What do QSO absorbers tell us about inflows/outflows?

Brice Ménard

CITA & Johns Hopkins Univ.

Absorption line spectroscopy

- 1969: Bahcall & Spitzer postulate that metal absorbers live within 100 kpc around galaxies

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ABSORPTION LINES PRODUCED BY GALACTIC HALOS

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AND

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Received March 24, 1969

ABSTRACT

We propose that most of the absorption lines observed in quasi-stellar sources with multiple absorption redshifts are caused by gas in extended halos of normal galaxies.

Absorption line spectroscopy

- 1969: Bahcall & Spitzer postulate that metal absorbers live within 100 kpc around galaxies

greater than 10^3, lead us to believe that most of the narrow absorption lines are produced in material not associated with the quasi-stellar sources in whose spectra they are detected. A few lines, which correspond to $v_{\rm rel}/c \lesssim 10^{-2}$, may plausibly be attributed to material associated with the emitting object.

The number P of galaxies intercepted between $z_{\rm em}$ and z_c (see Bahcall and Peebles 1969; we assume for simplicity $q_0 = \frac{1}{2}$ and $\Lambda = 0$) is

$$P = 2\left[\frac{R_0}{100\ \rm kpc}\right]^2 \left[\frac{N_0}{0.03\ \rm galaxy\ Mpc^{-3}}\right][(1 + z_{\rm em})^{3/2} - (1 + z_c)^{3/2}] \,. \qquad (1)$$

Here R_0 and N_0 are the local radius and number density of the galaxies, and the Hubble constant, H_0, has been set equal to 100 km sec^{-1} Mpc^{-1}. We assume that the galactic number density at z satisfies $N(z) = (1 + z)^3 N_0$ but that the average radius is independent of z (at least in the range z = 1–2). The value of 0.03 galaxy Mpc^{-3} used as

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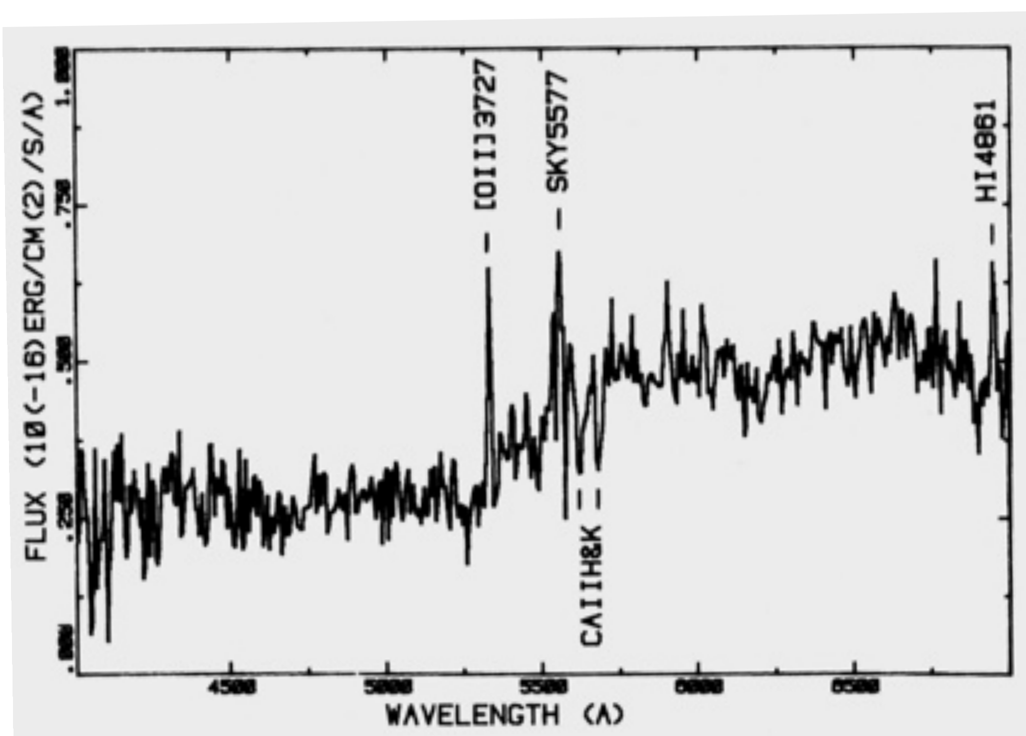
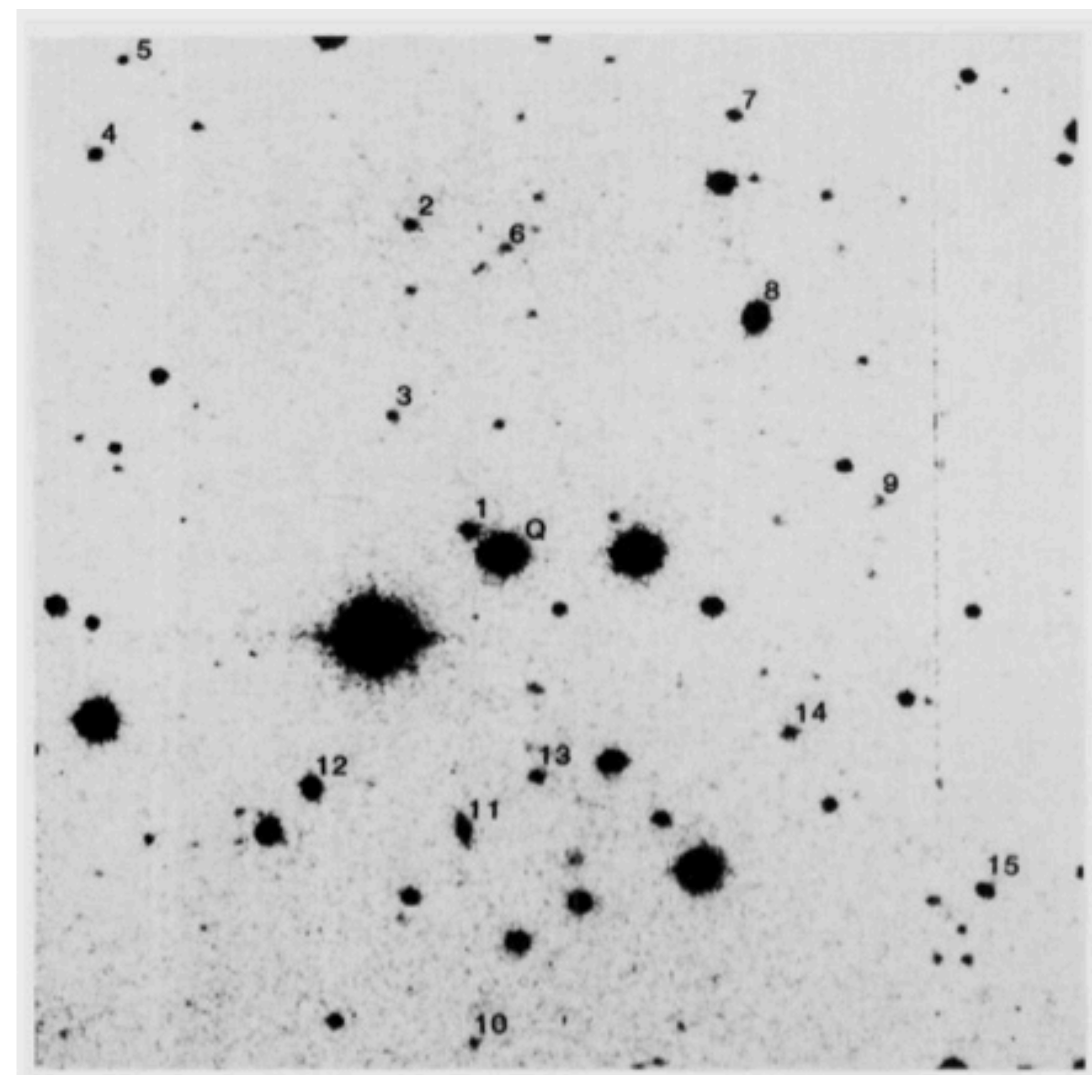
Letter to the Editor

ASTRONOMY AND ASTROPHYSICS

The Mg II absorption system in the QSO PKS 2128-12: a galaxy disc/halo with a radius of 65 kpc*

J. Bergeron
Institut d'Astrophysique, 98bis Bd Arago, F-75014 Paris, France





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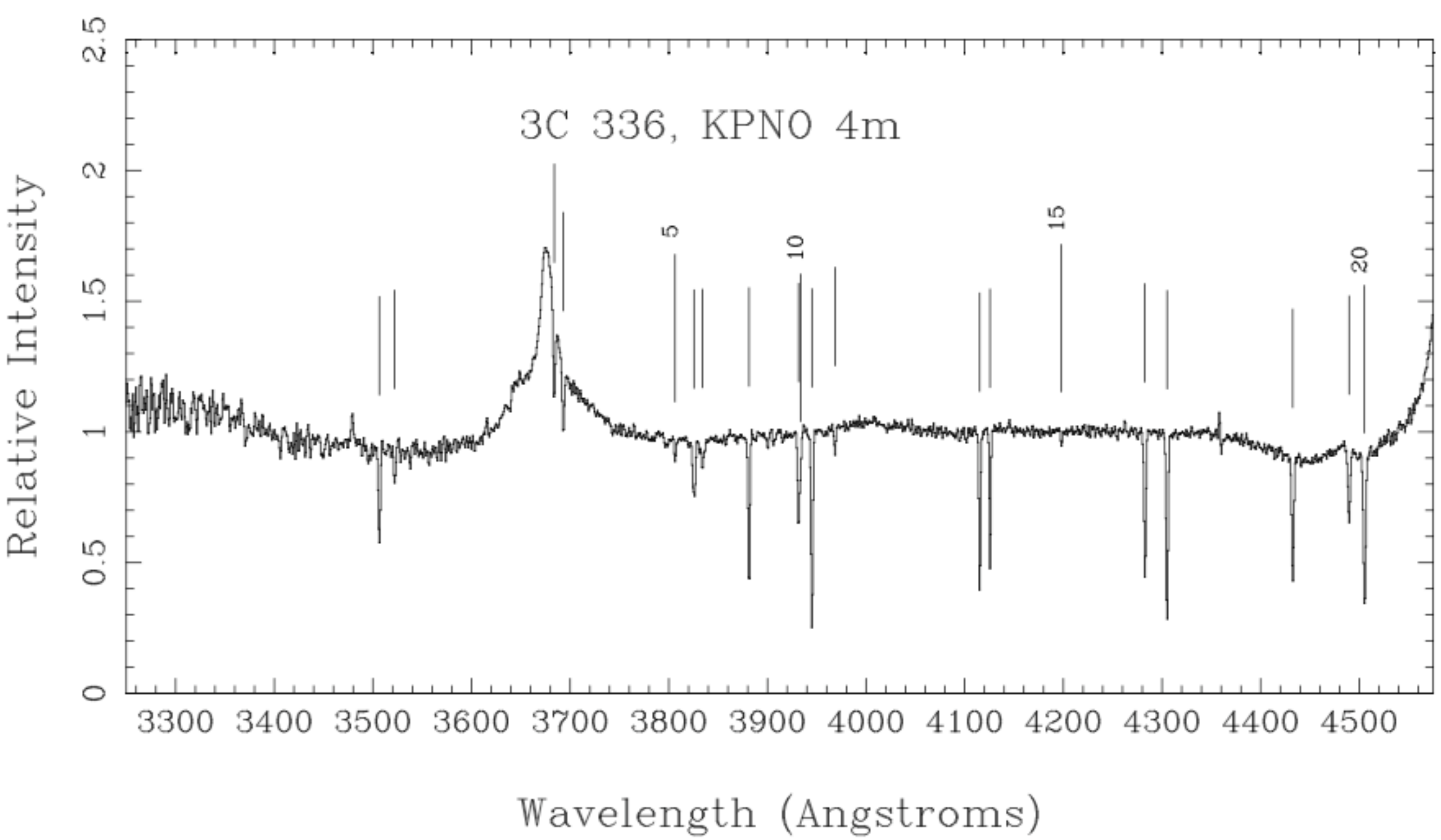

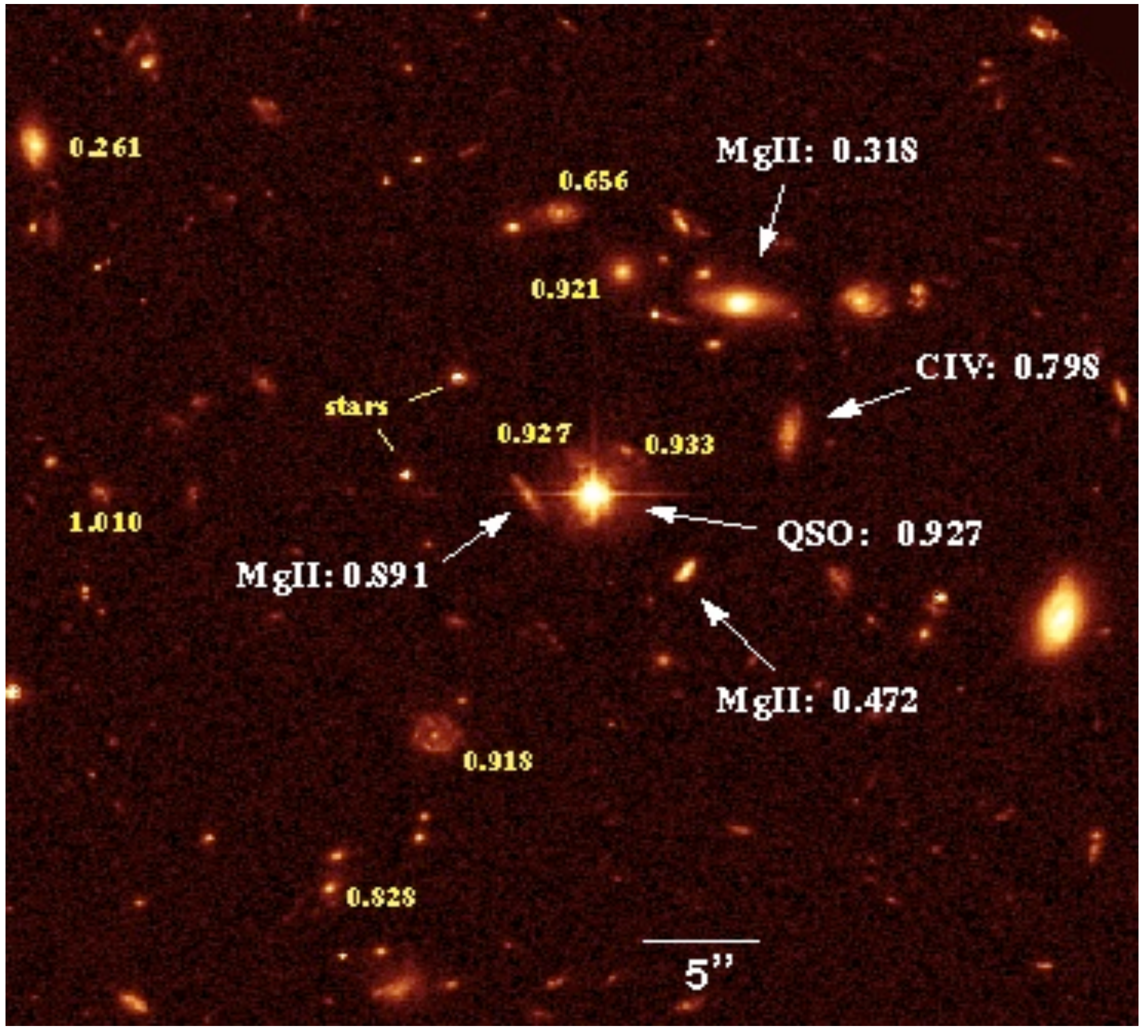

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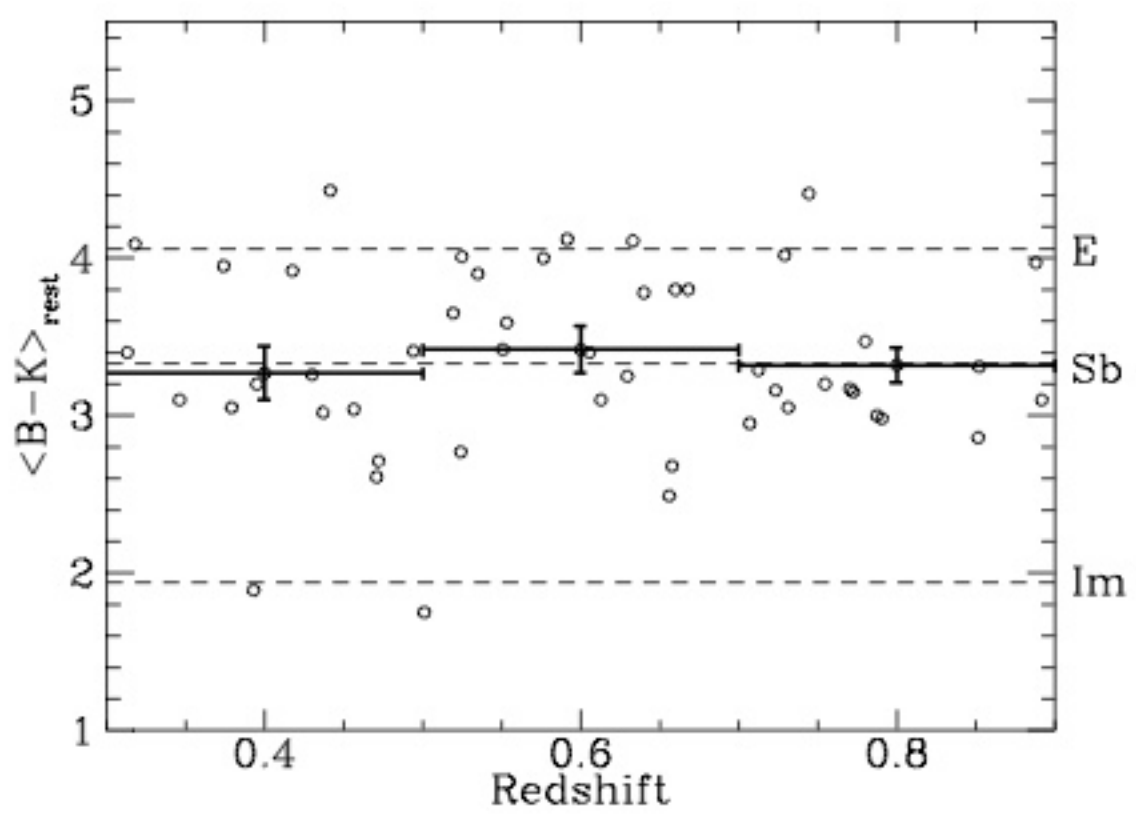

