Probing the high redshift galaxy formation and evolution using QSO absorption systems

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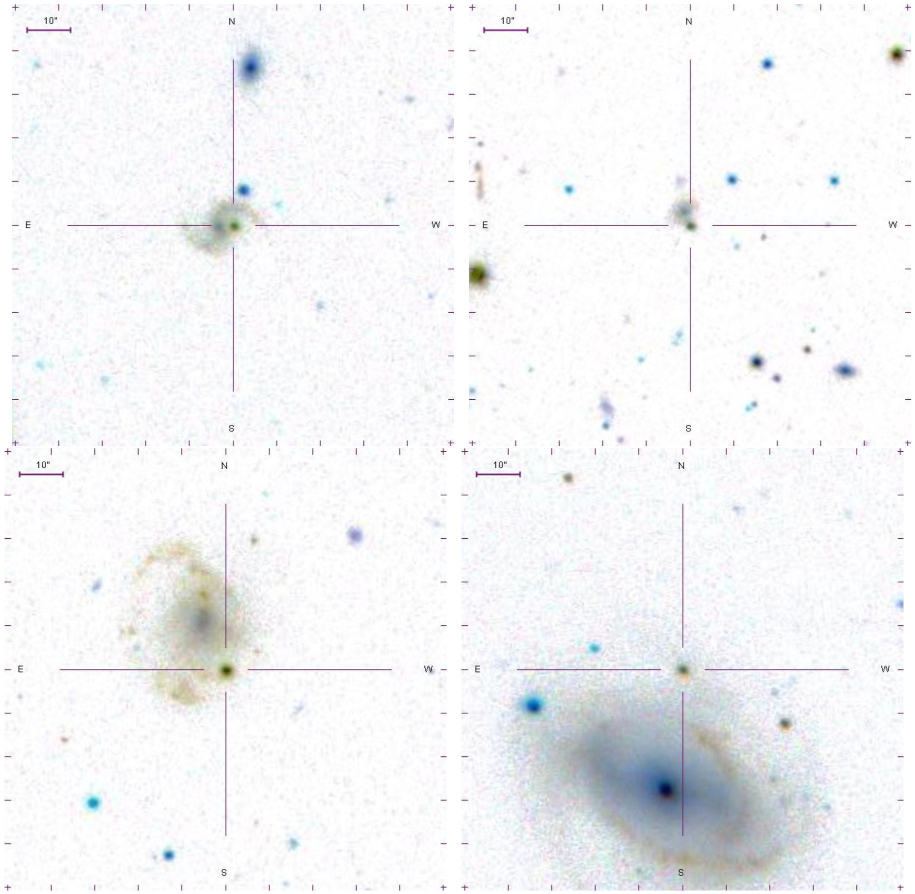
Outline of this talk:

- Low-z QSO-Galaxy Pairs ($z <$0.2)
- Mg II absorbers ($0.3 \leq z \leq 2.0$)
- Damped Lyman-α systems ($2.0 \leq z \leq 4.5$)
- Constraints on Ω_b: D/H and HD/2H_2.
- Variations of fundamental constants

QSO-Galaxy Pairs:



QSO-Galaxy Pairs: Ca II absorption

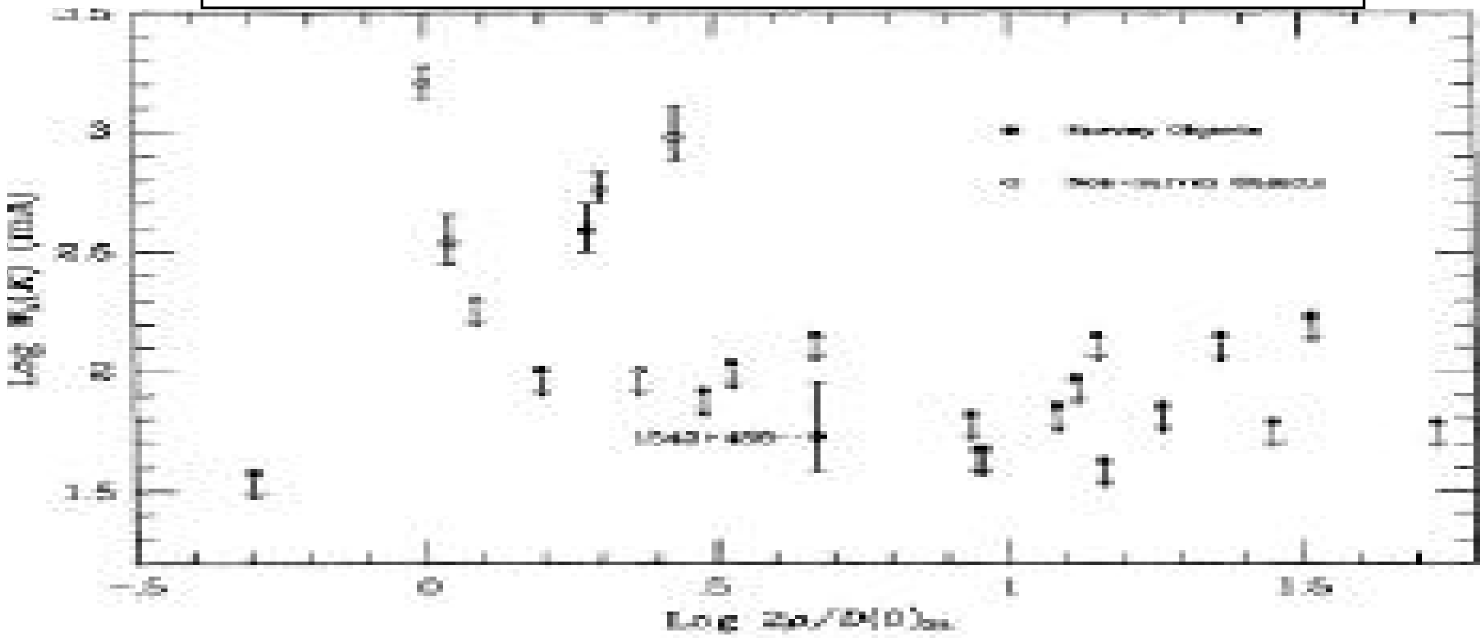


Figure 5. Plot of $\log[2\rho/D(0)_{25}]$, where $D(0)_{25}$ is the galaxy's optical diameter, versus $\log W_\lambda(K)$. Symbols have the same meaning as in Fig. 4. Apart from 1543+489, all cases of absorption are confined to within −1 and 3 $D(0)_{25}/2$, or about 0.8 of 2.3 Holmberg radii of the galactic centres. However, there are several cases of sight-lines within this value which do not show absorption, even to equivalent-width limits well below those of the positive detections.

Bowen et al. 1991, MNRAS, 249, 145

QSO-Galaxy Pairs:

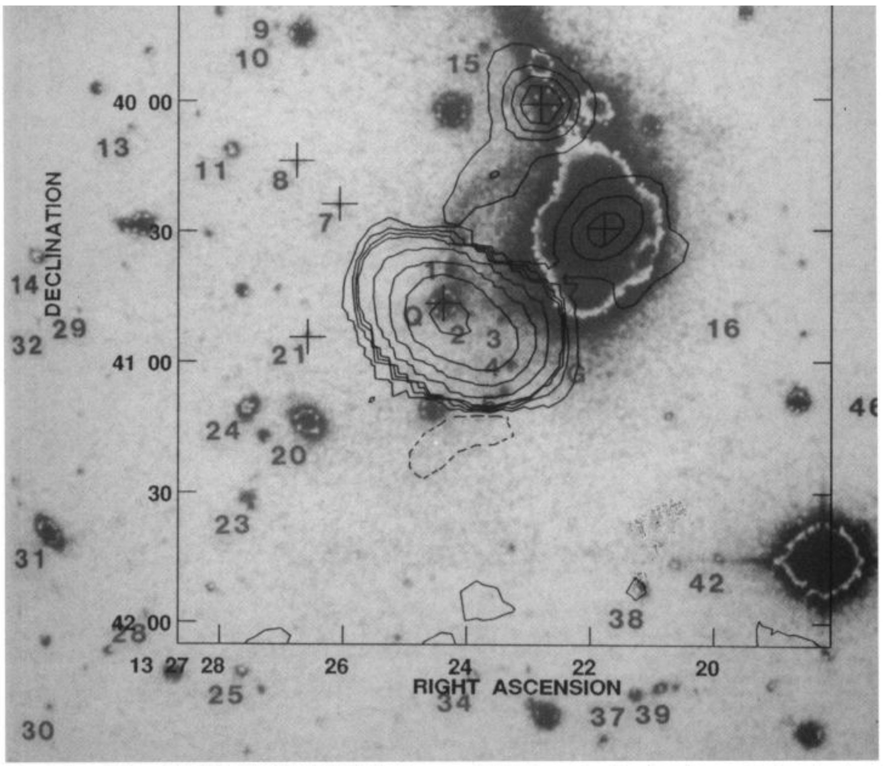


FIG. 1.—An optical image of PKS 1327−206—ESO 1327−2041 from Bergeron et al. (1987). Contours show the radio continuum emission from the galaxy and the quasar at 1.4 GHz, 12" resolution. Contour levels are −0.8, 0.8, 1.6, 2.4, 3.2, 9.7, 29, 81, and 234 mJy beam^{-1}. Crosses mark the position of the optical quasar (also marked with a Q), the galaxy center, and the peak of the radio continuum emission from the "tail" to the north, as well as three stars to the east of the galaxy used for astrometry.

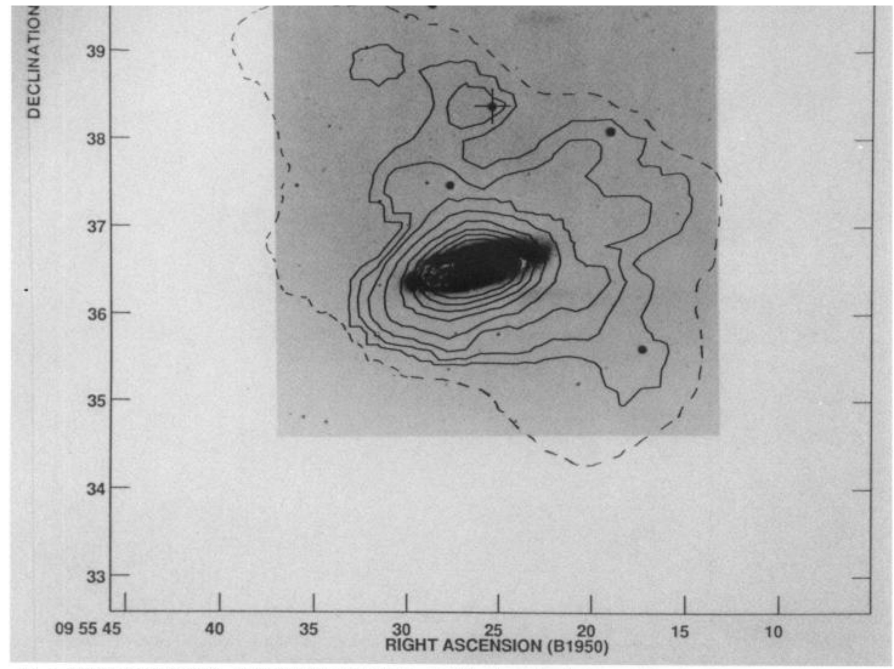
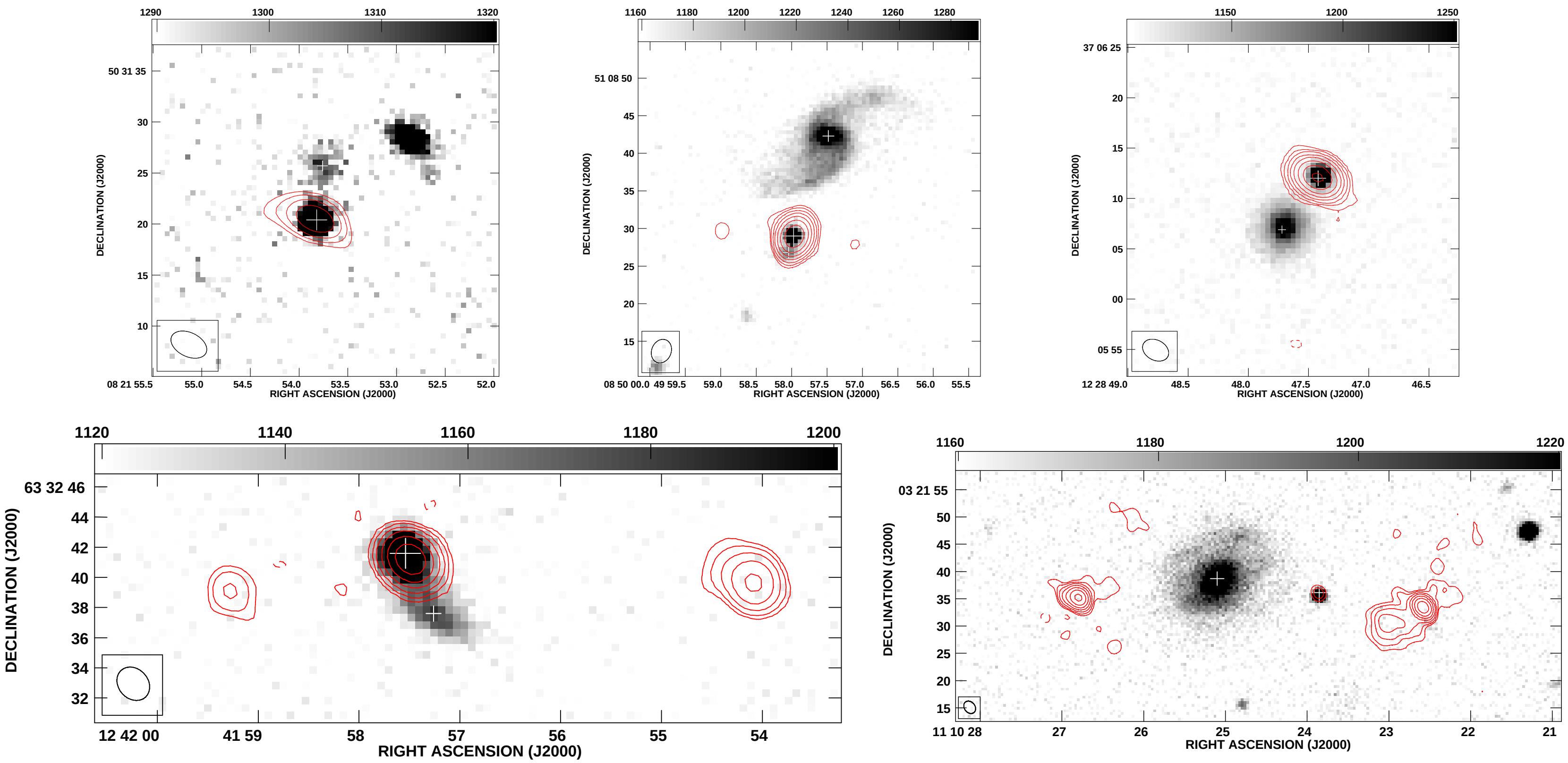


FIG. 5.—An optical image of 3C 232—NGC 3067 (kindly supplied by H. Arp). The contours show the integrated H I column density for NGC 3067. The solid contours are for data at 30" resolution. The dotted contour is for data at 50" resolution. Solid contour levels are 2.4, 6.1, 12, 24, 49, 73, 98, 122, 184 × 10^{19} atoms cm^{-2}. The dotted contour level is 2.2 × 10^{19} atoms cm^{-2}. A cross marks the position of the quasar.

CARILLI & VAN GORKOM (see 399, 375)

