Quasars probing high-z galaxies

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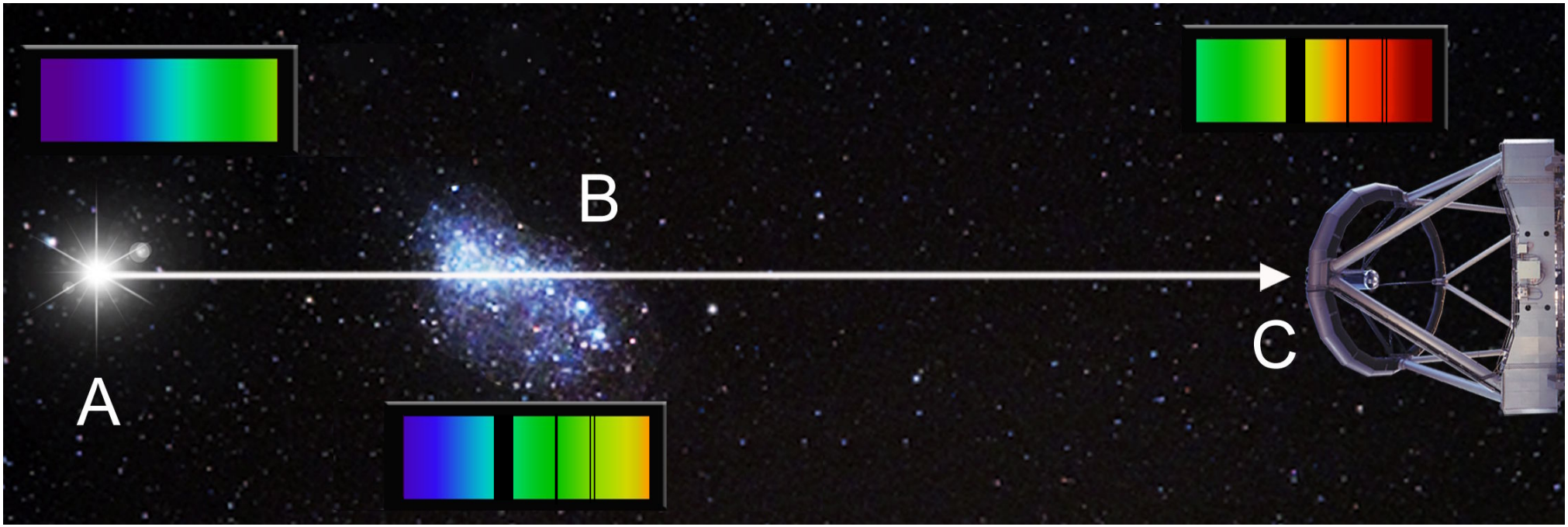
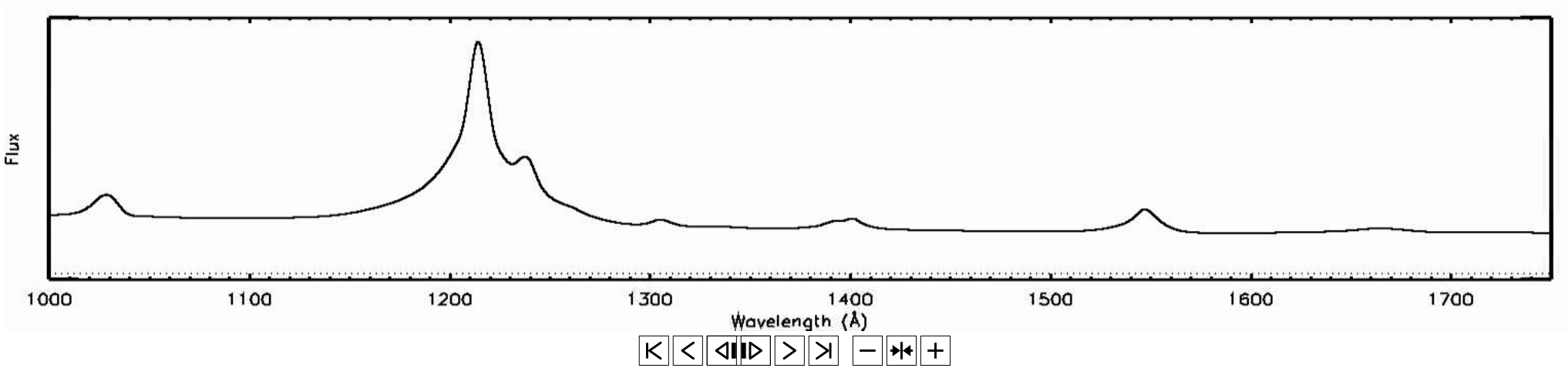
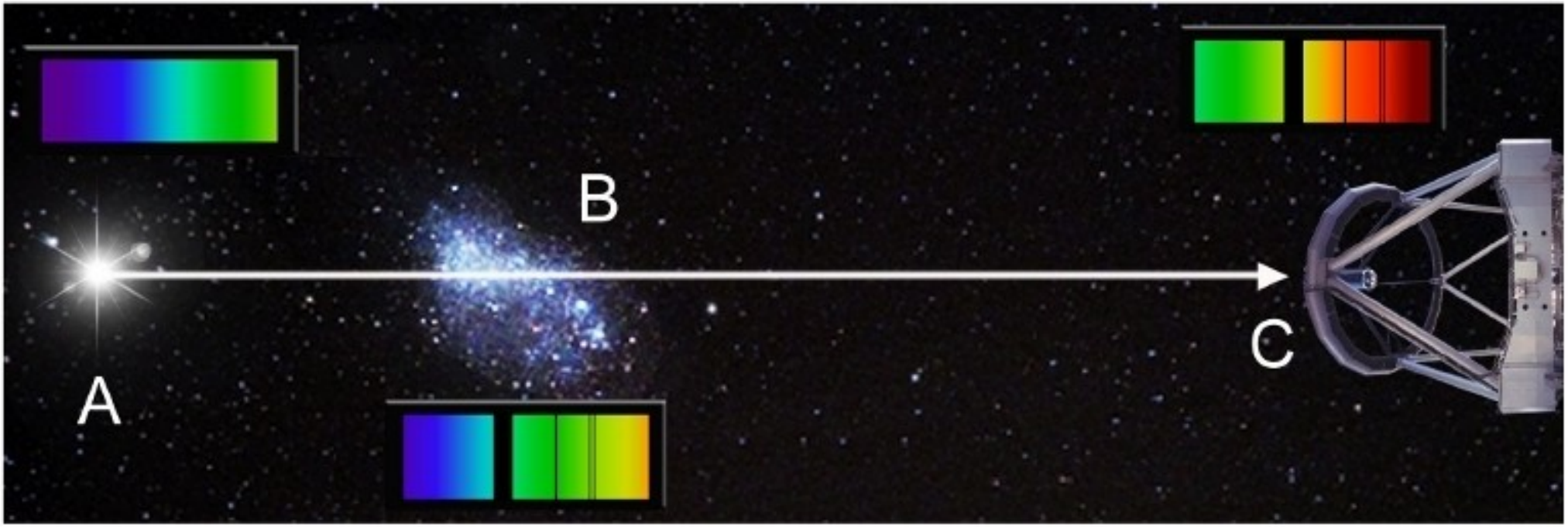
Quasar absorption lines