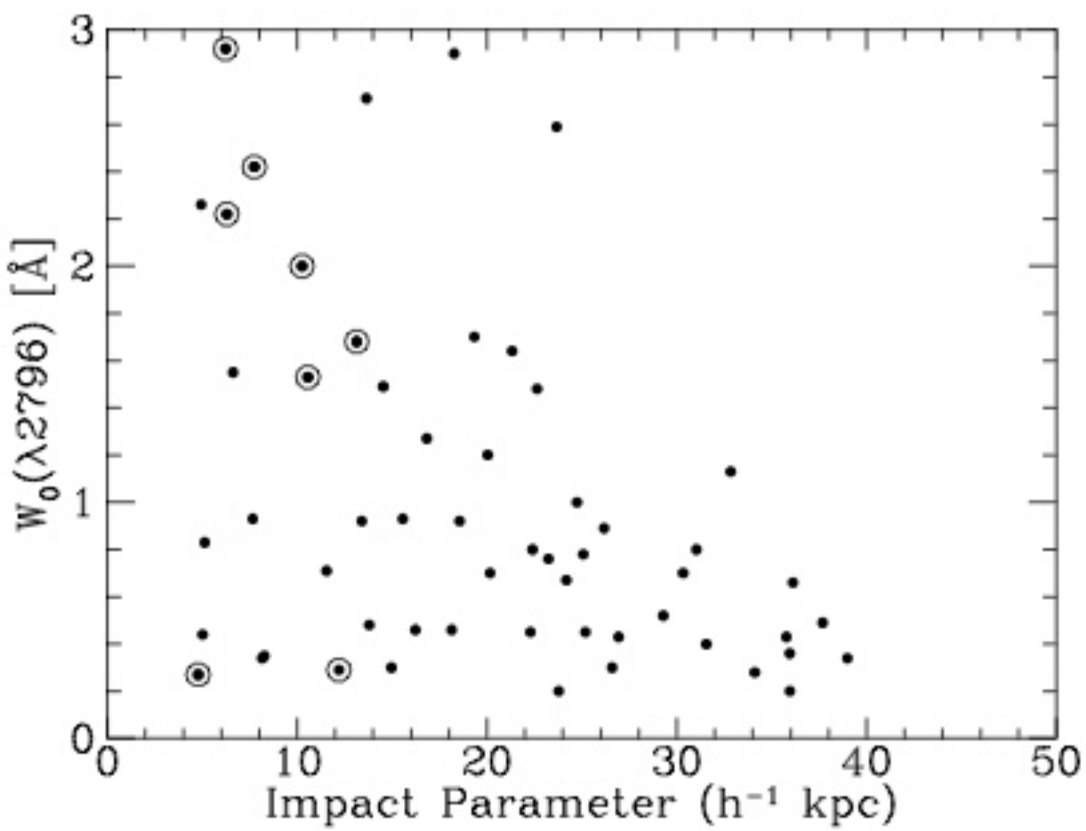

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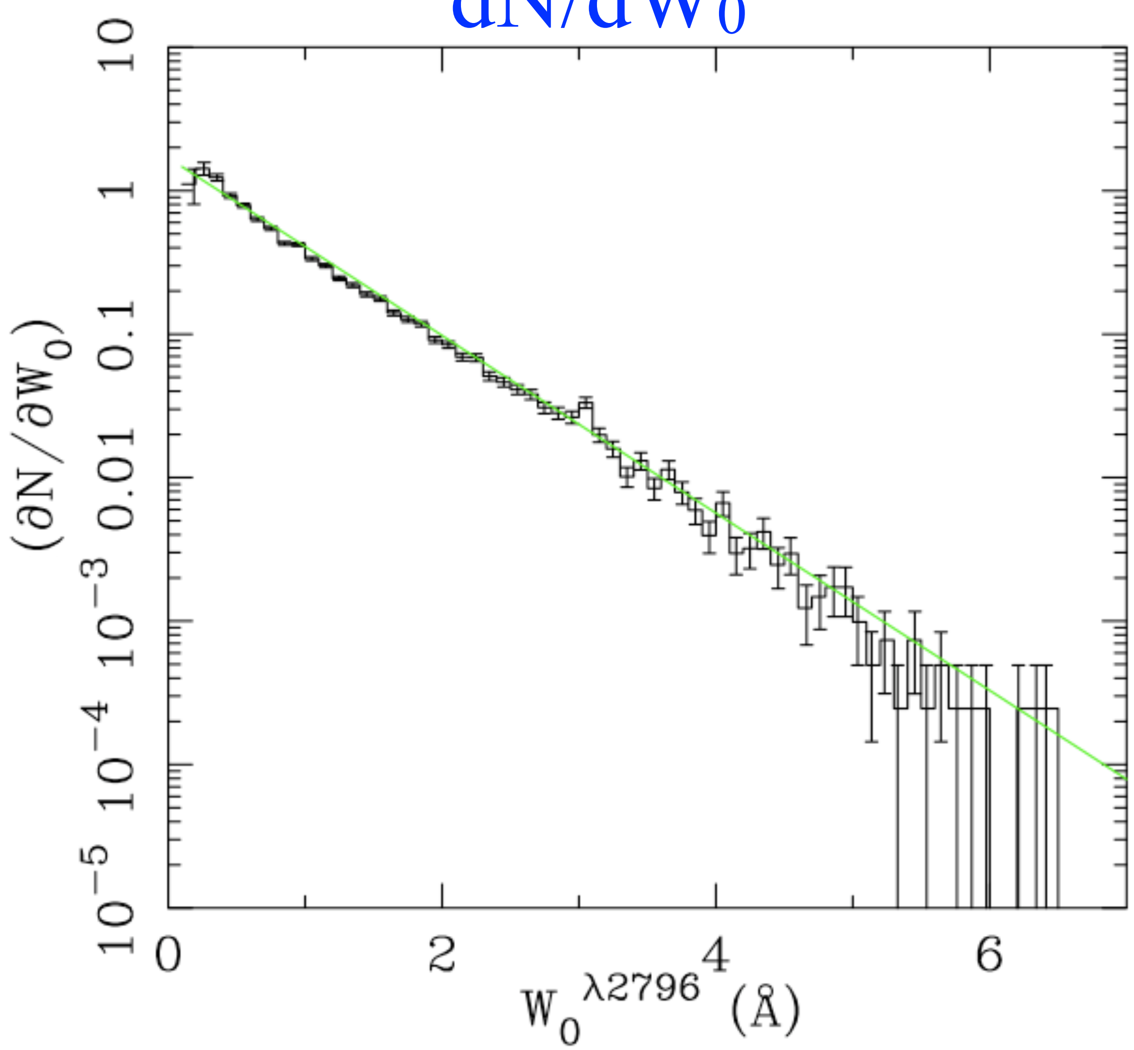
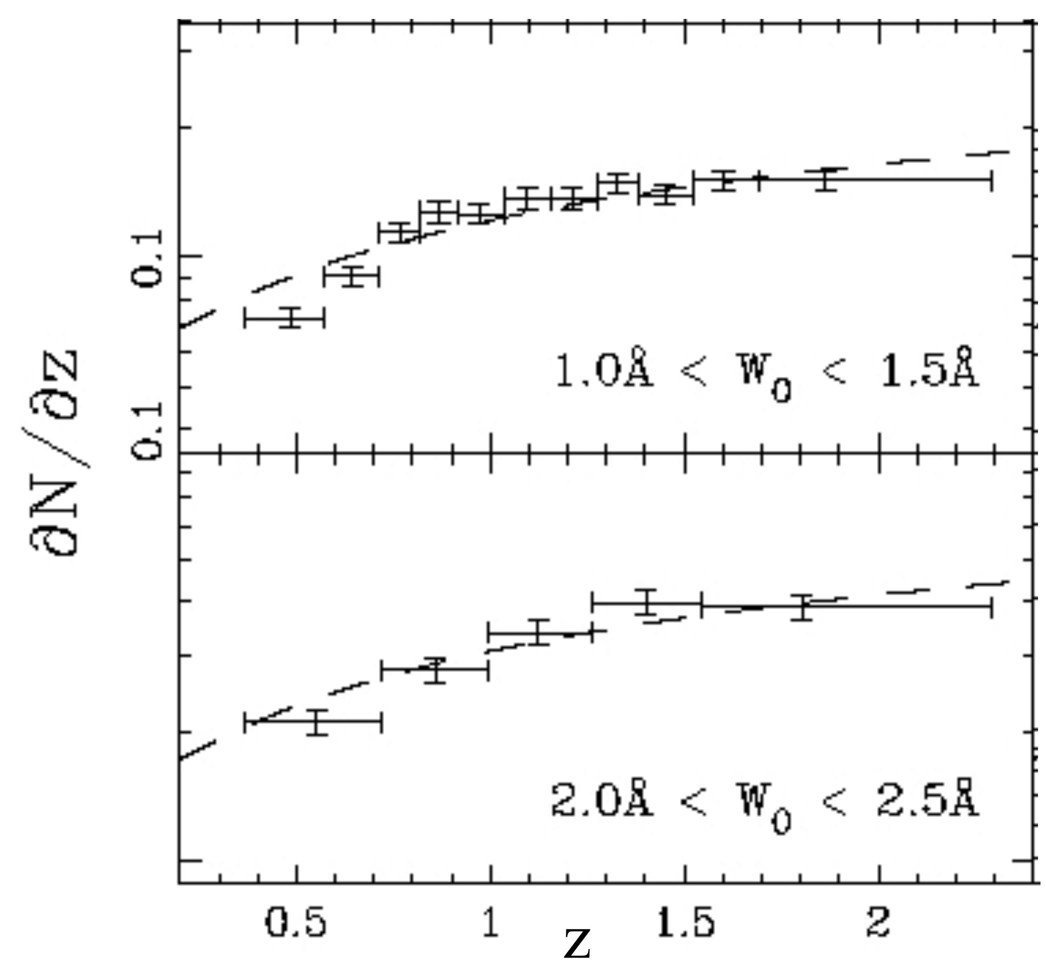
dN/dW_0



dN/dz



Nestor et al. (2005, 2010)

Absorption line spectroscopy

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- 2000-2010: statistical studies: 100,000 QSO spectra and ~20,000 metal absorbers

- 2010-2020: BOSS, BigBOSS, PFS (Subaru): towards one million QSO spectra
  galaxies are being used as background sources

Questions

1. What are these intervening absorbers?

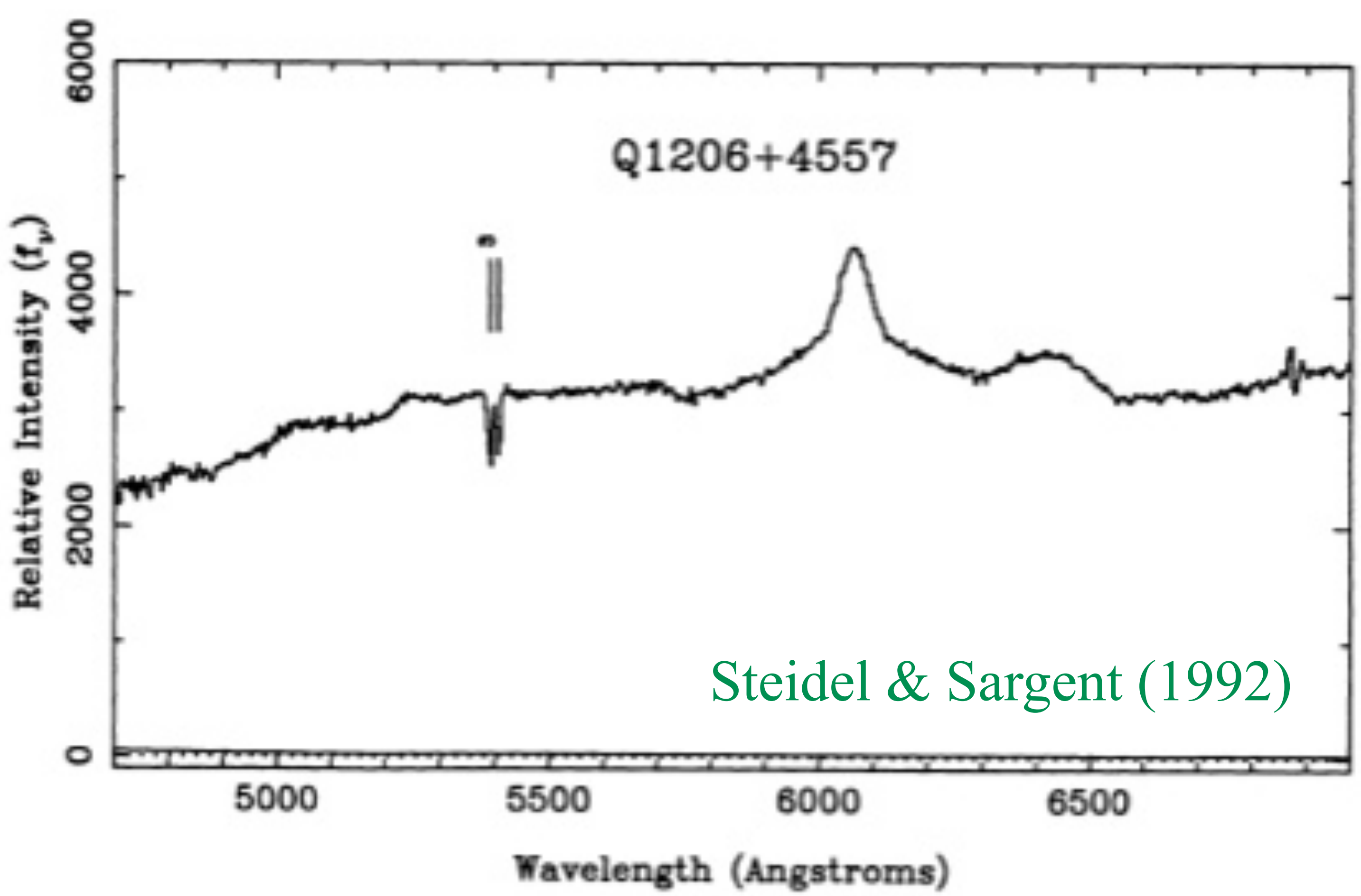
- incidence
- size, density, temperature
- metallicity, dust content
- velocity dispersion

2. How are they related to galaxies?

- direction of motion: going in or out?
- spatial distribution, covering factor, azimuthal angle
- correlation with galaxy type: luminosity, color, SFR

MgII as a tracer of baryons

Mg II	λλ 2796, 2803 Angstrom,	$z_{abs} > 0.4$
C IV	λλ 1548, 1550 Angstrom,	$z_{abs} > 1.5$
Si IV	λλ 1393, 1402 Angstrom,	$z_{abs} > 1.8$
N V	λλ 1238, 1242 Angstrom,	$z_{abs} > 2.2$
O VI	λλ 1031, 1037 Angstrom,	$z_{abs} > 2.8$
Ca II	λλ 3933, 3968 Angstrom,	$z_{abs} < 1.0$
Na I D	λλ 5889, 5895 Angstrom,	$z_{abs} < 0.3$

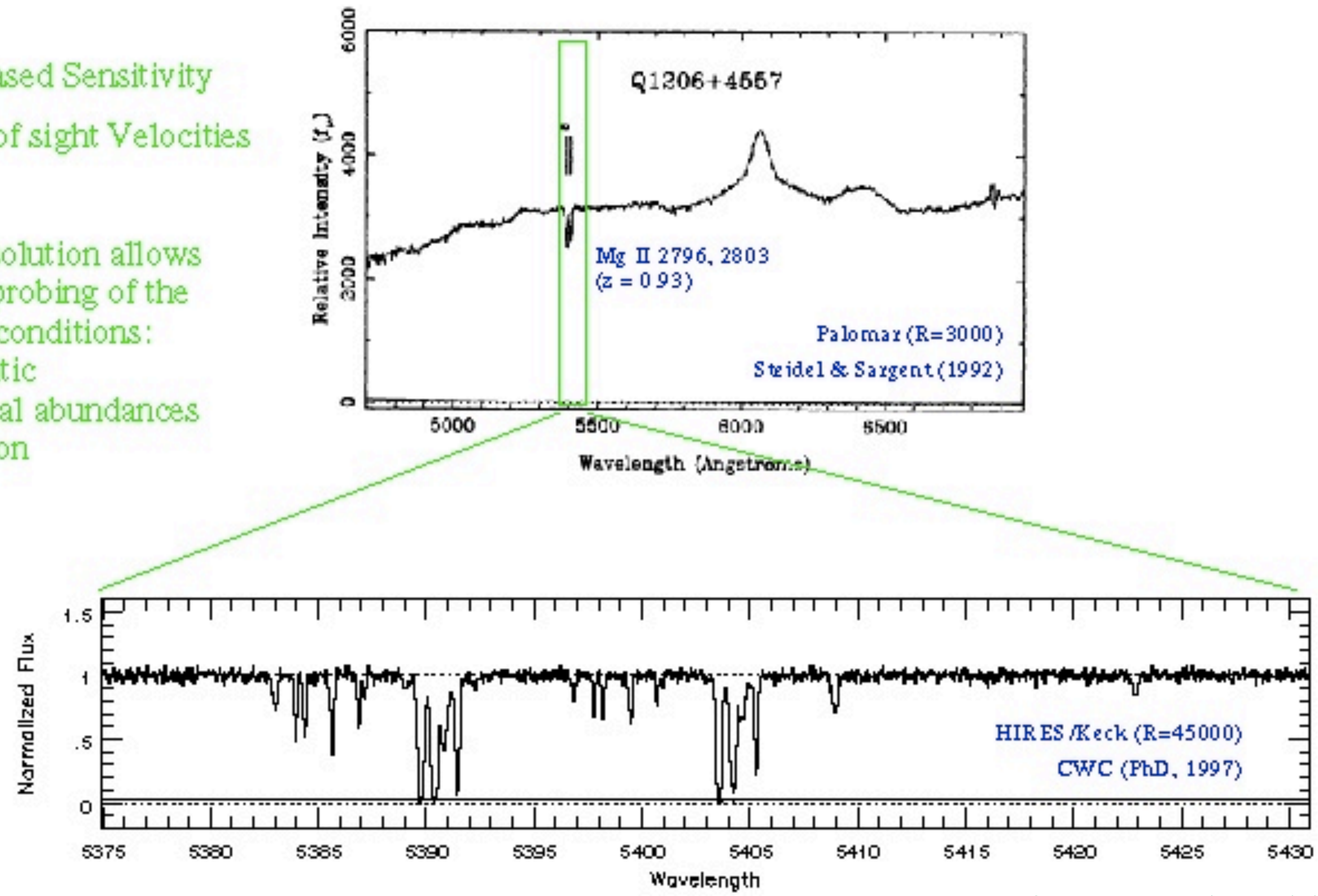


Absorber properties: high-resolution spectroscopy

(1) Increased Sensitivity

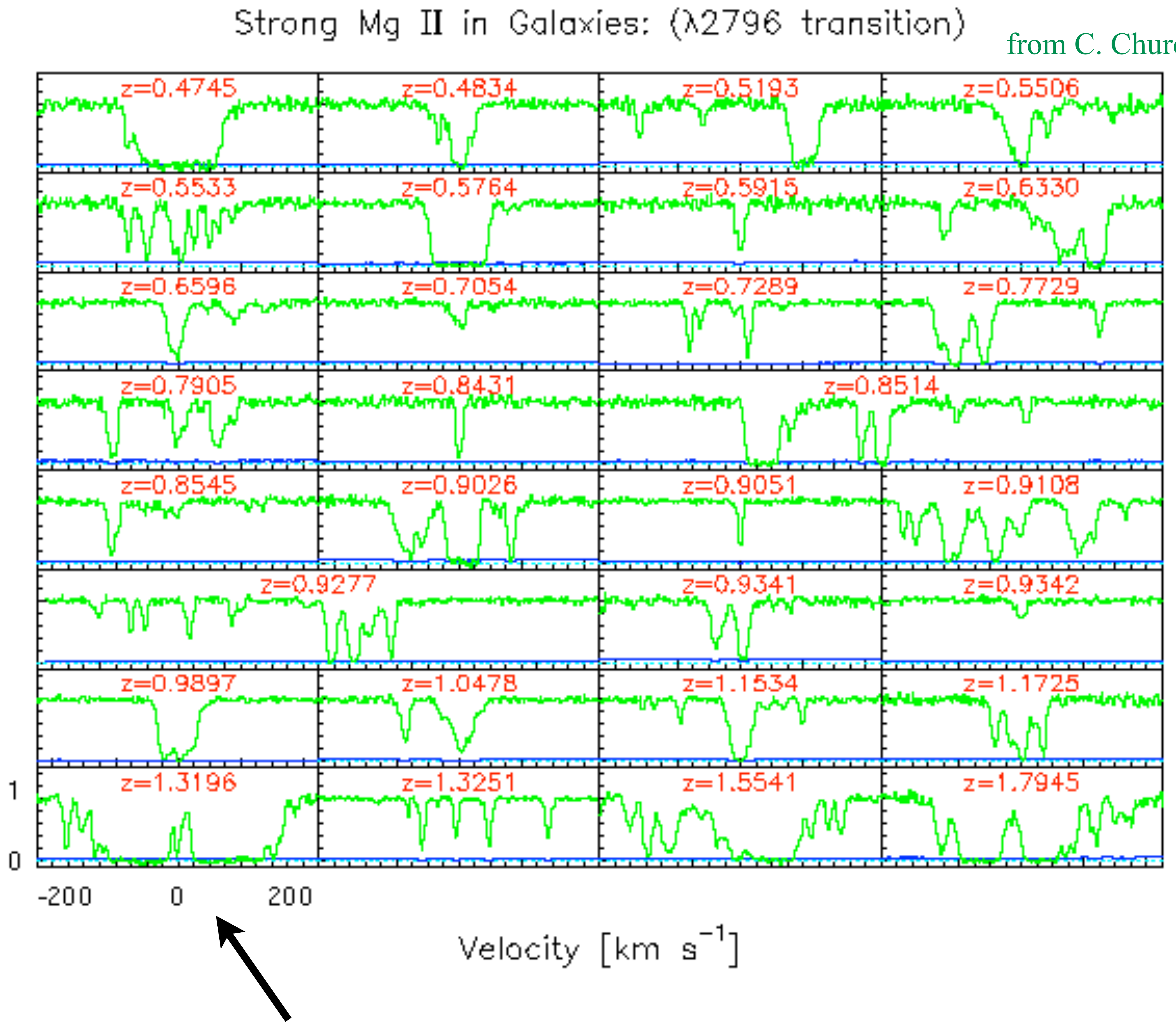
(2) Line of sight Velocities

High Resolution allows detailed probing of the physical conditions:
- kinematic
- chemical abundances
- ionization