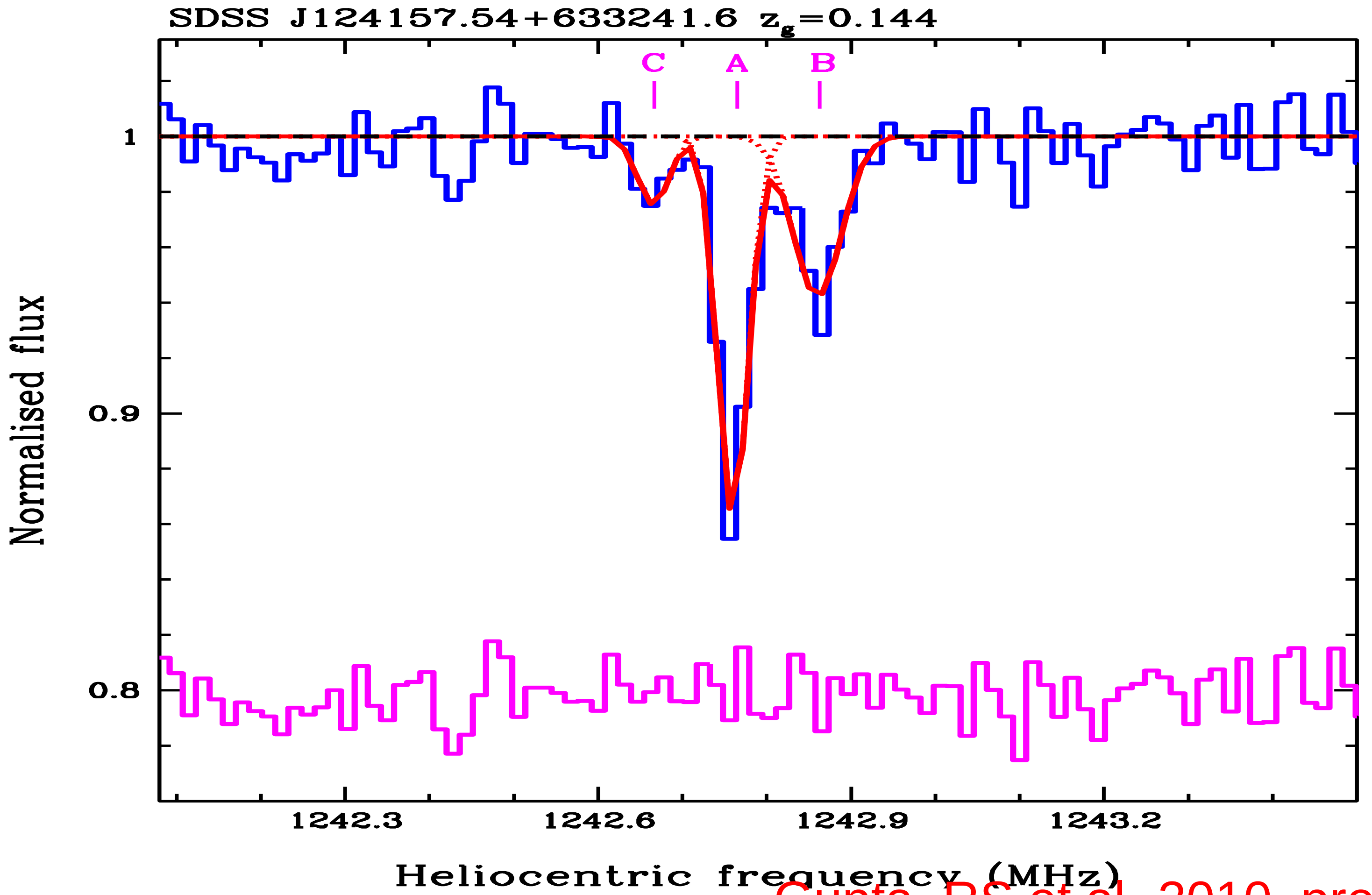
Carilli & Van Gorkom 1992,ApJ, 399, 373

QSO-Galaxy Pairs: GMRT mini-survey



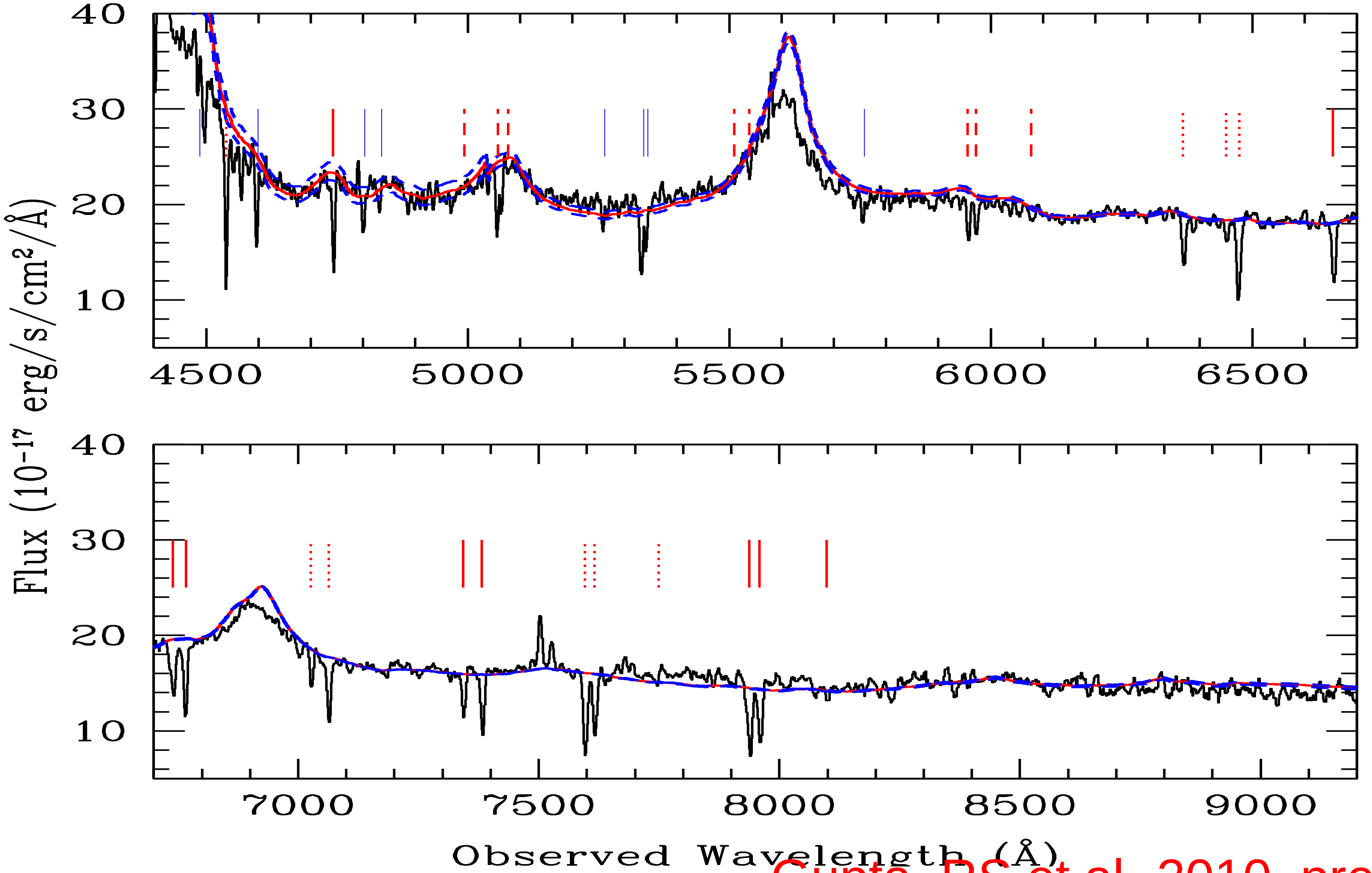
Gupta, Srianand, Bowen, Roy, Wadadekar & York 2010, preprint

QSO-Galaxy Pairs: GMRT detections



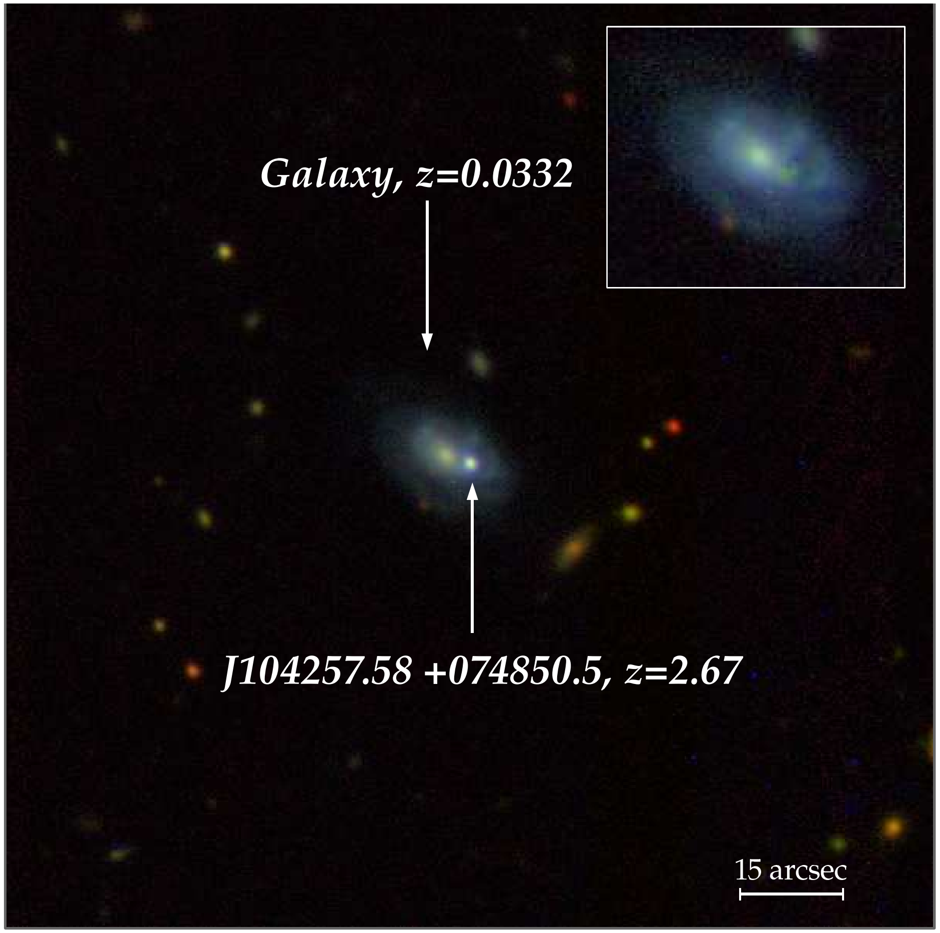
Gupta, RS et al. 2010, preprint

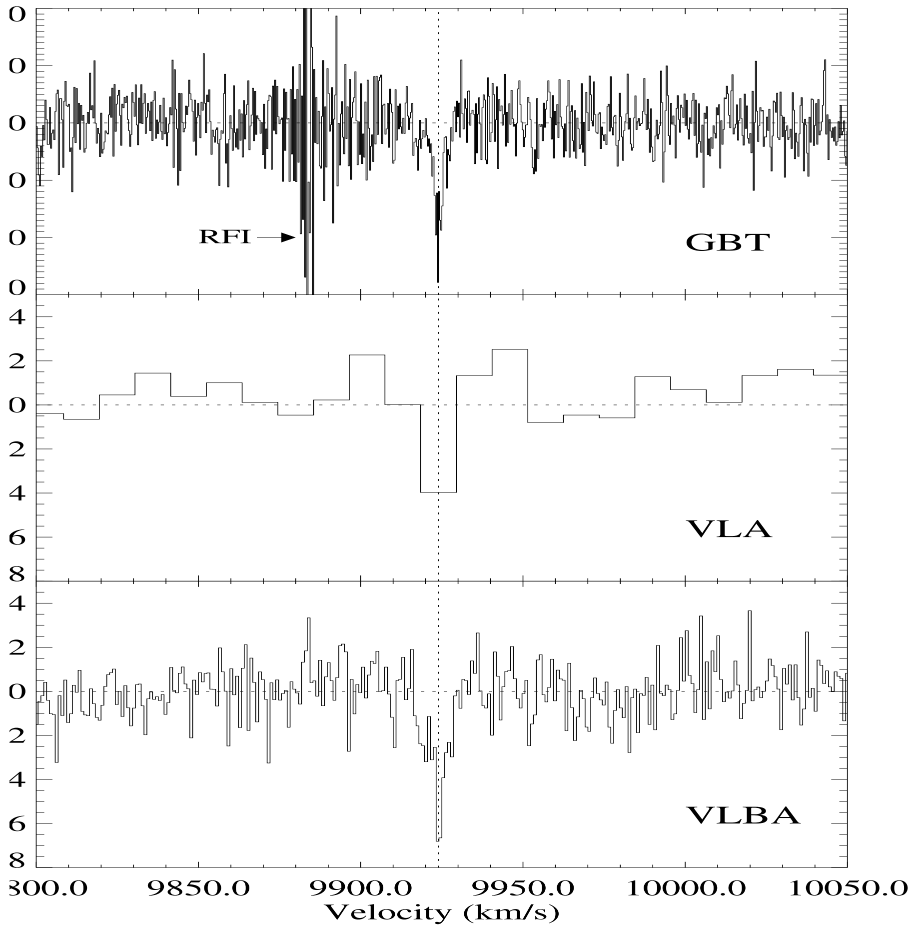
QSO-Galaxy Pairs: GMRT detections



Gupta, RS et al. 2010, preprint

QSO-Galaxy Pairs: 21-cm

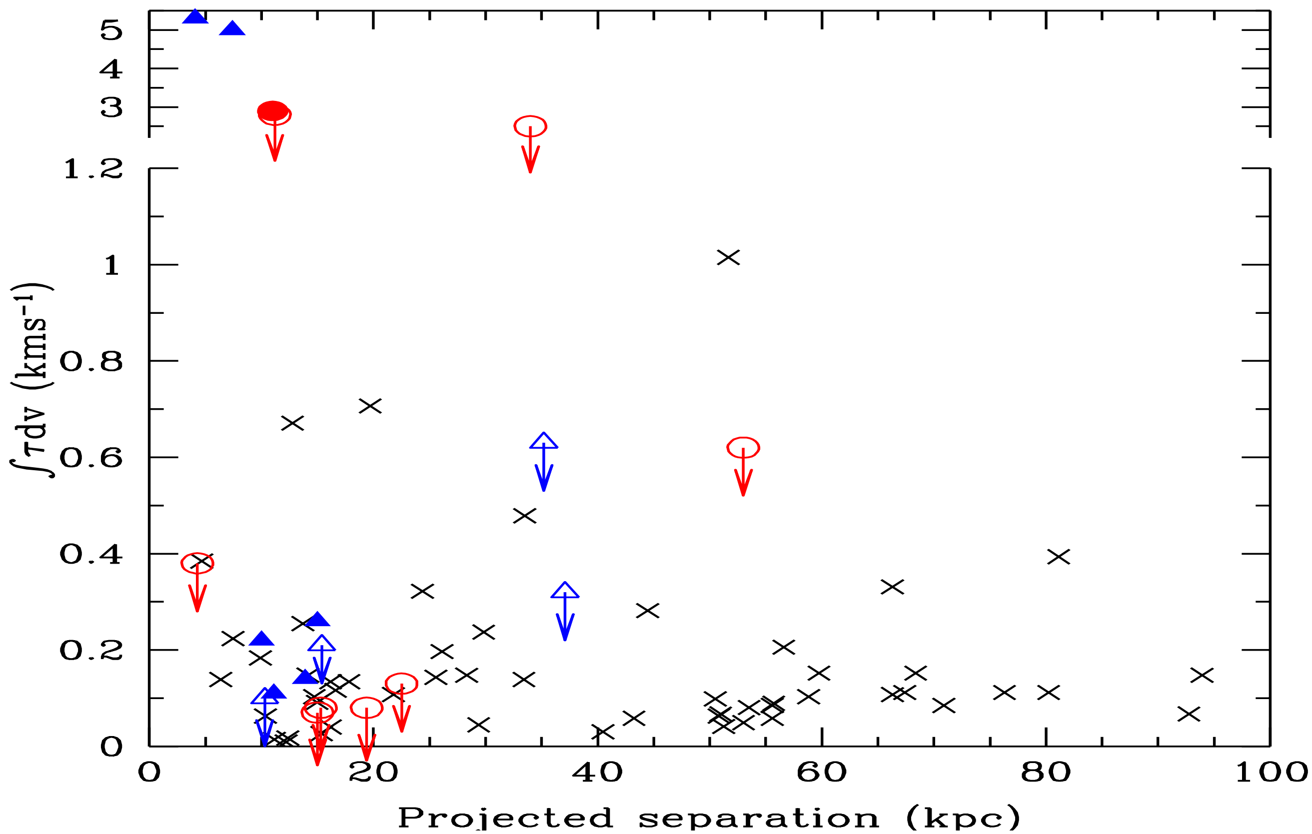




Borthakur et al. 2010, arXiv:0912.2575

QSO absorber-Galaxy Pairs: 21-cm

Gupta, RS et al. 2010, preprint

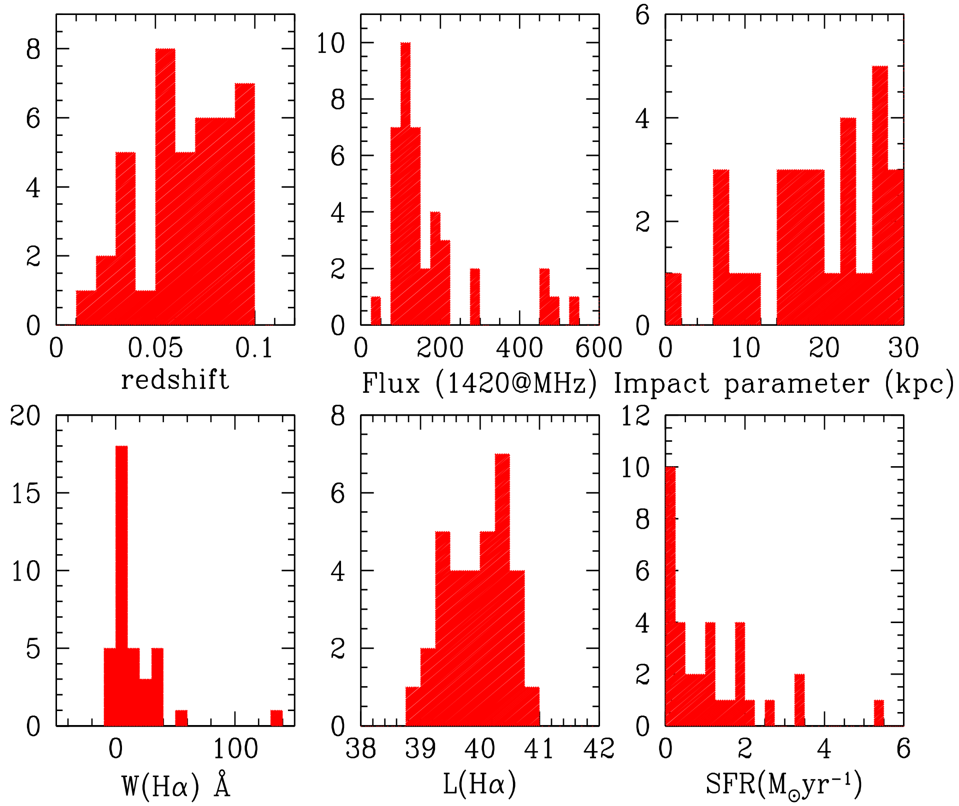


Data points: Boisse et al. (1988), Carilli & Van Gorkom (1992), Hwang & Chiou (2004) and Haschick et al. (1980)

QSO absorber-Galaxy Pairs: 21-cm

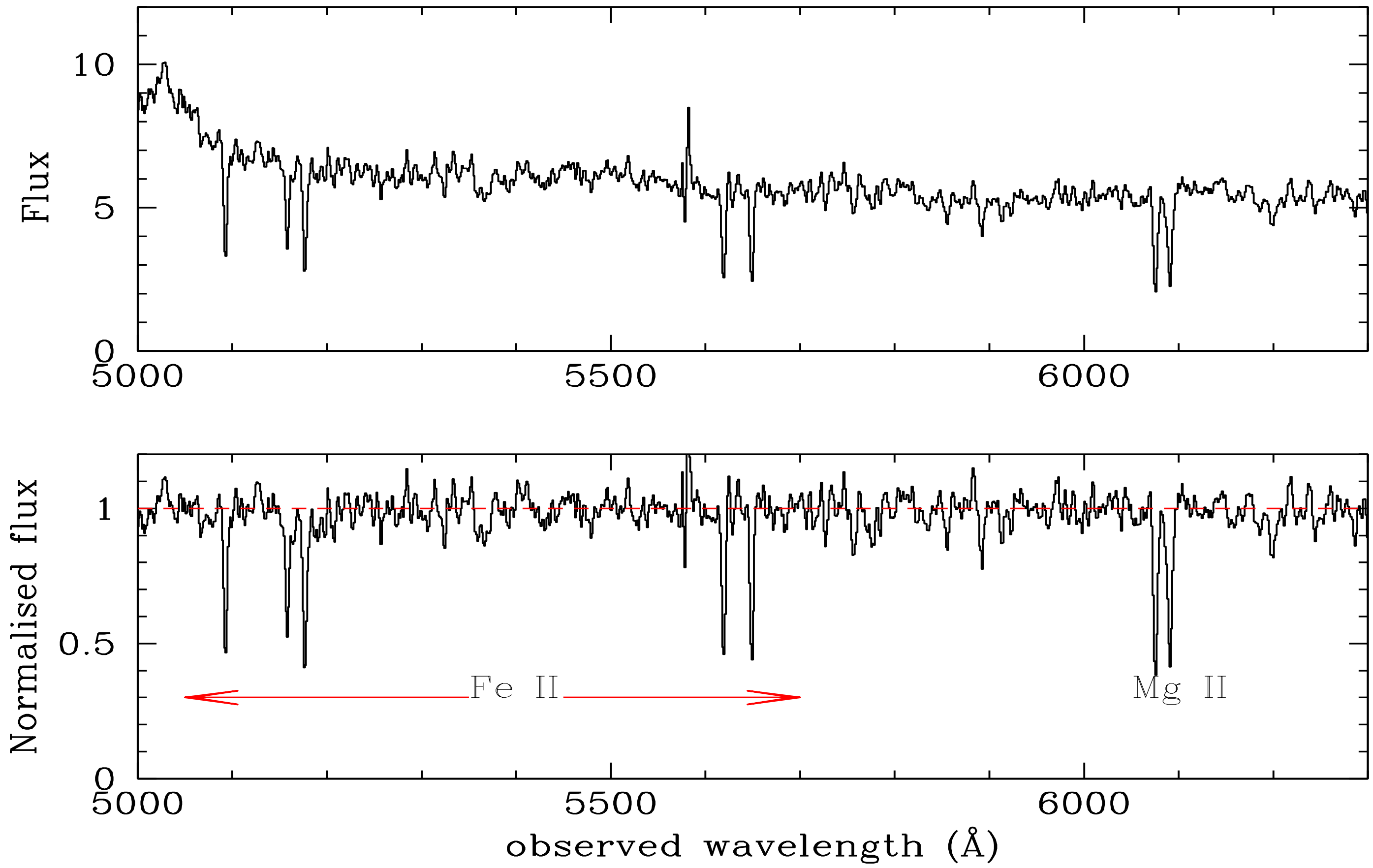
- 21-cm absorption is detected in 50% of the cases with $\int \tau dv \geq 0.1$ km/s when the impact parameter is $\leq$15 kpc.
- W(Ca K)$\geq$ 0.3 Å whenever 21-cm absorption is detected. However, the contrary is not true.
- The detections happen when the line of sight passes through isolated disks or through displaced H I gas through interactions.
- However, the sample size is small to investigate the effect of metallicity, dust, SFR etc.Also the impact parameter range $<$8 kpc is not well represented.

