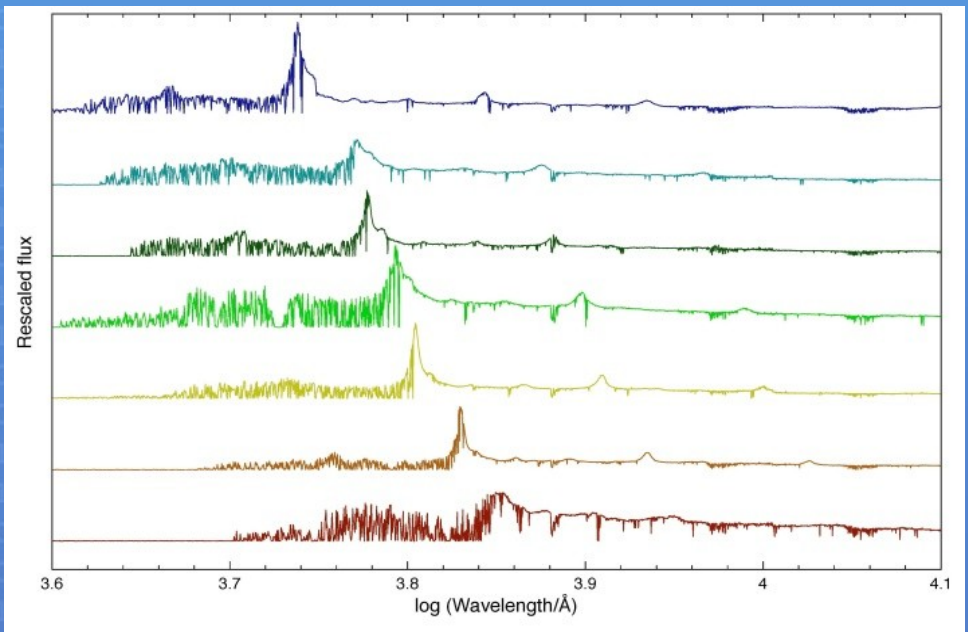
XQ-100: A legacy survey of 100 quasars and their absorption lines observed with VLT/XSHOOTER

S. López (U. de Chile) on behalf of the XQ-100 Collaboration

Centro de Astrofísca y Tecnologías Afines



George Becker, Lise Christensen, Stefano Cristiani, Guido Cupani, Kelly Denney, Mirka Dessauges-Zavadsky, Valentina D'Odorico, Sara Ellison, Martin Haehnelt, Fred Hamann, Joseph Hennawi, Vid Irsic, Tae-Sun Kim, Brice Ménard, Isabelle Pâris , J. Xavier Prochaska, Ruben Sanchez Ramirez, Marianne Vestergaard, Matteo Viel, Lutz Wisotzki, Gábor Worseck, Trystyn Berg, Pia Cortes, Serena Perrotta,, Rikke Lund Saust

This talk

- Context and motivation
- Survey design, observations, data reduction
- Selected ongoing science
- Science products

QSO spectrum: intervening absorption lines

- Trace the circum- & inter-galactic medium.
  - **CGM / ISM:**
    - probe gas abundances of heavy elements and gas that fuels galaxy formation
    - **galaxy formation and evolution**
  - **IGM:**
    - 90% baryons (mostly ionized)
    - probe the LSS, BAOs, UVB, re-ionization, primordial abundances
    - **cosmology**

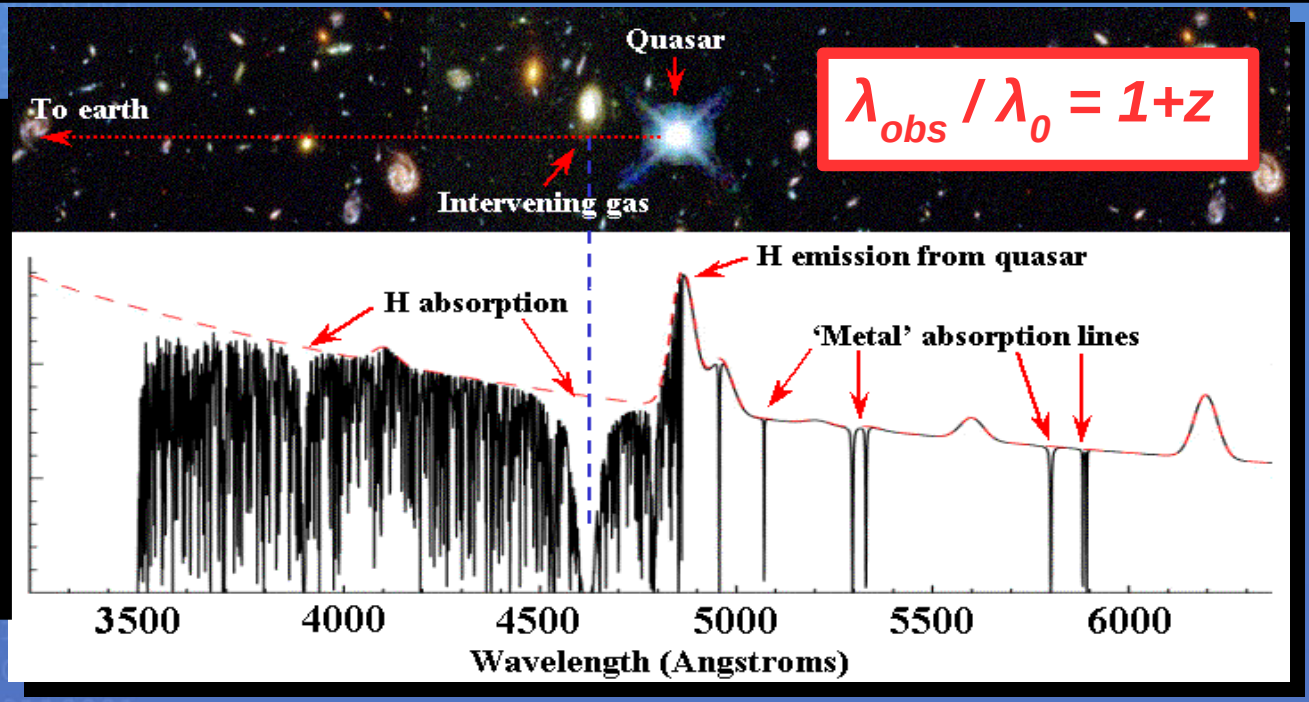


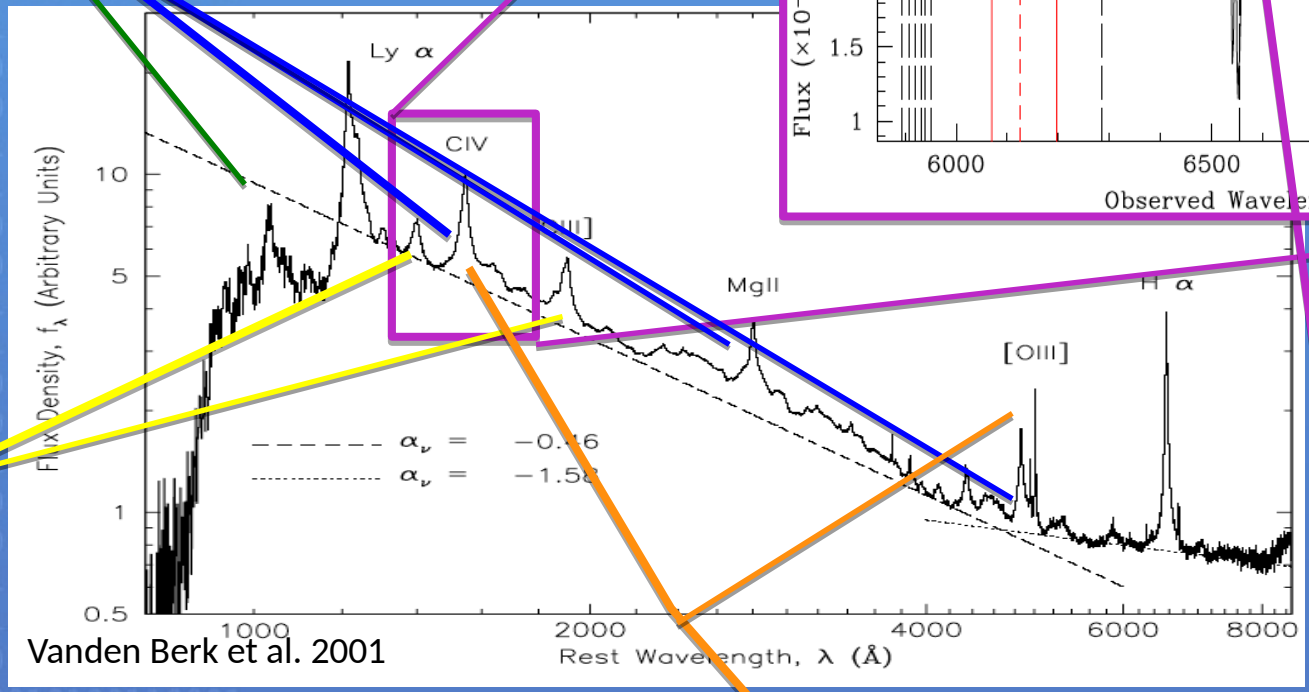
Figure by Joe Liske

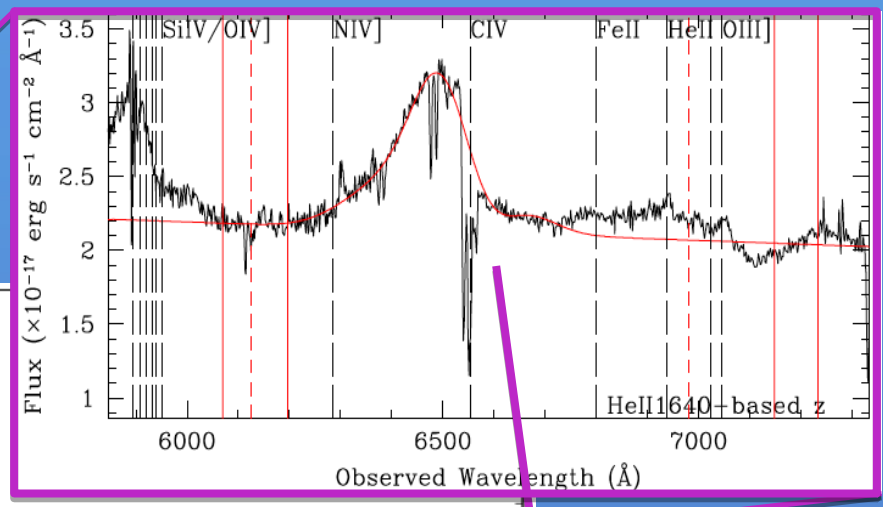
QSO spectrum: emission lines

$\lambda_{obs} / \lambda_0 = 1+z$

Broad Emission **Line Widths** and quasar **continuum luminosities**: black hole masses, accretion rates, bolometric luminosities (L/L_{edd})