from C. Churchill

MgII is a probe of metals weighted by cross-section and Δv

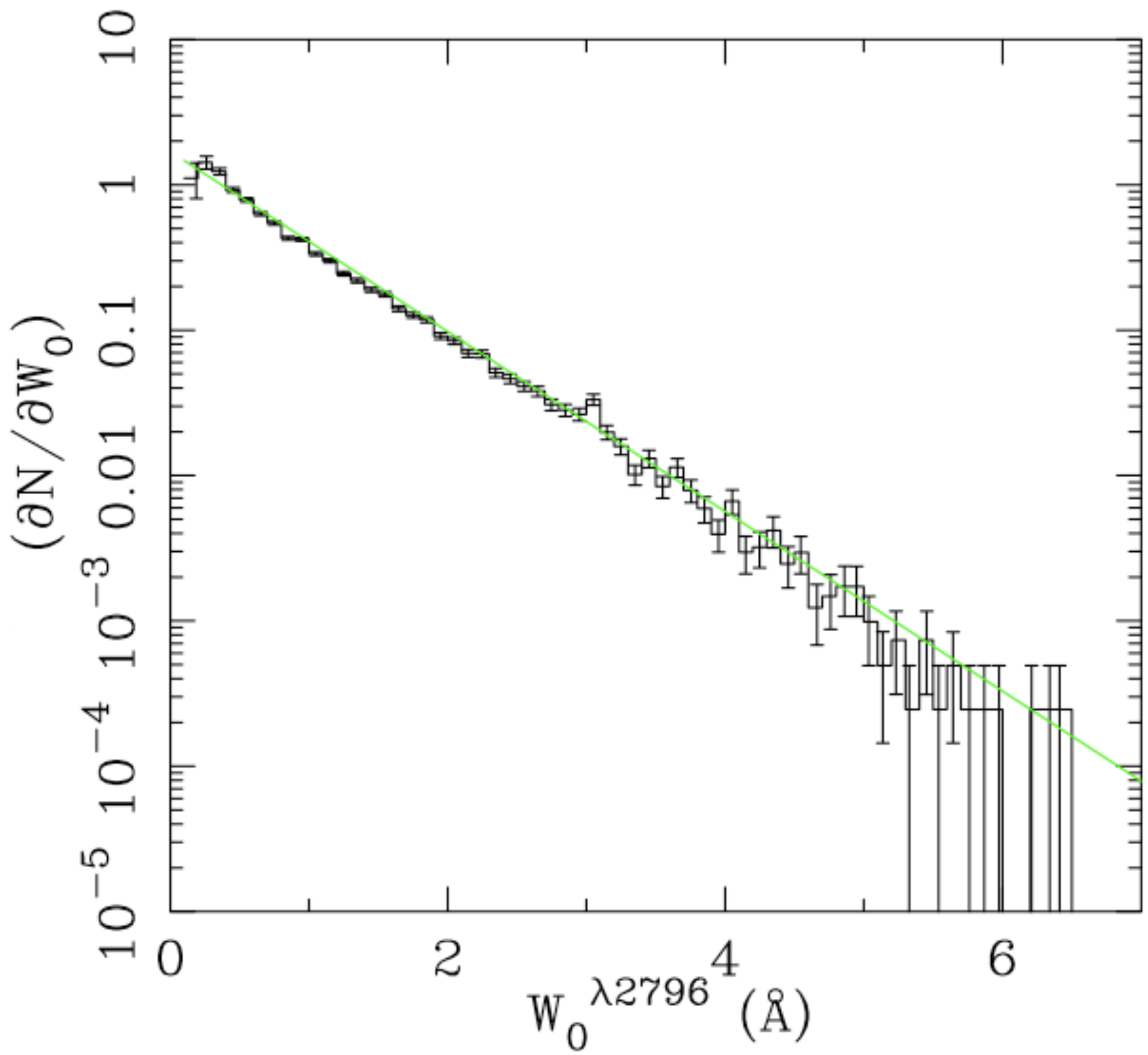


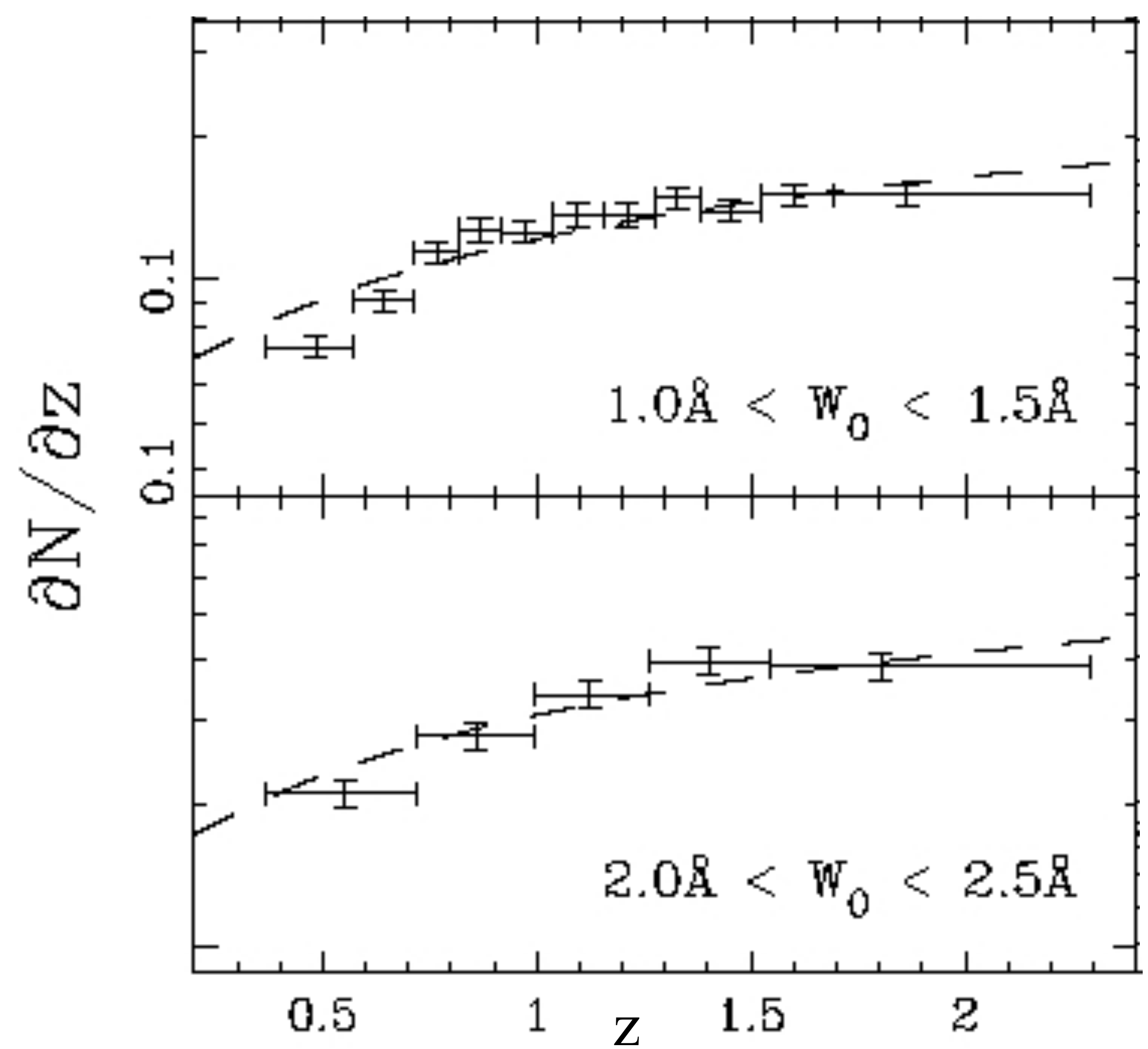
from C. Churchill's website

expanding shells (Bond et al., 2001)

MgII absorbers from the SDSS

dN/dW$_0$ Nestor et al. (2005, 2010) dN/dz

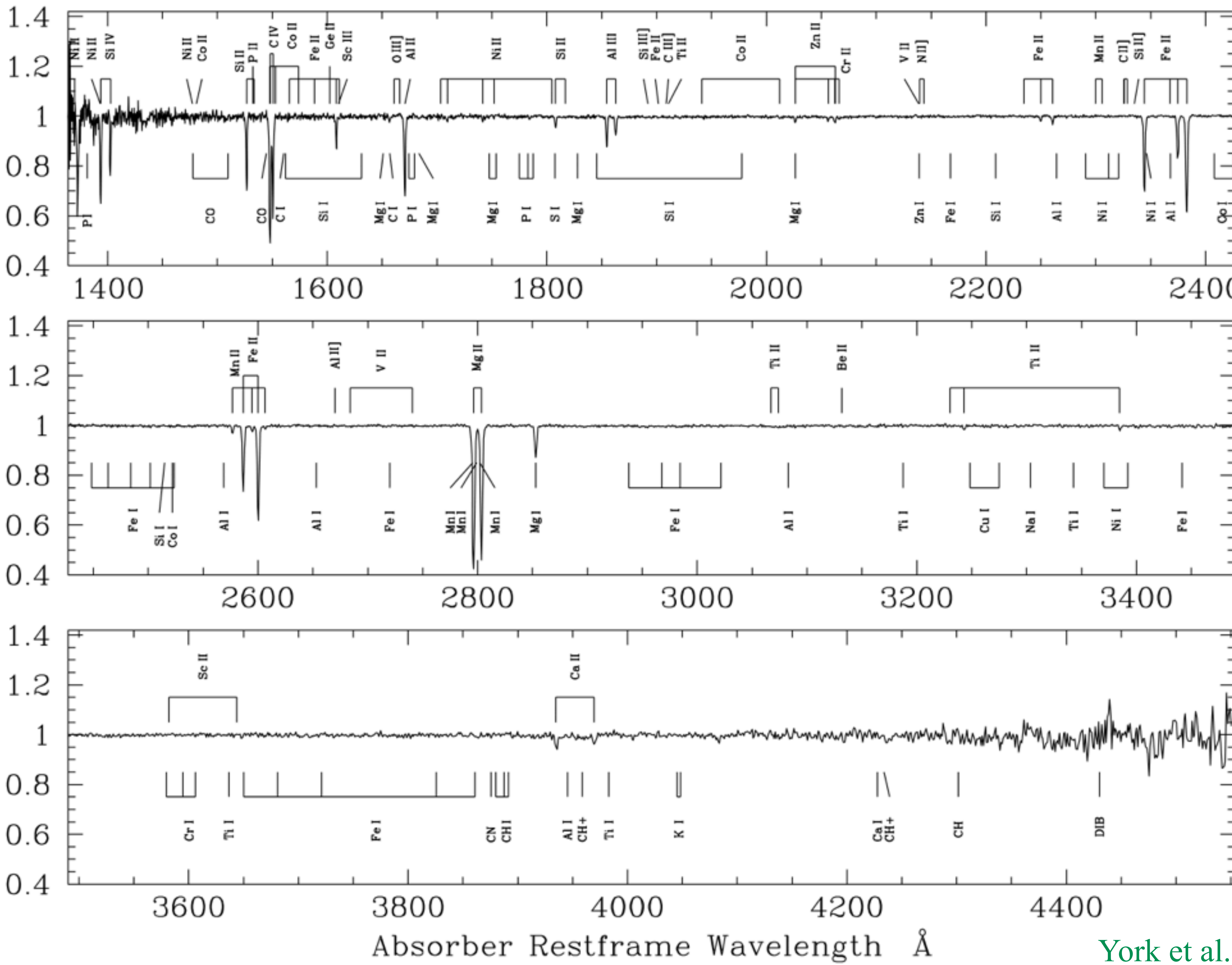




$\Delta v \sim 120$ km/s × W$_0$ [Ang.]

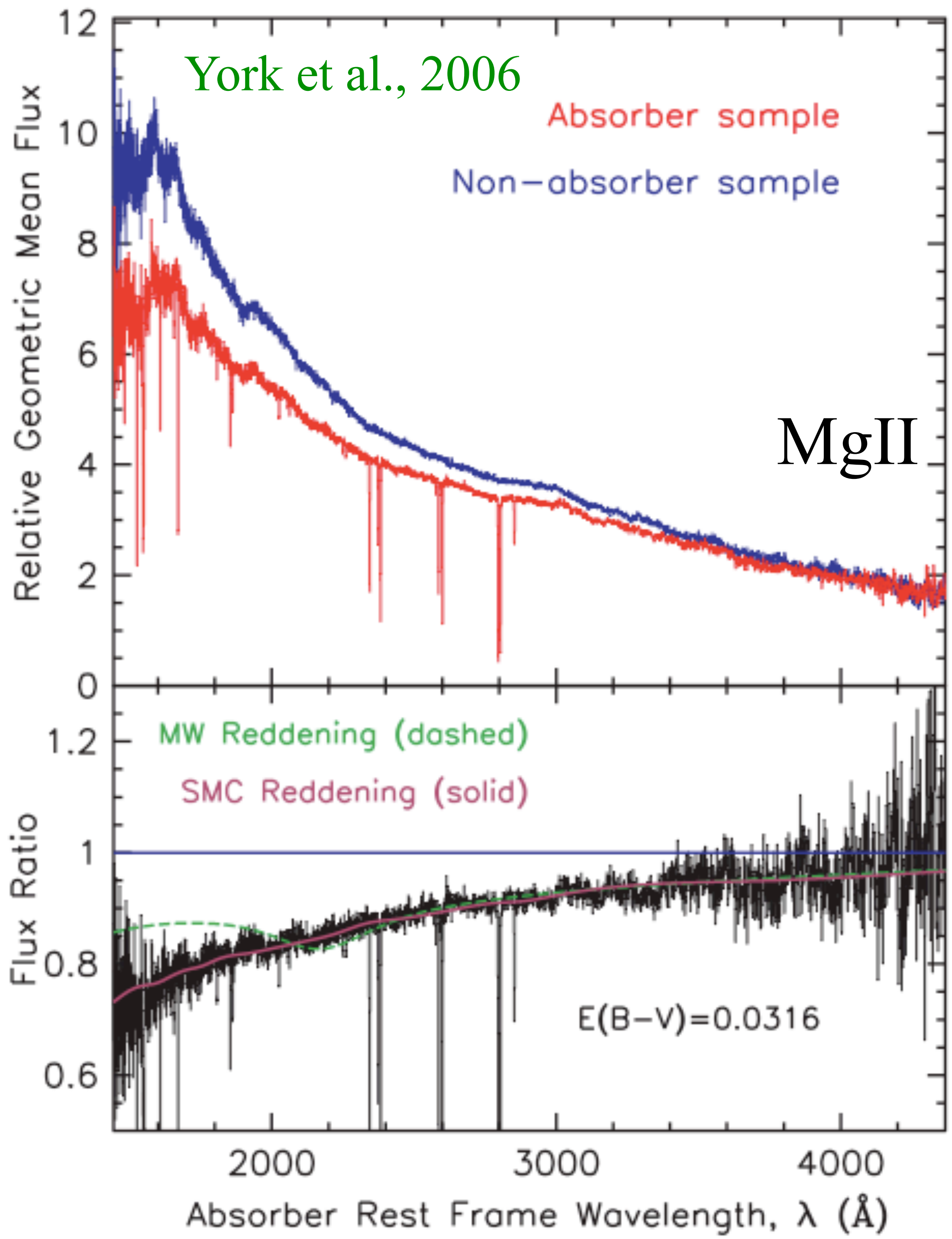
Prochter et al. (2006): "this evolution roughly tracks the global evolution of the star formation rate density."

Statistical analyses & composite spectra



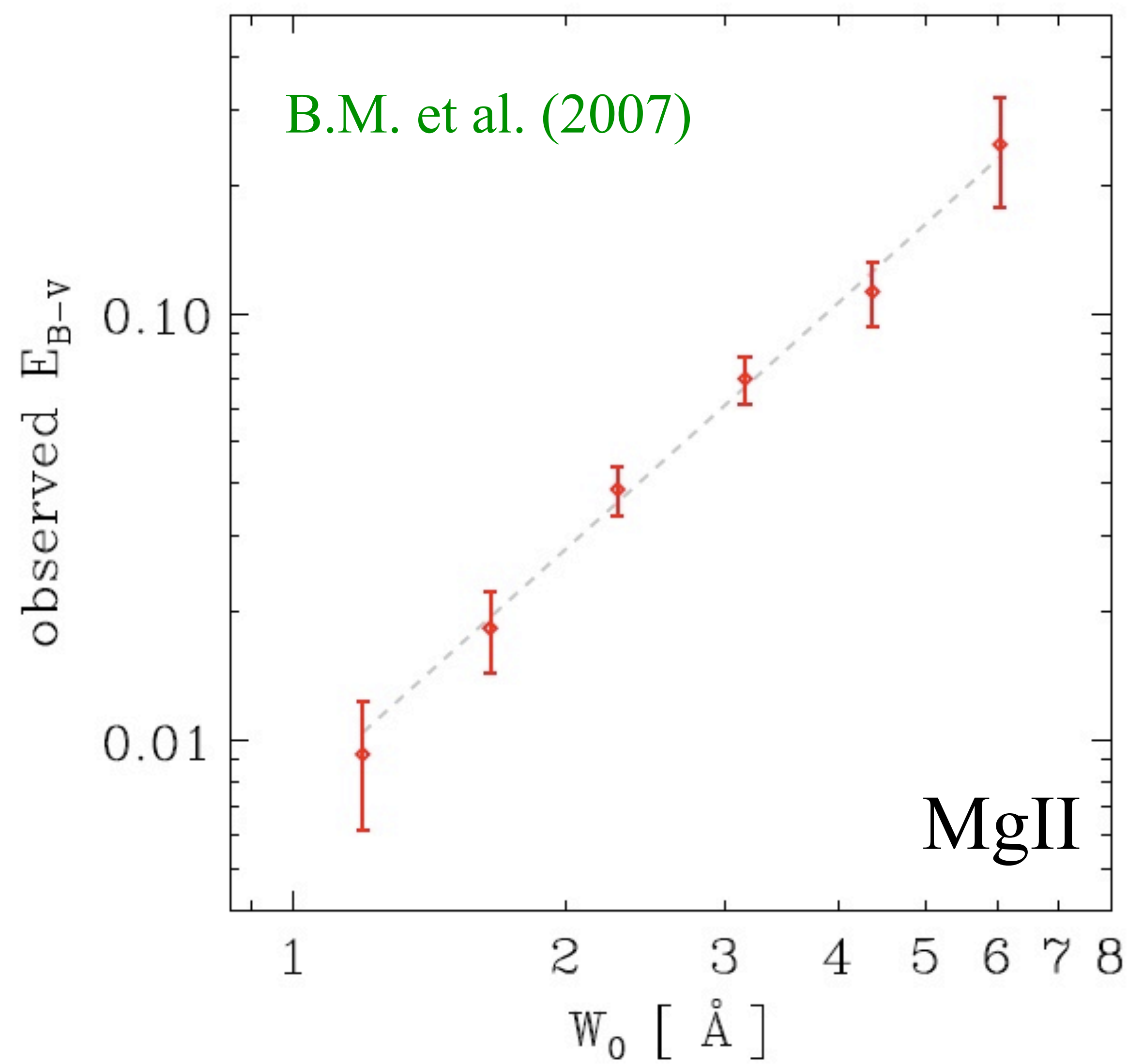
York et al. (2005)