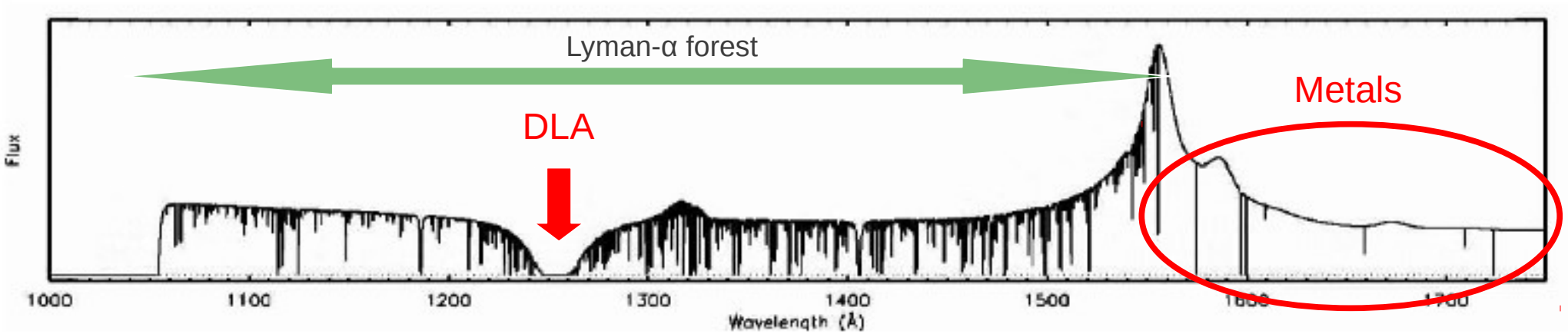


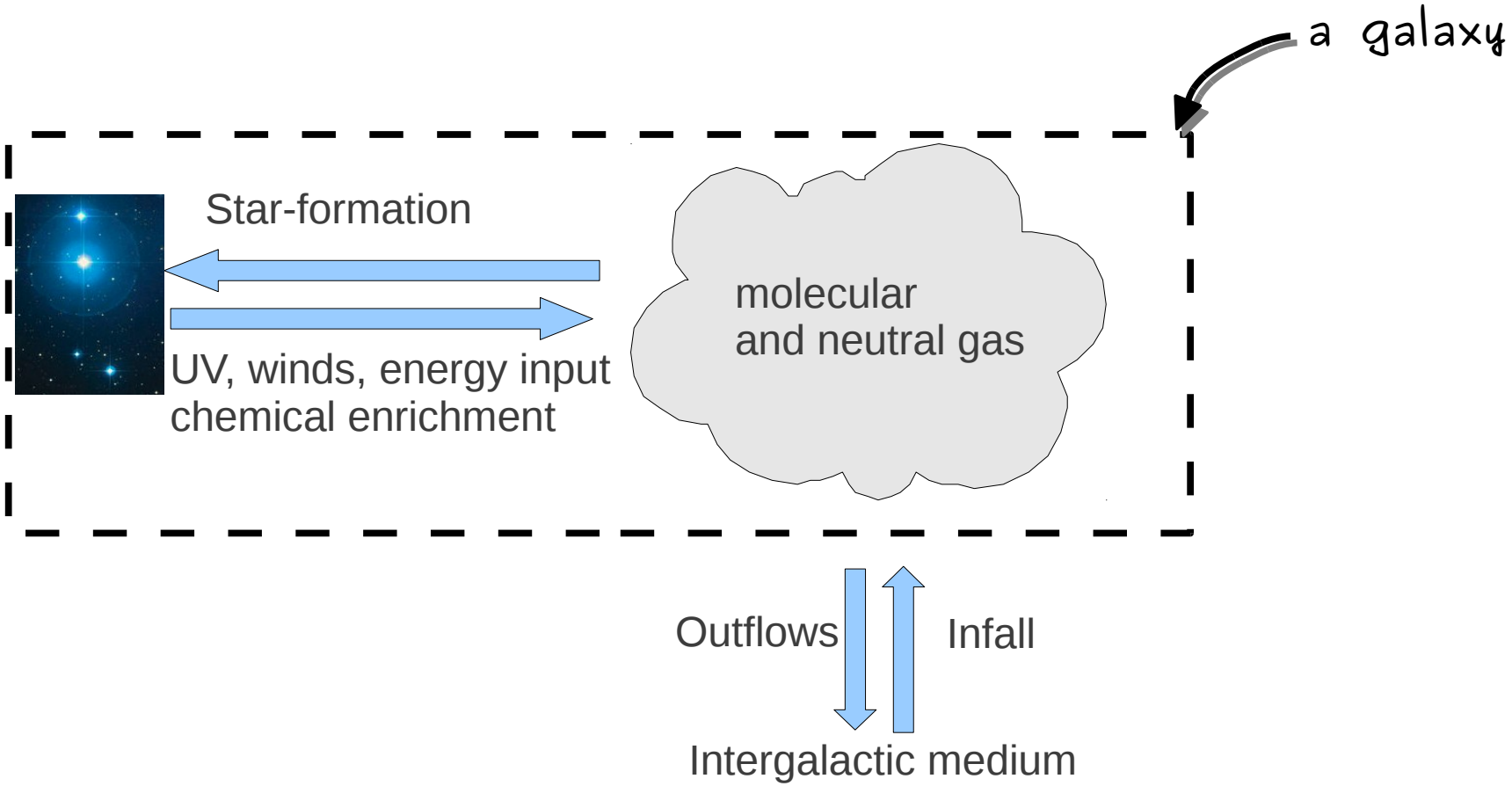
graphic: L. Fuentealba



Quasar absorption lines





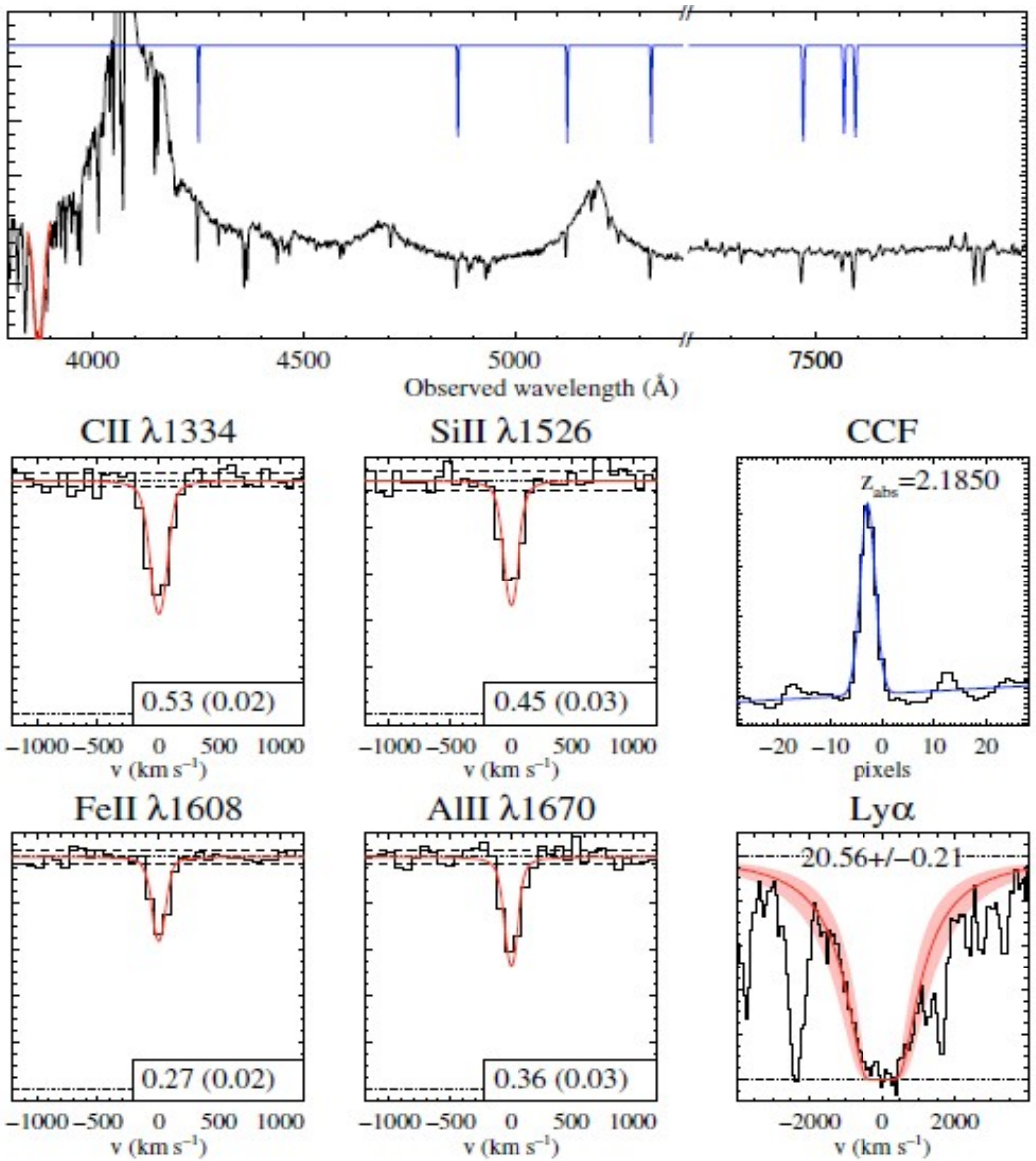


1. Amount, distribution and evolution of neutral gas?

2. Properties of the neutral ISM?

3. Link between ISM properties and host galaxy?

Search for neutral gas



Noterdaeme et al. 2009b, A&A, 505, 1087

~1000 DLAs discovered in the SDSS II – DR7: the largest database to date (not for long...)

