large Telescope to detect for the first time in the ultraviolet domain the carbon monoxide molecule. This detection will make it possible to obtain the most precise measurement of the cosmic temperature at such a remote spot.

A soft-spoken Dr Srianand said, "This research was a part of the Indo-French space co-operation project. Along with me, there were Pasquier Noterdaeme and Cédric Ledoux from ESO and Patrick Petitjean from IAP, France, also. We are basically into spectroscopy. This discovery will surely help us more in pursuing our research."

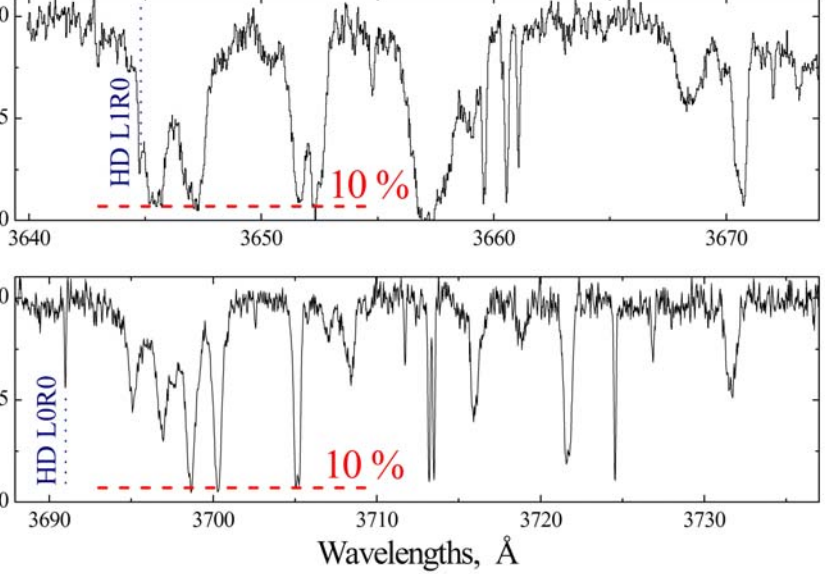
Interestingly, the team of astronomers aimed the UVES spectrograph on ESO's Very Large Telescope (biggest optical telescope in the world) for more than eight hours at a well-hidden galaxy whose light has taken almost 11 billion years to reach us. "We can determine the temperature pattern of the era with this discovery. Our findings coincided with the findings of those drawn from the models developed to verify the Big Bang theory. These helps in reinforcing the theory."

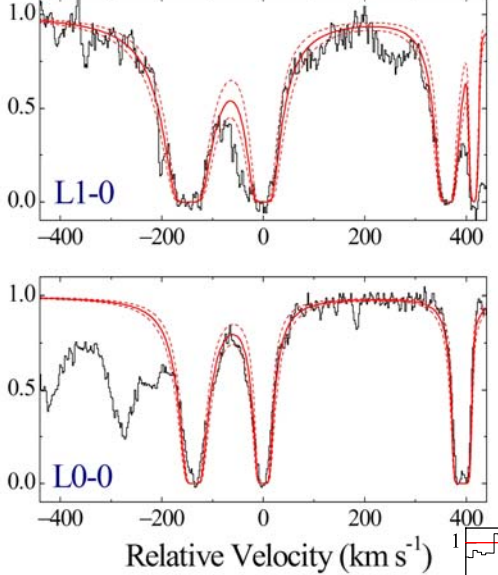
The same team had already broken the record for the most distant detection of molecular hydrogen in a galaxy that we see as it was when the Universe was less than 1.5 billion years old.

Incidentally, all the scientists working in this team have a connection with the IUCAA. While Pasquier Noterdaeme and Cédric Ledoux had visited the IUCAA as researchers, Patrick Petitjean is scheduled to come here in the immediate future.