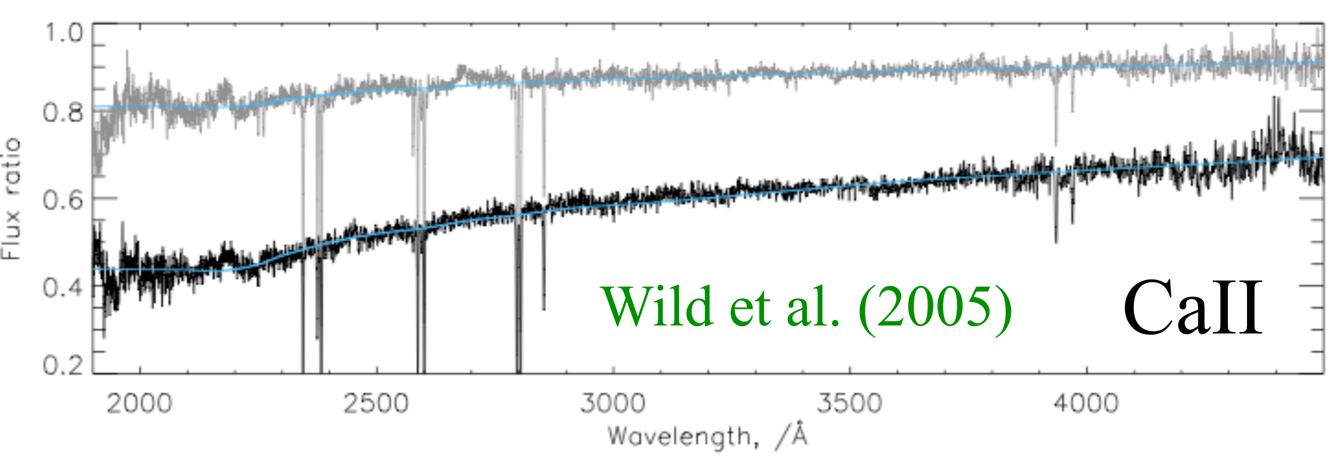
Metal absorbers are dusty



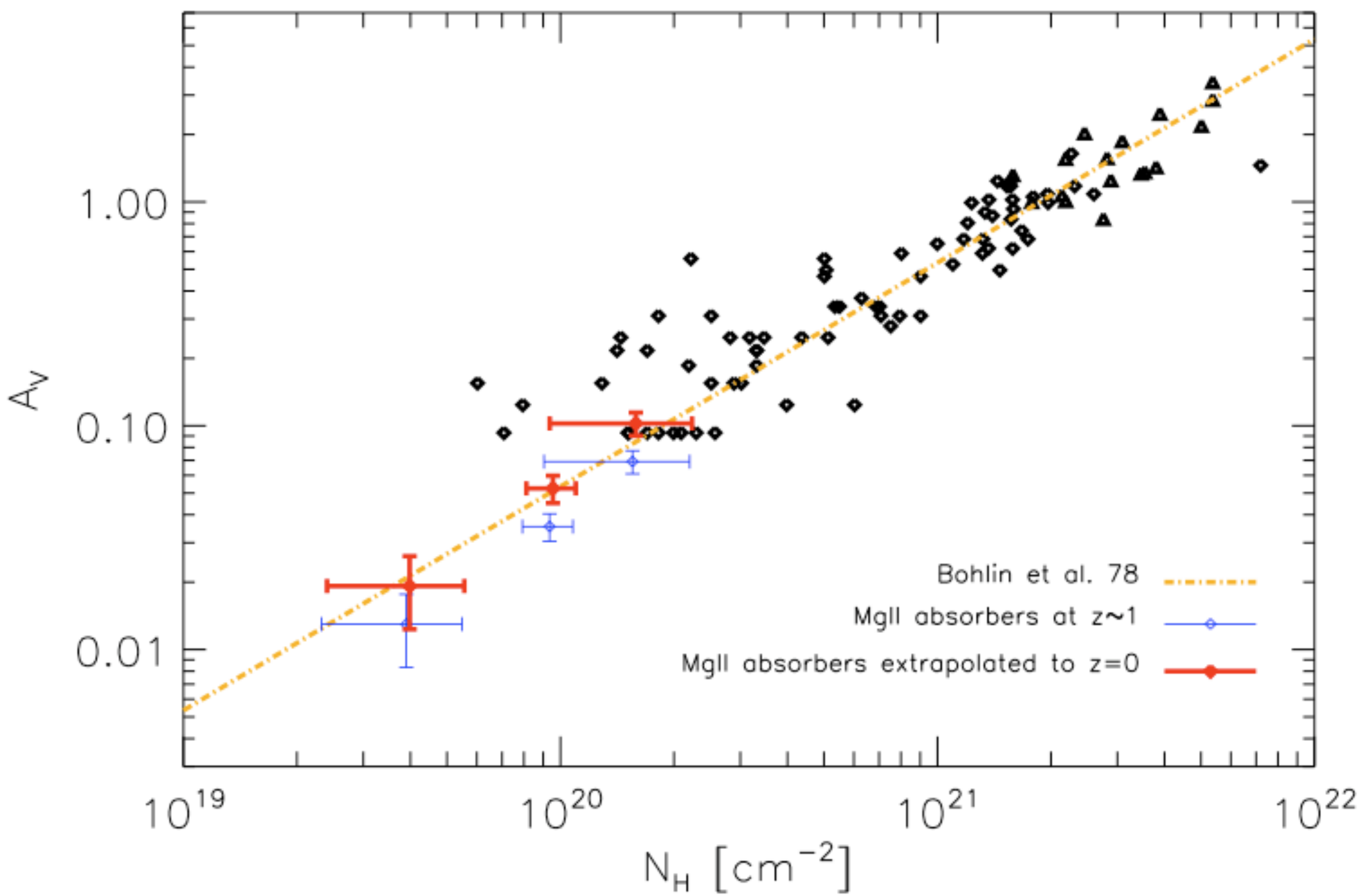
Reddening by absorbers: Fall & Pei (1989), B.M. & Péroux (2003), Khare et al. (2004), Murphy et al. (2004), Ellison et al. (2005), B.M. et al. (2007), Vladilo & Prochaska (2007), Wild et al. (2007)

dust also seen through depletion measurements. See Vladilo et al.





Dust-to-gas ratio



B.M. & Chelouche (2008)

Metal absorber properties

	consistent with	
	inflows	outflows
- higher incidence at high z	yes	yes
- distribution of W_0 (or Delta v)	?	?
- large Delta v	no	yes
- high dust-to-gas ratio	no	yes

Questions

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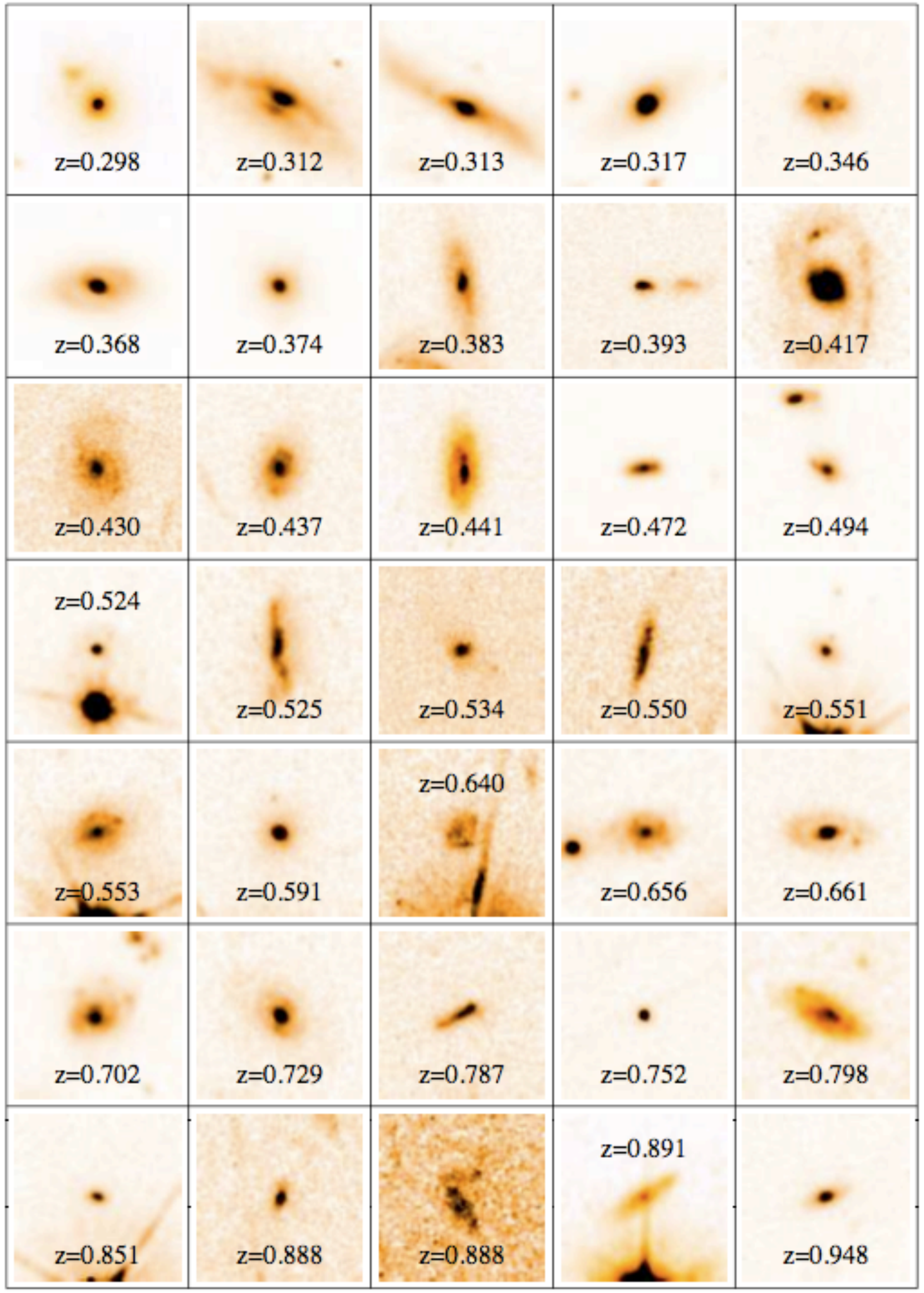
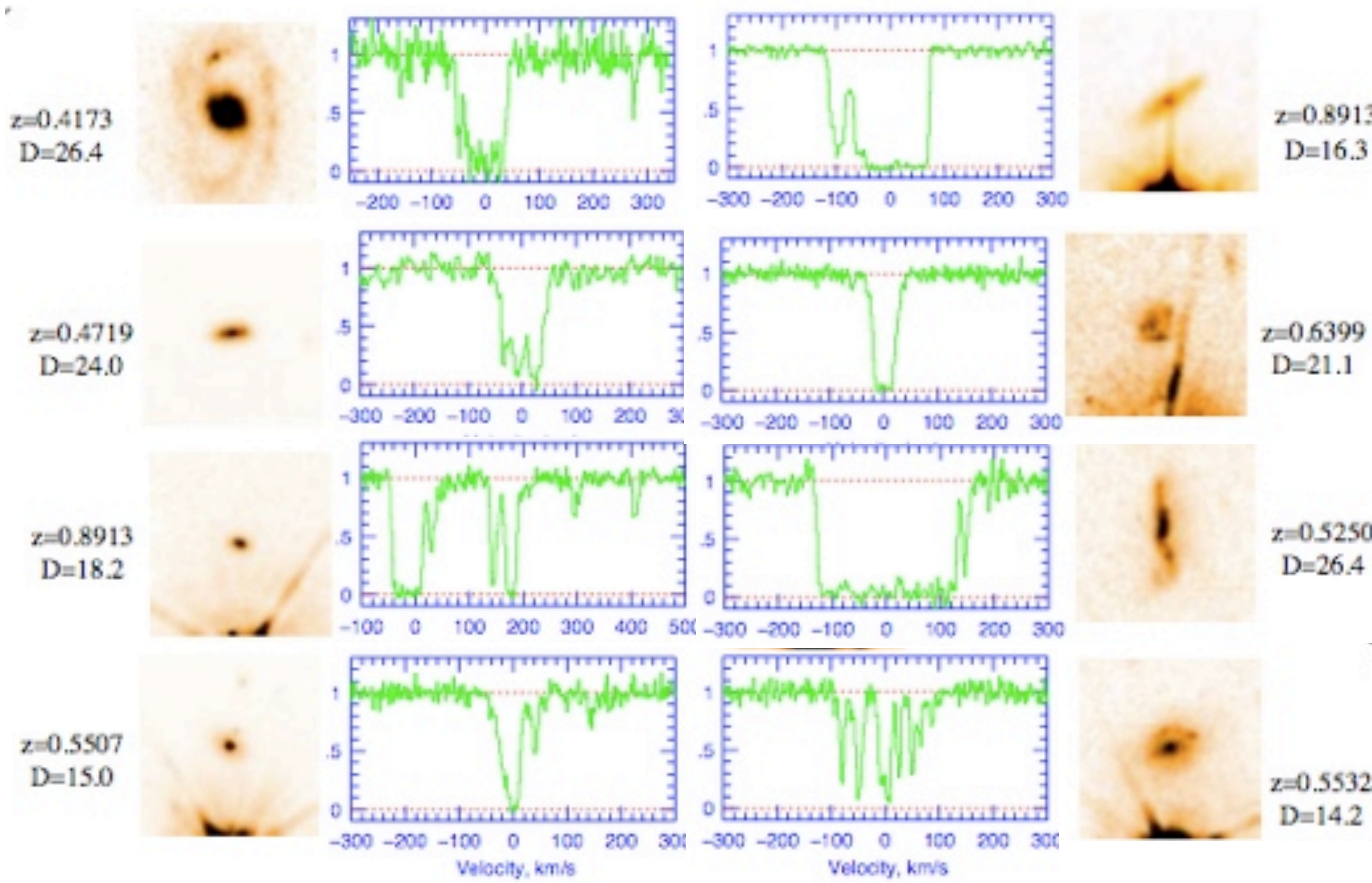
Studies of absorber-galaxy pairs



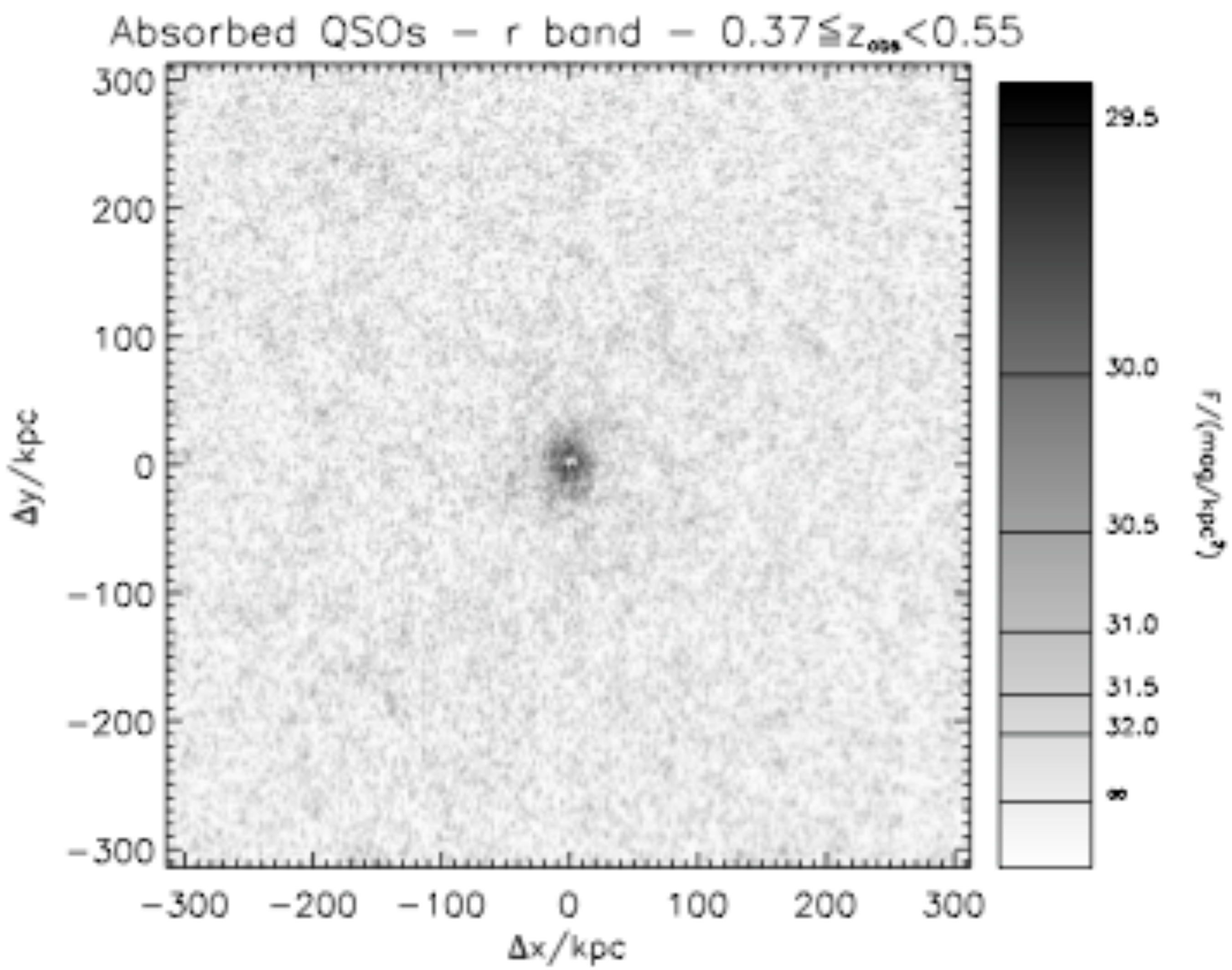


Apparent lack of correlation with galaxy properties

Churchill et al. (2006)
Kacprzak et al. (2007)

Imaging MgII absorbing galaxies with the SDSS

< QSO with absorber - nearby star >



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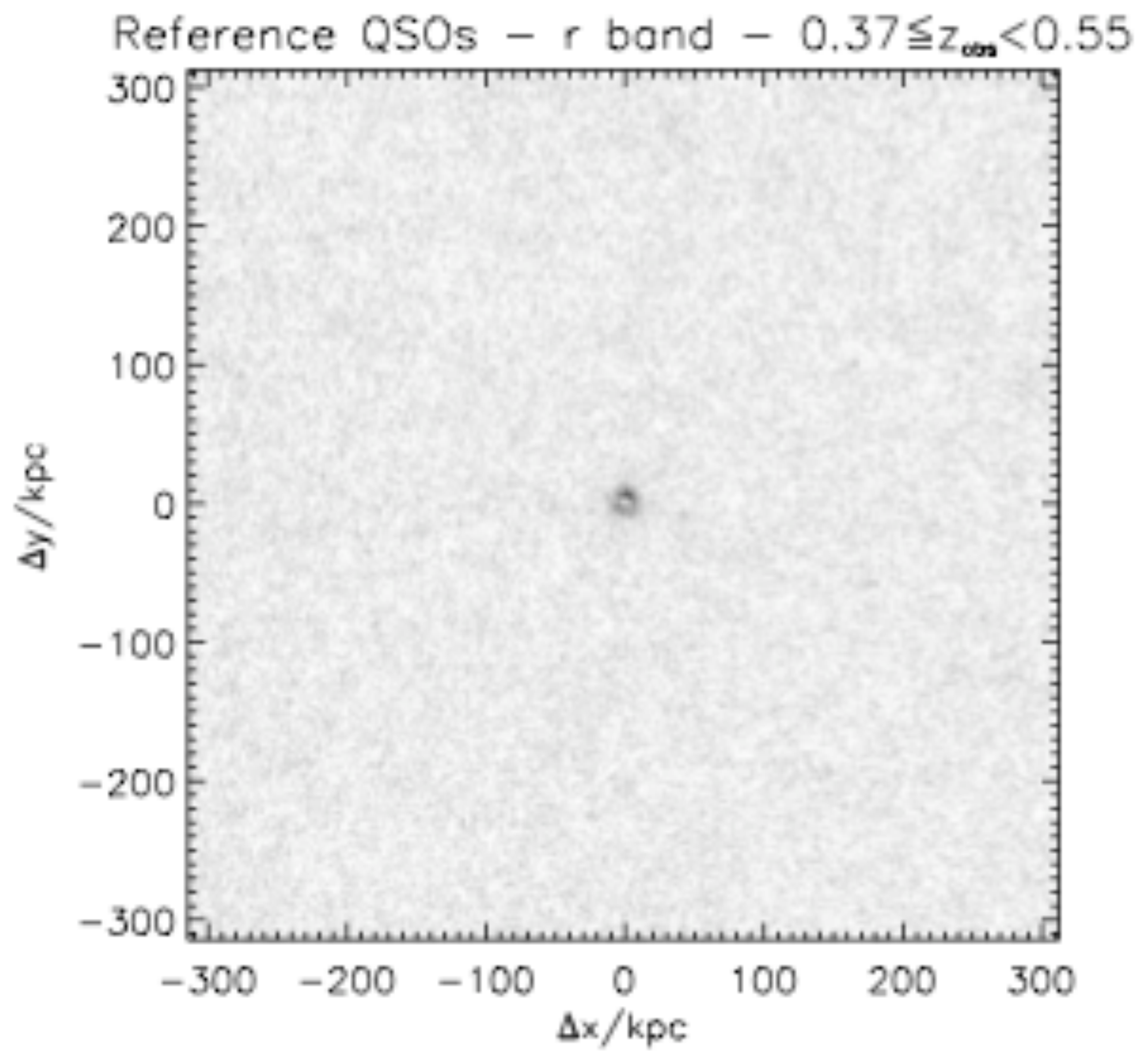
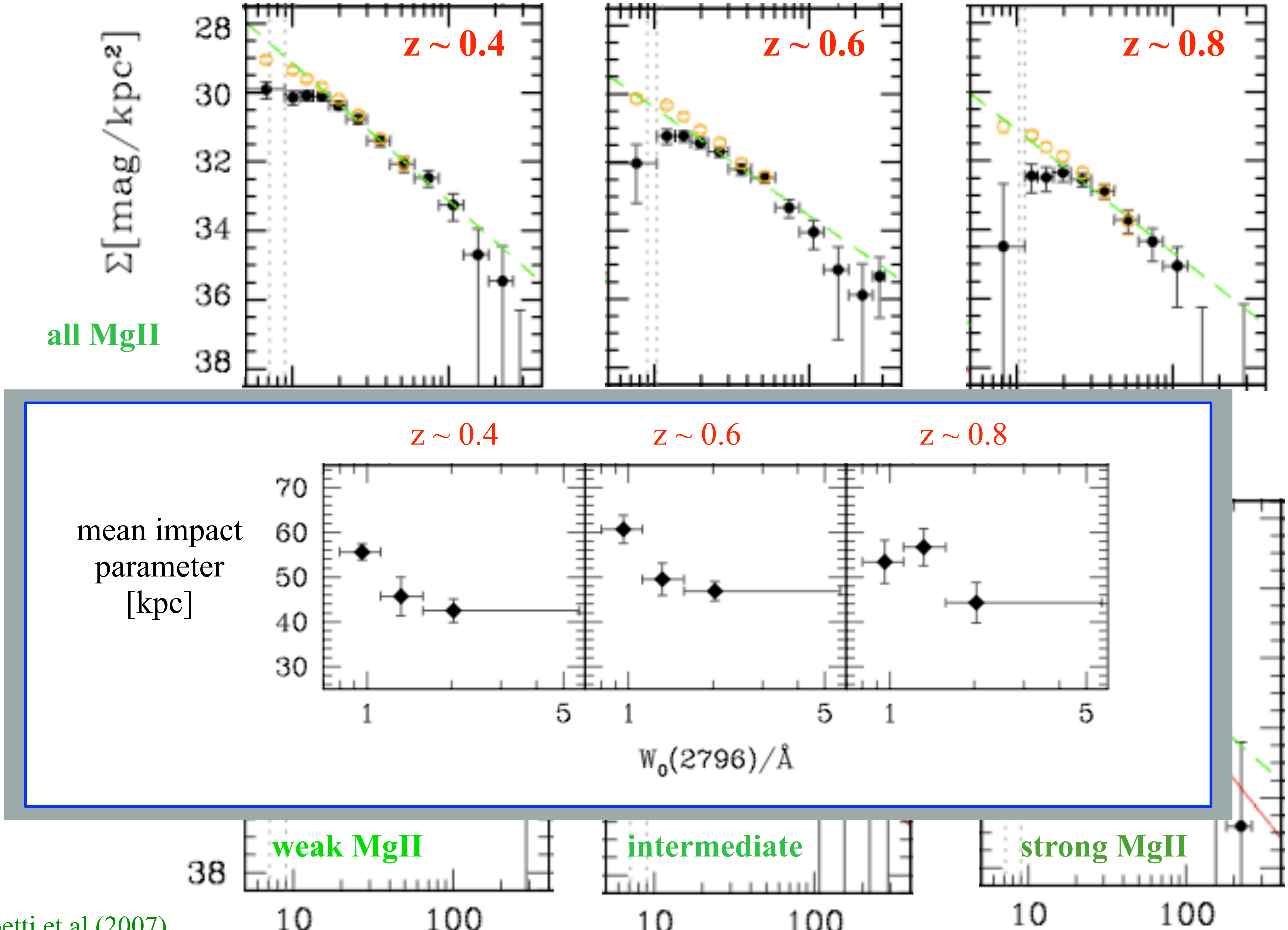


