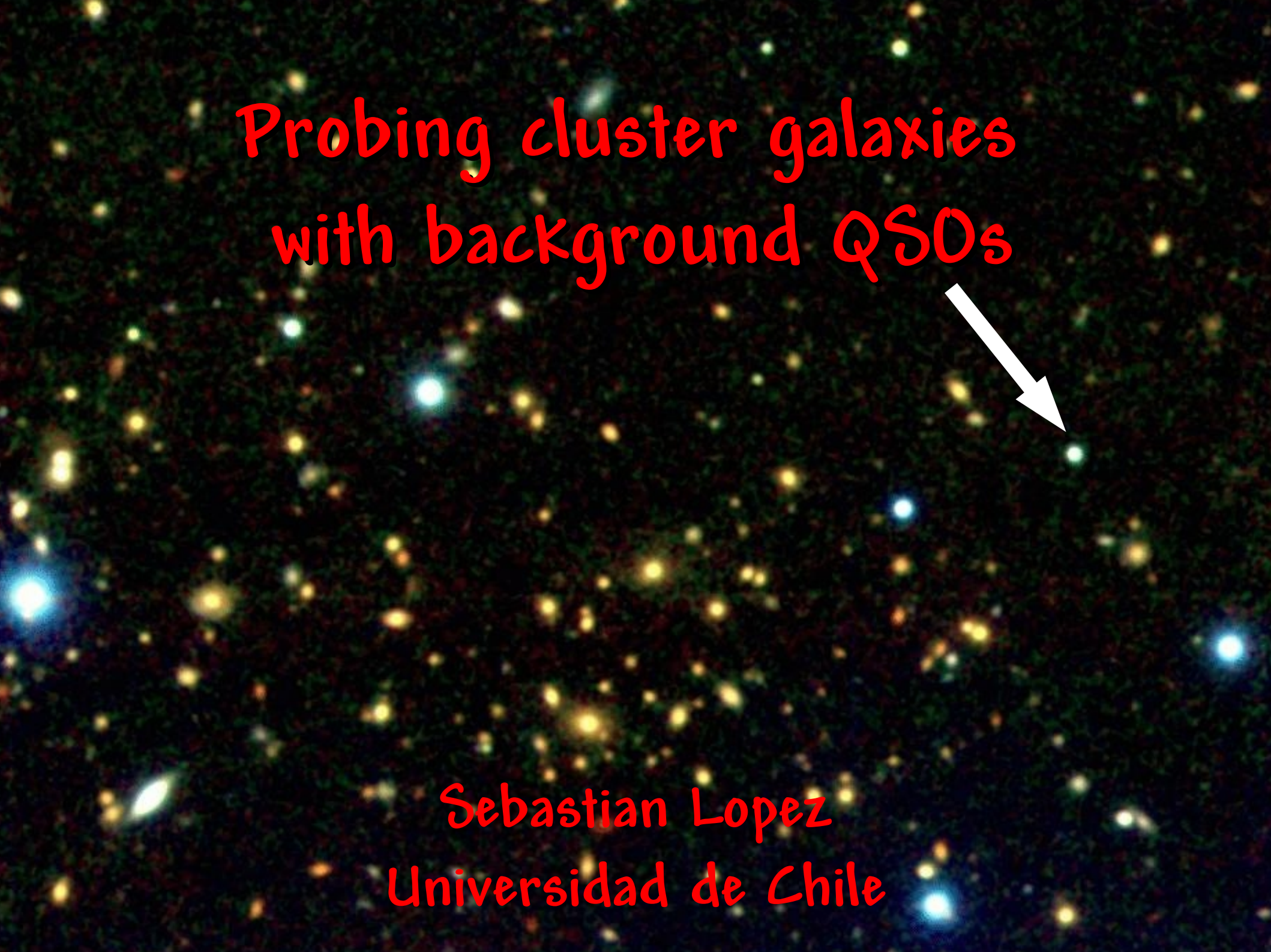

Probing cluster galaxies
with background QSOs
Sebastian Lopez
Universidad de Chile

QbC: The Quasars behind Clusters Survey

Outline

- Why quasar absorption lines
- Why clusters
- Fundamentals of absorption line surveys
- QbC Survey results
- Future

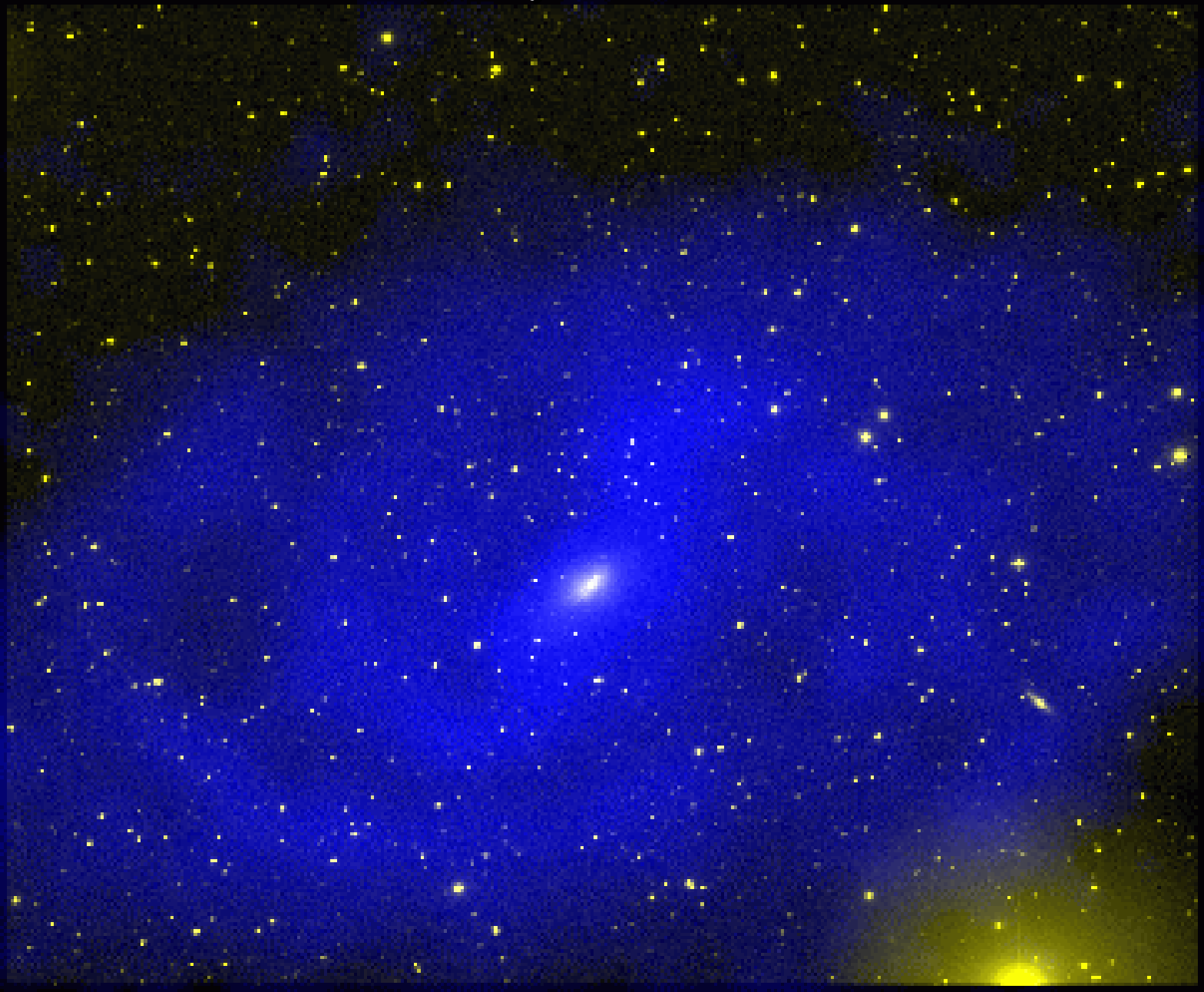
QbC: The Quasars behind Clusters Survey

- L. F. Barrientos (U. Catolica)
- D. G. Gilbank (U. of Toronto)
- M. D., Gladders (U. of Chicago)
- P. Lira (U. de Chile)
- J. Maza(U. de Chile)
- N. Padilla (U. Catolica)
- N. Tejos (U. de Chile)
- M. Vidal (U. de Chile)
- H. K. C. Yee (U. of Toronto)

Why quasar absorpion line systems?

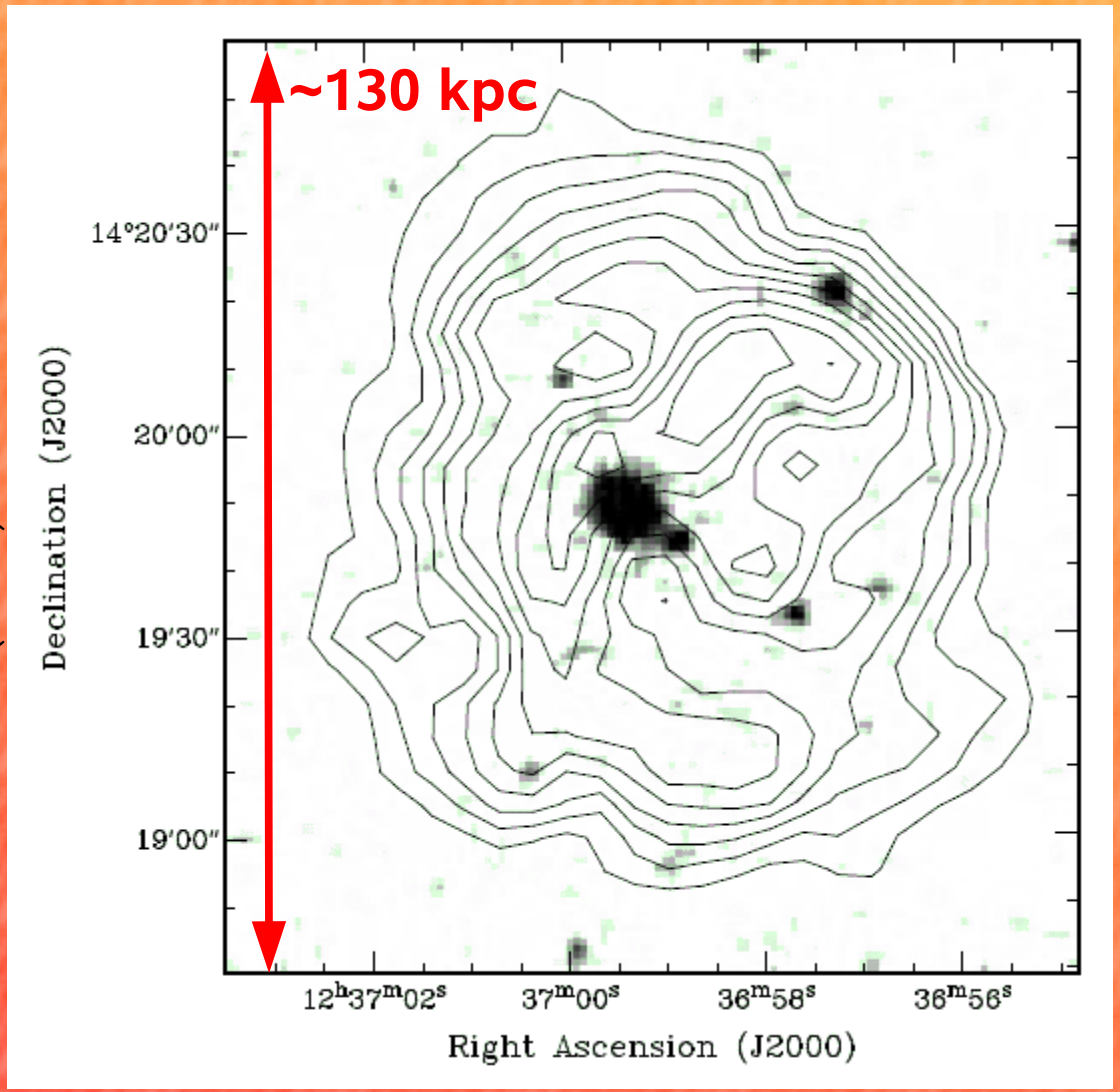
Quasar absorption line systems probe galaxies at large impact parameters.

Local Universe, 21cm Observations



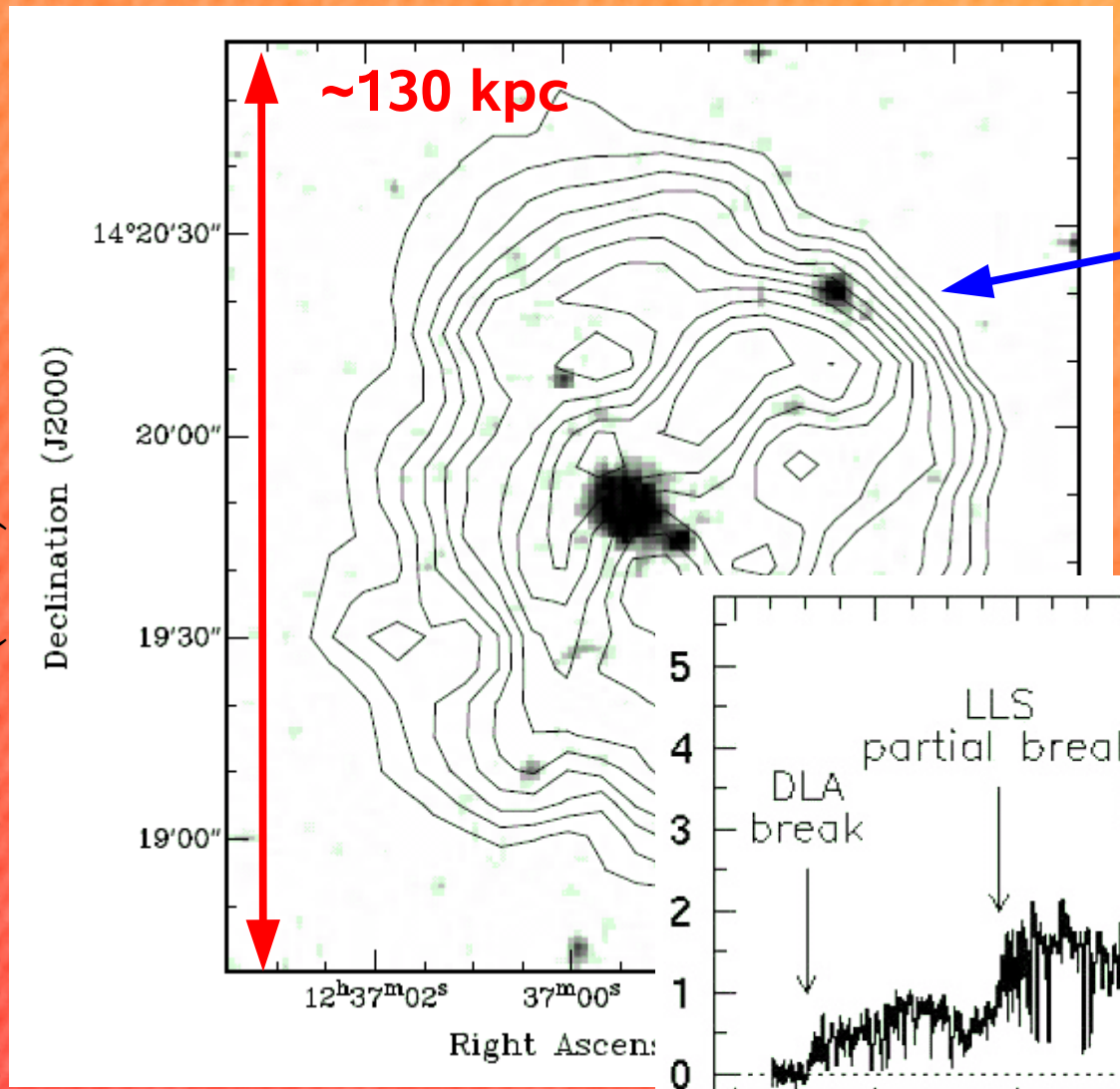
Maurer et al. (1996)