Cosmological density of neutral gas

Mass of gas associated to a DLA

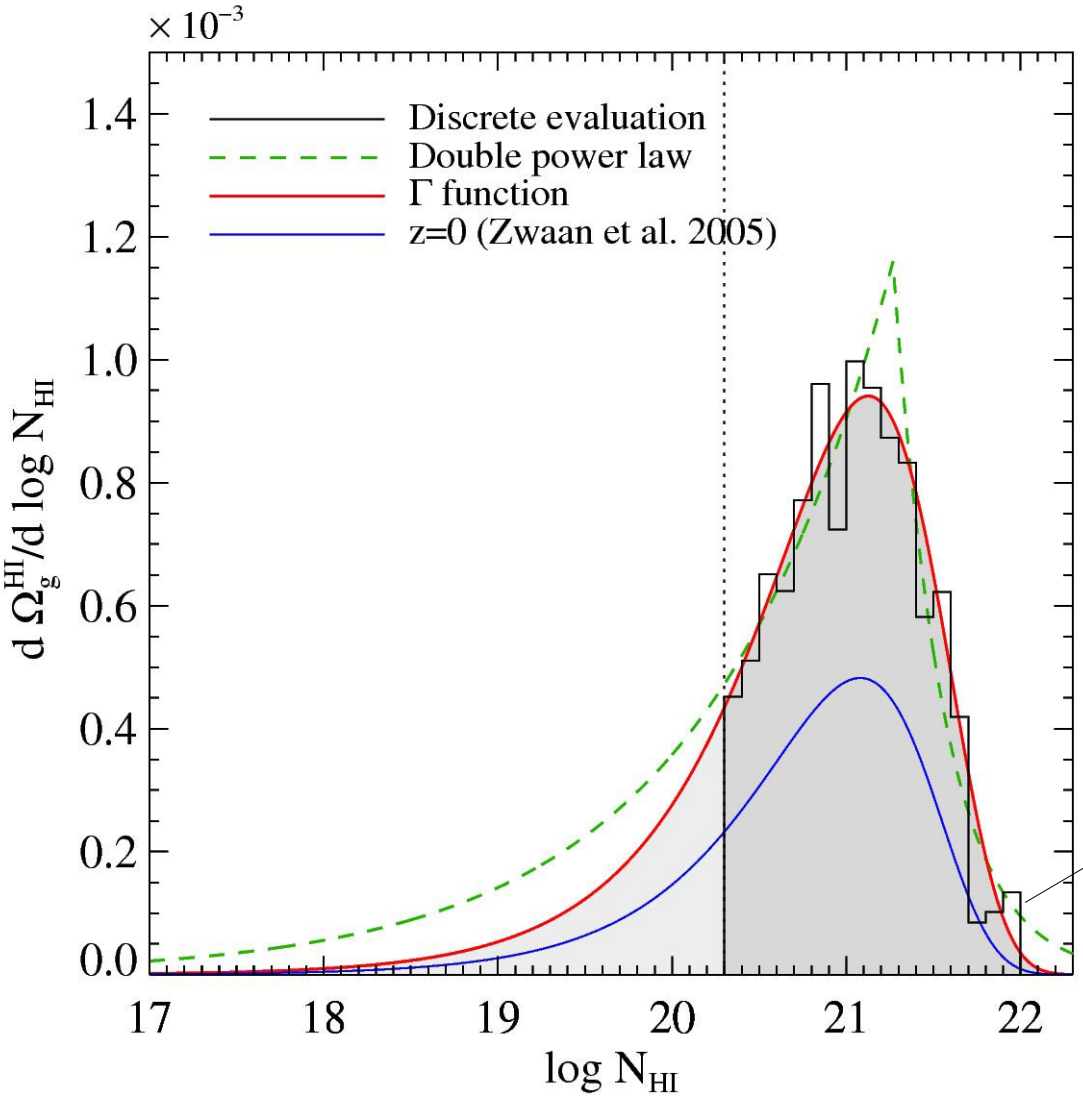
$$\Omega_{DLA} \propto n\sigma l\rho$$

$$\Omega_{DLA} \propto N(\mathrm{H\,I})d\mathcal{N}/dX$$

Does *not* depend on the nature of DLAs

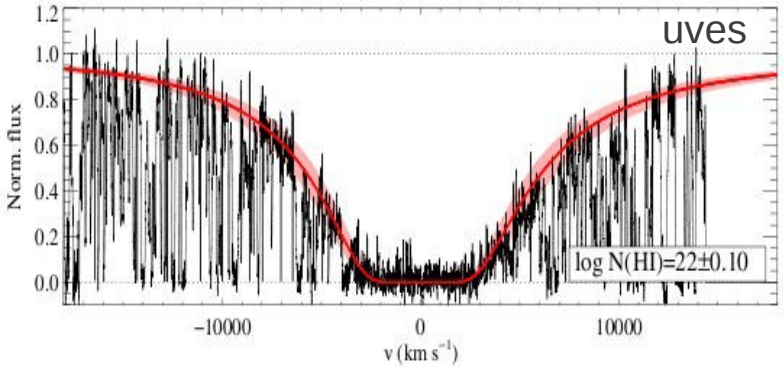
$$\Omega_g^{neut.}(X)dX = \frac{\mathrm{H}_0}{c}\frac{\mu m_\mathrm{H}}{\rho_c}\int_{N_{min}}^{N_{max}} N(\mathrm{H\,I}) f_{\mathrm{H\,I}}(N,X)dNdX \qquad \Omega_g^{\mathrm{DLA}}(X) = \frac{\mathrm{H}_0}{c}\frac{\mu m_\mathrm{H}}{\rho_c}\frac{\sum_{N(\mathrm{H\,I})\geq N_{min}} N(\mathrm{H\,I})}{\Delta X}$$

Contribution from different column densities



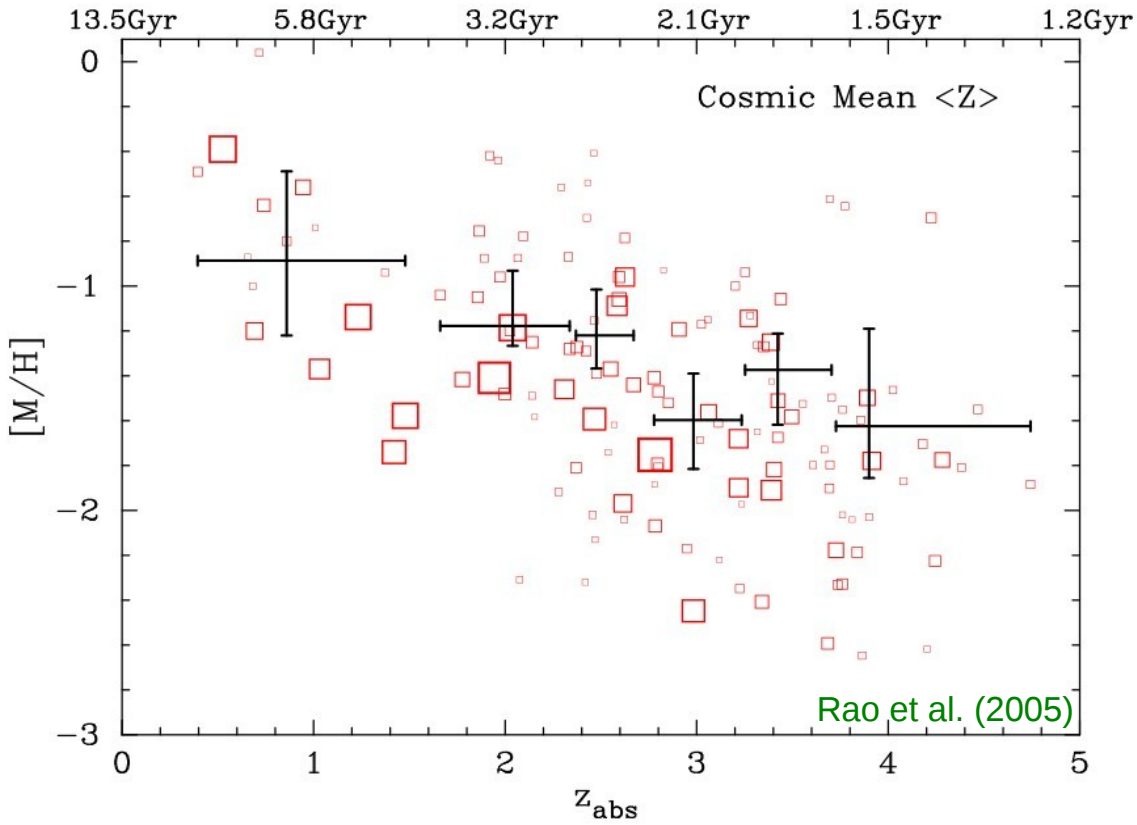
DLAs contribute ~80% of neutral gas at high-z