Spatial distribution of cold gas around galaxies

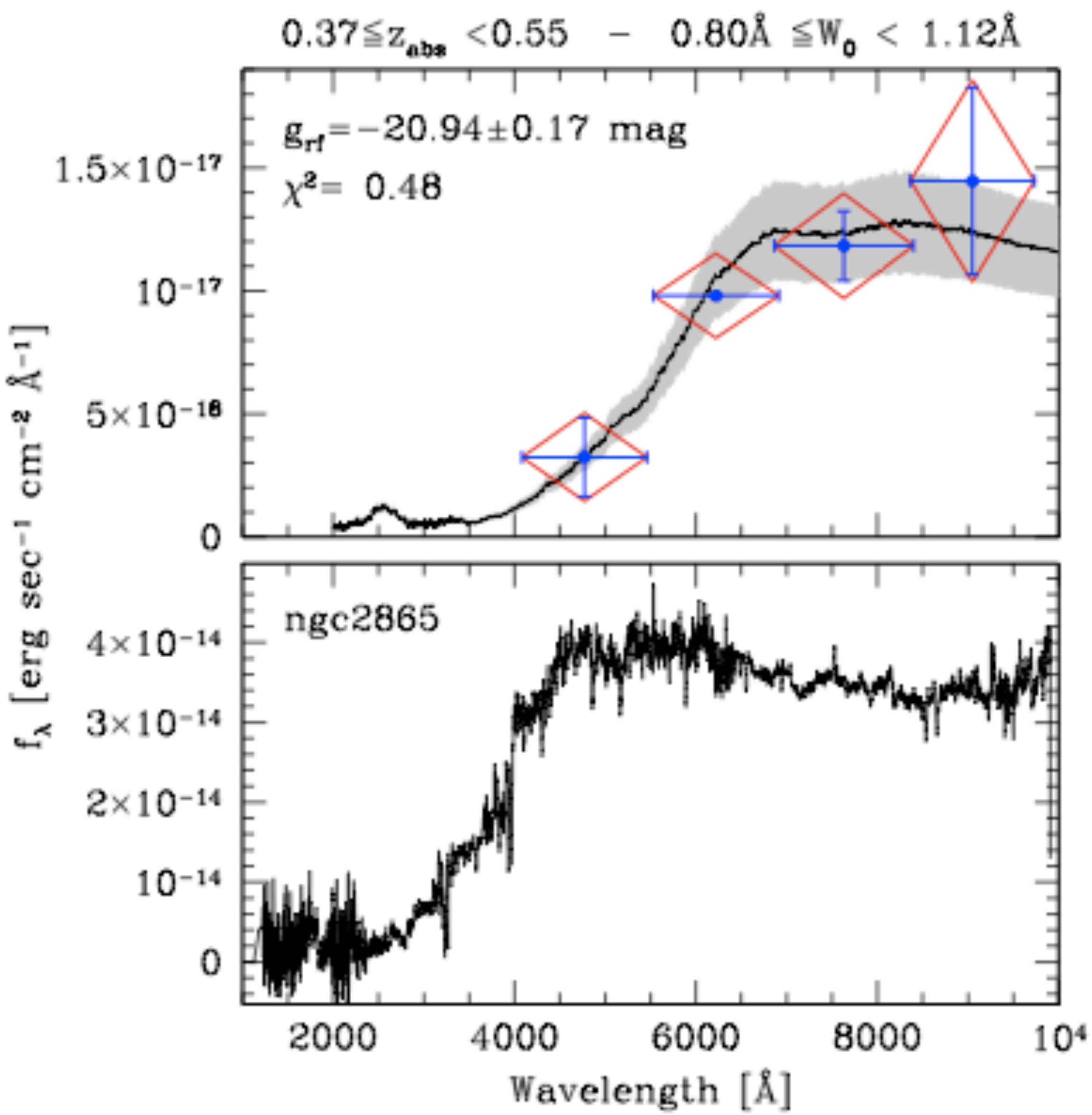


Zibetti et al (2007)

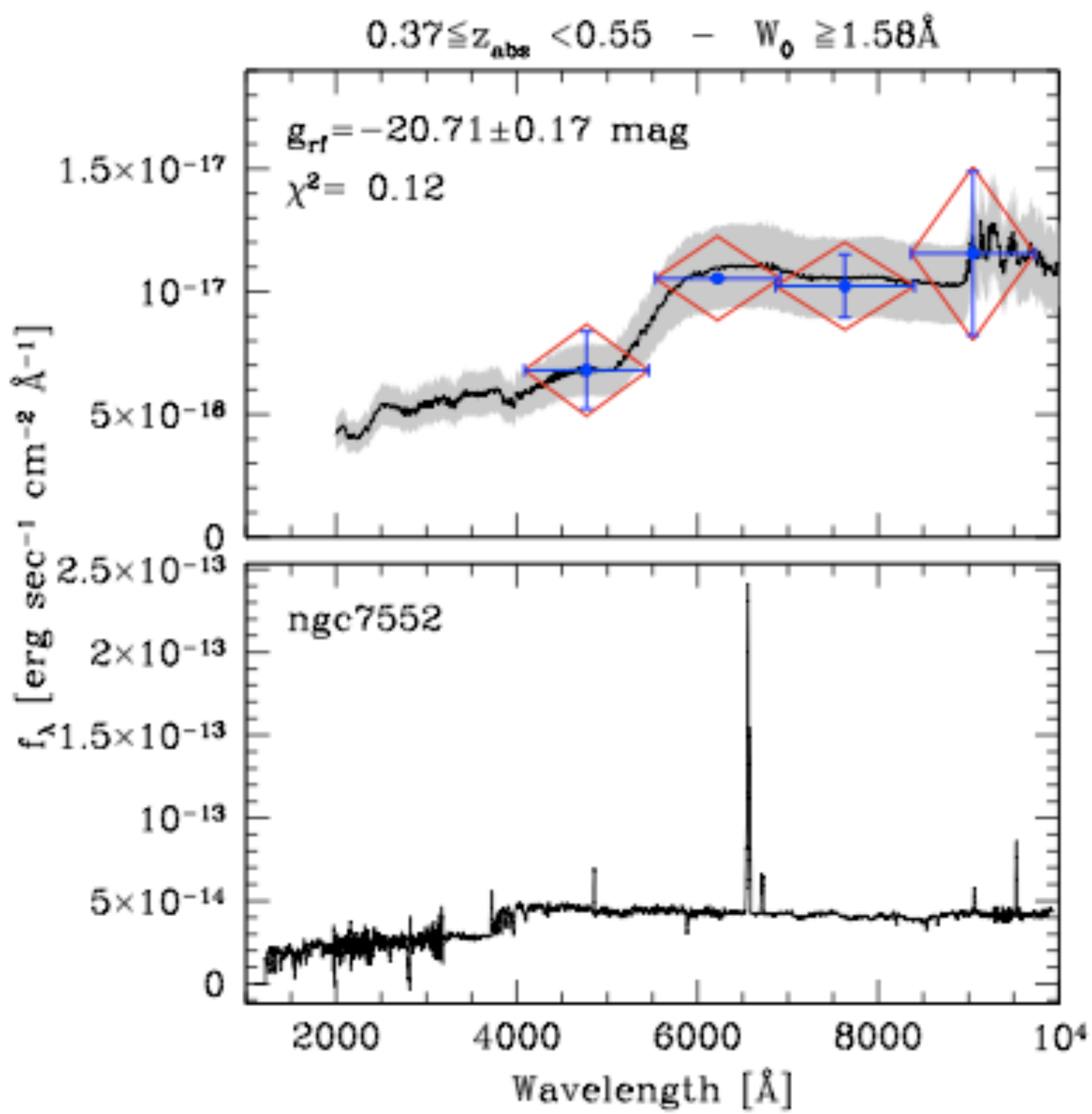
Photometric properties of the light excess

The detected light directly constrains the type of galaxies associated with the absorbers

Zibetti et al (2007)

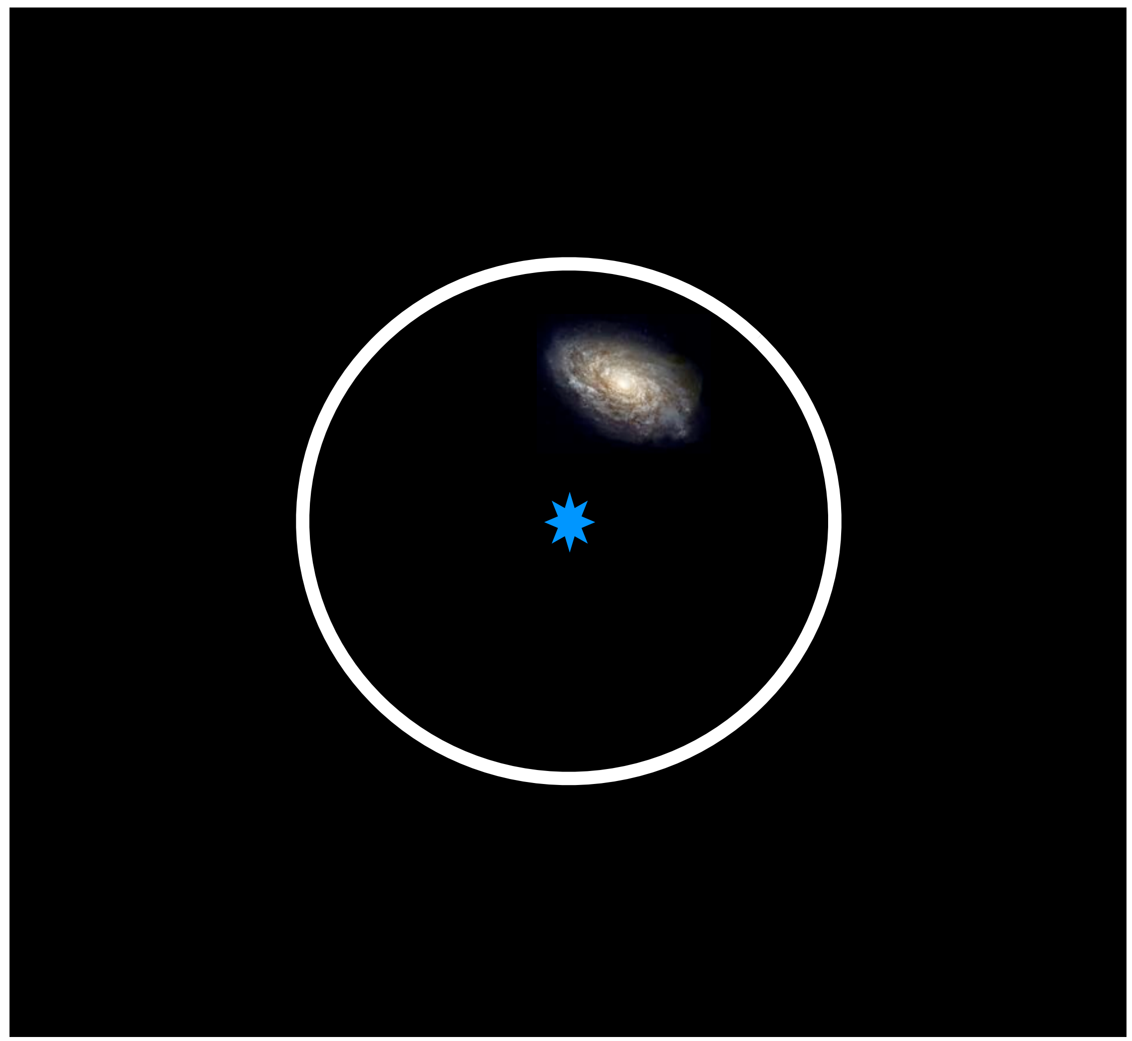


weak Mg II absorber

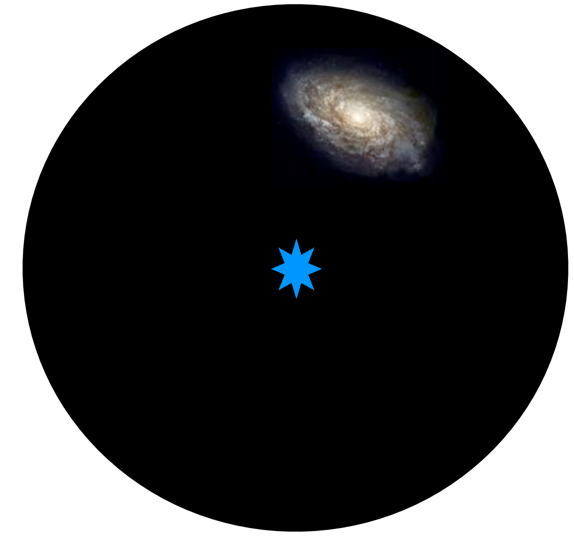


strong Mg II absorber

How can we probe OII emission with absorber systems?

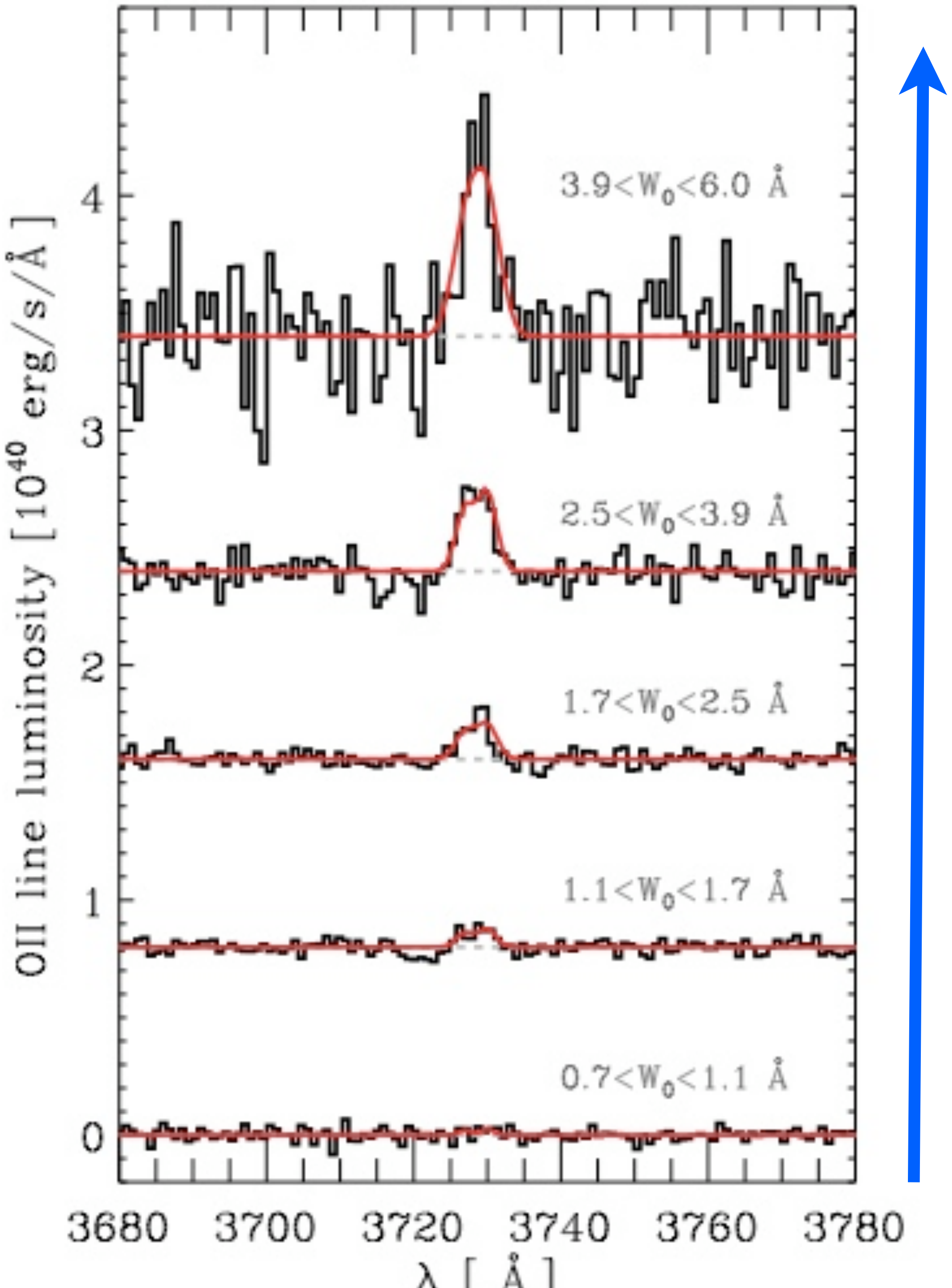


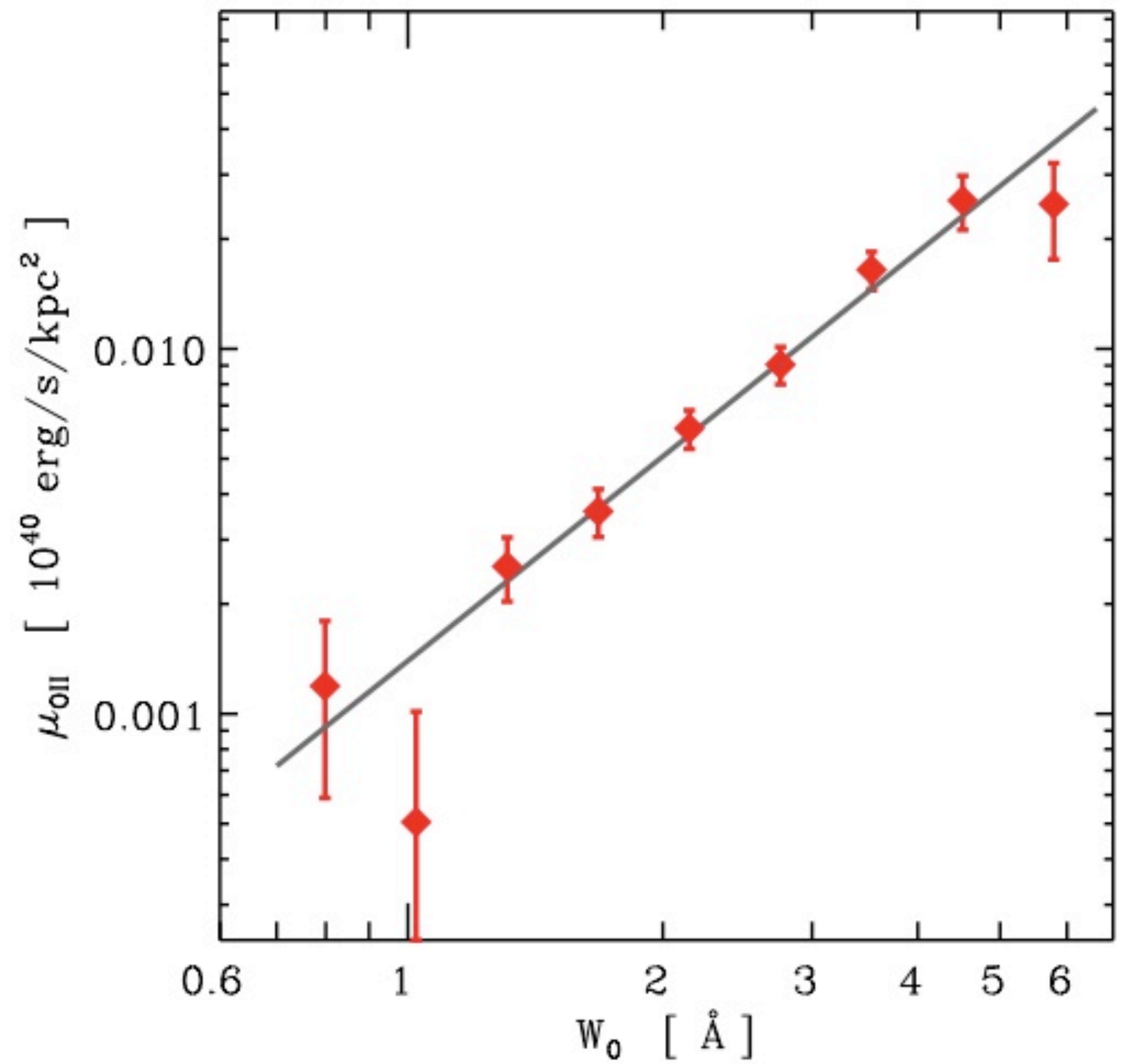
The MgII-star formation connection



OII line luminosity

MgII EW





Ménard et al. (2009)
Noterdaeme et al. (2009)