Local Universe, 21cm Observations

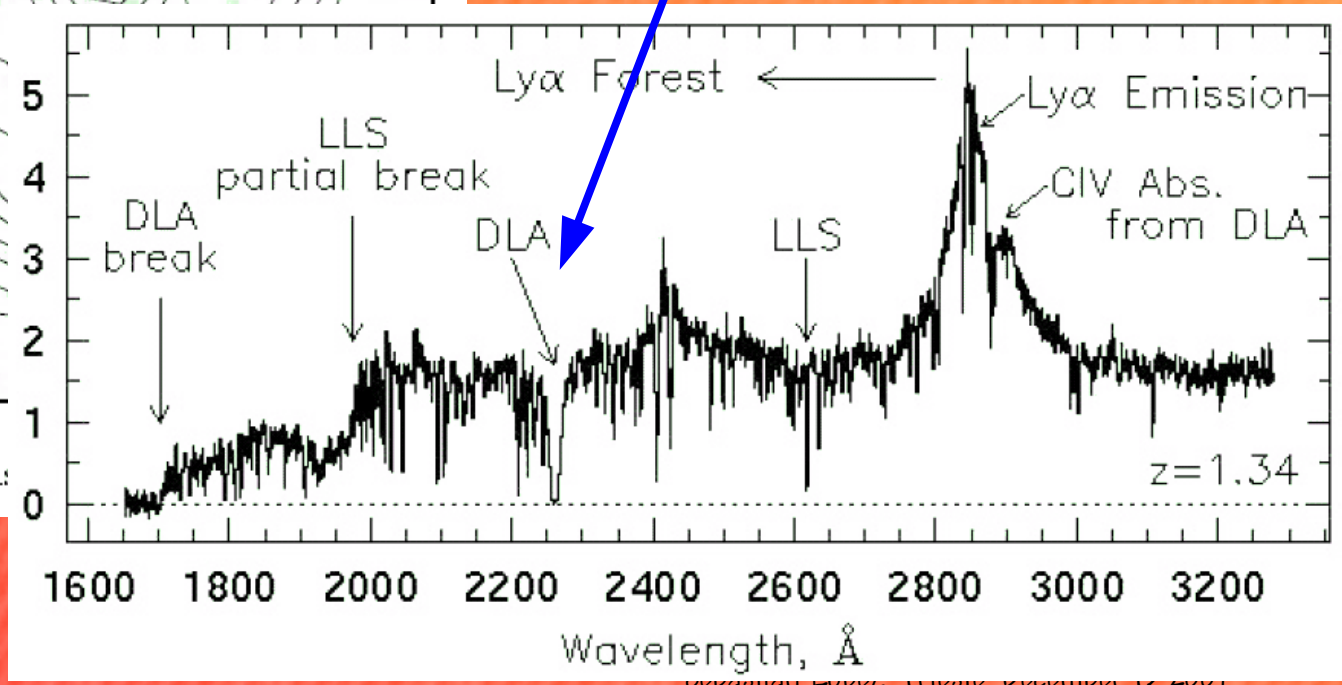


Sancisi & Fraternalli (2007)

QAL: high redshift Universe



N(HI)=8×10^{19} cm^{-2}



Sancisi & Fraternalli (2007)

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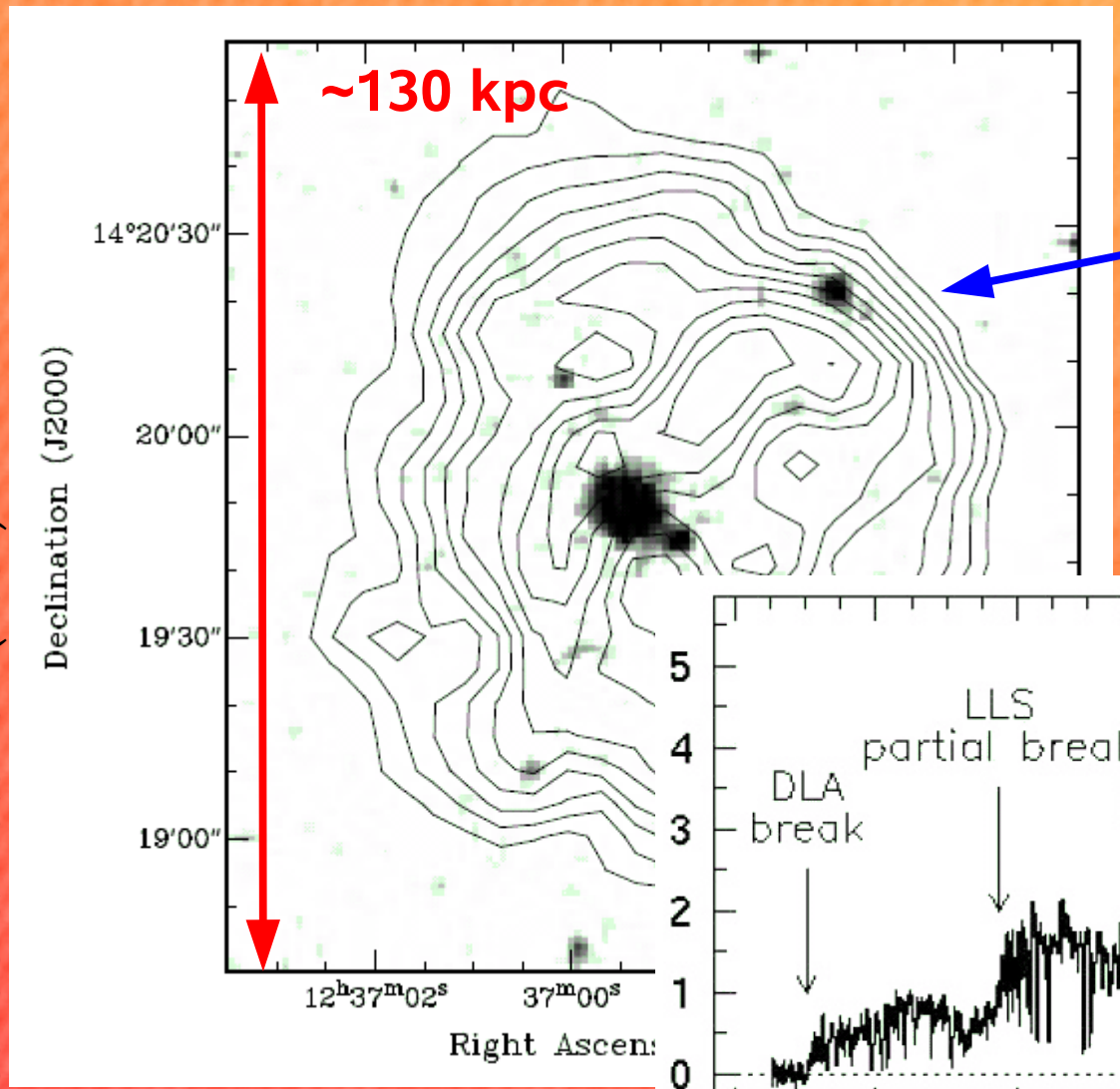

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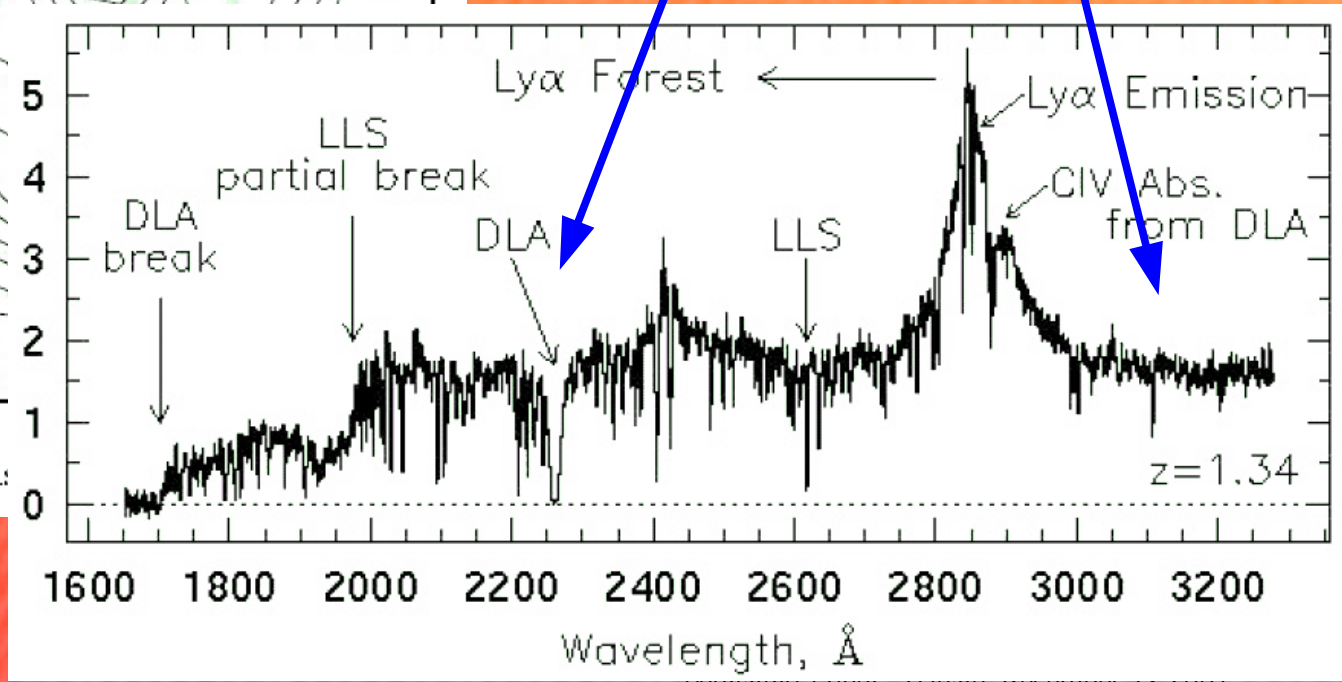
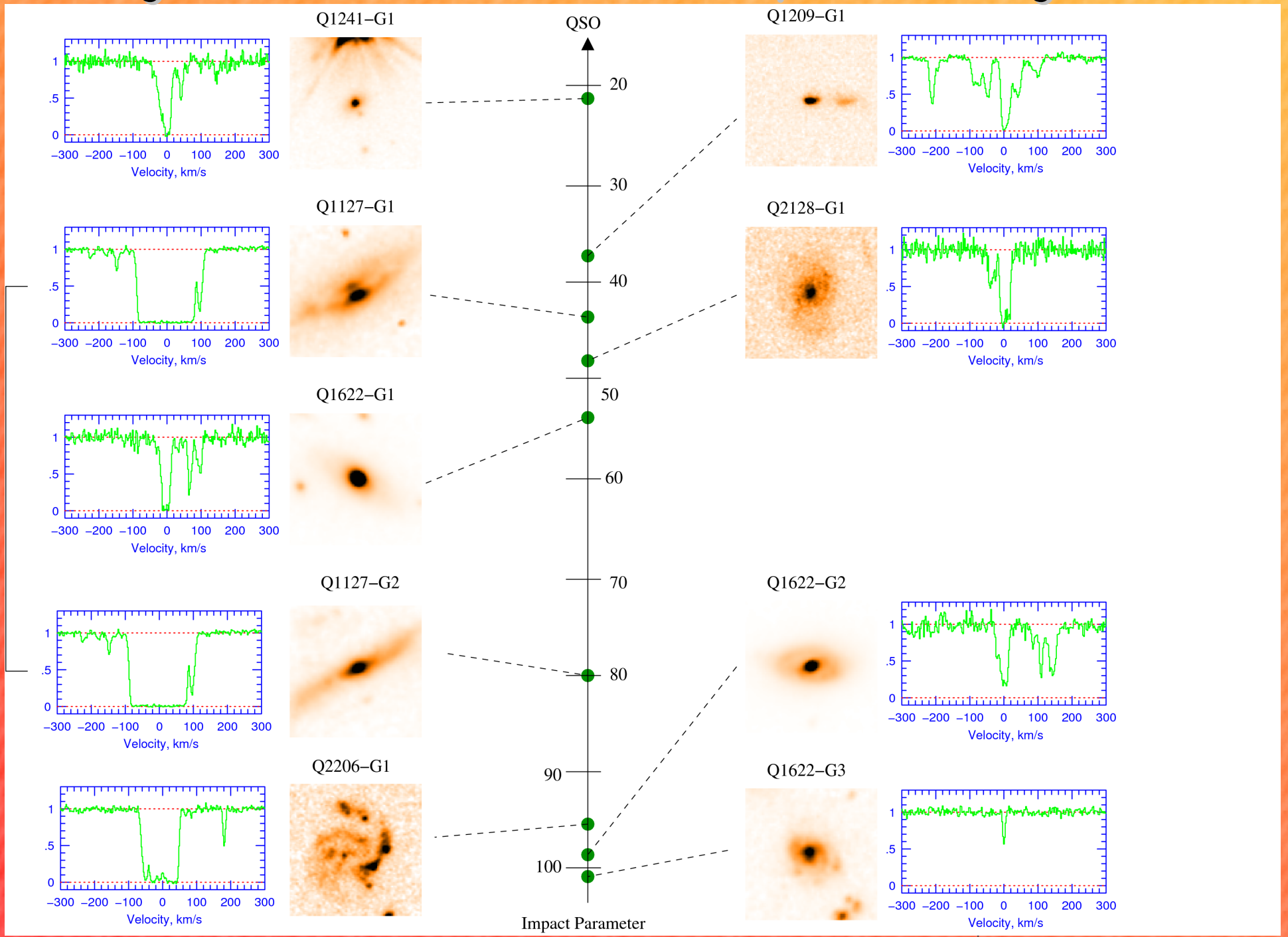
Redshifted Metal Lines