Same shape at z=0



Properties of the neutral ISM in distant galaxies

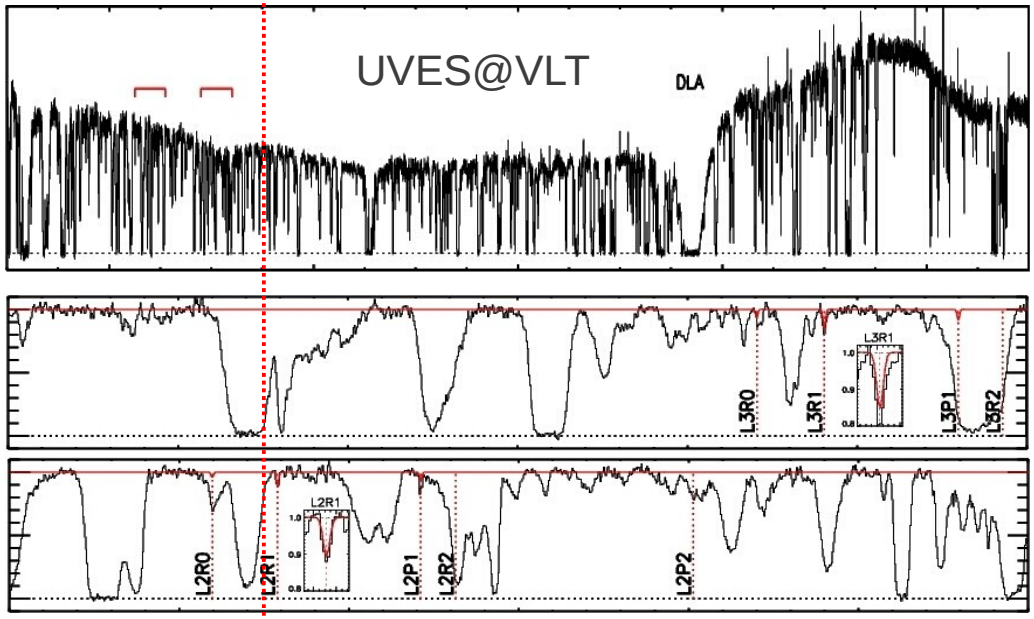
Metallicity



Abundance ratios: Stellar nucleosynthesis, dust depletion

Properties of the neutral ISM in distant galaxies

Molecules (H_2)



Physical conditions

- H_2 in 10% of the lines of sight
- Low molecular fractions

- Rotational levels of H_2: collisions, radiative excitations, shielding effects
- CI fine-structure levels: pressure,density

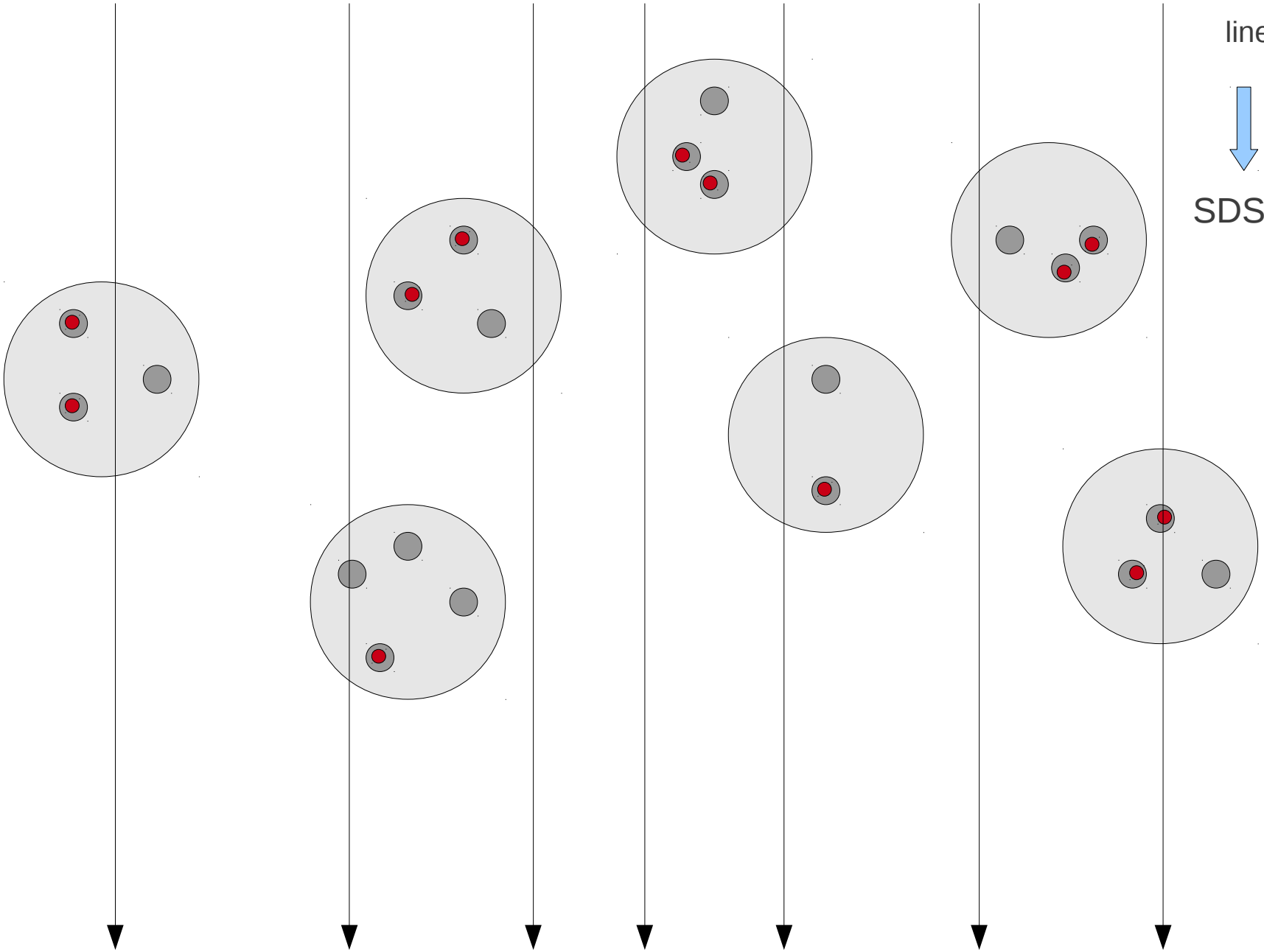
DLAs ⟹ diffuse ISM

Noterdaeme et al. 2008a, A&A, 481, 327

Noterdaeme et al. 2007a, A&A, 469, 425
Noterdaeme et al. 2007b, A&A, 474, 393

Q2

Where are denser/colder phases?