Another absorber/star formation connection

Weiner et al. (2009)

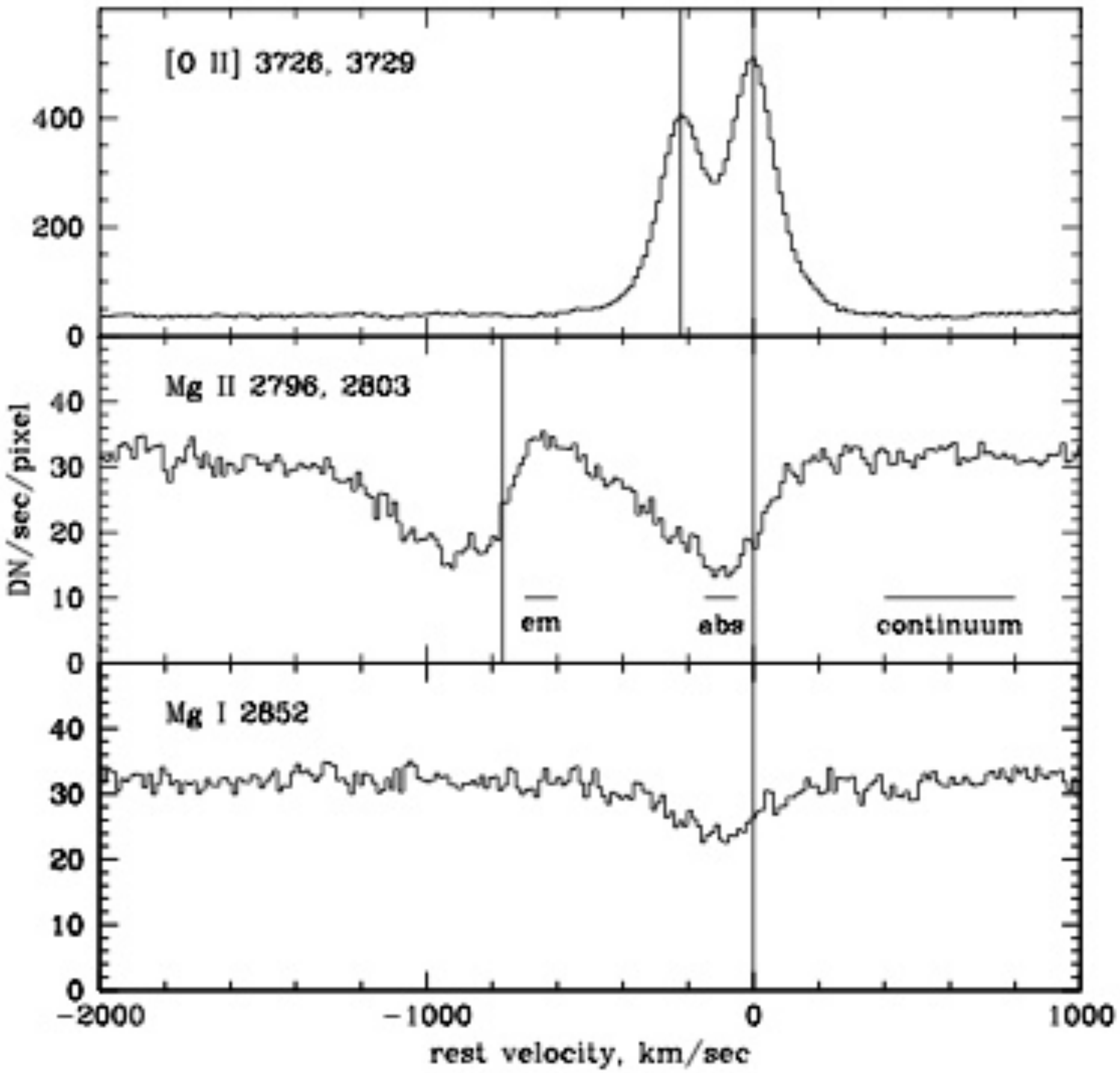


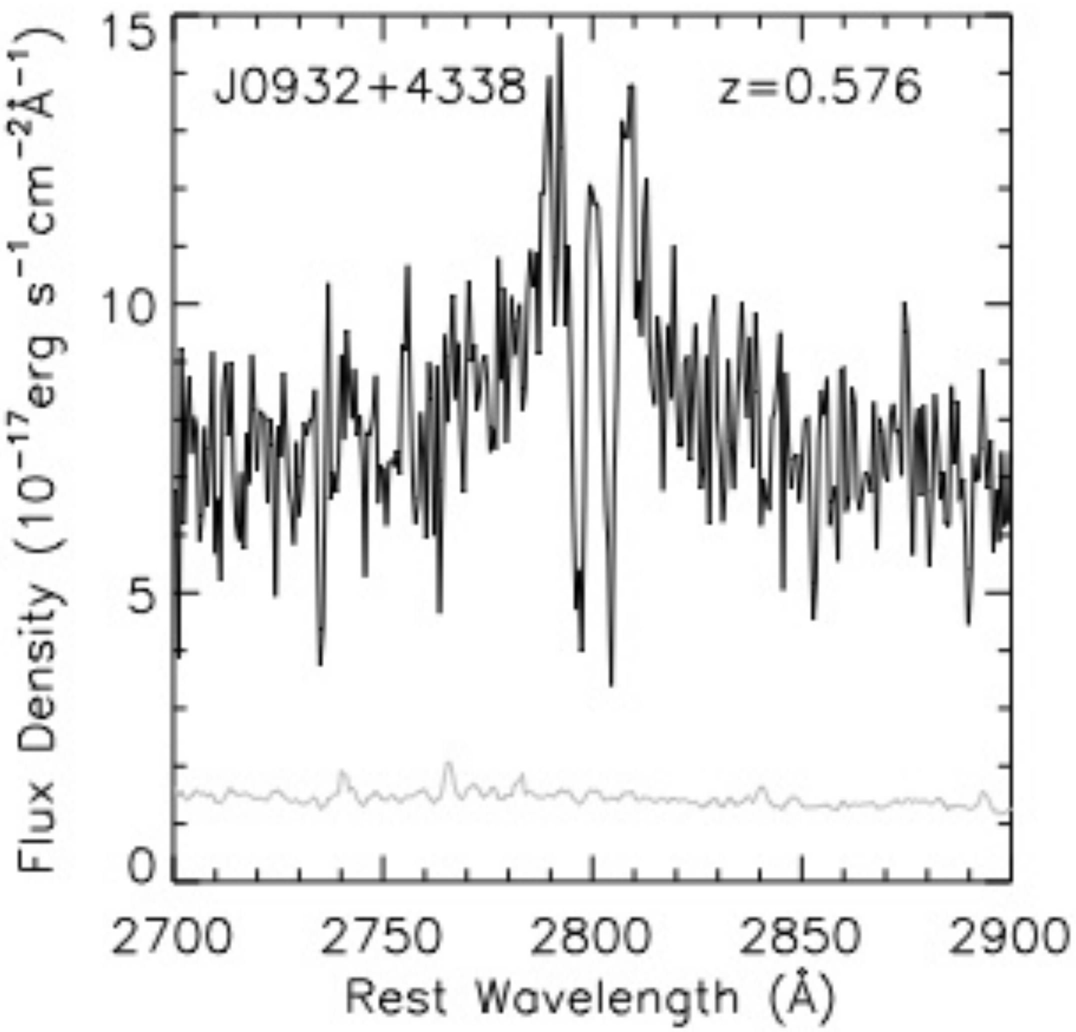
FIG. 3.— The [O II] 3726.0, 3728.8, Mg II 2795.5, 2802.7, and Mg I 2852.1 Å lines in the coadded spectrum of 1406 galaxies, relative to zero velocity as defined by the redshift derived from [O II]. The [O II] doublet lines are at

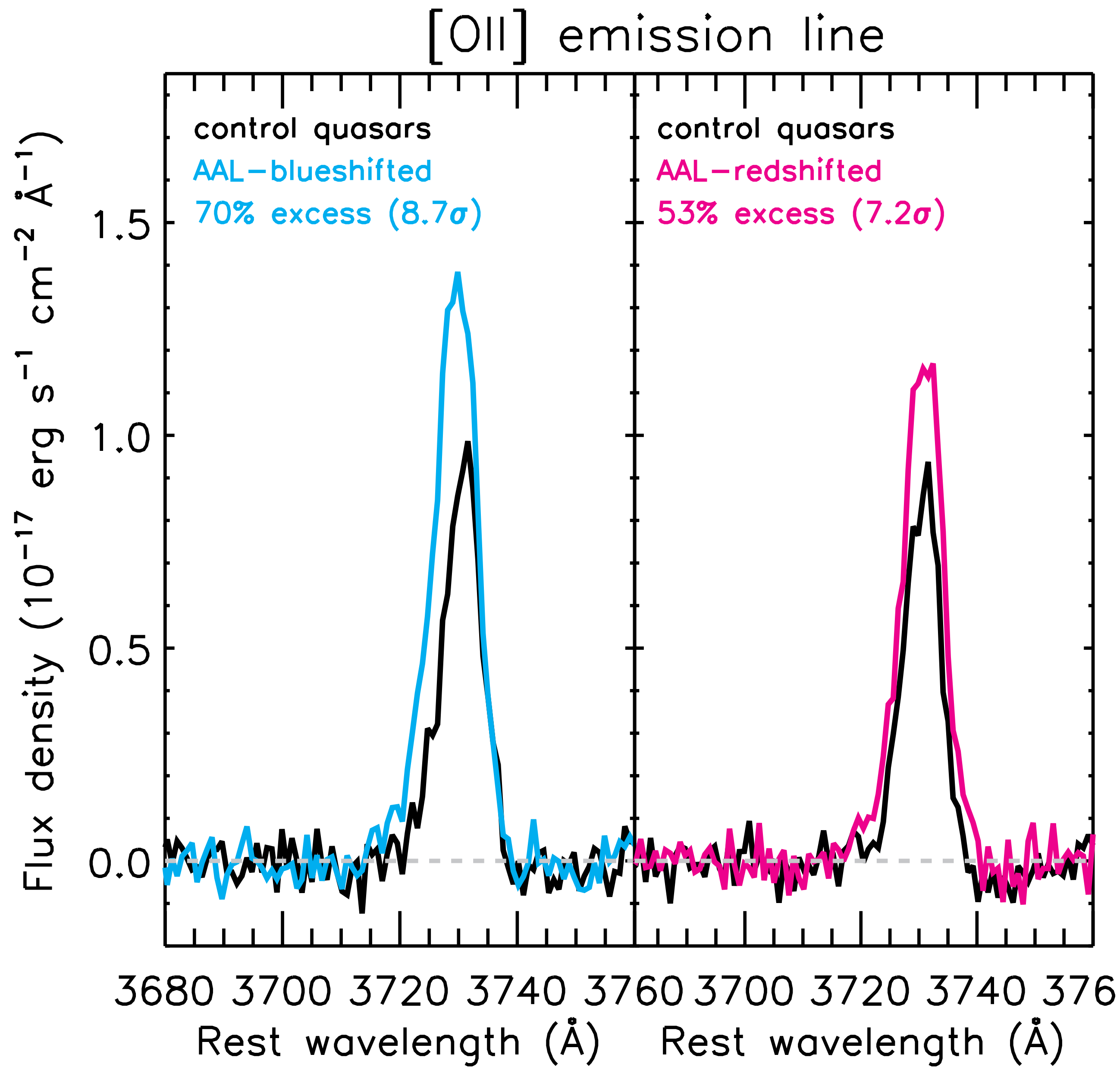
QSO absorbers: no information on directionality

Self absorption in galaxy spectra: no spatial information

These two sets of absorbers might trace the same outflowing material.

associated MgII absorbers and star formation in QSOs





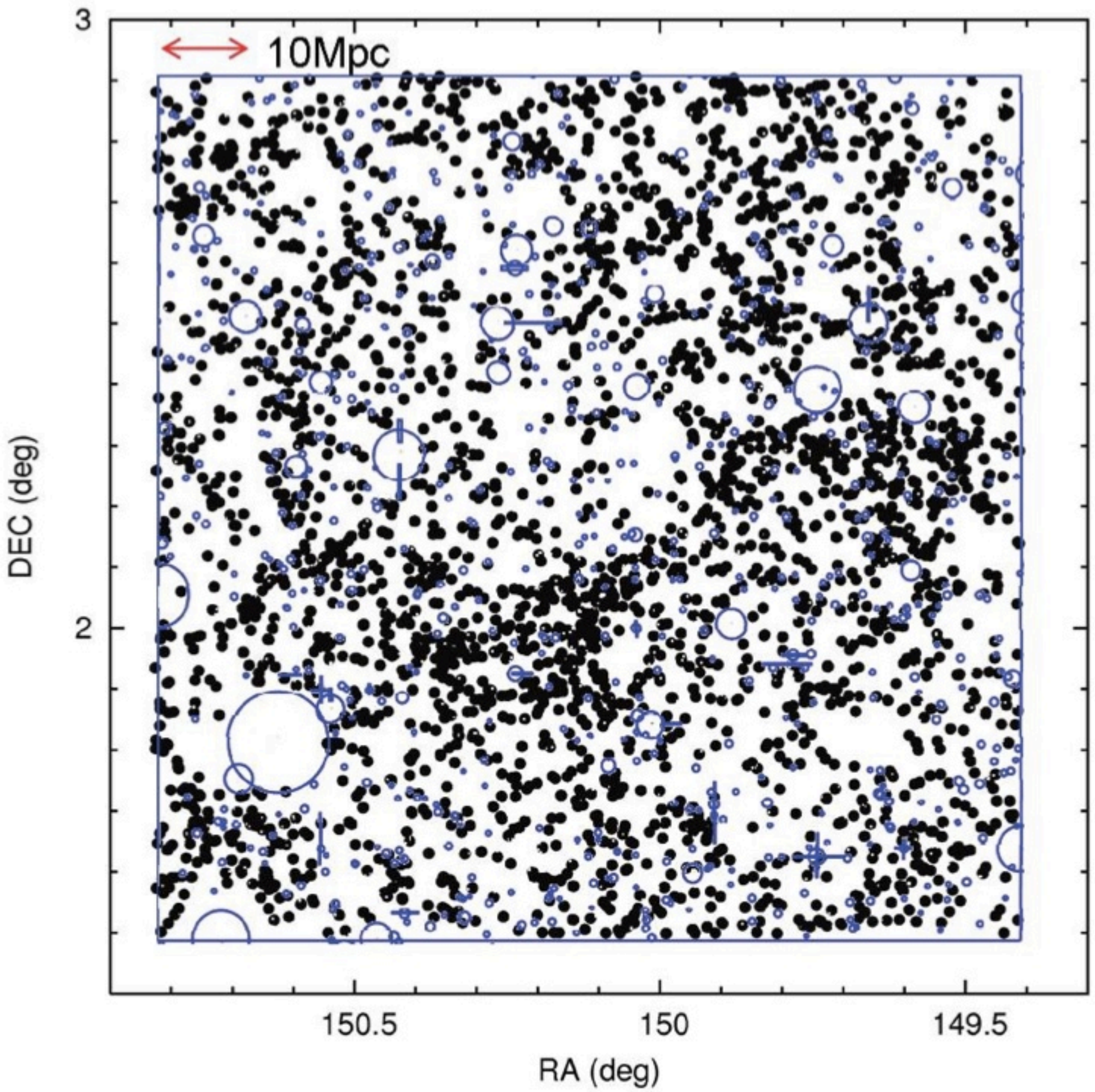
Shen & B.M. (2011)

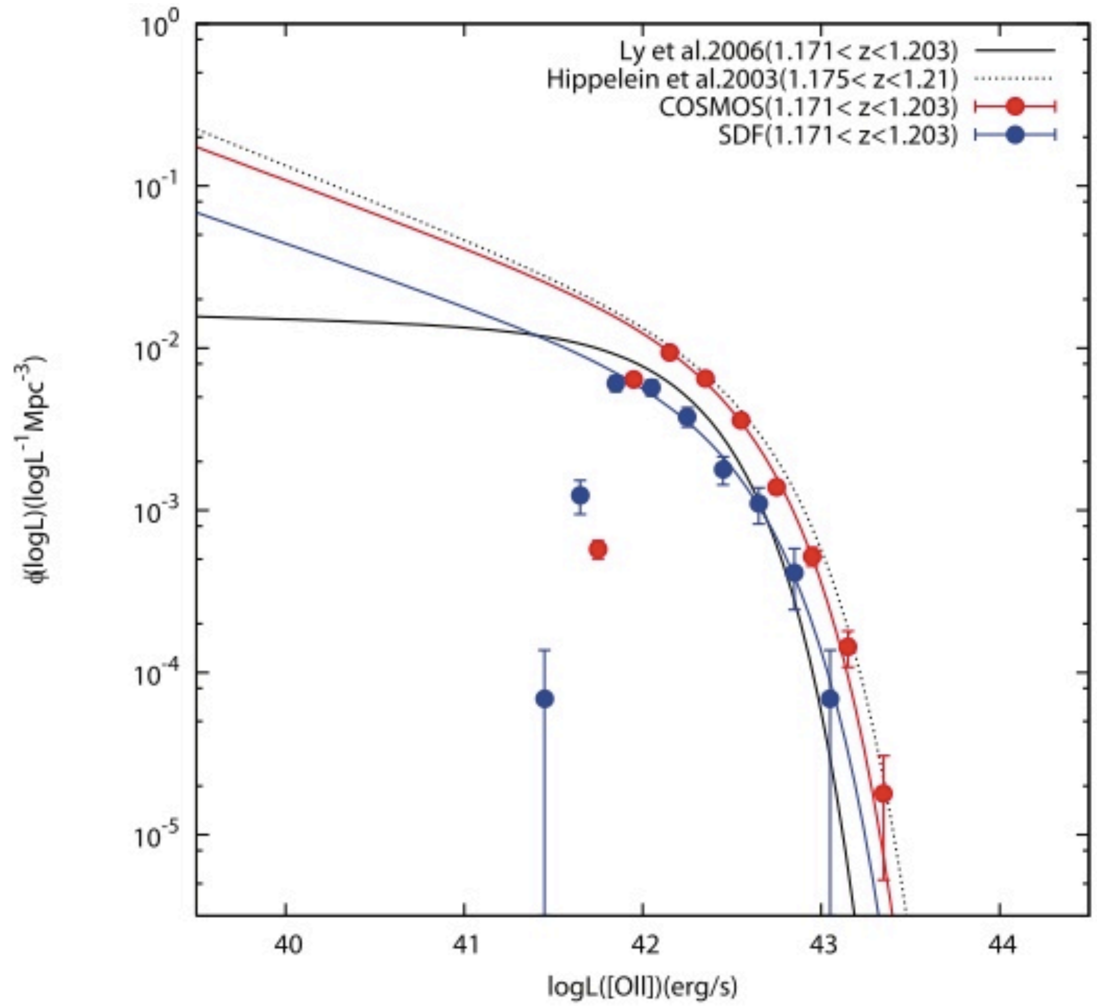
Metal absorber properties

consistent with

	inflows	outflows
- higher incidence at high z	yes	yes
- distribution of W_0 (or Delta v)	?	?
- large Delta v	no	yes
- high dust-to-gas ratio	no	yes
- stronger abs. around bluer galaxies	yes	yes
- absorbers correlate with SFR	yes	yes
- SFR correlates with blue-shifted abs.	?	yes