K. Denney



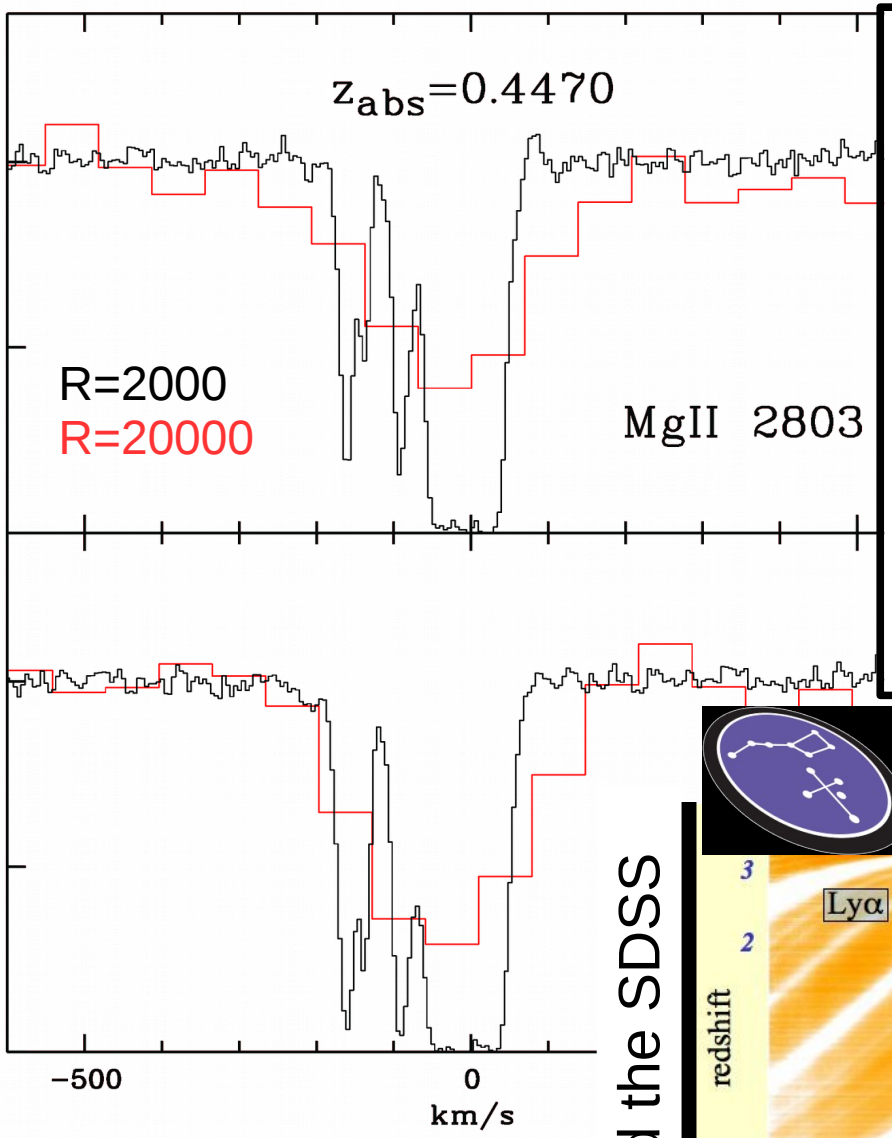


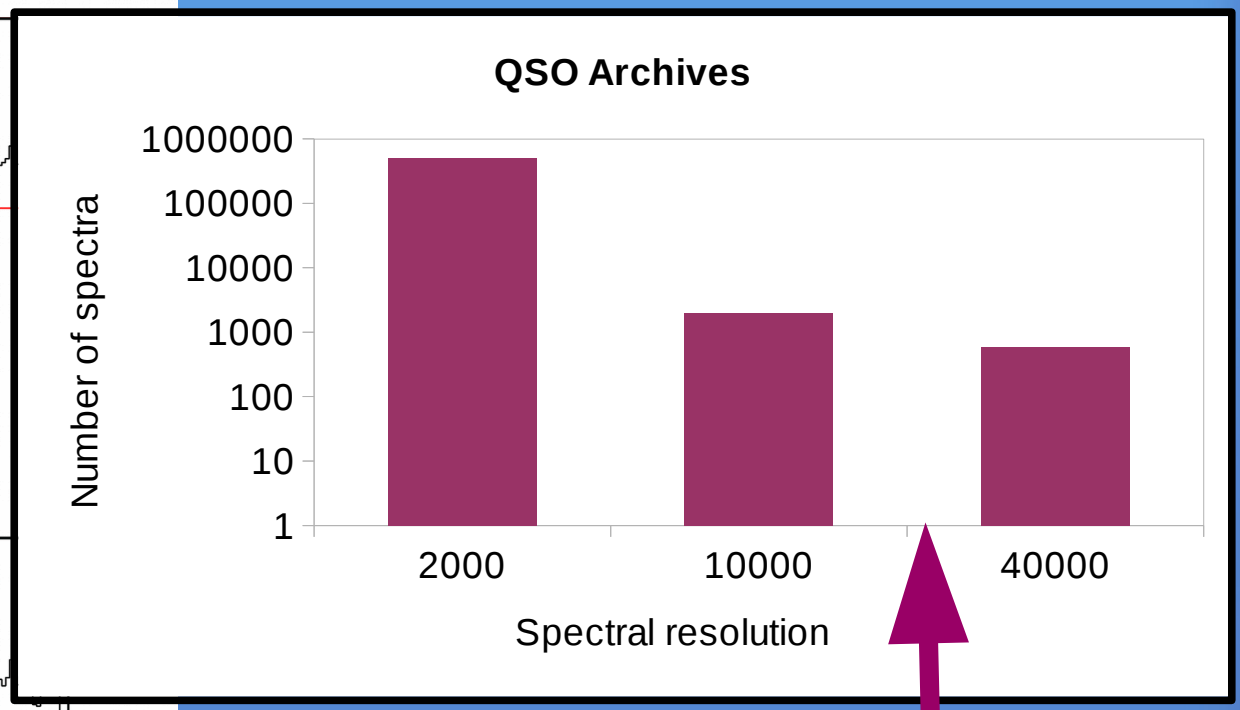
Absorption Line studies: metallicities; outflows; feedback

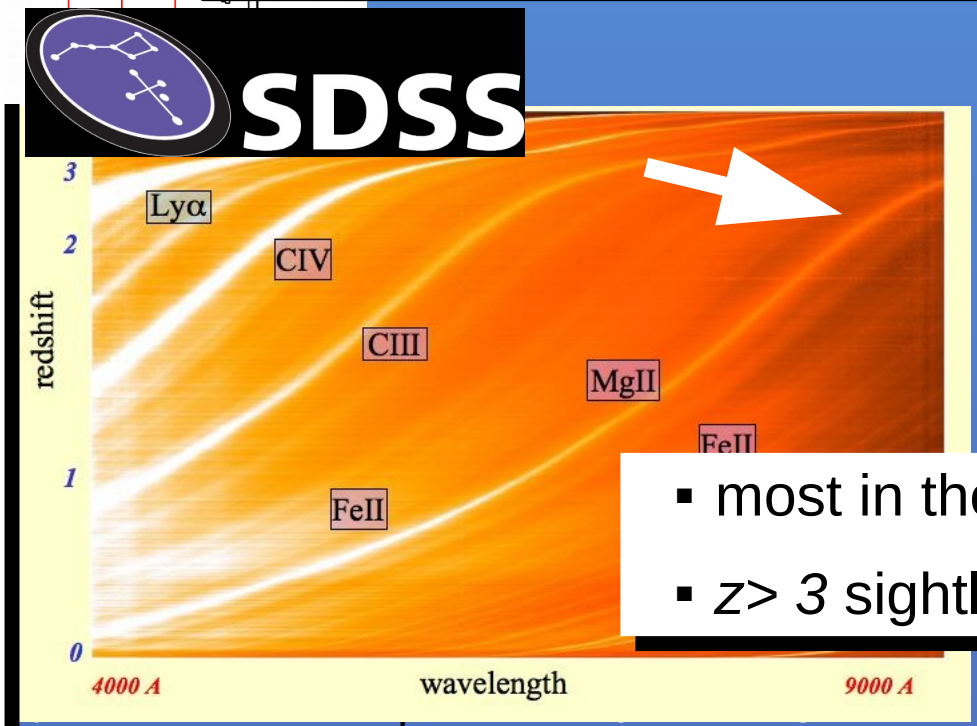
Broad Emission Line flux ratios: metallicity estimates, SED diagnostics

Broad and Narrow Emission Line Properties, e.g., profile shape, strength (EW), peak wavelength, asymmetries, etc.: accurate redshifts, nuclear structure, kinematics (outflows?), SED diagnostics

Echelle spectroscopy needed





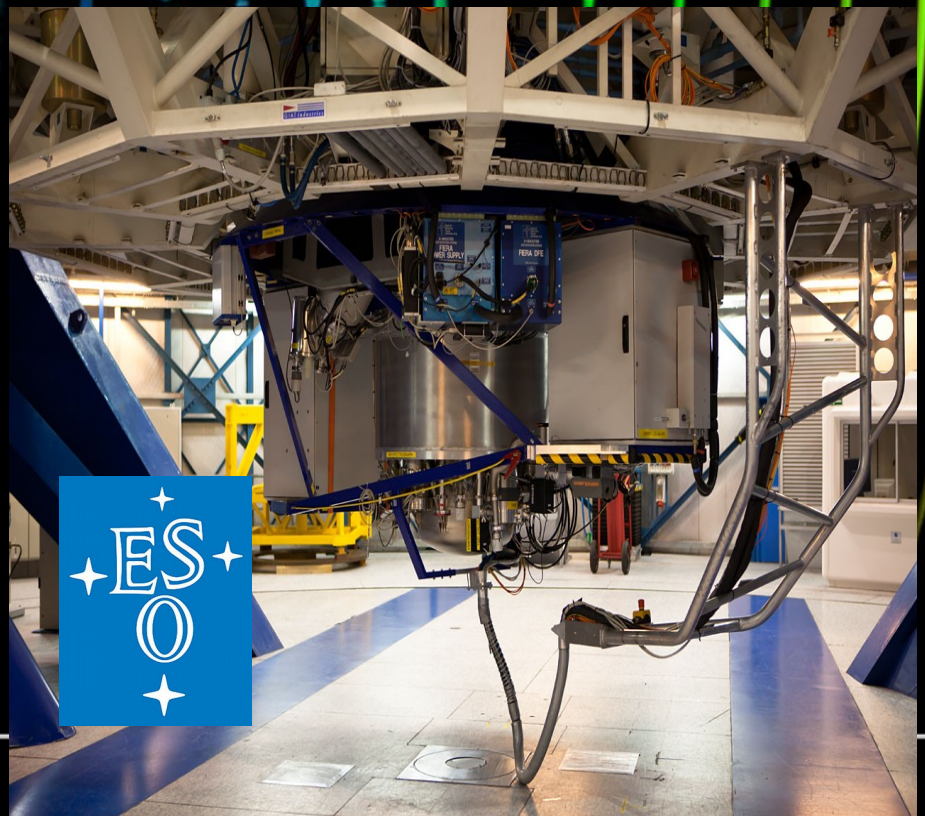


X. Fan and the SDSS

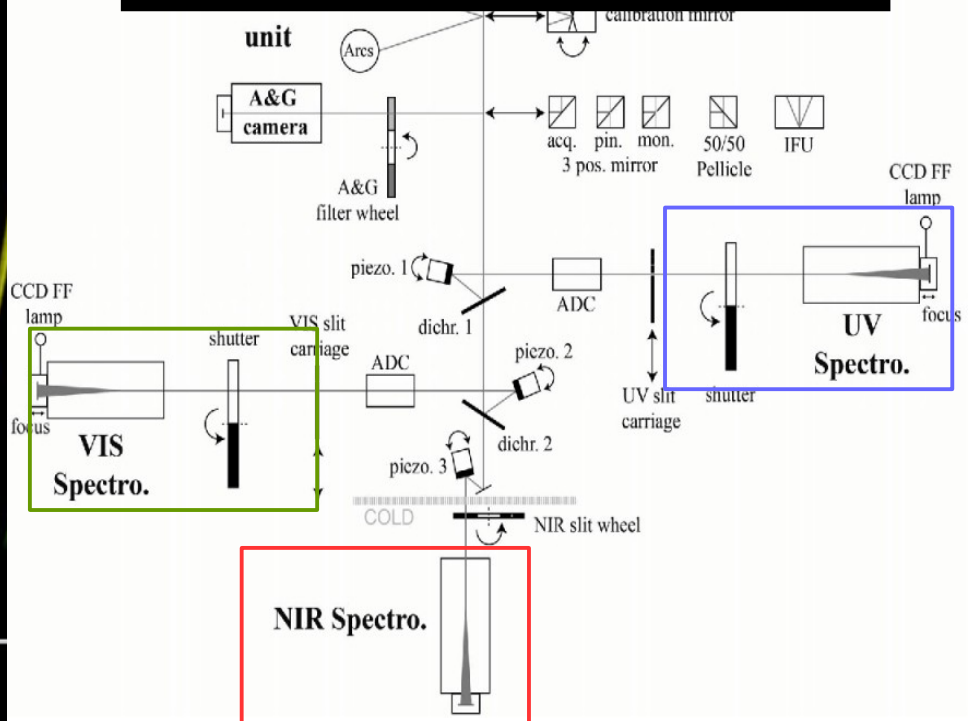
- most in the optical only
- *z*> 3 sightlines require NIR

XQ-100 survey

- Homogeneous sample of 100 VLT/XSHOOTER spectra of QSOs at z = 3.5–4.5
- CD, full spectral coverage 310-2400 nm
- R = **6000** (UVB) , **9000** (VIS), **6000** (NIR)
- SNR = 30 (median)
- 100 hours as an ESO LP within Chilean time



Three arms: UVB, VIS, NIR



Main science goals (team leaders)

- **Galaxies in Absorption**
  - MgII survey (Lopez)
  - DLA survey (Ellison)
- **CGM / IGM sciemce**
  - LLS survey (Prochaska)
  - Proximity effect (Worseck)
- **AGN science**
  - IR redshifts (Paris)
  - Physical properties of AGN (Hamann)
  - Associated absorbers (D'Odorico)
- **Cosmology**
  - Matter power spectrum (Viel)

Why 100

- **Galaxies in Absorption**
  - MgII survey (Lopez)
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- **AGN science**
  - IR redshifts (Paris)
  - Physical properties of AGN (Hama[illegible])
  - Associated absorbers (D'Odoric[illegible])
- **Cosmology**
  - Matter power spectrum (Viel)

Required signicance in *dN/dz* and flux-power spectrum dictates need for 100 QSOs

Why $3.5 < z < 4.5$

- **Galaxies in Absorption**
  - MgII survey (Lopez)
  - DLA survey (Ellison)
- **CGM / IGM sciemce**
  - LLS survey (Prochaska)
  - Proximity effect (Worseck)
- **AGN science**
  - IR redshifts (Paris)
  - Physical properties of AGN (Ha[illegible]nn)
  - Associated absorbers (D'Odo[illegible]co)
- **Cosmology**
  - Matter power spectrum (Viel)

- $z > 3.5$: every QSO contributes redshift path of at least 0.5 for Mg II survey in the NIR
- $z < 4.5$ avoids line crowding in the forest.