THE EXPERIMENT

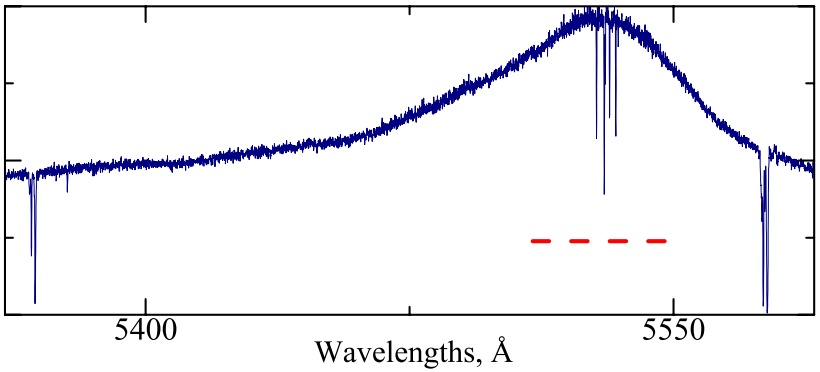
- Some of the molecules and atoms behave like a thermometer and respond to the temperature. In particular by looking at the properties of molecules like Carbon Monoxide (CO) one is able to measure this temperature quotient. This experiment was the first of its kind to detect these molecules in the distant Universe and then look at the spectroscopic signatures to infer the temperature of the background.
- This is the first detection of three species of molecules from the early Universe. A search was on for the last 25 years without much success. These observations will be very important for confirming the Big Bang theory and understanding how complex molecules formed and evolved in the Universe.

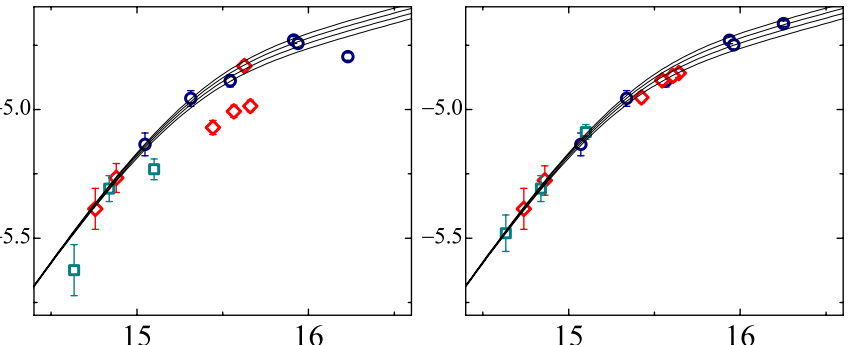




Covering factor

10-25% correctio





HD

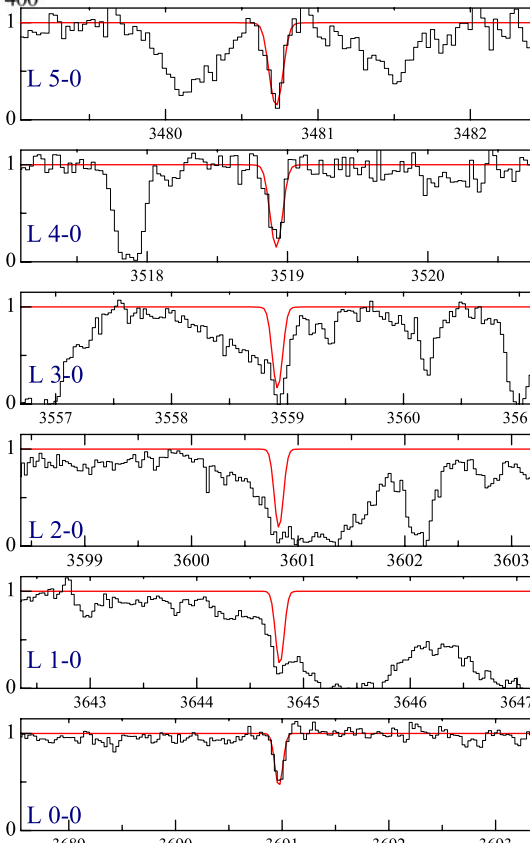
$HD/2H2=3.5x10^{-5}$

No astration

HD/2H2=D/H

-> Evidence for

Infall ?