QSO absorber-Galaxy Pairs: A new sample

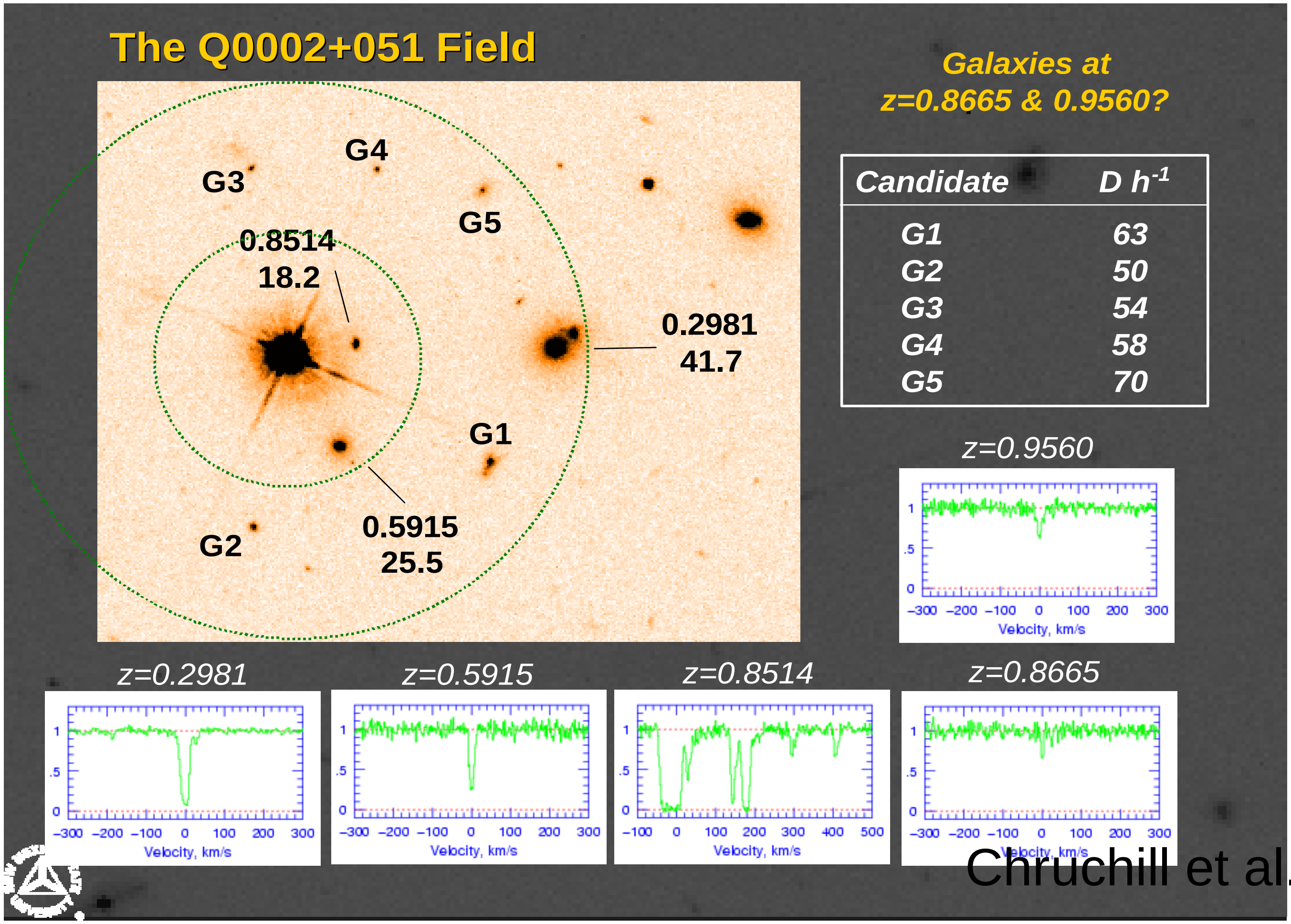


RS, Gupta, Noterdaeme & Muzahid

QSO absorber-Galaxy connection: Mg II systems

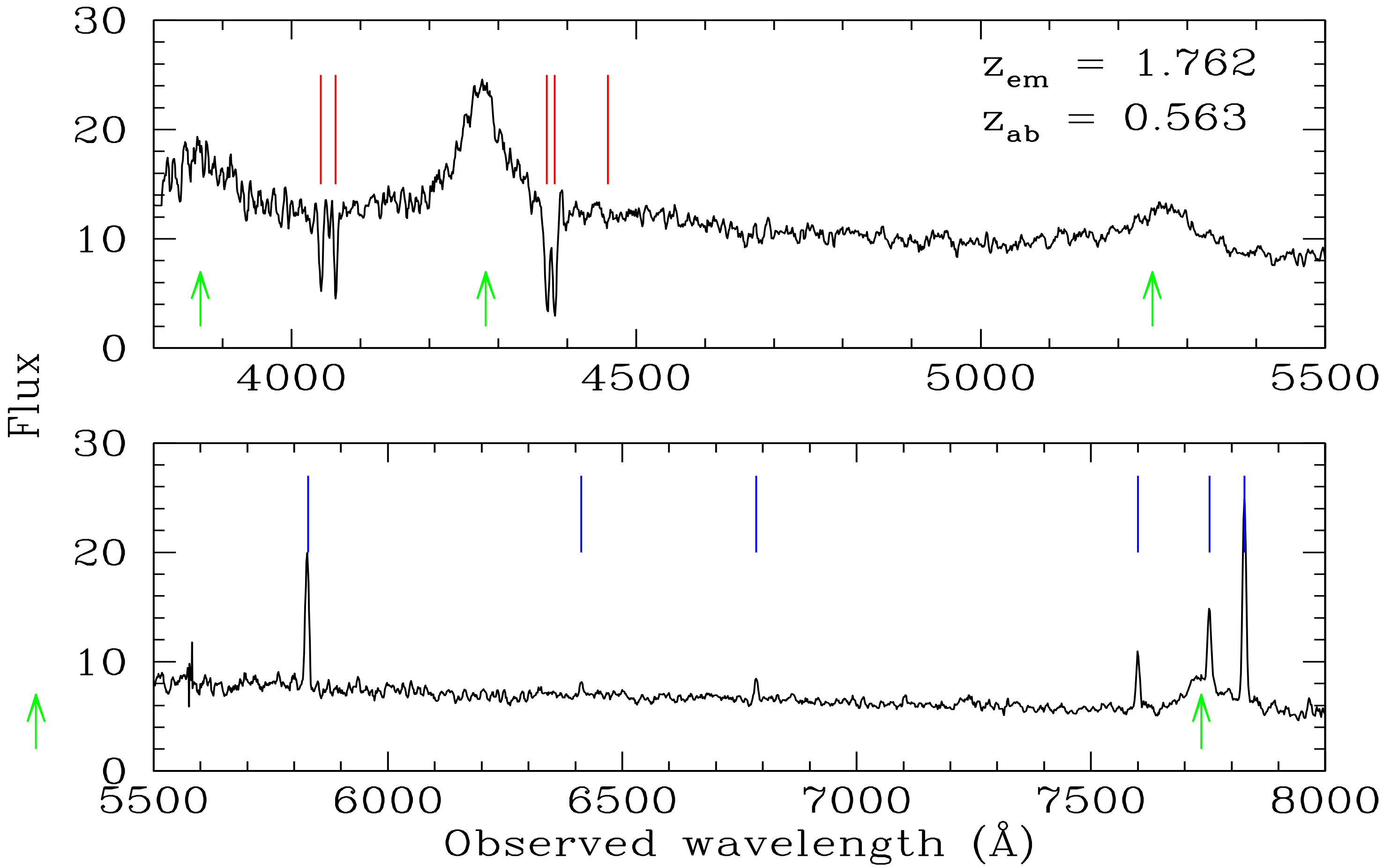


Galaxy metal absorption connections:low z



Chruchill et al. 2005)

Mg II systems: star-forming galaxies



Search for galaxy emission in SDSS-QSO spectra:

- Found 90 emission line galaxies at $z \leq 0.7$ using emission line templates.

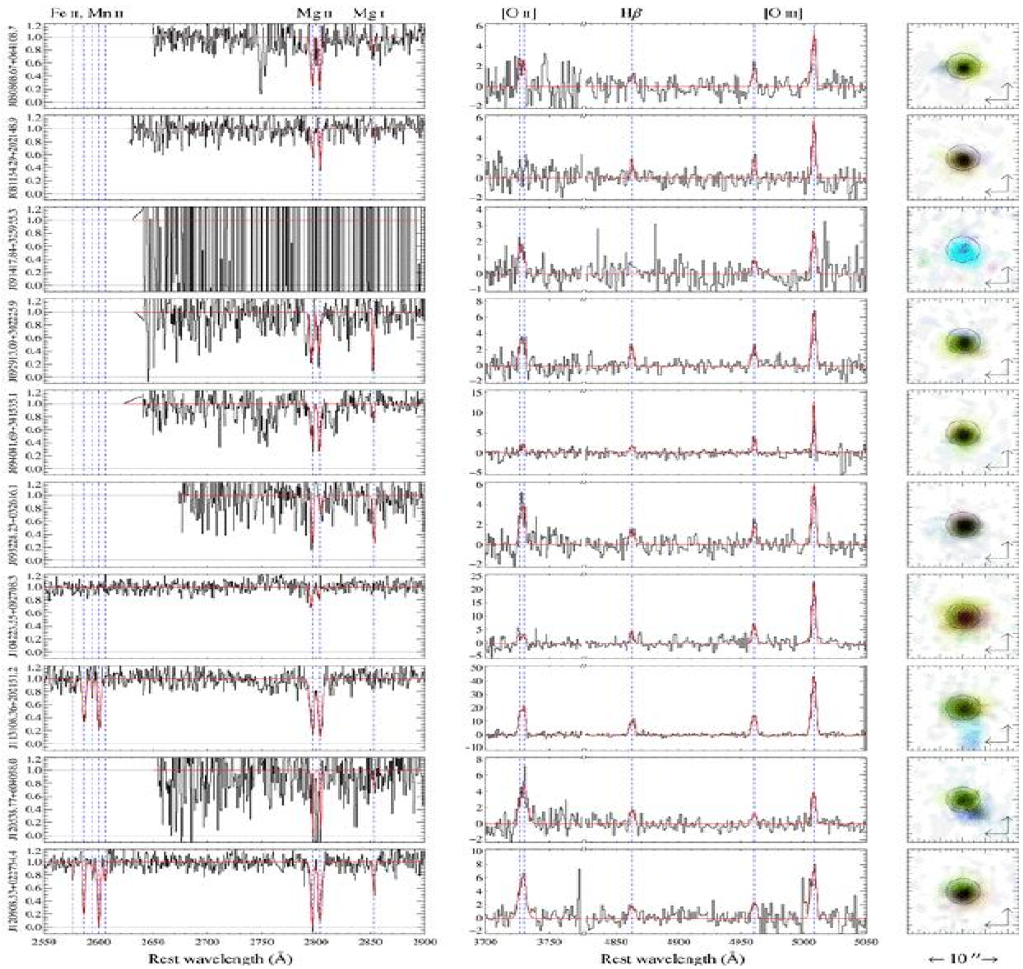
- There are 19 galaxies in the redshift range 0.4$\leq z \leq$0.7 for which SDSS covers Mg II absorption also.

- 80% of the galaxies show strong Mg II absorption, whenever covered Fe II lines are also detected.

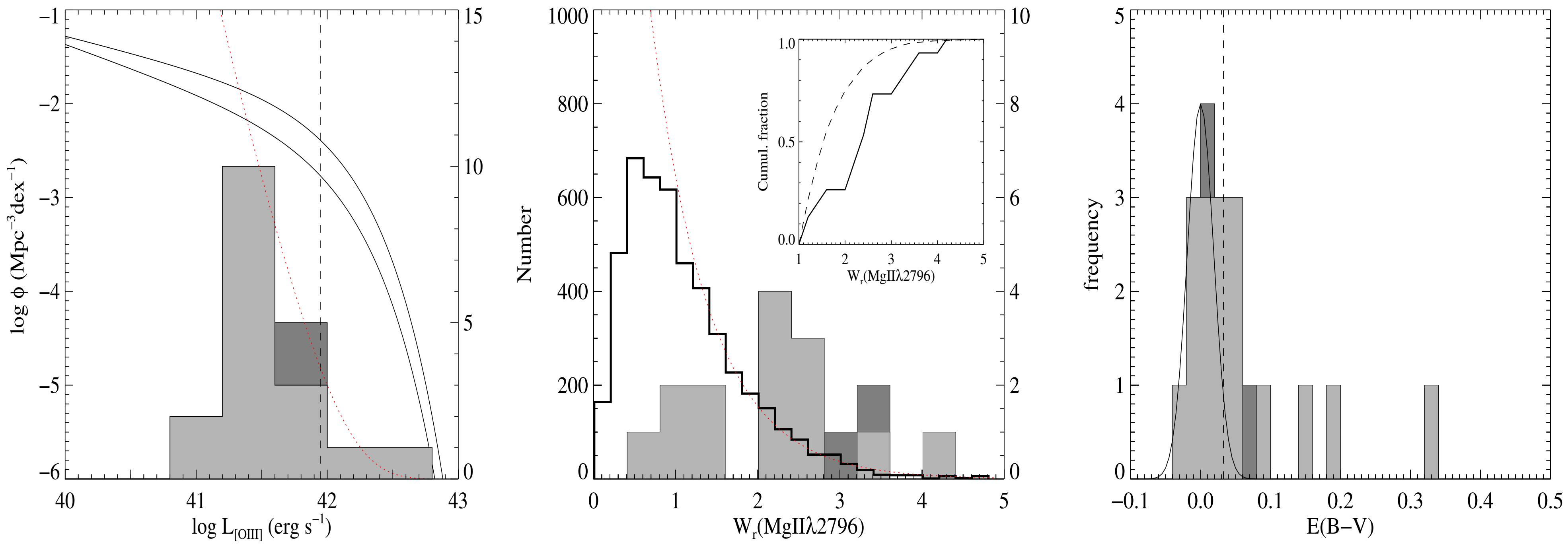
- SFR in the range 0.2-20 $M_\odot$ yr^{-1}.

Noterdaeme, Srianand & Mohan 2010, MNRAS, in press

Search for galaxy emission in SDSS-QSO spectra?