Unique spectroscopic QSO survey

- **Galaxies in Absorption**
  - MgII survey (Lopez)
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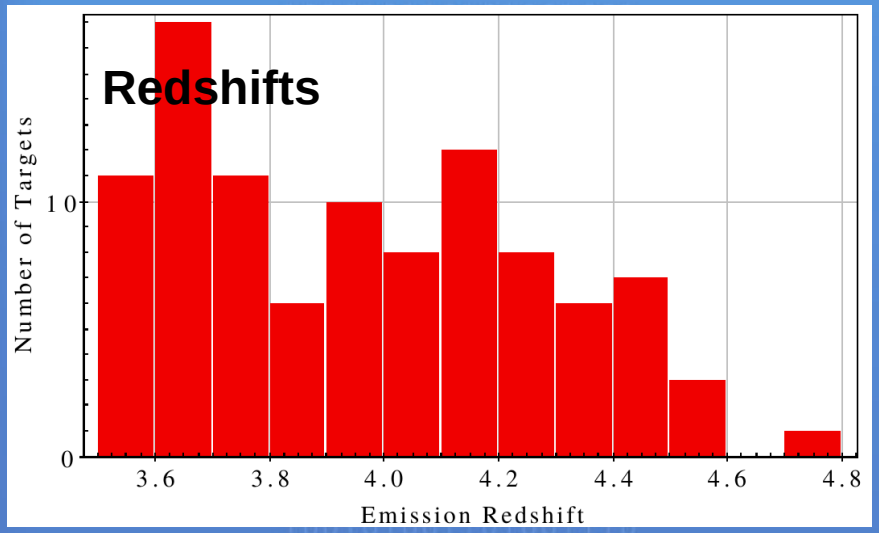
Combination of

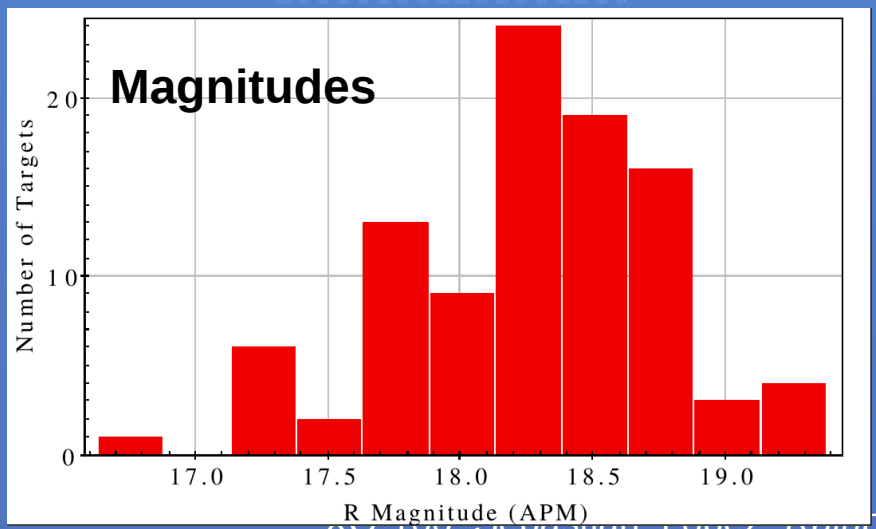
- blind survey
- high redshift
- echelle resolution,
- high S/N

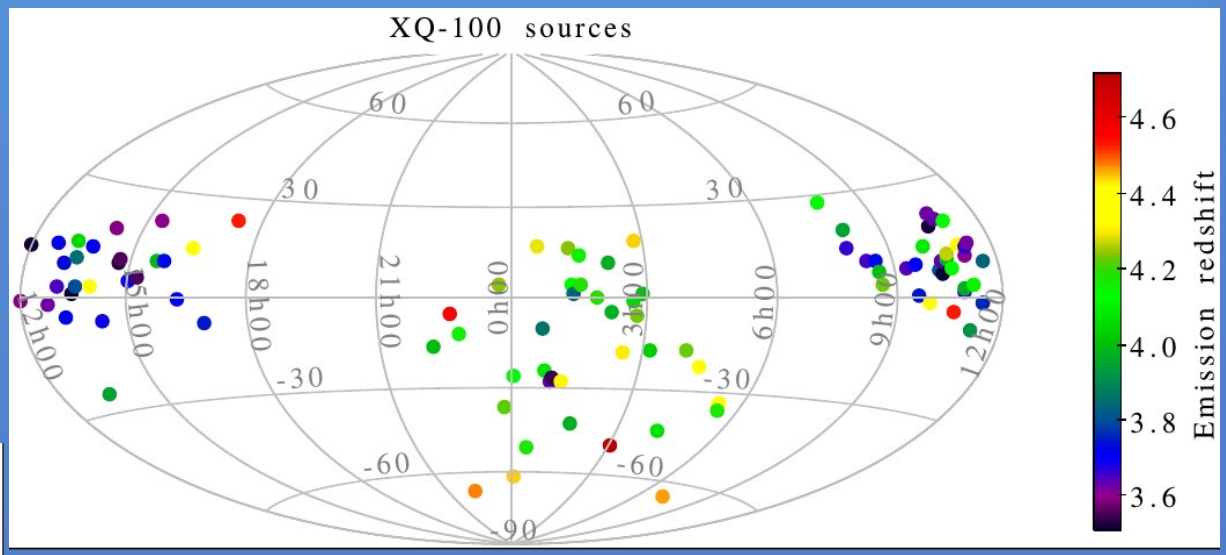
clearly a benefit for all science goals !

Target selection

- Targets selected initially from NED to have $z > 3.5$ and $\delta < 15$
- APM catalog checked to obtain uniform *R* magnitudes.
- Some additional targets selected from literature sources.
- Avoid SDSS color bias