Conclusion

-> Go for a larger sample : Selection criteria (deeper) X-shooter

-> Go deeper in the selection of quasars:

* down into the luminosity function

* detect obscured quasars

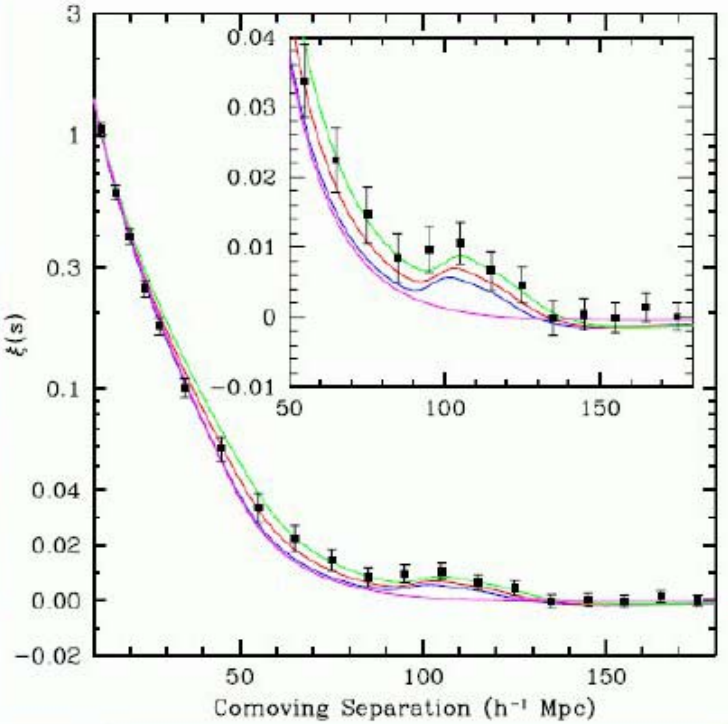
* big survey: BOSS – Big-Boss

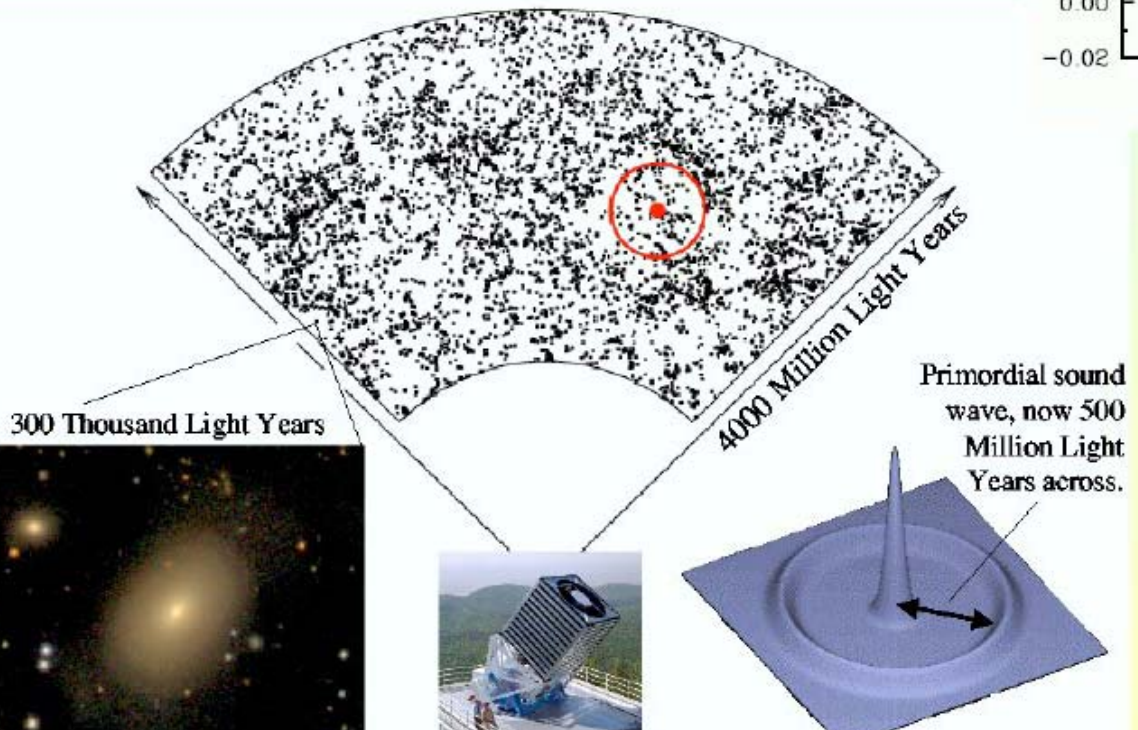
-> GRBs

Pic acoustique baryonique

Ondes détectées aujourd'hui
dans la distribution des baryons

50 000 galaxies SDSS





Eisenstein et al 2005

What about the Lyman-α

Baryon Oscillation Spectroscopic Survey (BOSS)

Started sept 2009

Part of SDSS-III, BOSS uses redshifts of 1.6M galaxies (z~0.5)and Lyman-α forest of 0.16 M quasars (z~2.5) to determine cosmological parameters.

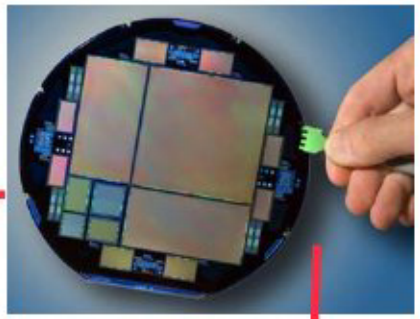
LBNL Leadership roles in BOSS:

PI: *David Schlegel*

Instrument Scientist: *Natalie Roe*

Survey Scientist: *Martin White*