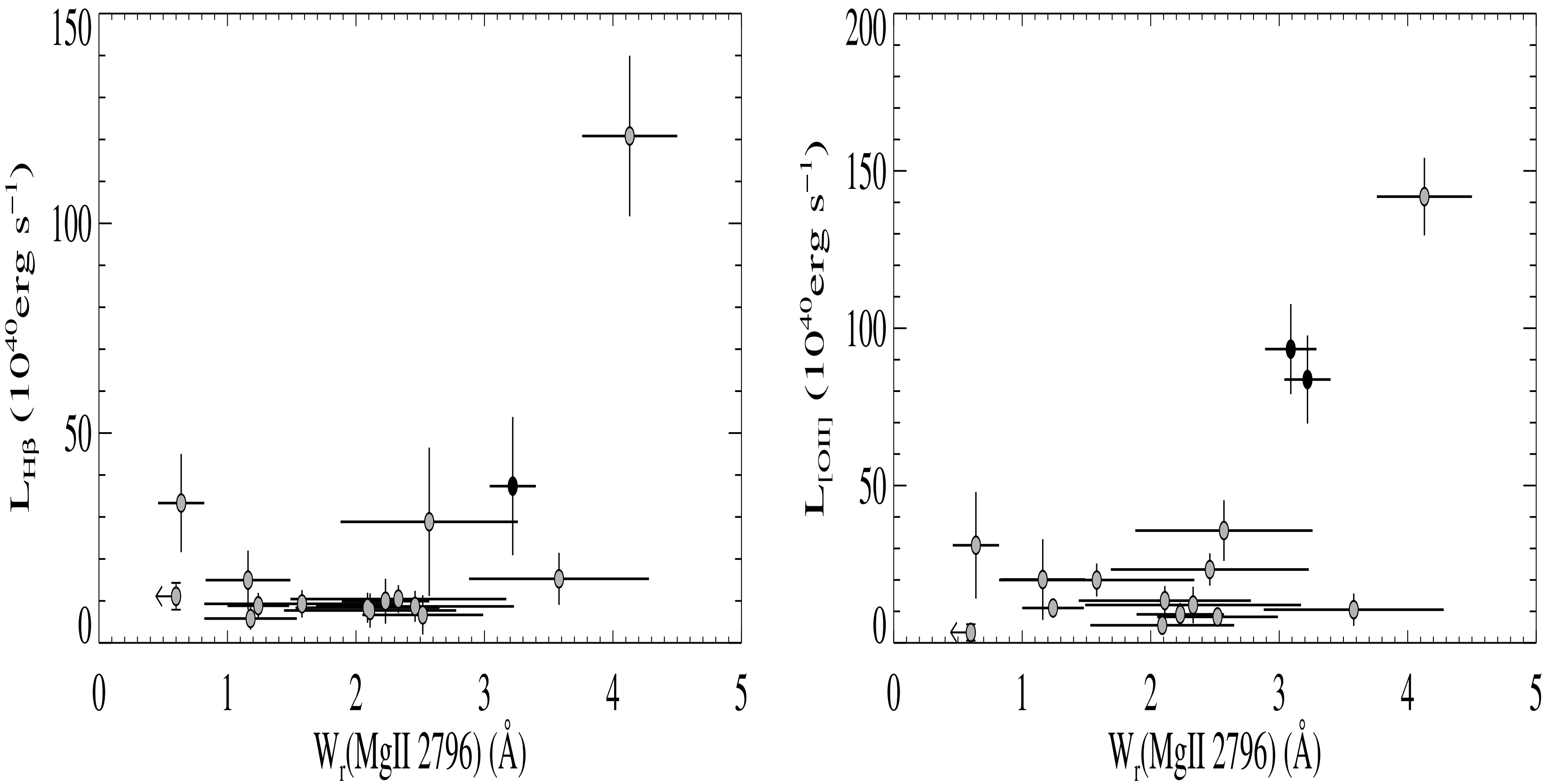


Properties of emission line selected Mg II systems



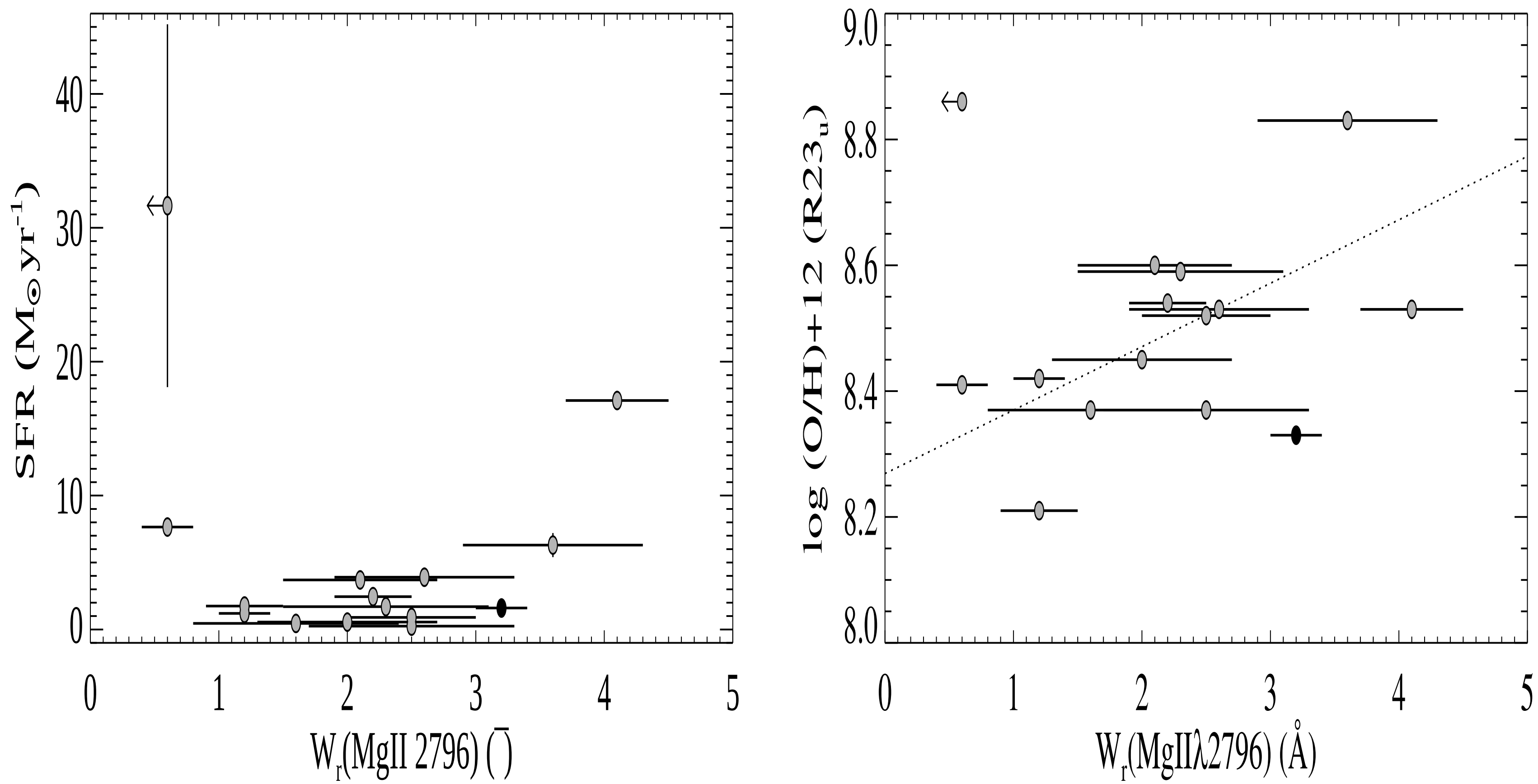
Noterdaeme, Srianand & Mohan 2010, MNRAS, in press

Properties of emission line selected Mg II systems



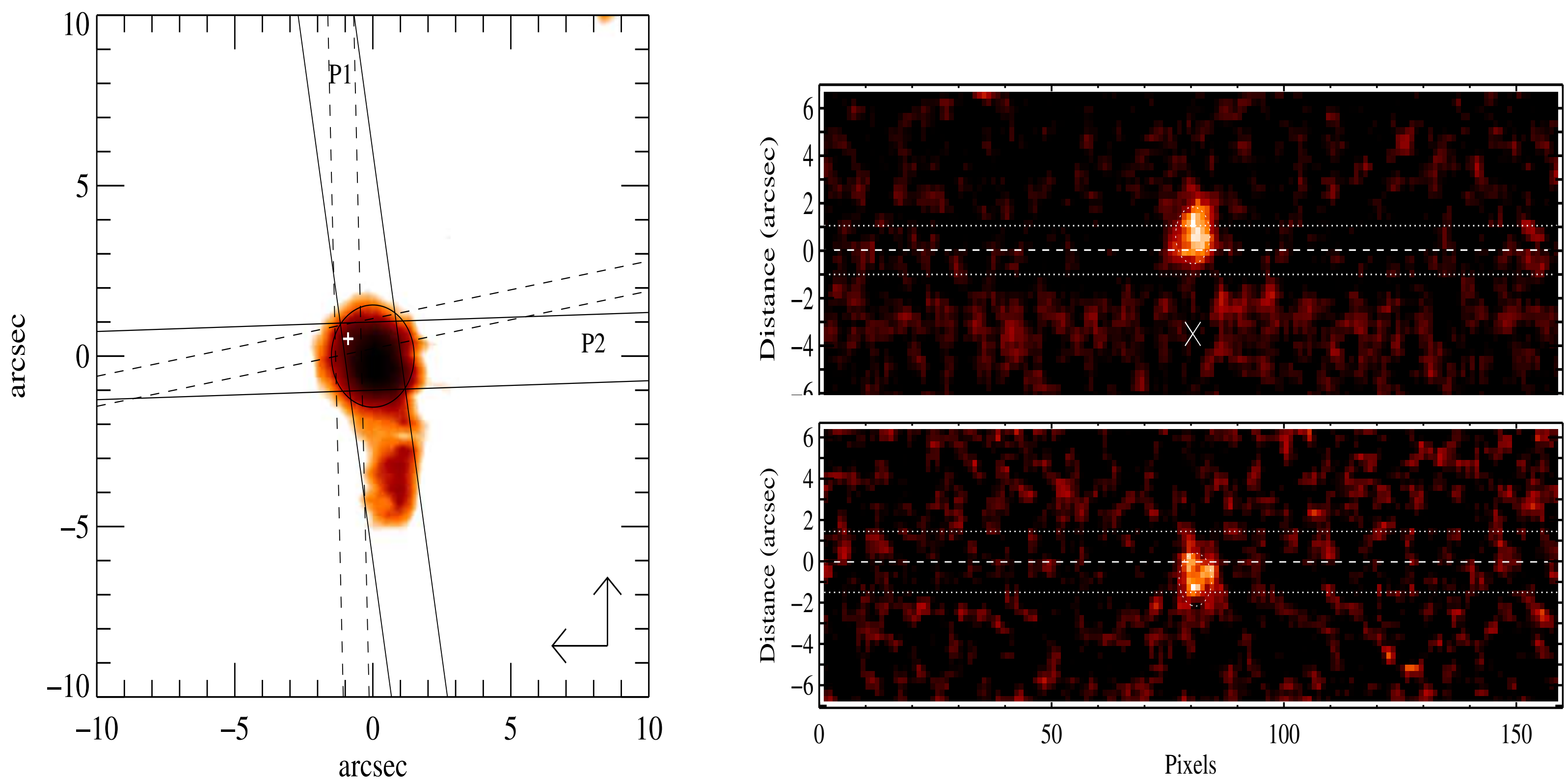
Noterdaeme, Srianand & Mohan 2010, MNRAS, in press

Properties of emission line selected Mg II systems



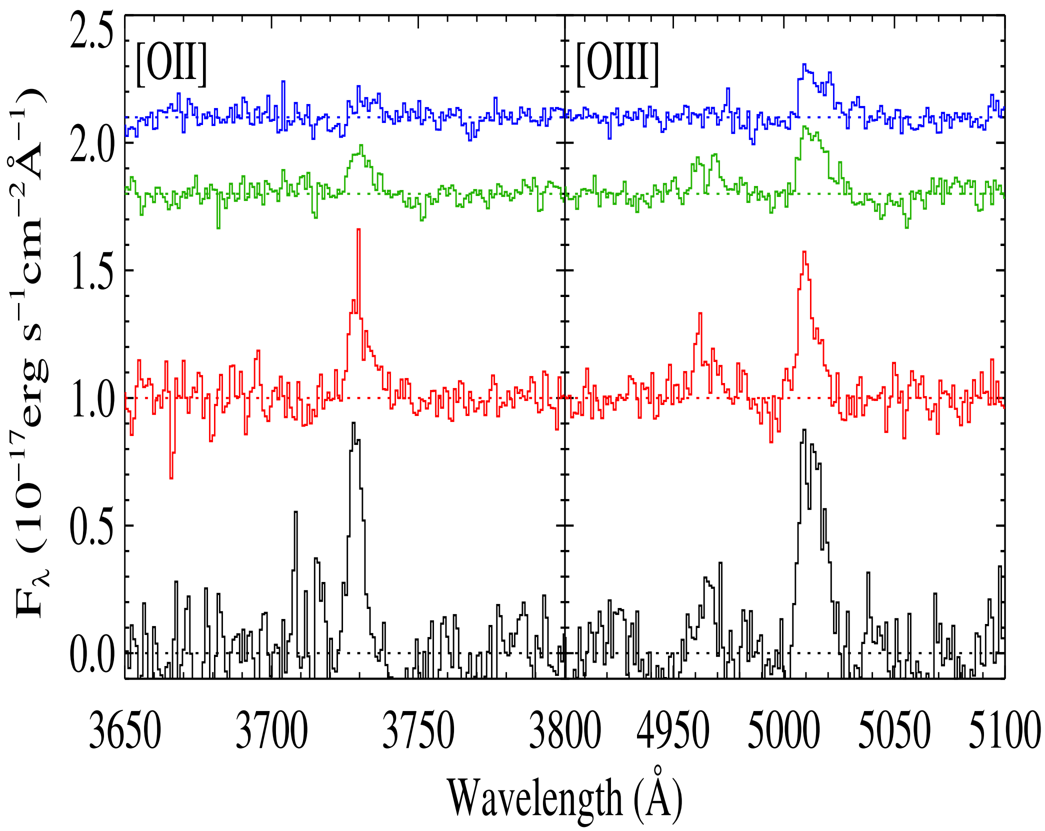
$$\log(\mathrm{O/H}) + 12 = 0.1\mathrm{W}(\mathrm{Mg\ II}) + 8.27$$

Triangulation and Impact parameter



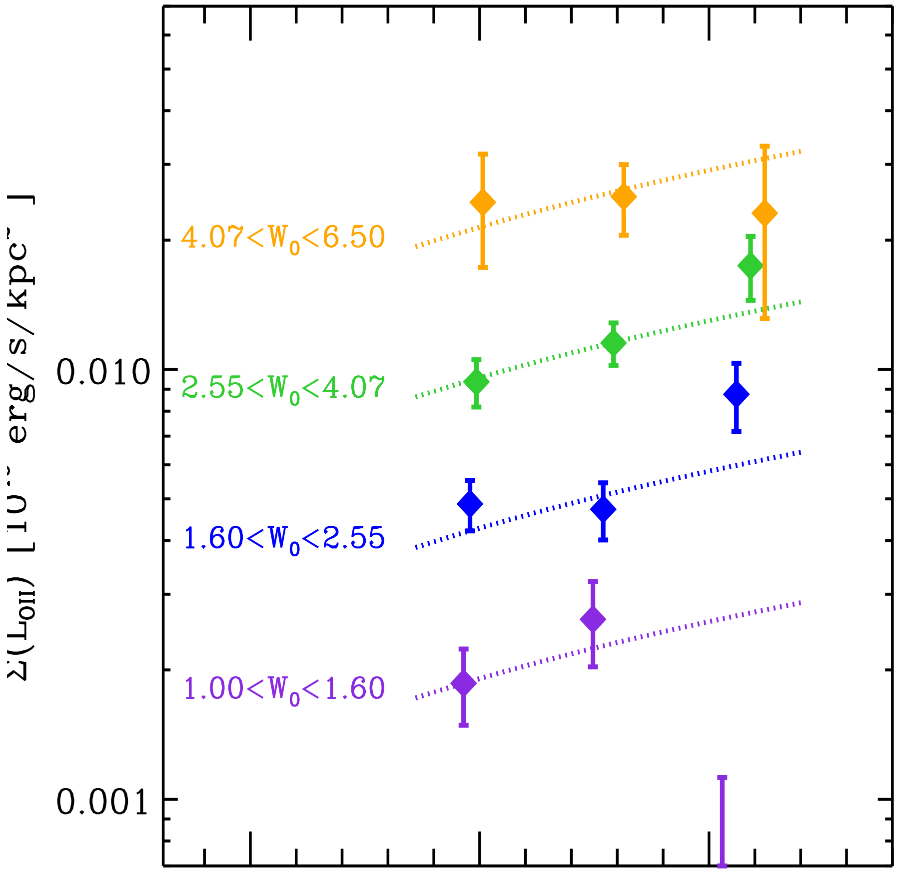
Noterdaeme, Srianand & Mohan, 2010, MNRAS

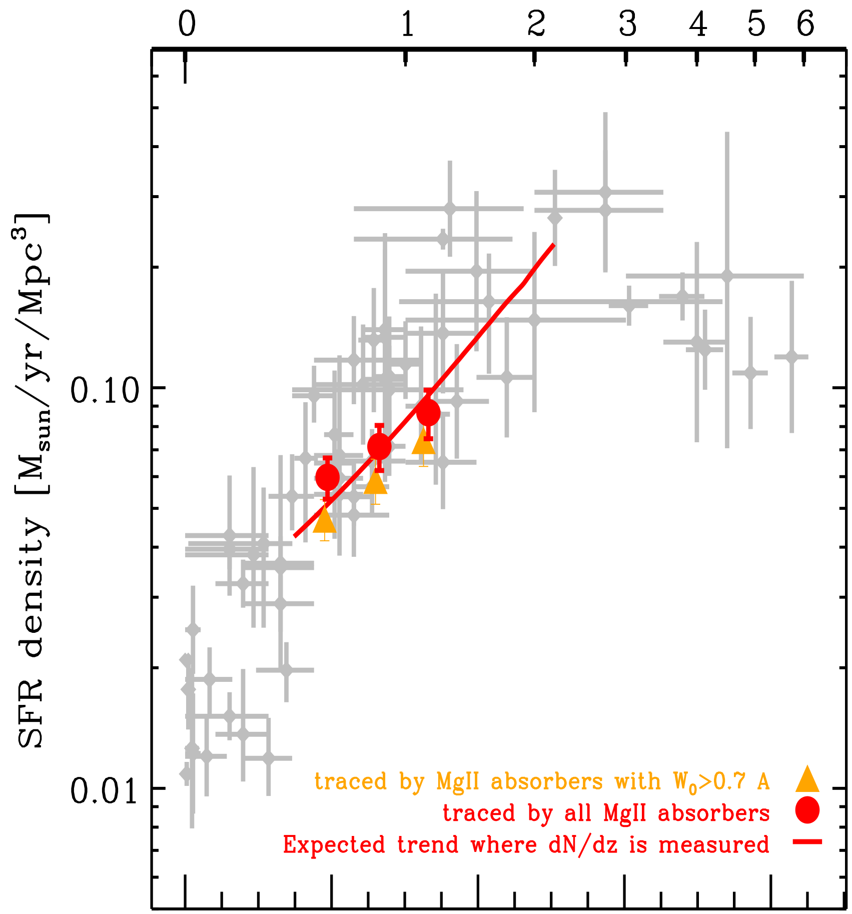
Average emission lines from Mg II systems at 0.4$\leq z \leq 0.7$



Noterdaeme, Srianand & Mohan, 2010, MNRAS

SFR density contributed by Mg II systems





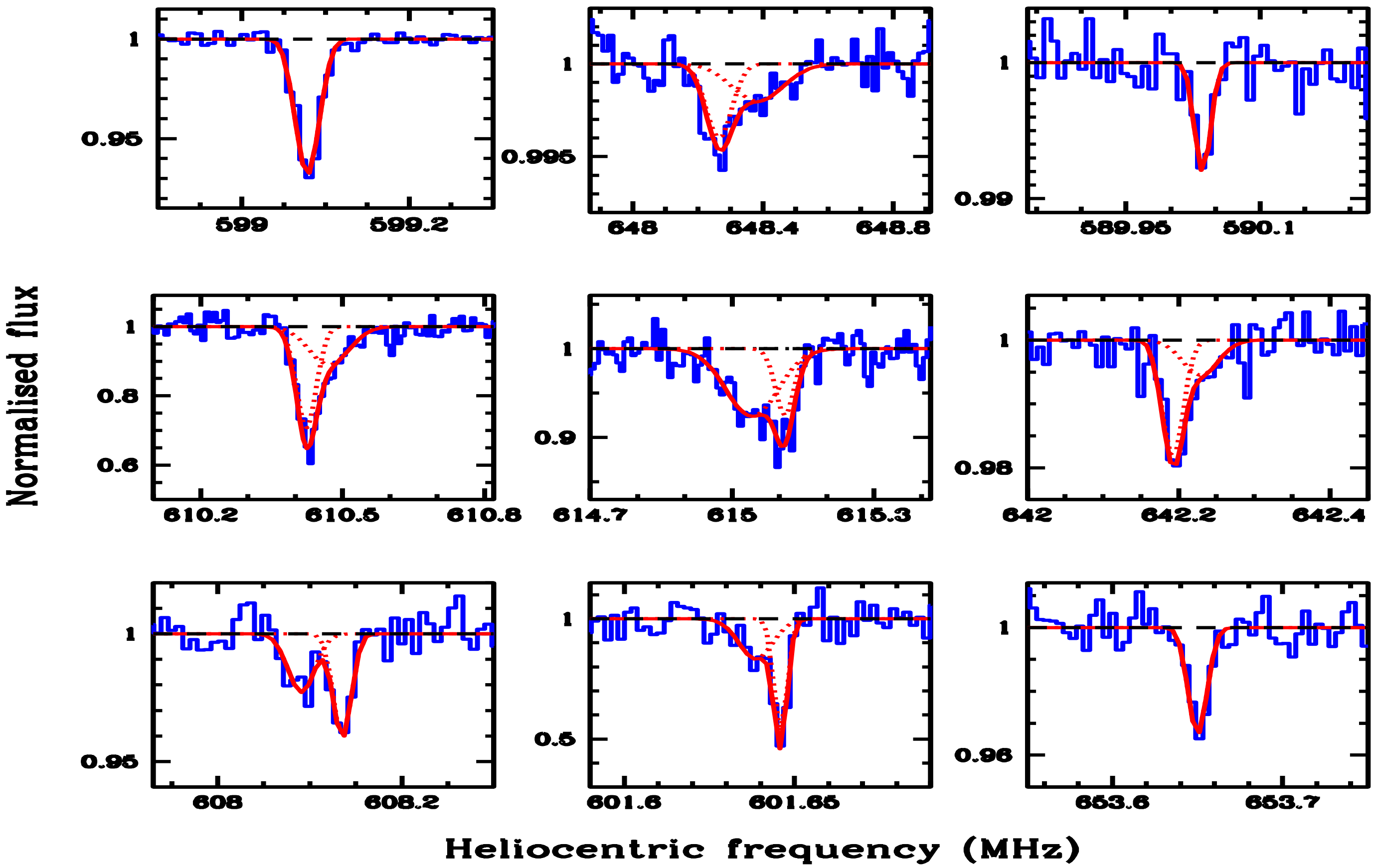
Ménard et al., 2010, arxiv

SDSS-GMRT sample of Mg II systems:

- Detection of Mg II systems in SDSS-DR7 with W(Mg II)$\geq$1Å using an automatic procedure.
- Select the systems with 1.15$\leq z \leq 1.45$ (2893 systems)
- Cross-correlate the SDSS QSO with NVSS and FIRST.
- Pick the systems with flux density at the redshifted 21 cm wavelength greater than 50 mJy (37 systems).
- 400hrs of observations are completed-and we now have 9 new detections. Five systems are in front of radio sources that are compact at milli-arcsec scales.