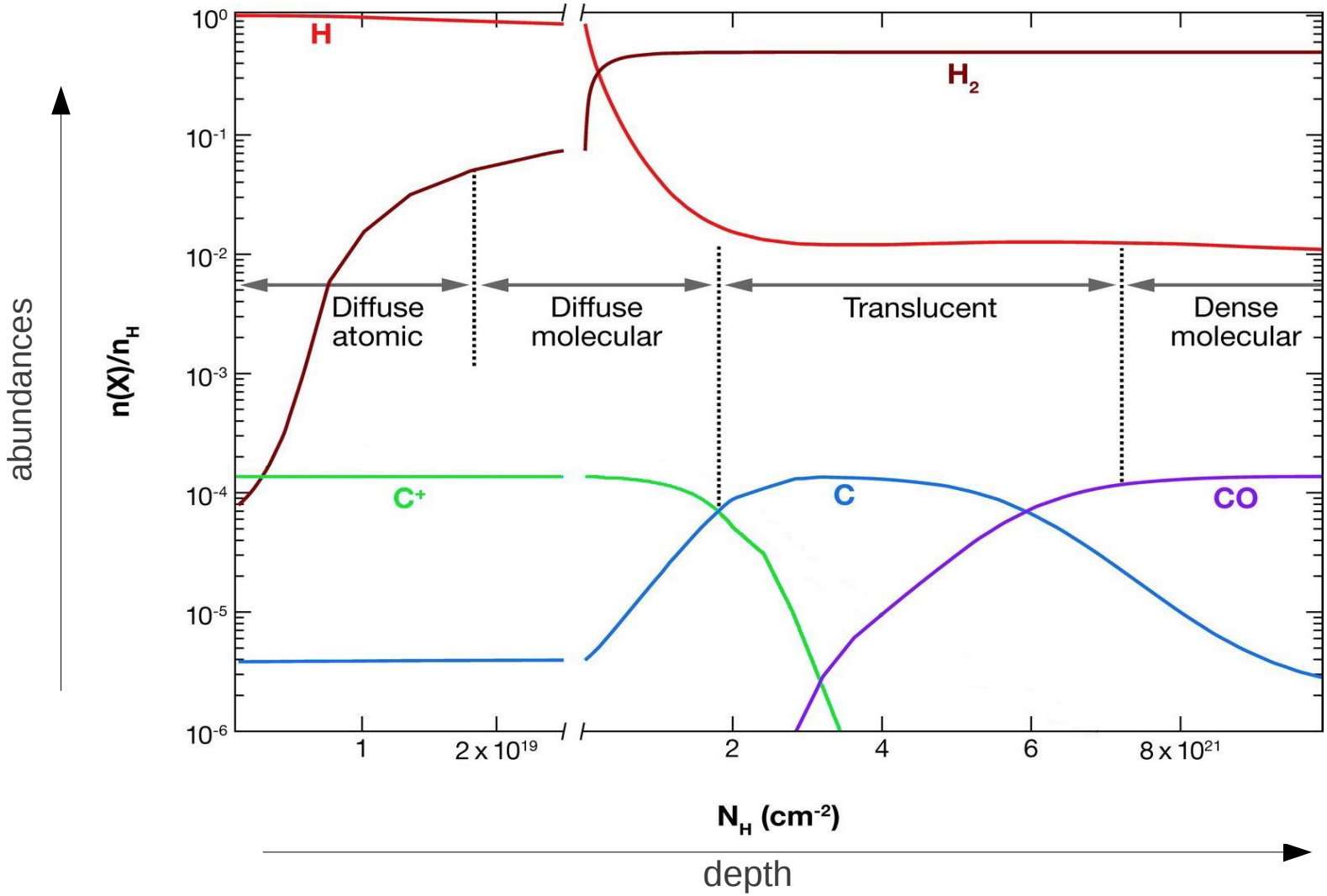
more
lines-of-sight!

SDSS → VLT

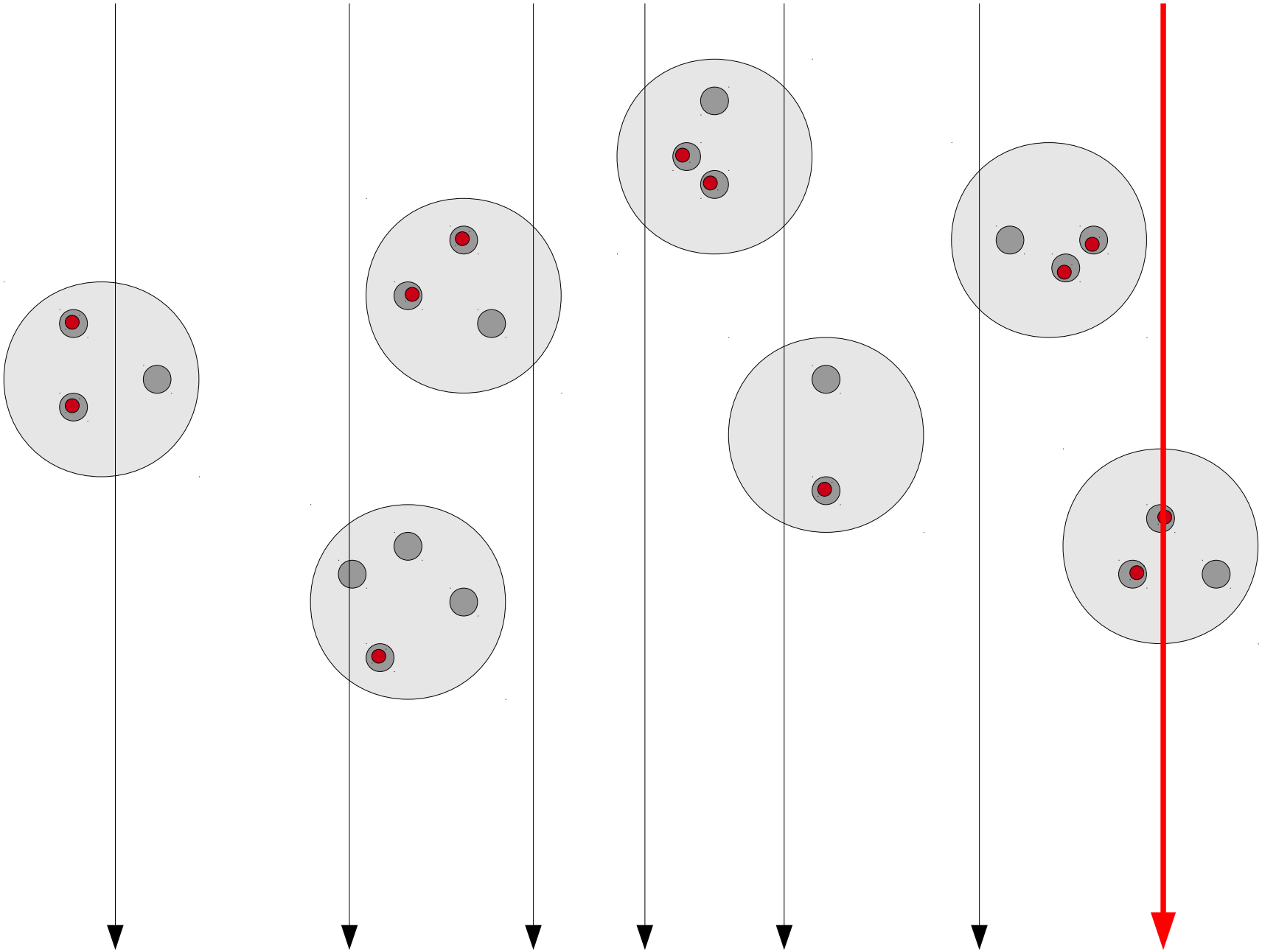
need
efficient
selection

Where are denser/colder phases?