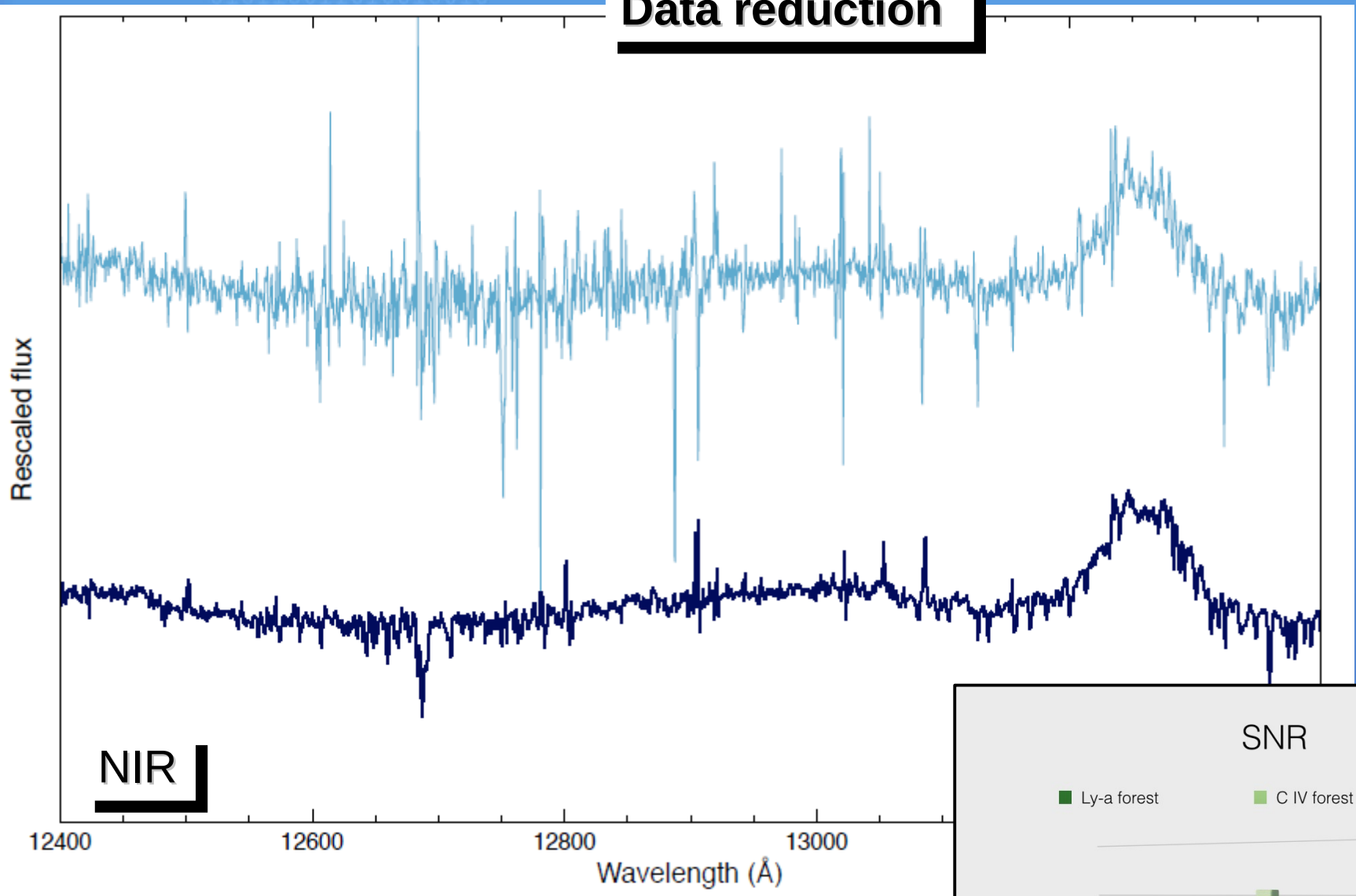


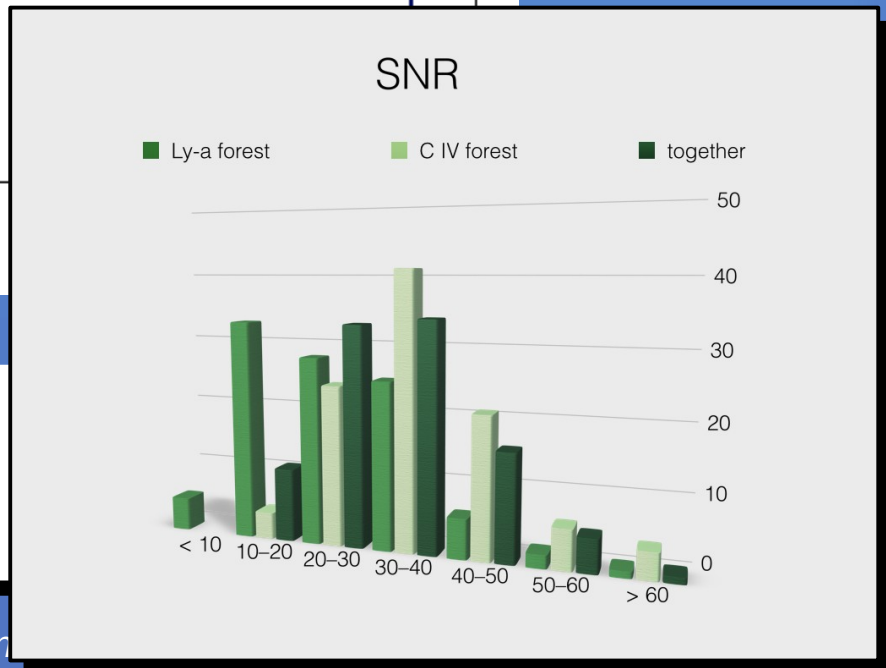


Observations taken between

April 2012 and April 2014

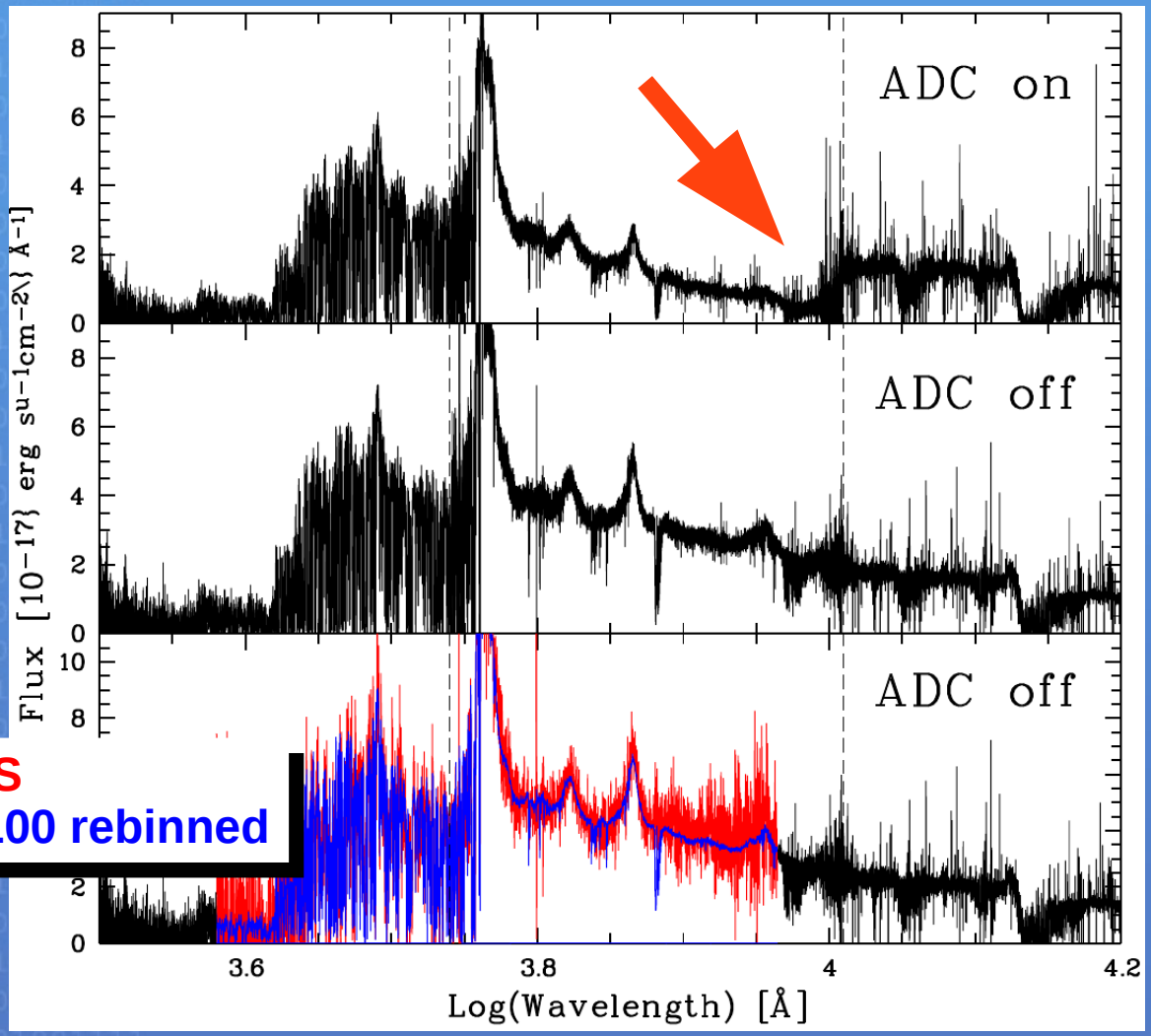
Data reduction





IDL pipeline (G. Becker) focused on optimized sky-subtraction and spectrum extraction.
More effective than ESO's v2.5.2 (2014).

ADC issues



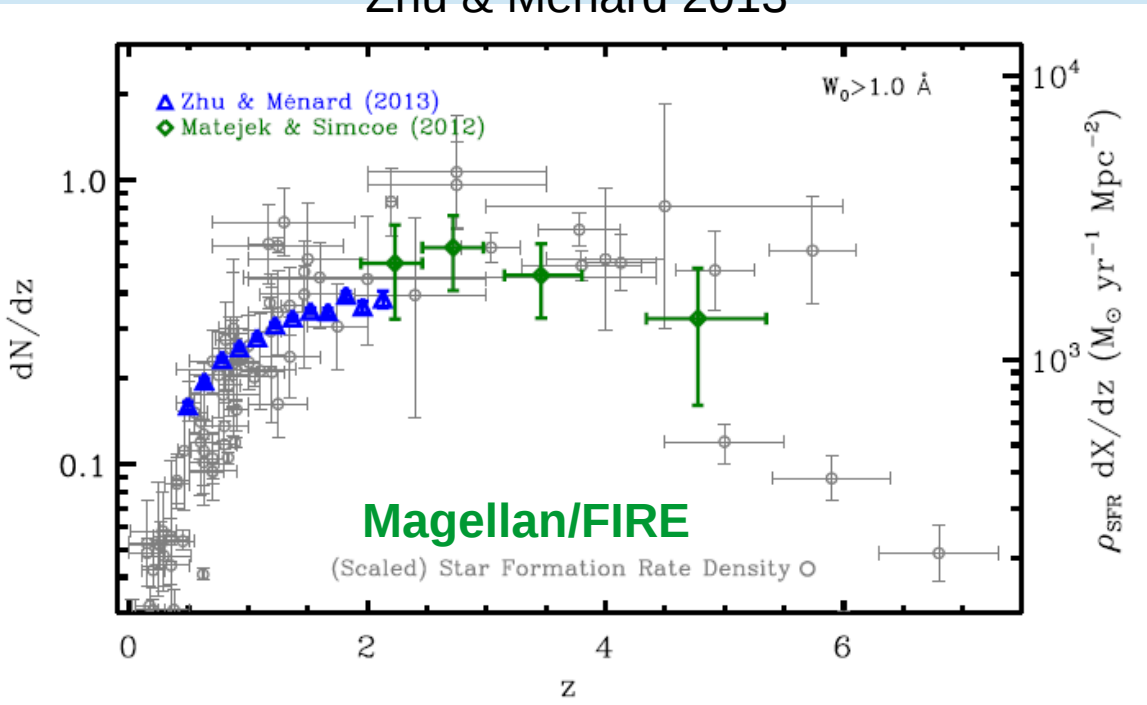
12/100 OBs repeated

Ongoing research with XQ-100

MgII survey (Lopez)

- **Galaxies in Absorption**
  - **MgII survey (**
  - DLA survey (Ellison)
- **CGM / IGM sciemce**
  - LLS survey (Prochaska)
  - Proximity effect (Worseck)
- **AGN science**
  - IR redshifts (Paris)
  - Physical properties of AGN (Hamann)
  - Associated absorbers (D'Odorico)
- **Cosmology**
  - Matter power spectrum (Viel)

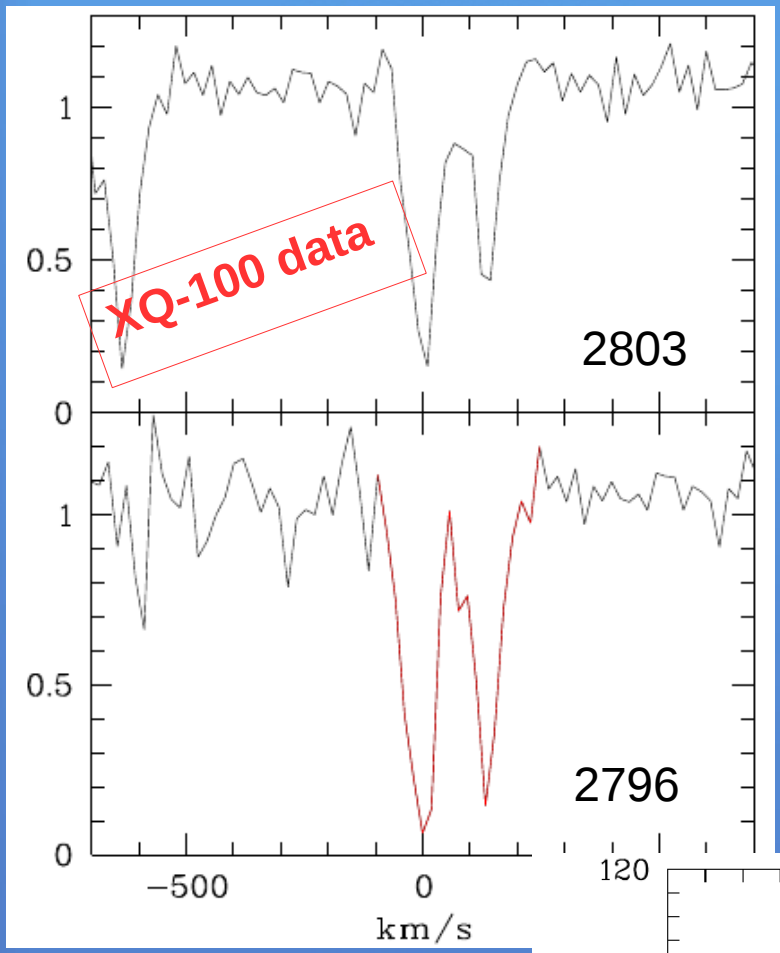
Zhu & Menard 2013



Strong MgII traces SFR

MgII survey

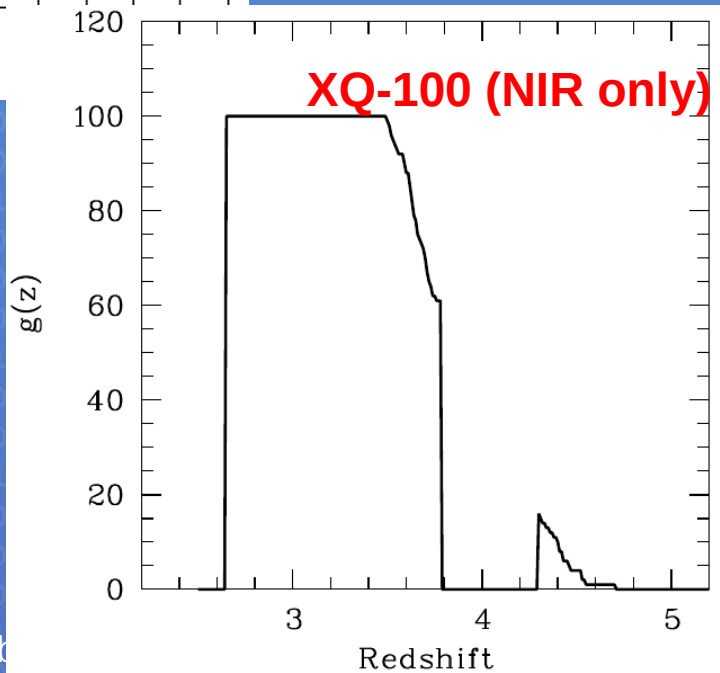
Lopez et al.