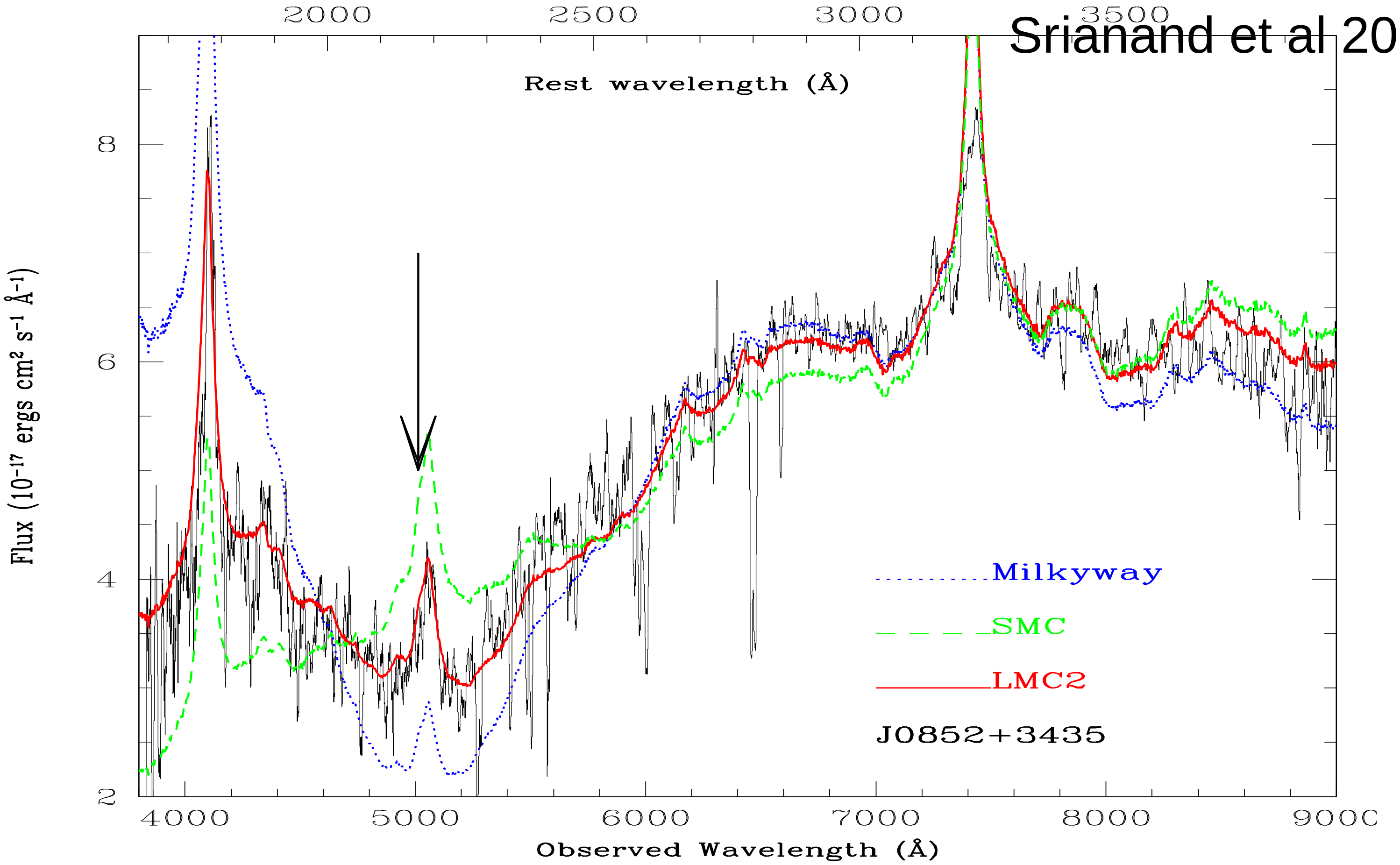
TEAM: R. Srianand (PI), Neeraj Gupta (ATNF), D.J. Saikia(NCRA), P. Petitjean(IAP), P. Notredome (IUCAA)

GMRT sample of 21-cm absorption:



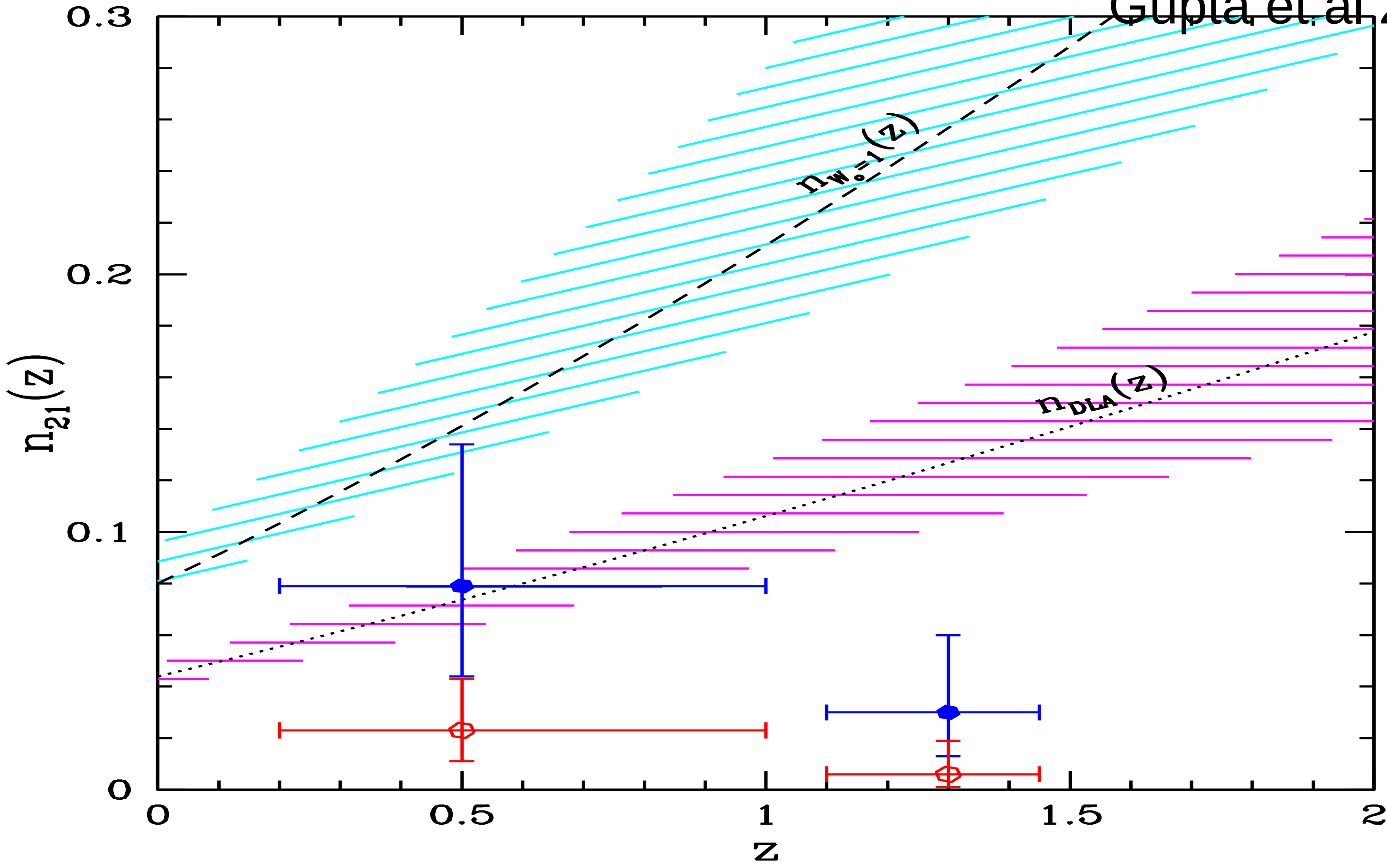
2170Å dust feature towards J0852+3432

Srianand et al 2009

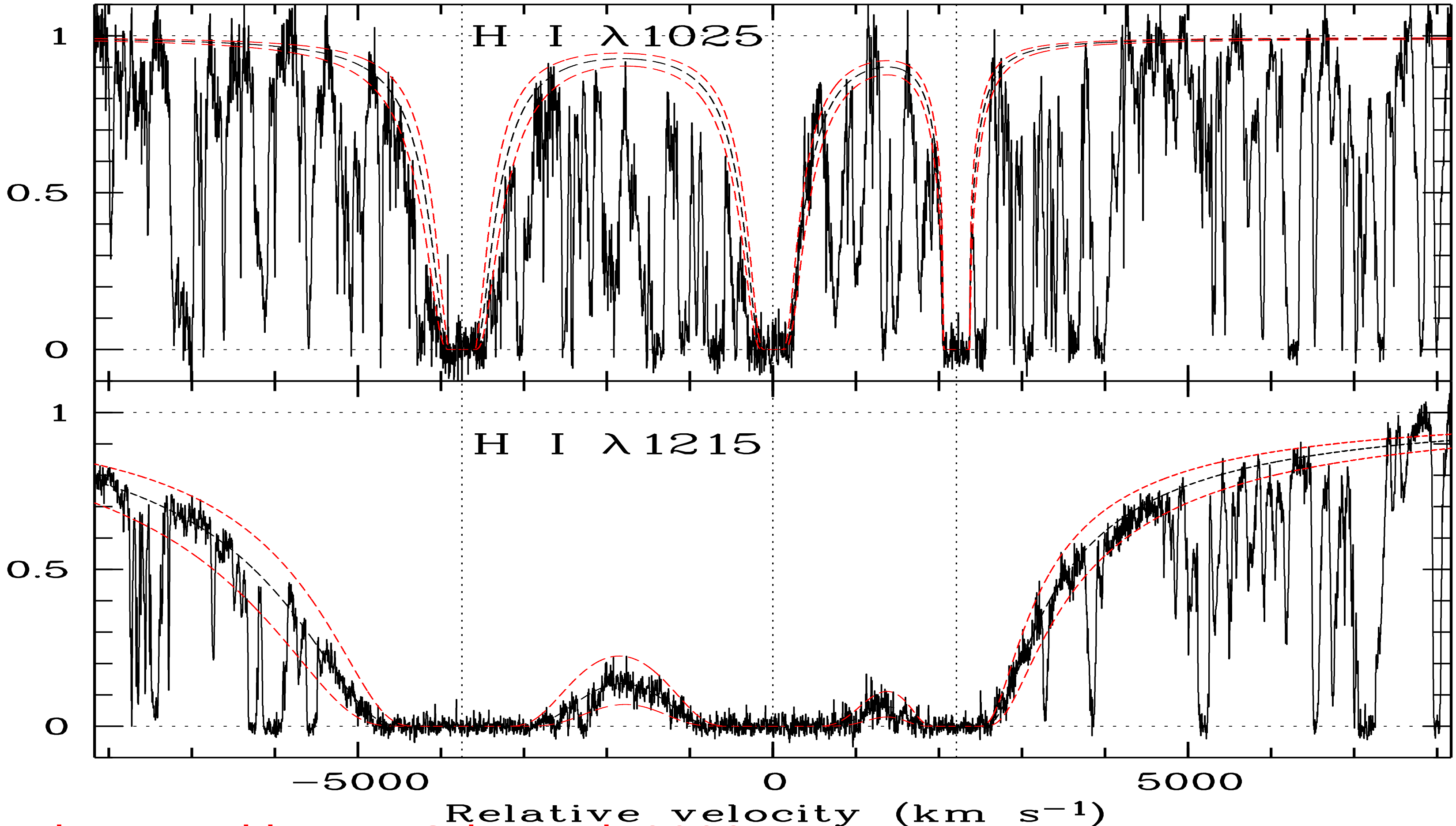


Redshift evolution of 21cm absorbers:

Gupta et.al 2009

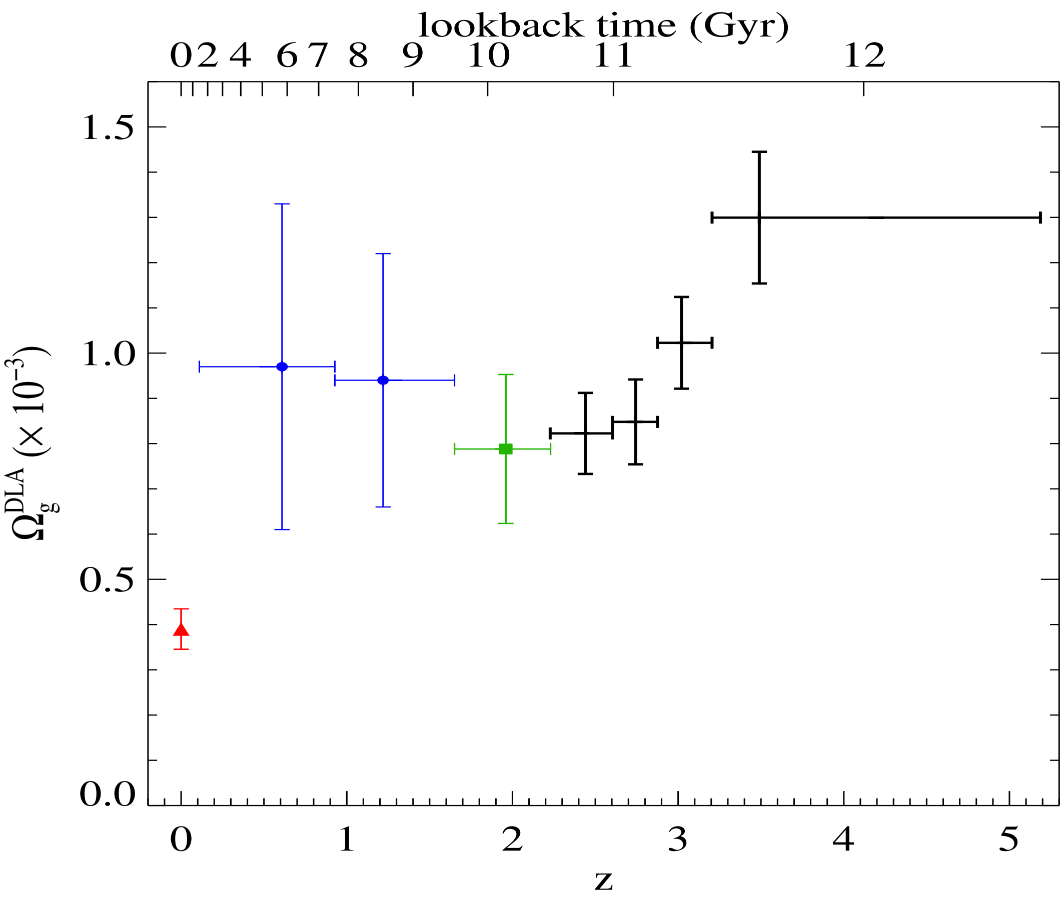


Damped Lyman-α systems



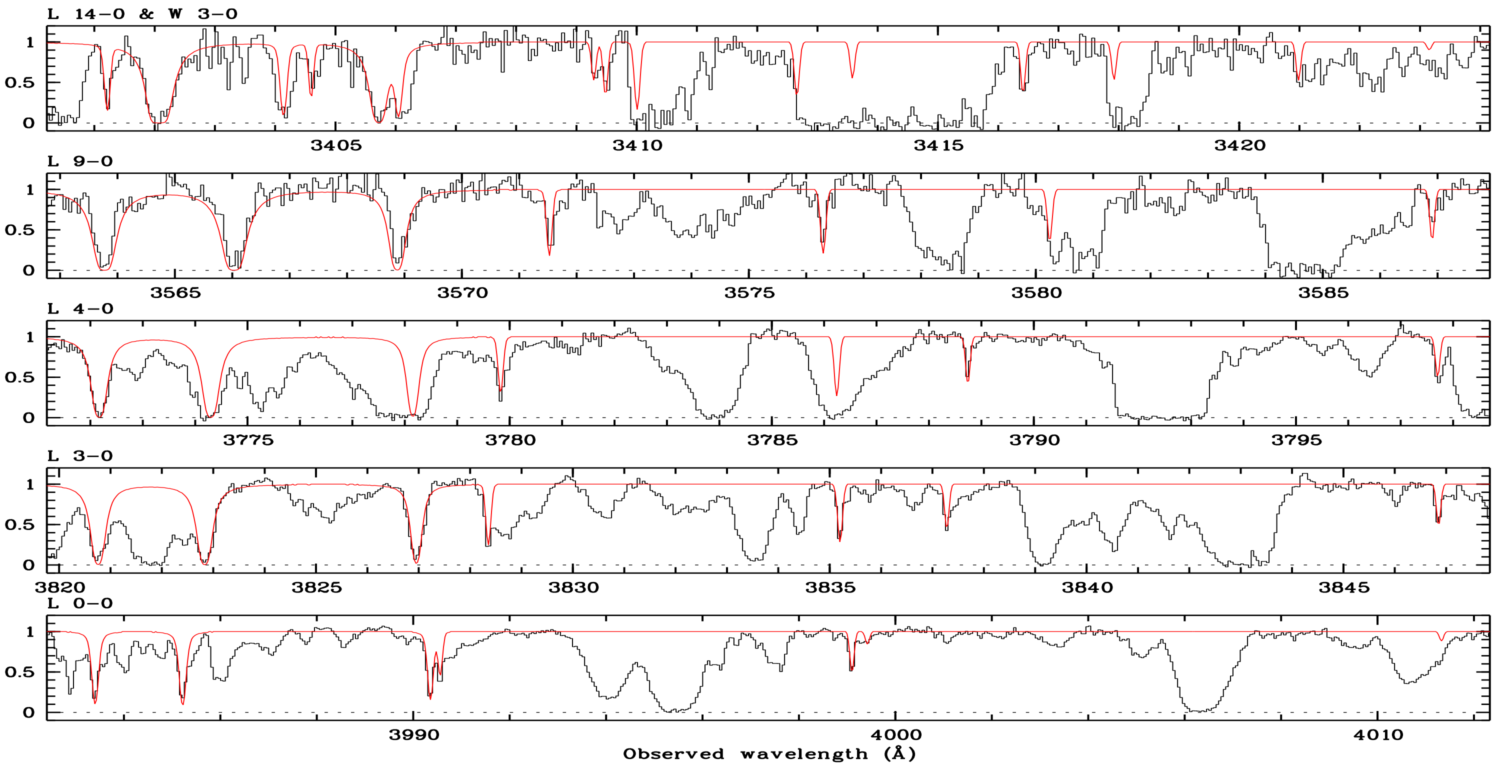
Ledoux, Petitjean & Srianand, 2003

Damped Lyman-α systems



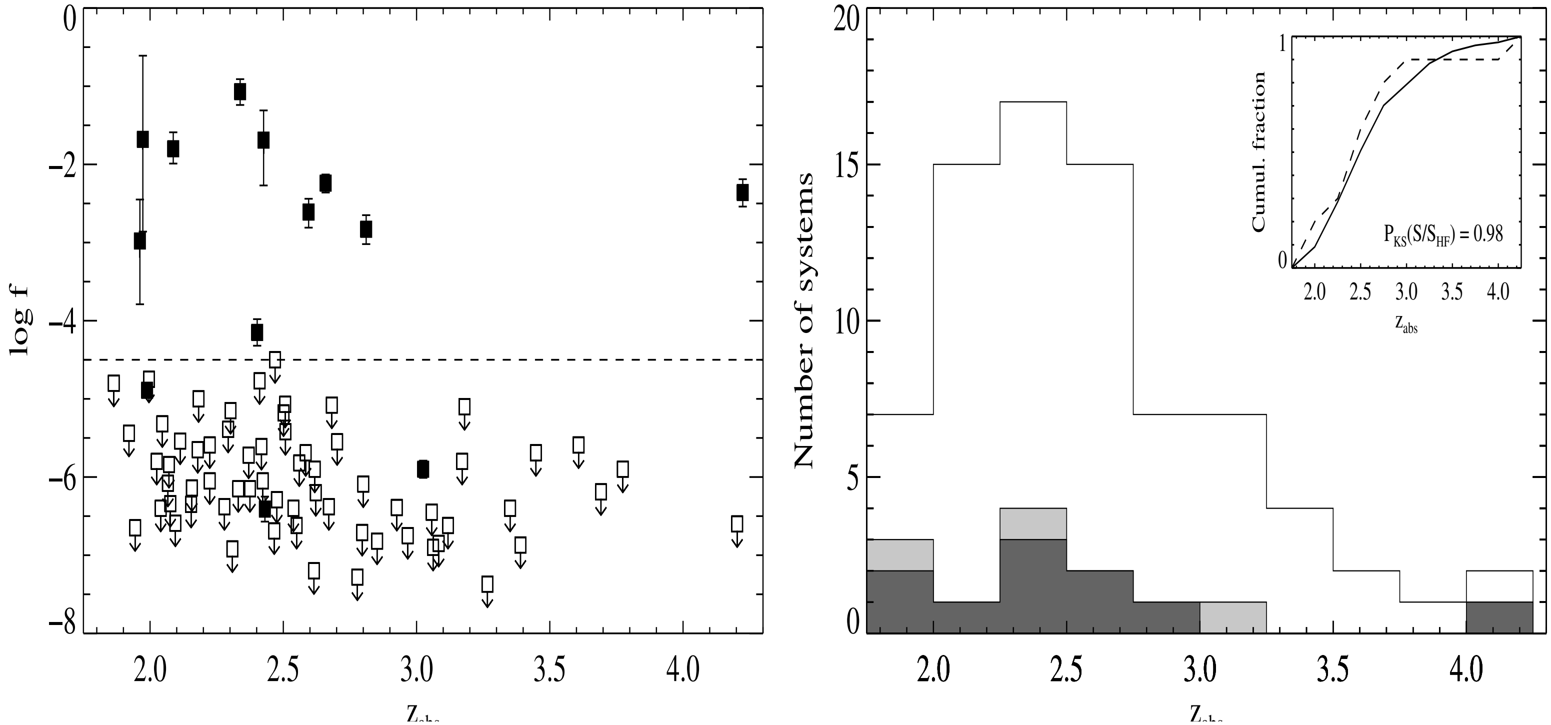
Noterdaeme, Petitjean, Ledoux & Srianand, 2008, A&A, 505, 1087

Molecular content of DLAs



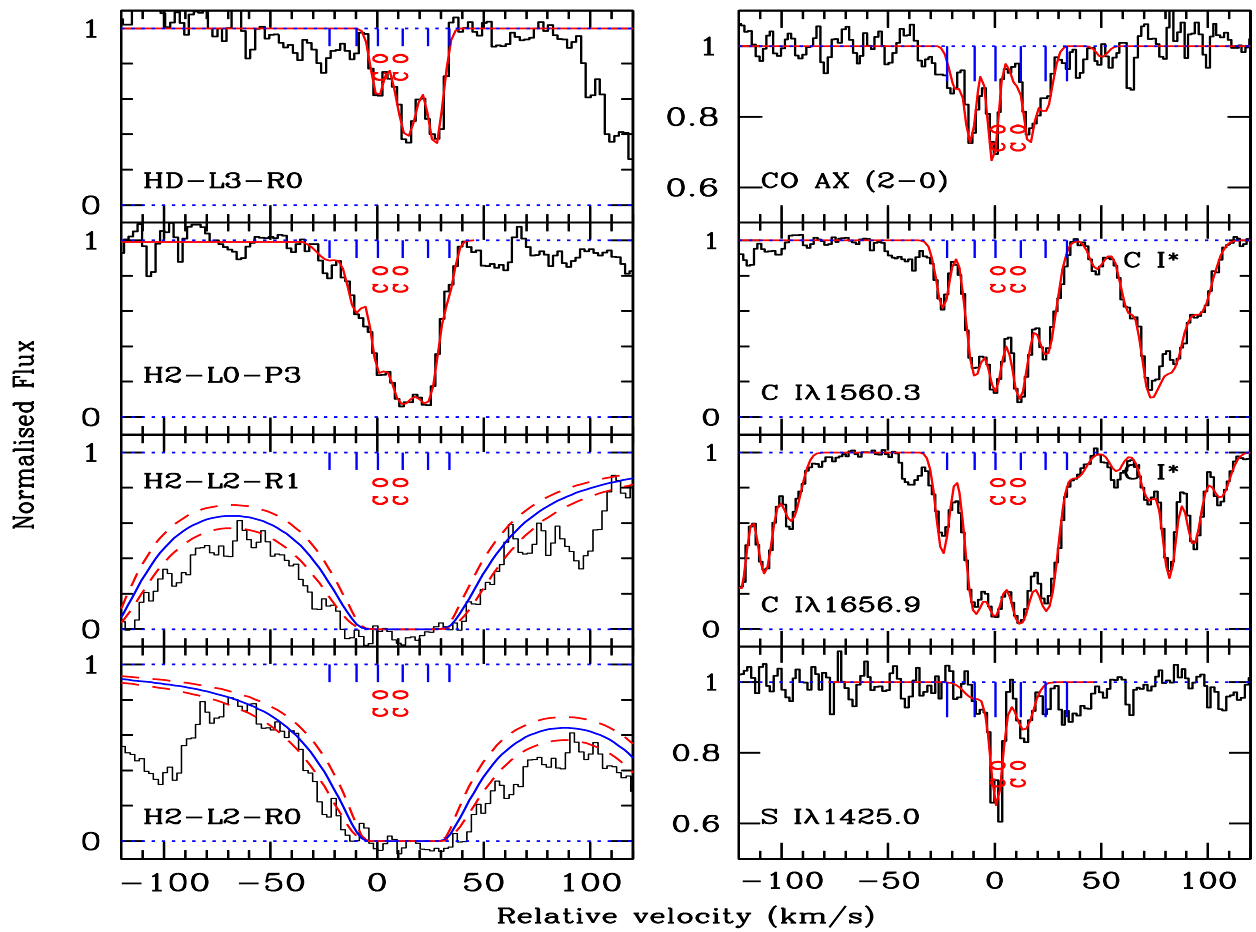
Petitjean et al. 2000, Ledoux et al 2003, Srianand et al. 2005 and Noterdaeme et al. 2008

Molecular content of DLAs

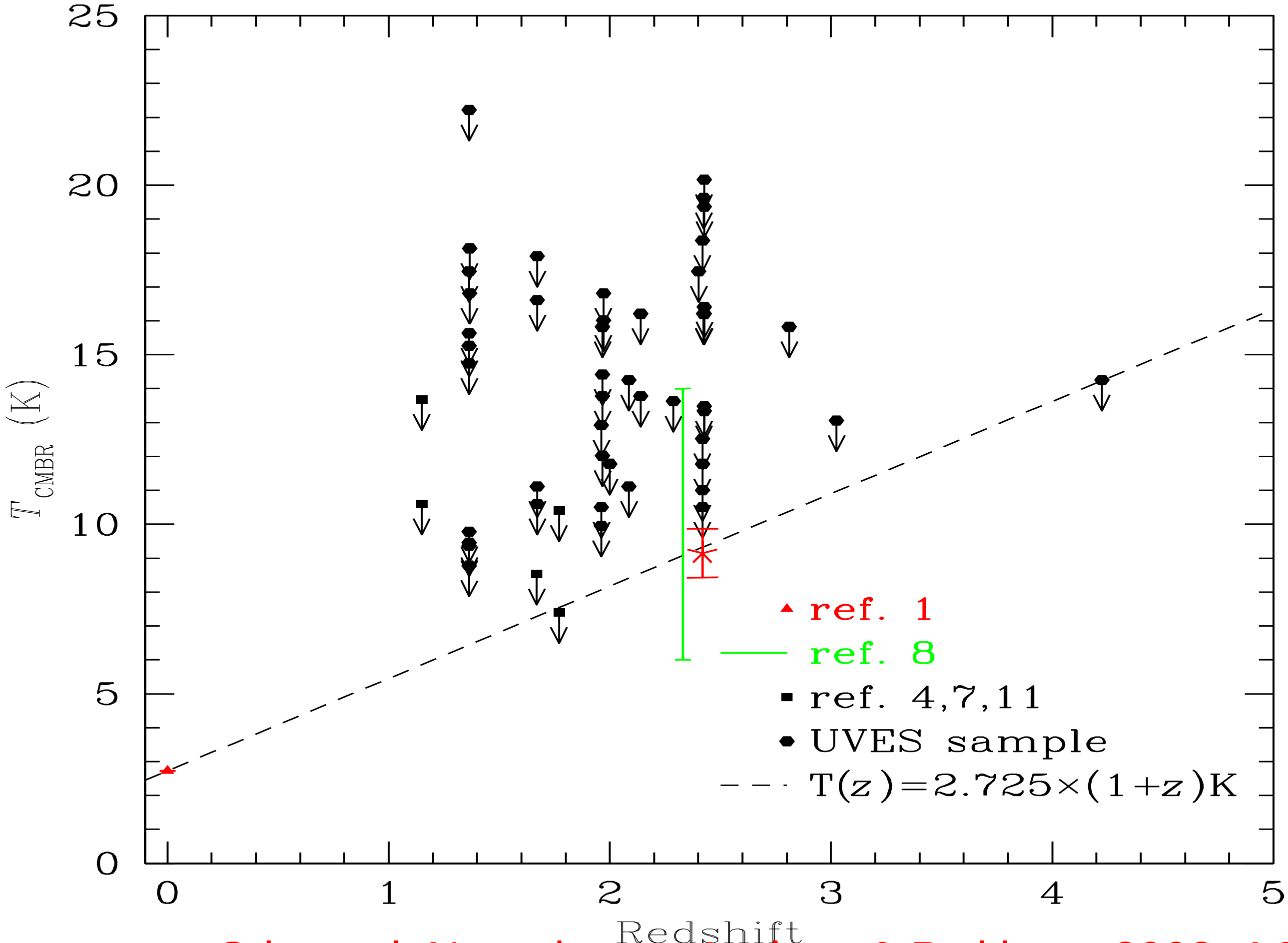


Noterdaeme et al. 2008, A&A, 481, 327

Begining to detect CO and HD at high-z

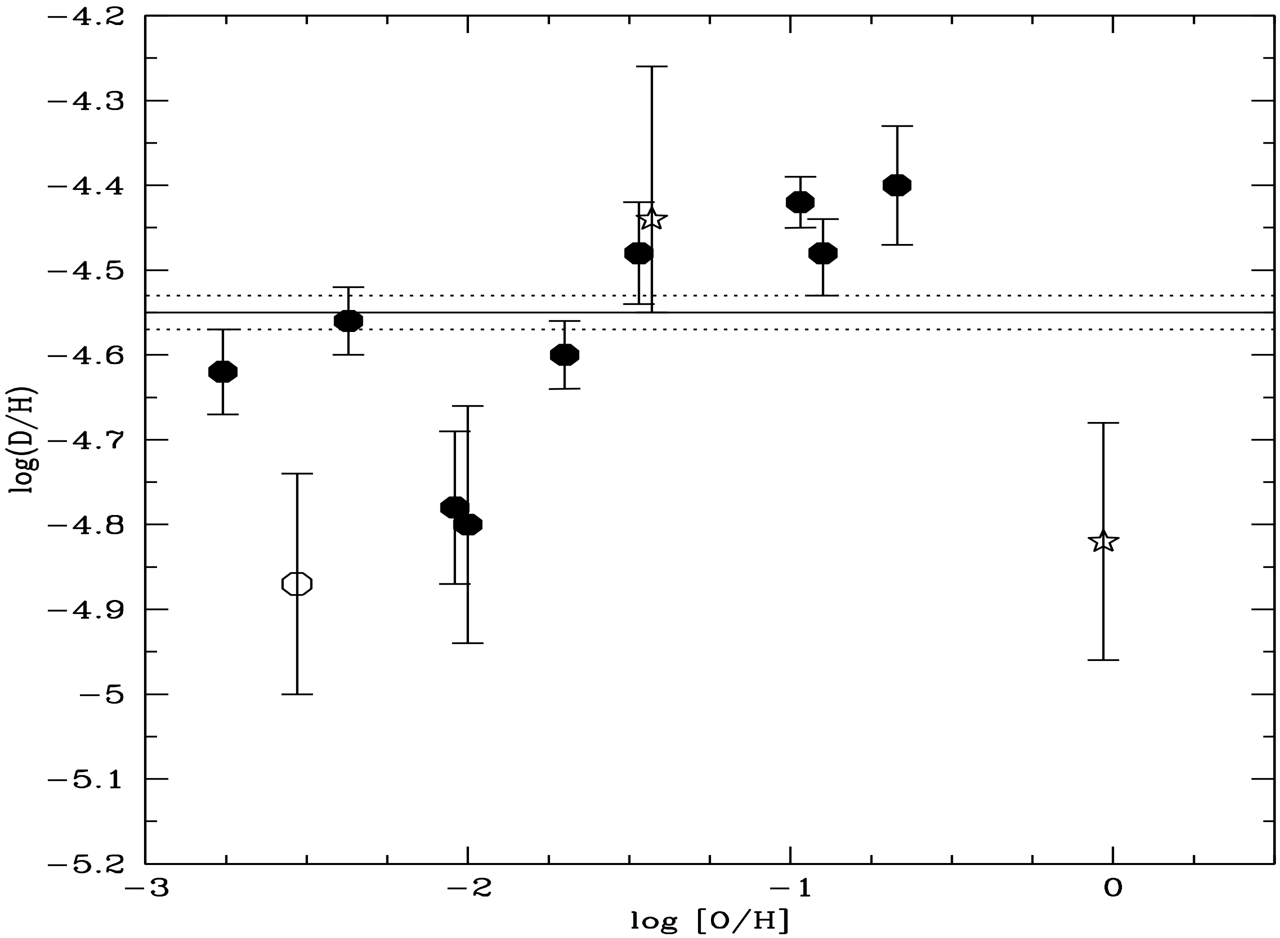


CO absorption and T(CMBR)