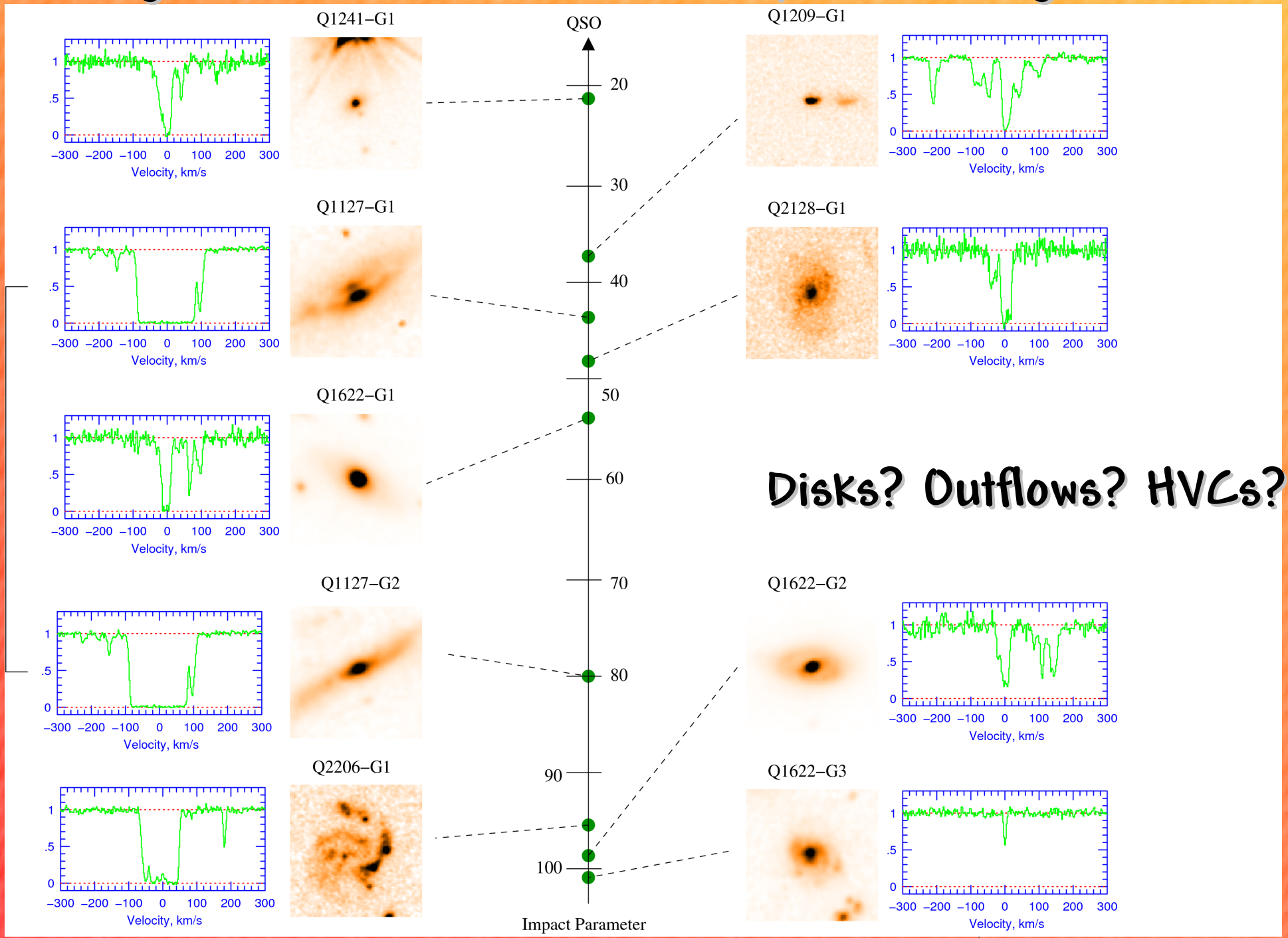
Sancisi & Fraternalli (2007)

MgII 2796,2803 Å traces Galaxy halos at high-z



Churchill et al.

MgII 2796,2803 Å traces Galaxy halos at high-z

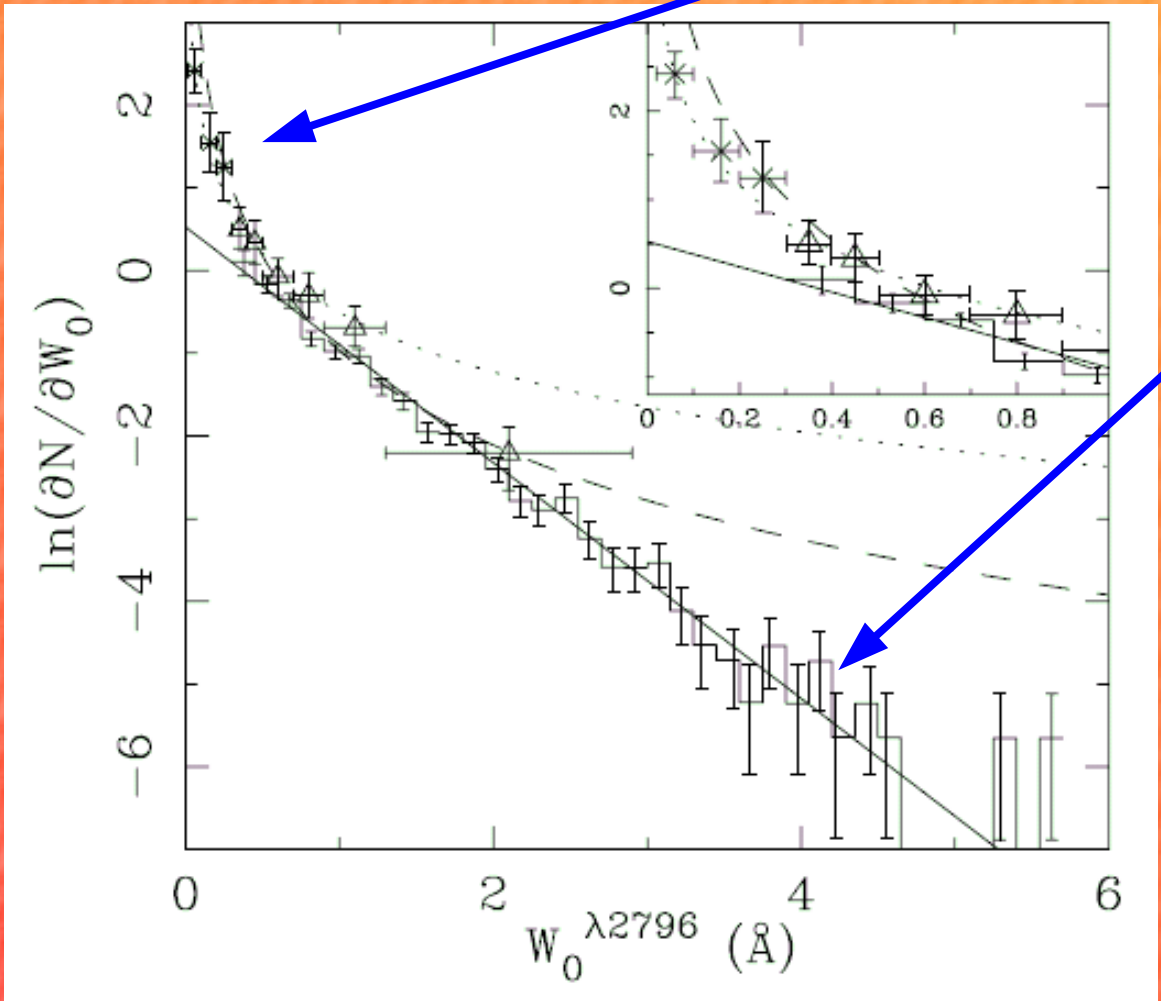


Disks? Outflows? HVCs?

Churchill et al.

MgII 2796,2803 Å traces Galaxy halos at high-z

W_0 < ≈ 0.3 Å, power-law



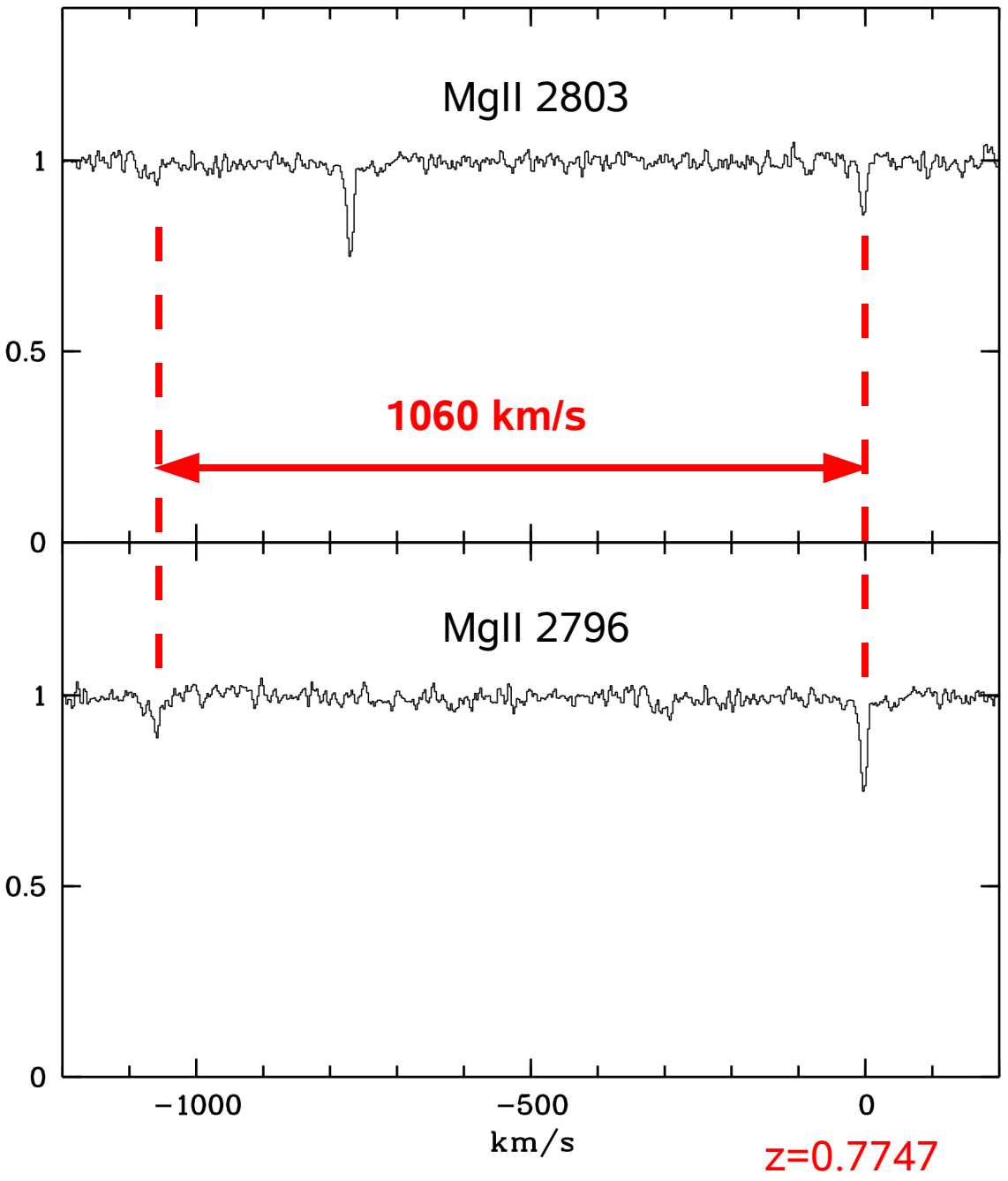
W_0 > 0.3 Å, exponential

Nestor et al.

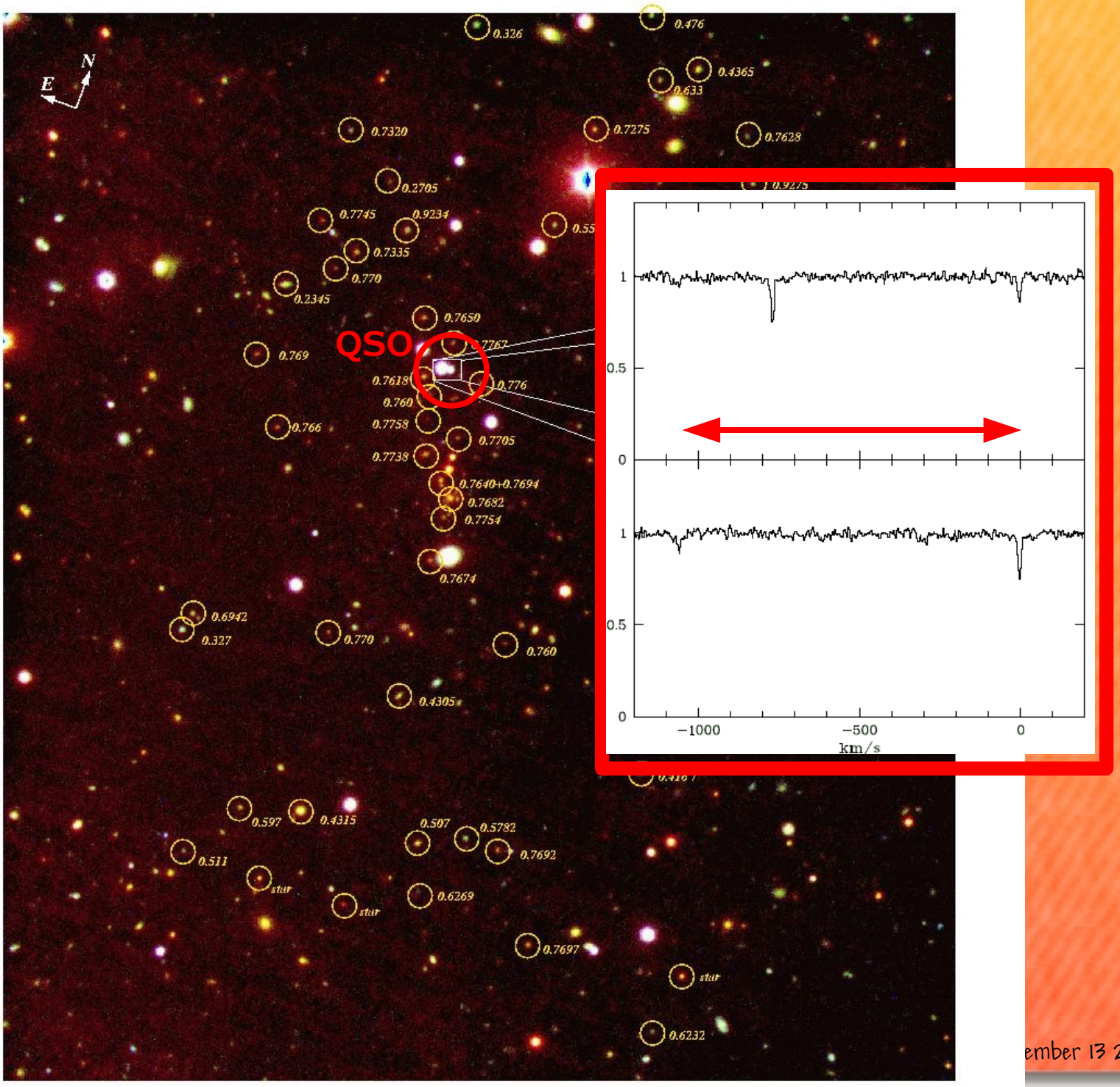
Disks? Outflows? HVCs?

Motivation for the present work...