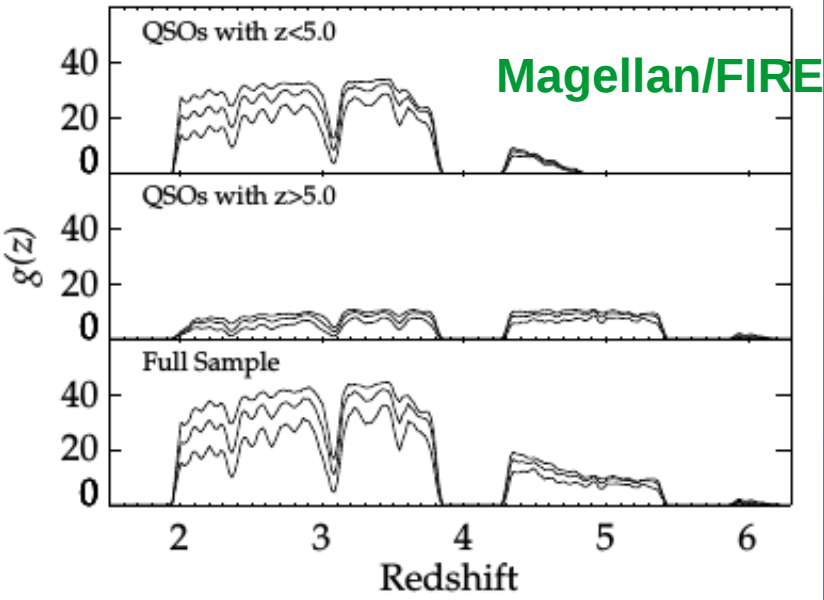


XQ-100

- 2-3X more sensitive (rEW~0.05 Å)
- ~2x Δz

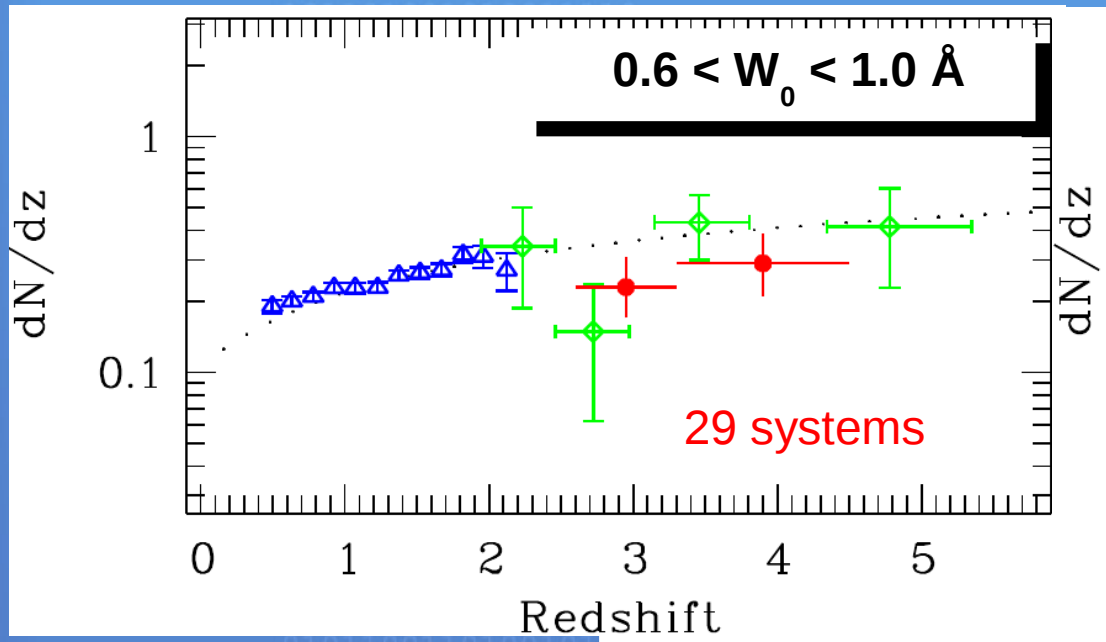
J1312+0841
z = 2.6594
W_0 = 1.04 ± 0.05 Å

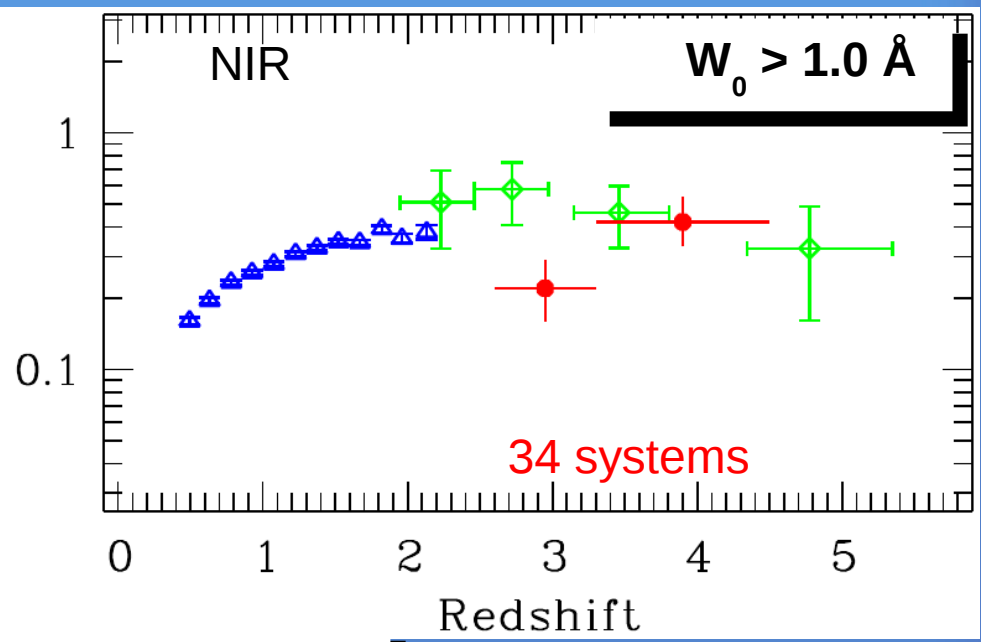




MgII survey

Lopez et al.





SDSS, Zhu & Menard (2013)

FIRE, Matejek & Simcoe (2014)

XQ-100 (NIR)

XQ-100 advantage: probe the weak MgII: $0.05 < W_0 < 0.6$ Å

DLA survey (Ellison)

- **Galaxies in Absorption**
  - MgII survey (Lopez)
  - **DLA survey (Ellison)**
- **CGM / IGM scien**
  - LLS survey (Procha
  - Proximity effect (Wors
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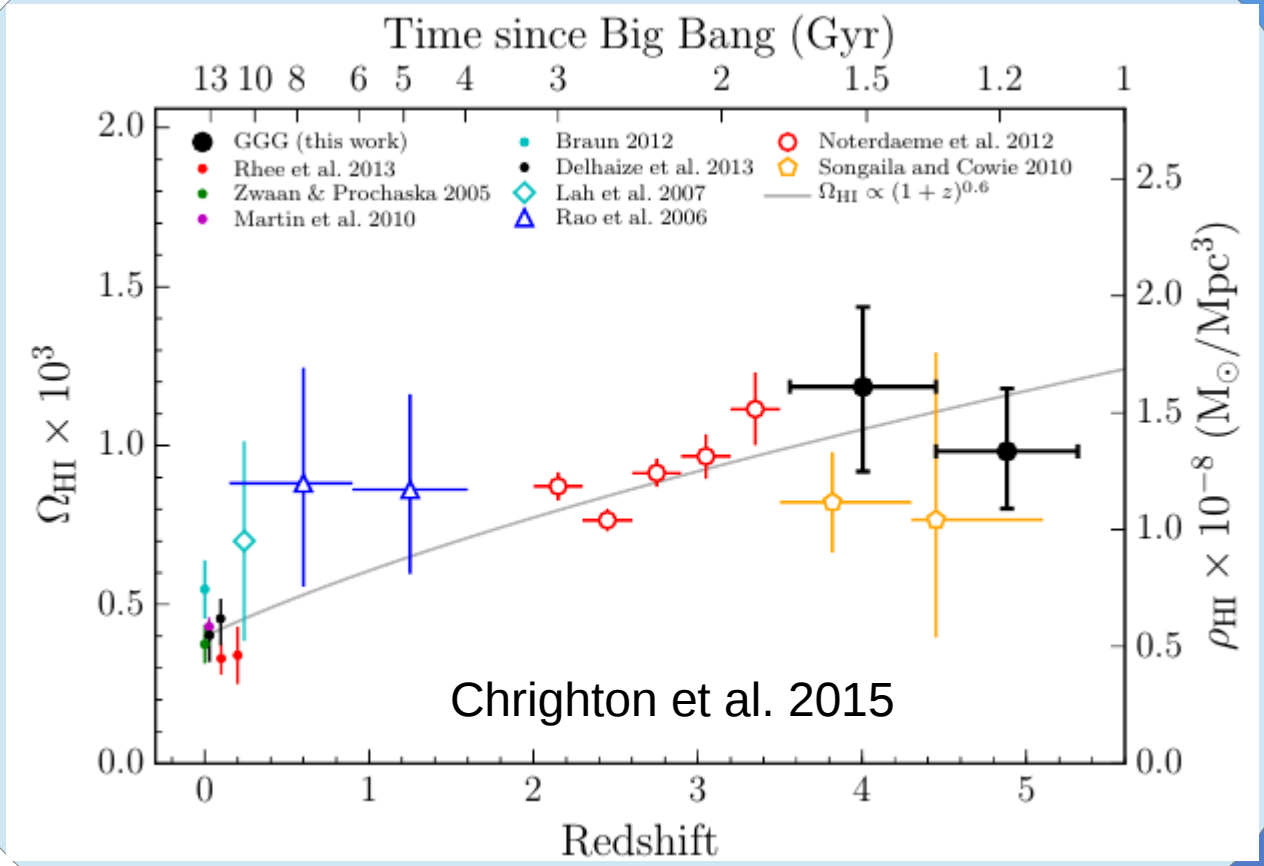
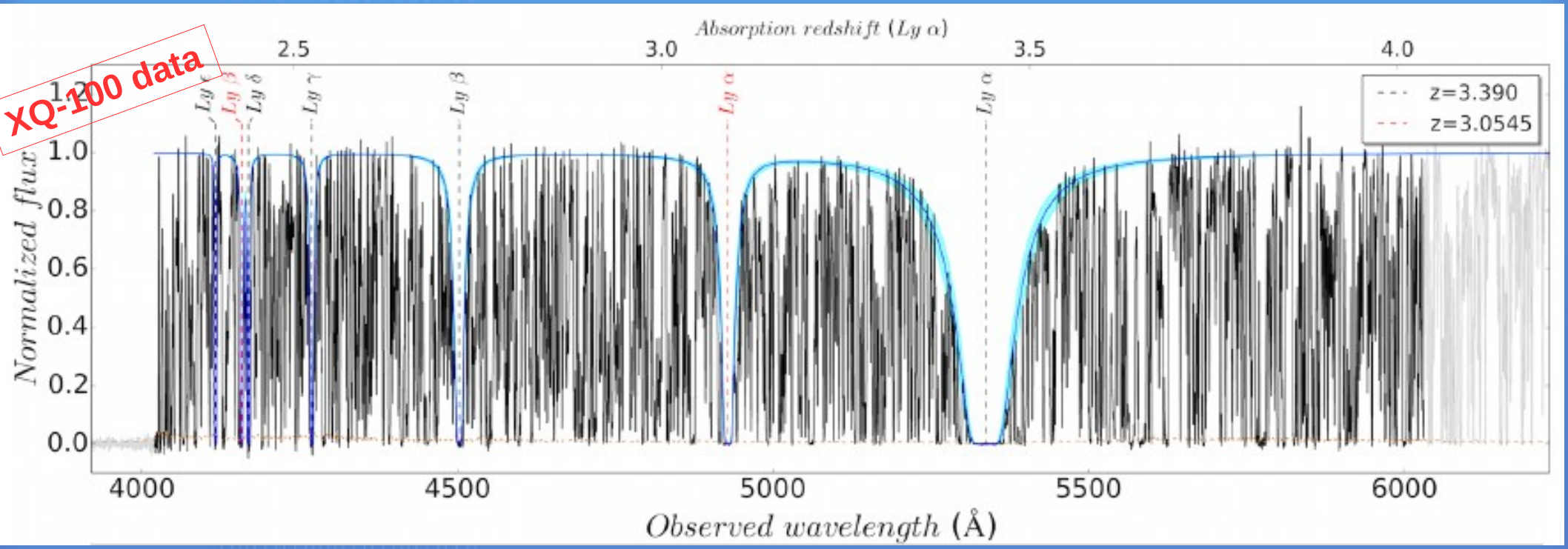
  - Matter power spectrum (Viel)



XQ-100 R/SNR: blending, abundances



Cosmic density of neutral gas in DLAs
Sanchez-Ramirez, Ellison et al. (submitted)
(see talk by Trystyn Berg)

Metal abundances in DLAs
Berg, Ellison et al.
(see talk by Trystyn Berg)

LLS survey (Prochaska)