The OII luminosity function from narrow-band surveys





$$\mathcal{L}_{OII} = 10^{40.35^{+0.08}_{-0.06}}\ \mathrm{erg/s/Mpc}^3$$

$$\mathrm{SFR} = 0.32^{+0.06}_{-0.04}\ \mathrm{M}_\odot/\mathrm{yr/Mpc}^3$$

z = 1.2, Delta z = 0.03
COSMOS field, 2 deg^2
3200 OII emitters

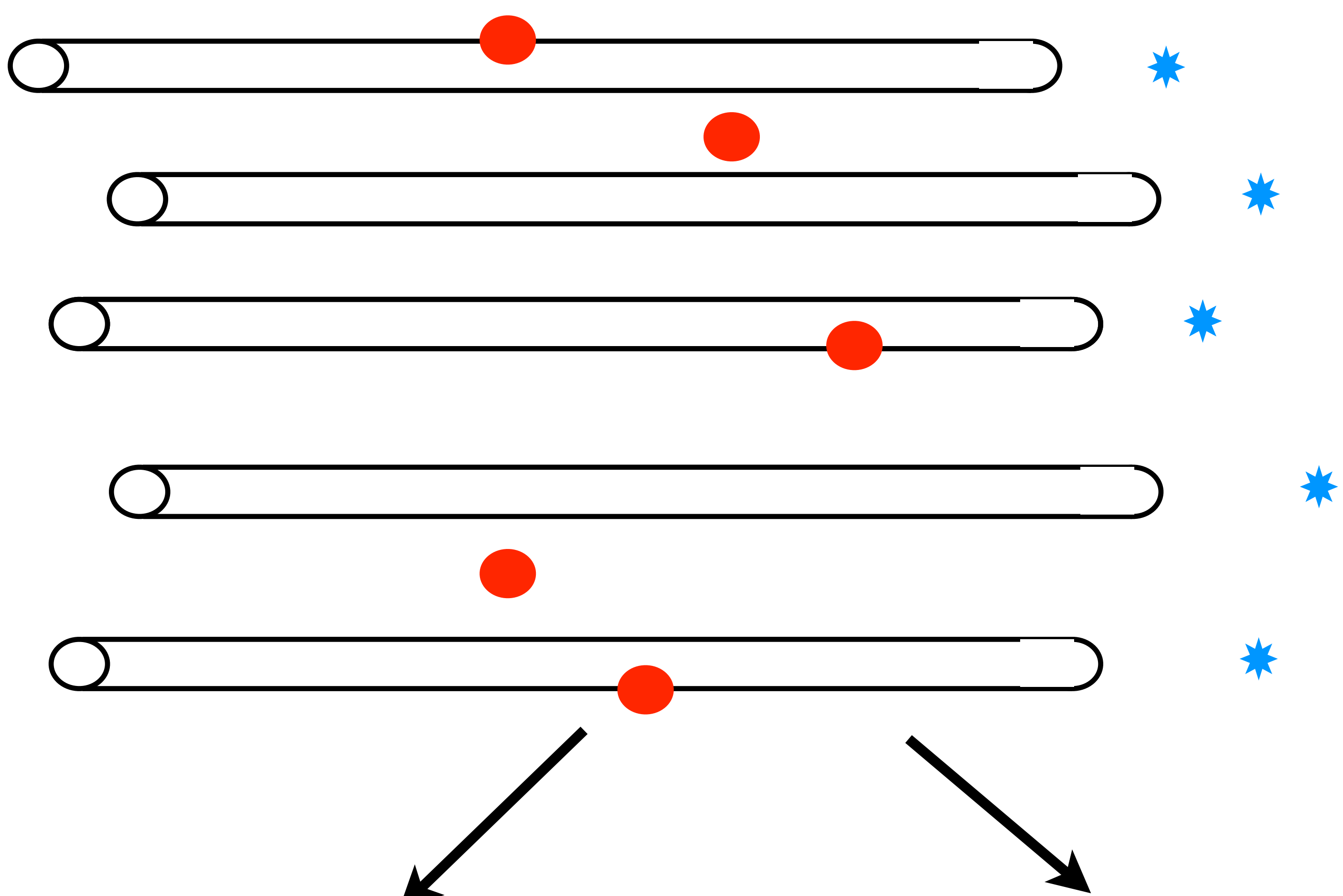
Takahashi et al. (2007)

Measuring the luminosity *density* traced by MgIIs

$$\mathcal{L}_{OII} = \frac{L_{OII}}{V}$$

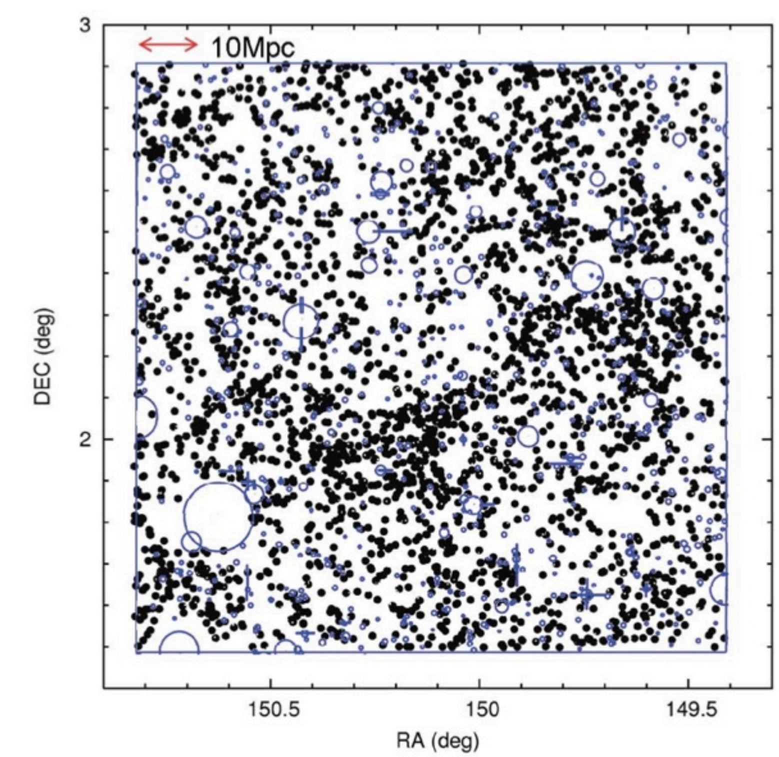
OII Luminosity

Total volume probed
(towards all QSOs)



L_{OII}

V ~



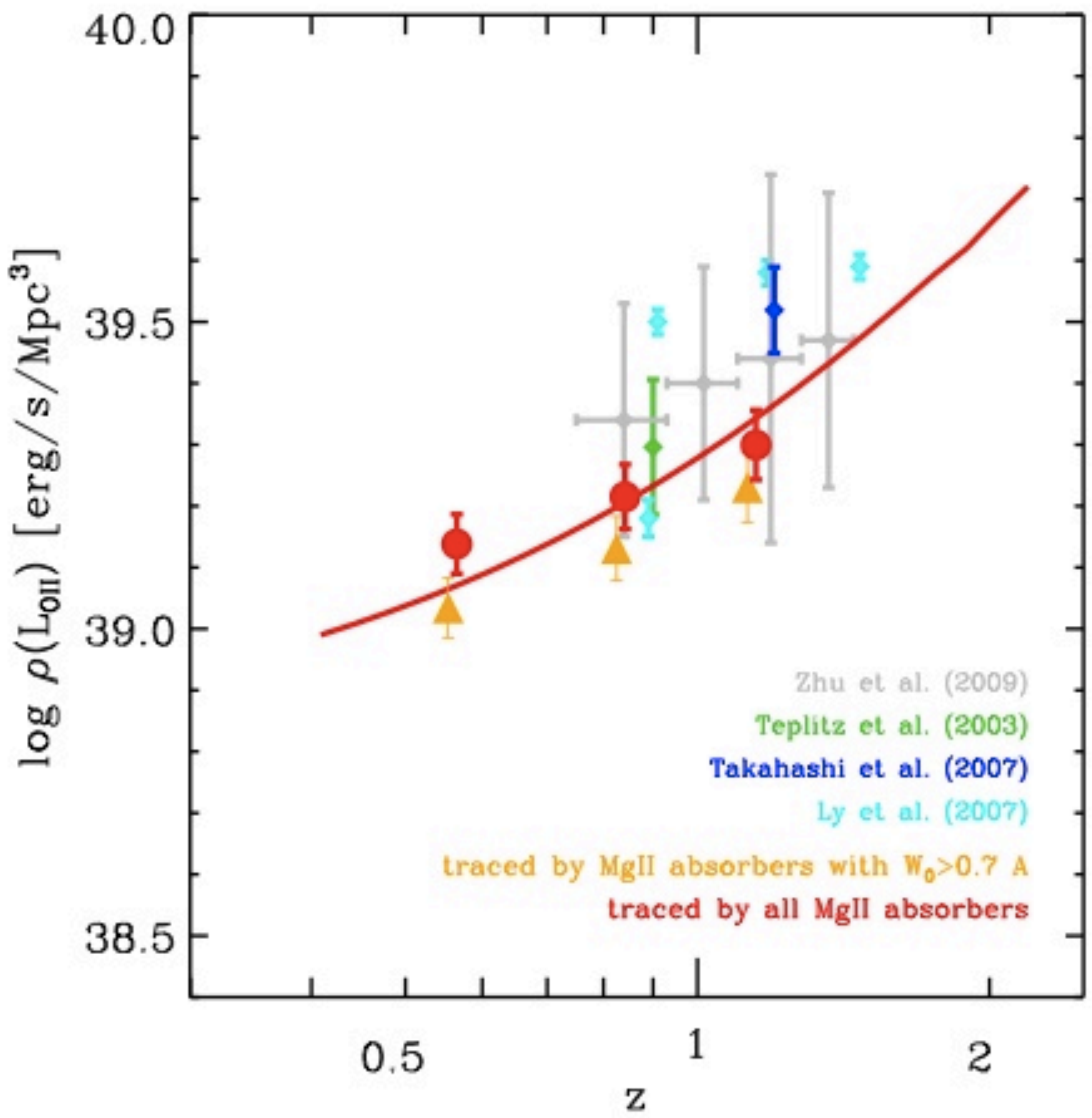
MgII absorbers trace star formation

$$\mathcal{L}_{OII} = \frac{L_{OII}}{V}$$

$$\mathcal{L}_{OII}(z) \quad = \quad \Sigma_{\mathrm{L_{OII}}}(z)\,\frac{\mathrm{d}N}{\mathrm{d}z}\,\mathcal{E}(z)$$

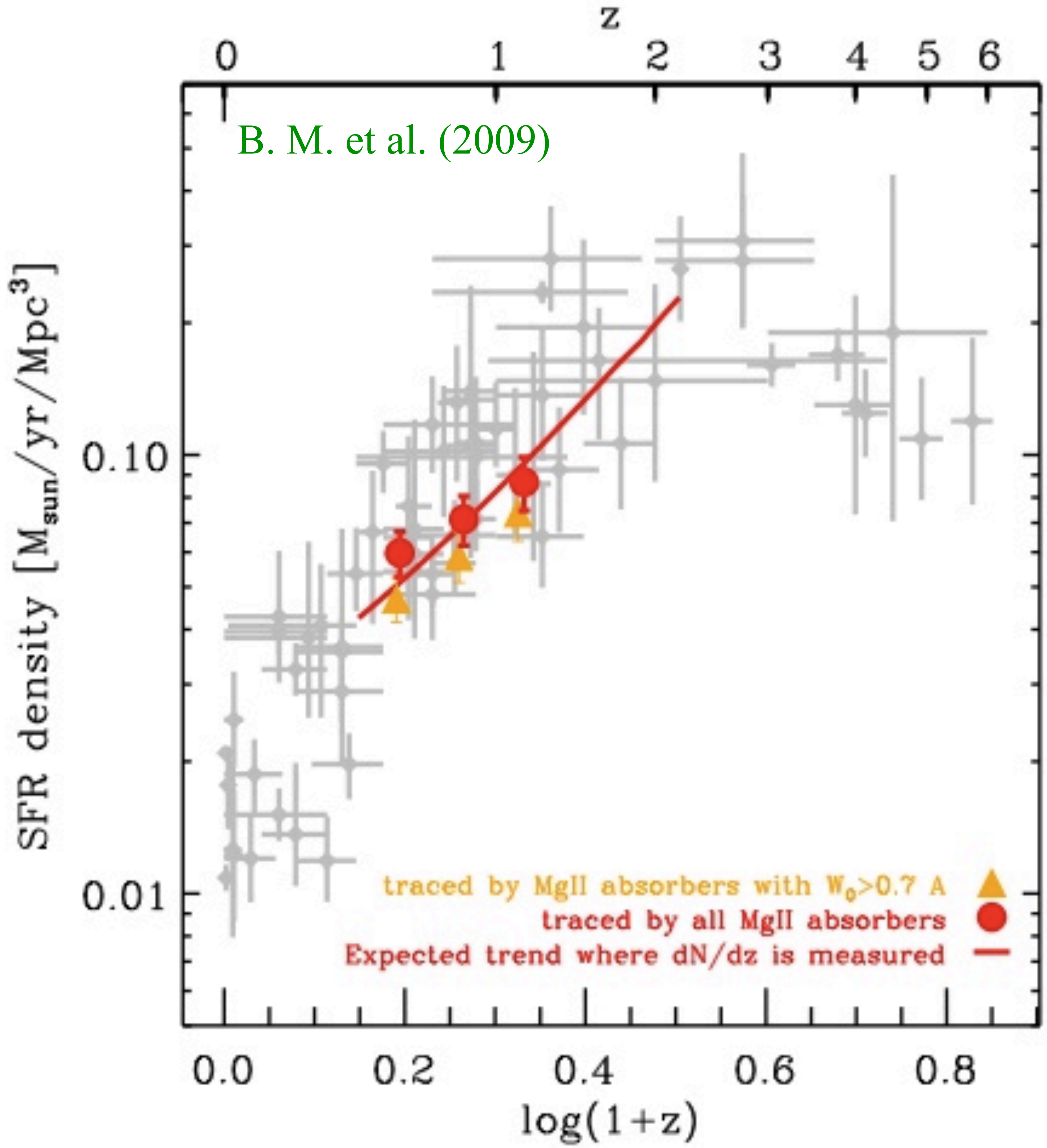
$$\mathcal{E}(z) = \frac{\mathrm{d}z}{\mathrm{d}r}\,\frac{1}{(1+z)^2}$$

No assumption used



B. M. et al. (2009)

MgII absorbers: a new probe of star formation



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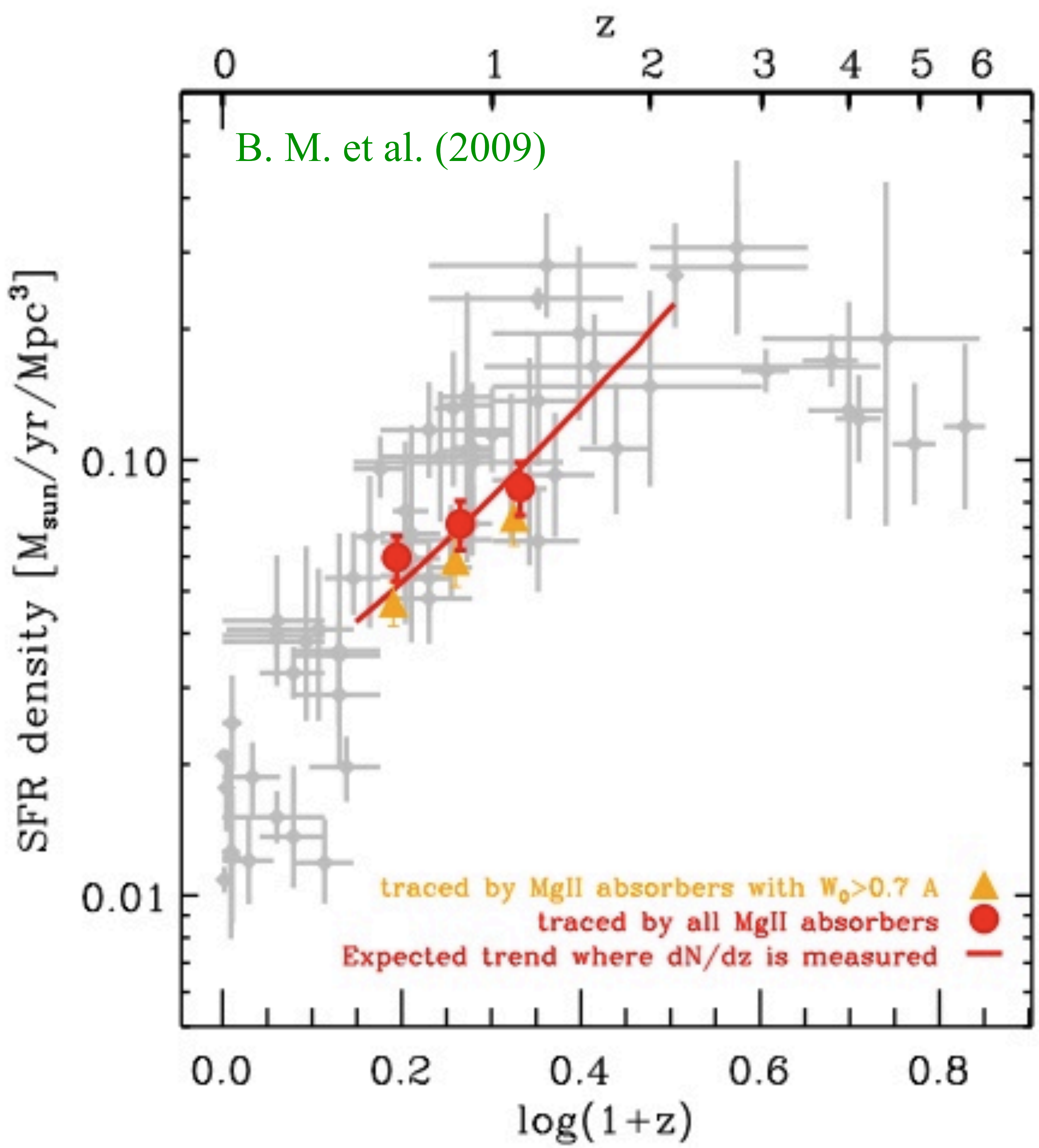
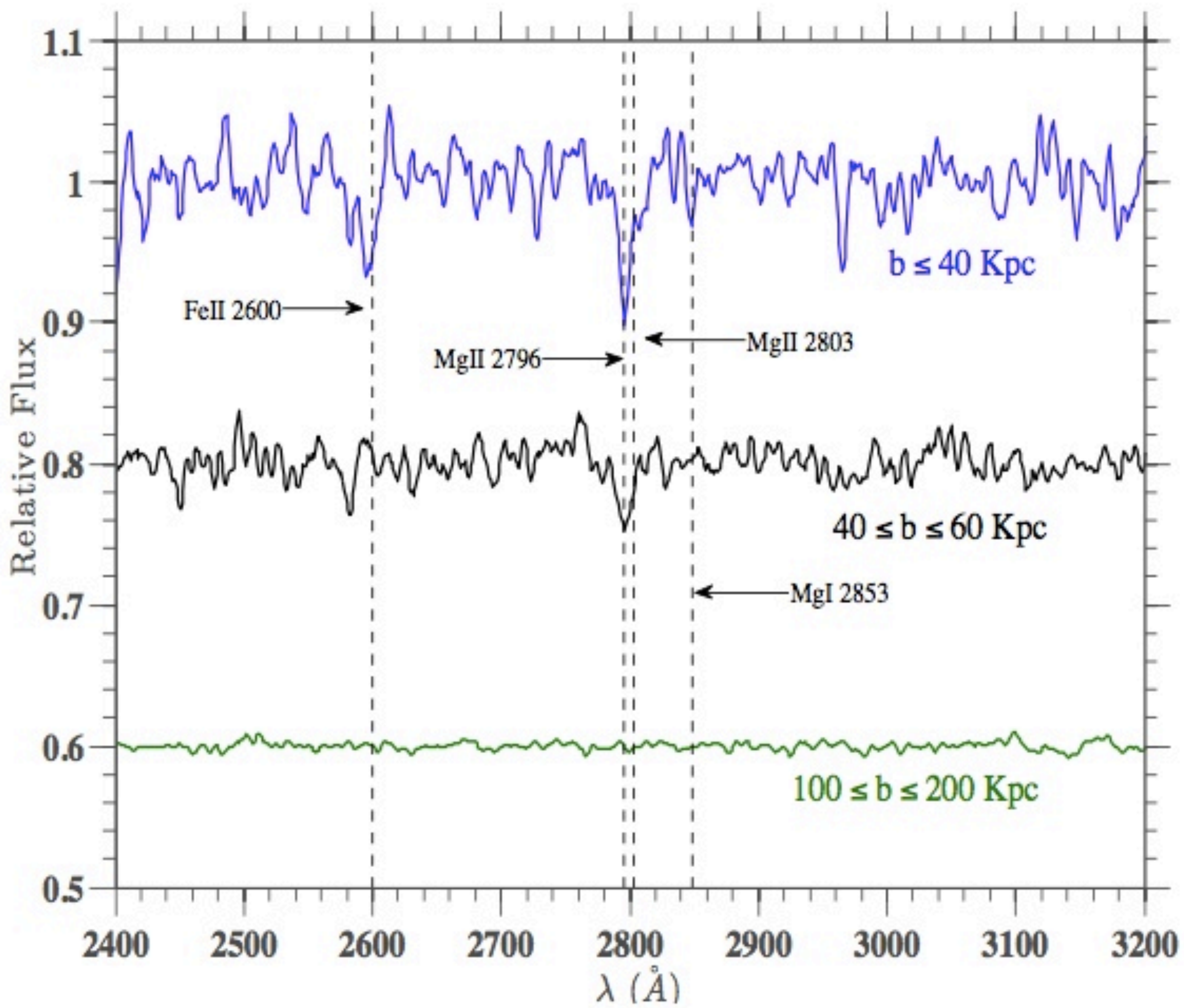
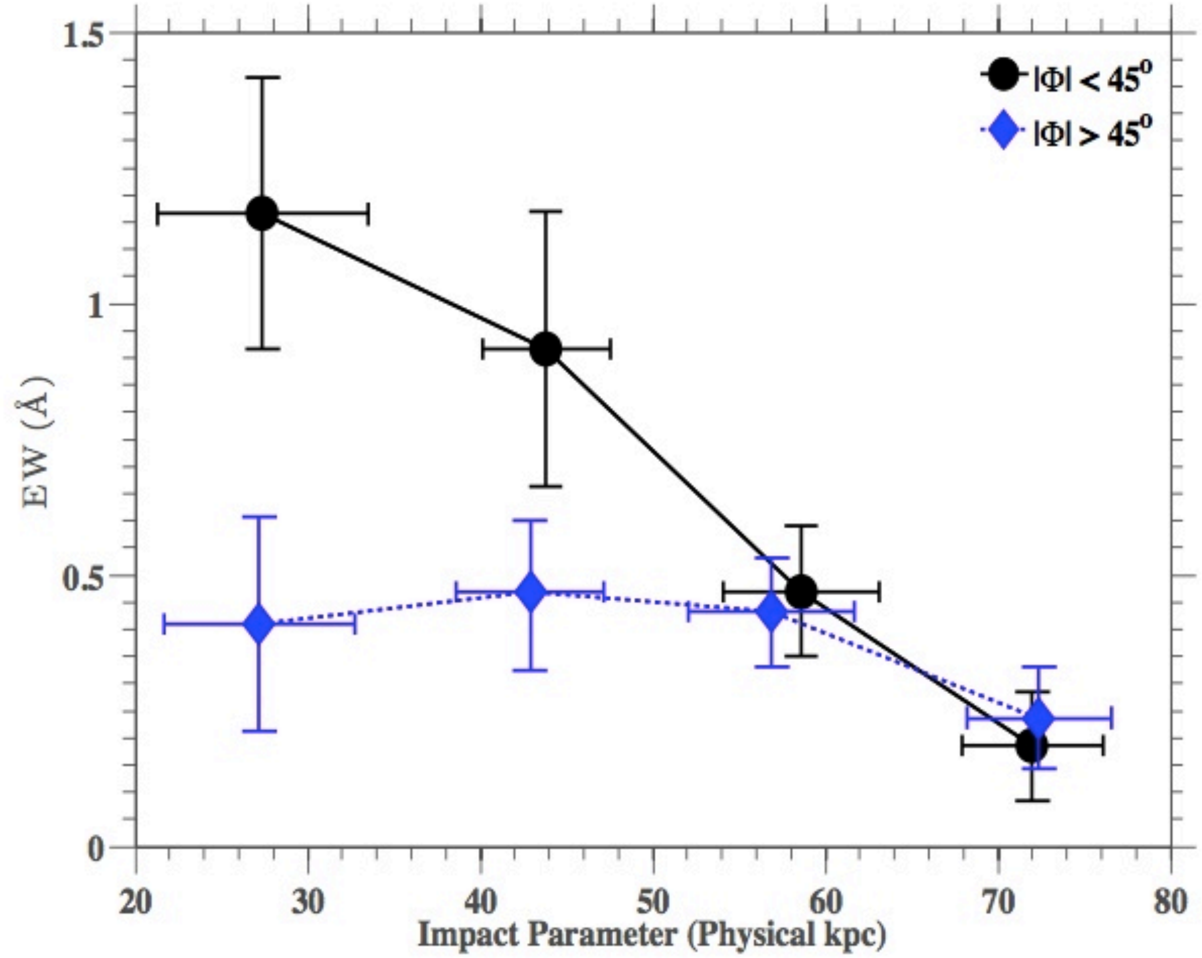