QSO RXJ0911.4+0551



RXJ0911+05: Massive cluster at z=0.7689±0.002 (Kneib et al. 2000)



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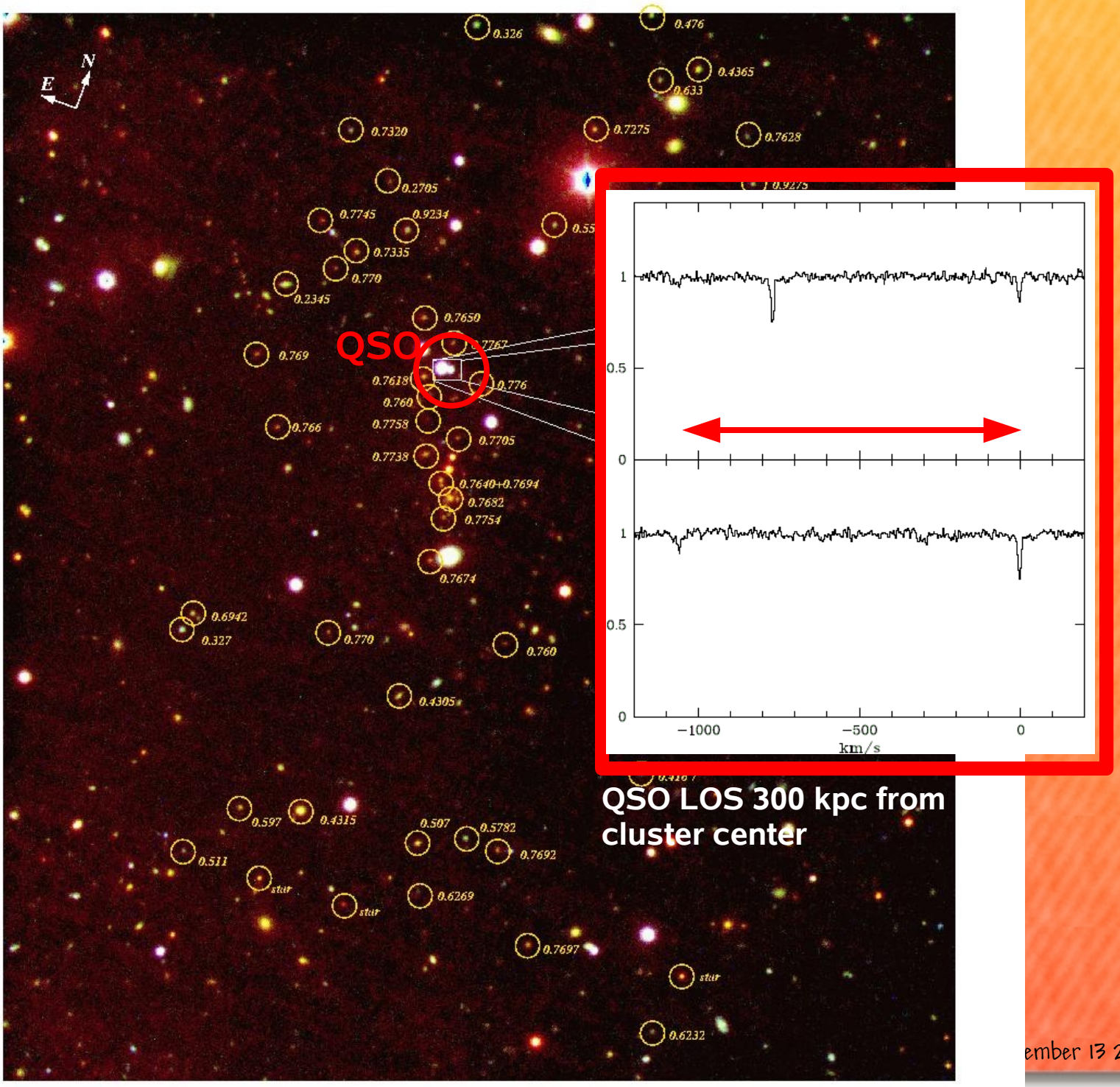

QSO LOS 300 kpc from cluster center

What is the incidence of MgII systems in high-z cluster galaxies?

Why is this question important?

Because clusters...

- have many galaxies at the same cosmic time
- are the densest environments in the Universe
- induce galaxy transformations
- can be traced to high-z

Why is this question important?

Because clusters...

- have many galaxies at the same cosmic time
- are the densest environments in the Universe
- induce galaxy transformations
- can be traced to high-z

...will tell us about the field MgII population

Surveys of Absorption Line Systems

$$\frac{dN}{dz} = N(z)\frac{(1+z)^2}{\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}}$$

$$N(z) = \frac{c}{H_o}n(z)\sigma(z).$$

What you expect

Courtesy of Chris Churchill

Surveys of Absorption Line Systems

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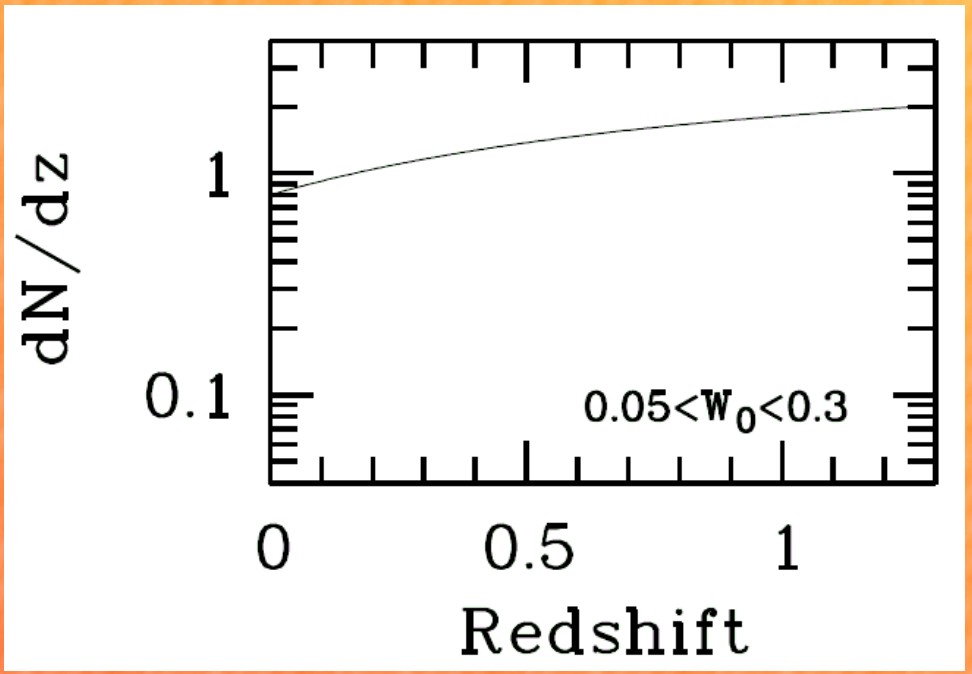

Courtesy of Chris Churchill

Surveys of Absorption Line Systems

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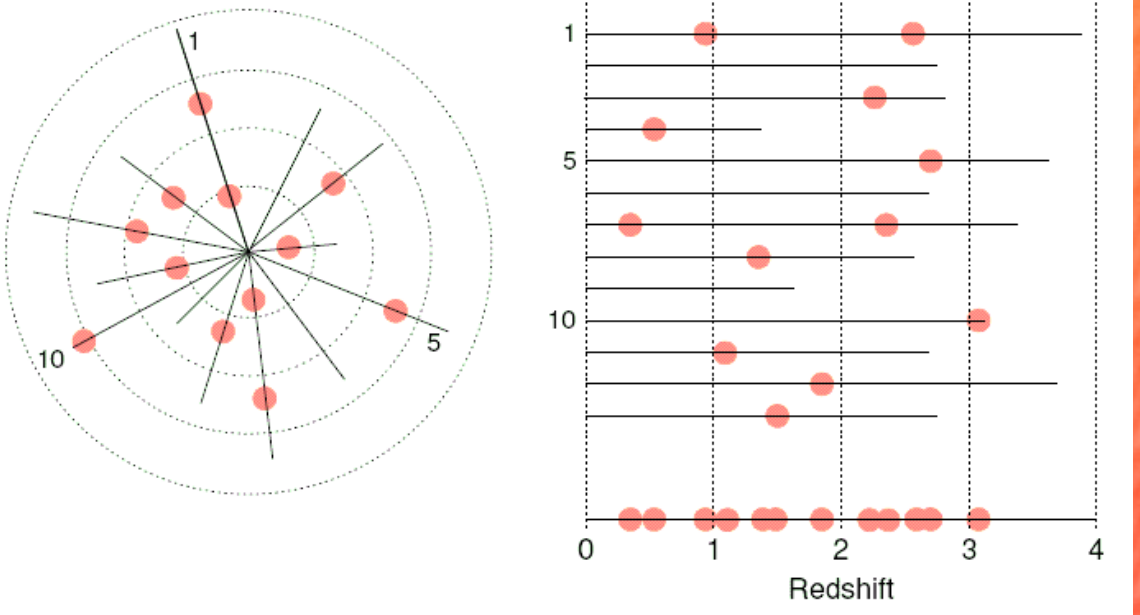

Courtesy of Chris Churchill

$$\mathcal{N}(\langle z \rangle) \equiv \frac{dN(\langle z \rangle)}{dz} = \frac{N_{abs}}{\Delta Z(W_{min})}$$

What you measure

Surveys of Absorption Line Systems

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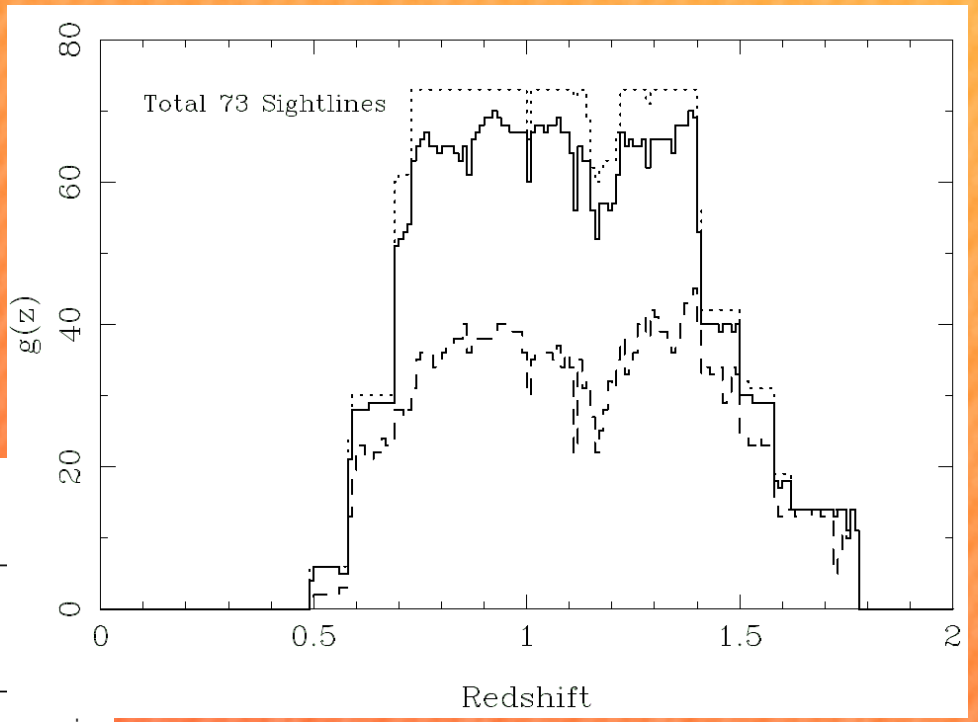
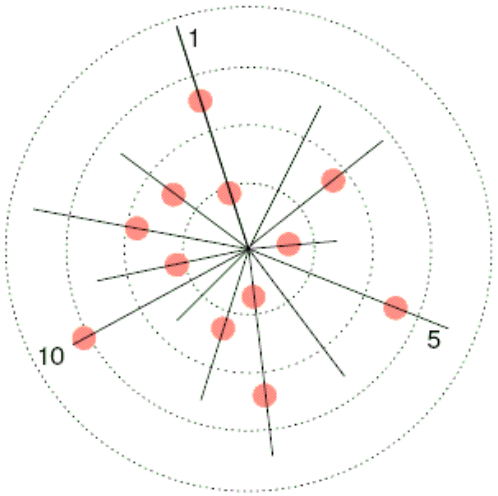
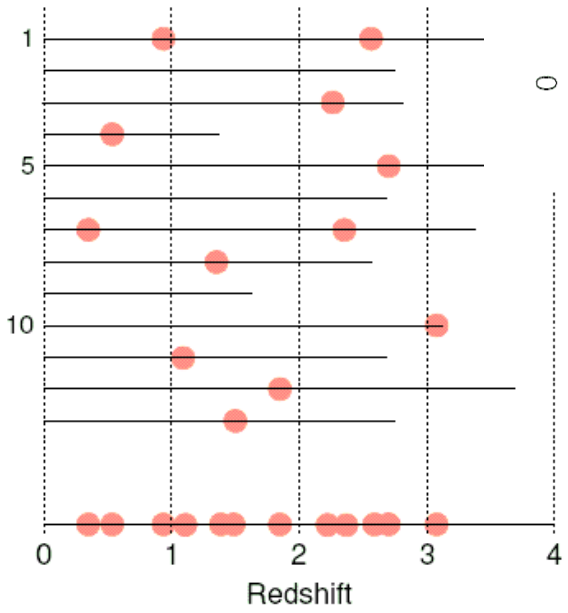
What you expect