- **Galaxies in Absorption**
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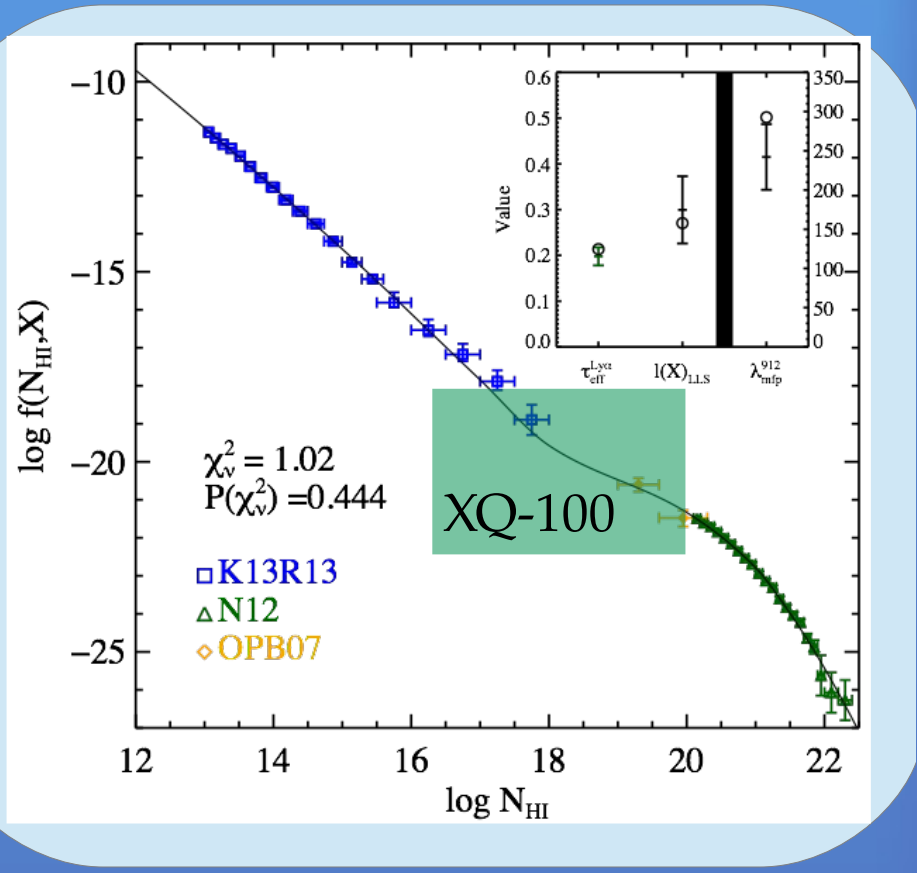


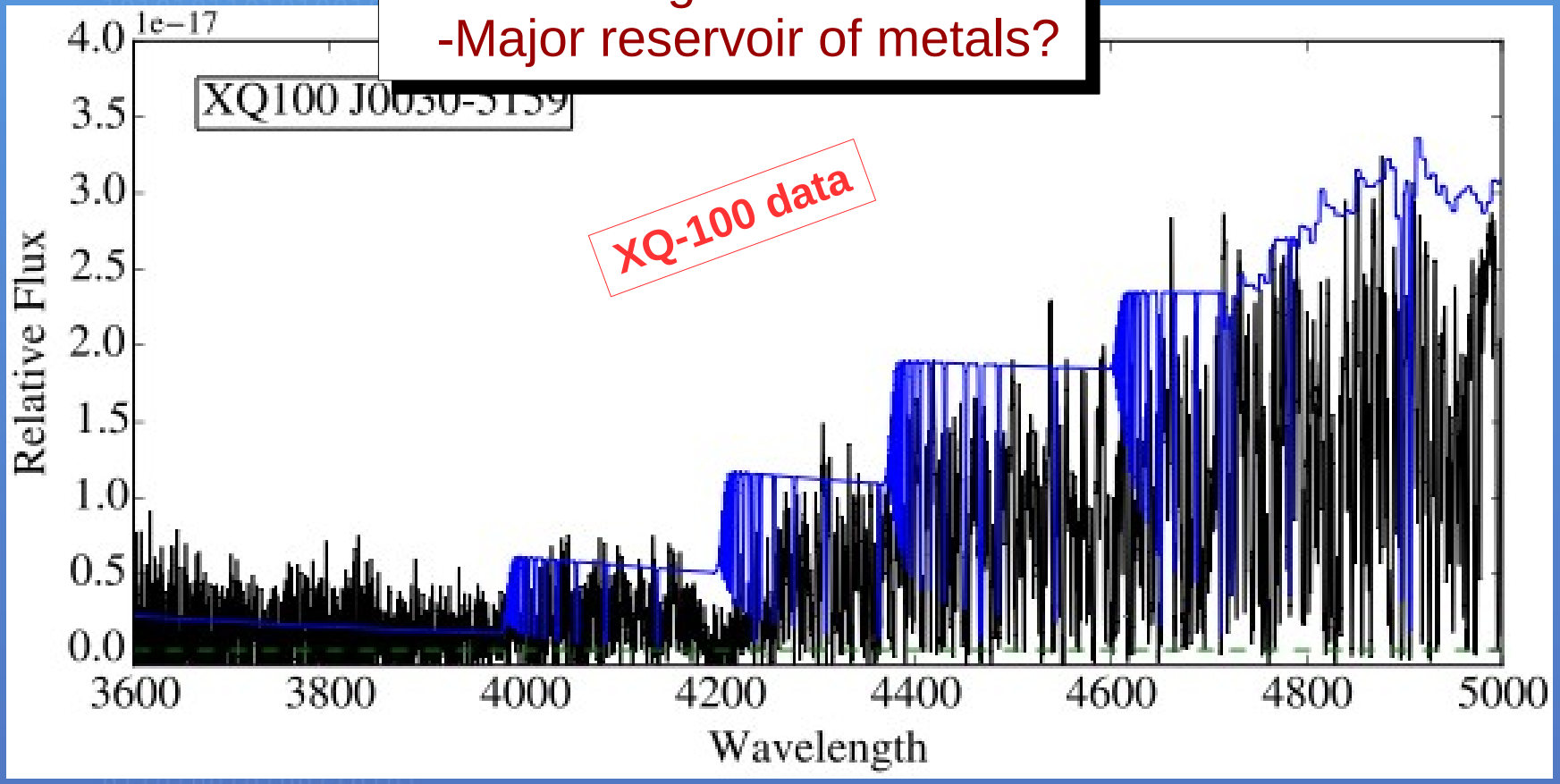
- Significant opacity to ionizing radiation
- No proper survey performed to date

Lyman-limit systems in XQ-100

Ribaudo, Prochaska, O'Meara et al.

Scientific Motivations:

- -Mean Free Path (λ^{MFP})
- -Estimate of the EUVB
- -Probe of galactic halos
- -Major reservoir of metals?



XQ-100 has terrific combination of SNR, *R*, and spectral coverage. Sufficient dataset to reveal 100+ pLLS at z~3-4

AGN science

- **Galaxies in Absorption**
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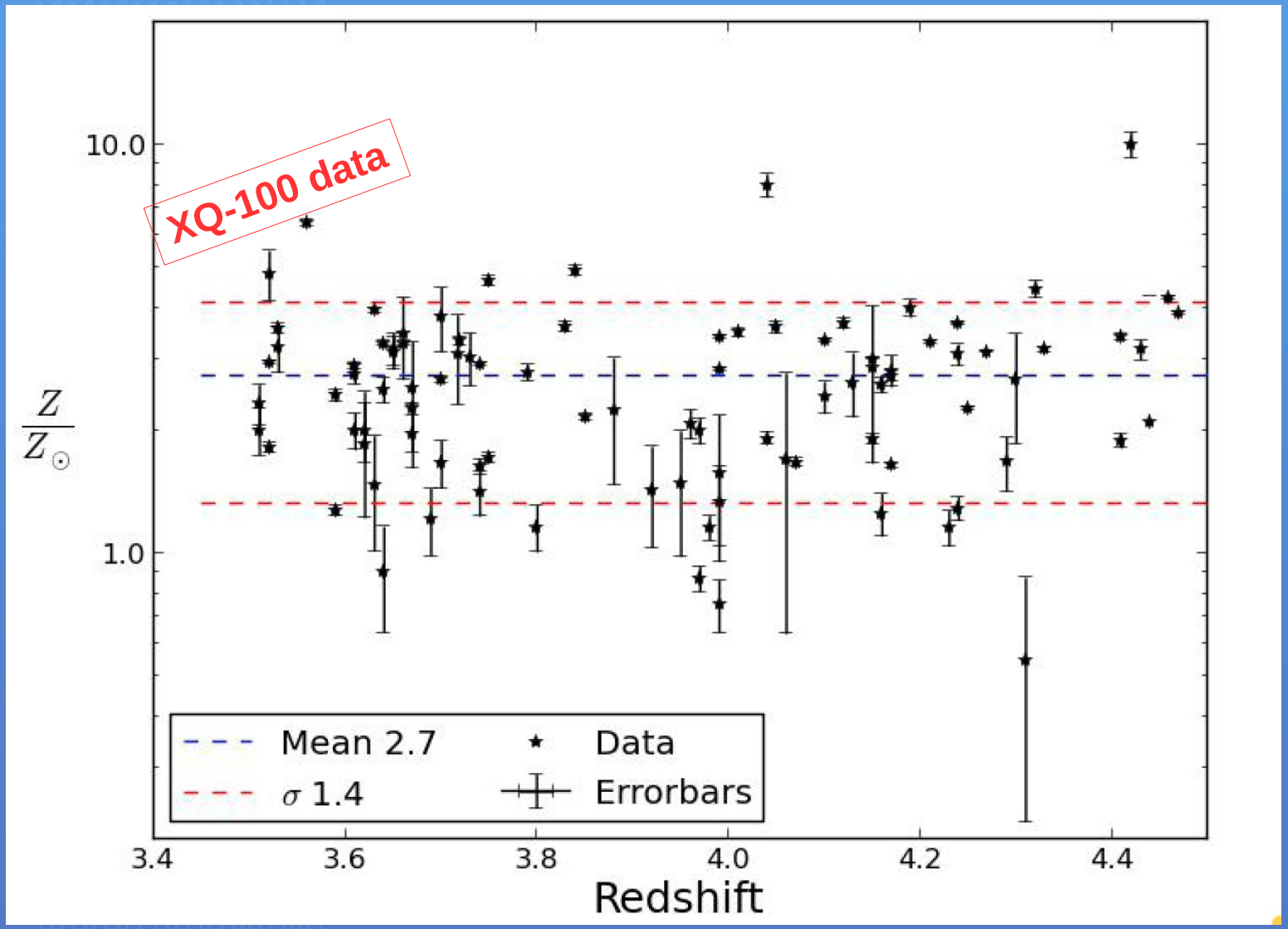
Probe high-redshift and high-luminosity quasars with CIV/MgII in one single sample

AGN science (I): Metallicities in the Broad Line Region

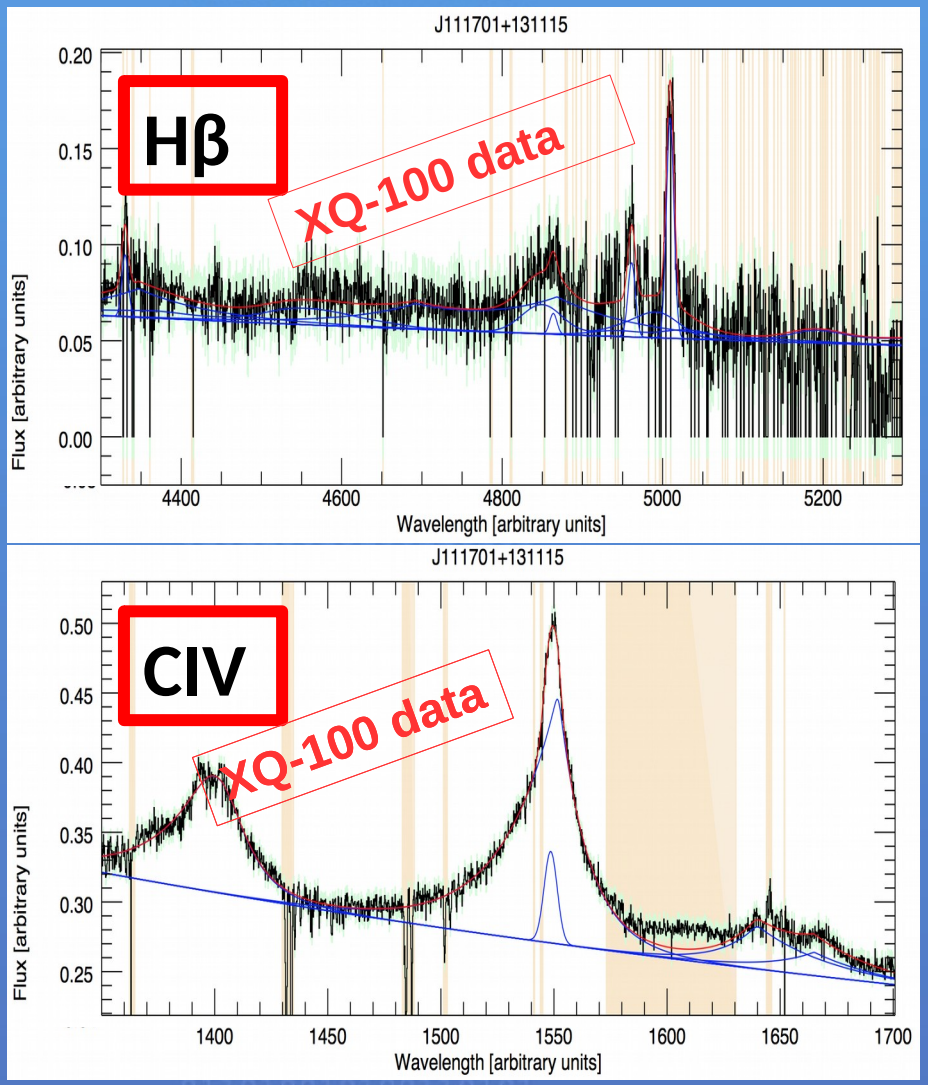
Vestergaard, Hamann et al.