Structure of an ISM cloud



Here they are

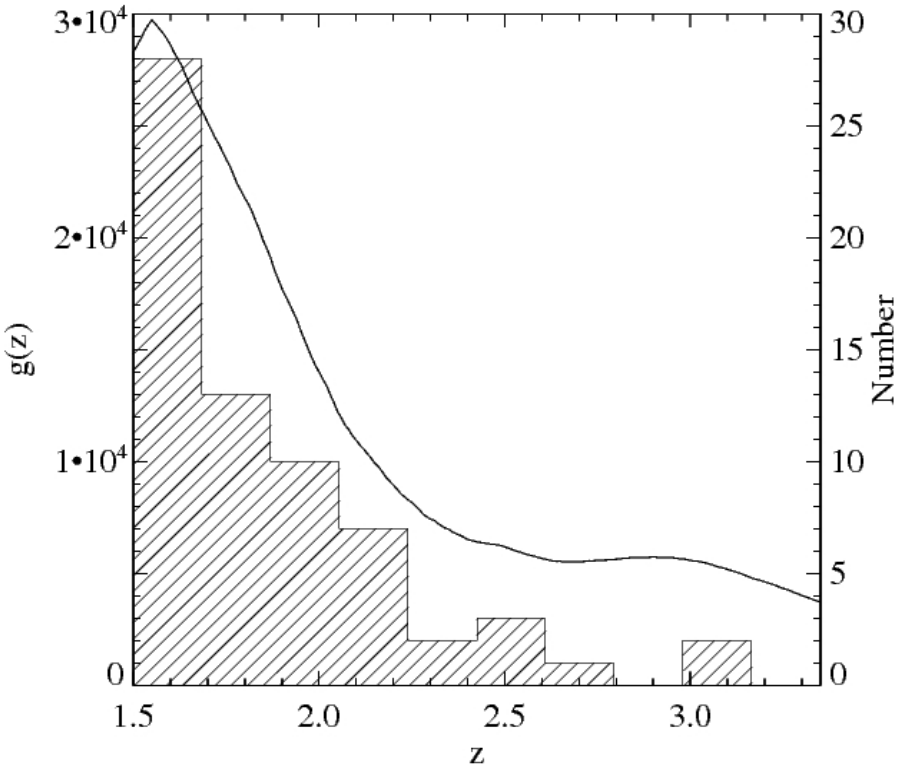


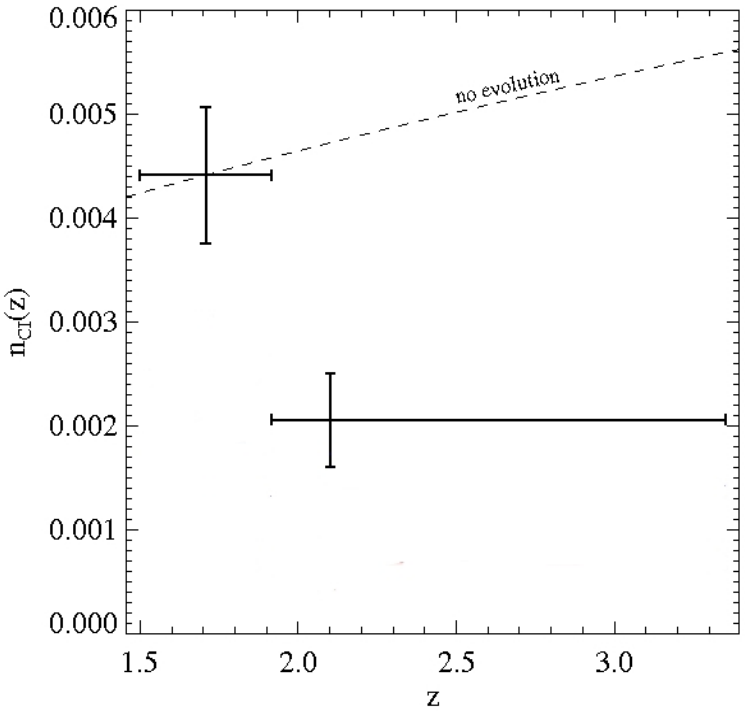
Q2

New population of QSO absorbers

1. <u>Automatic selection</u>: 40 000 quasars of the SDSS at z>1.5 → 66 CI systems

2. <u>Intensive observations</u> with UVES and Xshooter





Ledoux et al., in prep

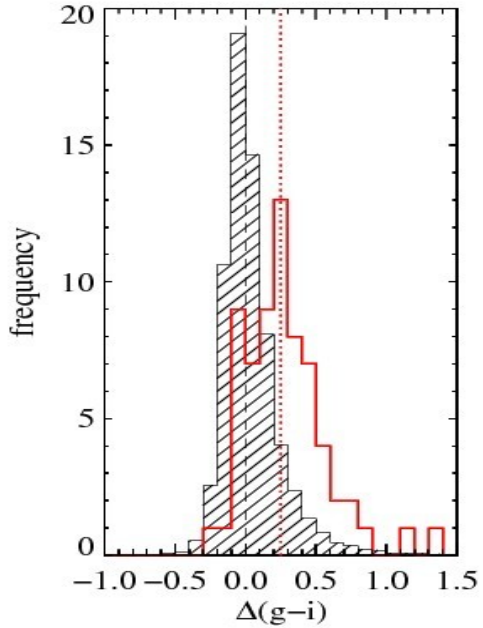
Q2

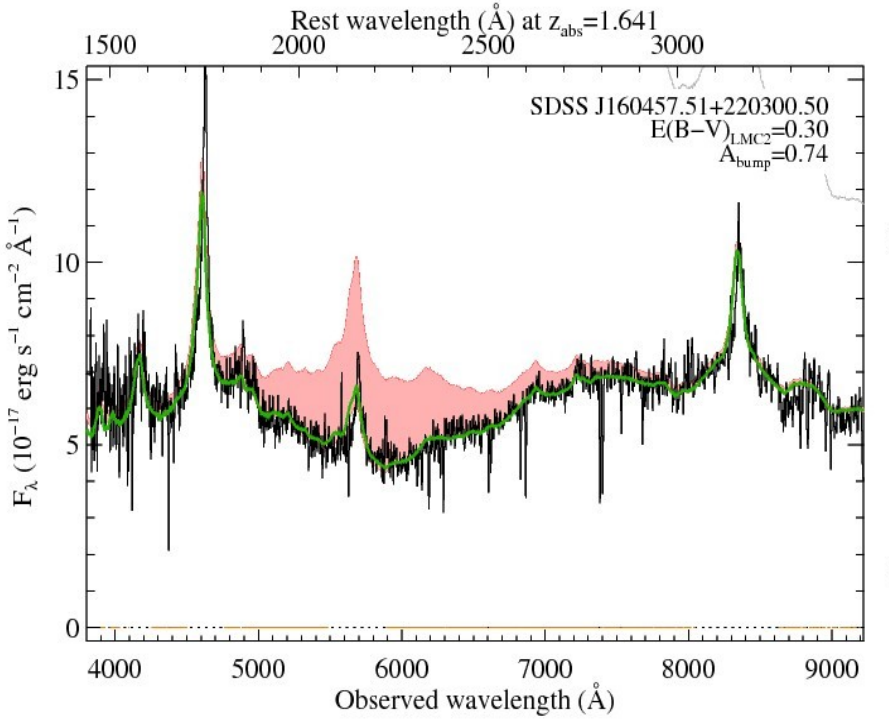
New population of QSO absorbers

1. Automatic selection: 40 000 quasars of the SDSS at z>1.5 → 66 CI systems

2. Intensive observations with UVES and Xshooter

Evidence for dust: reddening & UV bumps



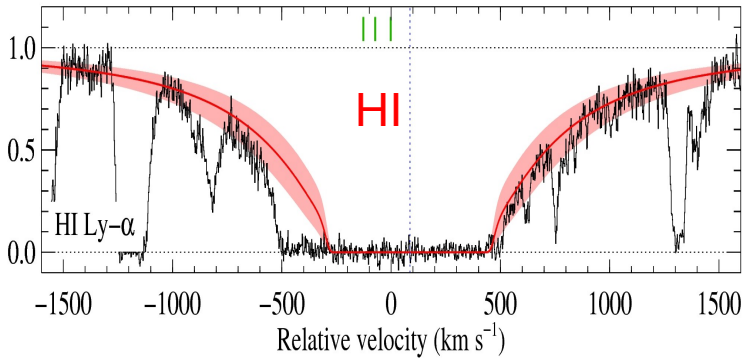


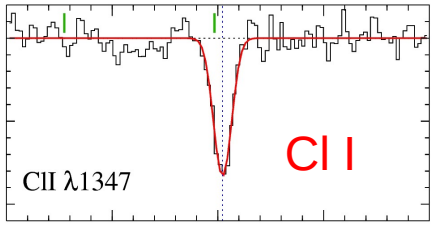
see Noterdaeme et al. 2009a, A&A, 503, 765; Ledoux et al., in prep

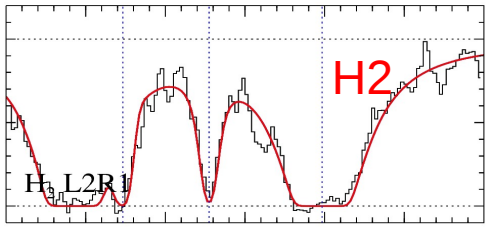
Q2

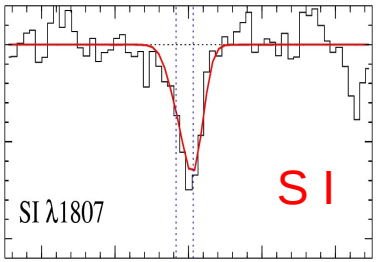
New population of QSO absorbers

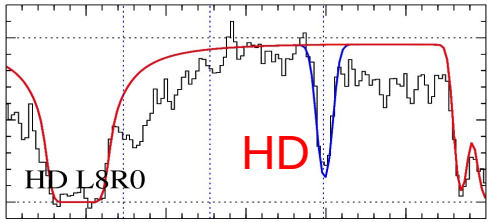
1. Automatic selection: 40 000 quasars of the SDSS at z>1.5 → 66 CI systems
2. **Intensive observations with UVES and Xshooter** ISM chemistry at high-z!