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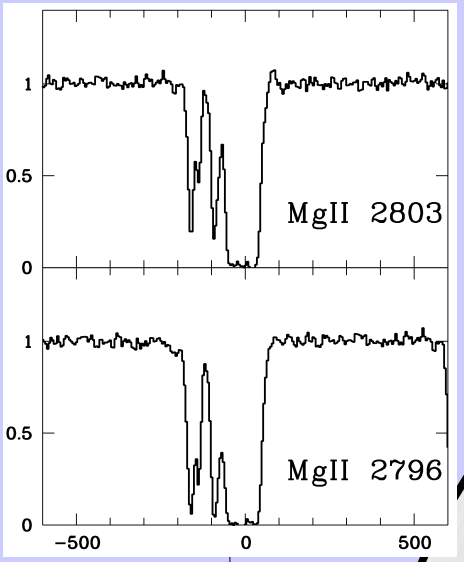
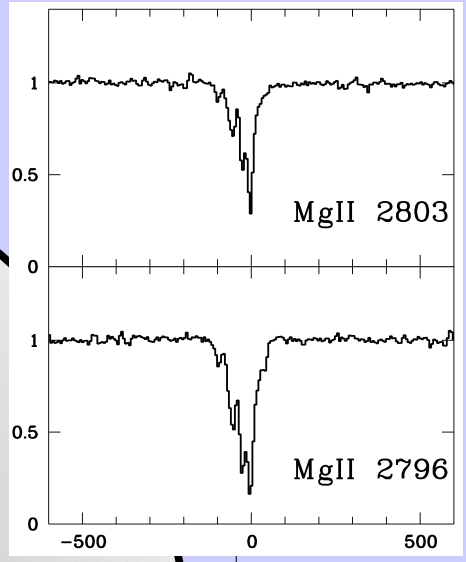
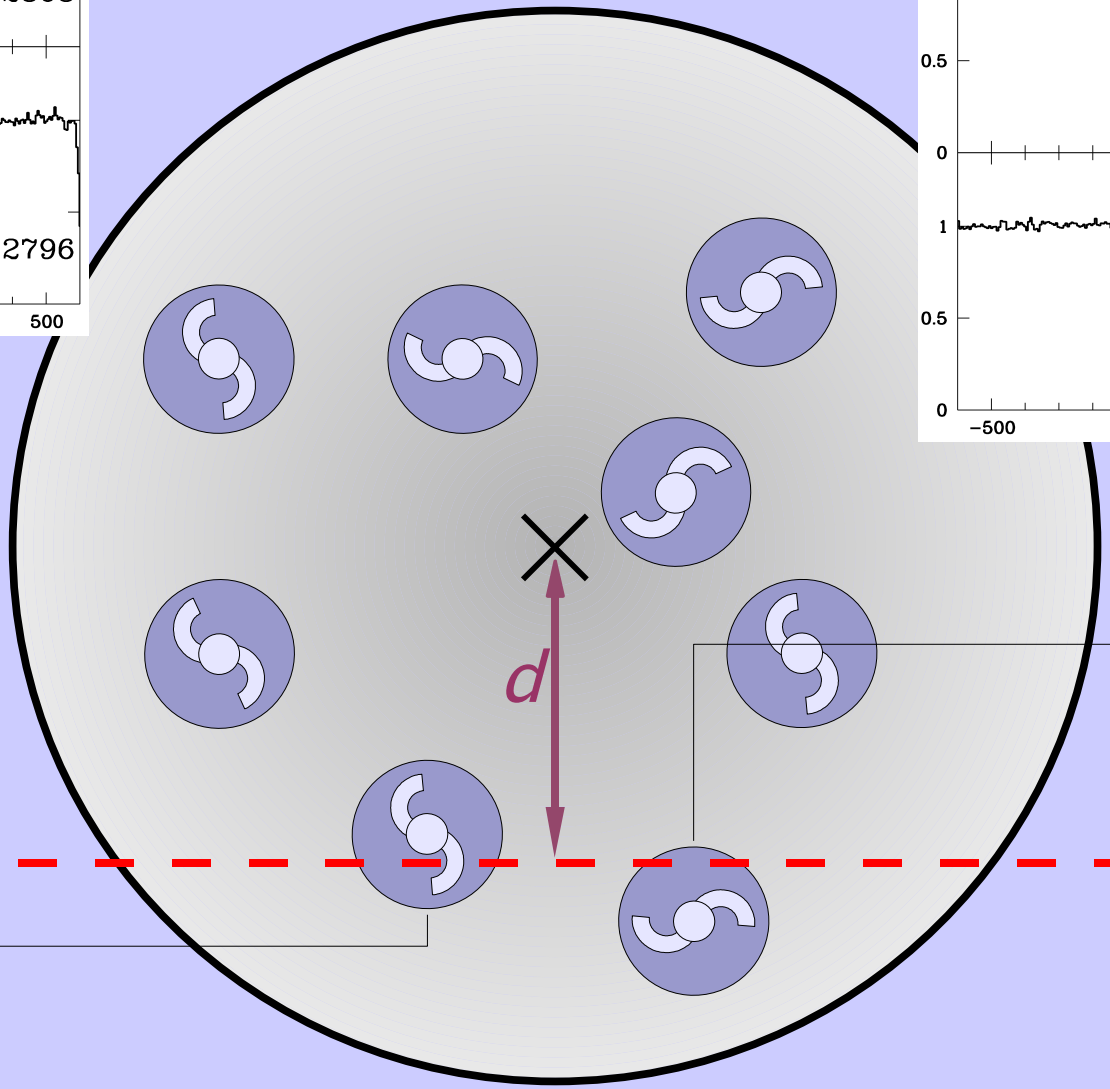
What you measure

Courtesy of Chris Churchill

QbC: The Quasars behind Clusters Survey

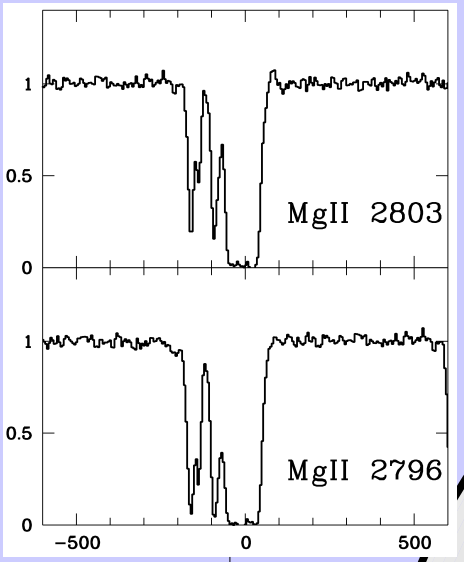






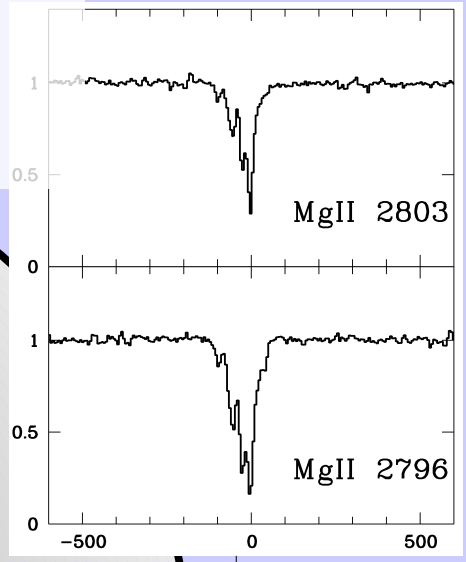
QSO

QbC: The Quasars behind Clusters Survey



Need QSO-Cluster pairs with:

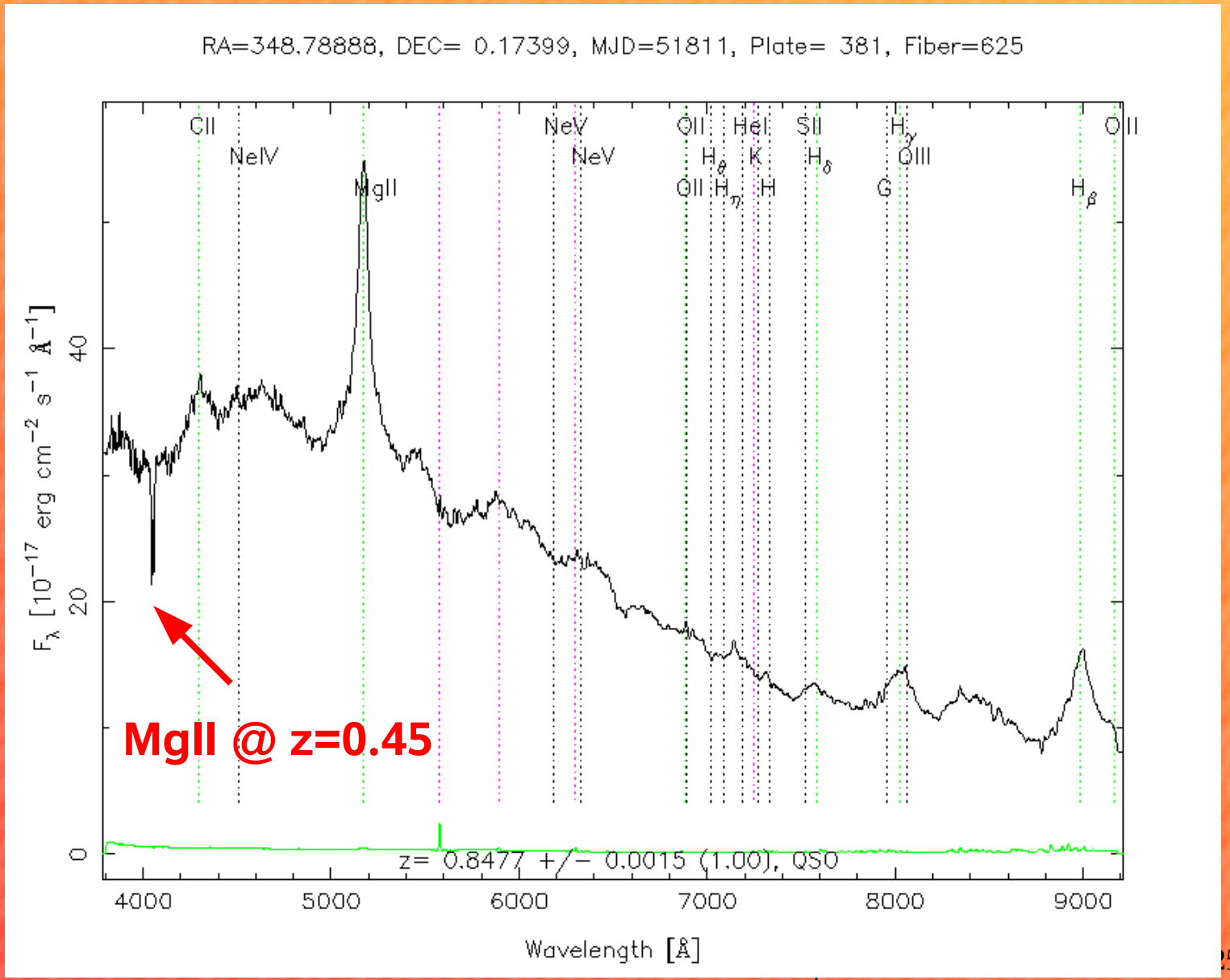
- $z_{QSO} > z_{cluster} > 0.2$
- **Impact parameter d<2Mpc**



QbC: The Quasars behind Clusters Survey

QSO Data

- SDSS
- DR3
- ~42000 QSOs.

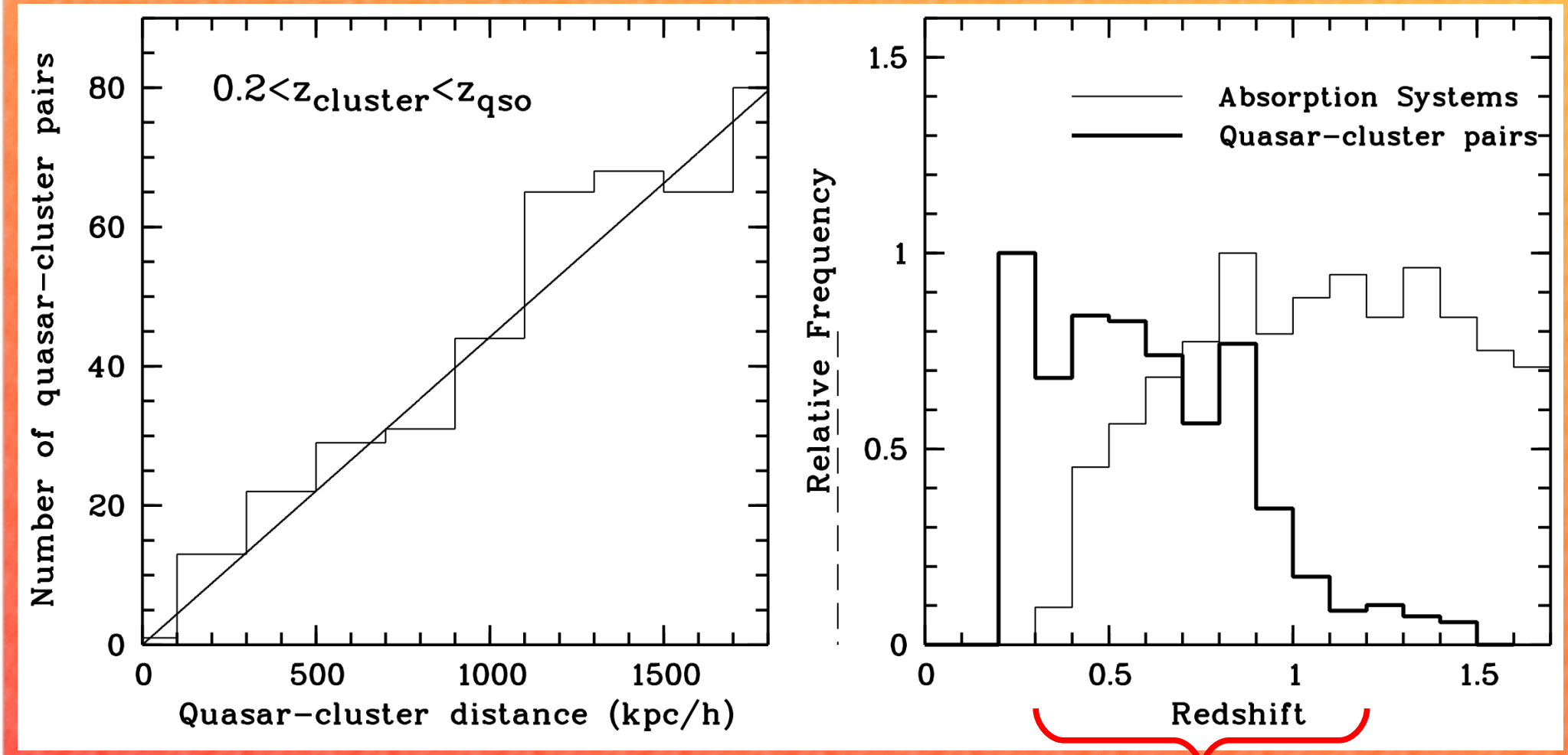


QbC: The Quasars behind Clusters Survey Cluster Data

- Red-Sequence Cluster Survey (RCS-1)
- 100 sq deg
- R- and z-bands
- Galaxy Clusters up to z~1.4
- Photo-z accurate to $\delta z \pm 0.1$
- Contamination ~3%.

Gladders et al., Barrientos et al.

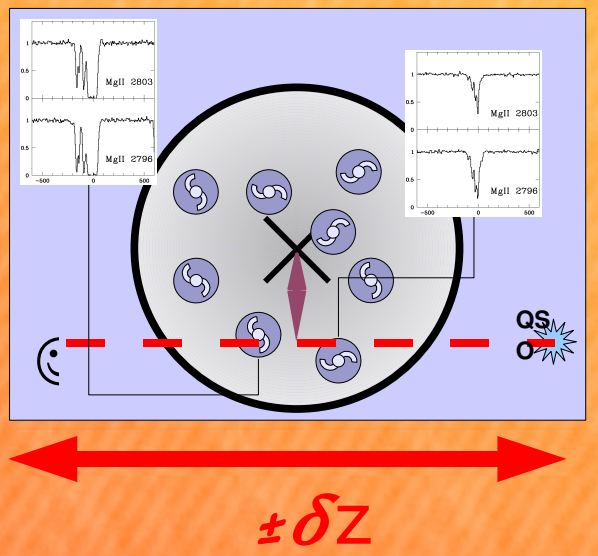
RCS - SDSS correlation: complete and homogeneous



Good overlap thanks to RCS!