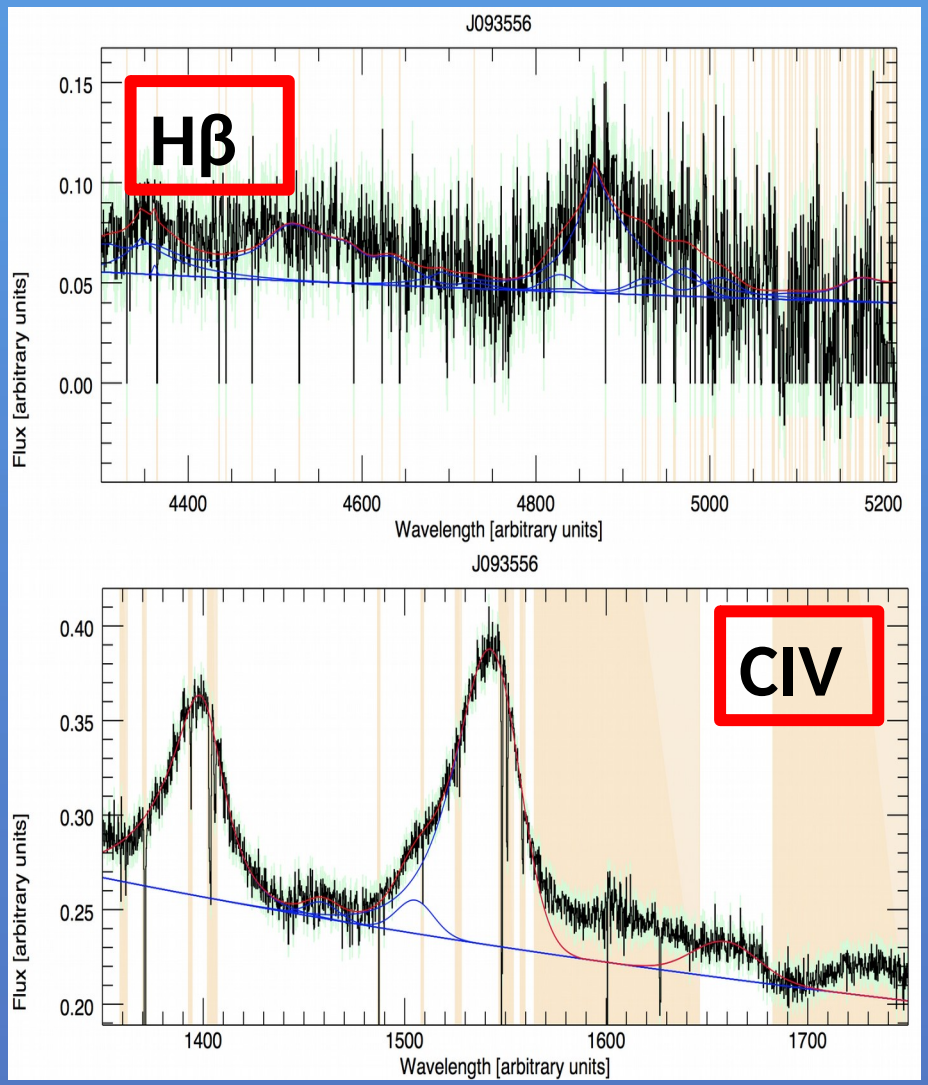


Wide range of metallicities across the relatively narrow redshift range.

AGN science (II):Using XQ100 Sample to probe non-variable flux in CIV SE Line Emission

Denney, Hamann et al.

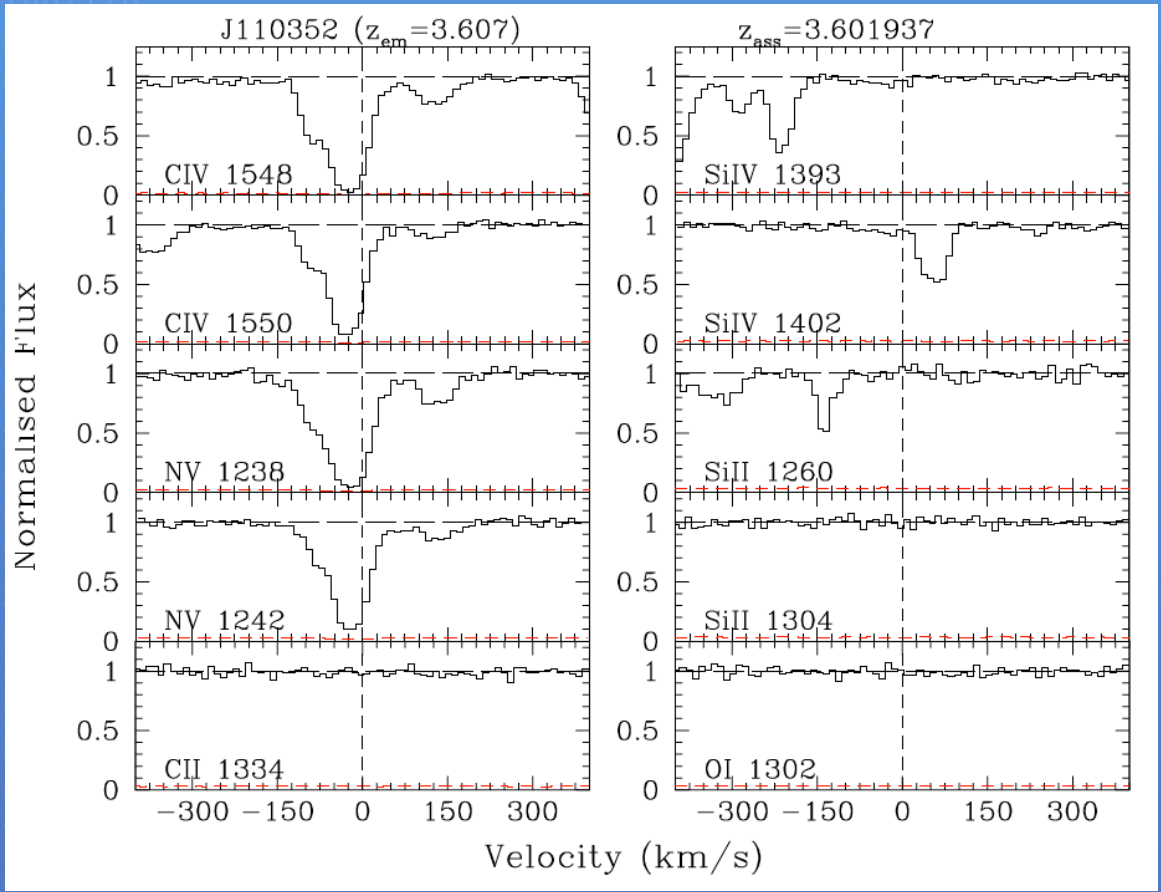




Narrow Associated Lines

Perrotta et al. (in prep)

(see talk by Valentina D'Odorico)



Matter power spectrum

- **Galaxies in Absorption**
  - MgII survey (Lopez)
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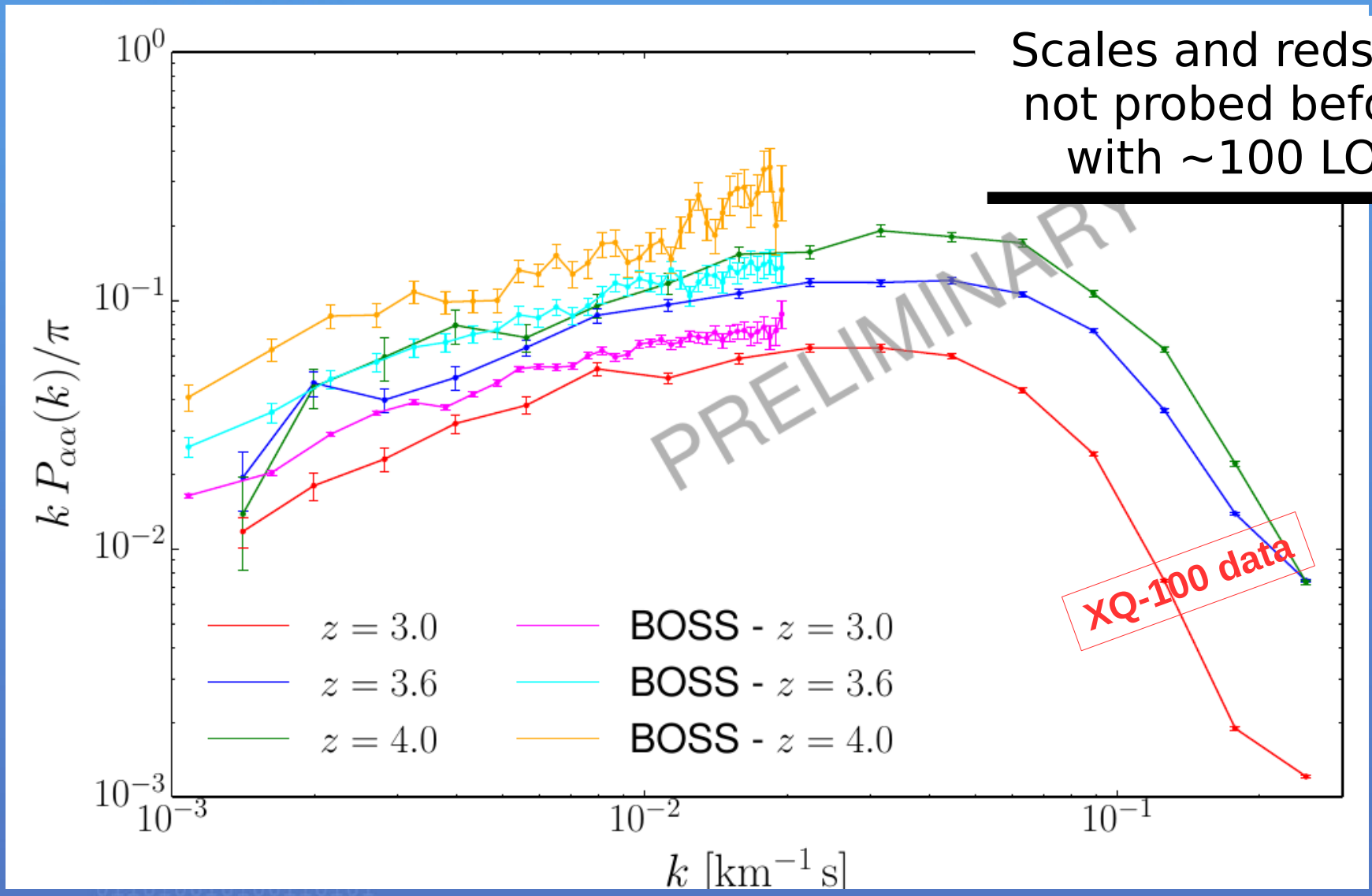
- **Cosmology**
  - **Matter power spectrum (Viel)**

Lyα forest traces
DM fluctuations

Matter power spectrum

Irsic, Viel et al.