Srianand, Noterdaeme, Ledoux & Petitjean, 2008, A&A, 482, L39

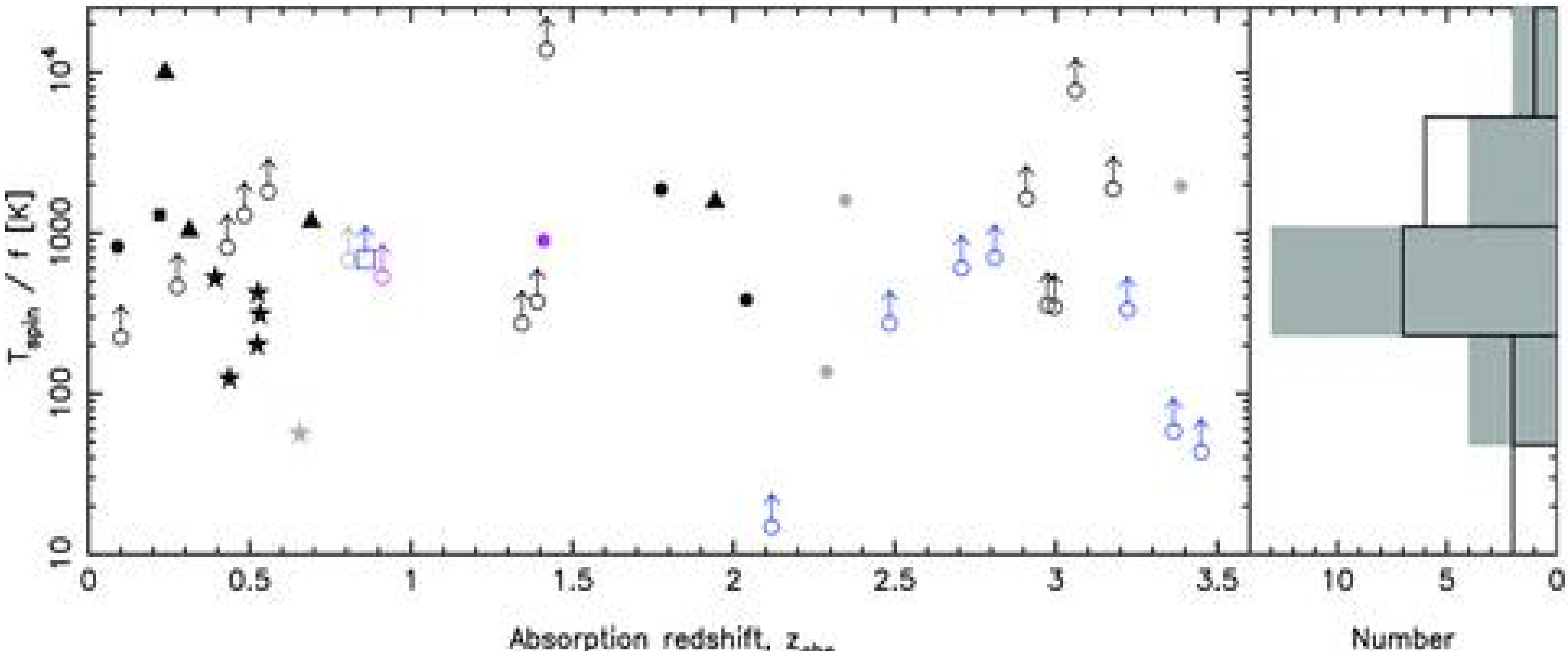
HD/$2H_2$ and Ω_b



Srianand et al 2010,MNRAS, in press

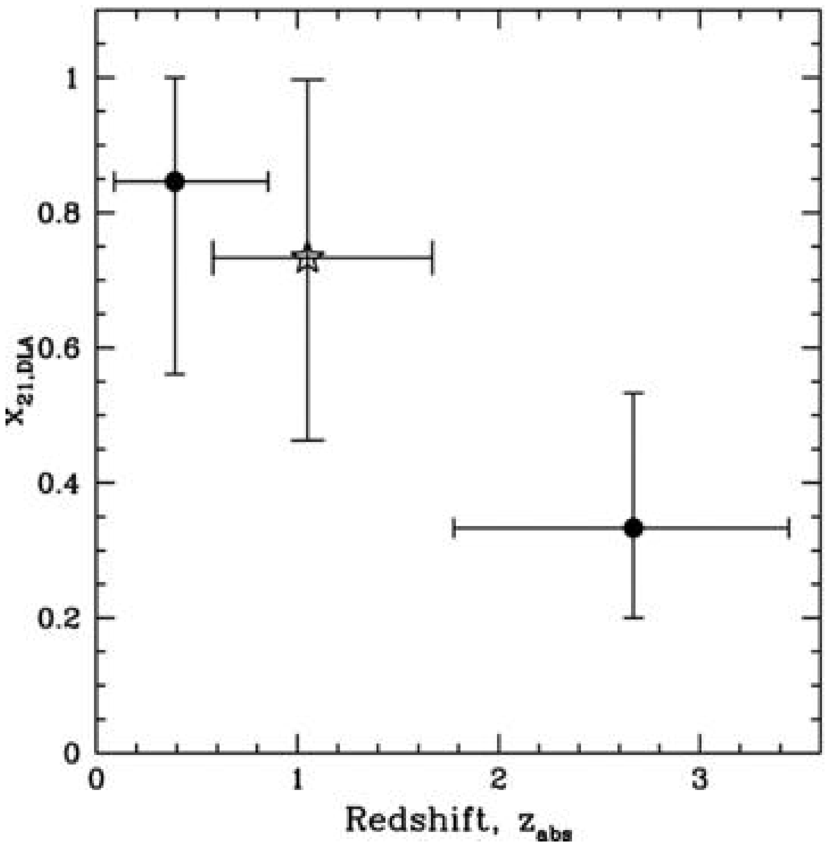
21-cm absorption in DLAs:

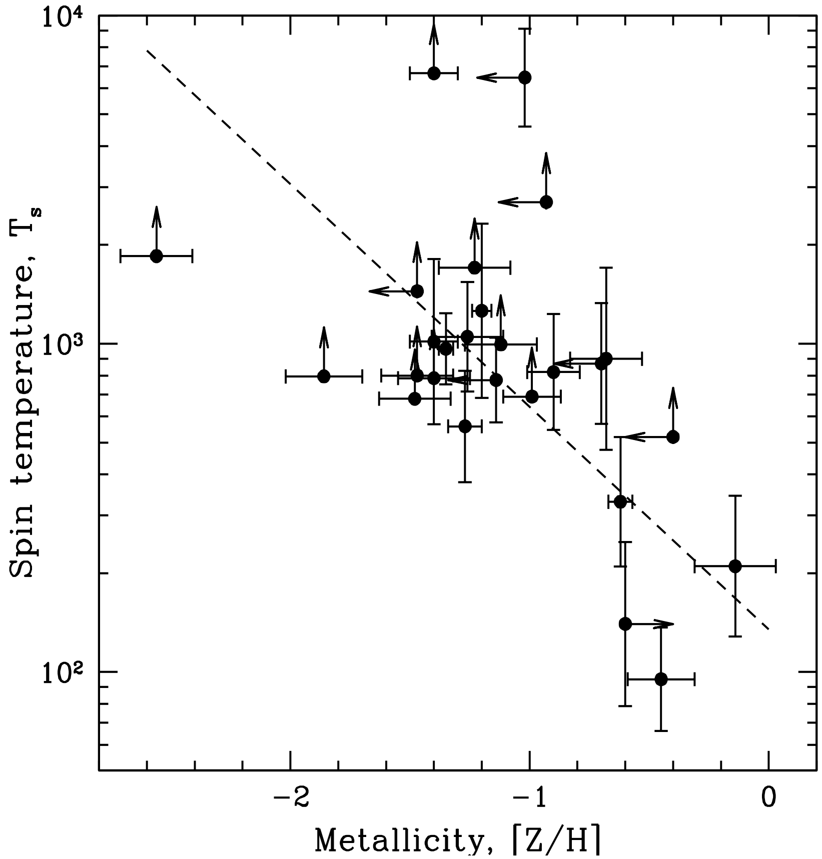
Curran et al. 2010, MNRAS, 402, 35



Detections are from Wolfe, Briggs, Kanekar, Chengalur, Lane and collaborators

21-cm absorption in DLAs:





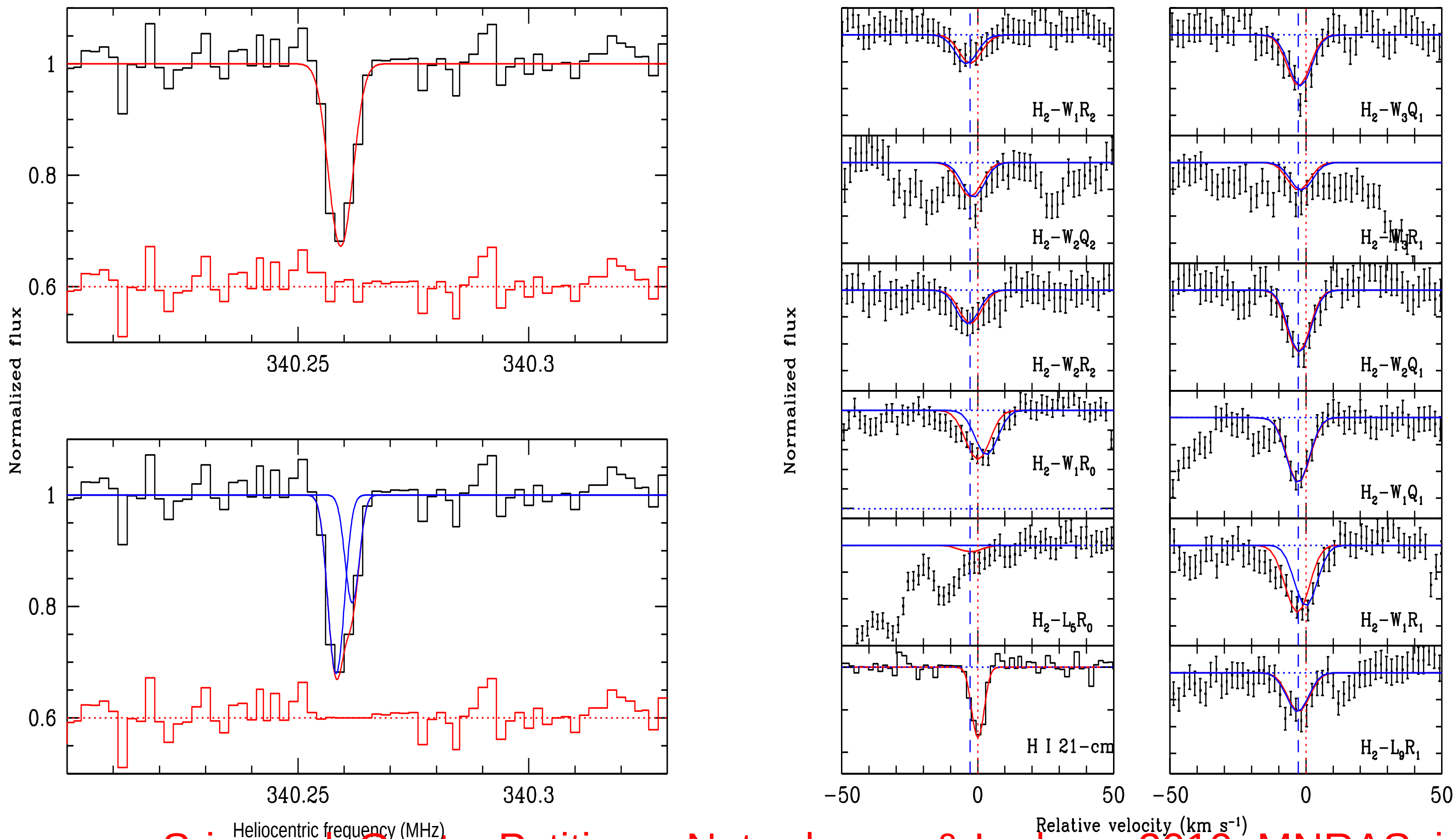
Kanekar et al. 2009, ApJ, 705,L40 and Kanekar et al. 2009, MNRAS, 396, 385

SDSS-GMRT-GBT sample of DLAs:

- Detection of DLAs at 2.2$\leq z \leq 3.5$ in SDSS-DR7 with using an automatic procedure (Noterdaeme et al. 2009, A&A,505,1087).
- Cross-correlate the SDSS QSO with NVSS and FIRST.
- Rejected systems that fall in the known RFI affected frequencies.
- Pick the systems with flux density at the redshifted 21 cm wavelength greater than 100 mJy (12 systems). All sources were imaged at GMRT in 610 MHz and 320 MHz.
- GMRT observations of 5 systems has resulted in one detection. GBT data are being analysed. VLBI observations are scheduled this cycle.

TEAM: R. Srianand (PI), Neeraj Gupta (ATNF), P. Petitjean(IAP), P. Notredome (IUCAA)

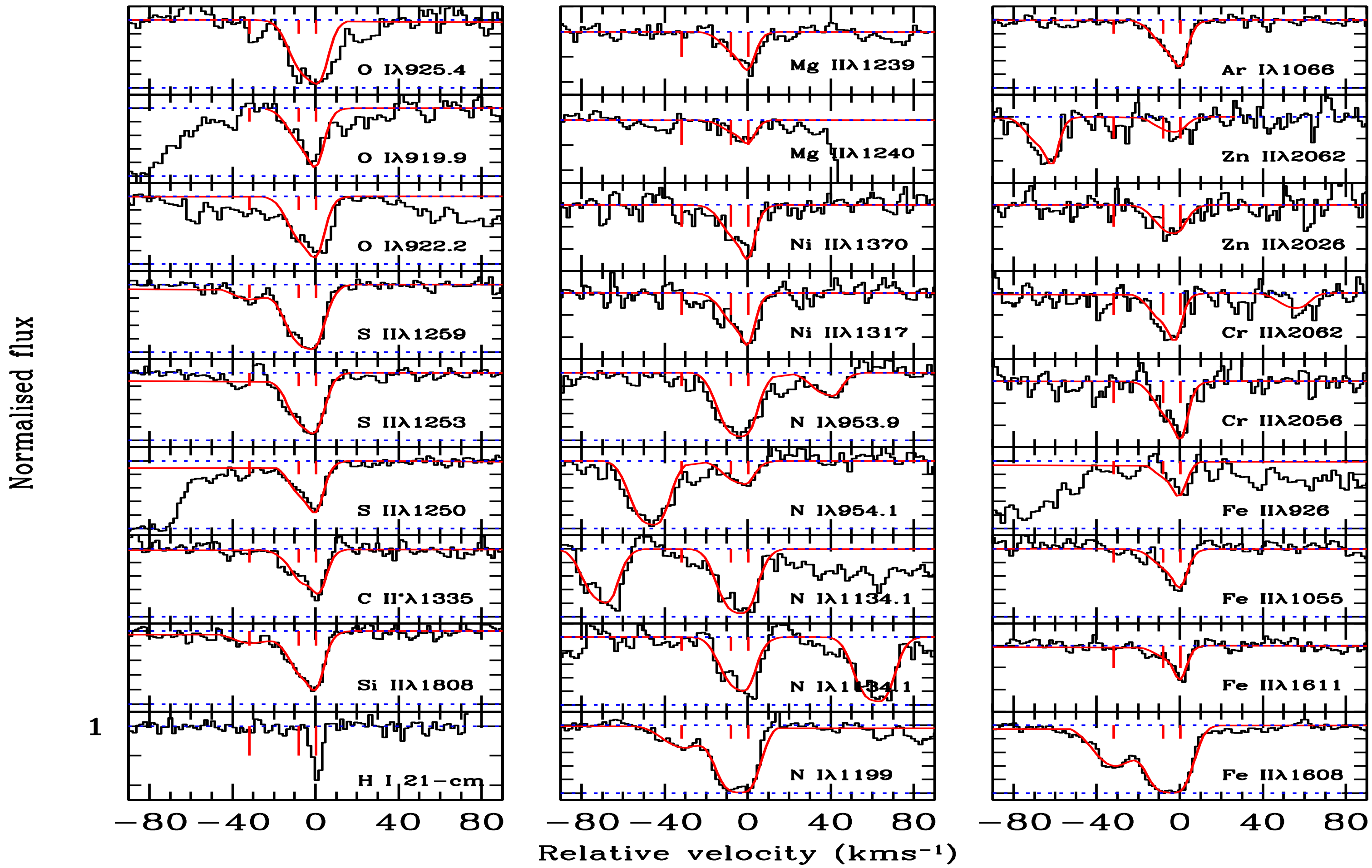
New 21-cm absorber at z = 3.17:



Srianand, Gupta, Petitjean, Noterdaeme & Ledoux, 2010, MNRAS, in press

New 21-cm absorber at z = 3.17:

$\Delta x/x = -(1.7 \pm 1.5 \pm 0.4) \times 10^{-6}$ where $x = \frac{\alpha^2 G_p}{\mu}$



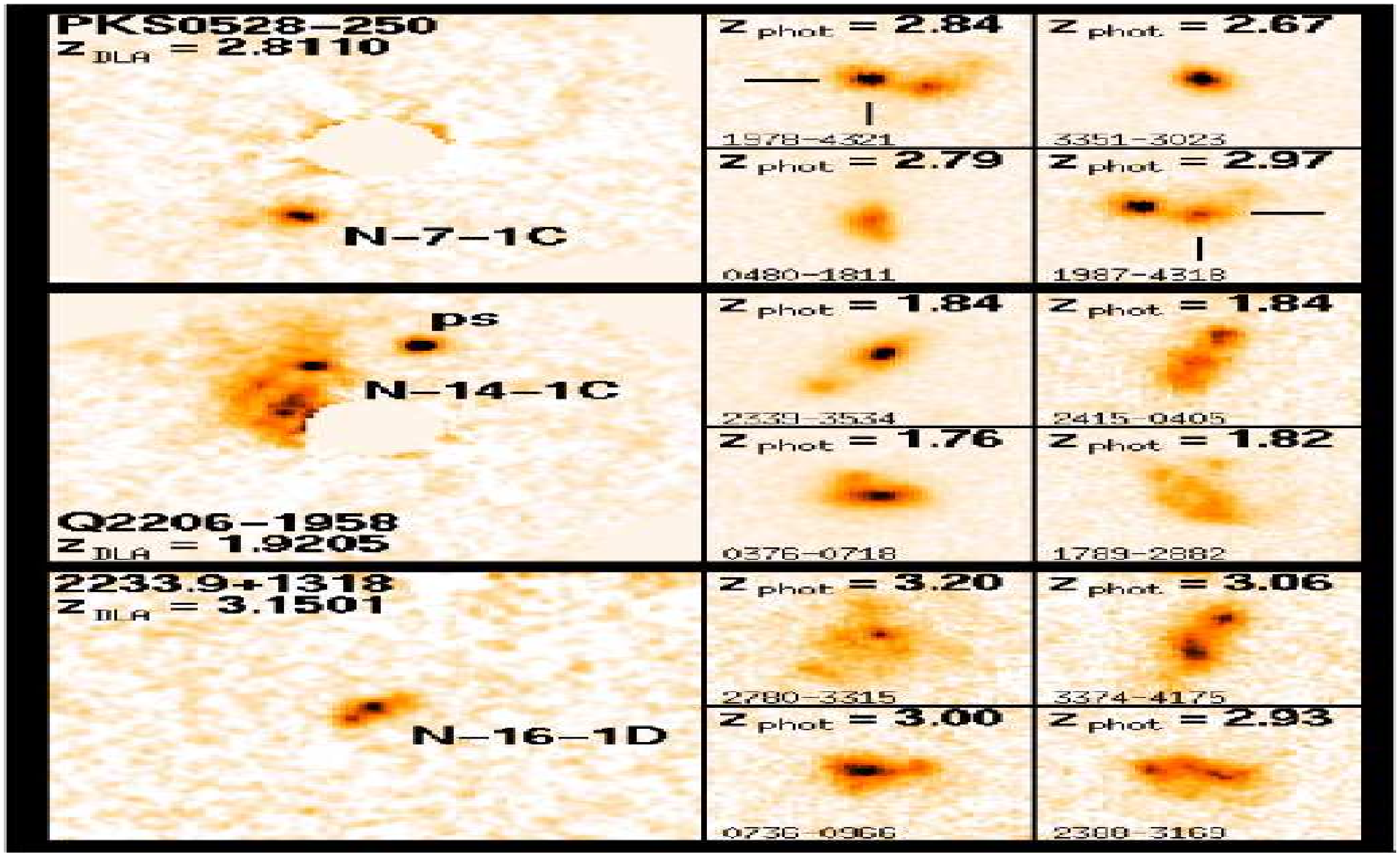
Star-formation in DLAs:

- Using fine-structure lines and cooling arguments (Wolfe et al. 2003)

- Using high J excitations of H_2 (Srianand et al. 2005)