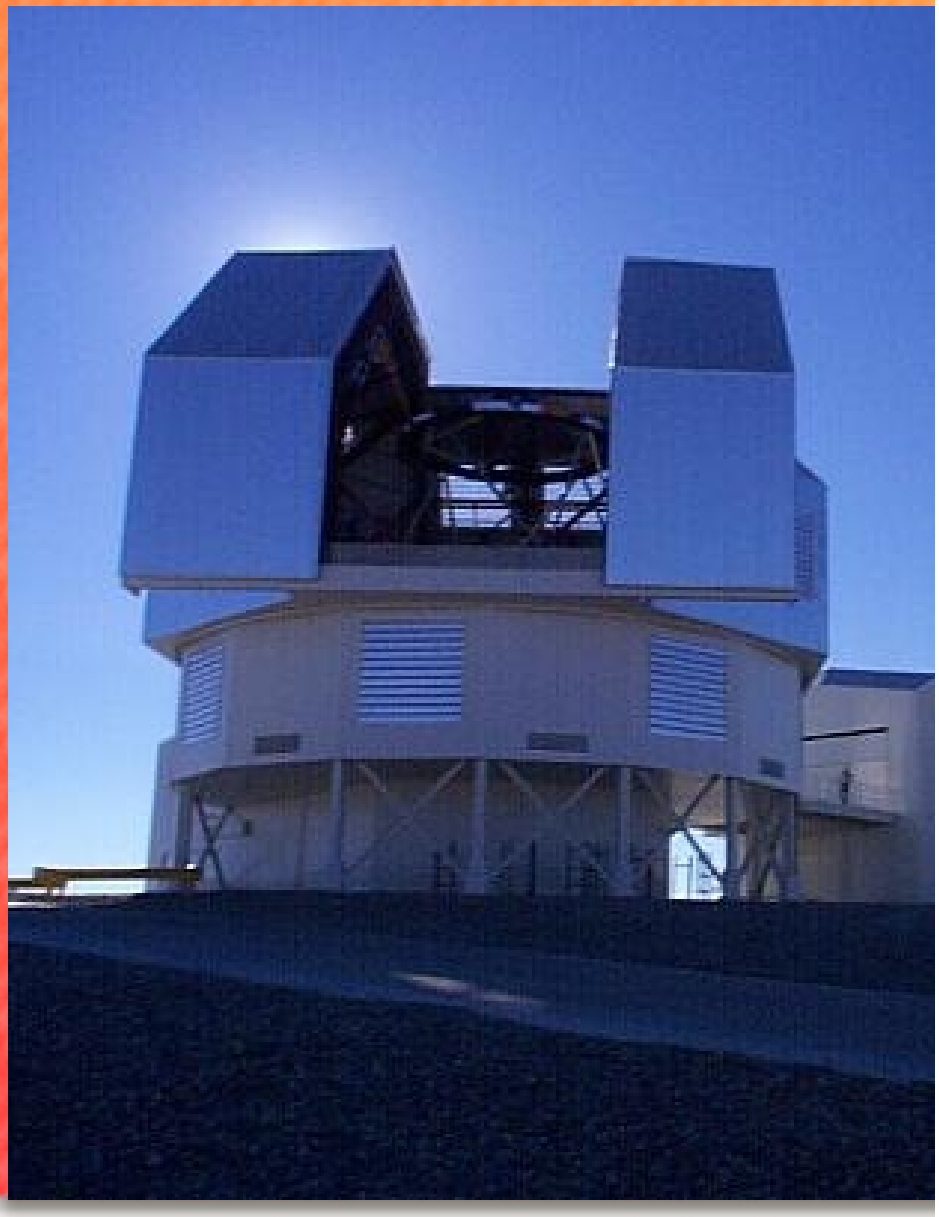
Ad-hoc redshift-path density

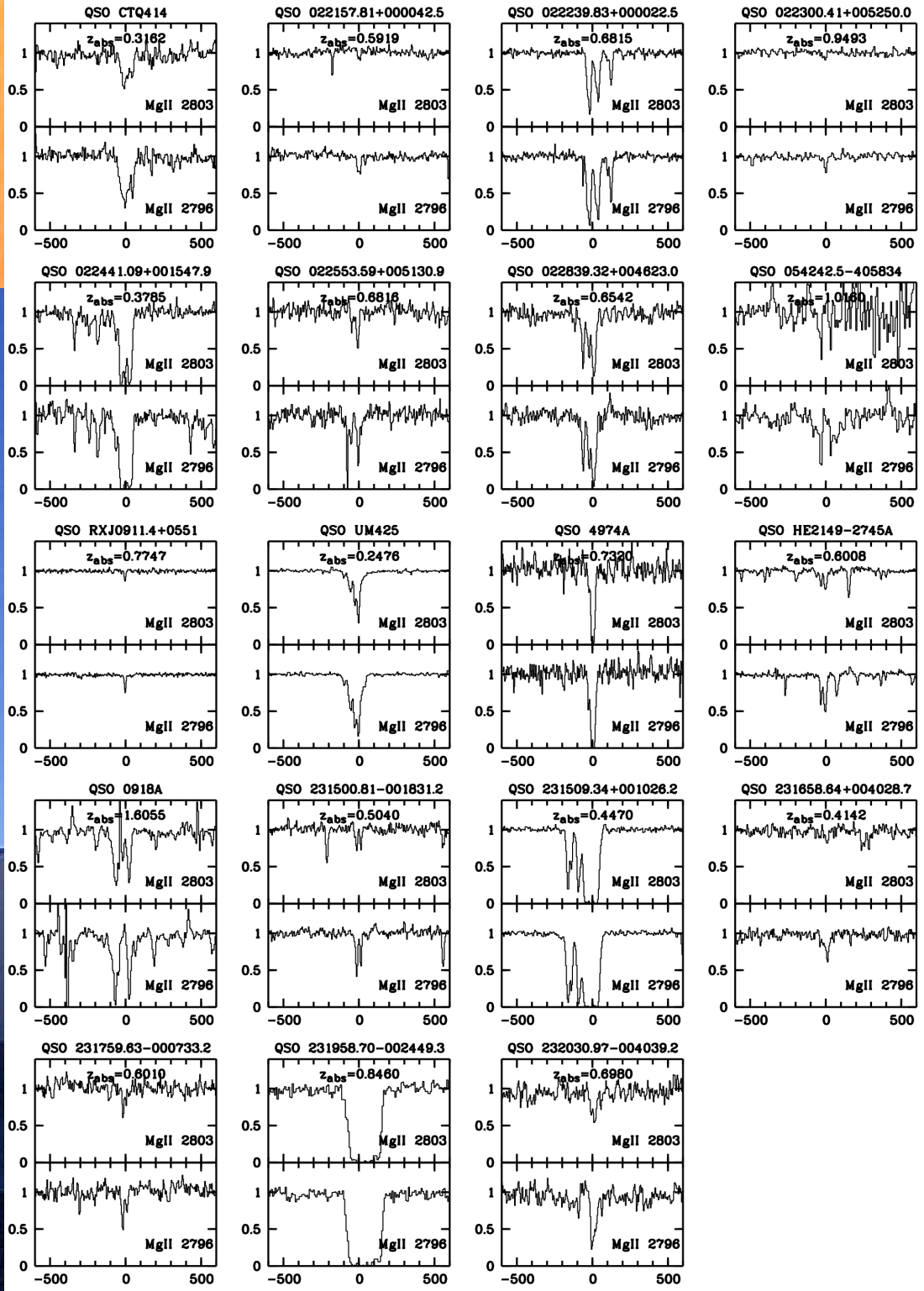
- $\delta z = \pm 0.1$ defines 'redshift intervals' to search for MgII absorption systems.
- Sum of redshift intervals determines the total redshift path of the survey, Δz_c
- Total number of absorption systems in the redshift path ('hits') gives us *dN/dz*, i.e. the probability of finding MgII in this cluster sample.



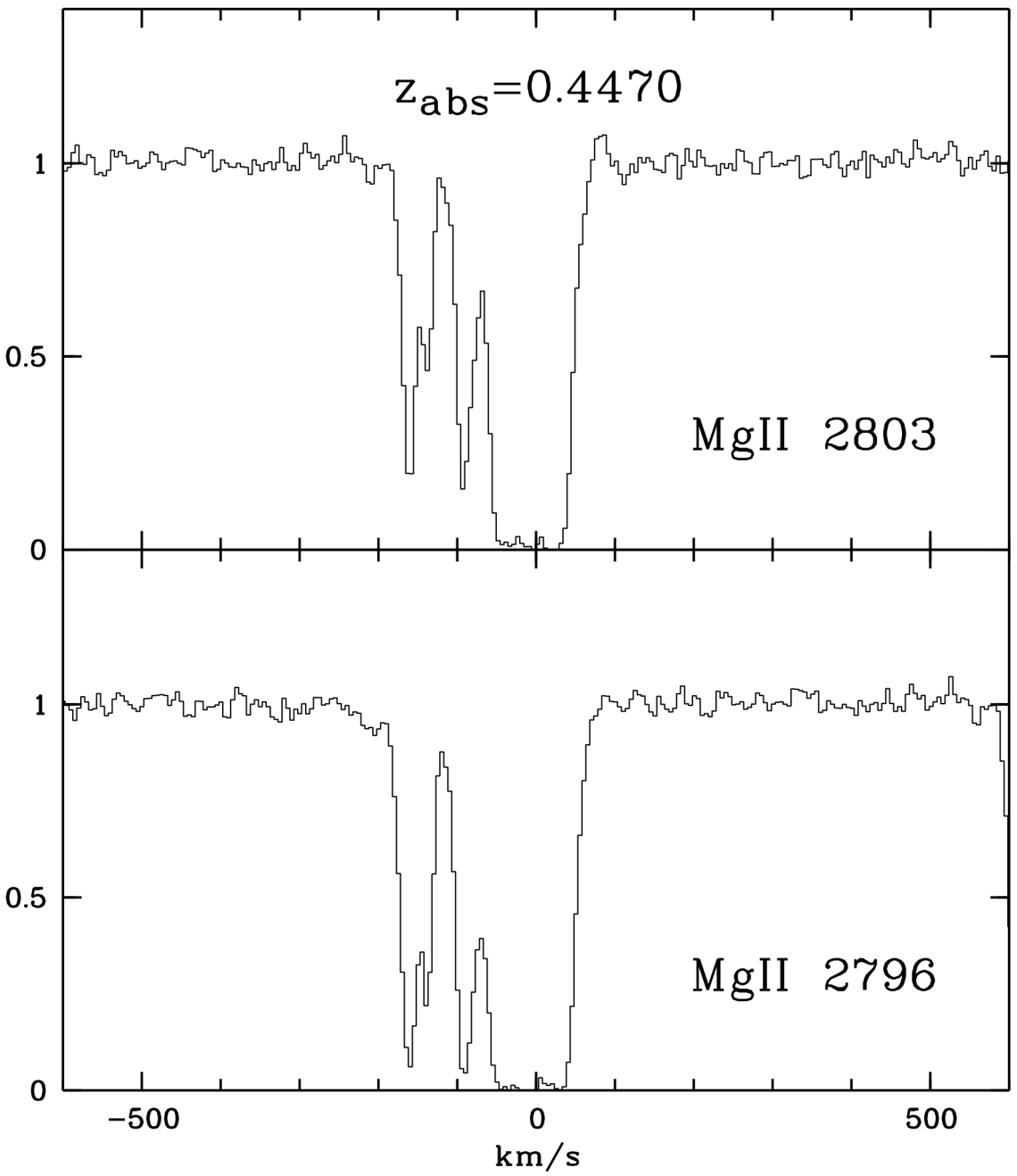
$$(dN/dz)_c(W_0, z_1, z_2) \equiv \frac{N_{\rm hits}(W_0, z_1, z_2)}{\Delta z_c(W_0, z_1, z_2)}$$

Magellan/MIKE
5 nights





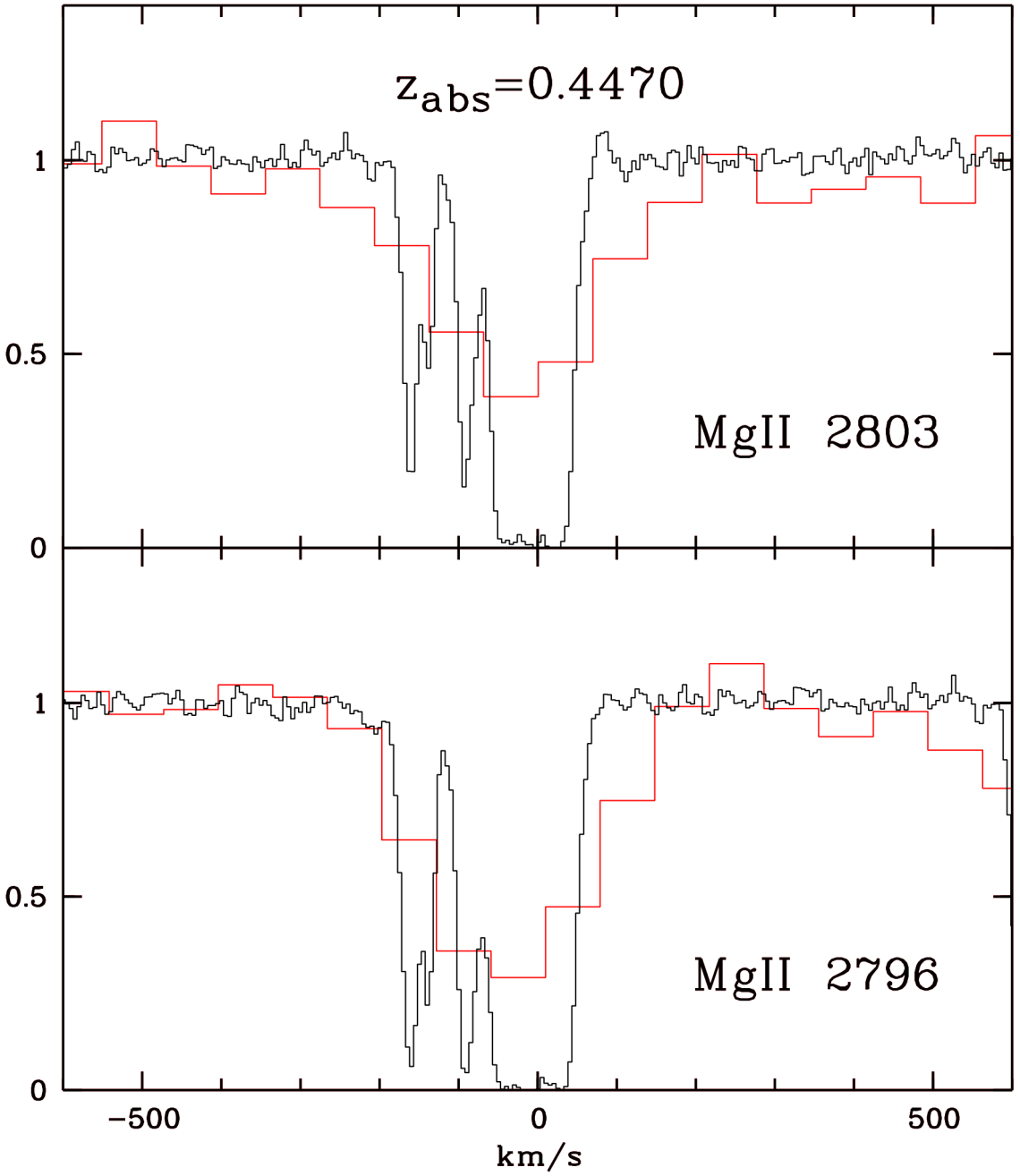
W_0 = 1.8 Å
(“ strong”)