SDSS telescope at Apache Point



Replace red CCDs on SDSS camera with w/red-sensitive LBNL/SNAP CCDs, making it possible to go to higher-z

DES: LBNL furnishes CCDs to upgrade the camera at CTIO for DES. LBNL science role: SNe and WL. Detectors for DES now in production at LBNL Microsystems Lab.

Sloan Foundation agreed to support SDSS-III. Proposals pending at DOE and NSF. MOUs signed or in negotiations with many institutions:

Arizona	LBNL
Brazilian group	LANL
UC Irvine	MPA Garsching
UCSC	MSU
Cambridge	New Mexico State
Case Western	NYU
FNAL	OSU
Florida	Penn State
French group	Portsmouth
Heidelberg	Astrn. Inst. Princeton
Japanese group	Princeton
Johns Hopkins	Virginia
Korean Inst. Adv. Study	Wasington

BOSS at IAP and APC

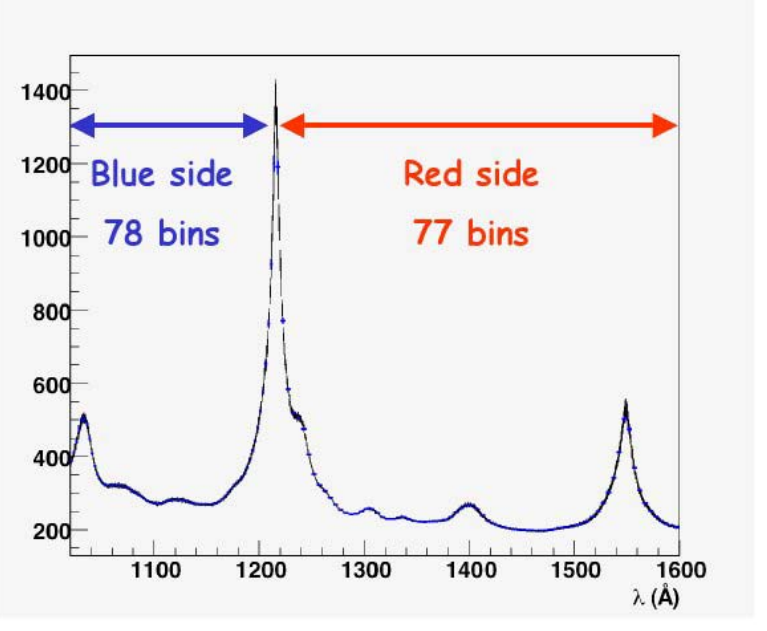
QSO target selection (from photometry) with neurone networks:

New method -> 10-15 QSO/sq deg over 8000 deg : Different methods are complementary

Parameterization of the spectra with NN

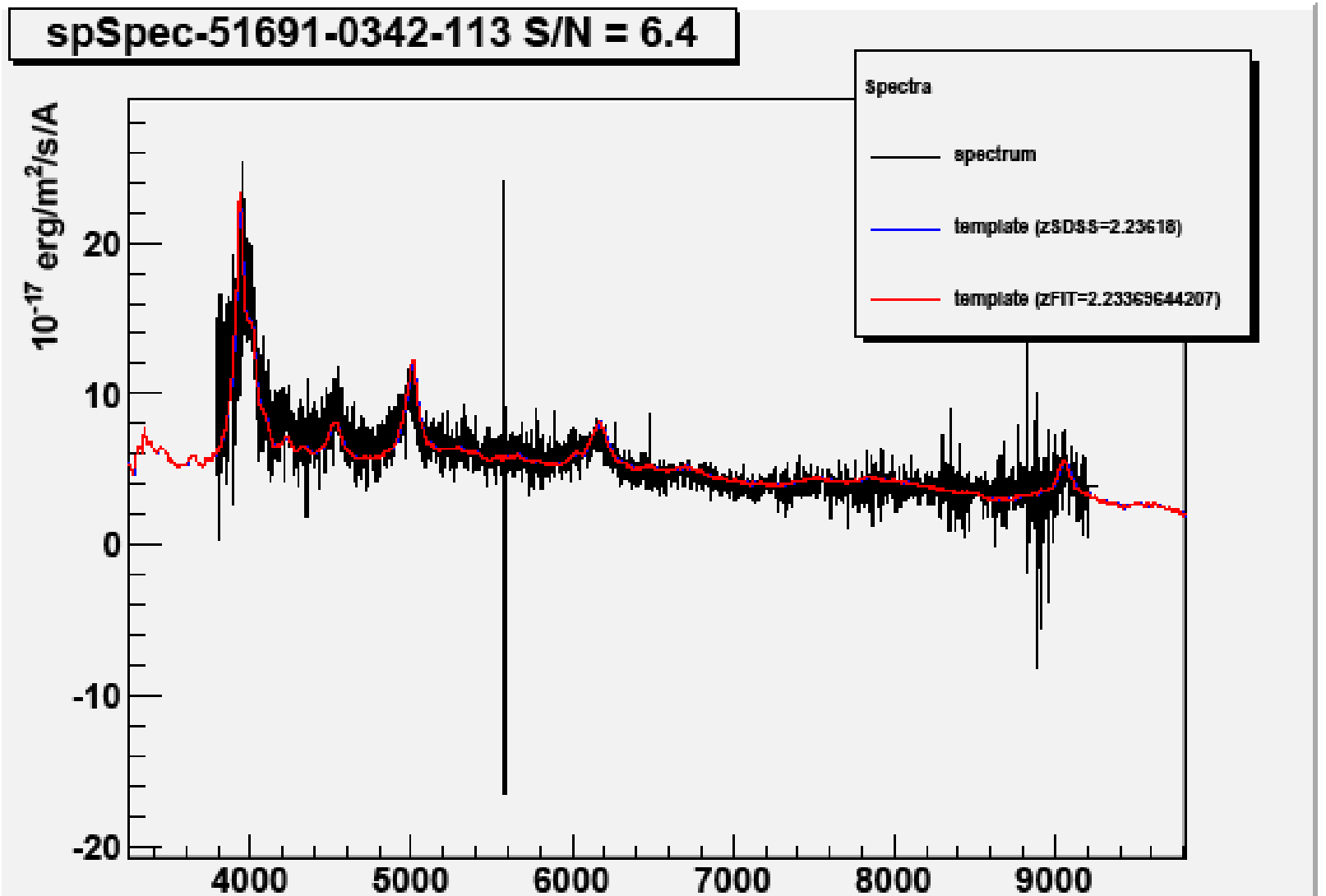
Strategy:

- Predict continuum in the Ly-α region knowing the red side spectrum (1216-1600Å)
- Training with a multi-layer perceptron (n_{in}:35:35:n_{out}) with the 50 QSO
- n_{in} inputs : QSO flux for n_{in} bins on red side
- n_{out} outputs : QSO flux for n_{out} bins on blue side

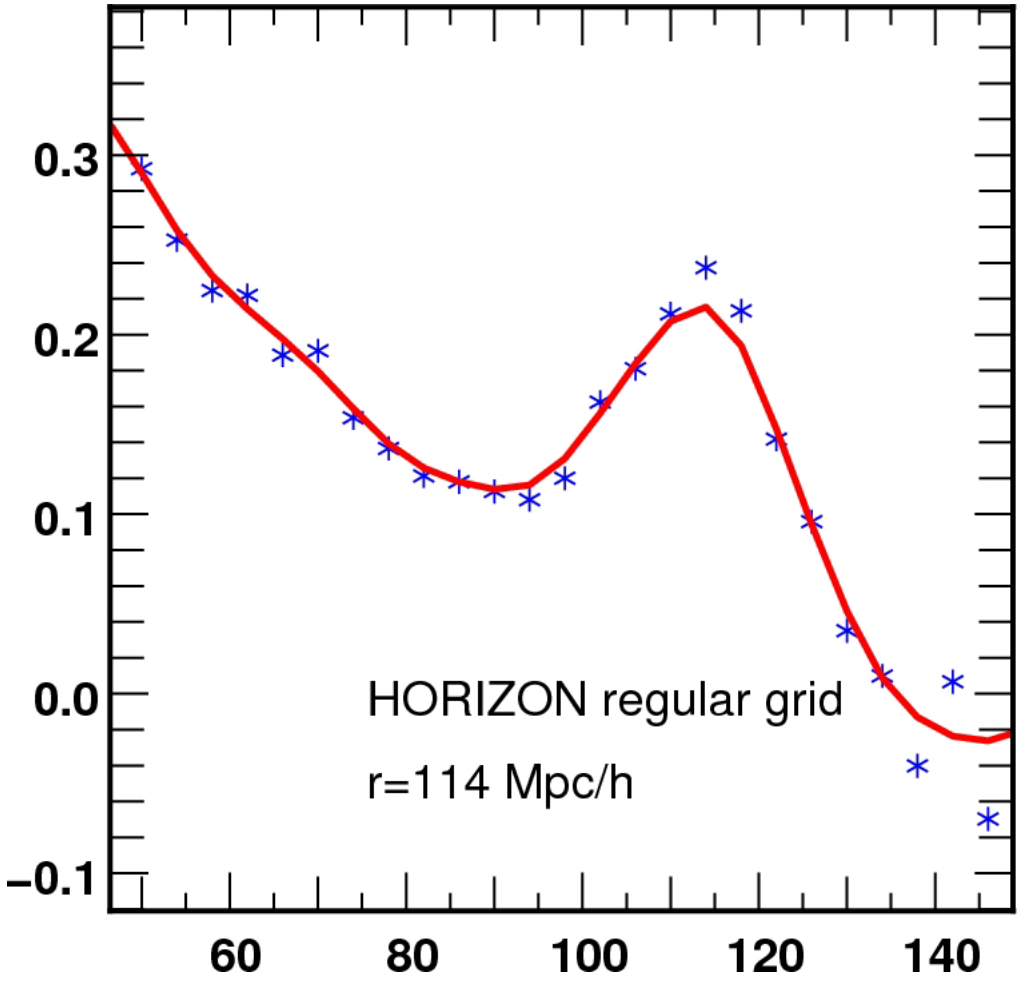


Redshift determination -> automatic procedures

Continuum determination (especially Lya forest)