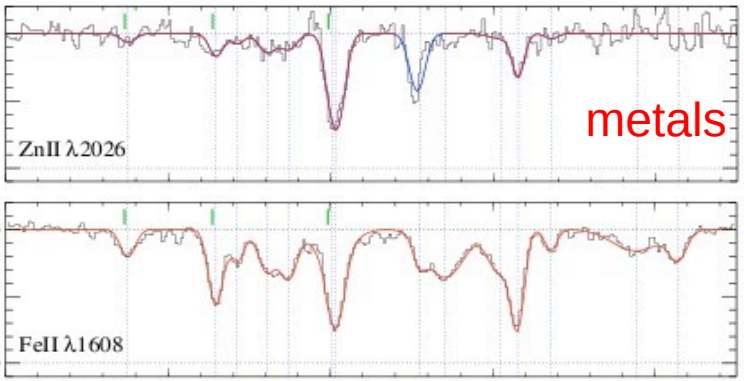


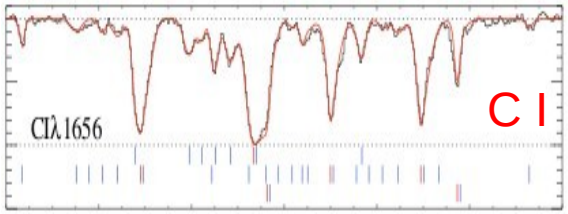


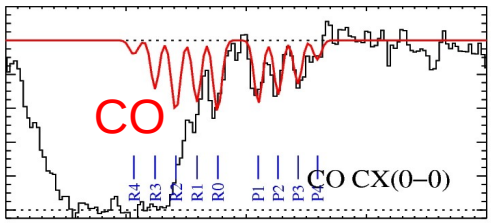






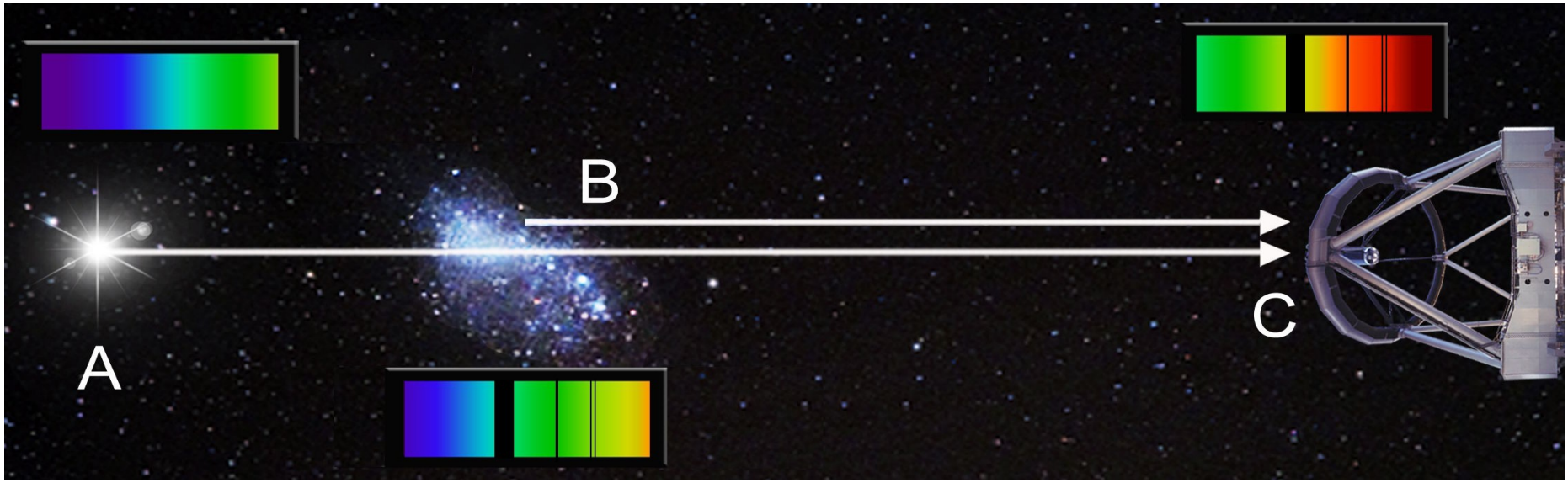






Noterdaeme et al., 2010b, A&A, 523, A80
Srianand et al. 2008a, A&A, 482, L39
Noterdaeme et al., 2009a, A&A, 503, 765

Search for galaxy counterparts

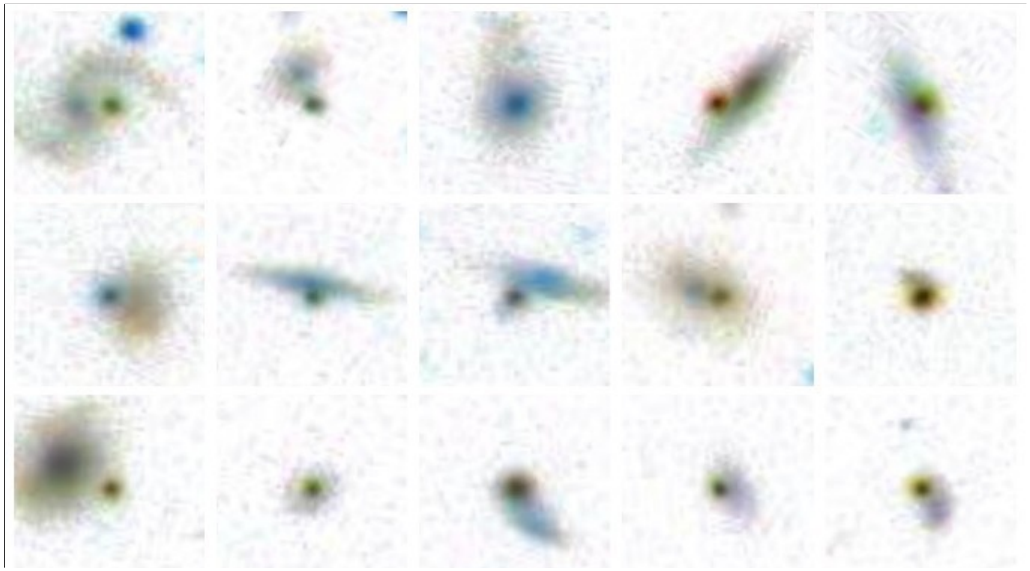


QUESTIONS: Nature of DLA galaxies?
Star-formation rates?
Physical extent?
Impact parameters?
Kinematics?

Q3

Search for galaxy counterparts

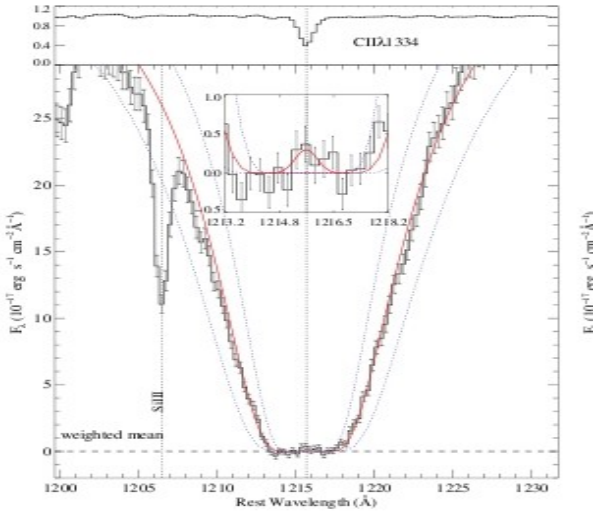
low and intermediate z



(see Noterdaeme et al. 2010a)

Idea no 1: stack spectra

high-z

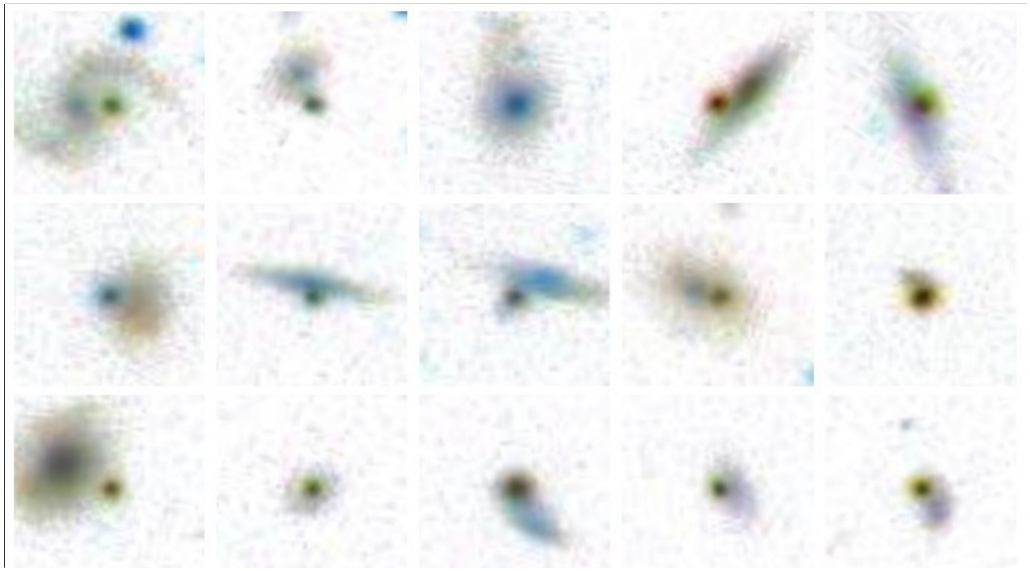


Rahmani et al. 2010

Q3

Search for galaxy counterparts

low and intermediate z



(see Noterdaeme et al. 2010a)

high-z

Idea no 2: target high-metallicity DLAs

Velocity – Metallicity relation (Ledoux et al. 2006)