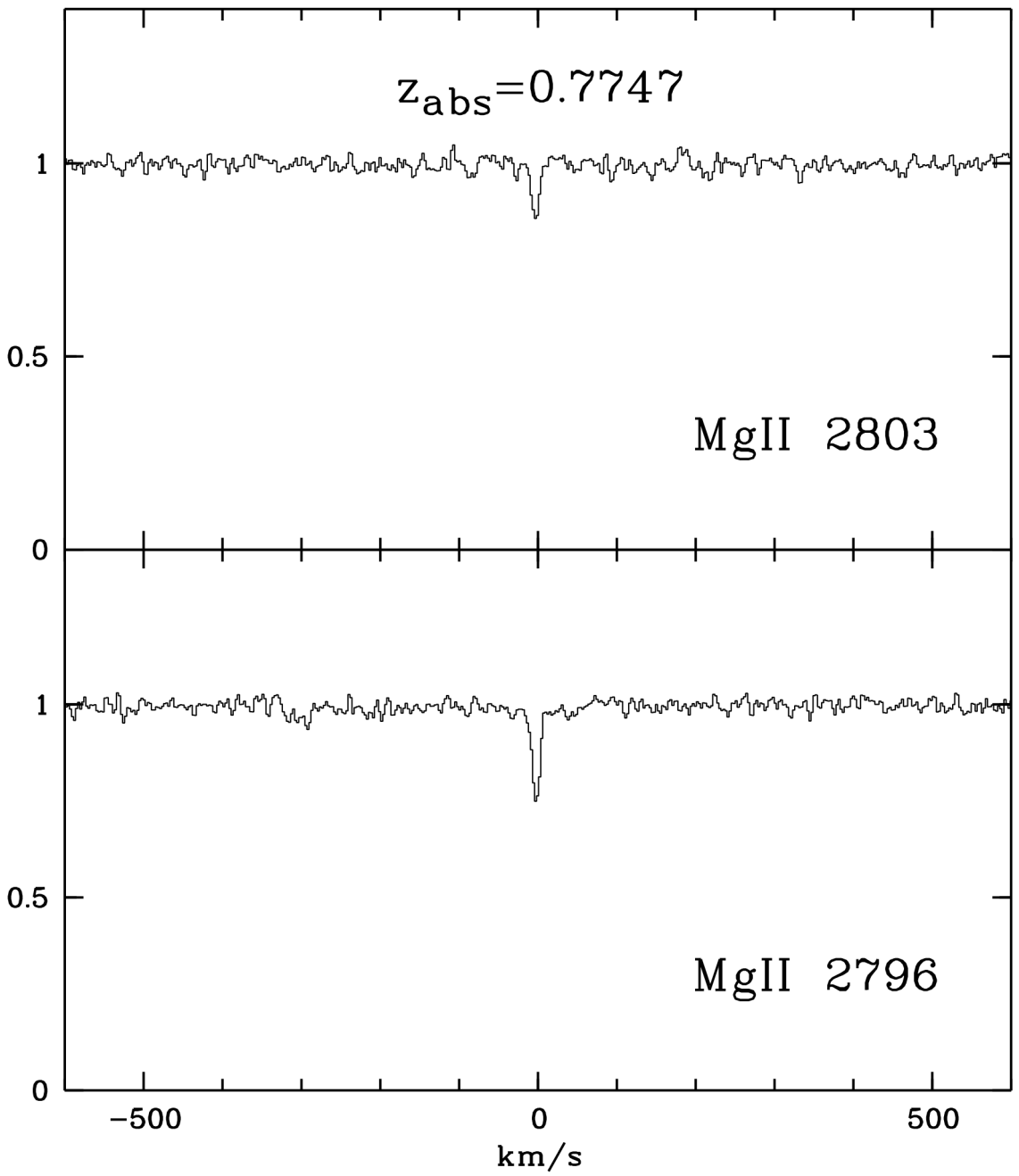
MIKE
SDSS

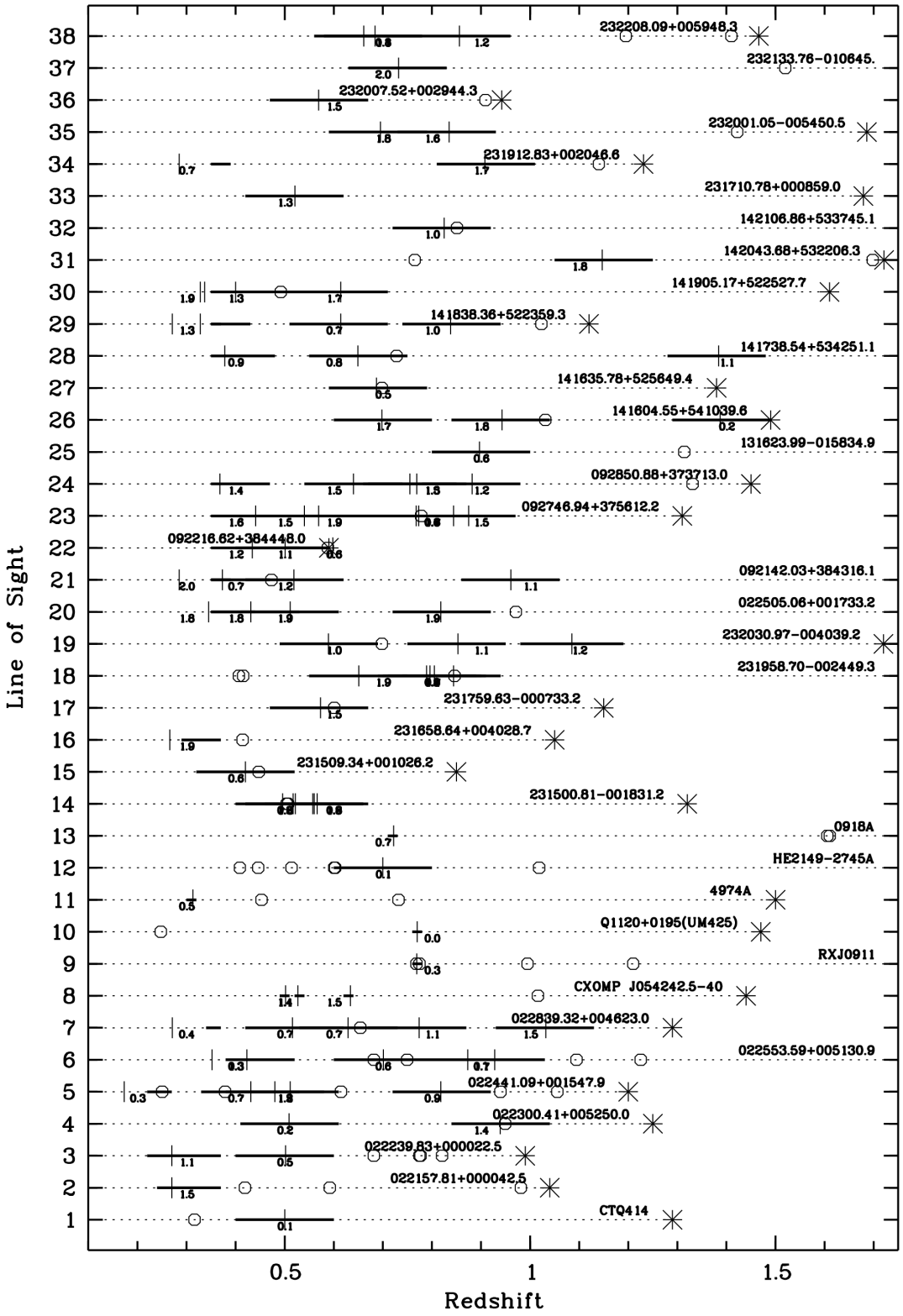
QSO 231509.34+001026.2

W_0 = 1.8 Å
(" strong")



W_0 = 0.033 Å
(“ weak”)





Lines of Sight surveyed

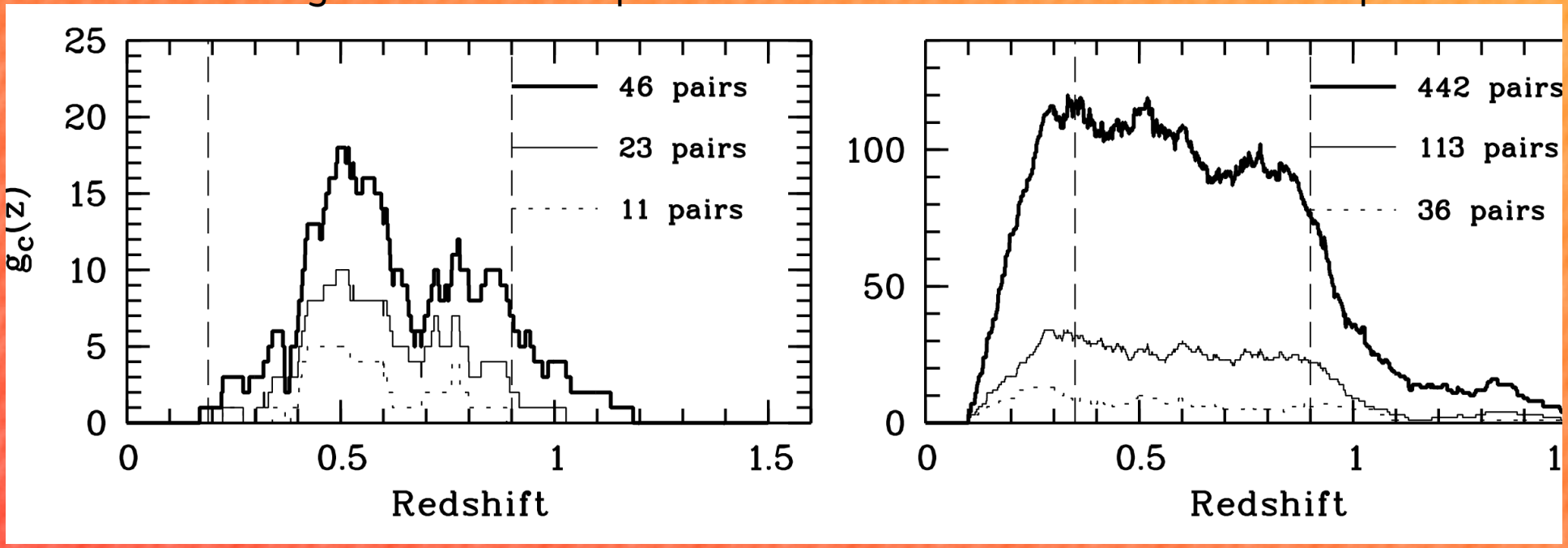
- 144 Low-resolution spectra
- 375 QSO-cluster pairs
- Δz = 57.0
- $W_0 > 1.00$ Å
- 23 absorbers

- 19 High-resolution spectra
- 46 QSO-cluster pairs
- Δz = 6.3
- $W_0 > 0.05$ Å
- 37 absorbers