Scales and redshift not probed before with ~100 LOS

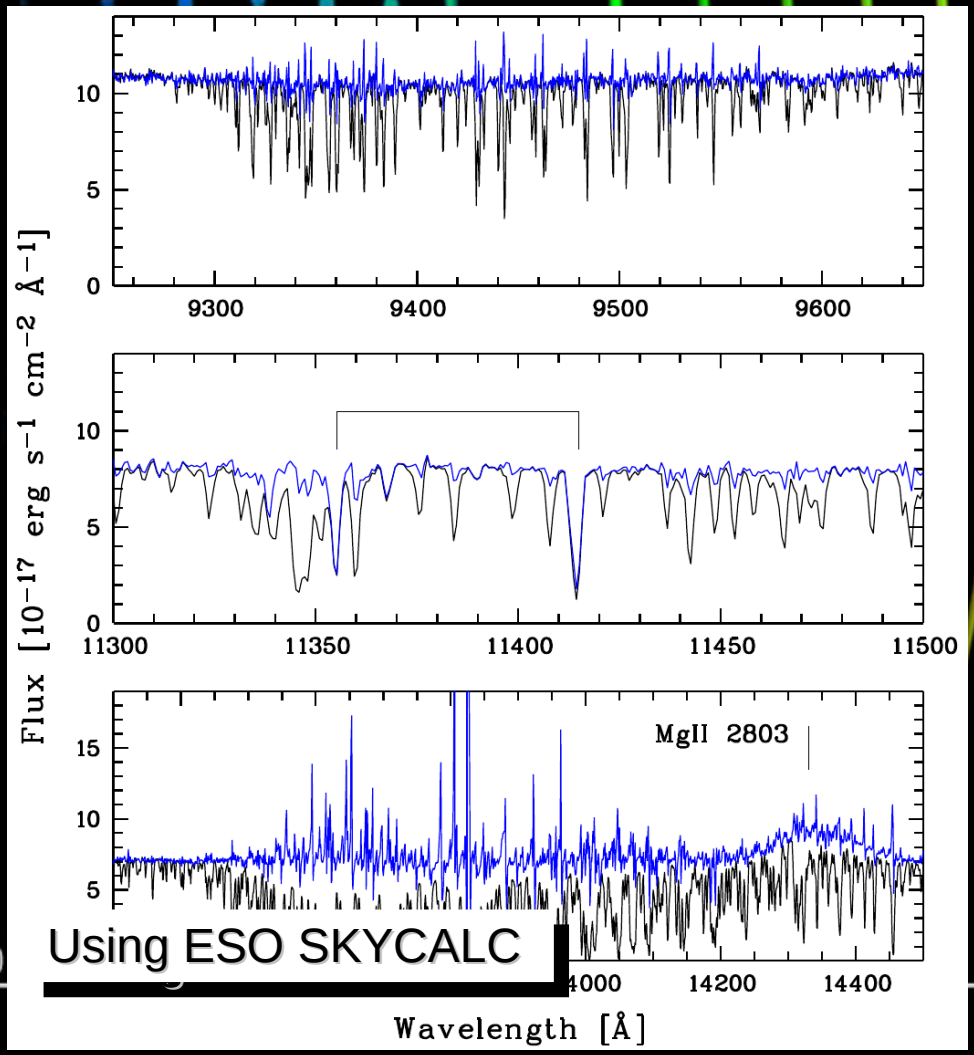
Unique combination of spectral resolution, S/N, and sample size

XQ-100 Products

High-level science data products

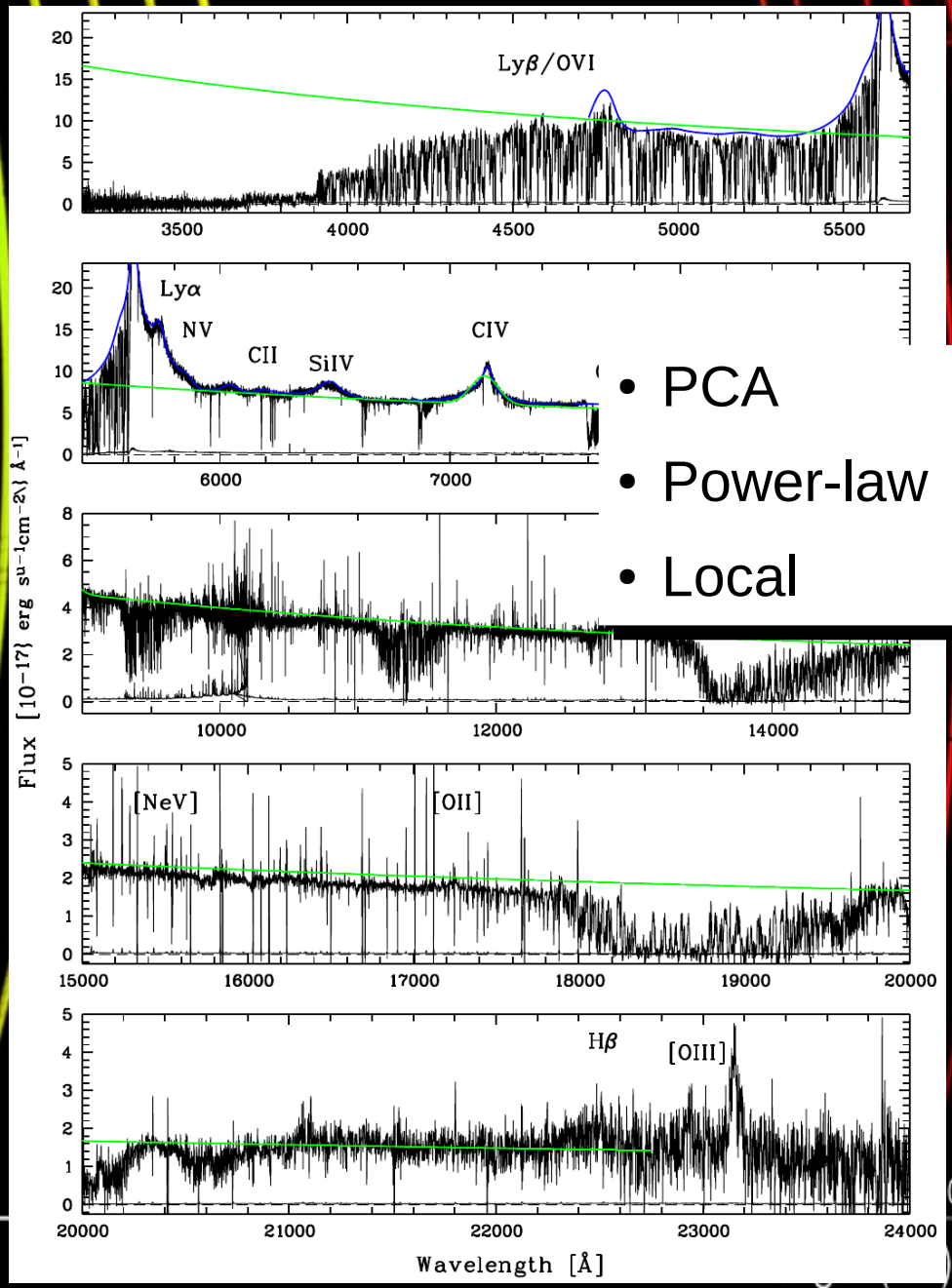
1. Merged spectra

2. Telluric correction, VIS & NIR



Using ESO SKYCALC

3. QSO continuum



- PCA
- Power-law
- Local

SDP and Phase 3

Three “data collections”

- ***XQ-100_raw***
  - Reduced, flux calibrated spectra of the separate UVB, VIS and NIR arms
- ***XQ-100_telluric***
  - Same as above but having telluric correction
- ***XQ-100_merged***
  - Merged spectra with 3 different continua fitted.

Summary file

Table A.3. Parameters associated to each XQ-

Column	Name	Format	Description
1	OBJ_NAME	STRING	Object name
2	RA	DOUBLE	Right Ascension in sexagesimal degrees (J2000)
3	DEC	DOUBLE	Declination in sexagesimal degrees (J2000)
4	FILE_NAME	STRING	Base of file names
5	Z_QSO	DOUBLE	Redshift (PCA)
6	ERR_ZQSO	DOUBLE	Error on QSO redshift (PCA)
7	N_OBS	SHORT	Number of XSHOOTER observations
8	MJD_OBS	INT32[3]	Modified Julian day of the spectroscopic observation
9	SEEING_START	FLOAT[3]	Seeing at the beginning of each spectroscopic observation (in arcsec)
10	SEEING_END	FLOAT[3]	Seeing at the end of each spectroscopic observation (in arcsec)
11	SNR_1700	FLOAT[3]	SNR at 1 700Å (rest) for each spectrum
12	SNR_3000	FLOAT[3]	SNR at 3 000Å (rest) for each spectrum
13	SNR_3600	FLOAT[3]	SNR at 3 600Å (rest) for each spectrum
14	CALIB_FLAG	FLOAT[3]	Calibration flags (one per XSHOOTER observation) 1- VIS flux-calibrated with a different standard star 2- residual spikes in the UVB 4- apparent (albeit slight) order-to-order fluctuations in the VIS 8- interrupted exposure
15	COMBINED_FLAG	SHORT	Combined spectrum flag (1 if combined, 0 if not)
16	COMBINED_SNR_1700	FLOAT	SNR at 1700Å (rest) of combined spectrum
17	COMBINED_SNR_3000	FLOAT	SNR at 3000Å (rest) of combined spectrum

Astronomy & Astrophysics manuscript no. XQ-100_3.0
September 30, 2015

Papers

XQ-100: A legacy survey of one hundred $3.5 \lesssim z \lesssim 4.5$ quasars observed with VLT/XSHOOTER *,†

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[3] Department o...
[4] Space Telesco...
[5] Dark Cosmolo... K-2100 Copen-hagen, Denma...
[6] Department o... USA
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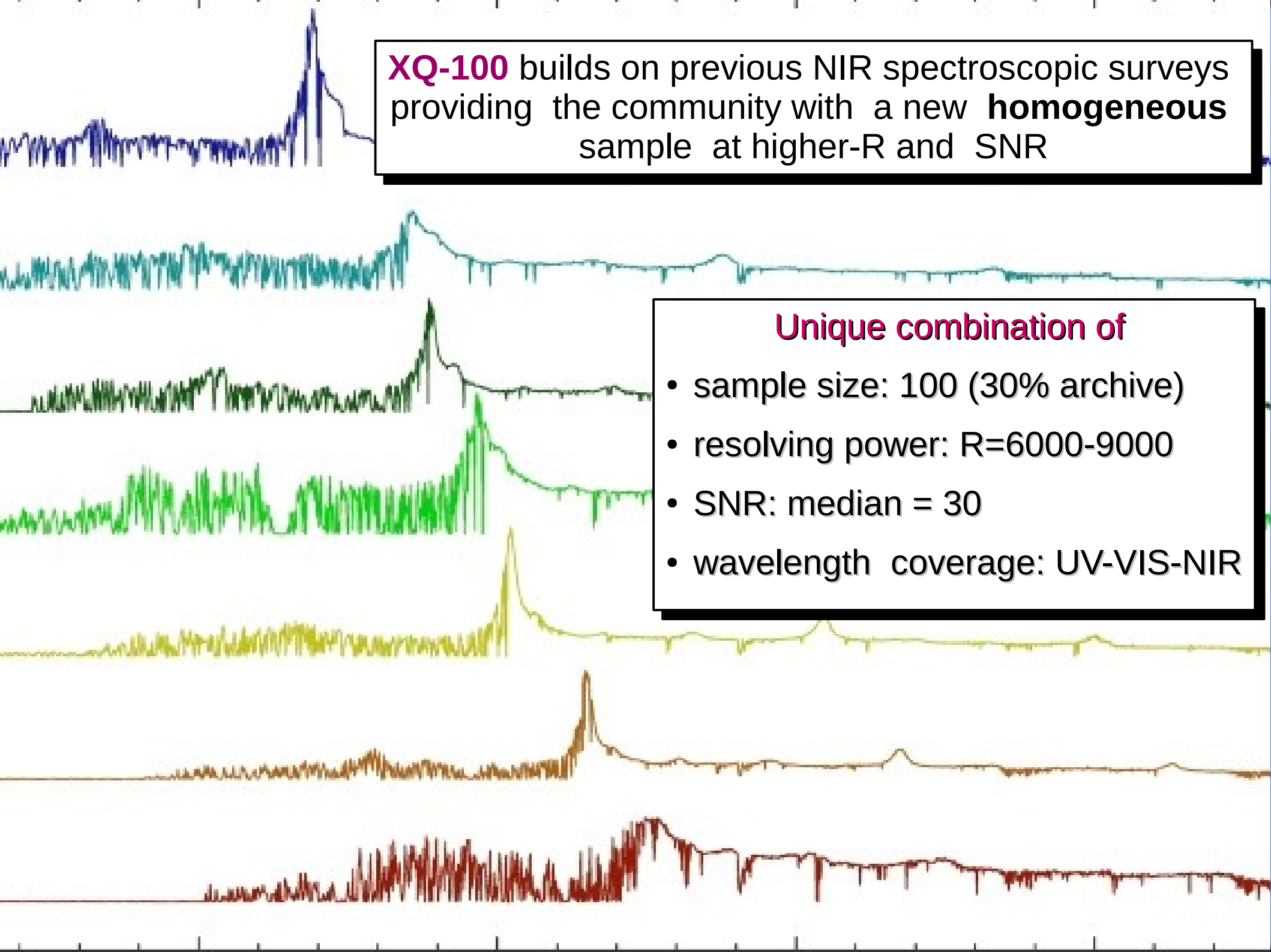
- **Lopez et al.**, survey design, reduction steps, SDP structure; to be submitted
- **Sanchez-Ramirez et al.,** DLAs, submitted
- **Berg et al.,** DLAs, in prep.
- **Perrotta et al.**, AALs, in prep.



XQ-100 builds on previous NIR spectroscopic surveys providing the community with a new **homogeneous** sample at higher-R and SNR

Unique combination of

- sample size: 100 (30% archive)
- resolving power: R=6000-9000
- SNR: median = 30
- wavelength coverage: UV-VIS-NIR