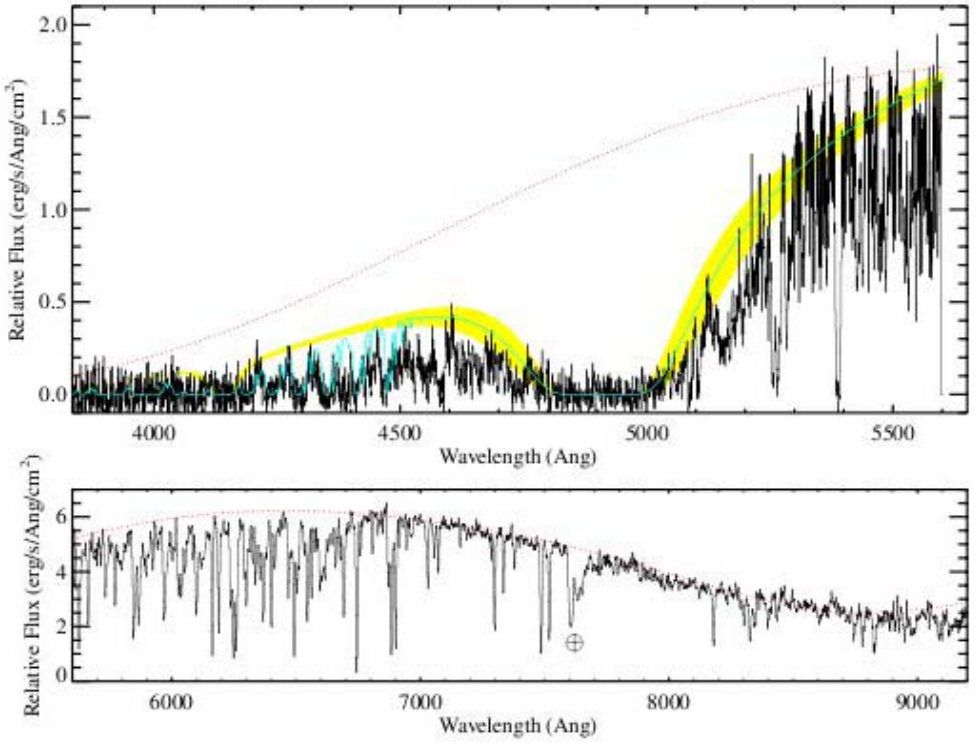
Mock surveys

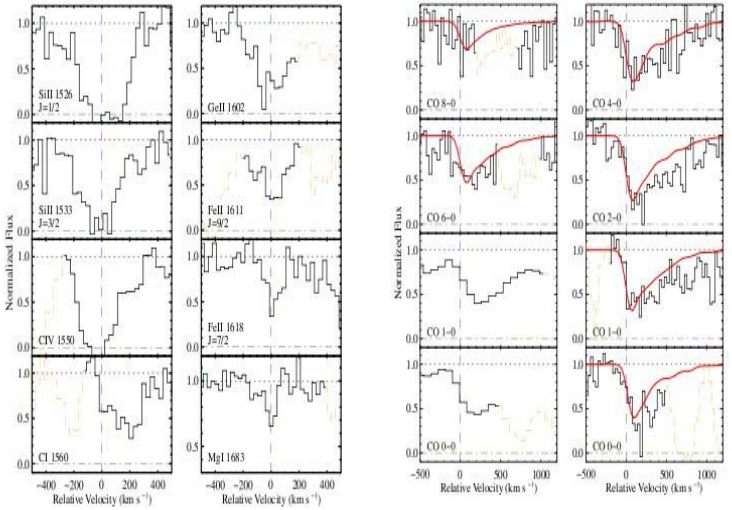


-> Test the real conditions in N-body simulations

BOSS: 160 000 quasars at z>2.2

H2 and CO in GRB080607 z=3.036





Log NHI = 22.7 Estimate of NH2 : 21.2 CO: 16.5; A(1100A) = 8 mag

Res : R=2800

Tco>100 K; 10<TH2<300K

Pb here: trade-off between resolution (UVES) and extinction (X-shooter)

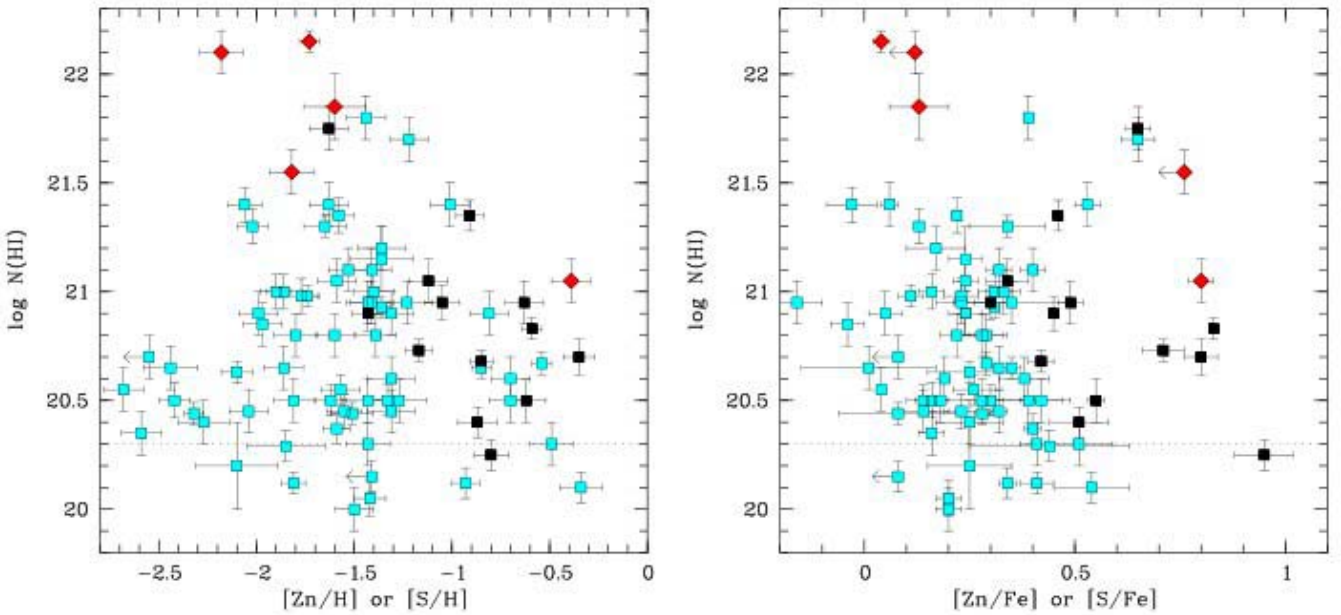
N highly uncertain

Complementarity

Prochaska et al., 2009, ApJ, 691, L27

H2 in GRBs

Ledoux et al., 2009, A&A, 506, 661



GRBs observed with UVES do not show H2 when they are expected to given metallicities and dust content => Bias ?

GRBs: Unique to correlate emission and absorption

-> SVOM

Conclusion

See you in 2014 for BOSS and the launch of SVOM…

Big-Boss : 4m telescope g=23 instead of 22

Better resolution than SDSS

Larger volume and 50-70 QSOs /sq degree