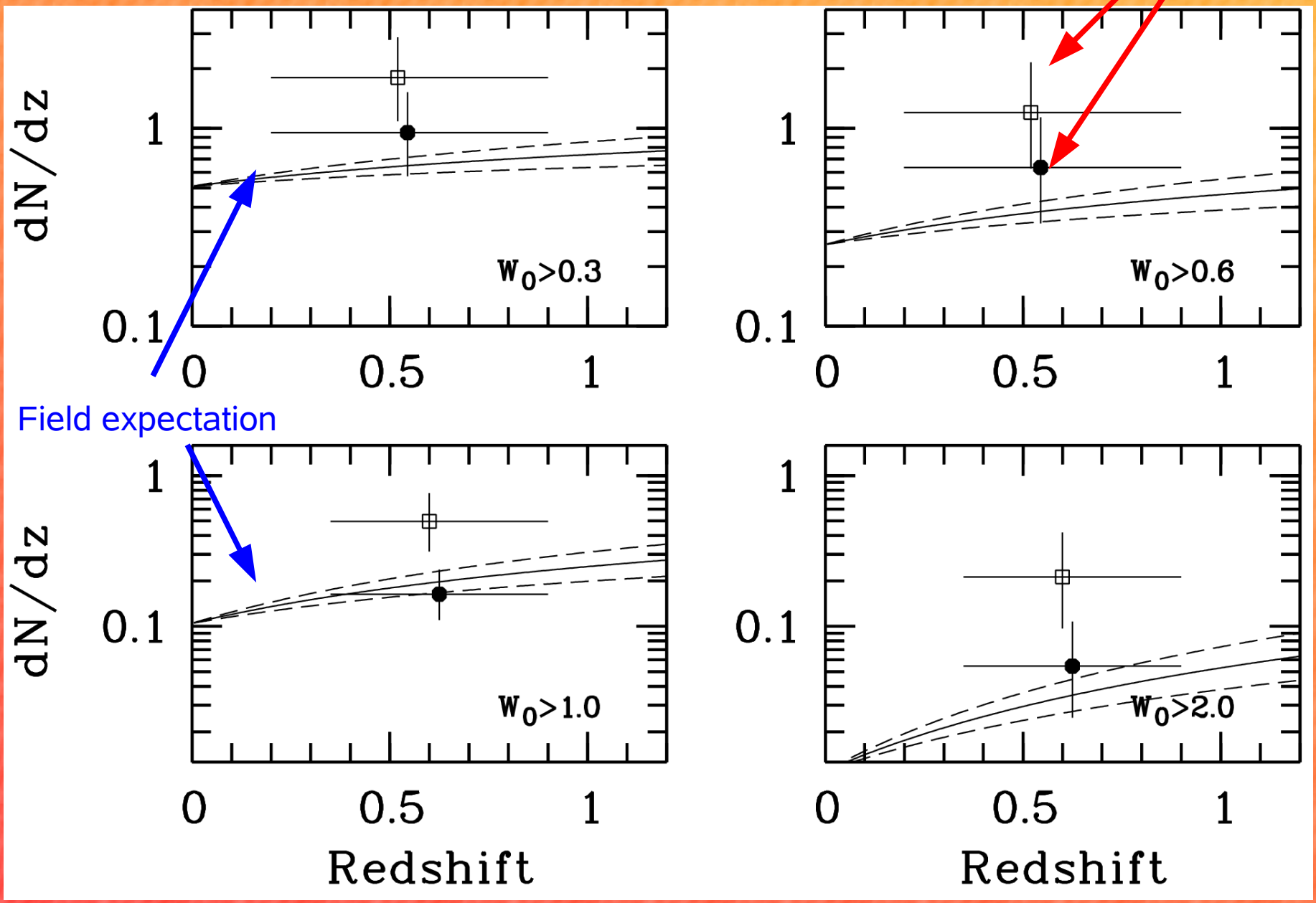
Survey Redshift Path Density

high-resolution sample

low-resolution sample

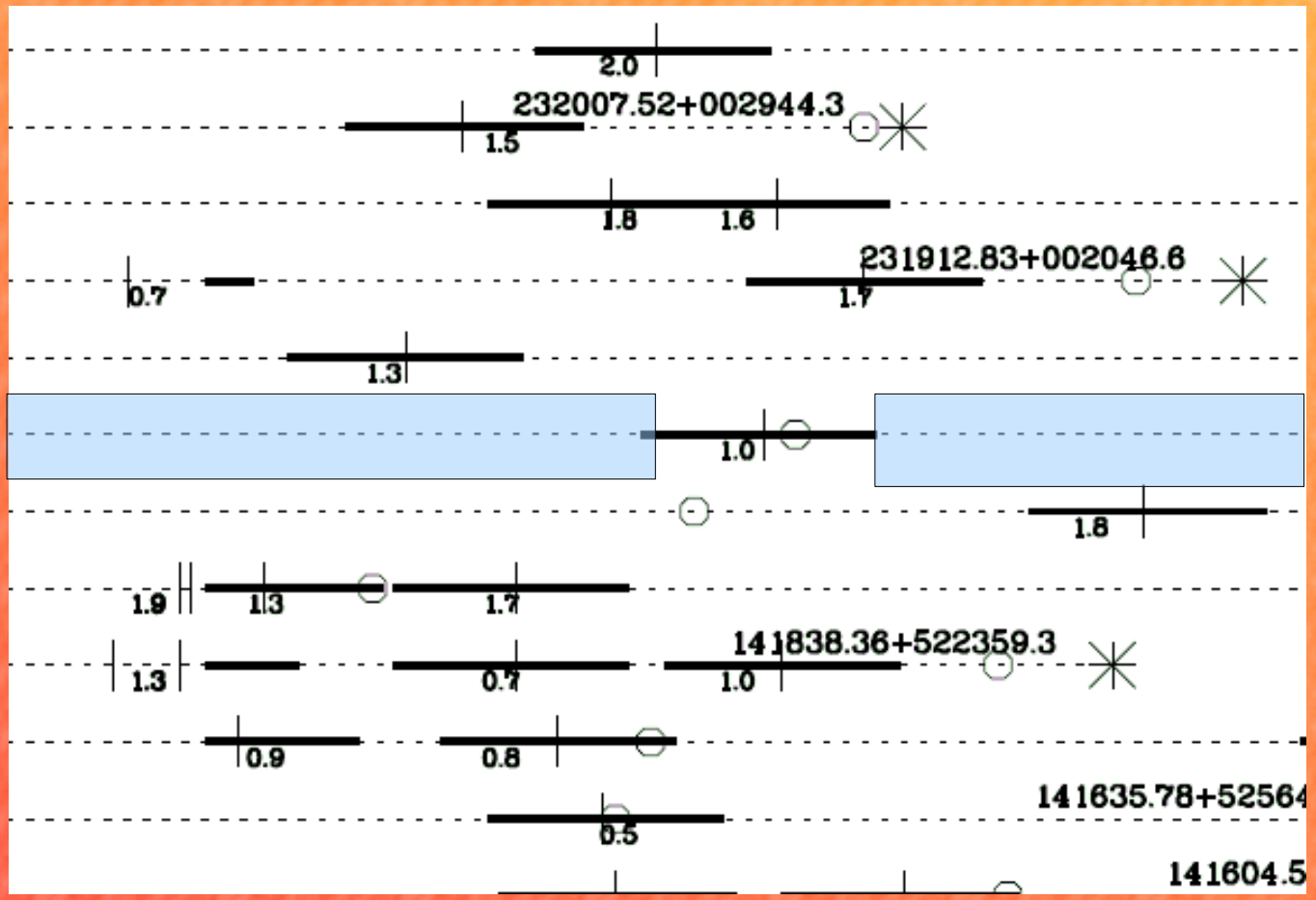


Incidence of MgII in clusters



L. et al. 2007 (ApJ, submitted)

Overdensity not due to chance aligments



Field expectation recovered

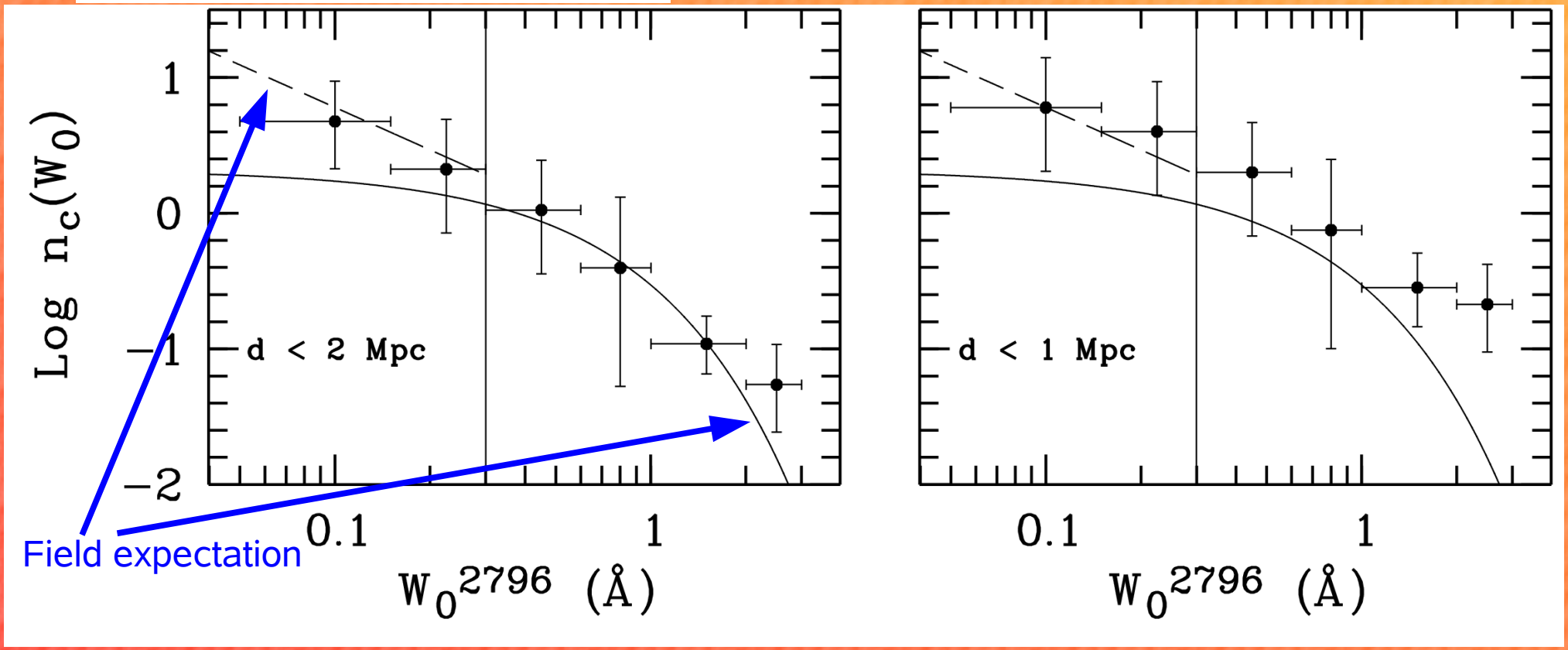
Incidence of MgII in clusters

MgII Redshift Path Density in $z = 0.3$-0.9 Clusters

Sample	W_0 [Å]	$d < 2$ Mpc		$d < 1$ Mpc				
		z-Path	Hits	z-Path	Hits	dN/dz		Excess
						Clusters	Field	
MIKE-RCS	[0.05,0.3]	6.3	5	3.3	4	1.20	1.09	**1.1**
	>0.3		6		6	1.80	0.68	**2.6**
SDSS-RCS	>1.0	57.0	9	14.3	7	0.50	0.16	**3.1**
	[2.0,3.0]		3		3	0.21	0.03	**6.4**
SDSS-RCS-*rich*	>1.0	18.1	5	5.5	4	0.73	0.16	**4.5**
	[2.0,3.0]		2		2	0.36	0.03	**9.1**

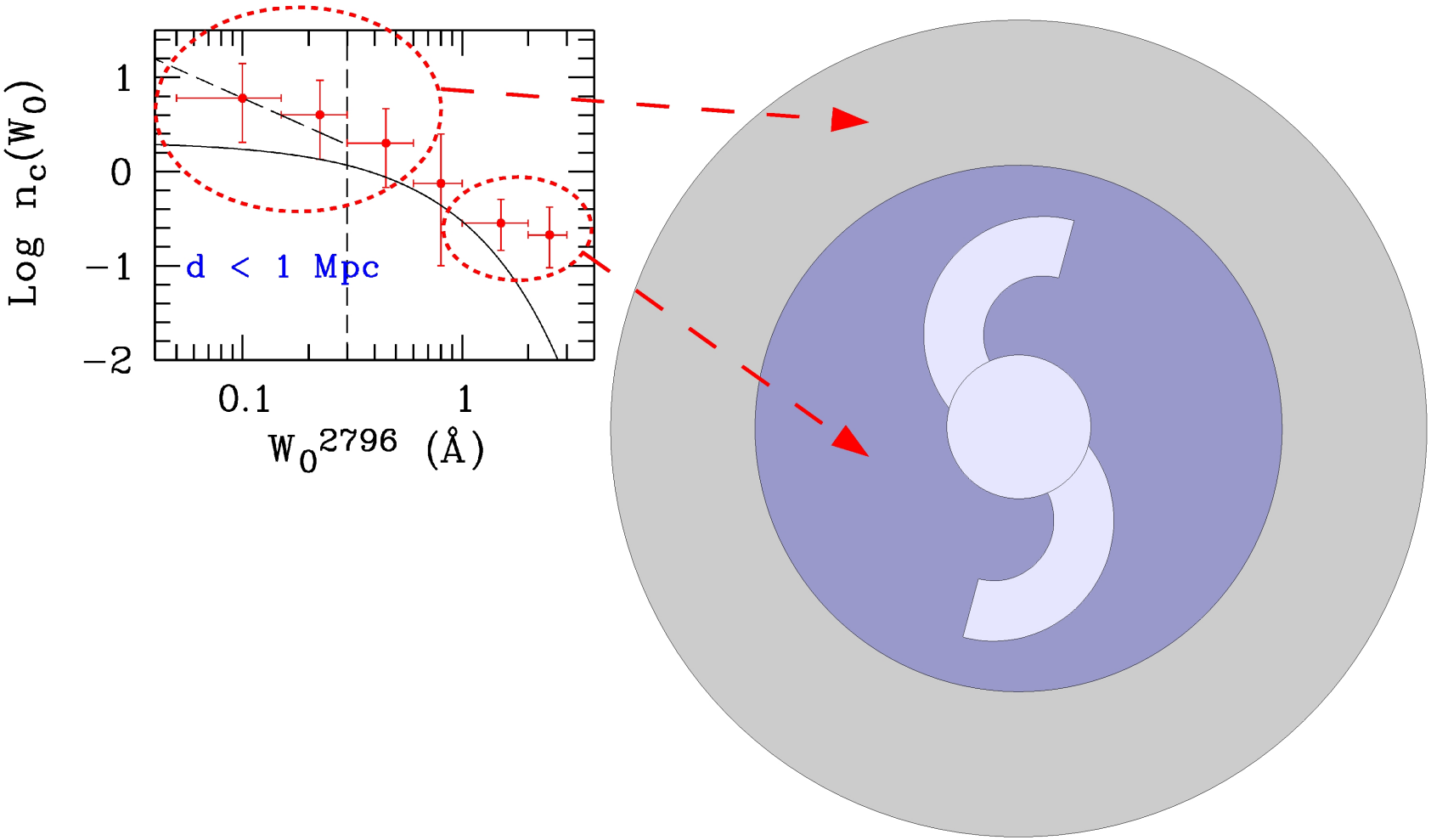
MgII Equivalent-Width distribution in Clusters

$$\int_{W1}^{W2} n_c(W_0, z_1, z_2) dW = (dN/dz)_c$$



L. et al. 2007 (ApJ, submitted)

Interpretation



Expected (Later-type) Galaxy Overdensity

$\delta_g = \delta - 1$?

$$(dN/dz)_c \propto n_c(z)\ \sigma_c(z)$$

From simulations:

$\log_{10}(M/M_\odot)$	$d < 2\ h_{71}^{-1}$ Mpc	$d < 1\ h_{71}^{-1}$ Mpc	$d < 0.5\ h_{71}^{-1}$ Mpc
13	1.7	8.2	34.0
14	10.0	40.0	132.0

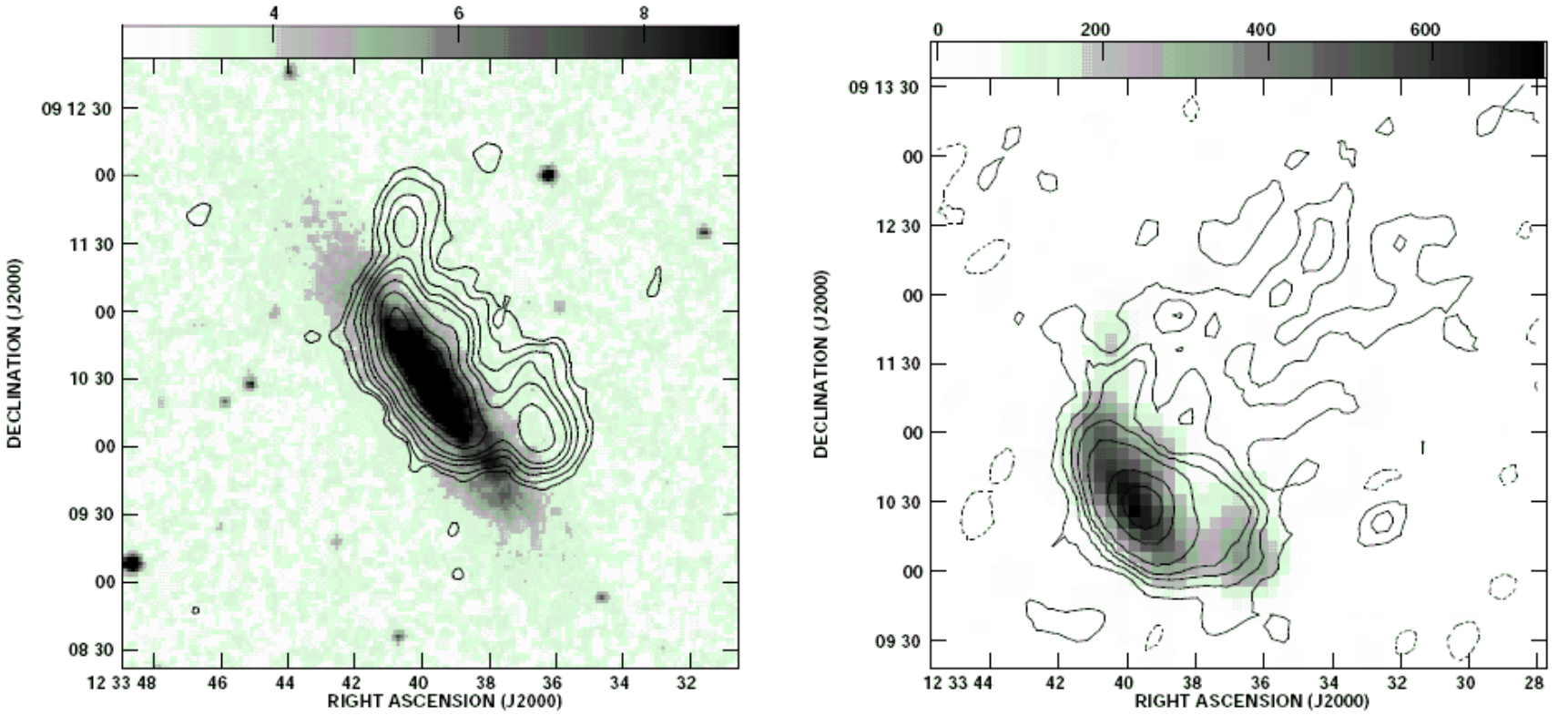
Summary of results

- Intermediate redshift cluster galaxies also host MgII absorbers.
- Strong absorbers are a factor of ~10x more abundant than those in the field (a 3σ result). The signal is stronger for
  - more massive clusters
  - smaller impact parameters.
- Weak absorbers conform to the field statistics.
- Complementary redshift path gives field statistics, so hits are not due to chance alignments.

Implications

- Excess of strong absorbers consistent with the overdensity of cluster galaxies expected from numerical simulations.
- Lack of weak absorber overdensity indicates between 1 and 2 orders of magnitude less MgII cross section than in the field.
- Most plausible explanation: halos giving rise to weak MgII have been truncated by processes inherent to the cluster environment (e.g., ram pressure stripping).

Virgo galaxies, 21cm



Kenney & Koopmann

- Most plausible explanation: halos giving rise to weak MgII have been truncated by processes inherent to the cluster environment (e.g., ram pressure stripping).

QbC: The Quasars behind Clusters Survey

Near future

- Gravitational lensing
- Halo sizes
- Ionization
- RCS-2 + SDSS DR5 = factor 10 more pairs!