↓

Mass – Metallicity

↓

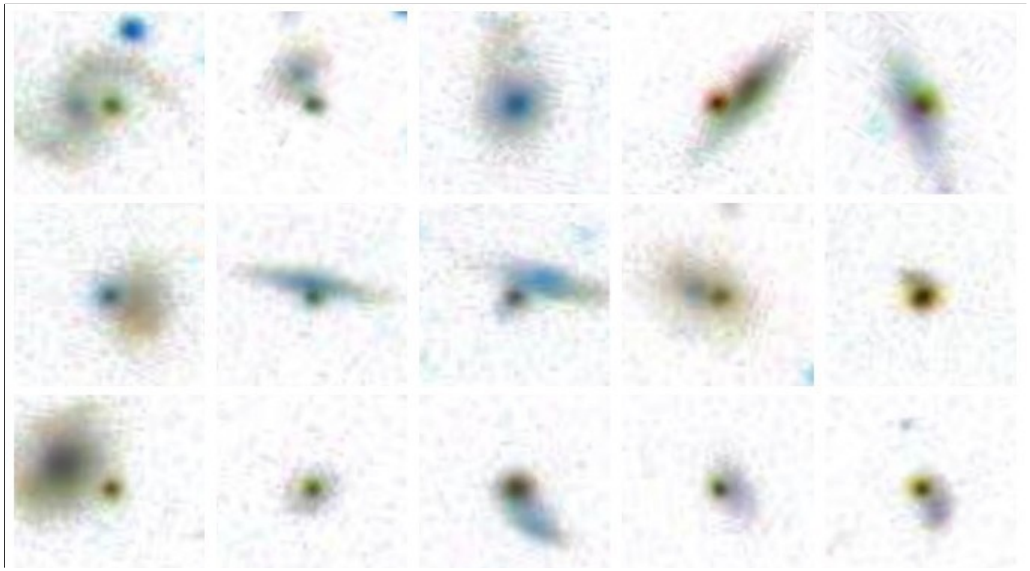
Luminosity - Metallicity

Results: 3 detections (Fynbo et al. 2010, Fynbo et al. 2011, in prep)

Q3

Search for galaxy counterparts

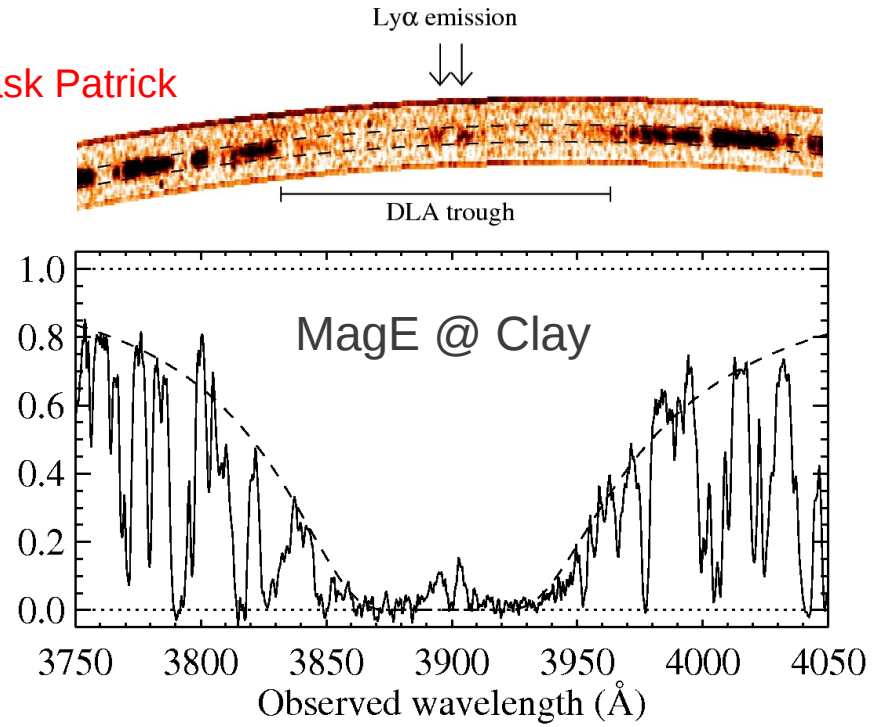
low and intermediate z



(see Noterdaeme et al. 2010a)

Idea no 3: ask Patrick

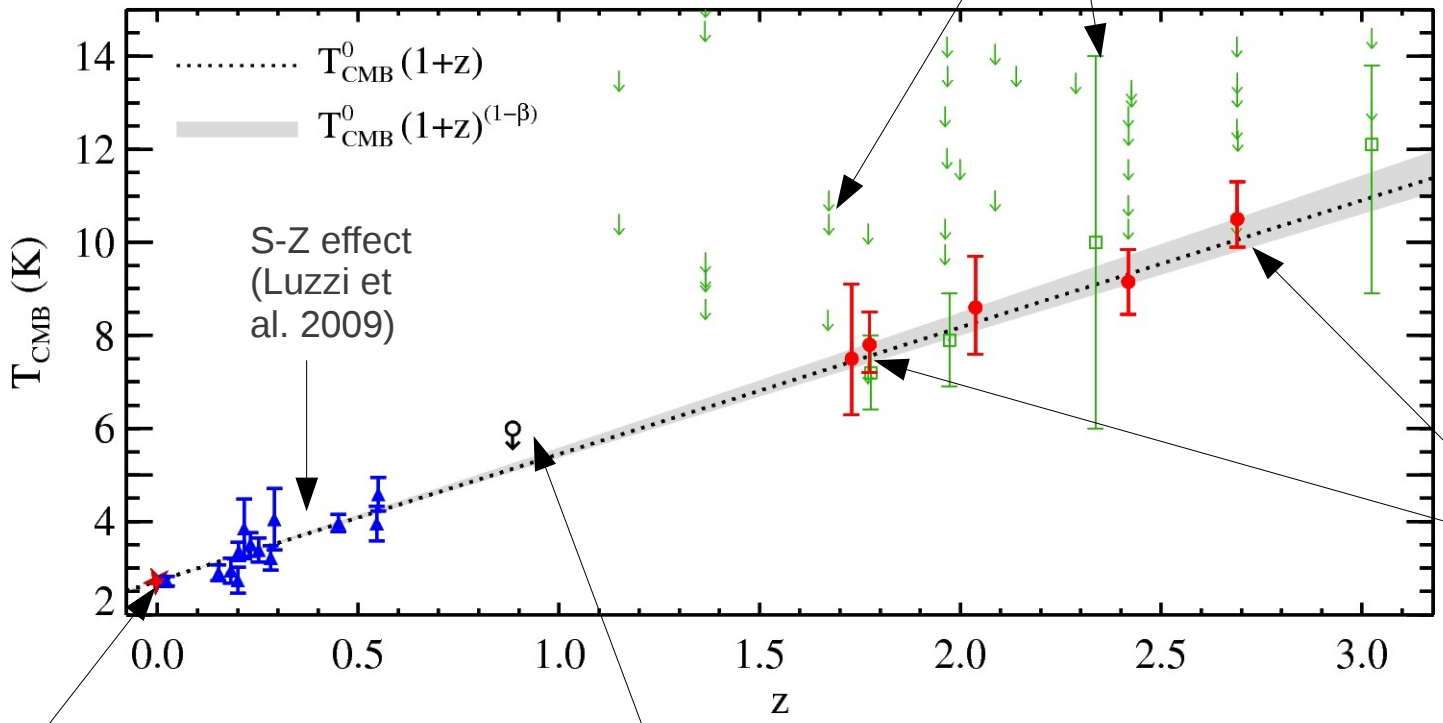
high-z



Evolution of the Cosmic Microwave Background temperature

atomic carbon (Songaila et al. 1994, Cui et al. 2005, Ge et al. 1997, Srianand et al. 2000, Molaro et al. 2002)

Strongly supports the adiabatic cooling of the Universe (β=-0.007+/-0.027)



CO

Molecules (sub-mm, CEST): Wiklind & Combes 1996

COBE (Mather et al. 1999)
T=2.725+/-0.002 K

CN at z=0 (Herzberg 1950): "From the intensity ratio of the lines with K=0 and K=1 a rotational temperature of 2.3 K follows, which has of course only a very restricted meaning."

Noterdaeme et al. 2011, A&A, 526, L7

Conclusion

thank you!