$$\mathcal{L}_{OII}(z) \quad = \quad \Sigma_{\mathrm{L_{OII}}}(z)\,\frac{\mathrm{d}N}{\mathrm{d}z}\,\mathcal{E}(z)$$

metal absorption in background galaxies

Bordoloi et al. (2011), COSMOS survey
See also Steidel et al. (2011)





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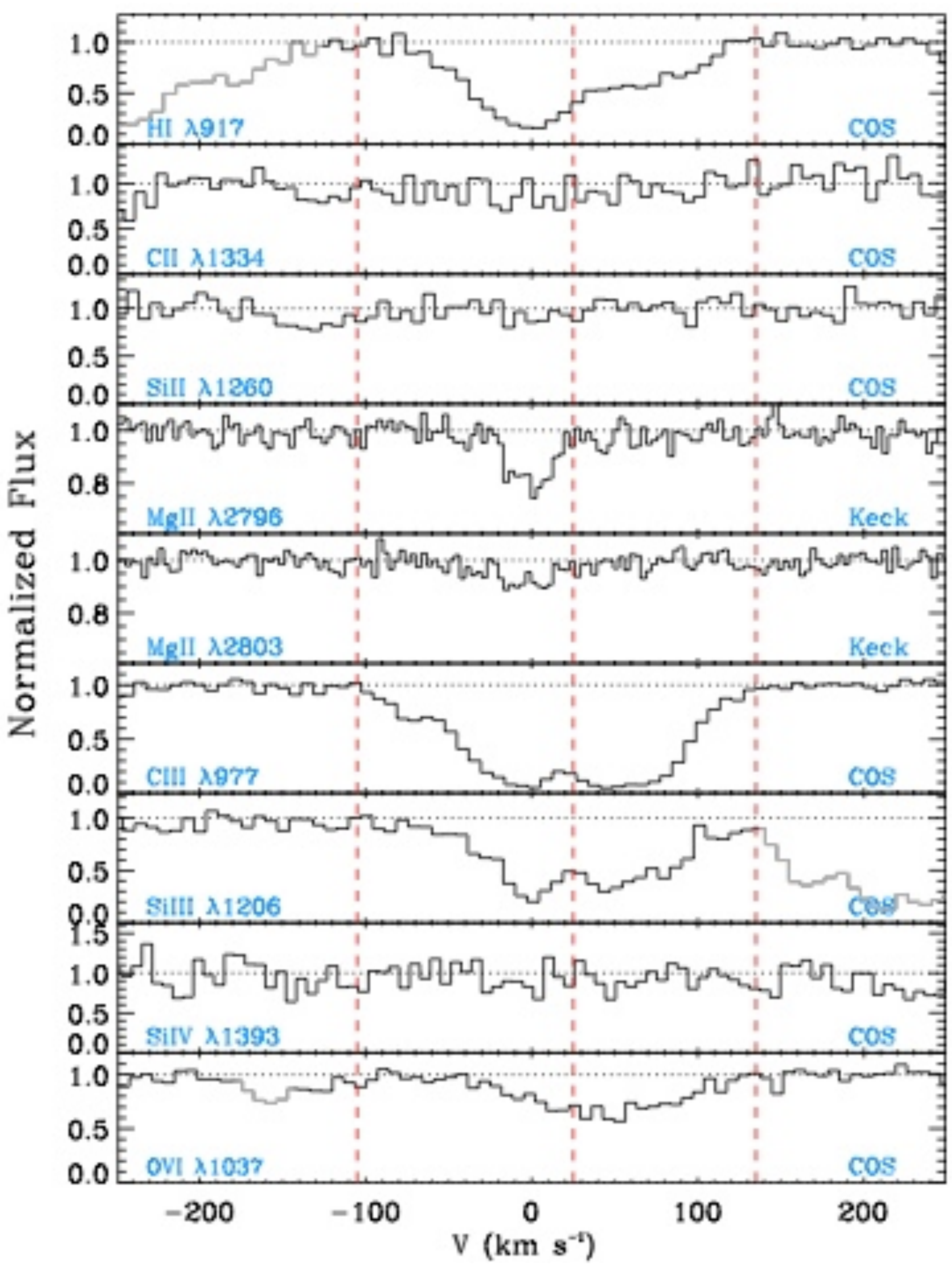
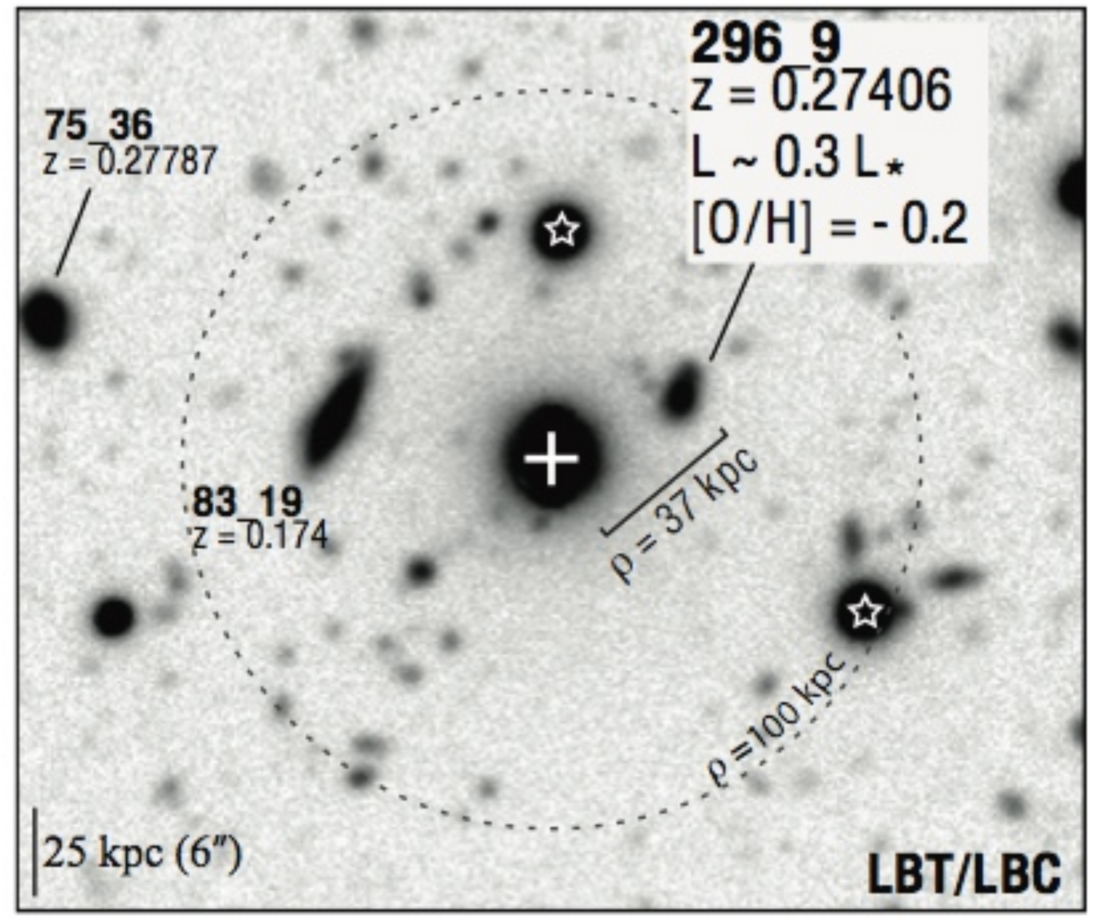
- higher incidence at high z	yes	yes
- distribution of W_0 (or Delta v)	?	?
- large Delta v	no	yes
- high dust-to-gas ratio	no	yes
- stronger abs. around bluer galaxies	yes	yes
- absorbers correlate with SFR	yes	yes
- SFR correlates with blue-shifted abs.	?	yes
- excess perpendicular to galactic disks	no	yes

Evidence for cold accretion?

Ribaudo et al. (2011)





The absorber indicates low metallicity ([Mg/H] = −1.71 ± 0.06) photoionized gas but the matching galaxy shows near solar metallicity ([O/H] = −0.20 ± 0.15).

Summary

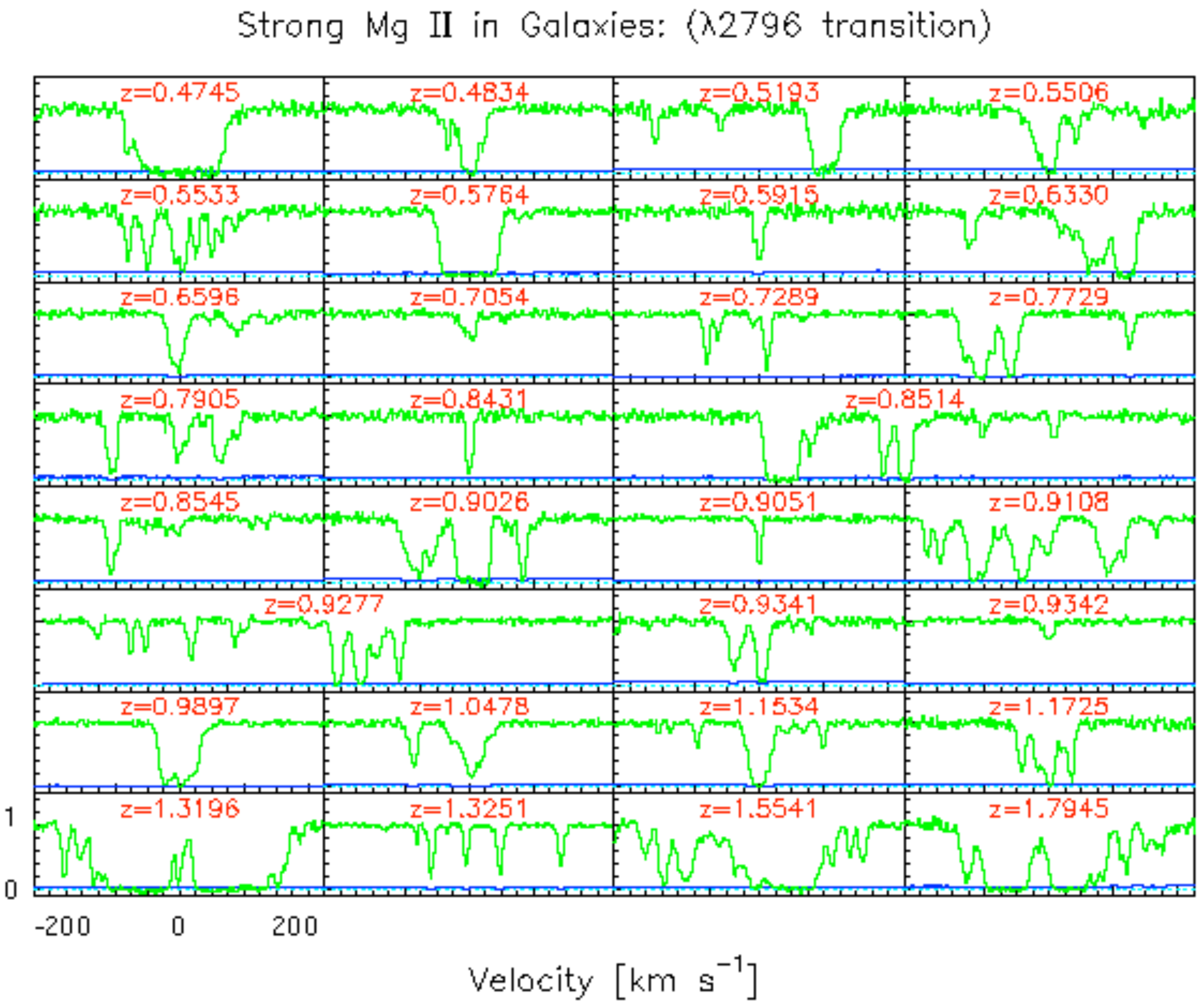
Strong metal absorbers probe galaxy halos up to 50-100 kpc

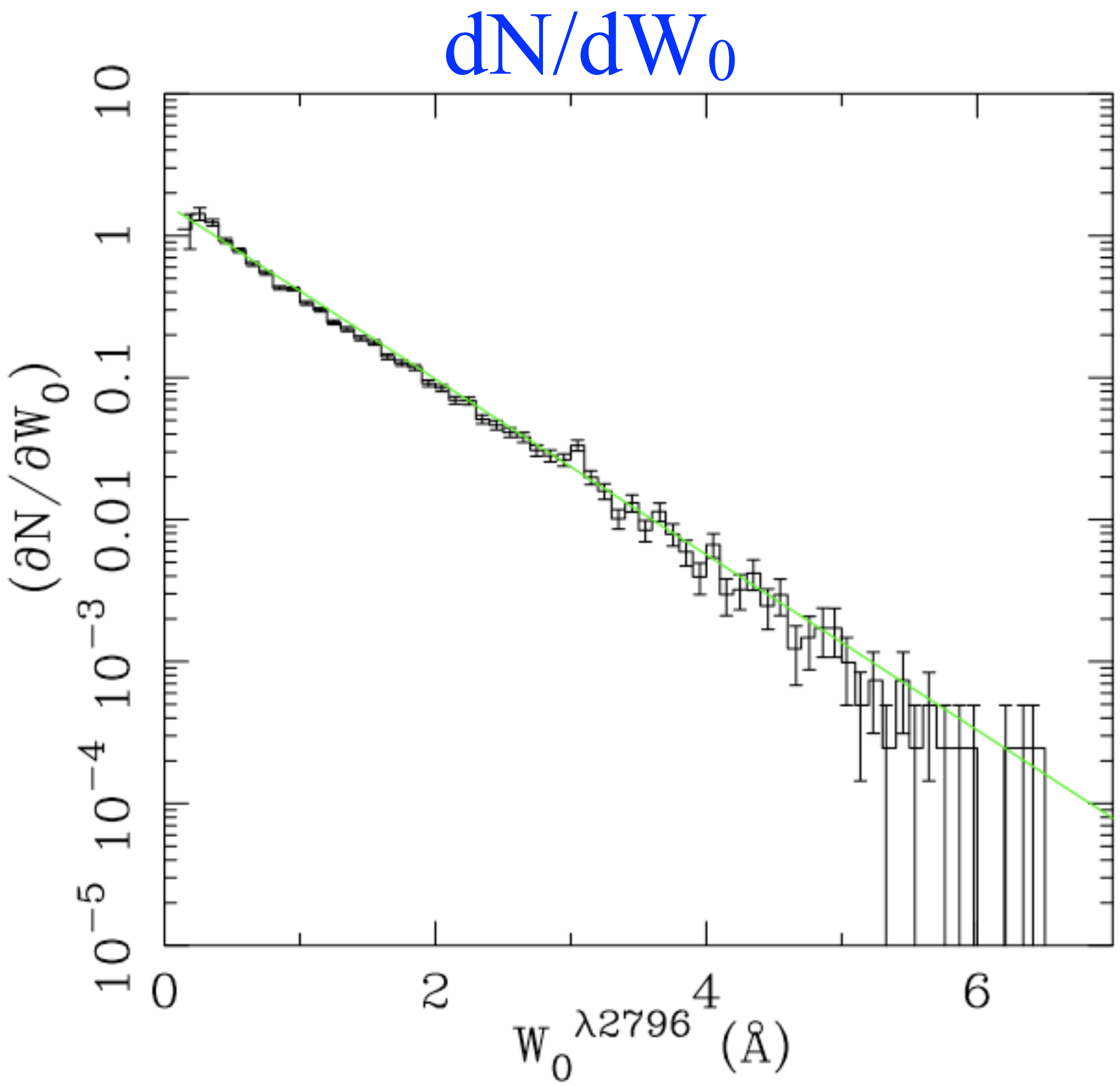
We can now quantify their incidence, spatial extend, covering factor, dust content, etc...

Most of these strong metal absorbers are consistent with being due to outflows.

- What is the fraction of absorbers tracing infalling material?
- What mechanism drives the value of W_0?
- How to include this information in our models of galaxy formation?

Summary





- How to include this information in our models of galaxy formation?