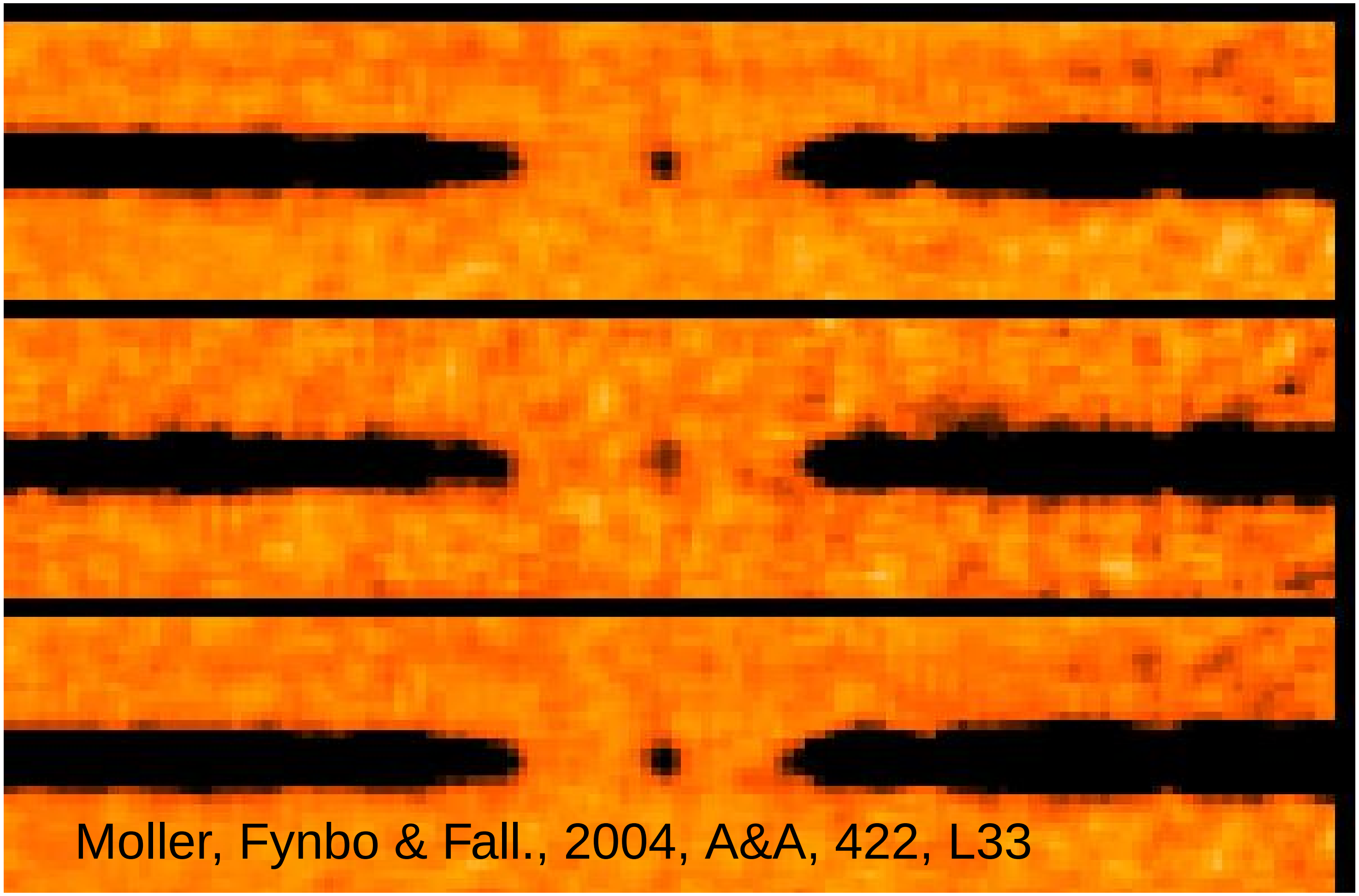
- Direct detection of galaxies either in continuum emission or through Lyman$-\alpha$ emission.

Star-formation in DLAs: Continuum emission

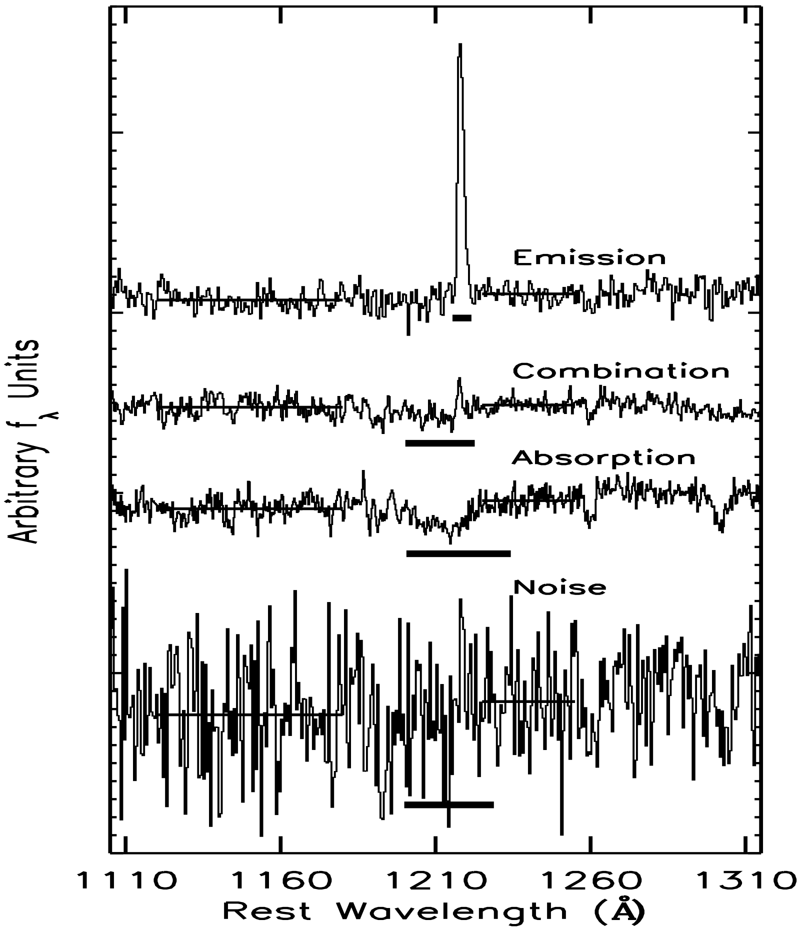


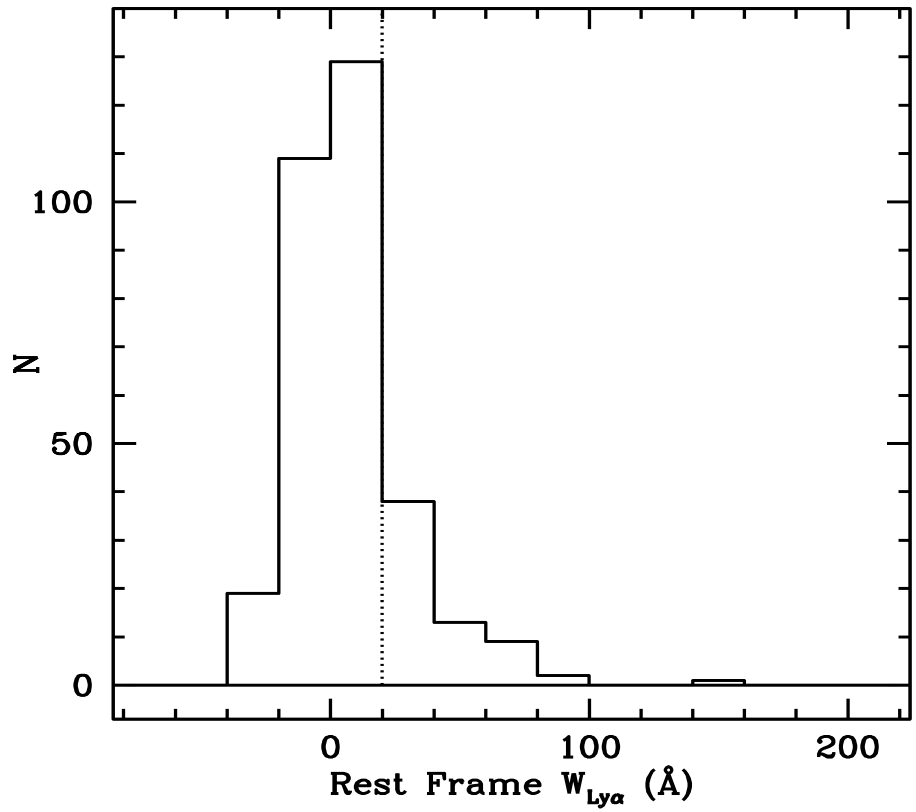
Most of these have high metallicity absorbers−Moller et al., 2002

Star-formation in DLAs: Lyman-α line



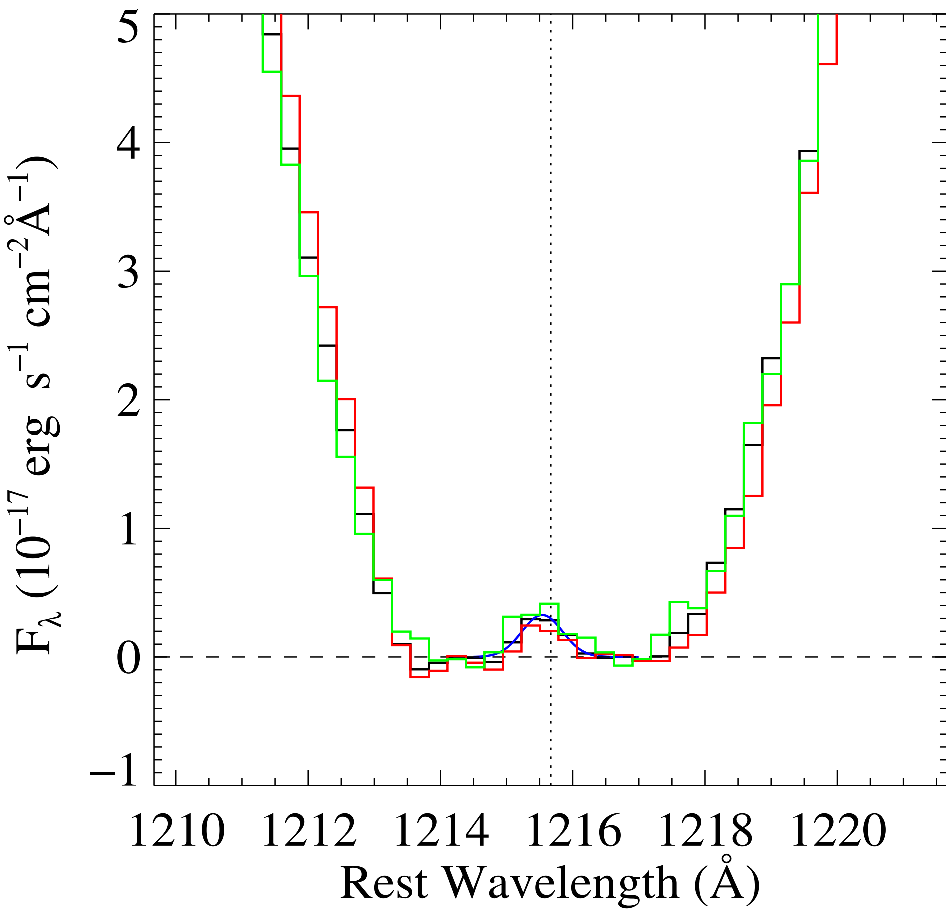
Lyman$-\alpha$ from Lyman break galaxies:





Kornei et al. 2009, ApJ, in press

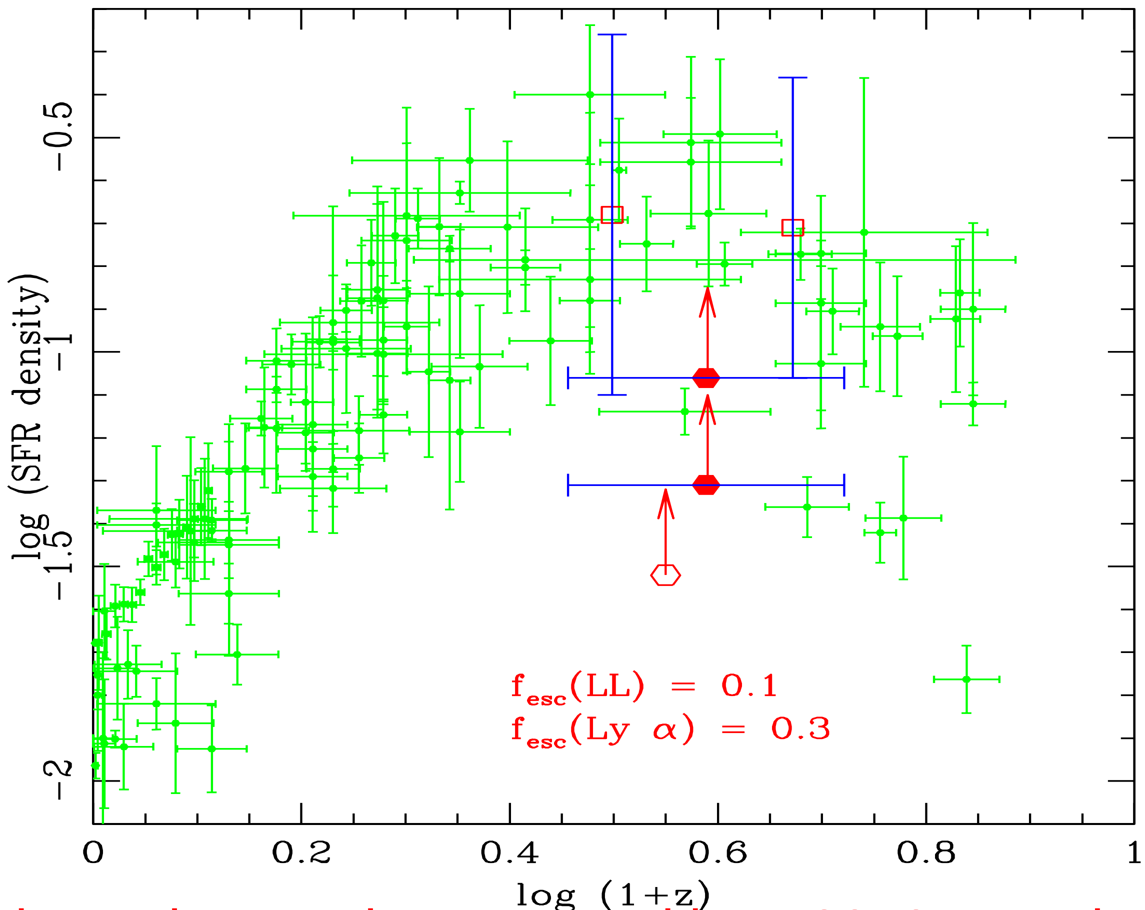
DLAs: Average Lyman-α emissivity



- Mean redshift = 2.877
- FWHM = 176 km/s
- F(Lyα) = 2.8$\times 10^{-18}$ erg/s/cm^2
- L(Lyα) = 2.04$\times 10^{41}$ erg/s
- $\dot{M} = \frac{\mathrm{L(Ly\alpha)}}{0.68 h\nu_\alpha f_{Ly}\,(1-f_{LL}) N_\gamma}$
  (Samui, Srianand, Subramanian, 2009)
- $\dot{\rho}_* = \frac{A}{A_p} < \dot{\xi} > \frac{dN}{dX}$
  (Wolfe et al., 2003)

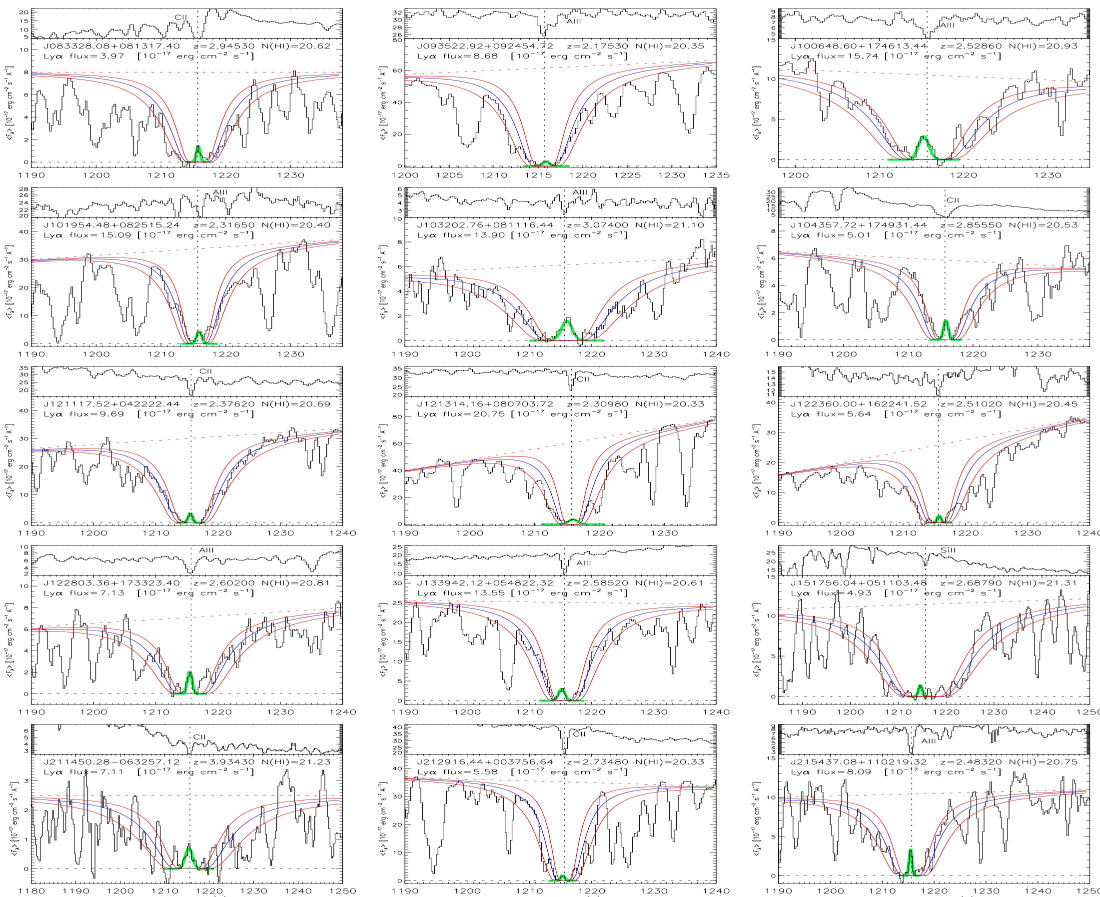
Rahmani, Srianand, Noterdaeme & Petitjean 2010, preprint

DLAs: Star-formation rate density



Rahmani, Srianand, Noterdaeme & Petitjean 2010, preprint

Lyman$-\alpha$ from DLAs:



Summary:

- Thanks to SDSS and followup studies we are making good progress with the QSO absorbers galaxy connection.

- Direct detection of emission line galaxies responsible for the QSO absorption has openup the possibility to connect the parameters derived from nebular emission lines and from QSO absorption lines.

- SFR density contributed by Mg II systems and DLAs are subtantial to the global SFR density.

- Indications are that at high redshift the volume filling factor (or covering factor) of the Cold neutral gas is less.

- There are indications that QSO are not colour selected when we detect CO or 2175 dust features. Thus there are possible missing red QSOs that can probe the central regions of galaxies.

- HST-COS and STIS observations will be very useful.